GAHCHO KUÉ PROJECT

ENVIRONMENTAL IMPACT STATEMENT

SECTION 11.7

SUBJECT OF NOTE: VEGETATION

December 2010 09-1365-1004

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11.7 SUBJECT OF NOTE: VEGETATION

11.7.1 Introduction

11.7.1.1 Context

This section of the Environmental Impact Statement (EIS) for the Gahcho Kué Project (Project) consists solely of the Subject of Note: Vegetation. In the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) issued on October 5, 2007, the Gahcho Kué Panel (2007) selected this subject of note because of concerns related to the introduction of foreign, parasitic, or invasive plant species.

This subject of note includes a detailed assessment of effects from the Project on vegetation. Additional information pertaining to vegetation, including riparian areas, is also included in the following key lines of inquiry:

- Caribou (Section 7);
- Water Quality and Fish in Kennady Lake (Section 8); and
- Downstream Water Effects (Section 9).

All effects on vegetation are assessed in detail in this subject of note; however, assessments that may overlap slightly are provided in the following subjects of note:

- Air Quality (Section 11.4);
- Mine rock and Processed Kimberlite Storage (Section 11.5);
- Permafrost, Groundwater, and Hydrogeology (Section 11.6);
- Traffic and Road Issues (Section 11.8);
- Carnivore Mortality (Section 11.10);
- Other Ungulates (Section 11.11);
- Species at Risk and Birds (Section 11.12);
- Climate Change Impacts (Section 11.13); and
- Tourism Potential and Wilderness Character (Section 12.7.3).

Where there is overlap between this subject of note and another key line of inquiry or subject of note, information will be provided in both locations to the extent required by the Terms of Reference.

11.7.1.2 Purpose and Scope

The purpose of the Subject of Note: Vegetation is to meet the Terms of Reference for the EIS issued by the Gahcho Kué Panel. The Table of concordance for the Terms of Reference for the Subject of Note: Vegetation is shown in Table 11.7-1. The entire Terms of Reference document is included in Appendix 1.I and the complete Table of concordance for the EIS is in Appendix 1.II of Section 1, Introduction of the EIS.

This subject of note includes an assessment of the potential for introduction of any foreign, parasitic, or invasive species from the Project, as well as management and environmental design features that will be implemented to reduce this effect. The effects of increased dust deposition generated from the exposed lake bed, roads, and construction and operation of the mine on vegetation, and resulting indirect effects on wildlife, are included in this assessment. Direct disturbance from the Project footprint to plant populations and communities are assessed. Effects on rare plants are assessed in detail in this subject of note; however, potential effects of the Project on plant species at risk will also be summarized in the Subject of Note: Species at Risk and Birds (Section 11.12). Baseline studies and effects from the Project on geology, terrain, and soils are presented in Appendix 11.7.I.

11.7.1.3 Study Areas

11.7.1.3.1 General Location

The Project is situated north of the eastern arm of Great Slave Lake in the Northwest Territories (NWT) at Longitude 63° 26’ North and Latitude 109° 12’ West. The Project is about 140 kilometres (km) northeast of the nearest community, Łutselk’e, and 280 km northeast of Yellowknife, as shown at the beginning of Section 11 (Figure 11.1-1).

The Project is located within an area that is transitional from boreal to tundra conditions (Scott 1995; Bliss 2000). A distinction between boreal-like and tundra-like vegetation can be determined based on ecoclimatic zones (or "ecozones"). Ecozones are subdivided into relatively homogenous ecoregions based on additional biophysical attributes (Wiken 1986; Environment Canada 2004, internet site). The Project is associated with two ecoregions (Canadian Biodiversity 2005, internet site; CCEA 2005, internet site (Ecosystem Classification Group 2008):

- Mackay Lake High Subarctic (HS) Ecoregion, which is within the Western Taiga Shield Ecozone; and
- Takijuq Lake Ecoregion, which is within the Southern Arctic Ecozone.

Table 11.7-1 Terms of Reference Pertaining to Vegetation

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
3.1.3 Existing Environment: Development Location	Describe the physical location of the proposed development (with maps), including ecozone(s) and ecoregion(s)	11.7.1.3, 11.7.2.1
3.1.3 Existing Environment: Physical Environment	Describe the bedrock and subsurface conditions, including: - bedrock type, depth, and composition	Appendix 11.7.I
	Describe the surficial materials and soils, including: - unconsolidated materials and terrain types, including thickness - land forms, including bogs, fens, and peat plateaus - soil types, including groups, series, and type	Appendix 11.7.I
	Describe the bedrock and subsurface conditions, including: - locations, type of materials, size and depth of deposit - permafrost and ice conditions within deposits including discussion of material stability - quantity and availability of granular materials	Appendix 11.7.I
	Describe areas of potential instability, including: - areas of geological instability, geological hazard, and seismicity	Appendix 11.7.I
3.1.3 Existing Environment: Vegetation	Describe vegetation types in the Project area (including a map and any classification systems relevant to the area).	11.7.2
	Describe species present in the Project area and identification of any species that are valued or rare.	11.7.2.3
	Describe baseline levels of contamination of local vegetation including lichen indicator species.	11.7.2.3.5
	Describe the existing natural fire regime, including frequency and past events.	11.7.2.1
5.2.12 Biophysical Subjects of Note: Vegetation	Include an assessment of the probability of introducing any foreign, parasitic, or invasive species, as well as management options in the case of such an introduction.	11.7.3.4
	Address the potential of dust (from lake bed or exposed surfaces, including roads) to adversely affect vegetation by changing snow melt and plant phenology, or by any other means.	11.7.4
	Any effects of dust on wildlife (as a result of changes to vegetation) must be described.	11.7.5
7 (7-4) Other Issues	Remaining issues pertaining to vegetation include:	
	- increase in invasive species	11.7.3.4
	- impacts from increased dust on vegetation	11.7.3.4
	- stress to rare plant populations	11.7.4.1.2

Table 11.7-1 Terms of Reference Pertaining to Vegetation (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
3.2.7 Follow-up Programs	The EIS must include a description of any follow up programs, contingency plans, or adaptive management programs the developer proposes to employ before, during, and after the proposed development, for the purpose of recognizing and managing unpredicted problems. The EIS must explain how the developer proposes to verify impact predictions. The impact statement must also describe what alternative measures will be used in cases were a proposed mitigation measure does not produce the anticipated result.	11.7.10

Source: *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Gahcho Kué Panel 2007).

11.7.1.3.2 Study Area Selection

The Terms of Reference for this subject of note did not specify a geographic study area for vegetation. However, to assess the potential effects of the Project on vegetation, it is necessary to define appropriate spatial boundaries (Section 6.4.1). The selection of baseline vegetation study areas was based on two criteria:

- expected extent of Project-related effects; and
- expected extent of the Project in combination with other developments in the region.

11.7.1.3.3 Vegetation Study Areas

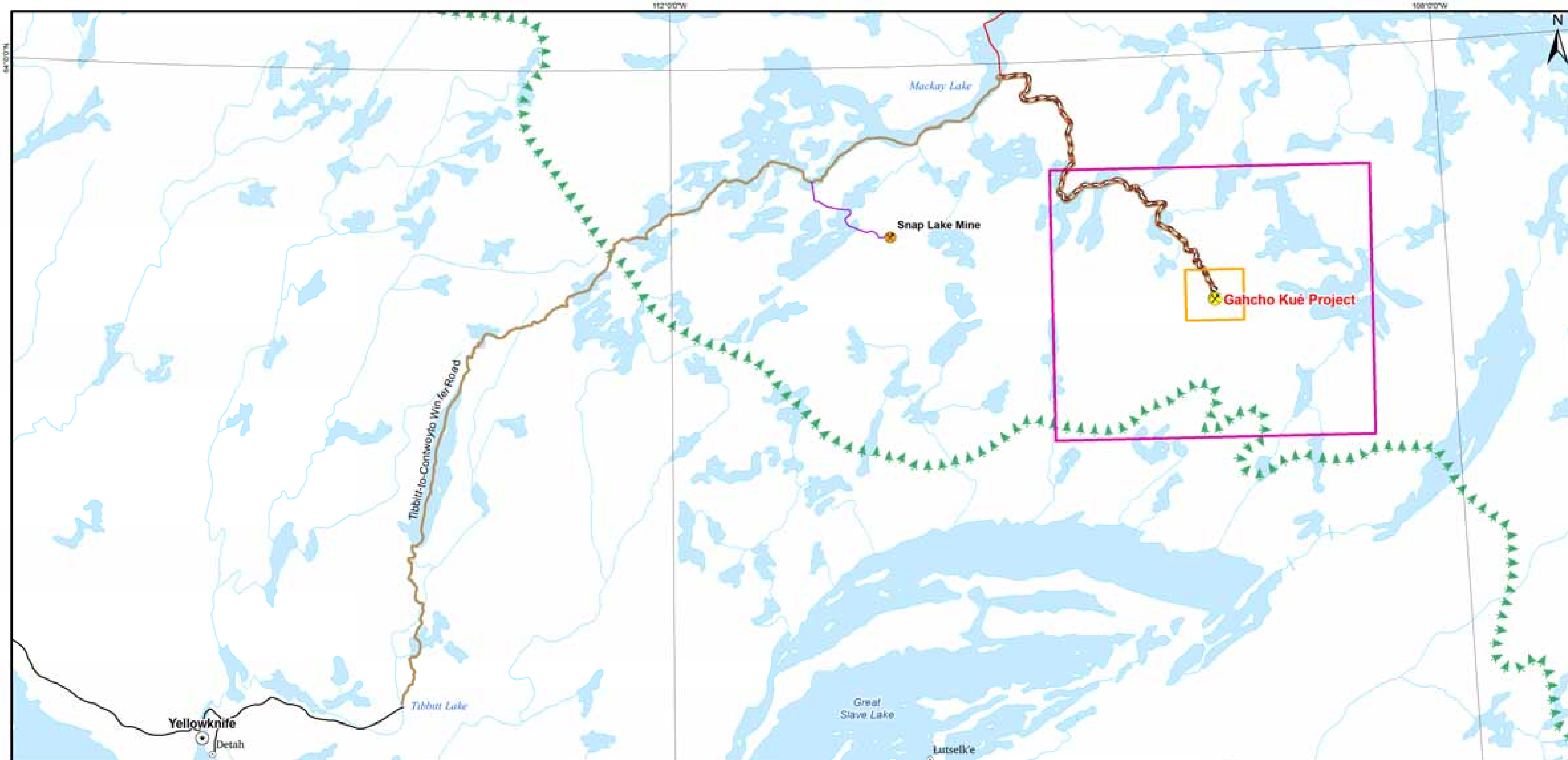
The Subject of Note: Vegetation was completed within the following spatial boundaries:

- portion of Tibbitt-to-Contwoyto Winter Road from Tibbitt Lake to MacKay Lake;
- Winter Access Road Study Area;
- Regional Study Area (RSA);
- Local Study Area (LSA).

The LSA used for the effects assessment has not changed from that used for the baseline study. The RSA for the subject of note includes the baseline RSA. The Winter Access Road to its junction with the Tibbitt-to-Contwoyto Winter Road is defined and evaluated separately from the baseline RSA. The vegetation study areas for the Subject of Note: Vegetation, are shown in Figure 11.7-1.

Regional Study Area

The RSA is approximately 5,700 km^2. This RSA boundary was chosen as a biophysical area that would capture larger-scale potential indirect effects from the Project. The RSA is also the scale used to determine cumulative effects from adjacent land use activities.



LEGEND

- Gahcho Kué Project
- Existing Mine
- Territorial Capital
- Populated Place
- Highway
- Existing Winter Road
- Tibbitt to Contwoyto Winter Road
- Winter Access Road
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Treeline
- Local Study Area
- Regional Study Area
- Tibbitt-to-Contwoyto Winter Road and Winter Access Road Study Area

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Vegetation Study Areas

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83
Scale: 1:1,000,000 (20 10 0 20 Kilometres)	
FILE No: SON-11.6-001-GIS	DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 4
OFFICE: GOLD-SAS	DRAWN: ANK / CHECK: JV

De Beers Canada

Figure: 11.7-1

The Winter Access Road from the Project to the junction with the Tibbitt-to-Contwoyto Winter Road at MacKay Lake crosses the RSA, but the northwest corner of the RSA is also extended to include the remainder of the Winter Access Road. The Winter Access Road Study Area comprises a 500 metre (m) buffer on either side of the route and covers an area of 12,004 hectares (ha). The 500 m buffer on either side of the road alignment was based on previous studies by EBA Engineering Consultants Ltd. (EBA) for the Tibbitt-to-Contwoyto Winter Road (EBA 2002).

Local Study Area

The LSA for the Subject of Note: Vegetation is 19,500 ha and corresponds with the boundaries established for the wildlife baseline LSA (Annex F). The boundaries were chosen based on the area that may be influenced by the Project, and where the majority of direct Project-related effects will likely occur. The LSA also is intended to capture small-scale indirect effects, such as dust deposition.

11.7.1.4 Content

Section 11.7 provides details of the impact analysis and assessment related to vegetation. The headings in Section 11.7 are arranged according to the sequence of steps in the assessment. The following briefly describes the content under each heading of this subject of note.

- **Existing Environment** summarizes baseline information for vegetation, including the general environmental setting in which the Project occurs, methods used to collect baseline vegetation data, and the baseline results for vegetation (Section 11.7.2).
- **Pathway Analyses** identifies all the potential pathways by which the Project could affect vegetation, and provides a screening level assessment of each identified pathway after applying environmental design features and mitigation that should reduce or eliminate these effects (Section 11.7.3).
- **Effects to Vegetation Ecosystems and Plants** explains the scientific methods that were used to predict residual effects to vegetation (including species at risk and traditional use plants) as a result of the Project and presents the results (Section 11.7.4).
- **Related Effects to Wildlife** explains the residual effects to wildlife related to vegetation as a result of the Project (Section 11.7.5).
- **Residual Effects Summary** summarizes the residual effects to vegetation that are predicted to remain after all environmental design features and mitigation to eliminate or reduce negative effects has been incorporated into the Project design (Section 11.7.6).

- **Residual Impact Classification** describes methods used to classify residual effects, and summarizes the classification results (Section 11.7.7).
- **Environmental Significance** summarizes the overall impacts from the Project on vegetation, and considers the entire set of pathways to evaluate the significance of impacts from the Project on vegetation (Section 11.7.8).
- **Uncertainty** discusses sources of uncertainty surrounding the predictions of effects to vegetation (Section 11.7.9).
- **Monitoring and Follow-up** describes monitoring programs, contingency plans, and adaptive management strategies related to vegetation (Section 11.7.10).
- **References** lists all documents and other material cited in the text in this section (Section 11.7.11).
- **Glossary, Acronyms, and Units** explains the meaning of scientific, technical, or other uncommon terms used in this section. In addition, acronyms and abbreviated units are defined (Section 11.7.12).

11.7.2 Existing Environment

11.7.2.1 General Setting

The Project is located within an area that is transitional between boreal and tundra conditions (Scott 1995; Bliss 2000). A distinction between boreal-like and tundra-like vegetation can be made based on ecoclimatic zones (or “ecozones”). Ecozones are broad geographical units defined according to general climate, vegetation, and terrain conditions (EcoRegions Working Group 1989). Ecozones are subdivided into relatively homogenous ecoregions based on additional biophysical attributes (Environment Canada 2004; Wiken 1986).

The Project is associated with two ecozones and two ecoregions. The RSA and Winter Access Road Study Area are both situated largely within the Taiga Shield Ecozone and corresponding MacKay Upland HS Ecoregion (Ecosystem Classification Group 2008). To the northern end of these study areas, portions fall within the Southern Arctic Ecozone and Takijuq Lake Ecoregion. The LSA is fully within the Taiga Shield Ecozone and Mackay Upland HS Ecoregion.

The boundary between the Taiga Shield Ecozone and Southern Arctic Ecozone represents the approximate limit of tree growth in the north. Tree cover becomes increasingly discontinuous, forming lichen woodlands and eventually open arctic tundra.

The Mackay Lake HS Ecoregion is topographically variable with level to gently rolling terrain except in the southeast along the East Arm of Great Slave Lake (Ecosystem Classification Group. 2008). Lakes are common in the lowlands, while rock outcrops are common in the uplands. Dystric Brunisols with Turbic, Static, and Organic Cryosols are the dominant soils (see Annex D for definitions). Permafrost, continuous and discontinuous, is common in this ecoregion (Environment Canada 2004, internet site; CCEA 2005, internet site).

The most common upland cover types are shrub tundra and open spruce woodlands. Other vegetation includes dwarf birch (*Betula glandulosa* Michx.), mountain cranberry *(Vaccinium vitis-idaea* L.*)*, northern Labrador tea (*Ledum palustre* L.), common Labrador tea *(Ledum groenlandicum* Oder*)* red bearberry *(Arctostaphylos rubra*), black crowberry *(Empetrum nigrum* L. ssp.*)* and lichens (Ecosystem Classification Group 2008).

The terrain of the Takijuq Lake Upland Ecoregion consists of broad, sloping uplands, plateaus, and lowlands. Unvegetated rock outcrops are common on upland terrain while lakes are common in the lowlands. Turbic and Static Cryosols are associated on upland sites with sandy, morainal, and glaciofluvial parent soil materials, while Organic Cryosols are the dominant lowland soils (Environment Canada 2004; CCEA 2005).

The vegetation of the Takijuq Lake Upland Ecoregion is also part of the tundra boreal forest transition, and is characterized by scrub birch, willows, northern Labrador tea (*Ledum palustre)*, and blueberries (*Vaccinium* spp.). Depressions and lowland habitats are dominated by willows, sphagnum mosses (*Sphagnum* spp.), and sedge tussocks. Isolated stands of spruce are present at the southern boundary of this ecoregion (Environment Canada 2004; CCEA 2005).

The fire history of the area was assessed using the Canadian Large Fire Database of the Canadian Forest Service (2007). The Canadian Large Fire Database represents a compilation of provincial and territorial fire reports for all fires greater than 200 ha that have occurred in Canada since the 1950s. Two fires were recorded within the southernmost portion of the RSA, one from 1973 (705 ha) and one from 1989 (250 ha). Within 100 km of the RSA boundary, a total of 34 fires have been documented. They range in size from 200 to 25,000 ha and date back to 1960 (with the most recent being from 1994). The 25,000 ha fire occurred in 1994 and was located approximately 40 km to the southwest of the RSA boundary. Two other large fires occurred approximately 70 km directly south of the RSA boundary, and were 15,000 ha (in 1994) and 24,000 ha (in 1976) in size. Fires are infrequent in the vicinity of the Project, largely because it is situated at the northern extent of the treeline. Further north within the Southern Arctic Ecozone, fires become even less frequent.

11.7.2.2 Methods

Baseline soils and vegetation studies for the Project used a variety of mapping and field survey methods. A complete description of the methods, databases, existing vegetation, and rare plant and plant community occurrences is provided in Annex E.

Terrestrial surveys were conducted within the LSA, RSA, and Winter Access Road Study Area during July and August 2004, and July 2005. For baseline studies, the Winter Access Road Study Area included a 500 m buffer on each side of the road from Kennady Lake to the edge of the RSA. Terrain, soils, and vegetation data were collected at three levels of detail:

- detailed plots (comprehensive level for terrain, soil, and vegetation information);
- ground inspection forms (intermediate reconnaissance level); and
- visual plots (map polygon confirmation level).

The Ecological Landscape Classification (ELC) method used for the Project followed the British Columbia terrestrial ecosystem mapping (TEM) approach for sampling design, data collection, and mapping (RIC 1998). The ELC mapping scheme for the LSA also conformed to previous ELC mapping for the Ekati Mine (Rescan Environmental Consultants Ltd. 1995) and the Tibbitt-to-Contwoyto Winter Road projects (EBA 2002).

Mapped polygons were identified that contained either a single ecosystem type (termed “simple”), two ecosystem types (termed “complex”) or three ecosystem types (termed “very complex”). The proportion of a polygon occupied by any one ecosystem type is termed a “decile” and is measured in tenths (RIC 1998). The leading ecosystem type (i.e., the one covering the highest proportional area within a polygon) is commonly referred to as the dominant ecosystem type.

Mapping for the RSA and Winter Access Road Study Area followed the land cover mapping approach used by Matthews et al. (2001). The approach involves mapping broad ecosystem units (BEUs) at an intermediate level of resolution (25 m x 25 m raster cell size), assisted by satellite image analysis and classification. The wildlife baseline (Annex E) mapped BEUs in vector format, while this section of the EIS mapped BEUs in raster format. The use of raster format is required for fragmentation analysis, and decreases the computer processing time for wildlife habitat modeling. Some minor differences in the areas of individual BEU classes resulted from converting the vector coverage to the raster coverage. However, this was expected and does not affect the assessment results.

Sampling intensities conformed to "Level 4" TEM mapping recommendations (RIC 1998). A total of 34 detailed plots, 156 ground inspection forms (GIFs), and 266 visuals were completed within the LSA. One detailed plot, 16 GIFs, and 195 visuals were completed within the RSA. A total of three detailed plots, 14 GIFs, and 38 visuals were completed within the Winter Access Road Study Area. Samples were pooled where the areas of the LSA, RSA, and Winter Access Road Study Area overlapped.

IKONOS™ imagery and black and white aerial photography were reviewed in advance of field sampling in 2004. Proposed sampling locations were then identified based on a stratification of pre-typed ecosystem types. The ELC field sampling program was designed so that each of the ecosystem types present in the respective study areas received a level of sampling effort proportional to their coverage.

Vegetation data collected within detailed and GIF plots included estimates of plant species abundance (as percent cover) and tree mensuration (e.g., age, height, diameter at breast height [DBH]) data. Site information collected in association with detailed, GIF, and visual plots included: slope, aspect, elevation, slope position, structural stage, successional stage, exposure, microtopography, and coarse woody debris. Additional terrain and soil data were collected within both the detailed and GIF plots.

Rare plant surveys were undertaken in 2004 and 2005 within the proposed Project footprint. Habitats with limited distribution due to the presence of uncommon terrain features within the LSA were sampled as well. A complete list of plant species was compiled for each site using patterned and meander searches.

Data collected as part of the ELC investigations contributed to the assessment of biodiversity within the LSA. The ELC mapping of the LSA provided the spatial information required for the calculation of various map-based metrics that help to describe the complexity of the LSA. The ELC field plot data were used in the calculation of two diversity indices (species richness and species evenness), which also helped to describe diversity of the LSA at a finer scale.

Metal and chemical concentrations in soils and plants within the LSA were analyzed. Plant species were selected based on:

- their broad occurrence in the area;
- their value for human and/or wildlife consumption; and
- their value as "natural" recolonizing species and/or potential reclamation species.

11.7.2.3 Results

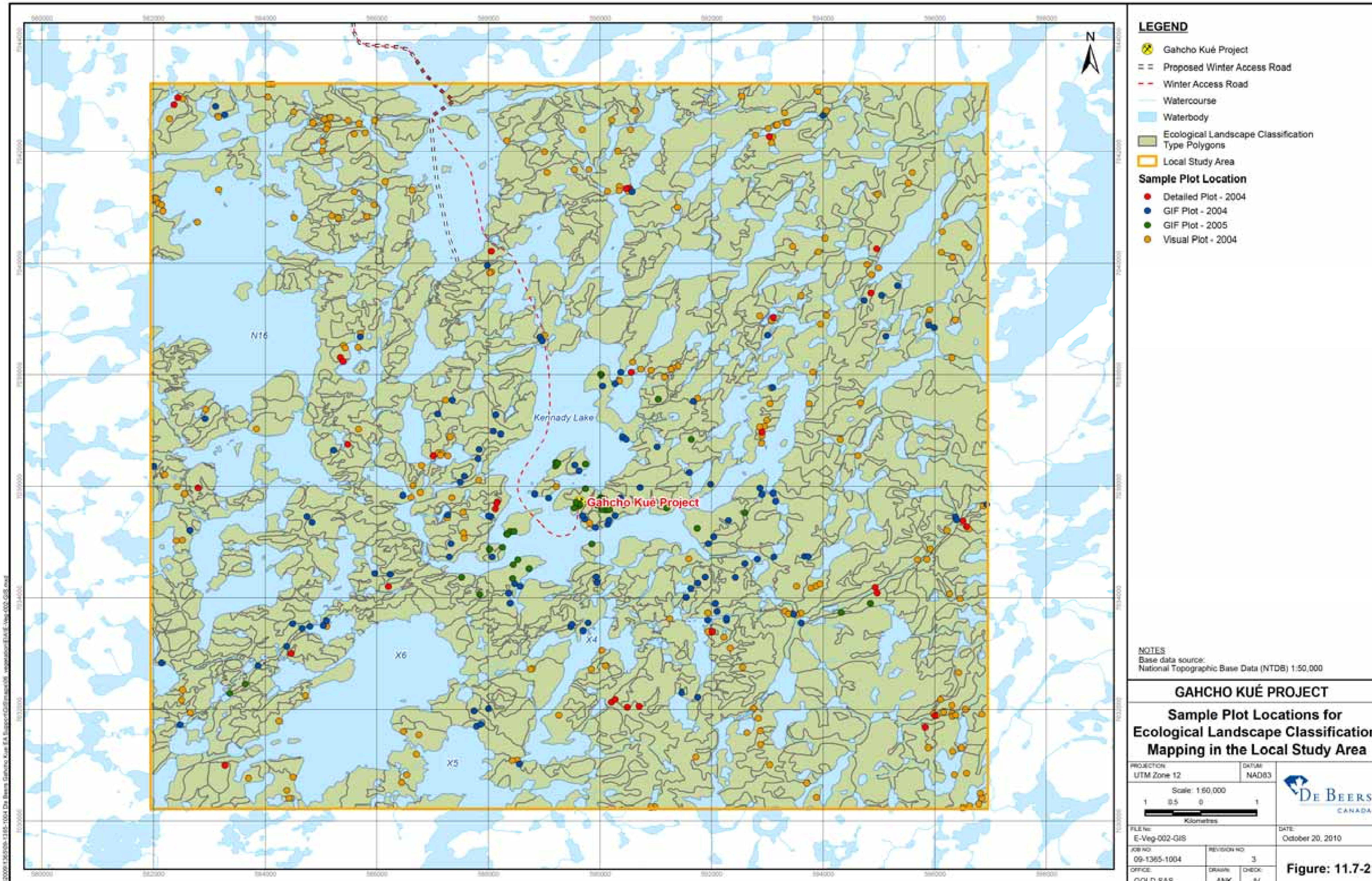
11.7.2.3.1 Ecosystem Types

The LSA contains 1,307 ELC polygons (with 2,785 corresponding deciles), of which 35.4 percent (%) were visited during sampling (Table 11.7-2; Figure 11.7-2). The sampling program satisfied the “Level 4” TEM survey intensity requirements (RIC 1998). A total of 197 plant and lichen species were identified during field sampling including four trees, 33 shrubs, 38 forbs, eight rushes, 32 sedges, ten grasses, 35 mosses, two liverworts, and 35 lichens.

Table 11.7-2 Numbers of Detailed, Ground Inspection Form, and Visual Plots Associated with Ecosystem Types in the Local Study Area

Ecological Landscape Classification (ELC)		Detailed Plots	Ground Inspection Form	Visual Plots	Total Plots
Code	**Name**				
Upland Class					
BE	Scrub Birch – Crowberry Tundra	1	36	35	72
BF	Boulderfield (sparsely vegetated)	-	1	2	3
BL	Scrub Birch – Labrador Tea Tundra	9	41	68	118
PE	Spruce – Lichen Woodland	2	6	7	15
RO	Rock Outcrop	-	-	4	4
SS	Saxifrage – Moss Campion Xerophytic Tundra	2	15	5	22
Wetland/Riparian Class					
BC	Scrub Birch – Bluejoint Shrub Tundra	2	2	9	13
BR	Scrub Birch – Cloudberry Low Shrub Tundra	5	22	48	75
CA	Water Sedge – Narrow-leaved Cottongrass Fen	1	7	13	21
CE	Round-Fruited Sedge – Chamisso's Cottongrass Fen	1	1	7	9
EA	Sheathed Cottongrass – Bog Rosemary Sedge Fen	2	12	39	53
EM	Water Sedge – Horsetail Shallow Shore Marsh	1	-	1	2
FA	Floating Aquatic – Shallow Open Water	1	2	1	4
RB	Scrub Birch – Riparian Shrub	-	-	-	-
SH	Willow – Sedge Low Shrub Fen	1	-	-	1
SR	Willow – Nagoonberry Shrub	5	6	18	29
Water Class					
LA	Lake	-	-	-	-
PD	Pond (water greater than 2 m deep and less than 50 ha in size)	-	-	-	-
OW	Shallow Open Water (water less than 2 m deep)	-	-	-	-
Disturbance Class					
RP	Road	-	-	-	-
RR	Camp (anthropogenic)	-	-	-	-
Total		**33**	**151**	**257**	**441**

ha = hectare; m = metre; - = not applicable.



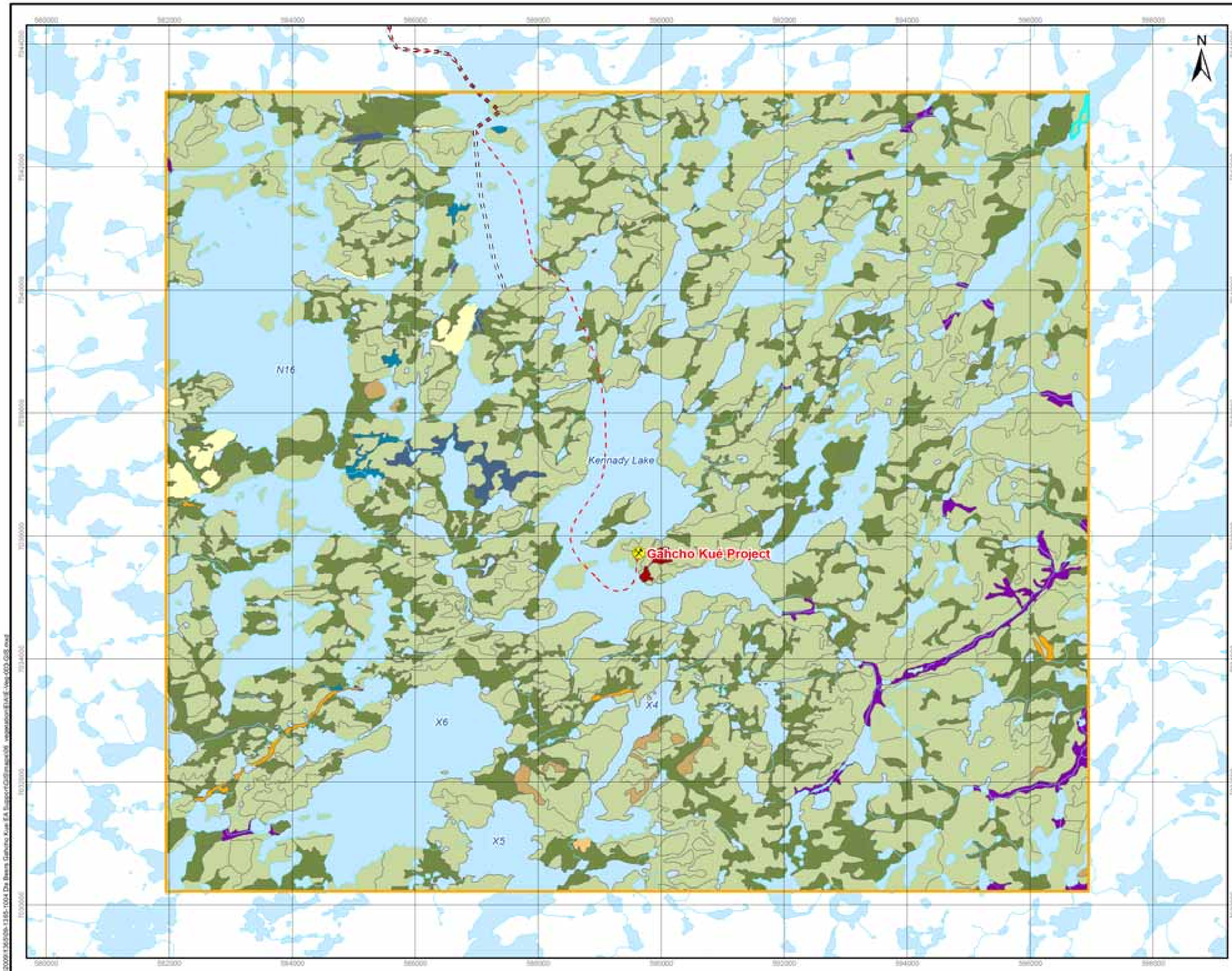
N16
Kennady Lake
Gahcho Kué Project
X4
X6
X5
N
LEGEND
Gahcho Kué Project
Proposed Winter Access Road
Winter Access Road
Watercourse
Waterbody
Ecological Landscape Classification Type Polygons
Local Study Area
Sample Plot Location
Detailed Plot - 2004
GIF Plot - 2004
GIF Plot - 2005
Visual Plot - 2004
NOTES
Base data source:
National Topographic Base Data (NTDB) 1:50,000
GAHCHO KUÉ PROJECT
Sample Plot Locations for Ecological Landscape Classification Mapping in the Local Study Area
PROJECTION: UTM Zone 12
DATUM: NAD83
Scale: 1:60,000
1 0.5 0 1
Kilometres
DE BEERS CANADA
FILE No: E-Veg-002-GIS
DATE: October 20, 2010
JOB NO: 09-1365-1004
REVISION NO: 3
OFFICE: GOLD-SAS
DRAWN: ANK
CHECK: JV
Figure: 11.7-2

Dominant ecosystem types are those that occur as single ecosystems in simple polygons or as the leading ecosystem type in complex (two ecosystem types) or very complex (three ecosystem types) polygons. The spatial distribution of dominant ecosystem types and open water conditions is illustrated in Figure 11.7-3.

Data describing the cover and abundance of ecosystem types within the LSA are listed in Table 11.7-3. Several ecosystem types (the Scrub Birch – Cloudberry Low Shrub Tundra [BR], Sheathed Cottongrass – Bog Rosemary Sedge Fen [EA], Round-Fruited Sedge – Chamisso's Cottongrass Fen [CE], Water Sedge – Narrow-leaved Cottongrass Fen [CA], Scrub Birch – Bluejoint Shrub Tundra [BC], and Willow – Nagoonberry Shrub [SR] and Scrub Birch – Riparian Shrub [RB] units) are associated with wetlands or riparian areas, and are considered more sensitive to disturbance. Seven ecosystem types (Boulderfield (sparsely vegetated) [BF], Saxifrage – Moss Campion Xerophytic Tundra [SS], Scrub Birch – Crowberry Tundra [BE], Scrub Birch – Labrador Tea Tundra [BL], Spruce – Lichen Woodland [PE], Lake (open water) [LA], Camp (anthropogenic) [RR]), some of which are wetlands and riparian associations, cover less than 1% of the LSA.

Due in part to landscape variability, a number of ecosystem polygons were mapped as complex (i.e., containing two ecosystem types) or very complex (i.e., containing three ecosystem types). Of the 1,307 polygons (2,785 deciles) mapped, 433 were simple polygons, 270 were complex, and 604 were very complex. The distribution of simple, complex and very complex polygons is summarized in Table 11.7-3.

The most common ecosystems that formed complexes with others were the Scrub Birch – Labrador Tea Tundra (BL) and Scrub Birch – Cloudberry Low Shrub Bog (BR) ecosystem types. The greater number of complex units in these ecosystems is due, in part, to the high coverage they have within the LSA. The distribution of simple, complex and very complex polygons is illustrated in Figure 11.7-4.



LEGEND

- Gahcho Kué Project
- Proposed Winter Access Road
- Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Dominant Ecological Landscape Classification

- BC - Scrub Birch – Bluejoint Shrub Tundra
- BE - Scrub Birch – Crowberry Tundra
- BL - Scrub Birch – Labrador Tea Tundra
- BR - Scrub Birch – Cloudberry Low Shrub Bog
- CA - Water Sedge – Narrow-leaved Cottongrass Fen
- CE - Round-fruited Sedge – Chamisso's Cottongrass Fen
- EA - Sheathed Cottongrass – Bog-rosemary Sedge Fen
- LA - Lake
- PE - Spruce – Lichen Woodland
- RR - Rural/Camp
- SR - Willow – Nagoonberry Shrub
- SS - Saxifrage – Moss Campion Xerophytic Tundra

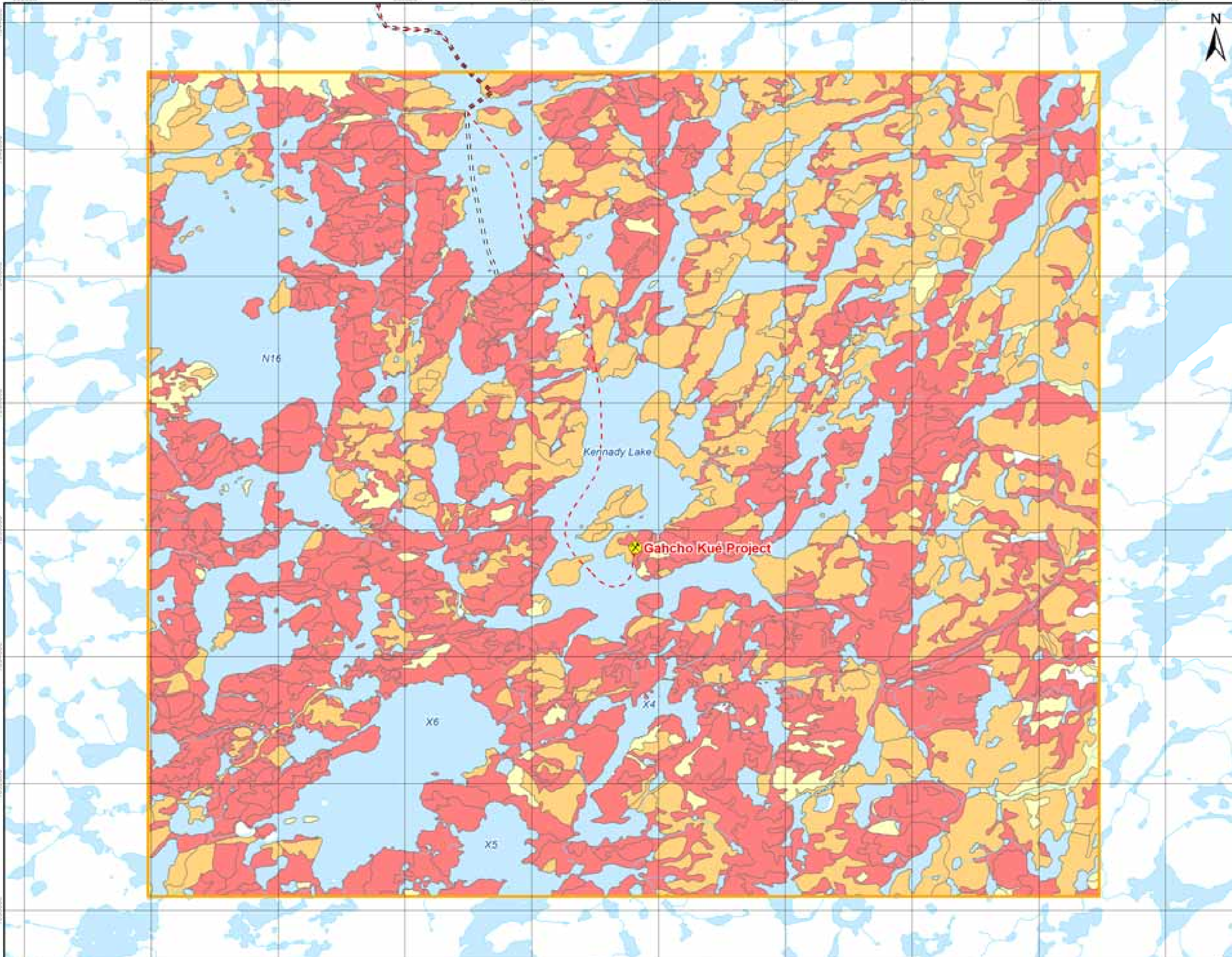
NOTES
Base data source:
National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Dominant Ecological Landscape Classification in the Local Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:60,000 (1 0.5 0 1 Kilometres)	DE BEERS CANADA
FILE No: E-Veg-003-GIS	DATE: October 19, 2010
JOB NO: 09-1365-1004	REVISION NO: 2
OFFICE: GOLD-SAS	DRAWN: ANK CHECK: JV

Figure: 11.7-3



LEGEND

- Gahcho Kué Project
- Proposed Winter Access Road
- Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Complex Ecological Landscape Classification

- Simple
- Complex
- Very Complex

NOTES
Base data source:
National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Complex Ecological Landscape Classification Type Polygons in the Local Study Area

PROJECTION: UTM Zone 12		DATUM: NAD83	DE BEERS CANADA
Scale: 1:60,000 (1 0.5 0 1 Kilometres)			
FILE No: E-Veg-004-GIS			DATE: October 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 2		**Figure : 11.7-4**
OFFICE: GOLD-SAS	DRAWN: ANK	CHECK: JV	

Table 11.7-3 Distribution of Simple, Complex, and Very Complex Ecosystem Polygons in the Local Study Area

Ecological Landscape Classification (ELC)		Area	Percent of LSA	Total Number of Deciles	Mean Polygon Size[a]	Simple (1 Ecosystem/ Polygon)		Complex (2 Ecosystems/ Polygon)		Very Complex (3 Ecosystems/ Polygon)	
						Area	Number of Deciles	Area	Number of Deciles	Area	Number of Deciles
Code	Name	(ha)	(%)	(#)	(ha)	(ha)	(#)	(ha)	(#)	(ha)	(#)
Upland Class											
BF	Boulderfield (sparsely vegetated)	5.4	<0.1	4	1.4	0.0	0	0.5	1	4.9	3
SS	Saxifrage – Moss Campion Xerophytic Tundra	26.3	0.1	14	1.9	0.0	0	14.8	9	11.5	5
BE	Scrub Birch – Crowberry Tundra	295.9	1.5	97	3.1	0.0	0	39.1	20	256.8	77
BL	Scrub Birch – Labrador Tea Tundra	6,951.1	35.6	663	10.5	385.7	61	3,666.9	248	2,898.5	354
PE	Spruce – Lichen Woodland	88.5	0.5	24	3.7	38.4	6	11.1	4	39.1	14
	upland class subtotal	*7,367.4*	*37.8*	*802*	*9.2*	*424.0*	*67*	*3,732.4*	*282*	*3,210.9*	*453*
Wetland/Riparian Class											
CE	Round-Fruited Sedge – Chamisso's Cottongrass Fen	610.1	3.1	222	2.7	1.9	1	1.6	1	606.6	220
BC	Scrub Birch – Bluejoint Shrub Tundra	15.5	0.1	15	1.0	0.0	0	0.0	0	15.5	15
BR	Scrub Birch – Cloudberry Low Shrub Tundra	4,009.6	20.6	818	4.9	9.2	6	1,345.0	233	2,655.4	579
RB	Scrub Birch – Riparian Shrub	89.0	0.5	42	2.1	1.2	1	28.4	10	59.4	31
EA	Sheathed Cottongrass – Bog Rosemary Sedge Fen	1,417.4	7.3	472	3.0	0.0	0	16.6	9	1,400.8	463
CA	Water Sedge – Narrow-leaved Cottongrass Fen	47.4	0.2	23	2.1	15.1	9	2.4	1	29.9	13
SR	Willow – Nagoonberry Shrub	166.1	0.9	56	3.0	64.5	14	14.4	4	87.2	38
	wetland/riparian class subtotal	*6,355.2*	*32.6*	*1,648*	*3.9*	*91.9*	*31*	*1,408.5*	*258*	*4,854.8*	*1,359*
Water Class											
LA	Lake (open water)	5,767.9	29.6	334	17.3	5,767.9	334	0.0	0	0.0	0
	water class subtotal	*5,767.9*	*29.6*	*334*	*17.3*	*5,767.9*	*334*	*0.0*	*0*	*0.0*	*0*
	ELC subtotal	*19,490.5*	*100.0*	*2,784*	*7.0*	*6,283.8*	*432*	*5,140.9*	*540*	*8,065.7*	*1,812*
Disturbance Class											
RR	Camp (anthropogenic)	9.3	<0.1	1	9.3	9.3	1	0.0	0	0.0	0
	disturbance subtotal	*9.3*	*<0.1*	*1*	*9.3*	*9.3*	*1*	*0.0*	*0*	*0.0*	*0*
Total		**19,499.8**	**100.0**	**2,785**	**7.0**	**6,293.2**	**433**	**5,140.9**	**540**	**8,065.7**	**1,812**

[a] Mean polygon size is based on the proportional size of the ELC unit within a polygon as individual polygons may contain up to three ELC units.

Note: Due to rounding, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent; < = less than; LSA = Local Study Area.

11.7.2.3.2 Broad Ecosystem Units

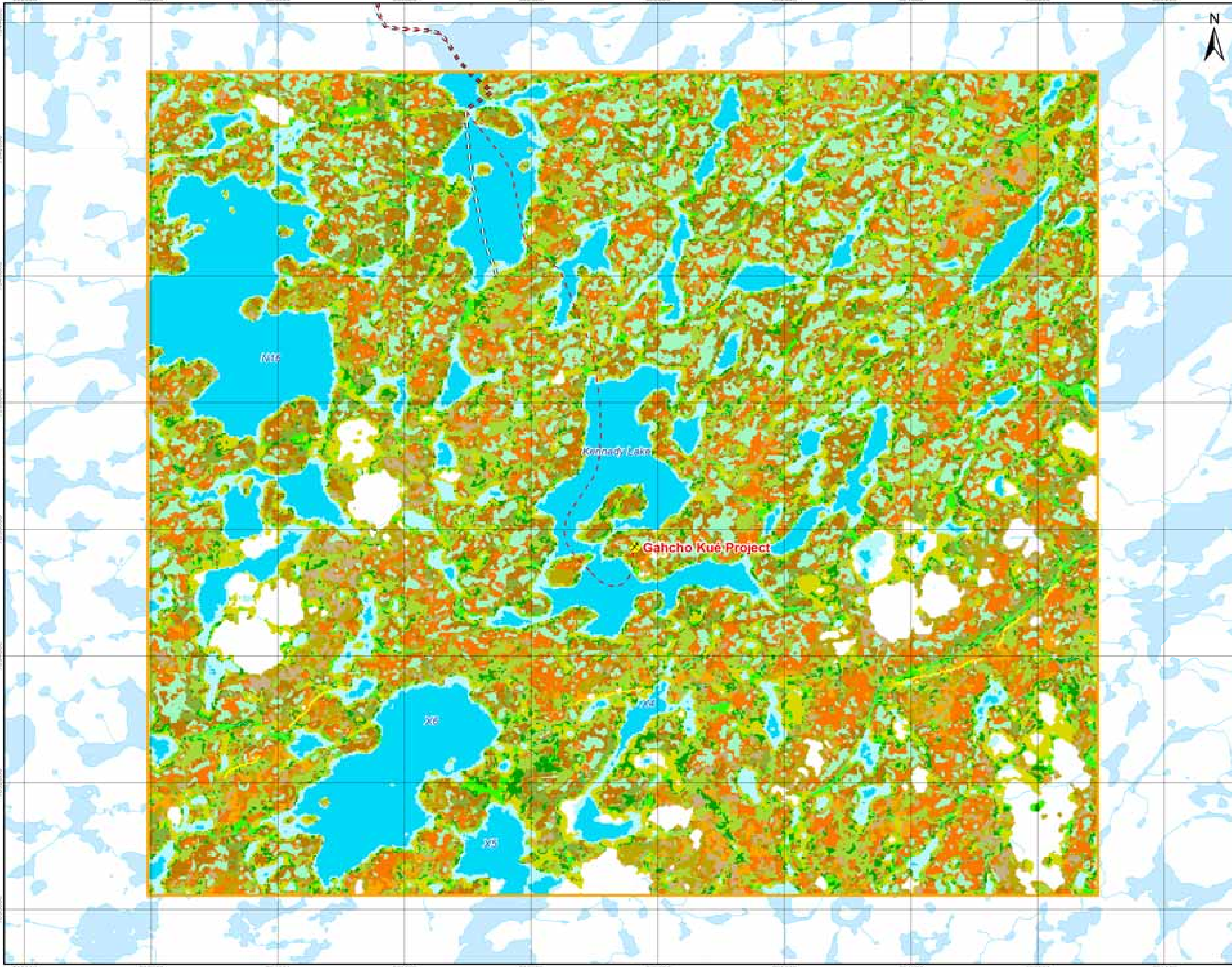
Fifteen BEUs were identified within the LSA (Figure 11.7-5). Mapped BEUs included seven upland classes, five wetland/riparian classes, two water classes, and one unclassified unit. The BEUs with the greatest areal coverage are Deep Water (13.7%), Tussock/Hummock (Sedge Association) (11.1%), Peat Bog (10.6%), Heath Tundra (<30% Rock) (10.0%), Heath/Bedrock (30 to 80% Bedrock) (9.9%), and Sedge Wetland (9.4%) (Table 11.7-4).

Table 11.7-4 Distribution of Broad Ecosystem Units in the Local Study Area

Broad Ecosystem Unit Class		(ha)	% of LSA
Code	**Name**		
Upland Class			
BEAS	Bedrock Association (>80% Bedrock)	420.6	2.2
BOAS	Boulder Association (>80% Boulders)	551.9	2.8
ESCO	Esker Complex	20.0	0.1
HETU	Heath Tundra (<30% Rock)	1,942.4	10.0
HEBE	Heath/Bedrock (30 to 80% Bedrock)	1,923.1	9.9
HEBO	Heath/Boulders (30 to 80% Boulders)	1,150.2	5.9
SPFO	Spruce Forest	804.1	4.1
	upland class subtotal	*6,812.2*	*34.9*
Wetland/Riparian Class			
BISE	Birch Seep	767.9	3.9
PEBO	Peat Bog	2,074.3	10.6
TASH	Riparian Tall Shrub	727.2	3.7
SEWE	Sedge Wetland	1,831.0	9.4
TUHU	Tussock/Hummock (Sedge Association)	2,157.4	11.1
	wetland class subtotal	*7,557.8*	*38.8*
Water Class			
DEWA	Deep Water	2,668.1	13.7
SHWA	Shallow Water	1,618.7	8.3
	water class subtotal	*4,286.8*	*22.0*
Unclassified			
UC	Unclassified	843.1	4.3
	unclassified subtotal	*843.1*	*4.3*
Total		**19,499.8**	**100.0**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent.



LEGEND

- Gahcho Kué Project
- Winter Access Road
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Broad Ecosystem Unit

- Sedge Wetland
- Spruce Forest
- Heath Boulder
- Shallow Water
- Tall Shrub
- Peat Bog
- Boulder Association
- Deep Water
- Bedrock Association
- Tussock Hummok
- Heath Bedrock
- Birch Seep
- Esker Complex
- Heath Tundra
- Unclassified

NOTES
Base data source:
National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Broad Ecosystem Units in the Local Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:60,000 1 0.5 0 1 Kilometres		
FILE No: E-Veg-005-GIS		DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 2	Figure : 11.7-5
OFFICE: GOLD-SAS	DRAWN: ANK / CHECK: JV	

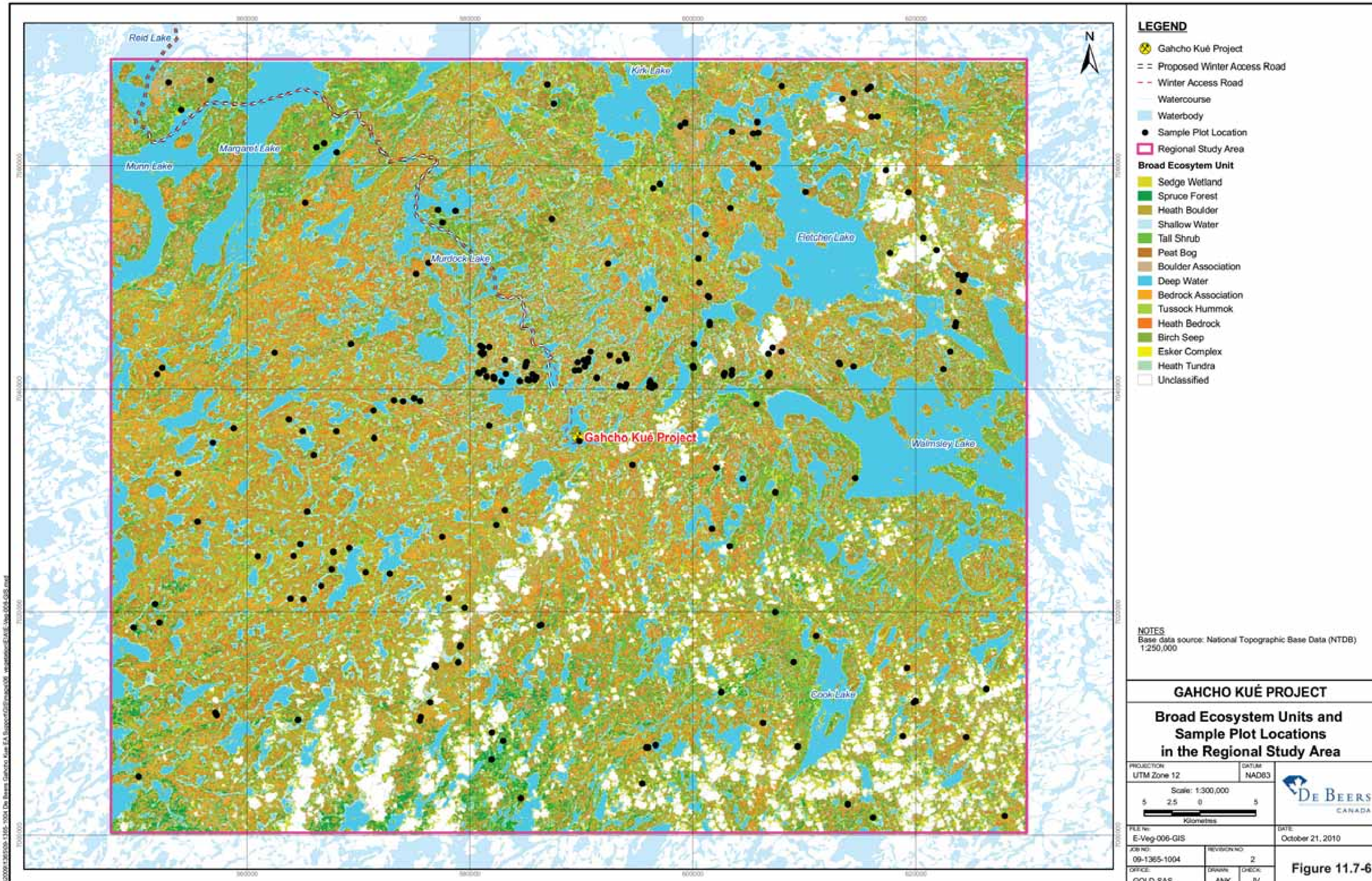
Fifteen BEUs were identified within the RSA (Figure 11.7-6). Mapped BEUs included seven upland classes, five wetland/riparian classes, two water classes, and one unclassified unit. The BEUs with the greatest areal coverage are Deep Water (DEWA) (17.0%), Sedge Wetland (SEWE) (9.9%), Tussock/Hummock (TUHU) (Sedge Association) (9.1%), Peat Bog (PEBO) (8.5%), Heath/Boulders (HEBO) (30 to 80% Boulders) (7.8%), and Heath/Bedrock (HEBE) (30 to 80% Bedrock) (6.8%) (Table 11.7-5).

Table 11.7-5 Distribution of Broad Ecosystem Units in the Regional Study Area

Broad Ecosystem Unit (BEU) Class		Number of Field Observations	Baseline	
Code	**Name**		**(ha)**	**% of RSA**
Upland Class				
BEAS	Bedrock Association (>80% Bedrock)	25	24,677.7	4.3
BOAS	Boulder Association (>80% Boulders)	4	18,928.6	3.3
ESCO	Esker Complex	12	621.4	0.1
HETU	Heath Tundra (<30% Rock)	16	24,353.7	4.3
HEBE	Heath/Bedrock (30 to 80% Bedrock)	19	38,570.3	6.8
HEBO	Heath/Boulders (30 to 80% Boulders)	31	44,502.4	7.8
SPFO	Spruce Forest	19	32,359.6	5.7
	upland class subtotal	*126*	*184,013.8*	*32.3*
Wetland Class				
BISE	Birch Seep	2	27,618.1	4.8
PEBO	Peat Bog	11	48,333.6	8.5
TASH	Riparian Tall Shrub	21	31,324.1	5.5
SEWE	Sedge Wetland	34	56,198.9	9.9
TUHU	Tussock/Hummock (Sedge Association)	10	51,645.7	9.1
	wetland class subtotal	*78*	*215,120.3*	*37.8*
Water Class				
DEWA	Deep Water	5	96,879.8	17.0
SHWA	Shallow Water	3	37,128.9	6.5
	water class subtotal	*8*	*134,008.7*	*23.5*
Unclassified				
UC	Unclassified	0	36,535.4	6.4
	unclassified subtotal	*0*	*36,535.4*	*6.4*
Total		**212**	**569,678.2**	**100.0**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent.


Reid Lake
Kirk Lake
Margaret Lake
Munn Lake
Murdock Lake
Fletcher Lake
Gahcho Kué Project
Walmsley Lake
Cook Lake
N
LEGEND
Gahcho Kué Project
Proposed Winter Access Road
Winter Access Road
Watercourse
Waterbody
Sample Plot Location
Regional Study Area
Broad Ecosytem Unit
Sedge Wetland
Spruce Forest
Heath Boulder
Shallow Water
Tall Shrub
Peat Bog
Boulder Association
Deep Water
Bedrock Association
Tussock Hummok
Heath Bedrock
Birch Seep
Esker Complex
Heath Tundra
Unclassified
NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000
GAHCHO KUÉ PROJECT
Broad Ecosystem Units and Sample Plot Locations in the Regional Study Area
PROJECTION: UTM Zone 12
DATUM: NAD83
Scale: 1:300,000
5 2.5 0 5
Kilometres
DE BEERS CANADA
FILE No: E-Veg-006-GIS
DATE: October 21, 2010
JOB NO: 09-1365-1004
REVISION NO: 2
OFFICE: GOLD-SAS
DRAWN: ANK
CHECK: JV
Figure 11.7-6

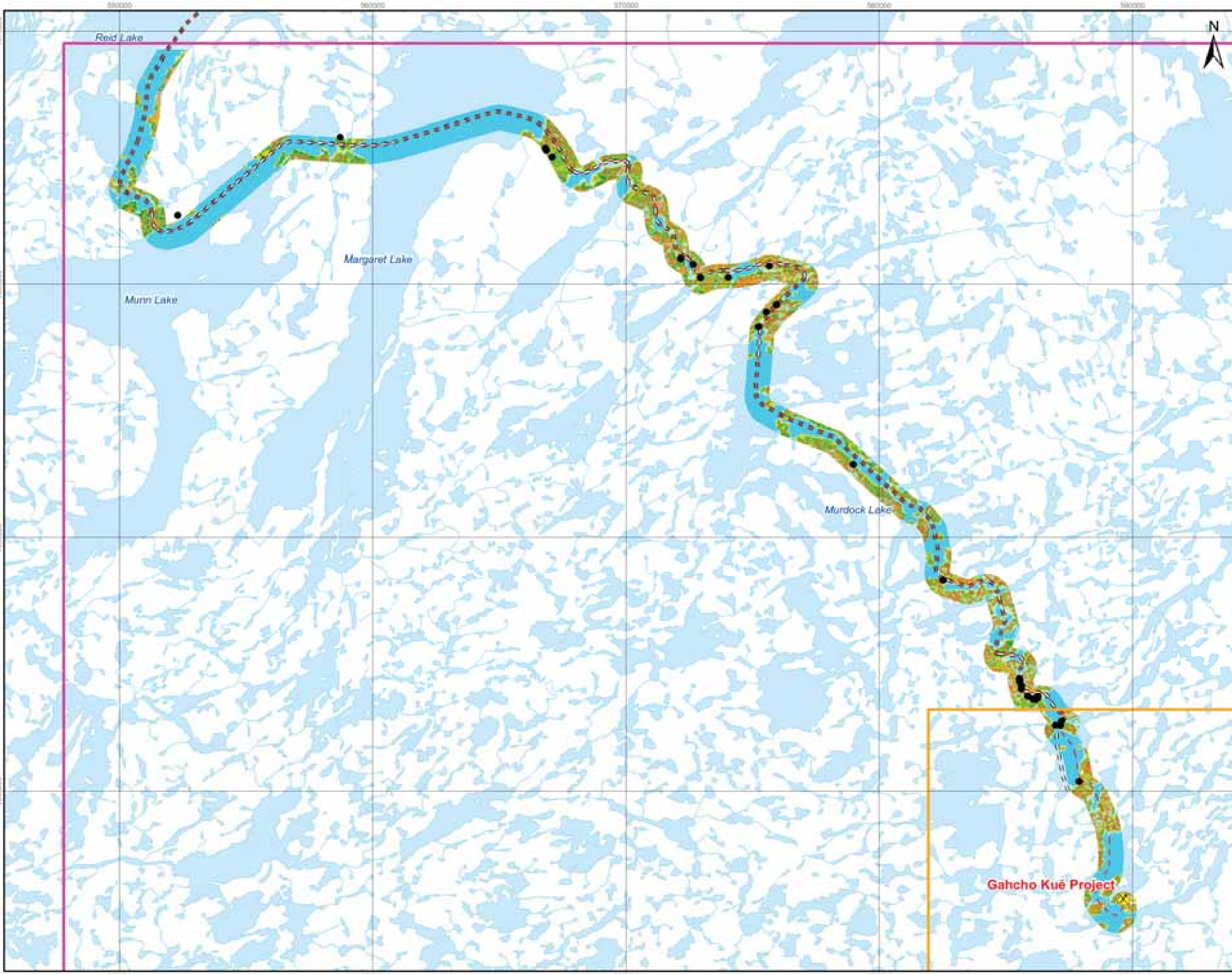
The Winter Access Road Study Area was classified into 15 BEUs (14 of which were mapped, including one unclassified map unit) (Figure 11.7-7, Table 11.7-6). Deep Water (DEWA) forms the vast majority (47.8%) of the Winter Access Road Study Area. Shallow Water (SHWA), Tussock-Hummock (TUHU), and Sedge Wetland (SEWE) associations are the next largest units, covering approximately 9.5, 6.5, and 5.7% of the Winter Access Road Study Area, respectively. Approximately 0.4% of the Winter Access Road Study Area could not be classified due to cloud cover.

Table 11.7-6 Distribution of Broad Ecosystem Units in the Winter Access Road Study Area

Broad Ecosystem Unit (BEU) Class		Area (ha)	% of Winter Access Road Study Area
Code	Name		
Upland Class			
BEAS	Bedrock Association (>80% Bedrock)	220.5	1.8
BOAS	Boulder Association (>80% Boulders)	92.3	0.8
ESCO	Esker Complex	84.1	0.7
HETU	Heath Tundra (<30% Rock)	607.2	5.1
HEBE	Heath/Bedrock (30 to 80% Bedrock)	386.1	3.2
HEBO	Heath/Boulders (30 to 80% Boulders)	425.5	3.5
SPFO	Spruce Forest	353.6	2.9
	upland class subtotal	2,169.3	18.1
Wetland/Riparian Class			
BISE	Birch Seep	489.0	4.1
PEBO	Peat Bog	587.3	4.9
TASH	Riparian Tall Shrub	362.8	3.0
SEWE	Sedge Wetland	684.8	5.7
TUHU	Tussock/Hummock (Sedge Association)	779.1	6.5
	wetland class subtotal	2,903.0	24.2
Water Class			
DEWA	Deep Water	5,735.7	47.8
SHWA	Shallow Water	1,145.7	9.5
	water class subtotal	6,881.4	57.3
Unclassified			
UC	Unclassified	50.0	0.4
	unclassified subtotal	50.0	0.4
Total		12,003.6	100.0

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent.



LEGEND

- Gahcho Kué Project
- Proposed Winter Access Road
- Winter Access Road
- Watercourse
- Waterbody
- Sample Plot Location
- Local Study Area
- Regional Study Area

Broad Ecosytem Unit

- Sedge Wetland
- Spruce Forest
- Heath Boulder
- Shallow Water
- Tall Shrub
- Peat Bog
- Boulder Association
- Deep Water
- Bedrock Association
- Tussock Hummok
- Heath Bedrock
- Birch Seep
- Esker Complex
- Heath Tundra
- Unclassified

NOTES

Base data source: National Topographic Base Data (NTDB) 1:250,000

GAHCHO KUÉ PROJECT

Broad Ecosystem Units and Sample Plot Locations in the Winter Access Road Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:150,000 (2 1 0 2 Kilometres)	DE BEERS CANADA
FILE No: E-Veg-007-GIS	DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-SAS	DRAWN: ANK
CHECK: JV	

Figure 11.7-7

Traditional Use Plants

Berries and medicinal plants are an important resource for the traditional land users of the area. A review of existing information, particularly *Habitats and Wildlife of Gahcho Kué and Katth'l Nene* (LKDFN 1999), identified the following plant species of interest, which are found in the RSA. Where possible, the likely corresponding scientific names of these species are provided (in brackets):

- beaked willow (*Salix bebbiana*);
- green alder (*Alnus viridis*);
- bear berries (*Arctostaphylos* spp.);
- juniper berries (*Juniperus communis*);
- black berries (unknown species);
- Labrador tea (*Ledum* spp.);
- black lichen (unknown species);
- lingon berry (Vaccinium vitis-idaea);
- black spruce trees;
- northern bog laurel (*Kalmia polifolia*);
- blueberries;
- *Sphagnum* (moss);
- bog birch (dwarf birch) (*Betula nana*);
- spiny wood fern (*Dryopteris expansa*);
- cloudberries (Rubus chamaemorus);
- spray paint lichen (*Icmadophila ericetorum*);
- club lichen (red pixie cup) (*Cladonia* spp.);
- spruce trees (*Picea* spp.);
- cranberries (*Oxycoccus microcarpus*);
- turf moss (unknown species);
- crowberries (*Empetrum nigrum*); and
- whiskey jack eye (unknown species).

Berries

The most commonly harvested berries include raspberries (*Rubus strigosus,* which was not identified in the review of existing information), blueberries, cranberries, cloudberries, and crowberries. These berries are typically found throughout the RSA. According to the reviewed information, the Denesoline believe that blueberries harvested on the barrenlands taste better than those below the treeline (LKDFN 2001, 2002, 2003, 2005).

Based on reports by the LKDFN (2005), summer and fall berry patches (raspberries, blueberries, cloudberries, cranberries, and crowberries) are mostly located around Łutselk'e and down the Snowdrift River. Raspberries are harvested in mid-summer, blueberries and cloudberries in summer, and cranberries and crowberries in early fall.

Medicinal Plants

Several medicinal plants were traditionally harvested including Labrador tea, club lichen, juniper berries, crowberries, spiny wood fern, cranberry, spruce (*Picea* spp.) gum, and northern bog laurel (Fort Resolution Elders 1987; LKDFN 1999). Many of these plants are common in the RSA.

11.7.2.3.3 Rare Plants

Rare plant species considered for study included any plant species listed as rare in:

- "NWT Species 2000: General Status Ranks of Wild Species in the Northwest Territories" (GNWT 2000); and
- "The Rare Vascular Plants in the Northwest Territories" (McJannet et al. 1995), as well as those listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007).

Lists of rare species are dynamic and change as new information becomes available or as the status of the population changes. The list of species considered is shown in Table 11.7-7.

Table 11.7-7 Rare Plants Potentially Present in the Local Study Area

Species Name	Common Name	Global Rank
Acorus calamus	sweetflag	G5
Alisma plantago-aquatica	water-plantain	G5
Arabis holboellii var. *pinetorum*	rock-cress	G5
Callitriche anceps	water starwort	G5
Caltha palustris var. *palustris*	marsh-marigold	G5

Table 11.7-7 Rare Plants Potentially Present in the Local Study Area (continued)

Species Name	Common Name	Global Rank
Carex arcta	narrow sedge	G5
Carex crawfordii	Crawford's sedge	G5
Carex heleonastes	Hudson Bay sedge	G4
Carex prairea	prairie sedge	G5
Carex retrorsa	turned sedge	G5
Carex sychnocephala	one-beaked sedge	G4
Carex trisperma	three-seeded sedge	G5
Cornus suecica	dogwood	G5
Crassula aquatica	pigmyweed	G5
Danthonia spicata	povery oat grass	G5
Descurainia pinnata ssp. *brachycarpa*	green tansy mustard	G5
Draba norvegica	Norwegian draba	G5
Dryopteris carthusiana	spinulose shield fern	G5
Elatine triandra	waterwort	G5
Elymus canadensis	Canada wild rye	G5
Epilobium leptophyllum	willow-herb	G5
Erigeron acris var. *debilis*	northern daisy fleabane	G5
Erigeron yukonensis	fleabane	G3
Hudsonia tomentosa	sand heather	G5
Juncus stygius ssp. *americanus*	marsh rush	G5
Juncus vaseyi	big-head rush	G3
Lycopus uniflorus	bugleweed	G5
Myriophyllum alterniflorum	water-milfoil	G5
Najas flexilis	naiad	G5
Nymphaea tetragona	white water lily	G5
Pedicularis macrodonta	lousewort	G4
Phegopteris connectilis	shield-fern	G5
Poa secunda	Sandberg blue grass	G5
Potamogeton foliosus var. *foliosus*	leafy pondweed	G5
Potamogeton illinoensis	pondweed	G5
Potamogeton obtusifolius	blunt-leaved pondweed	G5
Potamogeton robbinsii	Robbin's pondweed	G5
Potamogeton subsibiricus	pondweed	G3
Ranunculus pensylvanicus	buttercup	G5
Rhynchospora alba	white beak-rush	G5
Rorippa crystallina	marsh yellow cress	G1
Sarracenia purpurea	pitcher-plant	G5
Valeriana dioica var. sylvatica	northern valerian	G5

Rare plant surveys were conducted during 2004 and 2005 in the LSA and did not result in the identification of any rare plants. The absence of rare plant observations does not preclude the potential for rare plants to inhabit the area. Even the best-conducted plant survey can miss rare plant occurrences at a site because the abundance of a species can vary annually. For example, some plant species have the ability to withstand stresses by storing seed for extended periods. Climatic fluctuations may not allow the species to produce flowers, making them difficult to spot and identify. A general vegetation management plan and several follow-up monitoring programs (including one addressing effects to species at risk specifically) have been recommended for the Project (Section 11.7.10) and could easily incorporate additional, targeted rare plant surveys. Appropriate mitigation practices and protocols will be implemented should any rare plants be identified.

Based on the rare plant surveys, ecosystem types present in the LSA, and habitat requirements of listed species, ecosystem types were ranked according to their ability to support rare plant species in the LSA (Table 11.7-8). Areas with a high habitat potential, that could potentially support 15 to 19 rare plant species, cover approximately 10.4% of the LSA (Table 11.7-9). Only 0.2% of the area was considered to have moderate potential. The remainder of the LSA (89.4%) has low to very low potential or no potential to support rare plant species. The distribution of rare plant habitat potential for the dominant ecosystems in the LSA is displayed in Figure 11.7-8.

Table 11.7-8 Rare Plant Habitat Potential for Ecosystem Types in the Local Study Area

Ecosystem Type	Description	Total Potential Rare Plant Species	Rank[(a)]
LA	lake	0	nil
PD	pond	0	nil
BC	riparian, scrub birch – bluejoint shrub tundra	1	very low
BL	upland, scrub birch – Labrador tea tundra	1	very low
RR	rural/camp	1	very low
BE	upland, scrub birch – crowberry tundra	2	very low
BR	wetlands, scrub birch – cloudberry low shrub bog	2	very low
RB	riparian, scrub birch – riparian shrub	–[(b)]	very low
RO	upland, rock outcrop	3	very low
RP	upland, road	3	very low
BF	upland, boulderfield	4	very low
PE	upland, spruce – lichen woodland	4	very low
SS	upland, saxifrage – moss campion xerophytic tundra	4	very low
SR	riparian, willow – nagoonberry shrub	6	low
OW	shallow open water	8	low
SH	wetlands, willow – sedge low shrub fen	9	low
FA	wetlands, floating aquatic – shallow open water	11	moderate
CA	wetlands, water sedge – narrow-leaved cottongrass fen	14	moderate
CE	wetlands, round-fruited sedge – Chamisso's cottongrass fen	16	high
EA	wetlands, sheathed cottongrass – bog-rosemary sedge fen	17	high
EM	wetlands, water sedge – horsetail shallow shore marsh	18	high

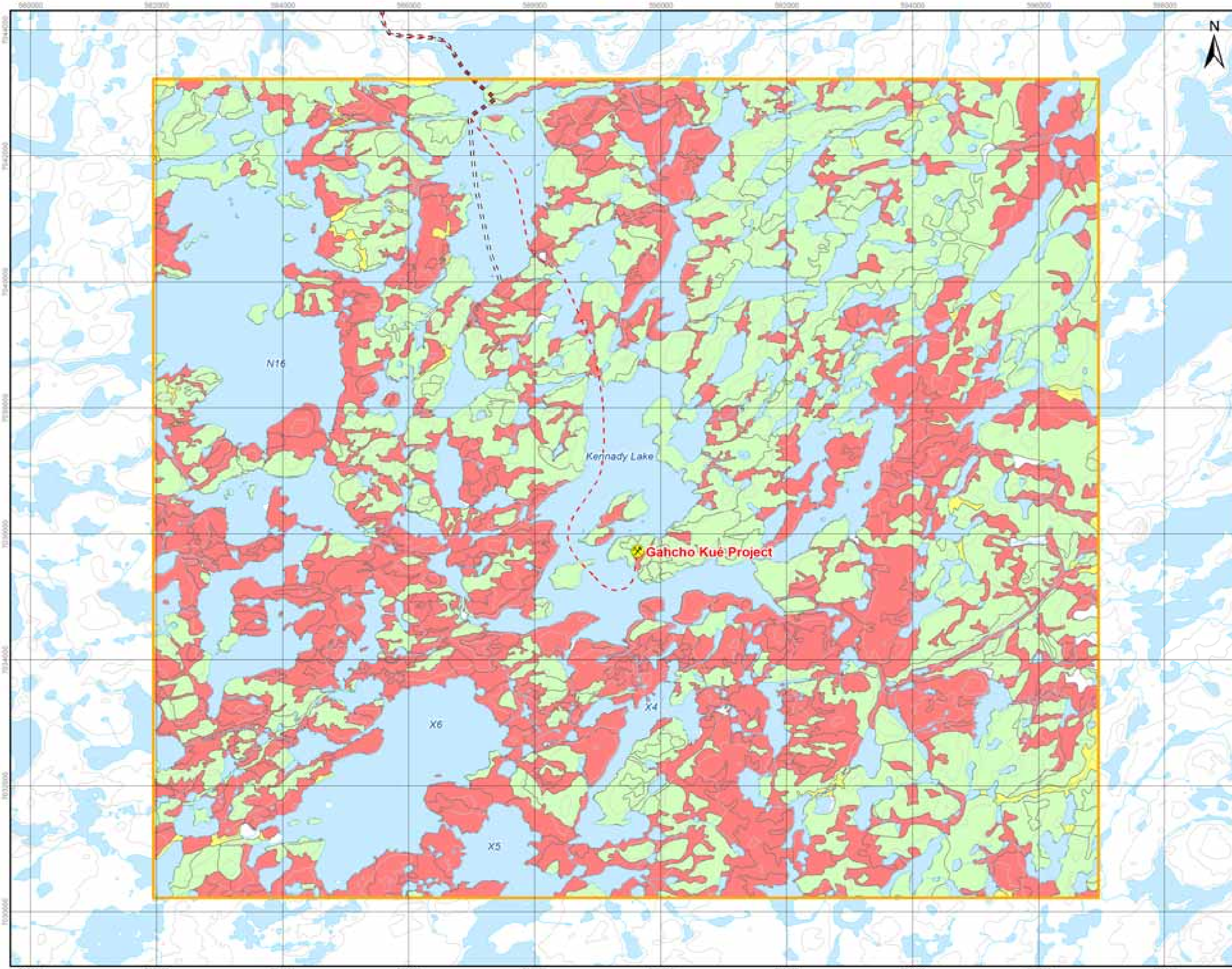
(a) Very low = 1 to 4 plants; low = 5 to 9 plants; moderate = 10 to 14 plants; high = 15 to 19 plants; very high = 20+ plants.
(b) No data. Therefore, assumed same ranking as scrub birch – cloudberry low shrub bog ecosystem type.

Table 11.7-9 Rare Plant Habitat in the Local Study Area

Habitat Potential	Potential Number of Rare Plants Species	Total Area	Percent of Total Area
		(ha)	(%)
nil	0	5,767.9	29.6
very low	1 to 4	11,490.9	58.9
low	5 to 9	166.1	0.9
moderate	10 to 14	47.4	0.2
high	15 to 19	2,027.6	10.4
Total	**n/a**	**19,499.8**	**100.0**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent; n/a = not applicable.



LEGEND

- Gahcho Kué Project
- Proposed Winter Access Road
- Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Rare Plant Habitat Potential

- High
- Moderate
- Low
- Very Low

NOTES
Base data source:
National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Rare Plant Habitat Potential in the Local Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:60,000 (1 0.5 0 1 Kilometres)	DE BEERS CANADA
FILE No: E-Veg-008-GIS	DATE: October 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-SAS	DRAWN: ANK / CHECK: JV

Figure: 11.7-8

11.7.2.3.4 Biodiversity

Species richness and evenness are variable within the LSA (Table 11.7-10). Shrub-dominated ecosystem types (e.g., riparian, willow – nagoonberry shrub [SR], scrub birch – Labrador tea tundra [BL]) have the greatest species richness as well as high within-habitat variability. Shrub-dominated and forested (e.g., Spruce – Lichen Woodland [PE]) ecosystem types within the LSA provide quality habitat for some wildlife. The ecosystem types that dominate the landscape in the LSA include Scrub Birch – Labrador Tea Tundra (BL), Lake (LA) (open water), and Scrub Birch-Cloudberry Low Shrub Bog (BR).

Table 11.7-10 Species Richness and Evenness in the Local Study Area

Ecosystem Type	Description	Number of Plots	Species Richness[a]	Species Evenness[a]
SR	riparian, willow – nagoonberry shrub	10	16 to 21	0.56 to 0.79
BL	upland, scrub birch – Labrador tea tundra	50	16 to 19	0.66 to 0.79
CE	wetlands, round-fruited sedge – Chamisso's cottongrass fen	2	15 to 19	0.63 to 0.77
EA	wetlands, sheathed cottongrass – bog-rosemary sedge fen	14	14 to 19	0.64 to 0.78
FA	wetlands, floating aquatic – shallow open water	3	14 to 19	0.63 to 0.97
BC	riparian, scrub birch – bluejoint shrub tundra	4	12 to 18	0.57 to 0.76
BE	upland, scrub birch – crowberry tundra	37	12 to 16	0.78 to 0.83
BR	wetlands, scrub birch – cloudberry low shrub bog	27	12 to 16	0.69 to 0.88
PE	upland, spruce – lichen woodland	16	9 to 17	0.81 to 0.89
CA	wetlands, water sedge – narrow-leaved cottongrass fen	8	8 to 15	0.77 to 0.97
SS	upland, saxifrage – moss campion xerophytic tundra	17	5 to 12	0.76 to 0.88
BF	upland, boulderfield	1	8	0.76
EM	wetlands, water sedge – horsetail shallow shore marsh	1	8	0.56
LA	Lake (open water)	0	n/a	n/a

[a] Range for richness and evenness.

n/a = not applicable.

Species richness is highest for the Willow – Nagoonberry Shrub (SR), and Scrub-birch – Labrador Tea Tundra (BL) ecosystem types. Richness estimates were lowest for the Saxifrage – Moss Campion Xerophytic Tundra (SS), Boulderfield (BF), and Water Sedge – Horsetail Shallow Shore Marsh (EM) ecosystem types (Table 11.7-10).

The highest evenness values were recorded in the Water Sedge – Narrow-leaved Cottongrass Fen (CA) and Floating Aquatic – Shallow Open Water (FA) ecosystem types. Consistently high evenness values were also recorded for the Spruce – Lichen Woodland (PE) ecosystem type, indicating that while the number of species present was variable, their distribution and abundance within the plot was fairly even. The lowest evenness values were recorded in the Water

Sedge – Horsetail Shallow Shore Marsh (EM), Willow – Nagoonberry Shrub (SR) and Scrub Birch Bluejoint Shrub Tundra (BC) ecosystem types.

The LSA has 1,307 landscape-level patches present. Landscape-level patches were calculated for 11 ecosystem types, one lake unit (LA), and one disturbance class (RR) (Table 11.7-11). Patch number and area were greatest for the Scrub Birch – Labrador Tea Tundra (BL), Scrub Birch – Cloudberry Low Shrub Bog (BR), and Lake (LA) ecosystem types.

Table 11.7-11 Landscape-Level Diversity of Dominant Ecological Landscape Classification Units in the Local Study Area

Ecological Landscape Classification (ELC)		Number of Polygons	Total Area
Code	**Name**	**(No.)**	**(ha)**
Upland Class			
BE	Scrub Birch – Crowberry Tundra	9	97.9
BL	Scrub Birch – Labrador Tea Tundra	577	10,229.4
PE	Spruce – Lichen Woodland	12	64.5
SS	Saxifrage – Moss Campion Xerophytic Tundra	8	29.0
Wetland/Riparian Class			
BC	Scrub Birch – Bluejoint Shrub Tundra	2	11.6
BR	Scrub Birch – Cloudberry Low Shrub Tundra	315	3,008.3
CA	Water Sedge – Narrow-leaved Cottongrass Fen	12	76.6
CE	Round-Fruited Sedge – Chamisso's Cottongrass Fen	5	33.5
EA	Sheathed Cottongrass – Bog Rosemary Sedge Fen	6	8.2
RB	Scrub Birch – Riparian Shrub	1	1.2
SR	Willow – Nagoonberry Shrub	25	162.5
Water Class			
LA	Lake	334	5,767.9
Disturbance Class			
RR	Camp (anthropogenic)	1	9.3
Total		**1,307**	**19,499.8**

Note: (1) Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

(2) Number of polygons and total area are based on the dominant ecosystem type of each polygon.

No. = number; ha = hectare.

11.7.2.3.5 Baseline Metal Concentrations

Baseline metal concentrations were established for plant tissue samples collected from six sites in the LSA, including one site on processed kimberlite materials. Samples were collected from the following plant species: alpine bearberry (*Arctostaphylos alpina*), barren-ground willow (*Salix niphoclada*), bluejoint reedgrass (*Calamagrostis canadensis*), bog bilberry (*Vaccinium uliginosum*), cloudberry (*Rubus chamaemorus*), crowberry (*Empetrum nigrum*), fireweed (*Epilobium angustifolium*), mountain cranberry (*Vaccinium vitis idaea*), northern Labrador tea (*Ledum palustre*), and scrub birch.

No firm conclusions regarding current metal concentrations in plant tissues were possible due to the lack of published guidelines. However, of the samples analyzed, some had noticeably higher concentrations of aluminum, iron, manganese, and zinc (Table 11.7-12). These observations were particularly evident in samples collected from the processed kimberlite sites generated during bulk sampling. Plant tissue metal concentrations will be used for future monitoring during the operations, closure, and reclamation phases. Future metal concentrations in plant tissue will be compared to baseline values to determine if changes in metal levels are occurring. Noticeable changes in metal concentrations over time could be further analyzed using a risk assessment approach to determine the potential exposure risks to wildlife that may be using the plants in the area as a food source.

Table 11.7-12 Average Concentrations and Standard Deviations of Selected Metals in Plants

Plant Species	Unit/Sample Size	Aluminum (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Zinc (mg/kg)
Alpine bearberry	5	158.4±132	74.4±48	40.28±10	60.36±15
Barren-ground willow	1	46	73	88	46
Bluejoint reedgrass	3	152.33±103	142.33±66	215.33±96	41.2±5
bog bilberry	5	297.2±423	208.8±305	248.2±127	38.9±12
Cloudberry	1	106	89	422	66
Crinkled snow lichen	3	125.67±36.5	154.67±70	171±20.7	45.67±6.1
Crowberry	5	475.8±830	265±472	264±146	17.56±3
Curly snow lichen	3	117±66	164±77	127.67±44.9	41.67±16
Fireweed	3	361±284	295.67±233	141.97±70	50±18
Green reindeer lichen	6	202.5±258.8	268.67±280.6	36.83±41.9	29±4.6
Grey reindeer lichen	6	174±89.6	270.83±140	96.5±39.5	32.67±6.8
Mountain cranberry	6	474.17±496	228±275	809.33±244	29.63±14
Northern bog sedge	2	65±45.3	156.5±72.8	41.5±5	31.5±29
Northern Labrador tea	5	104.2±9	62.6±11	464.2±247	30.58±5
Scrub birch	6	273.5±533	280.67±510	238±97	135.07±44
Sheathed sedge	1	124	296	81	15
Star-tipped reindeer lichen	5	245±97	331.4±138	55.8±12.6	24.4±4.8

mg/kg = milligrams per kilogram; ± = plus/minus.

11.7.3 Pathway Analysis

11.7.3.1 Methods

Pathway analysis identifies and assesses the issues and linkages between the Project components or activities, and the correspondent potential residual effects on vegetation ecosystems, plants, and traditional users. Pathway analysis is a three-step process for determining linkages between Project activities and environmental effects that are assessed in Sections 11.7.4 to 11.7.8. Potential pathways through which the Project could influence vegetation ecosystems and plants were identified from a number of sources including:

- the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Gahcho Kué Panel 2007) and the Report of Environmental Assessment (MVEIRB 2006);
- a review of the Project Description and scoping of potential effects by the environmental assessment and Project engineering teams for the Project; and
- consideration of potential effects identified for the other diamond mines in the NWT.

The first part of the analysis is to produce a list of all potential effects pathways for the Project. Each pathway is initially considered to have a linkage to potential effects on vegetation ecosystems and plants. This step is followed by the development of environmental design features and mitigation that can be incorporated into the Project to remove the pathway or limit (mitigate) the effects to vegetation ecosystems and plants. Environmental design features and mitigation include Project designs and environmental best practices, and management policies and procedures. Environmental design features were developed through an iterative process between the Project's engineering and environmental teams to avoid or mitigate effects.

Knowledge of the ecological system and environmental design features and mitigation is then applied to each of the pathways to determine the expected amount of Project-related changes to the environment and the associated residual effects (i.e., after mitigation) on vegetation ecosystems and plants. For an effect to occur, there has to be a source (Project component or activity), a change in the environment, and a correspondent effect on vegetation ecosystems and plants.

Project activity → change in environment → effect on valued component (VC)

Pathway analysis is a screening step that is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the Project. This screening step is largely a qualitative assessment, and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects on vegetation ecosystems and plants. Pathways are determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features. Each potential pathway is assessed and described as follows:

- no linkage – pathway is removed by environmental design features and mitigation so that the Project results in no detectable environmental change and, therefore, no residual effects to a VC relative to baseline or guideline values;

- secondary - pathway could result in a measurable and minor environmental change, but would have a negligible residual effect on a VC relative to baseline or guideline values; or
- primary - pathway is likely to result in a measurable environmental change that could contribute to residual effects on a VC relative to baseline or guideline values.

Primary pathways require further effects analysis and impact classification to determine the environmental significance from the Project on the persistence of vegetation ecosystems and plants, and continued opportunity for traditional and non-traditional use of vegetation. Pathways with no linkage to vegetation ecosystems and plants or that are considered minor are not analyzed further or classified in Sections 11.7.4 to 11.7.8 because environmental design features and mitigation will remove the pathway (no linkage) or residual effects can be determined to be negligible through a simple qualitative evaluation of the pathway (secondary). Pathways determined to have no linkage to vegetation ecosystems or plants or those that are considered secondary are not predicted to result in environmentally significant effects on the persistence of vegetation ecosystems or plants. Primary pathways are assessed in more detail in Sections 11.7.4 to 11.7.8.

11.7.3.2 Results

Pathways potentially leading to effects on vegetation ecosystems and plants include direct and indirect effects (Table 11.7-13). These changes may ultimately affect the persistence of vegetation ecosystems and plants, and continued opportunity for traditional and non-traditional use of vegetation. Evaluation of effects on vegetation ecosystems and plants also considers changes to hydrology, water quality, air quality, and soil quality during the construction, operation, and closure of the Project, as well as effects remaining after closure.

Because potential pathways are based primarily on public concerns identified during the Mackenzie Valley Environmental Impact Review Board (MVEIRB) scoping process (MVEIRB 2006). Many environmental design features were incorporated during the development of the Project to address these issues by reducing or eliminating potential effects. Also, preliminary analysis may have shown that potential effects considered during issue scoping are so small that they are not relevant. Other potential pathways are considered to be primary and are included in the effects analysis. The following sections discuss the potential pathways relevant to vegetation ecosystems and plants.

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Project Footprint (e.g., pits, Fine PKC Facility, Coarse PK Pile, and mine rock piles)	• direct loss and fragmentation of vegetation ecosystems and plants	• backfilling the mined-out pits with PK and mine rock will decrease the on-land Project footprint • compact layout of the surface facilities will limit the area disturbed at construction and increase site operations efficiency • mine rock will be used as the source of aggregate production, thereby, reducing the need for separate quarries • soil, overburden, and lakebed sediments from areas of disturbance will be salvaged and stockpiled during the pit and mine rock pile development for use at closure to the extent practical • where practical, natural drainage patterns will be used to reduce the use of ditches or diversion berms • to the extent practical, the total amount of area disturbed by Project activities at any one time will be reduced through the use of progressive reclamation • at closure, transportation corridors and the airstrip will be scarified and loosened to encourage natural revegetation, and re-contoured where required • culverts or stream-crossing structures will be removed and natural drainage re-established • conditions will be monitored over time to evaluate the success of the Closure and Reclamation Plan and, using adaptive management and newer proven methods as available, adjust the Plan, if necessary • De Beers will actively liaise with other mine operators in the Canadian Arctic to understand the challenges and successes they have encountered with respect to reclamation • reclamation trials will be completed throughout the Project life to determine which prescriptions may be most effective for reclamation	Primary

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Project Footprint (e.g., pits, Fine PKC Facility, Coarse PK Pile, and mine rock piles) (continued)	• effects to soil and permafrost can lead to changes in vegetation ecosystem structure and composition	• during winter months, clear areas fro construction using a snow packed surface • revegetate disturbed areas as soon as possible • manage drainage around infrastructure to reduce pooling of water at the surface • insulate thaw-sensitive slopes • compact layout of the surface facilities will limit the area disturbed at construction • limit the road footprint disturbance area, while maintaining safe construction and operation practices • use coarser materials for road construction to minimize frost effects • building foundations will be built on bedrock not susceptible to frost heave to minimize thawing of permafrost in sensitive areas • organic and/or topsoil horizons will not be stripped in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence	Secondary
Winter Access Road and Tibbitt-to-Contwoyto Winter Road	• road footprint may cause changes to vegetation quality (i.e., vegetation degradation), quantity and fragmentation of vegetation ecosystems	• use of snow or ice pads of sufficient thickness to limit damage to overland portages between lakes • discontinued use of road when surface becomes too soft • use of proven best practices for Winter Road construction	Secondary
Construction and operations (e.g., equipment operation, aircraft/vehicles, airstrip, processing and storage facilities)	• human recreational activity can disturb vegetation	• establish site rules for recreational walking on and offsite • prohibit recreational off-road use of all terrain vehicles • environmental sensitivity training for on-site personnel	No linkage
	• introduction of invasive plant species can change vegetation ecosystem composition	• use of clean equipment	Secondary

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction and operations (e.g., equipment operation, aircraft/vehicles, airstrip, processing and storage facilities) (continued)	• dust deposition may cover vegetation and lead to physical and/or physiological damage of vegetation ecosystems and plants	• a program of carbon and energy management will be implemented once the generators are commissioned • generator efficiencies and equipment will be tuned for optimum fuel-energy efficiency • load management will allow for the optimization of the load factors on the generators • pumping circuits will be operated and efficiencies will be optimized to minimize noise disturbances • power and heat use to reduce energy use, and therefore air emissions, will be reviewed on a regular basis • recovered heat from the main electrical generators will be used to heat the accommodations complex and the central process and maintenance facilities • piping will be insulated for heat conservation • personnel arriving at or leaving the site will be transported by bus, therefore, reducing the amount of traffic between the airstrip and the accommodation complex • compact layout of the surface facilities will reduce traffic, and therefore dust and air emissions, around the site • watering of roads, airstrip, and laydown areas will facilitate dust suppression • enforcing speed limits will assist in reducing production of dust	Secondary
	• dust deposition and air emissions may change vegetation quality through changes in the chemical content of soil and air		Secondary
	• project activities may alter local climate and cause changes to plant phenology		No linkage

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction and operations (e.g., equipment operation, aircraft/vehicles, airstrip, processing and storage facilities) (continued)	• chemical spills (including de-icing fluid runoff) may degrade vegetation ecosystems	• processing of the kimberlite ore will be mechanical, with limited use of chemicals • hazardous, non-combustible waste and contaminated materials will be temporarily stored in the waste storage transfer area in sealed steel or plastic, wildlife-resistant drums, and shipped off-site for disposal or recycling • chemicals such as de-icing fluid, acids, solvents, battery acids, and laboratory agents will be collected in lined trays and drums, and stored in suitable sealed containers in the waste transfer area • the waste transfer storage area will include a lined and enclosed pad for the collection and subsequent return of hazardous waste to suppliers or to a hazardous waste disposal facility • emulsion materials will be stored at the emulsion plant where spills would be 100% contained within the building • all fuel storage tanks will be designed and constructed according to the American Petroleum Institute 650 standard and placed in a lined and dyked containment area to contain any potential fuel spills • aviation fuel will be stored in self-contained, Underwriters Laboratories Canada-rated envirotanks mounted on an elevated pad at the air terminal shelter • aviation fuel for helicopters will be stored in sealed drums inside a lined berm area near the airstrip • to prevent accumulation and/or runoff of de-icing fluids at the airstrip from aircraft de-icing operations, aircraft will be sprayed in a specific area that will be equipped with swales to collect excess fluids if necessary • puddles of de-icing fluids in the swales will be removed by vacuum truck and deposited into waste de-icing fluid drums for shipment to recycling facilities if necessary • an Emergency Response and Contingency Plan has been developed • spill containment supplies will be in designated areas • any spills will be isolated and immediately cleaned up by a trained spill response team consisting of on-site personnel who will be available at all times	No linkage

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Mine Rock Management	• leaching of PAG mine rock may degrade vegetation communities	• mine rock used to construct the dykes will be non-acid generating (NAG) • any mine rock containing kimberlite will be separated from the tundra by at least 2 m of inert and kimberlite-free rock to prevent drainage with low pH • any PAG mine rock, as well as any barren kimberlite, will be sequestered within the interior of the mine rock piles in areas that will allow permafrost to develop or will be underwater when Kennady Lake is refilled • till from ongoing pit stripping will be used to cover PAG rock placed within the interior of the structure to keep water from penetrating into that portion of the repository • the PAG rock will be enclosed within enough NAG rock that the active frost zone (typically two meters) will not extend into the enclosed material and water runoff will occur on the NAG rock cover areas • to confirm the lower levels remain frozen, temperature monitoring systems will be placed in the mine rock piles as they are being constructed • minimal water is expected to penetrate to the PAG rock areas • only non-reactive mine rock will be placed on the upper and outer surfaces of the mine rock pile; the thickness of the cover layer is predicted to be sufficient so that the active freeze-thaw layer remains within the non-reactive mine rock • thermistors will be installed within the mine rock piles to monitor the progression of permafrost development; the upper portion of the thick cover of clean mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are expected to remain permanently frozen	No linkage

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Site Water Management	• release of seepage and surface water runoff (including erosion) from the Fine PKC Facility, Coarse PK Pile, and mine rock piles may degrade vegetation communities	• the performance of the dykes will be monitored throughout their construction and operating life; instrumentation monitoring together with systematic visual inspection will provide early warning of many conditions that can contribute to dyke failures and incidents. Additional mitigation will be applied, if required. • a system of ditches and sumps will be constructed, maintained, and upgraded throughout the operation phase of the Project to manage groundwater from the open pits. • no substantial runoff and seepage from the mine rock piles is expected • a soil-bentonite slurry cutoff wall through a till fill zone placed over the overburden and the overburden to the bedrock surface has been adopted as the main seepage control for the diversion dyke separating Areas 7 and 8 • the cut-off wall for the dyke separating Areas 7 and 8 will be protected by a downstream filter zone and mine rock shell zone • for the retention dyke that separates Areas 3 and 4, Areas 5 and 6, and Areas 4 and 6, a wide till core has been selected as the main seepage control • the water retention dyke separating Area 2 and Lake N7, as well as diversion dykes dealing with Lakes A3, A4, B1, N13, D2, E1, and E3 will have a liner keyed into the competent frozen ground or bedrock to control seepage • the PAG rock will be enclosed within enough NAG rock to prevent the active zone (typically 2 m) from extending into the enclosed material and water runoff will occur on the NAG rock cover areas • thermistors will be installed within the mine rock piles to monitor the progression of permafrost development; the upper portion of the thick cover of mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are expected to remain permanently frozen • only non-reactive mine rock will be placed on the upper and outer surfaces of the mine rock pile; the thickness of the cover layer is predicted to be sufficient so that the active freeze-thaw layer remains within the non-reactive mine rock	No linkage

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Dewatering of Kennady Lake	• changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from dewatering of Kennady Lake may affect the quantity of vegetation	• Lake N11 is capable of accepting water at the proposed discharge rate without erosion damage to downstream watercourses • dykes will be constructed to divert fresh water from entering areas of Kennady Lake • the height of the diversion structures will be designed such that the excess water from the surrounding sub-watershed will remain in the original N watershed • dewatering and operation discharges will be limited so that pumping will not increase discharges above the baseline two-year flood levels in downstream lakes and channels	Primary
	• dewatering may result in newly established vegetation on the exposed lakebed sediments		Secondary
Closure and Reclamation	• changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from refilling of Kennady Lake may affect the quantity of vegetation	• mined-out pits will be backfilled with PK and mine rock to reduce the time required for filling these portions of Kennady Lake because less water is required to refill the partially backfilled pits • Kennady Lake will be refilled using natural runoff and supplemental waters drawn from Lake N11 • while fine PK is being discharged in the mined-out pits (primarily Hearne, but potentially 5034), process water will not be reclaimed from the pits Instead the slurry discharge water will be used to accelerate the infill of the mined-out pits; the process will facilitate a more rapid re-filling and progressive reclamation of Area 6 within Kennady Lake • the 5034 Pit will be backfilled to the extent possible with mine rock and the remaining space will be eventually filled with water once mining in the Tuzo Pit is complete • the Tuzo Pit will be allowed to flood following the completion of the operations phase; natural watershed inflows will be supplemented by pumping water from Lake N11 • the pumping rates are anticipated to be managed such that the total outflow from Lake N11 does not drop below the 1 in 5-year dry conditions	Primary

Table 11.7-13 Potential Pathways for Effects on Vegetation Ecosystems and Plants (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Closure and Reclamation (continued)	• long-term seepage from the Coarse PK Pile and mine rock piles may cause local changes to vegetation quality	• the PAG rock will be enclosed within enough non-AG rock to prevent the active zone (typically 2 m) from extending into the enclosed material and water runoff will occur on the NAG rock cover areas • thermistors will be installed within the mine rock piles to monitor the progression of permafrost development The upper portion of the thick cover of mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are expected to remain permanently frozen • the Coarse PK Pile will be shaped and covered with a layer of mine rock of a minimum 1 m to limit surface erosion • only non-reactive mine rock will be placed on the upper and outer surfaces of the mine rock piles; the thickness of the cover layer is predicted to be sufficient so that the active freeze-thaw layer remains within the non-reactive mine rock • no substantial runoff and seepage from the mine rock piles is expected	No linkage

CCME = Canadian Council of Ministers of the Environment; m = metre; NAG = non-acid generating; NO_X = nitrogen oxide; PK = processed kimberlite; PKC = processed kimberlite containment; NAG = non-acid generating; PAG = potentially acid generating; PAI = potential acid input.

11.7.3.3 Pathways with No Linkage

A pathway may have no linkage if the activity does not occur (e.g., effluent is not released), or if the pathway is removed by environmental design features and mitigation so that the Project results in no detectable (measurable) environmental change and residual effects to vegetation. The pathways described in the following bullets are anticipated to have no linkage to vegetation, and will not be carried through the effects assessment.

- Human recreational activity can disturb vegetation.

Increased human activity in and around the Project site can lead to the further disturbance of vegetation ecosystems and plants. Environmental design features such as controlled access to site, the establishment of rules for recreational walking on- and off-site, prohibited recreational off-road use of all terrain vehicles, and environmental sensitivity training for staff will be implemented to mitigate these potential effects (Table 11.7-13). Limiting human activity to already disturbed areas will also restrict the possibility for any additional effects to vegetation in the vicinity of the Project footprint. As human recreational activity in the LSA will be controlled, no detectable physical changes to vegetation communities outside of the Project footprint are anticipated. Consequently, this pathway was determined to have no linkage to effects on the persistence of vegetation ecosystems, listed plant species, and traditional use plant species.

- Chemical spills (including de-icing fluid runoff) within the Project footprint, the airstrip or along the Winter Access Road or Tibbitt-to-Contwoyto Winter Road may cause negative changes to vegetation ecosystems or plants.

Chemical spills are usually localized, and are quickly reported and managed. Mitigation practices identified in the Emergency Response and Contingency Plan (Section 3, Appendix 3.I, Attachment 3.I.1), and environmental design features will be in place to limit the frequency and extent of chemical spills at the Project, and along the Winter Access Road and the Tibbitt-to-Contwoyto Winter Road (Table 11.7-13). The following are examples of environmental design features and mitigation practices that will be used to reduce the risk from chemical spills:

  – Spill containment supplies will be available in designated areas where fuel and chemicals are stored.
  – Fuel storage tanks will be designed and constructed according to the American Petroleum Institute 650 standard.

- Aviation fuel for helicopters will be stored in sealed drums inside a lined berm area at the helipad.
- Aircraft will be sprayed with de-icing fluids in a specific area at the airstrip that will be equipped with swales to collect excess fluids if necessary.
- Puddles of de-icing fluids in the swales will be removed by a vacuum truck and deposited into waste de-icing fluid drums for shipment off-site and recycling if necessary.
- All petroleum products will be stored in approved containers and in areas with secondary containment.
- Fenced areas will be established for the handling and temporary storage of hazardous wastes.

The implementation of the Emergency Response and Contingency Plan, environmental design features, mitigation, and monitoring programs is expected to result in no detectable change to vegetation from chemical spills. Consequently, this pathway was determined to have no linkage to effects on the persistence of vegetation ecosystems, listed plant species, and continued opportunity for traditional and non-traditional use of these plant species.

- Project activities may alter local climate and cause changes to plant phenology.

Plant phenology is driven by both genetics and the surrounding environment (Walker et al. 1995). Plant species respond to environmental cues (e.g., snowmelt, temperature changes) that trigger different biological processes (e.g., bud burst, flowering). The responses can vary among species, with some species being more sensitive and quick to respond than others. Environmental cues can be disrupted by marked changes in climatic patterns (above and beyond that considered to be annual variation). These changes can further affect the biological processes of plants that are associated with them.

Project activities could change local climate, which could add stress to plants and affect phenology. Project activities and resulting site conditions that may have an effect include:

- Increased dust deposition resulting in earlier snowmelt.
- Drier substrate conditions as a result of fill placement.
- Local albedo effects, creating warmer and cooler slopes on artificial topographic features.

- Wetter substrate conditions where water has become locally impounded.
- Snow compaction, removal, or loading, particularly along pathways and roadways.
- Altered exposure, primarily through shading, by infrastructure.

Environmental design features will be in place (e.g., fugitive dust management, design water management structures to maintain drainage and restrict ponding, optimize infrastructure placement) that should reduce the development of microclimates such as those listed above (Table 11.7-13). The effects, if any, of these microclimates on plant phenology would be experienced at a very fine scale (e.g., level of the individual plant or group of individuals). Various adaptations and strategies exist, particularly at the edge of species ranges that can contribute to an individual group's ability to survive. These strategies could include adjusting or shifting phenology in response to a changing climate or other perceived pressures. Natural seasonal variation and other phenological controls (e.g., insect cycles and wildlife grazing) that act on plants tend to operate at broader scales than those of Project activities.

Implementation of environmental design features is expected to result in no detectable changes to local natural seasonal variation, which is one of the primary drivers of plant phenology overall (Post and Stenseth 1999). Consequently, this pathway was determined to have no linkage to effects on the persistence of vegetation ecosystems, listed plant species, and traditional use plant species.

- Leaching of potentially-acid generating (PAG) mine rock may degrade vegetation communities.

Any PAG mine rock, as well as any barren kimberlite, will be sequestered within the interior of the mine rock piles in areas that will allow permafrost to develop or will be underwater when Kennady Lake is re-filled (Table 11.7-13). Overburden, including lakebed sediments, will be used to cover any areas in the core of the mine rock piles where PAG mine rock is sequestered. The overburden (including sediments), which consist mainly of till, will provide a low permeability barrier that should limit infiltration and encourage water to flow over the surface of the mine rock pile, rather than through it. Water quality will be monitored on site, and additional mitigation will be applied if required to limit changes to the environment.

Further, the PAG rock will be enclosed with enough non-acid generating (NAG) rock that the active zone (typically 2 m) will not extend into the enclosed material, and water runoff will occur on the NAG rock cover areas (Table 11.7-13). While all water will not be stopped completely from penetrating the till and NAG rock envelop, the amounts that may penetrate deeper into the pile are expected to be trapped in void spaces and likely freeze. Minimal water is expected to penetrate to the PAG rock areas. To confirm the lower levels remain frozen, temperature monitoring systems will be placed in the mine rock piles as they are being constructed (Table 11.7-13).

Experience at the Ekati Diamond Mine suggests that coarse kimberlite in direct contact with the naturally acidic tundra soils can lead to drainage with low pH. Therefore, barren kimberlite or mine rock mixed with kimberlite will not be placed directly on the tundra soils, and will be separated from the tundra by at least 2 m of inert and kimberlite-free clean rock (Table 11.7-13).

Progressive reclamation and closure of the mine rock piles will involve contouring and re-grading. The piles will not be covered or vegetated, consistent with the approaches in place at the Ekati Diamond Mine and Diavik Diamond Mine. Thermistors will be installed within the mine rock piles to monitor the progression of permafrost development (Table 11.7-13). The upper portion of the thick cover of clean mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the processed kimberlite (PK) and PAG rock sequestered below are predicted to remain permanently frozen.

Overall, leaching of PAG mine rock is not expected to result in a detectable change to vegetation relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects on the persistence of vegetation ecosystems and plants.

- Release of seepage and surface water runoff from the PK and mine rock piles may change water quality and degrade vegetation communities.
- Long-term seepage from the Coarse PK Pile and mine rock piles may cause local changes to water quality and degrade vegetation communities.

Water-borne chemicals can adversely affect habitat quality through surface water runoff and seepage. Environmental design features and mitigation have been incorporated into the Project to eliminate or reduce potential effects from surface water runoff and seepage (Table 11.7-13). Runoff and seepage from the Fine PKC Facility, coarse PK, and mine rock piles will not be released to the environment outside the Project footprint during construction and operations, with the exception of a monitored discharge to Lake N11. Runoff from the coarse PK and mine rock piles will be contained in the affected basins and drain to either Area 3 or to one of the mined-out pits using natural drainage channels (Table 11.7-13). Natural drainage channels will provide opportunities for monitoring runoff quality, and additional mitigation will be applied if required to limit changes to the existing environment outside of the footprint.

The Coarse PK Pile will not be designed to have a single point of release for seepage and runoff. Any runoff will flow through natural channels within the watershed and be retained in the controlled basin associated with Area 4, which in later years represents the Tuzo Pit area (Table 11.7-13). Groundwater entering the open pits during mining will be routed by ditches to a series of sumps. Groundwater inflows collected in the pit dewatering systems will be discharged to either Area 5 or the process plant where groundwater will be incorporated in the fine PK and pumped to the Fine PKC Facility.

As part of reclamation, the Fine PKC Facility will be covered with a 1 to 2 m layer of NAG mine rock. The facility will be graded so that surface runoff will flow towards Area 3. The final geometry of the cover layer will be graded to limit ponding of water over the mine rock covered fine PK in Areas 1 and 2 of the Fine PKC Facility. Permafrost development in the Fine PKC Facility and underlying talik is expected to occur over time. Thermistors will be installed in the Fine PKC Facility to monitor the formation of permafrost in the solids. The Coarse PK Pile will also be shaped and covered with a layer of mine rock of approximately 1 m thick to limit surface erosion (Table 11.7-13). Runoff will be directed to Area 4.

Overall, release of seepage and surface water runoff from the PK and mine rock piles, and long-term seepage from the Coarse PK Pile and mine rock piles is not expected result in a detectable change to vegetation ecosystems and plants relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects on the persistence of vegetation ecosystems, listed plant species, and traditional use plant species.

11.7.3.4 Secondary Pathways

In some cases, both a source and a pathway exist, but the Project is anticipated to result in a minor environmental change, and would have a negligible residual effect on vegetation relative to baseline or guideline values (e.g., a slight increase in a chemical parameter above Canadian Council of Ministers of the Environment (CCME) guidelines for soils, but would not affect vegetation ecosystems and plants). The pathways described in the following bullets are anticipated to be secondary, and will not be carried through the effects assessment.

- Effects to soil and permafrost can lead to changes in vegetation ecosystem structure and composition.

The Project footprint occurs within the southern extent of the continuous permafrost zone (NRC 1993). Freeze induced displacement of soil (i.e., frost jacking) and thaw induced displacement (i.e., subsidence) of soil are the main issues related to permafrost degradation (i.e., loss or alteration). Changes to thaw penetration and thickness of the active layer affect hydrology, soil moisture and nutrient availability, therefore affecting vegetation. A summary of the analysis of this pathway is provided in Appendix 11.7.I (Section 11.7.I.3).

The following are examples of environmental design features and mitigation practices that will be used to reduce the potential effects from permafrost and associated subsidence on vegetation.

- During winter months, clear areas for construction using a snow packed surface.
- Revegetate disturbed areas as soon as possible.
- Manage drainage around infrastructure to reduce pooling of water at the surface.
- Insulate thaw-sensitive slopes.
- Limit the mine footprint disturbance area.
- Limit the road footprint disturbance area, while maintaining safe construction and operation practices.
- Use coarser materials for road construction to minimize frost effects.
- Insulate infrastructure, where possible.
- Building foundations will be built on bedrock not susceptible to frost heave to reduce thawing of permafrost in sensitive areas.
- Organic and/or topsoil horizons will not be stripped in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence.

Implementation of these environmental design features and mitigation is expected to have a minor influence on permafrost relative to baseline conditions (secondary pathway; Table 11.7-13). Consequently, residual effects on the persistence of vegetation ecosystems, listed plant species, and traditional use plant species are anticipated to be negligible.

- Winter road footprint may cause changes to vegetation quality (i.e., vegetation degradation), quantity, and fragmentation of vegetation ecosystems.

The construction and operation of the Winter Access Road connecting the Project with the Tibbitt-to-Contwoyto Winter Road will follow best practices (e.g., use of snow or ice pads of sufficient thickness to minimize damage to overland portages between lakes; discontinued use of road when ground surface becomes too soft). These are practices that are implemented in the design, construction, and operation of the Tibbitt-to-Contwoyto Winter Road, and have proven to be successful in limiting the effects to vegetation (EBA 2002). As such, only minor compression of vegetation comprising the portages is anticipated. Some degradation to vegetation along the boundary between lakes and shorelines may also occur.

Minor vegetation degradation may also result from spills or accidents that may occur along the road (see above); the mitigation and management of spills is provided in the Emergency Response and Spill Contingency Plan (Section 3, Appendix 3.I, Attachment 3.I.1). Safety practices and policies implemented during the construction and operations phases (e.g., strict adherence to speed limits and regulations) should limit the likelihood of accidents and spills, thus reducing the potential effect to vegetation. The overall effect from the Winter Access Road and the Tibbitt-to-Contwoyto Winter Road on vegetation ecosystems and plants is expected to be negligible.

- Introduction of invasive plant species can cause changes in vegetation communities.

The potential introduction of invasive plants (species whose establishment and often rapid spread can adversely affect ecosystems, habitats and/or other species [Haber 1997]), is often associated with developments due to the types of activities involved. The successful establishment of invasive plants into an area depends on several factors, including:

- Availability of suitable habitat.
- Means of access.
- Dispersal mechanism.

The ground disturbance associated with construction activities can create the type of habitat favoured by invasive plant species. Transportation corridors to and from construction areas provide a means of access, as well as additional habitat in the form of disturbed road edges. Vehicles and machinery can serve as dispersal mechanisms for plant propagules (seeds and/or vegetative parts) that can get lodged in tires, the undercarriage, or mud on the surface of the vehicle.

The low incidence of invasive plants occurring in the Arctic has been attributed to factors such as harsh climatic conditions, the presence of permafrost, and limited land development (Schrader and Hennon 2005; Carlson and Shephard 2007). Recent studies of the changes in Alaskan flora over time have revealed that invasions may just be delayed and that the levels of development and invasive plant propagules present have reached a point that they may now become more noticeable (Carlson and Shephard 2007).

Effective mitigation strategies are required early in project planning to address the introduction, spread, and effects of invasive species on the environment (Haber 1997). Preventing invasive plant species from entering an area is often more efficient and cost effective than dealing with their removal once established (Clark 2003; Polster 2005; USDA 2006; Carlson and Shephard 2007). Arctic areas are still at a considerable advantage in this respect, as much of the land has not been affected by human development, and non-native plants are largely restricted to populated and high-use areas (Carlson and Shephard 2007). Cleaning equipment prior to transportation on site and while at site is anticipated to limit the introduction of non-native species from the Project and control their potential spread into natural areas (Table 11.7-13).

Overall, the potential for introduction of invasive plant species is anticipated to have a minor influence on vegetation ecosystem composition relative to baseline conditions (secondary pathway; Table 7.4-1). Therefore, the residual effects on the persistence of vegetation ecosystems and plants are predicted to be negligible.

- Dust deposition may cover vegetation and lead to physical or physiological damage of vegetation ecosystems and plants.

Accumulation of dust (i.e., total suspended particulate [TSP] deposition) produced from the Project may result in local direct changes to the quantity of vegetation available within the LSA. Air quality modelling was completed to predict the spatial extent of dust deposition from the Project. Air quality modeling was completed for the baseline case, construction case, and application case. The baseline case also includes emissions from the Snap Lake Mine (Section 11.4).

As per the Terms of Reference, a construction case was modeled for the Project. Typically, the construction phase will have lower emissions than the operations phase of a project. As expected, the construction case emissions are much lower than the application case emissions, and therefore, result in lower predictions than those for the application case. The assessment of the application case (i.e., operations) is anticipated to capture the maximum effects resulting from the Project.

Sources of dust deposition modelled in the application case include blasting activities, haul roads, the processing plant, activities at the mine pits and other ancillary facilities (e.g., mine rock piles, Coarse PK Pile, and Fine PKC Facility), and vehicle traffic along the Winter Access Road. Environmental design features and mitigation have been incorporated into the Project to reduce potential effects from dust deposition (Table 11.7-13). For example, the watering of roads, airstrip, and laydown areas will facilitate dust suppression. Although these environmental design features and mitigation will be implemented to reduce dust deposition, assumptions incorporated into the model are expected to contribute to conservative estimates of deposition rates (Section 11.4).

The results of the air quality modelling predicted that the maximum annual dust deposition resulting from the Project is 6,292 kg/ha/y within the Project development area boundary (i.e., Project footprint) and 5,520 kg/ha/y outside of the Project development area boundary (Table 11.7-14). The maximum deposition that occurs is mostly associated with the mine pits and haul roads. The maximum deposition rate for dust is predicted to occur within 100 m of the Project footprint. The strongest effects from dust are generally confined to the immediate area adjacent to the dust source, such as roads (Walker and Everett 1987).

Table 11.7-14 Summary of Key Predicted Annual Deposition Rates from the Project

Substance	Criteria	Maximum Predicted Deposition Rate		
		Local Study Area Baseline	Application	
			Outside Project Development Area Boundary	Distance to Maximum from the Project Development Area Boundary
TSP Annual	none	0.00 kg/ha/y	5,520 kg/ha/y	0 m
PAI Annual	0.25 keq/ha/y [(a)]	0.06 keq/ha/y	0.96 keq/ha/y	0.2 m

[(a)] Criteria is based on the Clean Air Strategic Alliance (CASA 1999).
m = metre; kg/ha/y = kilograms per hectare per year; keq/ha/y = kiloequivalent per hectare per year; TSP = total suspended particulate; PAI = potential acid input.

Increased dust deposition has been documented to have varying effects on plants (Forbes 1995; Walker and Werbe 1980; Spatt and Miller 1981; Walker and Everett 1987). However, Auerbach et al. (1997) states that although the species composition may change and the aboveground biomass is lowered due to dust deposition, the ground cover is still maintained. Some species such as cloudberry, willow, and cottongrass were observed to be more abundant as a result of dust deposition (Forbes 1995).

Overall, direct effects from dust deposition are predicted to be largely confined within the Project development area boundary and are anticipated to result in a minor change to vegetation communities relative to baseline conditions (secondary pathway; Table 11.7-13). Subsequently, residual effects to the persistence of vegetation ecosystems, listed plant species, and traditional use plant species are predicted to be negligible.

- Dust deposition and air emissions may change vegetation quality through changes in the chemical content of soil and air.

Accumulation of dust (i.e., TSP deposition) and concentrations of air emissions produced from the Project may result in a local indirect change on the quality of vegetation within the LSA. Air quality modelling was completed to predict the spatial extent of dust deposition and air emissions from the Project (Section 11.4). Air quality modelling was completed for the baseline case, the construction case, and the application case. The baseline case includes background concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM), as well as background potential acid input (PAI) depositions from the regional modelling network. The baseline case also includes air emissions from the Snap Lake Mine (Section 11.4). Maximum changes in air emissions were predicted using the application case (operation phase).

Sources of dust deposition and air emissions modelled in the application case include blasting activities, haul roads, the processing plant, activities at the mine pits and other ancillary facilities (e.g., mine rock piles, Coarse PK Pile and Fine PKC Facility), and vehicle traffic along the Winter Access Road. Environmental design features and mitigation have been incorporated into the Project to reduce potential effects from dust deposition (Table 11.7-13). For example, the watering of roads, airstrip, and laydown areas will facilitate dust suppression. In addition, programs will be instituted to review power and heat use to reduce energy use. Although these environmental design features and mitigation will be implemented to reduce dust deposition and air emissions, assumptions incorporated into the model are expected to contribute to conservative estimates of emission concentrations and deposition rates (Section 11.4).

Haul trucks travelling on the Winter Access Road have the potential to transfer dust from vehicles and loads during the winter months (e.g., dust deposited on wheels and undercarriage while at mine sites and in Yellowknife). However, the relative contribution of these loads to the overall dust accumulation in the area along the roads is considered to be negligible. During the winter, dust that accumulates on snow may settle on vegetation during the spring melt. Although snow melting does not result in “washing away” of dust, the dust that has accumulated on snow during the winter may be diluted during snow melt and spring freshet, and eventually removed by rain. The air emissions from the Winter Access Road were included in the application case and assumed that the road was in operation for 63 days (Section 11.4). In general, annual emissions from the Winter Access Road are anticipated to result in no detectable changes to vegetation.

The results of the air quality modelling predicted the maximum annual dust deposition resulting from the Project is 6,292 kg/ha/y within the Project development area boundary and 5,520 kg/ha/y outside of the Project development area boundary (Table 11.7-14). The maximum deposition that occurs is mostly associated with the mine pits and haul roads. The maximum predicted dust deposition rate outside the Project development area boundary is predicted to occur within 100 m of the Project footprint (Table 11.11-3). The strongest effects from dust are generally confined to the immediate area adjacent to the dust source, such as roads (Walker and Everett 1987). Walker and Everett (1987) and Everett (1980) reported that effects were confined to a 50 m buffer on either side of a road. Moreover, Meininger and Spatt (1988) found that most of effects occurred within 5 to 50 m of a road, with less obvious effects observed between 50 m and 500 m from a road.

The PAI modelling predicted maximum deposition rates of 0.06 kiloequivalent per hectare per year (keq/ha/y) and 0.96 keq/ha/y beyond the Project development area boundary for the baseline and application case, respectively (Table 11.7-14). The maximum deposition occurs at 0.2 m from the Project footprint near the three mine pits and around of the plant site, where haul road emissions are coupled with those from the power generation plant. Interpretation of PAI predictions is based on the Clean Air Strategic Alliance (CASA 1999) deposition loading benchmarks, including the critical threshold of 0.25 keq/ha/y for the most sensitive ecosystems. The area outside the Project development area boundary (footprint) that is predicted to have above the critical load of 0.25 keq/ha/y is estimated at 169 ha, extending up to 500 m from the Project development area boundary.

The air emissions modelling results show that predicted peak concentrations for SO_2 are below the Ambient Air Quality Standards for NWT for the application case (Table 11.7-15). Annual peak concentrations for NO_2 are predicted to slightly exceed guidelines at 64.3 micrograms per cubic metre ($\mu g/m^3$). The area of exceedances is predicted to occur near the South Mine Rock Pile and the haul roads along the south side of the development area (Table 11.7-15). The Annual maximum TSP concentration outside the Project development area boundary is predicted to be 604.8 μg/m^3, compared to the NWT standard of 60 μg/m^3. The area that is predicted to exceed the NWT standard extends no further than approximately 1 km from the Project development area boundary.

Table 11.7-15 Summary of Key Predicted Peak Annual Air Quality Concentrations in the Regional Study Area

Substance	Criteria (μg/m^3)	Maximum Predicted Concentration			
		Baseline		Application	
		Concentrations in the Regional Study Area (μg/m^3)	Distance to Peak Predictions (km)	Concentrations Outside Project Development Area Boundary (μg/m^3)	Distance to Peak Predictions (km)
NO_2 Annual	60	11.9	86.1	**64.3**	1.6
SO_2 Annual	30	3.0	86.1	4.8	2.9
TSP Annual	60	7.1	8.5	**604.8**	1.6
$PM_{2.5}$ Annual	none	2.2	86.1	24.1	1.6

Note: A predicted value that exceeds a criterion is accentuated in bold.

μg/m^3 = micrograms per cubic metre; km = kilometres; NO_X = nitrogen oxides; NO_2 = nitrogen dioxide; SO_2 = sulphur dioxide; $PM_{2.5}$ = particulate matter; TSP = total suspended particulate.

Although concentrations are predicted to be above baseline conditions, the anticipated changes to soil quality are localized and considered minor. The maximum predicted annual TSP deposition rate is expected to occur within 100 m of the Project footprint. Changes to the elemental concentrations in soil from TSP deposition are expected to be below CCME (2007) soil quality guidelines (Appendix 11.7.I, Section 11.7.I.4.3). Therefore, changes to the chemical content of soil should not affect the soils ability to support vegetation. In addition, the deposition predictions are considered to be conservative and therefore, the deposition rates are likely overestimated (Section 11.4). Overall, changes in vegetation communities due to dust deposition and air emissions are anticipated to be minor relative to baseline conditions (secondary pathway; Table 11.7-13). Consequently, residual effects to the persistence of vegetation ecosystems, listed plant species, and traditional use plant species are predicted to be negligible.

- Dewatering may result in newly established vegetation on the exposed lakebed sediments.

The development of the Project will require the dewatering of Kennady Lake, resulting in the exposure of a portion of the lake-bed. Although it is anticipated that the sediment would solidify and form a hardpan crust, there is potential for vegetation to establish on the exposed lake-bed sediments. The exposure of bare, nutrient-rich lakebed sediments can provide a substrate that may favour the establishment of rapid colonizing plants, some of which could be weedy, invasive species (Shafroth et al. 2002). If the substrate remains moist during the initial stages of plant colonization, then riparian plant species may become established on the exposed lakebed. Over time as the substrate becomes drier, the species composition may shift to plants more commonly found in upland areas.

The lack of fine sediment around the periphery of Kennady Lake, and the consistent presence of boulder and cobble through the shallow areas of the lake, will effectively limit colonization of the lakebed by terrestrial vegetation through vegetative propagation (i.e., root growth). Vegetation is more likely to be established through seed dispersal and subsequent germination, with the seeds being dispersed across the nearshore rocky habitat to colonize the fine sediments that are currently located in the deeper sections of the lake (Section 8). Vegetation is expected to establish slowly and coverage would be patchy. Initial colonizers are thought to be graminoids (grasses and sedges).

The anticipated effects on riparian vegetation will be localized, and it is expected that dewatering will result in a minor change to the quantity of plants relative to baseline conditions (secondary pathway; Table 11.7-13). Therefore, the residual effects to the persistence of vegetation ecosystems and plants from the dewatering of Kennady Lake are predicted to be negligible.

11.7.3.5 Primary Pathways

The following primary pathways are analyzed and classified in the effects assessment.

- Direct loss and fragmentation of vegetation ecosystems and plants.
- Changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from dewatering of Kennady Lake may affect the quantity of vegetation.
- Changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from refilling of Kennady Lake may affect the quantity of vegetation.

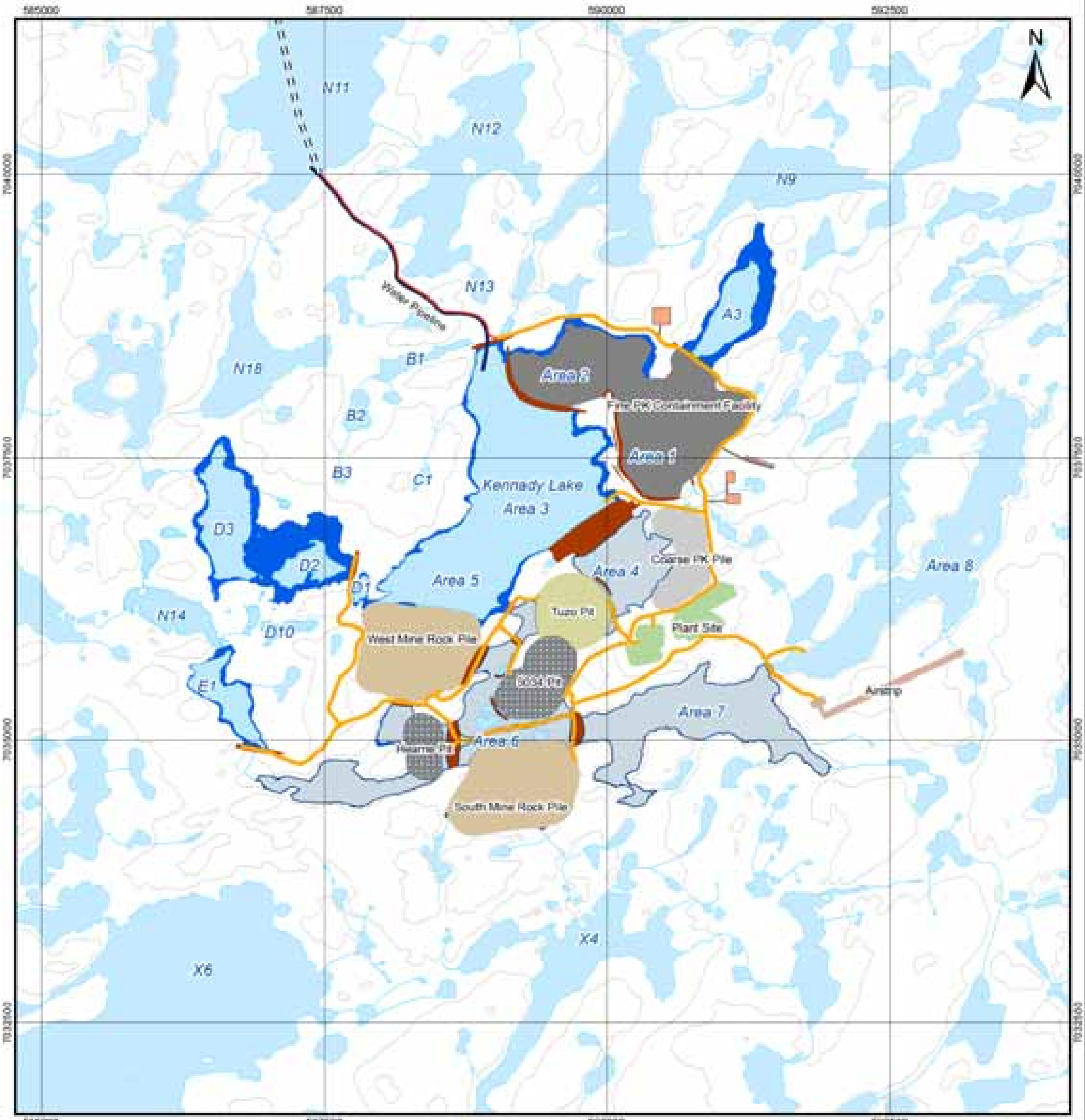
11.7.4 Effects to Vegetation Ecosystems and Plants

11.7.4.1 Effects from the Project Footprint

11.7.4.1.1 Methods

Due to the inherent sensitivity of the Arctic environment to disturbance, all vegetation ecosystems and associated plants were included in the analysis of effects. Particular emphasis was placed on the effects of the Project in relation to ecosystem types or plants considered especially sensitive to disturbance (e.g., wetlands and riparian areas), those with a restricted distribution in the study area (including rare plant communities), plant species listed as being “at risk”, and plant species identified from traditional use studies.

The effects to vegetation ecosystems and plants were assessed using ELC information developed for the LSA, BEU information developed for the RSA, field survey data, and the expected Project footprint (Figure 11.7-9). Effects to traditional use plants and species at risk (listed) plants are included in the analysis. The dominant ecosystem classification system was used to define vegetation communities for the LSA. This system is more refined and precise than BEUs, and therefore, more appropriate to predict and assess effects from the Project on vegetation ecosystems and plants (including listed and traditional use species). Broad ecosystem units are defined at a coarser scale and more appropriate for predicting regional (cumulative) effects to vegetation ecosystems and plants (and to wildlife from changes in vegetation). Areas of the vegetation ecosystem types present within the Project footprint were calculated to determine how much of each type would be affected by Project.



LEGEND

- Watercourse
- Waterbody
- N12 Lake Indentifer
- Contour (10m interval)
- = = Proposed Winter Access Road

Project Footprint

- Service Road
- Site Road
- Water Pipeline
- Airstrip
- Back-filled Pit
- Building
- Coarse PK Pile
- De-watered Lake Bed
- Dyke or Berm
- Fine PK Containment Facility
- Flooded Area
- Mine Rock Pile
- Open Pit
- Plant Site
- Water

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

PK = Processed Kimberlite

GAHCHO KUÉ PROJECT

Project Footprint

PROJECTION	DATUM
UTM Zone 12	NAD83

Scale 1:50,000

500 250 0 500

Metres

DE BEERS CANADA

FILE No			DATE
E-Perm-001-GIS			October 20, 2010
JOB NO	REVISION NO		
09-1365-1004	1		
OFFICE	DRAWN	CHECK	
GOLD-CAL	CW/ANK	JV	

Figure 11.7-9

11.7.4.1.2 Results

Vegetation Ecosystem Types and Communities

The total area of the Project footprint is estimated to be 1,235.4 ha. This includes 853.3 ha of mine and infrastructure that will directly impact terrestrial and aquatic resources (Table 11.7-16). An additional 382.1 ha also occurs within the extent of Project footprint but this area is represented by waterbodies that will remain as waterbodies at baseline and application, and therefore are not considered to be affected with respect to the terrestrial assessment.

The largest single components apart from the various infrastructure features, flooded areas, and dewatered lake beds (that will be returned to waterbodies at closure) are the mine rock covered Fine PKC Facility and Coarse PK Pile (11.9% of the total footprint area), the south mine rock pile (6.3% of the total footprint area), and the west mine rock pile (6.3% of the total footprint area).

The water levels of the components referred to as Area 3 - Kennady Lake (flooded area) (0.3% of the disturbance footprint) and flooded area (areas D2, D3 and E1) (7.0% of the disturbance footprint) will return to baseline levels at closure. The component referred to as raised A3 (flooded area) (1.8% of the Project footprint) will remain flooded beyond closure.

Certain footprint components will result in the permanent removal of vegetation and will not be subject to terrestrial reclamation and/or re-vegetation activities (e.g., areas temporarily flooded during operations, terrestrial portions of pits that will be water-filled upon closure, rock berms, Fine PKC Facility, Coarse PK Pile, and mine rock piles that will be capped with rock). Wherever possible, progressive reclamation will be carried out during the life of the Project in an effort to assist in the recovery of disturbed areas.

Table 11.7-16 Project Components and Associated Project Footprint during the Application Case

Project Component	Components Affecting Ecosystems		Components Not Affecting Ecosystems[a]	
	ha	% of Project Footprint	ha	% of Project Footprint
Mine and Infrastructure				
5034 Pit	36.2	2.9	-	-
Airstrip	9.6	0.8	-	-
Area 1 Perimeter Berm	0.5	0.0	-	-
Area 3 - Kennady Lake (flooded area)	3.9	0.3	-	-
Area 4 (de-watered lake bed)	45.2	3.7	-	-
Area 6 (de-watered lake bed)	74.2	6.0	-	-
Area 7 (de-watered lake bed)	98.4	8.0		
Building A	2.4	0.2	-	-

Table 11.7-16 Project Components and Associated Project Footprint during the Application Case (continued)

Project Component	Components Affecting Ecosystems		Components Not Affecting Ecosystems[a]	
	ha	% of Project Footprint	ha	% of Project Footprint
Building B	0.5	0.0	-	-
Building C	0.7	0.1	-	-
Building D	2.1	0.2	-	-
Conveyer Belt	0.0	0.0	-	-
Dyke A	1.4	0.1	-	-
Dyke B	18.3	1.5	-	-
Dyke C	1.6	0.1	-	-
Dyke D	0.7	0.1	-	-
Dyke E	1.2	0.1	-	-
Dyke F	1.5	0.1	-	-
Dyke G	1.8	0.1	-	-
Dyke H	1.3	0.1	-	-
Dyke I	3.1	0.2	-	-
Dyke J	0.6	0.0	-	-
Dyke K	3.1	0.2	-	-
Dyke L	5.2	0.4	-	-
Dyke M	0.8	0.1	-	-
Dyke N	4.2	0.3	-	-
Flooded Area (areas D2, D3 and E1)	87.0	7.0	-	-
Hearne Pit	16.7	1.3	-	-
Mill 1 (plant site)	16.3	1.3	-	-
Mill 2 (plant site)	9.6	0.8	-	-
Perimeter Berm	4.1	0.3	-	-
Raised A3 (flooded area)	22.7	1.8	-	-
Road	39.9	3.2	-	-
South Mine Rock Pile	77.8	6.3	-	-
Tuzo Pit	34.7	2.8	-	-
Mine rock Berm 2	0.1	0.0	-	-
Mine rock Covered Coarse PK	32.2	2.6	-	-
Mine rock Covered Fine PK/Coarse PK	115.1	9.3	-	-
Water Collection Pond Berm 3	0.5	0.0	-	-
Water Collection Pond Berm 4	0.1	0.0	-	-
Water Collection Pond Berm 6	0.5	0.0	-	-
West Mine Rock Pile	77.6	6.3	-	-
mine and infrastructure subtotal	*853.3*	*69.1*	-	-
Waterbody				
A3	-	-	23.7	1.9
Area 3 - Kennady Lake	-	-	209.5	17.0
Area Behind Dyke L - Kennady Lake	-	-	13.2	1.1
CP2	-	-	1.0	0.1

Table 11.7-16 Project Components and Associated Project Footprint during the Application Case (continued)

Project Component	Components Affecting Ecosystems		Components Not Affecting Ecosystems[(a)]	
	ha	% of Project Footprint	ha	% of Project Footprint
CP3	-	-	2.4	0.2
CP4	-	-	0.2	0.0
CP6	-	-	1.6	0.1
D10	-	-	4.4	0.4
D2	-	-	12.5	1.0
D3	-	-	38.4	3.1
E1	-	-	20.2	1.6
E2	-	-	2.0	0.2
Lake	-	-	5.3	0.4
N14	-	-	21.6	1.7
Submerged Fine PK/Coarse PK	-	-	26.2	2.1
waterbody subtotal	-	-	*382.1*	*30.9*
Grand Total	**853.3**	**69.1**	**382.1**	**30.9**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

(a) Project components will not have an effect on certain waterbodies that occur within the bounds of the Project footprint. These waterbodies will remain unaffected from baseline through closure. For example, the "Submerged Fine PK/Coarse PK" material is placed directly in an existing lake, and therefore is considered a waterbody feature from baseline to closure. Thus, while some of these waterbodies will be used for operational purposes, they are not considered to be affected for the purposes of the terrestrial assessment.

ha = hectare; % = percent; < = less than; PK = processed kimberlite.

Local Study Area

Approximately 392.5 ha (31.8% of the total Project footprint) is terrestrial (Table 11.7-17). Ecosystem types that will be disturbed most include the upland Scrub Birch – Labrador Tea Tundra (BL) unit (176.3 ha) and the wetlands Scrub Birch – Cloudberry Low Shrub Tundra (BR) unit (128.1 ha). These two ecosystems are also the most abundant ecosystem types within the LSA.

The wetlands Water Sedge – Narrow-leaved Cottongrass Fen (CA) unit will have 8.7 ha disturbed by the Project development; however, its restricted distribution and availability within the LSA (0.2% of the LSA) translates into approximately 18.3% of its current abundance being disturbed. The footprint components associated with the disturbance of the CA unit are the flooded areas (which may include areas D2, D3 and/or E1) (7.8 ha), the mine rock covered Fine PKC Facility and Coarse PK Pile (0.6 ha), and the mine rock piles (0.3 ha). The Project footprint is expected to disturb 459.7 ha of the Lake (LA) class (8.0% of this class or 2.4% of the LSA).

Table 11.7-17 Local Ecosystem Disturbances within the Project Footprint

Dominant Ecological Landscape Classification (ELC)		Baseline Case		Application Case		Closure Case		Net Change Baseline Case to Application Case			Net Change Application Case to Closure Case			Net Change Baseline Case to Closure Case		
Code	Name	(ha)	% of LSA	(ha)	% of LSA	(ha)	% of LSA	(ha)	% of Baseline Case ELC	% of LSA	(ha)	% of Application Case ELC	% of LSA	(ha)	% of Baseline Case ELC	% of LSA
Upland Class																
BF	Boulderfield (sparsely vegetated)	5.4	<0.1	5.4	0.0	5.4	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SS	Saxifrage – Moss Campion Xerophytic Tundra	26.3	0.1	26.3	0.1	26.3	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BE	Scrub Birch – Crowberry Tundra	295.9	1.5	287.3	1.5	287.3	1.5	-8.6	-2.9	-<0.1	0.0	0.0	0.0	-8.6	-2.9	-<0.1
BL	Scrub Birch – Labrador Tea Tundra	6,951.1	35.6	6,774.8	34.7	6,774.8	34.7	-176.3	-2.5	-0.9	0.0	0.0	0.0	-176.3	-2.5	-0.9
PE	Spruce – Lichen Woodland	88.5	0.5	88.5	0.5	88.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	upland class subtotal	*7,367.4*	*37.8*	*7,182.4*	*36.8*	*7,182.4*	*36.8*	*-184.9*	*-2.5*	*-0.9*	*0.0*	*0.0*	*0.0*	*-184.9*	*-2.5*	*-0.9*
Wetland/Riparian Class																
CE	Round-Fruited Sedge – Chamisso's Cottongrass Fen	610.1	3.1	593.3	3.0	593.3	3.0	-16.8	-2.8	-0.1	0.0	0.0	0.0	-16.8	-2.8	-0.1
BC	Scrub Birch – Bluejoint Shrub Tundra	15.5	0.1	15.5	0.1	15.5	0.1	-<0.1	-0.1	-<0.1	0.0	0.0	0.0	-<0.1	-0.1	-<0.1
BR	Scrub Birch – Cloudberry Low Shrub Tundra	4,009.6	20.6	3,881.6	19.9	3,881.6	19.9	-128.1	-3.2	-0.7	0.0	0.0	0.0	-128.1	-3.2	-0.7
RB	Scrub Birch – Riparian Shrub	89.0	0.5	88.9	0.5	88.9	0.5	-0.1	-0.1	-<0.1	0.0	0.0	0.0	-0.1	-0.1	-<0.1
EA	Sheathed Cottongrass – Bog Rosemary Sedge Fen	1,417.4	7.3	1,363.6	7.0	1,363.6	7.0	-53.8	-3.8	-0.3	0.0	0.0	0.0	-53.8	-3.8	-0.3
CA	Water Sedge – Narrow-leaved Cottongrass Fen	47.4	0.2	38.7	0.2	38.7	0.2	-8.7	-18.3	-<0.1	0.0	0.0	0.0	-8.7	-18.3	-<0.1
SR	Willow – Nagoonberry Shrub	166.1	0.9	166.1	0.9	166.1	0.9	-<0.1	-<0.1	-<0.1	0.0	0.0	0.0	-<0.1	-<0.1	-<0.1
	wetland/riparian class subtotal	*6,355.2*	*32.6*	*6,147.6*	*31.5*	*6,147.6*	*31.5*	*-207.6*	*-3.3*	*-1.1*	*0.0*	*0.0*	*0.0*	*-207.6*	*-3.3*	*-1.1*
	terrestrial subtotal	*13,722.6*	*70.4*	*13,330.0*	*68.4*	*13,330.0*	*68.4*	*-392.5*	*-2.9*	*-2.0*	*0.0*	*0.0*	*0.0*	*-392.5*	*-2.9*	*-2.0*

Table 11.7-17 Local Ecosystem Disturbances within the Project Footprint (continued)

Dominant Ecological Landscape Classification (ELC)		Baseline Case		Application Case		Closure Case		Net Change Baseline Case to Application Case			Net Change Application Case to Closure Case			Net Change Baseline Case to Closure Case		
Code	**Name**	**(ha)**	**% of LSA**	**(ha)**	**% of LSA**	**(ha)**	**% of LSA**	**(ha)**	**% of Baseline Case ELC**	**% of LSA**	**(ha)**	**% of Application Case ELC**	**% of LSA**	**(ha)**	**% of Baseline Case ELC**	**% of LSA**
Water Class																
LA	Lake (open water)	5,767.9	29.6	5,308.2	27.2	5,594.2	28.7	-459.7	-8.0	-2.4	286.0	5.4	1.5	-173.7	-3.0	-0.9
	water class subtotal	*5,767.9*	*29.6*	*5,308.2*	*27.2*	*5,594.2*	*28.7*	*-459.7*	*-8.0*	*-2.4*	*286.0*	*5.4*	*1.5*	*-173.7*	*-3.0*	*-0.9*
	ELC subtotal (terrestrial and water classes)	*19,490.5*	*100.0*	*18,638.2*	*95.6*	*18,924.2*	*97.0*	*-852.2*	*-4.4*	*-4.4*	*286.0*	*1.5*	*1.5*	*-566.2*	*-2.9*	*-2.9*
Disturbance Class																
DWLB	Dewatered Lake Bed	0.0	0.0	217.8	1.1	0.0	0.0	217.8	n/a	1.1	-217.8	-100.0	-1.1	0.0	n/a	0.0
FLDO	Flooded During Operations	0.0	0.0	113.5	0.6	90.8	0.5	113.5	n/a	0.6	-22.7	-20.0	-0.1	90.8	n/a	0.5
RR	Camp (anthropogenic), Mine and Infrastructure	9.3	<0.1	530.2	2.7	484.7	2.5	520.9	5,581.7	2.7	-45.5	-8.6	-0.2	475.4	5,094.0	2.4
	disturbance subtotal	*9.3*	*<0.1*	*861.6*	*4.4*	*575.6*	*3.0*	*852.2*[(a)]	*9,131.8*	*4.4*	*-286.0*	*-33.2*	*-1.5*	*566.2*	*6,067.2*	*2.9*
Total		**19,499.8**	**100.0**	**19,499.8**	**100.0**	**19,499.8**	**100.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

(a) The total area of the Project footprint is estimated to be 1235.4 ha. This includes 853.3 ha of mine and infrastructure that will directly impact terrestrial and aquatic resources (which includes 852.2 ha of native ecosystems and 1.1 ha of the existing camp that will be disturbed due to the Project for a total of 853.3 ha). An additional 382.1 ha also occurs within the extent of Project footprint but this area is represented by waterbodies that will remain as waterbodies at baseline and application, and therefore are not considered to be impacted as they relate to the terrestrial assessment.

ha = hectare; % = percent.; n/a = not applicable; < = less than.

Wetlands and riparian areas, which tend to be more sensitive to disturbance, will also be affected by the Project footprint. These vegetation ecosystems include the Scrub Birch – Cloudberry Low Shrub Tundra (BR) unit, as well as the Sheathed Cottongrass – Bog Rosemary Sedge Fen (EA), Round-Fruited Sedge – Chamisso's Cottongrass Fen (CE), Willow – Nagoonberry Shrub (SR), Scrub Birch – Riparian Shrub (RB), Scrub Birch – Bluejoint Shrub Tundra (BC) and Water Sedge – Narrow-leaved Cottongrass Fen (CA) units. A total of 207.6 ha or 3.3% of all wetlands and riparian areas within the Project footprint will be disturbed, representing 1.1% of the LSA.

In addition to the Water Sedge – Narrow-leaved Cottongrass Fen (CA), Round-Fruited Sedge – Chamisso's Cottongrass Fen (CE) and Sheathed Cottongrass – Bog Rosemary Sedge Fen (EA) ecosystems being sensitive to disturbance, they also have a moderate to high potential to support rare plant habitat. While no rare plants were identified during field surveys of the proposed Project site, the possibility of their presence in the area remains and disturbing habitat that may support higher numbers of rare plant species may negatively affect existing populations. The identification of possible rare plant occurrences within Project development areas will be further addressed through the vegetation management plan and follow-up monitoring programs proposed for the Project (Section 11.7.10). Appropriate mitigation practices and protocols will also be implemented should any rare plants be identified.

Regional Study Area

Similar to the LSA, the Project footprint is anticipated to disturb more aquatic habitat than terrestrial habitat within the RSA (Table 11.7-18). Absolute and relative differences in the amount of each ecosystem disturbed in the LSA and RSA (in particular, the water class) are due to the different mapping methods (i.e., the LSA used an ELC vector-based approach while the RSA used satellite imagery based on rasterized coverage).

Broad ecosystem units that will be affected most (e.g., occupy more than 5% of the Project footprint) include Deep Water (DEWA) (22.5% of the Project footprint), Shallow Water (SHWA) (11.7% of the Project footprint), Tussock-Hummock (TUHU) (6.5% of the Project footprint), Peat Bog (PEBO) (6.4% of the Project footprint), and Sedge Wetlands (SEWE) (6.0% of the Project footprint). However, at the scale of the RSA, less than 1% of any ecosystem type is expected to be disturbed by the Project footprint.

Table 11.7-18 Regional Ecosystem Disturbances within the Project Footprint

Broad Ecosystem Unit (BEU) Class		Baseline Case		Application Case		Closure Case		Net Change Baseline to Application			Net Change Application to Closure			Net Change Baseline to Closure		
Code	**Name**	**(ha)**	**% of RSA**	**(ha)**	**% of RSA**	**(ha)**	**% of RSA**	**(ha)**	**% of BEU**	**% of RSA**	**(ha)**	**% of BEU**	**% of RSA**	**(ha)**	**% of BEU**	**% of RSA**
Upland Class																
BEAS	Bedrock Association (>80% Bedrock)	24,677.7	4.3	24,673.9	4.3	24,673.9	4.3	-3.8	-<0.1	-<0.1	0.0	0.0	0.0	-3.8	-<0.1	-<0.1
BOAS	Boulder Association (>80% Boulders)	18,928.6	3.3	18,923.7	3.3	18,923.7	3.3	-5.0	-<0.1	-<0.1	0.0	0.0	0.0	-5.0	-<0.1	-<0.1
ESCO	Esker Complex	621.4	0.1	621.4	0.1	621.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HETU	Heath Tundra (<30% Rock)	24,353.7	4.3	24,295.5	4.3	24,295.5	4.3	-58.2	-0.2	-<0.1	0.0	0.0	0.0	-58.2	-0.2	-<0.1
HEBE	Heath/Bedrock (30 to 80% Bedrock)	38,570.3	6.8	38,539.8	6.8	38,539.8	6.8	-30.5	-0.1	-<0.1	0.0	0.0	0.0	-30.5	-0.1	-<0.1
HEBO	Heath/Boulders (30 to 80% Boulders)	44,502.4	7.8	44,486.9	7.8	44,486.9	7.8	-15.5	0.0	-<0.1	0.0	0.0	0.0	-15.5	<0.1	-<0.1
SPFO	Spruce Forest	32,359.6	5.7	32,324.3	5.7	32,324.3	5.7	-35.4	-0.1	-<0.1	0.0	0.0	0.0	-35.4	-0.1	-<0.1
	upland class subtotal	*184,013.8*	*32.3*	*183,865.5*	*32.3*	*183,865.5*	*32.3*	*-148.3*	*-0.1*	*-<0.1*	*0.0*	*0.0*	*0.0*	*-148.3*	*-0.1*	*-<0.1*
Wetland Class																
BISE	Birch Seep	27,618.1	4.8	27,593.5	4.8	27,593.5	4.8	-24.6	-0.1	-<0.1	0.0	0.0	0.0	-24.6	-0.1	-<0.1
PEBO	Peat Bog	48,333.6	8.5	48,254.5	8.5	48,254.5	8.5	-79.1	-0.2	-<0.1	0.0	0.0	0.0	-79.1	-0.2	-<0.1
TASH	Riparian Tall Shrub	31,324.1	5.5	31,300.3	5.5	31,300.3	5.5	-23.8	-0.1	-<0.1	0.0	0.0	0.0	-23.8	-0.1	-<0.1
SEWE	Sedge Wetland	56,198.9	9.9	56,125.2	9.9	56,125.2	9.9	-73.7	-0.1	-<0.1	0.0	0.0	0.0	-73.7	-0.1	-<0.1
TUHU	Tussock/Hummock (Sedge Association)	51,645.7	9.1	51,565.6	9.1	51,565.6	9.1	-80.1	-0.2	-<0.1	0.0	0.0	0.0	-80.1	-0.2	-<0.1
	wetland class subtotal	*215,120.3*	*37.8*	*214,839.0*	*37.7*	*214,839.0*	*37.7*	*-281.3*	*-0.1*	*-<0.1*	*0.0*	*0.0*	*0.0*	*-281.3*	*-0.1*	*-<0.1*
Water Class																
DEWA	Deep Water	96,879.8	17.0	96,601.4	17.0	96,760.1	17.0	-278.4	-0.3	-<0.1	158.7	0.2	<0.1	-119.7	-0.1	-<0.1
SHWA	Shallow Water	37,128.9	6.5	36,984.9	6.5	37,084.4	6.5	-144.0	-0.4	-<0.1	99.5	0.3	<0.1	-44.5	-0.1	-<0.1
	water class subtotal	*134,008.7*	*23.5*	*133,586.3*	*23.4*	*133,844.5*	*23.5*	*-422.4*	*-0.3*	*-0.1*	*258.2*	*0.2*	*<0.1*	*-164.2*	*-0.1*	*-<0.1*
Unclassified																
UC	Unclassified	36,535.4	6.4	36,534.0	6.4	36,534.0	6.4	-1.3	-<0.1	-<0.1	0.0	0.0	0.0	-1.3	-<0.1	-<0.1
	unclassified subtotal	*36,535.4*	*6.4*	*36,534.0*	*6.4*	*36,534.0*	*6.4*	*-1.3*	*-<0.1*	*-<0.1*	*0.0*	*0.0*	*0.0*	*-1.3*	*-<0.1*	*-<0.1*
	ecosystem class subtotal	*569,678.2*	*100.0*	*568,824.9*	*99.9*	*569,083.1*	*99.9*	*-853.3*	*-0.1*	*-0.1*	*258.2*	*0.0*	*0.0*	*-595.1*	*-0.1*	*-0.1*
Disturbance Class																
DWLB	Dewatered Lake Bed	0.0	0.0	217.8	<0.1	0.0	0.0	217.8	n/a	<0.1	-217.8	n/a	-<0.1	0.0	n/a	0.0
FLDO	Flooded During Operations	0.0	0.0	113.5	<0.1	90.8	<0.1	113.5	n/a	<0.1	-22.7	n/a	-<0.1	90.8	n/a	<0.1
MINE	Mine and Infrastructure	0.0	0.0	522.0	0.1	504.3	0.1	522.0	n/a	0.1	-17.7	n/a	-<0.1	504.3	n/a	0.1
	disturbance subtotal	*0.0*	*0.0*	*853.3*	*0.1*	*595.1*	*0.1*	*853.3*	*n/a*	*0.1*	*-258.2*	*n/a*	*-<0.1*	*595.1*	*n/a*	*0.1*
Total		**569,678.2**	**100.0**	**569,678.2**	**100.0**	**569,678.2**	**100.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Note: Some numbers are rounded to the nearest 10th decimal place for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent; n/a = not applicable; < = less than.

Traditional Use Plants

Approximately 2.9% and 0.1% of vegetation ecosystems, which include traditional use plants, within the LSA and RSA, respectively, will be removed due to Project infrastructure (Tables 11.7-17 and 11.7-18, respectively). These estimates represent a relatively small portion of both study areas. The traditional knowledge studies identified a number of concerns that traditional knowledge holders have expressed in the past regarding the potential effects to vegetation and plant communities due to mining activities. The primary concerns include the loss of ecosystems, vegetation contamination, and other effects on people. Traditional knowledge holders also consider water found in muskeg to be “good” if it is clear and cold and if the vegetation in the muskeg is healthy (Annex M Traditional Knowledge and Traditional Land Use Baseline).

Species at Risk

No plant species at risk were identified in the LSA and anticipated Project footprint during baseline studies (Section 11.7.2.3.4); however, this does not preclude the potential for listed (rare) plants to inhabit the area. Disturbance to habitat that may support rare plant species may negatively affect existing populations. The identification of possible rare plant occurrences within the Project site will be further addressed through the general vegetation management plan and follow-up monitoring programs (Section 11.7.10). Mitigation practices and protocols will also be implemented should any rare plants be identified.

Approximately 79.3 ha (0.4% of the LSA) of potential rare plant habitat (ranked moderate to high) will be directly disturbed by the Project (Table 11.7-19). The Sheathed Cottongrass – Bog-rosemary Sedge Fen (EA) will be most affected in terms of area; however, disturbance of the Water Sedge – Narrow-leaved Cottongrass Fen (CA) may be more ecological important due to its restricted distribution within the LSA.

Table 11.7-19 Disturbance of Ecosystems with a Moderate to High Potential of Supporting Rare Plant Habitat within the Project Footprint

Ecosystem Type	Footprint Area (ha)	LSA Area (ha)	Remaining LSA Area (ha)
EA - Sheathed Cottongrass – Bog Rosemary Sedge Fen	53.8	1,417.4	1,363.6
CE - Round-Fruited Sedge – Chamisso's Cottongrass Fen	16.8	610.1	593.3
CA - Water Sedge – Narrow-leaved Cottongrass Fen	8.7	47.4	38.7
Total	**79.3**	**2,074.9**	1,995.6

LSA = Locals Study Area; ha = hectare.

11.7.4.1.3 Cumulative Effects to Vegetation Ecosystems and Plants

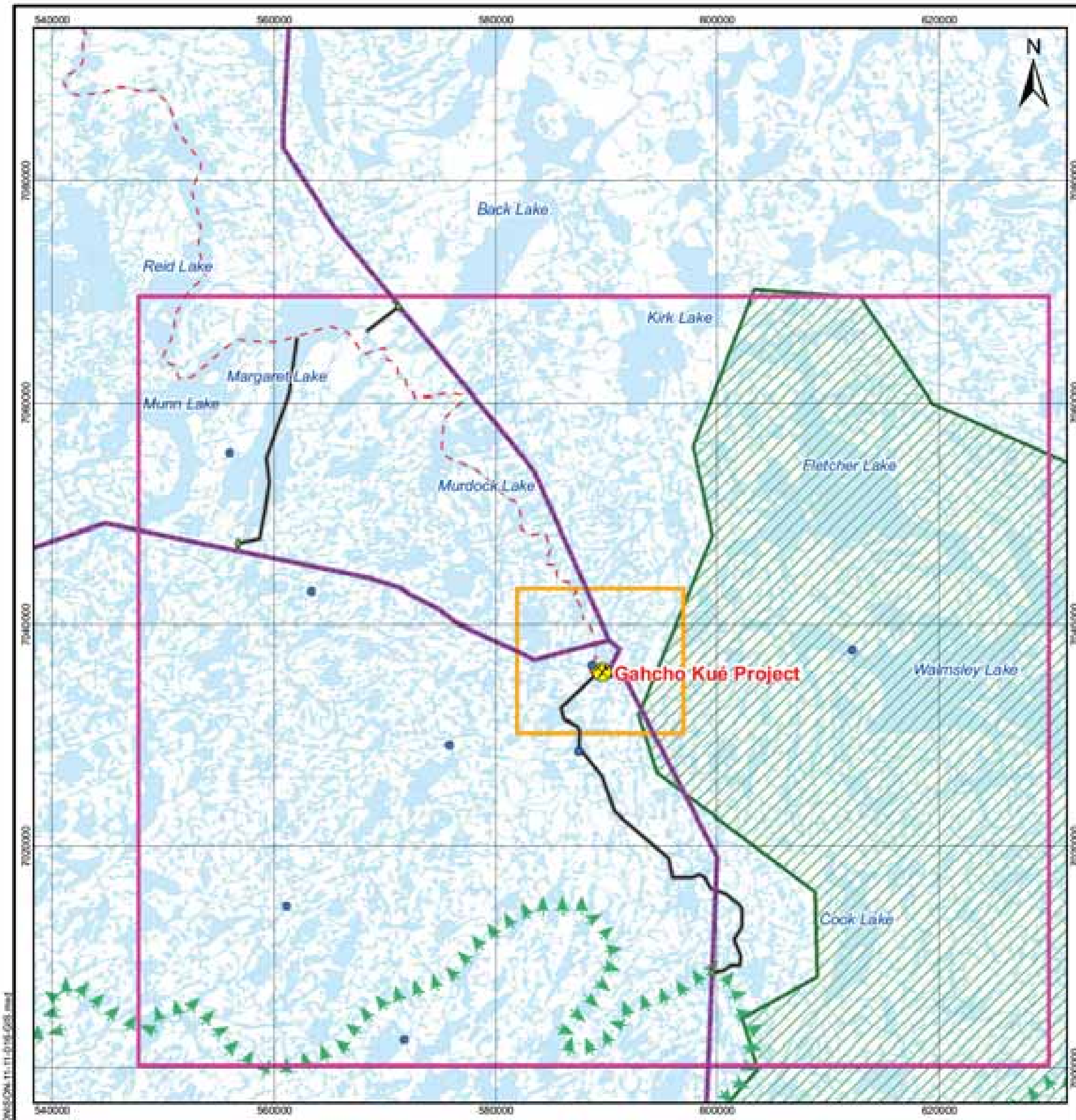
Methods

The cumulative effects to vegetation ecosystems and plants from the Project footprint and other previous, existing, and future developments in the RSA were analyzed through changes in the area and spatial configuration of BEUs on the landscape (i.e., landscape metrics). Landscape metrics for each BEU included total area, number of patches, and mean distance to the nearest similar patch. The identification of changes to these metrics provides an estimate of the cumulative loss and fragmentation to vegetation ecosystems (as BEUs) in the study area, which can affect regional-scale biodiversity, sensitive vegetation communities, and rare and traditional use plants. The analysis was completed for the non-winter period as pathway analysis predicted that effects to vegetation ecosystems and plants from the Winter Access Road would be negligible (Section 11.7.3).

Previous and existing developments in the study area include eight mineral exploration programs (including the Kennady Lake exploration program) (Figure 11.7-10). Data on the location and type of developments was obtained from the following data sources:

- Mackenzie Valley Land and Water Board (MVLWB): permitted and licensed activities within the NWT;
- Indian and Northern Affairs Canada (INAC): permitted and licensed activities within the NWT;
- INAC: contaminated sites database;
- company websites; and
- knowledge of the area and project status.

Initially, data indicating permitted and licensed activities were obtained in spreadsheet format. The file was examined for duplication of information (e.g., a water license and a land use permit for the same development). In cases where two or more pieces of location information for the same activity were present, the extra information was deleted from the file so that it contained only one point per development. Data associated with the location attributes (e.g., permit status, feature name) also were edited in some instances to update the information or standardize it for running modelling scenarios efficiently.



LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Treeline
- Local Study Area
- Regional Study Area

Previous and Existing Development

- Mineral Exploration
- Winter Access Road

Future Development

- Taltson Staging Area
- Taltson Transmission Line
- Winter Road
- Proposed East Arm National Park

NOTES

Base data source: National Topographic Base Data (NTDB) 1:250,000

G:\2009\1365\09-1365-1004 De Beers Gahcho Kue EA Support\GIS\mapping\SON\SON-11-11-016-GIS.mxd

GAHCHO KUÉ PROJECT

Previous, Existing and Reasonably Foreseeable Future Developments in the Regional Study Area

PROJECTION: UTM Zone 12		DATUM: NAD83	DE BEERS CANADA
Scale: 1:500,000 (10 5 0 10 Kilometres)			
FILE No: SON-11-11-016-GIS			DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 4		Figure 11.7-10
OFFICE: GOLD-SAS	DRAWN: ANK	CHECK: JV	

The information was used to generate a development layer within a Geographic Information System (GIS) platform. Because the database contains no information on the size of the physical footprint for exploration programs, a 500 m radius was used to estimate the area of the footprint for exploration sites (78.5 ha). The Project footprint was derived from the Project Description, and includes both the terrestrial and aquatic areas of disturbance. A 25 m wide right-of-way was applied to linear developments (e.g., proposed Taltson Hydroelectric Expansion Project), which matched the raster cell size of the BEU layer for the RSA (i.e., 25 m x 25 m). For all developments (including the Project), the physical footprint was carried through each assessment case (Section 6.6.2) as it was assumed that effects to the landscape had not yet been reversed. The development layer was then applied to the BEU classification of the study area for the baseline, application, and future cases (Table 11.7-19).

The baseline case includes the temporal changes in the number of previous and existing projects known to occur within the study area, which can include no previous development (Section 6.6.2). Environmental conditions on the landscape prior to human development (i.e., reference conditions) were also included in the analysis. Analyzing a range of temporal conditions on the landscape is fundamental to understanding the cumulative effects of increasing development on vegetation ecosystems. The application case occurs from construction of the Project, through the duration of predicted effects (i.e., until the effects are reversed or are deemed irreversible).

The future case includes the baseline case, application case, and reasonably foreseeable developments (Table 11.7-20). Currently, there are two known, reasonably foreseeable developments that may generate incremental effects on vegetation ecosystems in the study area:

- Taltson Hydroelectric Expansion Project; and
- Proposed East Arm National Park.

Table 11.7-20 Contents of Each Assessment Case

Baseline Case	Application Case	Future Case
Range of conditions from little or no development to all previous and existing projects[a] prior to the Project	baseline case plus the Project	application case plus reasonably foreseeable projects

(a) Includes approved projects.

The temporal boundary for cumulative effects from future developments is a function of the duration of effects from the Project on vegetation communities and plants. At a minimum, the time period for effects from the Project, and reasonably foreseeable developments would occur over 22 years (construction through closure). Except for the Taltson Hydroelectric Expansion Project (for which the anticipated footprint is known), effects analyses for the future case are mostly qualitative due to the large degree and number of uncertainties. There are uncertainties associated with the rate, type, and location of developments in the study area. There are also uncertainties in the direction, magnitude, and spatial extent of future fluctuations in vegetation, independent of Project effects. Consequently, potential cumulative effects from reasonably foreseeable developments (future case) other than the Taltson Hydroelectric Expansion Project are discussed in the section on uncertainty (Section 11.7.9)

Landscape metrics were determined using the program FRAGSTATS (Version 3.0) within a GIS platform for the reference, baseline, application, and future cases. The incremental and cumulative effects from the Project on the loss and fragmentation of BEUs were estimated by calculating the relative difference between the 2010 baseline and reference case, between the application and 2010 baseline case, and between the future and application case. The following equations were used:

- (2010 baseline value – reference value) / reference value
- (application value – 2010 baseline value) / 2010 baseline value
- (future case – application value) / application value

The resulting value was then multiplied by 100 to give the percent change in a landscape metric for each comparison, and provides both direction and magnitude of the effect. For example, a high negative value for BEU area would indicate an extensive loss of that BEU. Alternately, a negative value for mean distance to nearest neighbour indicates an increase in patch connectivity.

Results

At the scale of the RSA, the relative change in the amount of BEU area from reference to 2010 baseline conditions is less than 0.2% for each BEU type (Table 11.7-21). The predicted incremental loss of any BEU type from the Project relative to 2010 baseline conditions is less than or equal to 0.5% of the RSA.

Similarly, incremental habitat-specific changes from the Taltson Hydroelectric Expansion Project (future case) are expected to be less than 0.2%. The total combined loss of all BEUs in the RSA from the Taltson Hydroelectric Expansion Project is 0.9%. The cumulative direct disturbance to the landscape from the

Project and other previous, existing and future developments is predicted to be about 4.7% relative to reference conditions (Table 11.7-21).

Increasing development on the landscape has also resulted in marginal changes to the number and distance between similar BEU types in the RSA. For a particular habitat, development of previous and existing projects decreased the number of BEU patches on the landscape from 0 to 0.1% relative to reference conditions (Table 11.7-21). Broad ecosystem unit-specific changes in the mean distance to nearest similar patch were estimated to be less than 0.1%.

Similarly, application of the Project and other reasonably foreseeable projects changed the number and distance between similar patches on the landscape by less than 0.5%. The increase in mean distance to nearest neighbour is 0.1 m for heath tundra (HETU), tussock-hummock (TUHU), and sedge wetland (SEWE) habitats. The exception was for the future project case, which increased the number of esker patches by 1.4% and decreased the distance between eskers by 2.0% (Table 11.7-21).

Table 11.7-21 Change (%) in Area and Configuration of Broad Ecosystem Units from Development within the Regional Study Area during Baseline, Application, and Future Conditions

Broad Ecosystem Unit	Area (ha)	% Change to			Number of Patches	% Change to			Mean Nearest Neighbour Distance (m)	% Change to		
	Reference	2010 Baseline	Application	Future	Reference	2010 Baseline	Application	Future	Reference	2010 Baseline	Application	Future
Esker Complex	624	0.00	0.00	-0.02	145	0.00	0.00	1.38	769	0.00	0.00	-2.02
Spruce Forest	32,224	-0.08	-0.15	-0.07	96,659	-0.08	-0.18	0.01	78	0.01	0.04	0.02
Birch Seep	27,670	-0.10	-0.11	-0.09	63,001	-0.08	-0.13	0.02	88	0.03	0.03	0.01
Peat Bog	48,410	-0.10	-0.20	-0.08	84,575	-0.06	-0.10	0.08	76	-0.01	0.03	-0.03
Tussock Hummock	51,708	-0.11	-0.21	-0.07	99,588	-0.08	-0.15	0.04	73	0.01	0.06	0.00
Heath Bedrock	38,657	-0.09	-0.11	-0.08	55,211	-0.08	-0.11	0.07	85	0.01	0.01	-0.04
Heath Tundra	24,419	-0.02	-0.29	-0.12	30,635	-0.04	-0.08	0.08	122	-0.02	0.05	-0.05
Heath Boulder	44,559	-0.11	-0.07	-0.06	81,460	-0.09	-0.09	0.03	78	0.01	0.00	-0.01
Boulder Assoc.	18,930	-0.09	-0.07	-0.06	62,187	-0.09	-0.09	0.00	99	0.03	-0.01	0.01
Bedrock Assoc.	24,679	-0.08	-0.02	-0.05	59,630	-0.08	-0.07	0.03	94	0.00	-0.03	-0.02
Tall Shrub	31,334	-0.08	-0.14	-0.08	83,741	-0.09	-0.17	0.04	79	0.03	0.02	-0.01
Sedge Wetland	56,197	-0.11	-0.24	-0.06	53,616	-0.06	-0.21	0.12	84	0.02	0.09	-0.04
Shallow Water	37,151	-0.10	-0.50	-0.06	19,091	-0.03	-0.32	0.20	115	-0.01	0.29	-0.15
Deep Water	96,981	-0.13	-0.46	-0.02	3,566	0.06	-0.36	0.23	258	0.02	0.01	-0.36

Note: Percent change was measured as the relative incremental change from one time period to the next (e.g., reference [no development or minor amount of development] to 2010 baseline, 2010 baseline to application, and application to future).

ha = hectares; % = percent; m = metres.

11.7.4.2 Effects from Dewatering and Refilling of Kennady Lake

11.7.4.2.1 Methods

The effects to vegetation ecosystems and plants as a result of the dewatering of Area 4, 6 and 7 of Kennady Lake were assessed primarily through the review of available scientific literature. Specific information provided by hydrological modelling for the Project was also incorporated. At closure, dykes will be breached to return drainage flows and water levels to baseline conditions.

11.7.4.2.2 Results

The dewatering of Kennady Lake will be a gradual process and will result in the downstream flooding of terrestrial vegetation. Environmental design features have been included to limit erosion, and subsequently, reduce the potential for loss of riparian habitat. For example, discharges will be limited so that pumping will not increase discharges above the baseline 2-year flood levels in downstream lakes and channels. These levels were selected to reduce potential bank erosion and limit the changes to aquatic habitat quantity (Section 9).

Construction of dykes will cause changes to drainage flow patterns and surface water elevations in some lakes. For example, the construction of Dykes E and D will divert drainage flows from Lake B1 to N6 (Section 3). Construction of Dykes F and G will divert Lakes D3, D2, E1, and N14 through Lake N17. The construction of Dyke C will divert Lake A3 through Lake N9. In addition to diversion of drainage flows, the construction of these dykes will also raise baseline surface water elevations in Lakes D2, D3, E1, and A3. For example, it is anticipated that surface water elevations in Lakes D2 and D3 will increase from approximately 424.2 m and 425.4 m at baseline, respectively, to 427.0 m throughout the construction and operational phases (Section 3). Surface water elevation in Lake E1 is anticipated to increase from 425.2 m to 426.0 m. The greatest increase in lake levels is predicted to be in Lake A3 where surface water elevations will increase from 423.0 m to 426.5 m after the construction of Dyke C. Because of the anticipated changes in lake levels, riparian vegetation surrounding Lakes D2, D3, E1, and A3 will be removed during the construction of the diversion dykes, and prior to flooding (Section 3).

Flooding affects both soils and plants. The flooding of soil alters its ability to support plant growth, primarily by altering soil structure (e.g., aggregate breakdown, deflocculation of clays, and destruction of cementing agents). The chemistry and biology of soil can also be altered (e.g., decreased oxygen levels, increased carbon dioxide levels, increased solubility of mineral substances, aerobic organisms replaced by anaerobes) (Kozlowski 1997). Plant responses to flooding vary with plant species, genotype, rootstock, plant age, time of year and duration of flooding, and floodwater properties (Kozlowski 1997). Flooding adversely affects shoot growth, root growth, mycorrhizal populations, and reproductive growth. Plant stress is amplified when floodwater is deep enough to inundate shoots as well as roots (Visser et al. 2003) and flood effects tend to be more severe during the growing season compared to the dormant season (Kozlowski 1997).

The substrate of Kennady Lake is composed largely of fine mineral and organic materials (Section 9). During the dewatering process, a portion of these materials will likely be transported downstream, thus altering water quality by increasing the amount of total suspended solids (TSS) present. Debris (such as TSS) present in flowing water can physically damage riparian vegetation through abrasion and smothering (Shafroth et al. 2002; Luke et al. 2007). The deposition of deep sediments can also lead to anoxic soils and the accumulation of micronutrient levels that could be toxic to plants (Shafroth et al. 2002).

The deposition of shallow sediments could enhance plant growth by acting as a soil amendment, depending on the nutrient and organic content of the sediments. Alternatively, areas subject to prolonged flooding and deep sediment deposition may exhibit vegetation die back. While the burial of established vegetation by sediments could affect a localized segment of a stream, the seeds of some emergent wetlands plant species may remain viable for between 45 to 400 years (Shafroth et al. 2002) and could serve as a means of re-colonizing areas disturbed by flooding. Downstream effects to soil erosion and stability are expected to be negligible from lake dewatering (Appendix 11.7.I). Streams will have flow changes that will result in no additional changes to soil erosion outside of the existing channels. Lake level changes will be small (i.e., will be within the 1 in 2 year wet flood levels) and will result in negligible soil erosion effects.

Plant communities downstream of Kennady Lake that could be affected by the dewatering process include sedge-dominated wetlands and riparian areas, and upland tundra comprised primarily of dwarf woody vegetation. Wetlands and riparian plant species are better adapted to fluctuating water levels and should be able to withstand and rebound from extended flood conditions more successfully than their upland counterparts. Upland ecosystem types with more freely-drained soils and dwarf vegetation will likely be less resilient to prolonged flooding, and are expected to display a more adverse response to these conditions (Visser et al. 2003; Kozlowski 1997). Portions of the lake margin that are vegetated may die back if they are sensitive to water level declines resulting from dewatering (Shafroth et al. 2002).

The exposure of bare, nutrient-rich lakebed sediments can provide a substrate that may favour the establishment of rapid colonizing plants, some of which could be weedy, invasive species (Shafroth et al. 2002). If the substrate remains moist during the initial stages of plant colonization, wetlands and riparian plant species may become established on the exposed lakebed. Over time as the substrate becomes drier, the species composition may shift to plants more commonly found in upland areas.

Habitat potentially supporting rare plants and rare plant communities may also be affected if they occur within 100 m of the dewatered lake edge. These habitat types include the Sheathed Cottongrass – Bog-Rosemary Sedge fen unit (EA), the Round-fruited Sedge – Chamisso's Cottongrass fen unit (CE), and the Water Sedge – Narrow-leaved Cottongrass fen unit (CA), all of which have a moderate to high potential to support rare plants in the local area.

The progressive reclamation strategy will be extended to the water management of Kennady Lake, where portions of the lake will be isolated and brought back to compliant water levels and quality as quickly as possible. The closure water management plan requires annually pumping water from Lake N11 to Area 3 to reduce the overall time for the closure phase. The pumping rates are anticipated to be managed such that the total outflow from Lake N11 does not drop below the 1 in 5-year dry conditions. At closure, dykes will be breached to return drainage flows and water levels to baseline conditions. While most changes are predicted to revert back to natural conditions, it is anticipated that drainage flows of Lakes A3 to N9 will remain permanently and the surface water elevation in Lake A3 will remain above baseline conditions (Section 3).

The possible effects to plant communities downstream of Kennady Lake as a result of dewatering are anticipated to be local. The direct effects of flooding on plant communities are already accounted for in Section 11.7.4.1 (Table 11.7-17), with 90.8 ha being affected. It is anticipated that over the long-term, areas that are directly flooded during operations and lost over this time period will re-establish following closure.

For plant communities occurring along the margins of the dewatered or flooded areas, the effect will be dependent upon the type of communities present (e.g., wetland, riparian or upland). Wetlands and riparian communities are expected to be partially resilient to rising and fluctuating water levels, respectively, while uplands should be relatively unaffected by a decrease in the water level. Effects that may occur to communities located along the margin of influence are expected to be restricted to a relatively short distance away from that margin. A monitoring program will be designed and implemented to test predictions, particularly the magnitude and extent of changes to vegetation ecosystems and plants that are associated with edge effects of flooding and dewatering. Details are provided in Section 11.7.10.

11.7.5 Related Effects to Wildlife

Effects to vegetation ecosystems and plants from the Project are primarily associated with potential changes in food quantity and quality for ungulates such as caribou (*Rangifer tarandus*), muskoxen (*Ovibos moschatus)*, and moose (*Alces alces)*. Although other wildlife such as muskrat (*Ondatra zibethica*) and beaver (*Castor canadensis*) feed on riparian vegetation (and some upland plants), the effect from the Project is predicted to have a negligible influence on muskrat and beaver populations (Section 8, Section 9).

At the local scale, the Project footprint will alter 4.4% of the baseline LSA. Terrestrial habitat types (BEUs) that will be disturbed most include tussock-hummock (TUHU), sedge wetland (SEWE), and peat bog (PEBO) (all decreased by 0.4%). These habitats are some of the most abundant vegetation communities within the LSA (and RSA). Other terrestrial habitats altered by the Project footprint include heath tundra (HETU), heath tundra with bedrock or boulders (HEBE or HEBO), birch seep (BISE), and riparian tall shrub (TASH) (all decreased by less than 0.4% relative abundance in the LSA). No esker is expected to be altered. During construction and operation, the Project footprint will decrease the lake surface area within the LSA by 2.2%.

Effects from dust deposition, PAI, and other air emissions on vegetation are also expected to be mostly confined to the Project footprint. The potential change to vegetation from dewatering of Kennady Lake and related flooding is expected to be restricted to a relatively short distance away from the margins of the dewatered or flooded areas, which is a localized effect.

Overall, the local-scale effects from the Project on vegetation are expected to have a negligible direct influence on the quality and abundance of food for caribou (Section 7) and other ungulates (Section 11.11). The change in the availability of quality food for caribou and other ungulate populations is predicted to be well within the range of baseline values. Indirect effects from the Project (e.g., dust, noise, lights, and smells) on habitat for caribou, other ungulates, carnivores, and birds are analyzed and assessed in the relevant sections of this EIS (Sections 7, 11.10, 11.11, and 11.12).

11.7.6 Residual Effects Summary

Results from the effects analyses were used to describe the magnitude, duration, and geographic (spatial) extent of the predicted residual changes to vegetation ecosystems and plants. A strong effort has been made to express the expected changes quantitatively. For example, the magnitude (intensity) of the effect may be expressed in absolute or percentage values above baseline (existing) conditions or a guideline value. To date, threshold values identifying the point at which disturbance to vegetation ecosystems and plants might constitute an “ecological effect” or be assessed as “unsustainable” have not been developed. Instead, evaluations rely on best professional judgement and past experience with similar development projects.

The reversibility (which is linked to duration) of the change is described in years relative to Project phases, and the geographic extent of effects is expressed in area (ha) or distance (m, km) from the Project. In addition, the direction, likelihood, and frequency of effects also may be described.

11.7.6.1 Effects from the Project Footprint

Approximately 2.0% and 0.1% of vegetation ecosystems within the LSA and RSA, respectively, will be removed due to Project infrastructure. These estimates represent a relatively small portion of both study areas. Thus, the direct effects from the Project footprint on vegetation ecosystems and plants are local in spatial extent. The magnitude of the local change is predicted to be within the range of baseline conditions. The Water Sedge – Narrow-leaved Cottongrass Fen (CA) unit, a vegetation ecosystem type with a restricted distribution in the LSA (i.e., comprises 0.2% of the LSA), will have 8.7 ha disturbed by Project development. However, at the scale of the community, the magnitude of the expected loss of this community is 18.3% of existing baseline values.

Disturbances to arctic ecosystems are largely reversible; however, the length of time required for recovery is often long. Studies in the Arctic have shown that recovery can take from 20 to 75 years (Forbes et al. 2001; Walker and Everett 1991). Some of the disturbance associated with the Project footprint will be reversible given sufficient time (e.g., temporarily flooded areas). Irreversible disturbances are associated with features that will not be re-vegetated following Project closure (e.g., mine rock covered fine PK/coarse PK).

The spatial extent of effects to traditional use plants is predicted to be mostly local, but some changes from other developments may occur at the regional scale. Overall, approximately 2.9% and 0.1% of vegetation ecosystems, which include traditional use plants, within the LSA and RSA, respectively, will be removed due to Project. The magnitude of direct and indirect effects is predicted to approach the limits of natural variation or baseline values. Effects from permanent disturbance to vegetation communities (e.g., mine rock covered fine PK/coarse PK) are irreversible.

No plant species at risk were identified in the proposed Project footprint or habitats with limited distribution in the LSA during baseline studies; however, this does not preclude the potential for rare plants to inhabit the area. The spatial extent of potential effects to species at risk from the Project is predicted to be mostly local, but some changes from other developments may occur at the regional scale. Approximately 79.3 ha (3.8% of the LSA) of potential rare plant habitat (ranked moderate to high) will be directly disturbed by the Project. The magnitude of community-specific decreases in potential moderate to high rare plant habitat from the Project footprint ranged from 2.8 to 18.3% of the baseline case ELC. The magnitude of these effects is predicted to approach the limits of natural variation or baseline values. Effects from permanent disturbance to vegetation communities (e.g., mine rock piles) are irreversible.

The anticipated changes to regional biodiversity/landscape metrics will be largely represented by a decrease in the total area, patch number, and an increase in the mean distance between patch types. The magnitude of the cumulative direct disturbance to the vegetation communities in the RSA from the Project and other previous, existing and future developments is predicted to be about 5%. Potential changes should be reversible within 20 to 75 years after Kennady Lake is refilled.

11.7.6.2 Effects from Dewatering and Refilling of Kennady Lake

The dewatering of Kennady Lake will be a gradual process and will result in the downstream flooding of terrestrial vegetation. With the exception of Lake N11, water levels are not expected to exceed the 1 in 2-year flood level. Flooded conditions will likely last the entire open-water season, with the largest anticipated effects occurring between the outlet at Lake N11 and downstream to Lake 410.

The possible effects to plant communities downstream of Kennady Lake as a result of dewatering are anticipated to be local. Plant communities will be directly affected by flooding resulting in a loss of 90.8 ha, which is accounted for in the direct effects from the Project footprint. For plant communities occurring along the margins of the dewatered or flooded areas, the magnitude of the effect will be dependent upon the type of communities present (e.g., wetland, riparian or upland) and their resiliency to fluctuating water levels. The magnitude of the effect may be within or slightly exceed the limits of natural variation (baseline conditions).

Wetlands and riparian communities are expected to be most resilient to rising and fluctuating water levels, while uplands are expected to be relatively unaffected by a decrease in the water level. However, portions of the dewatered lake margin that are vegetated may die back if they are sensitive to water level declines resulting from dewatering (e.g., wetlands). The exposure of bare, nutrient-rich lakebed sediments can provide a substrate that may favour the establishment of rapid colonizing plants, some of which could be weedy, invasive species. Alternatively, along the margins of the flooded areas, upland ecosystem types with more freely drained soils will likely be less resilient to prolonged flooding, and are expected to display a more adverse response to these conditions. In general, the magnitude of effects to plant communities located along the dewatering and flooding margins are expected to be restricted to a relatively narrow impact zone. Effects are anticipated to be reversible in the long-term to these communities (i.e., within 20 to 75 years after Kennady Lake is refilled).

11.7.7 Residual Impact Classification

The purpose of the residual impact classification is to describe the residual effects from the Project on vegetation ecosystems and plants using a scale of common words (rather than numbers or units). The use of common words or criteria is a requirement in the Terms of Reference for the Project (Gahcho Kué Panel 2007). The following criteria must be used to assess the residual impacts from the Project:

- direction;
- magnitude;
- geographic extent;
- duration;
- reversibility;
- frequency;
- likelihood; and
- ecological context.

Generic definitions for each of the residual impact criteria are provided in Section 11.7.9.1.

11.7.7.1 Methods

In the EIS, the term “effect”, used in the effects analyses and residual effects summary, is regarded as an “impact” in the residual impact classification. Therefore, in the residual impact classification, all residual effects are discussed and classified in terms of impacts to vegetation ecosystems and plants.

The potential effects associated with the Project were assessed for all vegetation ecosystems and plants identified within the area due to their inherent sensitivity to disturbance. Emphasis was placed on discussing the effects to ecosystems and plants considered particularly sensitive to disturbance (e.g., wetlands and riparian areas), those with a restricted distribution in the study area (including rare plant communities), plant species listed as being "rare" or "at risk", and plant species identified from traditional use studies. Definitions for each of the residual impact criteria are provided below.

Direction: Impacts are described as being positive, or negative with respect to their effect on vegetation ecosystems and plants, traditional use plants, and species at risk.

Magnitude: Magnitude (i.e., intensity) is assessed as either an absolute or relative difference between predicted changes from the Project and baseline (existing) conditions or guideline values. As published guidelines are not available for vegetation ecosystems and plants, magnitude was assessed by comparing predicted impacts to baseline conditions and using best professional judgement in the selection of a category. The following categories have been defined:

- **Negligible** – impact is not detectable from natural variation or baseline values.
- **Low** – impact is within the range of natural variation or baseline values.
- **Moderate** – impact is at or slightly exceeds the limits of natural variation or baseline values.
- **High** – impact is beyond the upper or lower limit of natural variation or baseline values, so there is likely a change of state from baseline conditions.

Geographic Extent: Geographic extent is based on three scales: local, regional, and beyond regional. The impacts to vegetation ecosystems and plants (traditional use plants and plant species at risk in particular) have been discussed within both a local and regional scale, defined as follows:

- **Local** – uses the LSA boundary as the spatial extent and focuses on impacts from the Project footprint and lake dewatering; and
- **Regional** – uses the RSA boundary as the spatial extent and focuses on impacts from the Project footprint, and cumulative impacts from other developments in the region.

Duration: The following criteria have been defined to classify duration of the impact:

- **Short-term** – impact is reversible at the end of construction;
- **Medium-term** – impact is reversible at the end of closure;
- **Long-term** – impact is reversible within a defined length of time beyond closure, and
- **Permanent** – impact is not reversible or the duration is unknown.

Reversibility: Reversibility is the likelihood and time required for a system to recover after removal of the stressor, and is a function of resilience. Due to the complex relationships among biophysical components and unpredictable events, the recovery of the system following disturbance can result in the same or an altered state (Gunderson 2000; Folke 2006). The impact from disturbance may be reversible, but the exact nature of ecosystem properties and services may be different.

Disturbances to arctic ecosystems are largely reversible, however, the length of time required for recovery is often long (Forbes et al. 2001; Walker and Everett 1991). Reversible impacts in arctic environments that take longer to recover are generally less severe than effects that are considered irreversible. While arctic ecosystems can generally recover from disturbance, the resulting plant communities and assemblages may be different than the original, pre-disturbance conditions. Reversibility is classified as:

- **Reversible** – impact will not result in a permanent change of state of vegetation ecosystems and plants compared to “similar” environments not influenced by the Project (“similar” implies an environment of the same type, region, and time period); and
- **Irreversible** – impact is not reversible (i.e., duration of impact is unknown or permanent).

Likelihood: Describes the likelihood of an impact and/or event occurring:

- **Unlikely** – the impact is likely to occur less than once in 100 years;
- **Possible** – the impact will have at least one chance of occurring in the next 100 years;
- **Likely** – the impact will have at least once chance of occurring in the next 10 years; and

- **Highly Likely** – the impact is very probable (100% chance) within a year.

Frequency: Frequency identifies how often an impact or disturbance event will occur over the duration of the Project:

- **Isolated** – confined to a specific discrete period;
- **Periodic** – occurs intermittently but repeatedly over the assessment period; and
- **Continuous** – will occur continually over the assessment period.

Ecological Context: Ecological context refers to the type of the impact as well as the nature of the affected environmental component.

11.7.7.2 Results

Direct impacts from the Project footprint (i.e., vegetation loss) are local in geographic extent. Approximately 2% of existing wetland and upland vegetation in the LSA will be impacted by the Project footprint. However, on the scale of each community, the Project is predicted to disturb 2 to 4% of all vegetation ecosystem types that have moderate to high potential for supporting rare plant habitat. The exception is the Water Sedge – Narrow-leaved Cottongrass Fen (CA) unit, which is expected to be reduced by 18.3% relative to baseline conditions. Therefore, at the local scale, the magnitude of impacts from the Project footprint on plant populations is predicted to be low for most community types, and high for the Water Sedge – Narrow-leaved Cottongrass Fen (CA) unit (Table 11.7-22). Cumulative impacts on vegetation ecosystems and plants from fragmentation associated with the Project footprint and other developments are expected to be regional in geographic extent and negligible to low in magnitude. Changes to the number of patches of ecosystem communities and the mean distance to nearest similar patches is expected to range from 0 to 2%, and the cumulative disturbance from all developments is about 5% of the RSA.

Table 11.7-22 Summary of Residual Impact Classification of Primary Pathways for Effects from the Project on Vegetation Ecosystems and Plants

Pathway	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Direct loss and fragmentation of vegetation ecosystems and plants (including listed species) from the Project footprint.	negative	negligible to high	local to regional	permanent	periodic	irreversible	possible to highly likely
Changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from dewatering of Kennady Lake may affect the quantity of downstream vegetation.	negative	low to moderate	local	long-term	periodic	reversible	likely
Changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from refilling of Kennady Lake may affect the quantity of downstream vegetation.	negative	low to moderate	local	long-term	periodic	reversible	likely
Effects to vegetation ecosystems and plants can change the availability of plants for traditional use	negative	low to moderate	local to regional	long-term	continuous	reversible	likely

The frequency of direct impacts from the Project to vegetation will occur periodically during the life of the Project (i.e., construction activities and water level fluctuations are not continuous). Direct loss and fragmentation of vegetation ecosystems and plants is highly likely to occur, while the direct loss of listed plant species is possible because no listed plant species were recorded within the LSA. Impacts from changes in water levels are likely to occur, as are impacts to the availability of traditional use of plants.

Although progressive reclamation will be integrated into mitigation and management plans for the Project, and is part of the land use permits for existing developments, arctic terrestrial ecosystems are slow to respond to disturbance. In addition, not all the areas for the Project will be reclaimed. For example, as a result of locally expressed concerns, the mine rock cap on the Fine PKC Facility will not be vegetated to prevent it from becoming attractive to wildlife. The Fine PKC Facility, Coarse PK Pile, and mine rock piles will be permanent features on the landscape, covering approximately 302.7 ha.

Residual impacts to vegetation ecosystems and plants along the margins of Kennady Lake as a result of lake dewatering and refilling, and along the flooded margins of other downstream lakes, are anticipated to be local in geographic extent (Table 11.7-22). However, the magnitude of the impact will be dependent upon the type of communities present (e.g., wetlands, riparian, or upland) and their resiliency to rising, lowering, and fluctuating water levels. It is predicted that impacts to riparian vegetation will be within the range of baseline conditions (low magnitude) as species in this vegetation community are more tolerant of flooding (Richardson et al. 2007). Changes to upland vegetation will likely approach or exceed baseline values (moderate magnitude) as plants in terrestrial communities are typically less tolerant of a rise in water levels along lake margins (Richardson et al. 2007; Table 11.7-22). Wetlands are anticipated to be affected along the dewatered lake margin as a result of the lowering of water level. Impacts to vegetation ecosystems and plants from dewatering and refilling of Kennady Lake are anticipated to be reversible in the long-term (i.e., within 20 to 75 years after Kennady Lake is refilled).

Changes in the abundance and distribution of vegetation ecosystems and plants may influence gathering of plants for traditional and non-traditional uses. The magnitude of the impact will be dependent upon the type of communities present and their resiliency to fluctuating water levels. It is expected that the magnitude of impacts to vegetation ecosystems and plants will be low to moderate. Impacts to vegetation ecosystems and plants from the Project are expected to be reversible in the long-term (i.e., within 20 to 75 years after Kennady Lake is refilled).

11.7.8 Environmental Significance

11.7.8.1 Approach and Method

The Terms of Reference require that "the developer must provide its views on the significance of impacts" (Section 3.2.2; Gahcho Kué Panel 2007). Environmental significance was used to evaluate the significance of impacts from the Project on vegetation ecosystems and plants, and by extension, on the use of plants by people. The evaluation of significance was based on ecological principles, to the extent possible, but also involved professional judgment and experienced opinion.

The classification of residual impacts on primary pathways provides the foundation for determining environmental significance from the Project on the persistence of vegetation ecosystems and listed populations. Magnitude, geographic extent, and duration are the principal criteria used to predict significance (Section 6.7.3). Other criteria, such as frequency, ecological context, and likelihood are used as modifiers (where applicable) in the determination of significance.

Frequency may or may not modify duration, depending on the magnitude of the impact. Because the EIS assesses impacts to key VCs of concern, the ecological context is high, by definition. However, ecological context may be used to modify the environmental significance if the societal value is associated with traditional land use.

Likelihood will also act as a modifier that can influence environmental significance. Environmental impact assessment considers impacts that are likely or highly likely to occur; however, within the definition of likelihood there can be a range of probabilities that impacts will occur. In special circumstances, the environmental significance may be lowered if an impact is considered to have a very low likelihood of occurring, and increased for impacts with a very high likelihood of occurring.

Duration of impacts, which includes reversibility, is a function of ecological resilience, and these ecological principles are applied to the evaluation of significance. Although difficult to measure, resilience is the capacity of the system to absorb disturbance, and reorganize and retain the same structure, function, and feedback responses (Section 6.7.3). Resilience includes resistance, capability to adapt to change, and how close the system is to a threshold before shifting states (i.e., precariousness).

The evaluation of significance for vegetation ecosystems and plants considers the entire set of primary pathways that influence the assessment endpoint (e.g., persistence of listed and traditional use plant populations). The relative contribution of each pathway is used to determine the significance of the Project on vegetation ecosystems and plants, which represents a weight of evidence approach (Section 6.7.4). For example, a pathway with a high magnitude, large geographic extent, and long-term duration is given more weight in determining significance relative to pathways with smaller scale effects. The relative impact from each pathway is discussed; however, pathways that are predicted to have the greatest influence on changes to the persistence of vegetation ecosystems and plants would also be assumed to contribute the most to the determination of environmental significance.

Environmental significance is used to identify predicted impacts that have sufficient magnitude, duration, and geographic extent to cause fundamental changes to vegetation. The following definitions are used for assessing the significance of impacts on the persistence of vegetation ecosystems and plants, and the associated continued opportunity for traditional use of plants.

Not significant – impacts are measurable at the local or individual level, and strong enough to be detectable at the population level, but are not likely to decrease the resilience and increase the risk to population persistence.

Significant – impacts are measurable at the population level and likely to decrease the resilience and increase the risk to population persistence. A number of high magnitude and irreversible impacts at the population level (regional scale) would be significant.

11.7.8.2 Results

For all primary pathways influencing vegetation ecosystems and plants, the geographic extent of impacts was determined to be mostly local, with some regional-scale impacts associated other previous, existing, and future developments (Table 11.7-22). The likelihood of the impacts occurring is expected to be possible to highly likely for Project pathways (Table 11.7-22), which does not change the expected magnitude and duration (or environmental significance). The frequency of impacts to vegetation is anticipated to be periodic throughout the life of the Project (Table 11.7-22), which also does not change the predicted environmental significance of impacts on traditional use of culturally important plants or the persistence of listed plant populations.

At the local scale, the magnitude of the impact to vegetation ecosystems and plants from the Project is predicted to be low for most communities, and high for one community. Impacts from the permanent features of the Project (i.e., Fine PKC Facility, Coarse PK Pile, and mine rock piles) are irreversible (Table 11.7-22). Local-scale impacts of low to moderate magnitude, which are reversible in the long term, included effects to vegetation ecosystems from lake dewatering and refilling (i.e., margin effects due to flooding and dewatering). Local-scale impacts of low magnitude include colonization by weedy species within the dewatered lake bed, which are reversible in the long-term. There is a moderate degree of uncertainty in predicting the magnitude and geographic extent of the impacts. The area and location of the footprint is known, and the ELC has good precision, particularly at the local scale. For those pathways where the information is limited (i.e., effects from dewatering and re-filling of Kennady Lake on riparian vegetation), the changes were overestimated so that impacts would not be underestimated.

Based on the expected direct and indirect impacts from the Project on vegetation ecosystems and plants, it is predicted that the magnitude of impacts to the traditional use of plants, and the persistence of listed plant populations will be low to moderate (Table 11.7-22). The geographic extent is anticipated to be mostly local, with some regional impacts associated with cumulative impacts from other developments in the RSA. The magnitudes of cumulative impacts are negligible to low, and are predicted to not significantly affect the persistence of vegetation ecosystems, and listed and traditional plants within the RSA. The duration of most impacts should be reversible in the long term (Table 11.7-22).

Overall, the weight of evidence from the analysis of the primary pathways predicts that the Project should not result in significant adverse impacts to the persistence of vegetation ecosystems and listed plant species, and the use of traditional plants. Most changes from the Project should result in local-scale impacts to plants. The cumulative impacts from previous, existing, future activities in the region, and the Project should not negatively influence the resilience of vegetation communities, and traditional and listed plant populations. Subsequently, incremental and cumulative impacts from the Project and other developments should not have a significant adverse affect on the future use of traditional plants, or the persistence vegetation ecosystems and listed plant populations.

11.7.9 Uncertainty

The primary sources of uncertainty surrounding the identification of potential effects to arctic vegetation ecosystems and plants are largely associated with the degree to which effects may occur (e.g., magnitude and duration). It is understood that development activities will disturb vegetation communities; however, long-term monitoring studies documenting the resilience of these ecosystems and the degree to which they recover to are few, (e.g., Forbes 1992; Auerbach et al. 1997; Forbes et al. 2001).

Additionally, the effects associated with air emissions, dust deposition, and altered water level fluctuations have not been extensively studied, particularly in arctic environments. The anticipated effects have been extrapolated from studies conducted in more temperate climates or under controlled laboratory conditions. The identified sources of uncertainty affect the magnitude and duration components of the predictions. Impacts may have been overestimated due to the limited amount of long-term data available for similar settings.

Reasonably foreseeable developments in the RSA, such as Taltson Hydroelectric Expansion Project and the proposed East Arm National Park, also contribute to uncertainty in assessment predictions. The Taltson Hydroelectric Expansion Project will be a transmission line linking the Twin Gorges hydroelectric station on the Taltson River with the existing and proposed mines north of Great Slave Lake. The transmission line would pass through the RSA, connecting to the Project and the Snap Lake Mine. Infrastructure required for the project includes the placement of transmission towers, which will permanently disturb soil and vegetation at the location of the towers. It is assumed that best construction practices and site-specific investigations for traditional and rare plants, and rare plant habitat potential would be completed prior to installing the towers. Thus, the additional residual impact from the Taltson Hydroelectric Expansion project on rare and traditional plants (and vegetation ecosystems) is anticipated to be negligible. From a conservation perspective, the development of the proposed East Arm National Park would likely constitute a positive impact for vegetation and plant communities.

Measures that have been taken to reduce the uncertainty of predictions include incorporating available and applicable literature into the assessment of effects, relying on past experience (both in arctic and other climates), using conservative assumptions, and using best professional judgement. Additionally, follow-up monitoring will be implemented to examine the effects associated with the dewatering and downstream flooding of vegetation ecosystems and plants, and the potential effects of dust deposition.

11.7.10 Monitoring and Follow-up

Programs implemented during the life of the Project may be a combination of environmental monitoring to track conditions and implement further mitigation as required, and follow-up monitoring to verify the accuracy of impact predictions and adaptively manage and implement further mitigation as required.

11.7.10.1 Environmental Monitoring

Environmental monitoring will include the implementation of a vegetation management plan (VMP). Many of the activities described below have been designed to work in conjunction with other programs (e.g., soils, and closure and reclamation).

11.7.10.1.1 Vegetation Management Plan

Objectives

The objectives of the VMP are to maintain a healthy vegetative cover and to re-vegetate (either through natural or assisted means) disturbed areas to lower the overall effects of Project development on vegetation ecosystems and plants. Maintaining and re-establishing healthy vegetation is not only beneficial to vegetation ecosystems, but it also benefits wildlife through the maintenance and restoration of habitat, and reduces soils-related effects (such as erosion) that result from vegetation disturbance and removal.

General Practices that Limit Disturbance to Vegetation Ecosystems and Plants

Effective strategies to reduce the effects of development on vegetation ecosystems and plants include limiting the size of the footprint area (thus limiting the extent of disturbance) and optimizing the placement of infrastructure (e.g., avoiding sensitive ecosystems and plants). Restricting Project activities and operations to developed areas will also limit disturbance to adjacent areas. The size and placement of infrastructure has been addressed in the design stages of the Project and will be continuously refined as the Project progresses.

Re-vegetation will likely be a combination of natural colonization and the application of suitable seed and fertilizer (Section 10.4 Closure and Reclamation Plan). Reclaimed surfaces will be prepared in a manner that encourages re-vegetation via colonization by native species wherever possible.

Monitoring

The monitoring activities associated with Project construction, operations, and closure, are described below, and are designed to work in conjunction with other programs.

- **Identification of areas where vegetation is intact.** A general site survey to identify areas where healthy vegetation is maintained and where vegetation is showing signs of degradation will be carried out on a regular basis. Estimates of the extent of intact (undisturbed) and degraded vegetation will be recorded.

- **Identification of areas where re-vegetation is required.** Disturbed areas will be identified from the general site survey identified above, as well as from surveys conducted as part of the monitoring program associated with the closure and reclamation plan (Section 10). Disturbance estimates will include descriptions of areas that have been re-vegetated and an indication of treatment effectiveness. Test plots will be established at longer-term monitoring stations to evaluate treatment effectiveness as well.
- **Implementation of re-vegetation efforts.** Areas identified as requiring re-vegetation (e.g., from the general site survey and/or closure and reclamation monitoring) will be assigned an appropriate treatment. Vegetative material (seed or otherwise) will be composed of non-invasive species. The long-term re-vegetation goal is to facilitate and encourage the re-establishment of native vegetation. Treatments will be designed such that they optimize success (e.g., timing will coincide with favourable weather events).
- **Survey timing.** The timing of the surveys will be planned according to when the areas were re-vegetated and the potential for soil erosion. For example, areas with a high potential for soil erosion will likely be surveyed more frequently following treatment. Test plots will be established at longer-term monitoring stations.

11.7.10.2 Follow-up Monitoring

Effects from Dewatering of Kennady Lake

While it is understood that vegetation ecosystems and plants are likely to be affected by the dewatering of Kennady Lake and ensuing downstream flooding, the magnitude and extent of the indirect effects will be dependent upon the type of vegetation present (e.g., wetlands, riparian or upland tundra) and the zone of influence of the fluctuating water table. The follow-up monitoring program will be designed and implemented to test predictions, particularly the magnitude and extent of changes to vegetation ecosystems and plants that are associated with the dewatering and flooding.

The monitoring and follow-up will be conducted primarily by vegetation ecologists, with input from hydrologists and possibly fisheries biologists. Permanent sampling locations (e.g., as plots or transects) will be established within the affected area and at intervals extending away from the affected area to the point at which no effect is anticipated. Surveys will be initiated prior to the onset of dewatering and flooding and should continue at regular intervals (e.g., yearly). At each survey location, general site information will be collected, along with a detailed species list and estimates of species abundance (e.g., as percent cover). Site photographs will also be taken. The program will be developed further as Project details are refined.

Effects from Dust Deposition

While effects from dust deposition on vegetation ecosystems and plants were predicted to be negligible, a follow-up monitoring program will be established to verify the predicted effects in the area, and adaptively manage mitigation as needed. The study will be designed primarily by vegetation ecologists, with input from air quality and soils specialists. Permanent sampling locations (e.g., as plots or transects) will be established within a range of dust deposition zones, including suitable control sites. Dust deposition loads will be quantified within the survey areas in an effort to link loadings to the potential changes manifested in soil and vegetation ecosystems. Surveys will be initiated prior to construction and will continue at regular intervals. At each survey location, general site information will be collected, along with a detailed species list and estimates of species abundance (e.g., as percent cover). Site photographs will also be taken. The program will be developed further as Project details are refined.

Effects to Species at Risk

Additional surveys for plant species considered to be “at risk” within the Project footprint will be carried out in conjunction with other vegetation monitoring programs (e.g., those specified in the vegetation management plan, Kennady Lake dewatering, and dust monitoring program), as the compilation of a plant species list is included as a component. Particular attention would be paid to areas containing unique landforms and substrates that have a higher likelihood of supporting rare plant habitat.

Targeted surveys are also recommended prior to construction and land clearing activities. For larger areas, surveys would focus again on unique landforms and substrates due to their higher potential to provide rare plant habitat. A protocol to address any rare plants identified on-site will be developed as these programs progress and will incorporate adaptive management strategies and will adhere to current best practices for rare plant conservation and management.

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11.7.12 Acronyms and Glossary

11.7.12.1 Acronyms and Abbreviations

BEU	broad ecosystem unit
CCME	Canadian Council of Ministers of the Environment
DBH	diameter breast height
EBA	EBA Engineering Consultants Ltd.
EIS	Environmental Impact Statement
ELC	Ecological Landscape Classification
et al.	group of authors
GIF	ground inspection form
GIS	geographic information system
HS	High Subarctic
INAC	Indian and Northern Affairs Canada
IPMP	invasive plant management plan
LSA	Local Study Area
NO_X	nitrogen oxides
NO_2	nitrogen dioxide
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLWB	Mackenzie Valley Land and Water Board
NAG	non-acid generating
NWT	Northwest Territories
PAG	potentially acid generating
PAI	potential acid input
PKC	processed kimberlite containment
PM	particulate matter
$PM_{2.5}$	particulate matter with nominally smaller than 2.5 μm diameter
Project	Gahcho Kué Project
RSA	Regional Study Area
SO_2	sulphur dioxide
sp.	single species

spp.	multiple species
TEM	terrestrial ecosystem mapping
Terms of Reference	*Terms of Reference for the Gahcho Kué Environmental Impact Statement*
TSP	total suspended particulate
TSS	total suspended solids
VC	valued component
VMP	vegetation management plan

11.7.12.2 Units of Measure

%	percent
µm	micrometre
ha	hectare
keq	kilo-equivalent
km	kilometre
L	litre
m	metre
$\mu g/m^3$	microgram per cubic metres
kg/ha/yr	kilogram per hectare per year
keq/ha/yr	kilo-equivalents per hectare per year
kg N/ha/yr	kilograms of Nitrogen per hectare per year

11.7.12.3 Table of Ecosystem Types

Broad Ecosystem Units (BEU)

BAGD	Bare Ground
BEAS	Bedrock Association (greater than 80% Bedrock)
BISE	Birch Seep (riparian)
BOAS	Boulder Association (greater than 80% Boulders)
DEWA	Deep Water
ESCO	Esker Complex
HEBE	Heath / Bedrock (30 to 80% Bedrock)
HEBO	Heath / Boulders (30 to 80% Boulders)
HETU	Heath Tundra (less than 30% Rock)
OHDW	Open Herb-Dominated Wetlands
PEBO	Peat Bog

SEWE	Sedge Wetlands
SHWA	Shallow Water
SPFO	Spruce Forest
TASH	Tall Shrub (riparian)
TUHU	Tussock-Hummock (Sedge Association)

Ecological Landscape Classification (ELC)

BC	Scrub Birch – Bluejoint Shrub Tundra (riparian)
BE	Scrub Birch – Crowberry Tundra (upland)
BF	Boulderfield (sparsely vegetated, upland)
BL	Scrub Birch – Labrador Tea Tundra (upland)
BR	Scrub Birch – Cloudberry Low Shrub Tundra (wetlands)
CA	Water Sedge – Narrow-leaved Cottongrass Fen (wetlands)
CE	Round-Fruited Sedge – Chamisso's Cottongrass Fen (wetlands)
EA	Sheathed Cottongrass – Bog Rosemary Sedge Fen (wetlands)
EM	Water Sedge – Horsetail Shallow Shore Marsh (wetlands)
FA	Floating Aquatic (wetlands)
LA	Lake (open water)
OW	Shallow Open Water (open water)
PD	Pond (open water)
PE	Spruce – Lichen Woodland (upland)
RB	Scrub Birch – Riparian Shrub
RO	Rock Outcrop (sparsely vegetated, upland)
RP	Road (anthropogenic, upland)
RR	Camp (anthropogenic)
SH	Willow – Sedge Low Shrub Fen (wetlands)
SR	Willow – Nagoonberry Shrub (riparian)
SS	Saxifrage – Moss Campion Xerophytic Tundra (upland)

11.7.12.4 Glossary

Active layer	In environments with permafrost, is the top layer of soil that thaws during the summer and freezes again during the winter.
Albedo	The ratio of reflected solar radiation to the total incoming solar radiation received at the surface.
Anoxic	Without oxygen.
Anthropogenic	Pertaining to the influence of human activities.

Bogs	Sphagnum or forest peat materials formed in an ombrotrophic environment usually due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks. Mineral-poor, acidic and peat-forming wetlands that receives water only from precipitation.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch, and aspen.
Coniferous	Bearing cones or strobili (a cone-like cluster).
Critical Level	Concentration of pollutants in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems, or materials may occur according to present knowledge.
Critical Load	Quantitative estimate of an exposure, in the form of deposition, to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.
Deciduous	Tree species that lose their leaves at the end of the growing season.
Discontinuous	Marked by breaks or interruptions; intermittent.
Ecoregion	Ecological regions that have broad similarities with respect to soil, terrain, and dominant vegetation.
Ecosystem	An area where organisms and their physical environment endure as a system (Wiken 1986).
Ecosystem Type	Base unit identified in ELC mapping. Can be analogous to vegetation type but is generally used to describe ecosystems at a broader level.
Ecozone	Areas of the earth's surface representative of large and very generalized units characterized by interactive and adjusting abiotic and biotic factors. The ecozone lies at the top of the ecological hierarchy and defines, on a subcontinental scale, the broad mosaics formed by the interaction of macroscale climate, human activity, vegetation, soils, geological, and physiographic features of the country.
Esker	Long, narrow bodies of sand and gravel deposited by a subglacial stream running between ice walls or in an ice tunnel, left behind after melting of the ice of a retreating glacier.
Fens	Sedge peat materials derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral rich waters. Minerotrophic peat-forming wetlands that receive surface moisture from precipitation and groundwater. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.
Forbs	A broad-leaved herb, which is not a grass.
Fugitive dust	Contaminants emitted from any source except those from stacks and vents. Typical particulate sources include wind blown dust, bulk storage areas, open conveyors, construction areas, or roads.
Glaciofluvial	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Habitat	The place or environment where a plant or animal naturally or normally lives or occurs.

Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including other organisms.
Isopleths	A line on a map connecting places sharing the same feature (e.g., ground-level concentrations).
Microsite	The small subset of environments within a habitat that provide the specialized resources and conditions required for a phase in the life of an organism (Begon et al. 1990).
Nutrient Regime	The relative supply of nutrients available for plant growth at a given site.
Peatlands	Areas where there is an accumulation of peat material at least 40 cm thick. These are represented by bog and fen wetlands.
Permafrost	Permanently frozen ground (subsoil). Permafrost areas are divided into more northern areas in which permafrost is continuous, and those more southern areas in which patches of permafrost alternate with unfrozen ground.
Phenology	The relationship between periodic biological phenomena (e.g., flowering, dormancy) and climatic conditions.
Photosynthesis	A process in which carbon dioxide, water, and light energy are utilized by plants to synthesize glucose and oxygen.
Polygons	The spatial area delineated on a map to define one feature unit (e.g., one ecosystem type).
Potential Acid Input	A composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen, and base cations.
Riparian	Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain, or standing waterbody.
Sedge	Any plant of the genus *Carex*, which are perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stems, a spiked inflorescence, and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.
Solar Radiation	The principal portion of the solar spectrum that spans from approximately 300 nanometres (nm) to 4,000 nm in the electromagnetic spectrum. It is measured in W/m^2, which is radiation energy per second per unit area.
Species Evenness	A measure of equitability calculated to incorporate the sum of the proportional contributions of an individual species to the total population of a community.
Species Richness	The number of different species occupying a given area.
Structural Stage	Describes the existing dominant appearance or structure of an area. Factors such as disturbance history, stand age, species composition, and chance are all potential influences. Structural stages range from non-vegetated to old forests.
Successional Stage	A particular phase of the forest succession continuum with its own characteristic of age, structure, and composition of species. Stages may include the following: pioneer, young seral, maturing seral, old seral, young edaphic, mature edaphic, young climatic, mature climatic and disclimax.
Thermokarst	Pock-marked topography in northern regions caused by the collapse of permafrost features.
Total Suspended Particulate	A measure of the total particulate matter suspended in the air. This represents all airborne particles with a mean diameter less than 30 µm (microns) in diameter.

Total Suspended Solids	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Tundra	A vast, mostly flat, treeless Arctic region of Europe, Asia, and North America in which the subsoil is permanently frozen. The dominant vegetation is low-growing stunted shrubs, mosses, lichens.
Tussock	A clump or tuft.
Vascular Plants	Plants possessing conductive tissues (e.g., veins) for the transport of water and food.
Vegetation Type	Base unit of identification during field surveys. Can be analogous to ecosystem type but is generally used to describe vegetation at the site-level.

APPENDIX 11.7.I

GEOLOGY, TERRAIN, AND SOILS

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11.7.I.1 INTRODUCTION

11.7.I.1.1 PURPOSE AND SCOPE

This section presents the geology, terrain, and soils component of the Environmental Impact Statement (EIS) for the Gahcho Kué Project (Project). The purpose of this section is to meet the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) issued on October 5, 2007 (Gahcho Kué Panel 2007). The bedrock and surficial geology, geological hazards, seismicity, terrain, and soils are described as they relate to the Project.

De Beers Canada Inc. (De Beers) is providing its EIS for the Project to provide the Gahcho Kué Panel (Panel) with an understanding of the environmental significance of the Project. In completing this report, geological, terrain, and soil conditions were extensively studied to assess the Project feasibility and evaluate the technical, environmental, and other issues related to the utilization, management, and protection of these resources.

Characterization of the baseline conditions at local and regional scales is important to assess the potential effects from the Project on geology, terrain, and soil resources. Measurement endpoints for geology, terrain, and soils include the following:

- distribution of surficial materials;
- quality of surficial materials;
- terrain;
- soil quantity;
- soil quality;
- soil distribution;
- sensitivity for erosion and acidification; and
- reclamation suitability.

The effects from the Project on geology, terrain, and soils were not identified as a Key Line of Inquiry (KLOI) or Subject of Note (SON) in the Terms of Reference. Instead, the measurement endpoints for geology, terrain, and soils are linked to effects on other VCs (e.g., vegetation and wildlife), which are classified and evaluated for environmental significance (Section 6.3). Therefore, residual effects are described for geology, soils, and terrain; however, residual effects are not classified and environmental significance is not evaluated (Section 6.7).

Effects to valued vegetation and wildlife valued components are classified in their respective sections.

Eskers represent a terrain unit that has been identified as an important landscape feature for wildlife and human use. Effects to eskers are assessed in this section; however, the attributes of eskers for wildlife and human use are assessed in their respective sections. Effects to wildlife, including effects of changes to eskers are assessed in Section 7 for caribou (*Rangifer tarandus*) and in Section 11 for other wildlife species.

11.7.I.1.2 STUDY AREA

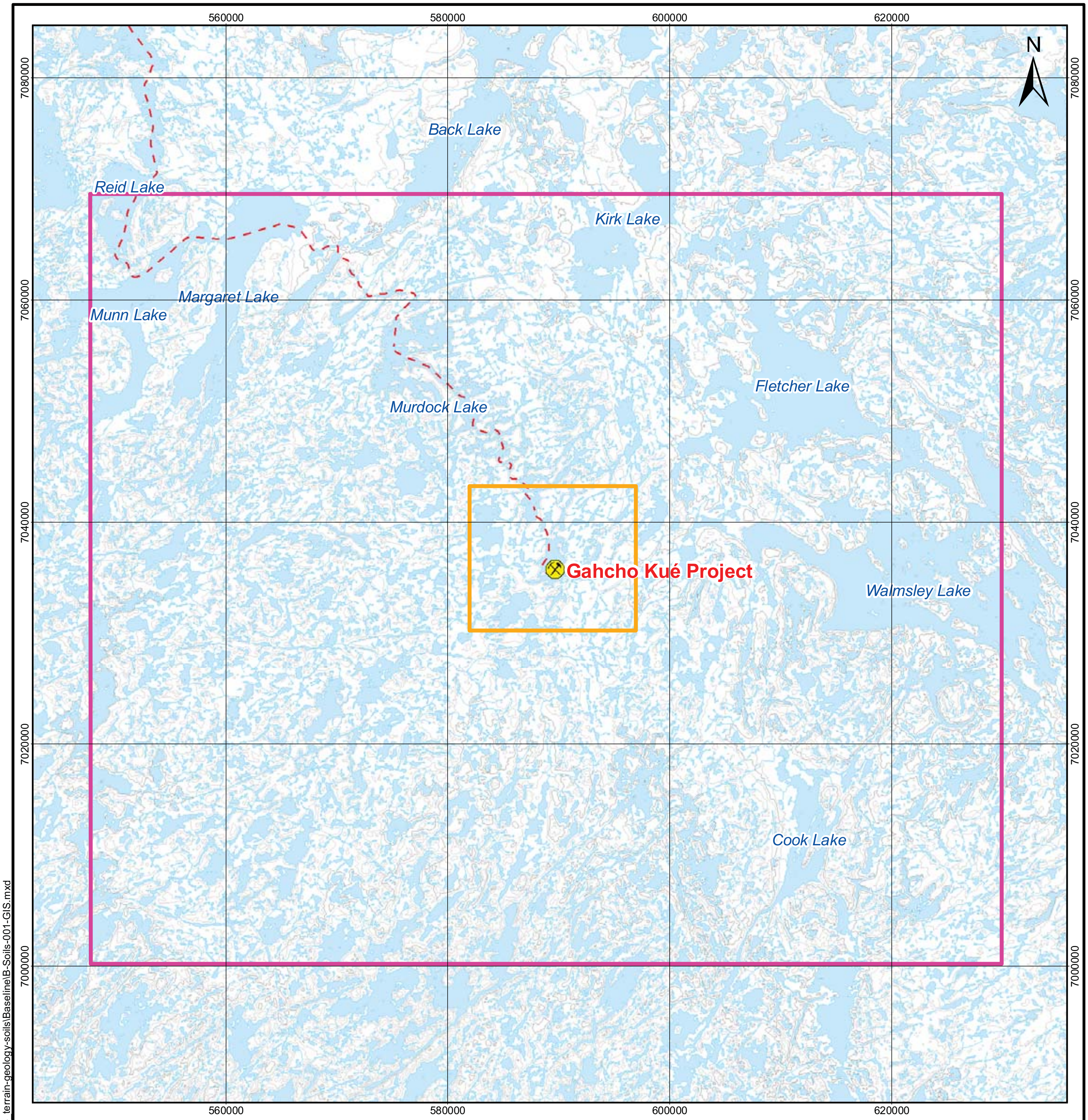
The geology, terrain, and soils study area used the same spatial boundaries used for the SON: Vegetation (Section 11.7):

- Regional Study Area (RSA);
- Local Study Area (LSA); and
- portion of Tibbitt-to-Contwoyto Winter Road from Tibbitt Lake to MacKay Lake.

The RSA is approximately 5,700 square kilometres (km^2) (Figure 11.7.I-1). This RSA boundary was chosen as a biophysical area that would capture larger-scale potential indirect effects from the Project. The total area of the RSA including the area of the Winter Access Road not in the RSA is 5,740 km^2.

The LSA is 19,500 ha and corresponds with the boundaries established for the vegetation baseline LSA (Section 11.7.1.3). The boundaries were chosen based on the area that may be influenced by the Project, and where the majority of direct Project-related effects will likely occur. The LSA also is intended to account for considerations such as effects of waterbody changes on associated soils.

The Winter Access Road from the Project to the junction with the Tibbitt-to-Contwoyto Winter Road at MacKay Lake crosses the RSA, but the northwest corner of the RSA is also extended to include the remainder of the Winter Access Road. Part of the Winter Access Road Study Area is within the RSA, and the remainder, to the northwest of the RSA, includes a 500 metre (m) buffer on either side of the road alignment based on previous studies by EBA Engineering Consultants Ltd. (EBA) for the Tibbitt-to-Contwoyto Winter Road (EBA 2002a).



G:\2009\1365\09-1365-1004 De Beers Gahcho Kue EA Support\GIS\maps\05_terrain-geology-soils\Baseline\B-Soils-001-GIS.mxd

LEGEND

- Gahcho Kué Project
- Winter Access Road
- Intermediate Contour (20 m interval)
- Index Contour (100 m interval)
- Watercourse
- Waterbody
- Local Study Area
- Regional Study Area

NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000

GAHCHO KUÉ PROJECT

Geology, Terrain, and Soils Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:500,000 (10 5 0 10 Kilometres)	
FILE No: B-Soils-001-GIS	DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 3
OFFICE: GOLD-SAS	DRAWN: MK / CHECK: JV

DE BEERS CANADA

Figure 11.7.I-1

11.7.I.1.3 CONTENT

The existing environment for geology, terrain, and soils is presented in Section 11.7.I.2. Aspects that are described include bedrock geology, geological stability, seismicity, Quaternary and Recent surficial deposits, terrain types and distribution, and soil types and distribution.

Traditional ecological knowledge as it relates to geology, terrain, and soils is discussed in Section 11.7.I.3. Potential pathways by which the Project could affect geology, terrain, and soils are described in Section 11.7.I.4, followed by a summary of the environmental design features that will reduce or eliminate the Project effects. Pathways are analyzed to determine Project components and activities that are primary, secondary, or have no linkage to changes on terrain and soils.

Primary pathways are completely analyzed for effects (Section 11.7.I.5). This is followed by the residual effects summary (Section 11.7.I.6), discussion of uncertainty (Section 11.7.I.7), and description of the recommended monitoring and follow-up (Section 11.7.I.8).

11.7.I.2 EXISTING ENVIRONMENT

11.7.I.2.1 METHODS

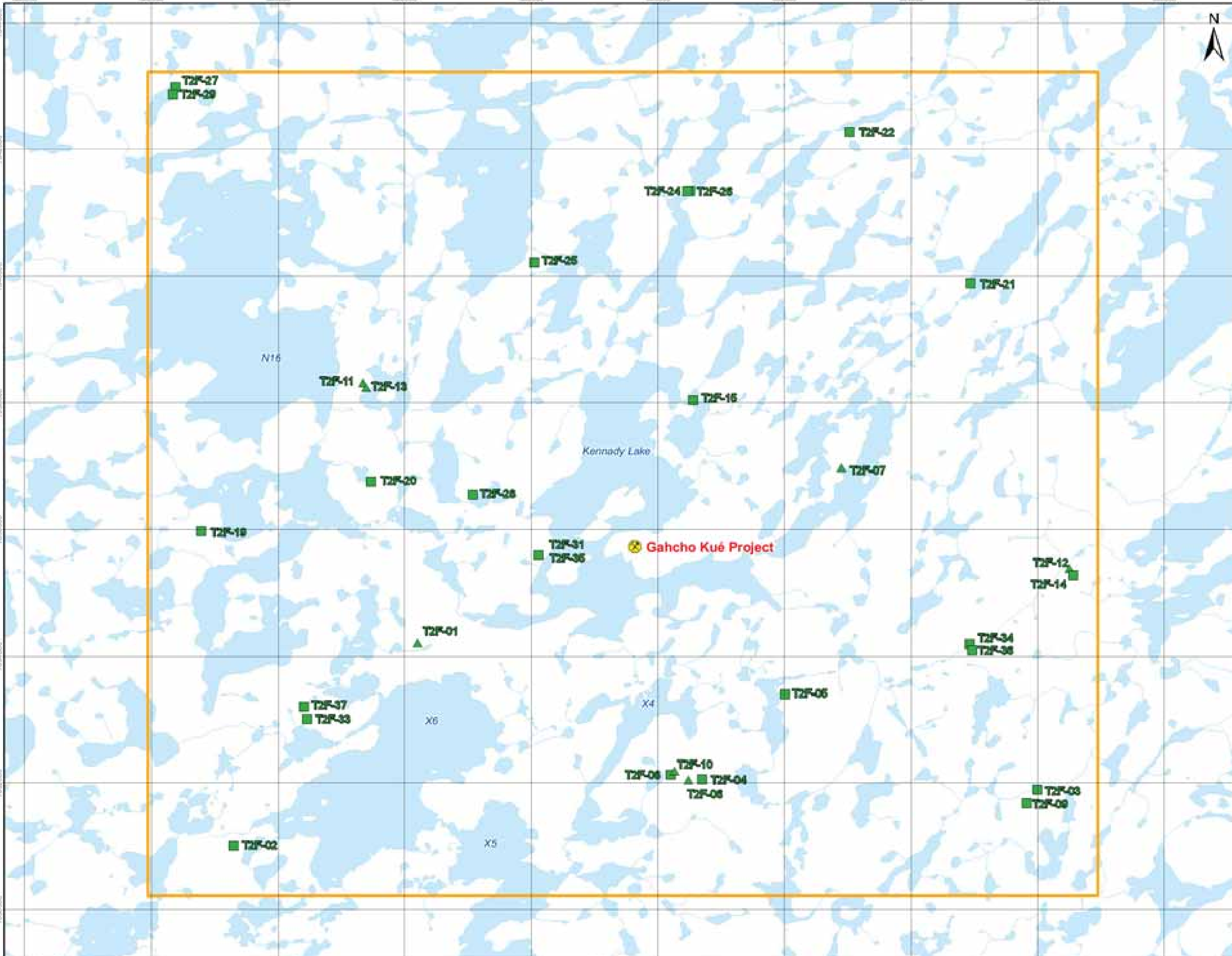
Geology, Terrain, and Soil Characterization

The existing baseline conditions were described using several sources, including background data review, air photo interpretation, on-site investigations, and laboratory analysis. Information gathered during the preparation of the baseline report was synthesized and analyzed with regard to the expected development effects (Annex D).

Much of the existing background information with regard to soils and terrain was derived from the ecological land survey of the Lockhart River area, Northwest Territories (Bradley et al. 1982). This report describes various biophysical features of the region, including soils, permafrost, vegetation, landforms, surficial materials, and climate. Following the literature review, aerial photographic interpretation was conducted using 1:10,000 black and white stereo photographs from 1997. Polygons were defined based on ecological differences and assigned preliminary soil and terrain attributes.

Field-checking procedures involved the selection of representative inspection sites by combined vegetation and soil field teams. A variety of terrain, soil, and vegetation data were collected through three different types of ground inspection plots. The classification scheme for the Ecological Landscape Classification (ELC) mapping within the LSA followed previous ELC mapping for the Ekati Diamond Mine and the Tibbitt-to-Contwoyto Winter Road projects. In 2005, a total of 37 detailed sites (Figure 11.7.I-2), 139 ground inspections, and 509 visuals were completed within the LSA and RSA. In 2007, soils were described at an additional 71 inspection sites.

Soil description and classification were based on the Canadian System of Soil Classification (Soil Classification Working Group 1998) and the Manual for Describing Soils in the Field (Agriculture Canada Expert Committee on Soil Survey 1983). Soil attributes described in the field included: horizon thickness and sequence, colour, texture, structure, consistence, effervescence (with hydrochloric acid as a qualitative field test for carbonates), presence of ground frost or ice, coarse fragments percentage, presence of mottles, and roots. Site attributes included: slope class, landform, parent material, surface stoniness and rockiness, drainage condition, and depth to water table or frozen soil. During the field sampling program, soil samples were collected at representative sites and submitted for analysis to the AMEC laboratory in Edmonton for chemical and particle size analyses.



LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Sample Site
- Sample Sites with Total Elemental Analysis
- Local Study Area

NOTES

Base data source:
National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Locations of ELC / Soil Inspection and Sampling Sites

PROJECTION: UTM Zone 12	DATUM: NAD83		DE BEERS CANADA
Scale: 1:60,000 (1 0.5 0 1 Kilometres)			
FILE No: B-Soils-005-GIS			DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 2		**Figure 11.7.I-2**
OFFICE: GOLD-SAS	DRAWN: MK	CHECK: JV	

Soil Quality Assessment

Soil Chemistry

Soil samples were collected at 28 of the 30 sites where soil pits were dug for detailed soil profile description. The samples were air dried and analyzed for all or some of the following parameters, depending on depth and organic matter content:

- texture – hydrometer method (Kalra and Maynard 1991);
- rubbed fibre (peat samples) – retained weight proportion of samples passed through a 1 millimetre (mm) sieve after processing a peat-water slurry ten minutes with a mixer-agitator;
- pH – of 1:2 soil:water mixture (Kalra and Maynard 1991);
- cation exchange capacity (CEC) – by neutral ammonium acetate extraction (Kalra and Maynard 1991); and
- exchangeable cations – by inductively coupled plasma optical emission spectroscopy (ICP-OES) (Kalra and Maynard 1991).

Surface organic (i.e., duff or peat) samples from seven sites and one sample of frozen mineral soil were analyzed for 16 trace elements (aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, thallium, vanadium, and zinc), in addition to calcium, magnesium, phosphorus, potassium, and sodium. The analyses were for "total" contents of elements by the United States Environmental Protection Agency (U.S. EPA 1997) 3060 method, which involves acid digestion of samples and elemental measurement by ICP-OES. The eight sites were from Dragon, Wolverine Lake, and Sled Lake Associations within the LSA and Lobster Lake from within the RSA (Figure 11.7.I-2).

Soil Erosion Susceptibility

Water erosion risk is assessed by applying the modified Universal Soil Loss Equation (USLE) as described by Tajek et al. (1985). The basic USLE equation is:

$$A = R \times K \times LS \times C \times P$$

where: A = annual soil loss; R = rainfall intensity; K = soil erosivity; LS = topography; C = cover; and P = conservation practices.

The USLE method was developed for agricultural soils and it is commonly calculated based on bare soil using the R, K, and LS factors only. This approach is applicable to other disturbed soil situations where the greatest risk of erosion occurs on bare soils resulting from recent disturbance and on stockpiled soils (Tajek et al. 1985). The R, K, and LS factors cannot be changed and represent the erosion risk for a given soil type when it is left unvegetated or without other protection. The system's six categories were simplified to three (low, moderate, and high) for the LSA to classify the soil ratings. The erosion risk classes and their potential soil losses are listed in Table 11.7.I-1.

Table 11.7.I-1 Water Erosion Risk Classes and Potential Soil Losses

Water Erosion Risk Class	System Category	Potential Soil Loss (t/ha/y)
Low	negligible	<6
Low	slight	6 to 11
Moderate	moderate	11 to 22
High	severe	22 to 33
High	very severe	33 to 55
High	extreme	>55

t/ha/y = tonnes per hectare per year; < = less than; > = more than.

Wind erosion risk was determined using a rating system based on soil texture, soil structure, soil moisture regime, and the binding of primary soil particles into aggregates. The method assumes conditions for a land surface that is isolated, level, smooth, unsheltered, wide, and bare with a non-crusted surface. The method is an adaptation from a United States Department of Agriculture system (Coote and Pettapiece 1989) and Alberta Agriculture (1985) (Table 11.7.I-2). The original classification consisted of eight categories, but was simplified to three classes, as presented in Table 11.7.I-2.

The wind erosion ratings pertain to areas where soils have been exposed due to clearing, and where the soil conditions are dry. Consequently, all soils with a normally wet moisture regime (Gleysolic and Organic soils) were classified as having a low wind erosion risk, regardless of texture. However, a change in management can result in a corresponding change in the risk of erosion due to wind. For example, the erosion risk for soils that are normally wet will be determined by the surface texture if they are allowed to dry out after clearing. The risk of wind erosion will decrease once vegetation is re-established in cleared areas.

Table 11.7.I-2 Wind Erosion Risk Classes and Potential Soil Losses

Wind Erosion Class[(a)]	USDA Erosion Class[(a)]	Properties of Soil	Dry Soil Aggregates >0.84 mm (weight %)	Potential Soil Loss (t/ha/y)
High	1, 2	1. very fine sand; fine sand; sand; coarse sand; 2. loamy very fine sand; loamy fine sand; loamy sand; humic organic materials	1 to 10	>300
High	3, 4, 4L	3. very fine sandy loam, fine sandy loam, sandy loam, coarse sandy loam 4. clay, silty clay, non-calcareous clay loam, or non-calcareous silty clay loam that has more than 35% clay content 4L. calcareous loam and silt loam or calcareous clay loam and silty clay loam	25	192
Moderate	5	non-calcareous loam and silt loam with less than 20% clay content; sandy clay loam; sandy clay; mesic organic materials	40	125
Moderate	6	non-calcareous loam and silt loam that has more than 20% clay content or non-calcareous clay loam that has less than 35% clay content	45	107
Low	7	silt, non-calcareous silty clay loam that has less than 35% clay content and fibric organic soil material	50	85
Low	8	soils not susceptible to wind erosion due to coarse fragments at the surface or to wetness	n/a	0

(a) Based on Coote and Pettapiece (1989) and Alberta Agriculture (1985).

USDA = United States Department of Agriculture; t/ha/y = tonne per hectare per year; > = more than;

mm = millimetre; % = percent; n/a = not applicable.

Soil Sensitivity to Acidification

The sensitivity of mineral soils to acid deposition was evaluated using guidelines in Wiens et al. (1987), and specifically the chemical criteria of Holowaychuk and Fessenden (1987). Soils were categorized as having high, medium, and low sensitivity ratings with respect to losses of base cations, acidification (pH decrease), and aluminum solubility based on the pH and cation exchange capacity (CEC) values of the surface (0 to 20 centimetres [cm]) soil. Overall soil sensitivity is derived for each soil according to the most limiting result of the three categories. In general, low soil pH and/or CEC correspond to high overall sensitivity of the soil. The sensitivity categories are presented in Table 11.7.I-3.

Table 11.7.I-3 Criteria for Rating the Sensitivity of Mineral Soils to Acidic Inputs

Soil Property		Sensitivity to			
Cation Exchange Capacity (cmol (+)/kg)	pH	Base Loss	Acidification	Aluminum Solubilization	Overall Sensitivity
<6	<4.6	H	L	H	H
	4.6 to 5.0	H	L	H	H
	5.1 to 5.5	H	M	H	H
	5.6 to 6.0	H	H	M	H
	6.1 to 6.5	H	H	L	H
	>6.5	L	L	L	L
6-15	<4.6	H	L	H	H
	4.6 to 6.0	M	L	H	M
	5.1 to 5.5	M	L–M	M	M
	5.6 to 6.0	M	L–M	L–M	M
	>6.0	L	L	L	L
>15	<4.6	H	L	H	H
	4.6 to 5.0	M	L	H	M
	5.1 to 5.5	M	L	M	M
	5.6 to 6.0	L	L–M	L–M	L
	>6.0	L	L	L	L

Source: Wiens et al. (1987) and Holowaychuk and Fessenden (1987).

L = low sensitivity; M = medium sensitivity; H = high sensitivity; < = less than; > = more than;

cmol = centimole; kg = kilogram.

Sensitivity rating for organic (peat) soils is based on the classification of peatlands into bog, poor fen, moderate rich fen, and extreme rich fen categories that are associated with certain chemical characteristics influencing their susceptibility to acid deposition (Turchenek et al. 1998). Each peatland type is rated as having high, medium, and low sensitivity (Table 11.7.I-4), corresponding to the three categories identified for mineral soils in Wiens et al. (1987). The peatland types were equated to soil associations, and the acidification sensitivity categories were applied to each of the mineral and organic soil types identified in the LSA.

Table 11.7.I-4 Criteria for Rating the Sensitivity of Organic Soils to Acidic Inputs

Peatland Type	Acid Sensitivity	H_2O pH Range[a]	Median pH	EC[b] µS/cm
Extreme rich fen	low	7.0 to 8.5	7.5	235 to 490
Moderate rich fen	low	5.5 to 7.0	6.4	14 to 120
Poor fen	medium	4.0 to 5.5	4.7	0 to 95
Bog	medium	3.5 to 3.9	3.7	0 to 20

Source: Based on Turchenek et al. (1998).

(a) H_2O pH Range = the pH of surface water (H_2O) in a peatland.

(b) EC = electrical conductivity (microSiemens per centimetre [µS/cm]).

Reclamation Suitability

The reclamation suitability of soils was evaluated to support salvage and reclamation planning. Construction activities will include removing and salvaging topsoil and subsoil for use in subsequent reclamation activities. Criteria to determine soil suitability for reclamation, developed in Alberta (Alberta Soils Advisory Committee 1987), were applied to the soil data. Although the criteria were developed for the prairie and forest regions, they reflect both soil suitability for plant growth and soil handling characteristics, and were considered generally applicable to the LSA. According to the criteria for forest soils, the upper lift (UL) of soils should consist of a mixture of the organic (litter, fibric, humic [LFH], or duff) and A-horizons of the soils, and a portion of the B-horizon to a depth up to 30 cm, depending on site-specific conditions. Salvage of a lower lift (LL) is recommended to develop adequate soil depth for rooting of vegetation. Thus, the reclamation suitability ratings require consideration of several soil chemical properties as summarized in Table 11.7.I-5 for surface and subsurface materials.

The soil associations within the LSA were rated as G (good), F (fair), P (poor), or U (unsuitable) for the surface and the subsurface components of their profiles. These soil quality criteria do not pertain to organic soils, and therefore, the rating 'O' was used to designate these soils. Organic soils can be excellent materials for use in topsoil replacement during reclamation when mixed with mineral materials. Both surficial and subsurface peat materials are considered suitable reclamation materials.

Table 11.7.I-5 Criteria for Evaluating Suitability of Soils for Reclamation

Soil Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Surface Soils				
pH	5.0 to 6.5	4.0 to 5.0 and 6.5 to 7.5	3.5 to 4.0 and 7.5 to 9.0	<3.5 and >9.0
Salinity (EC) dS m^{-1}	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
$CaCO_3$ equivalent (%)	<2	2 to 20	20 to 70	>70
Saturation (%)	30 to 60	20 to 30 or 60 to 80	15 to 20 or 80 to 120	<15 and >120
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	LS, SiC, C, HC, S	–
Moist consistency	very friable to friable	loose to firm	very firm	extremely firm
Stoniness (% of area)	<30	30 to 50	50 to 80	>80
Rockiness (% of area)	<20	20 to 40	40 to 70	>70
Subsurface Soils				
pH	5.0 to 7.0	4.5 to 5.0 and 7.0 to 8.0	3.5 to 4.5 and 8.0 to 9.0	<3.5 and >9.0
Salinity (EC) dS m^{-1}	<3	3 to 5	5 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
$CaCO_3$ Equivalent (%)	<5	5 to 20	20 to 70	>70
Saturation (%)	30 to 60	20 to 30 or 60 to 80	15 to 20 or 80 to 100	<15 and >100
Texture	FS, VFSL, L, SiL, SL	CL, SiC, SiCL	S, LS, S, C, HC	bedrock
Moist Consistency	very friable, friable, firm	loose, very firm	extremely firm	hard rock
Coarse fragments (% Vol) [(a)]	<30	30 to 50	50 to 70	>70
Coarse fragments (% Vol) [(b)]	<15	15 to 30	30 to 50	>50

Source: Adapted from Alberta Soils Advisory Committee (1987).

[(a)] Applicable where soil matrix texture is finer than sandy loam.

[(b)] Applicable where soil matrix texture is sandy loam and coarser.

EC = electrical conductivity; dS m-1 = deciSiemens per metre; SAR = sodium adsorption ratio; S = sand; LS = loamy sand; SL = sandy loam; FSL = fine sandy loam; L = loam; SiL = silt loam; CL = clay loam; SCL = sandy clay loam; SiCL = silty clay loam; C = clay; HC = heavy clay; $CaCO_3$ = calcium carbonate equivalent; < = less than; > = more than.

11.7.I.2.2 RESULTS

11.7.I.2.2.1 Physiographic Setting

The RSA (which includes the LSA) is located within the Bear-Slave Upland physiographic unit of the Canadian Shield physiographic region (Bostock 1970; Bradley et al. 1982). Massive Achaean granites, gneisses, sedimentary, and volcanic rocks of the Slave Geological Province underlie the area, forming a low-relief peneplain varying from 300 to 500 metres (m) in elevation (Bradley et al. 1982; Ecological Stratification Working Group 1996). Bedrock is the prominent control on the landscape and commonly occurs as surface outcrops or boulder fields. The local bedrock is commonly overlain by a thin to moderately thick bouldery till (Bradley et al. 1982). Lakes cover 20 to 30 percent (%) of the surface land area.

The elevation in the LSA ranges from a high of 440 metres above sea level (masl) at the crests of some hills, to approximately 395 masl in the lowland topography. Local relief is commonly in the range of 15 to 20 m on mainly gentle slope gradients, resulting in generally undulating to rolling topography. Higher relief hummocky topography occurs in areas of dominant bedrock control, which occurs in places in the LSA, but is most common in the southern part of the RSA. Relatively level to gently inclined areas between uplands are occupied by permafrost peatlands. Local drainage between waterbodies occurs through numerous, narrow watercourses that are shallow and not appreciably incised.

11.7.I.2.2.2 Biophysical Setting

The regional climate is continental subhumid with short, cool summers with very long daylight hours, and long, very cold winters with very short daylight hours (Bradley et al. 1982; Ecological Stratification Working Group 1996). From 1971 to 2000, annual precipitation averaged 272 millimetres (mm) with 147 mm or 54% as snow, and mean annual temperature averaged -7 degrees Celsius (°C) at Fort Reliance (Environment Canada 2005). The mean daily temperature was 9°C from May to September and -18ºC from October to April (Environment Canada 2005, internet site).

The general biophysical characteristics of the LSA are described within the context of the Ecological Framework for Canada. The framework delineates the land surface based on climatic parameters, physiography, vegetation, soil, water, and fauna (Ecological Stratification Working Group 1996, internet site). The LSA occurs in the Mackay Upland High Subarctic (HS) Ecoregion within the Taiga Shield Ecozone (Ecosystem Classification Group 2008).

The Mackay Lake HS Ecoregion is topographically variable with level to gently rolling terrain except in the southeast along the East Arm of Great Slave Lake (Ecosystem Classification Group. 2008). Lakes are common in the lowlands, while rock outcrops are common in the uplands. Dystric Brunisols with Turbic, Static, and Organic Cryosols are the dominant soils (see Annex D for definitions). Permafrost, continuous and discontinuous, is common in this ecoregion (Environment Canada 2004, internet site; CCEA 2005, internet site).

The most common upland cover types are shrub tundra and open spruce woodlands. Other vegetation includes dwarf birch (*Betula glandulosa* Michx.), mountain cranberry *(Vaccinium vitis-idaea* L.*)*, northern Labrador tea (*Ledum palustre* L.), common Labrador tea *(Ledum groenlandicum* Oder*)* red bearberry

(Arctostaphylos rubra), black crowberry *(Empetrum nigrum* L. ssp.*)* and lichens (Ecosystem Classification Group 2008).

11.7.I.2.2.3 Existing Bedrock Conditions

The granite bedrock of the Slave Geological Province (SGP) that both underlies and occurs as outcrops in the LSA is of Achaean origin. The SGP is an Achaean craton, with a rock record that spans the period from 4.05 to 2.55 billion years ago. This SGP is divided into western and eastern components based on the presence and absence, respectively, of a Mesoarchaean sialic basement. The Project is located within the eastern component, which is characterized by calc-alkaline bimodal volcanic rocks and thick sequences of greywacke and mudstone. The dominant rock types within the LSA are granite and gneissic granite. Metasediments have been mapped only along the eastern edge of the LSA; no metavolcanics have been mapped within the LSA (Cairns 2003; Cairns et al. 2003).

Four sets of Proterozoic mafic dykes have been mapped within the Walmsley Lake map area (Cairns 2003). Within the Lac de Gras area, four and possibly five sets of Proterozoic dykes have been identified with ages between 2.23 and 1.27 billion years (LeCheminant 1994). A dyke correlated with the Mackenzie dyke swarm is located to the northeast of the Tuzo kimberlite. The Project kimberlites constitute part of the southeast SGP kimberlite field, which is Cambrian in age, circa 545 to 525 million years (Hetman et al. 2003). Kimberlite rocks underlie lakes and are not exposed in any outcrops within the LSA (Baker 1998).

Geological hazards are considered to be related mainly to potential for slides and flows of material after thawing of permafrost. The local bedrock in the area is generally resistant to stress with a rare likelihood of rock falls in relatively steep terrain.

In terms of seismicity, the central part of the Northwest Territories is generally considered to be an inactive part of Canada without identifiable active faults. Further, it is quite distant from the other active seismic zones in Canada and is located within the stable portion of the Canadian Shield. Extensive studies carried out by the Geological Survey of Canada concluded that the Precambrian Cratonic Cores and Canadian Shield are relatively tectonically stable in the long-term (1 in 2,500 year return period), although not excluded from the potential for earthquakes (Natural Resources Canada 2007, internet site).

11.7.I.2.2.4 Existing Surficial Geology and Terrain Conditions

Achaean, Quaternary, and Holocene deposits cover the surface of the LSA. Quaternary glacial deposits and landforms within the area are related to the Late Wisconsin glaciation (25,000 to 10,000 years ago) (Hardy 1997, 2005). The study area comprises a drift-poor zone of till veneer (less than 2 m thick) and ice-moulded bedrock resulting in an overall low-relief landscape (Aylsworth and Shilts 1991).

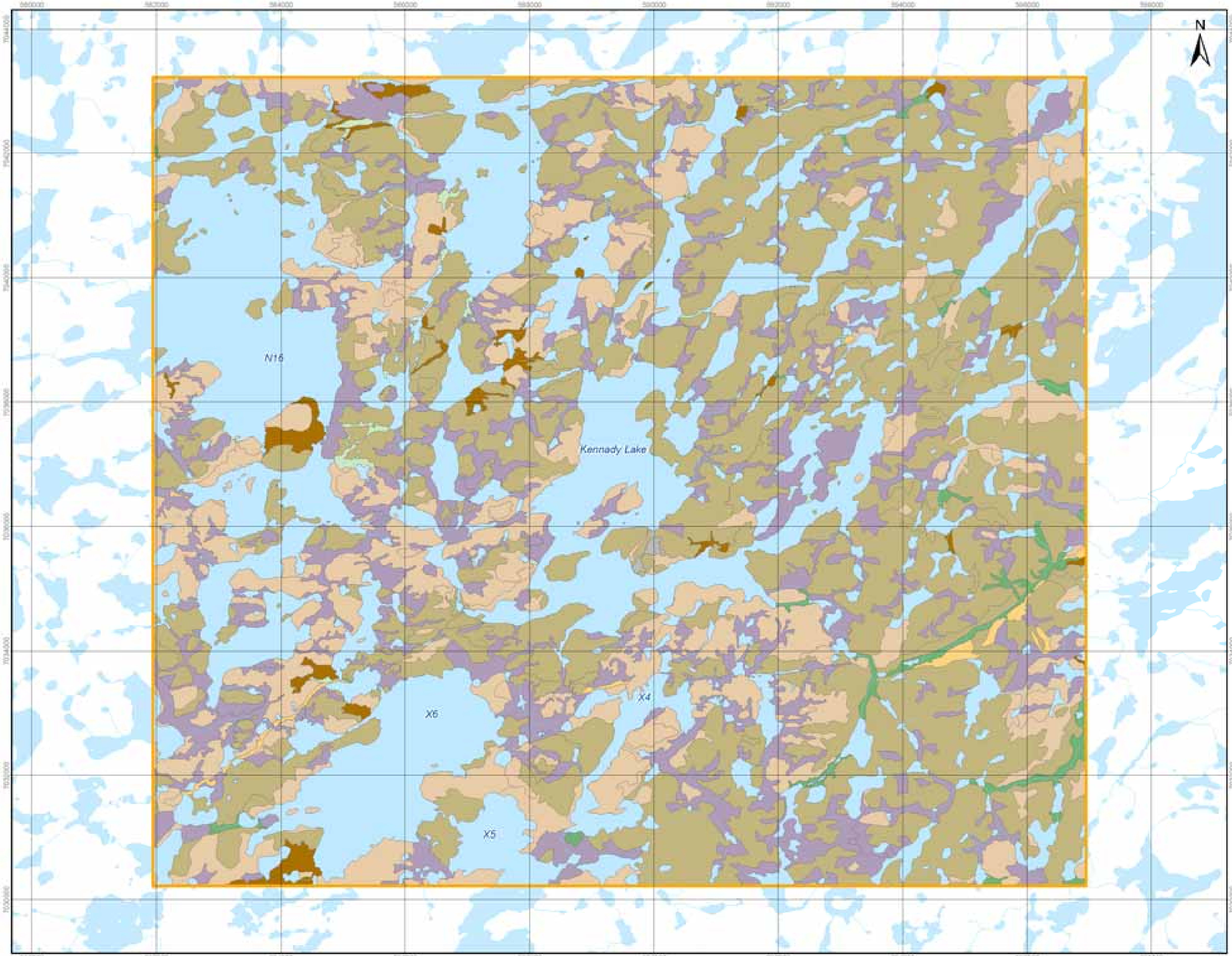
Much of the till within the RSA was deposited during glacial advance; however, it may have undergone subsequent modification by glacial meltwater or spillway development during deglaciation. Local till in topographic low areas is a matrix-supported diamict with textural characteristics of silt to medium sand (Hardy 1997, 2005). Till in some elevated localized areas, greater than 10 m above current water levels, is interpreted as ablation till based on a distinct difference in texture from the lower elevation till. This ablation till comprises a clast-supported sediment with a coarse-textured matrix ranging from medium sand to gravel (Hardy 1997).

Esker complexes occur in the RSA and LSA as both small, single-ridged eskers and large, multi-ridged, complex systems. Many of the eskers are discontinuous with localized preservation of remnants occurring. Outwash plains may be associated with eskers in places, and localized small glaciofluvial deltas occur at the terminus of some eskers.

Holocene deposits (10,000 years ago to present) consist of fluvial, lacustrine, limited aeolian, and organic (peat) materials. Peat deposits include both bogs and fens. Aeolian features are uncommon in the area, with the exception of localized erosion along exposed esker ridges, as evidenced by areas of bare sand blowouts on esker crests. Localized accumulations of lacustrine sediments were noted along lake margins where recent water level recession has occurred. In general, this lacustrine sediment is capped with an organic accumulation of peat.

Drainage networks between the numerous lakes in the region are characterized by the accumulation of fluvial sediments. The fluvial deposits appear to be quite thin (less than 1 m) and are overlain in most places by peaty deposits (Hardy 1997). A large portion of the area is characterized by organic (bog and fen peat) accumulation, which is promoted by low-relief topography.

The terrain in the LSA was described by developing a system of map units for material and landform types. The terrain categories were applied in mapping the terrain of the LSA. The terrain categories, their descriptions, and their spatial extent in the LSA are presented below in Table 11.7.I-6. A terrain map is presented in Figure 11.7.I-3.



LEGEND

- Watercourse
- Waterbody
- Local Study Area

Terrain Unit

Bog
Bog Dominated; peat plateau.
Includes Baseline Units: ***B; B-M/Ru; B-M/Ruh; B-Fv/Ri***

Bog and Fen
Bog and Fen Dominated; planar.
Includes Baseline Units: ***BN; BN-Fv/Ri; BN-M/Ru; BN-M/Ruh***

Glaciofluvial
Glaciofluvial; esker ridges.
Includes Baseline Units: ***FGr***

Fluvial
Fluvial veneer over Bedrock
Includes Baseline Units: ***Fv/Ri***

Moraine (Low Relief)
Morainal veneer and blankets over Bedrock; undulating.
Includes Baseline Units: ***M/Ru; M/Ru-B; M/Ru-B-Fv/Ri; M/Ru-BN; M/Ru-N***

Moraine (High Relief)
Morainal veneer and blankets over Bedrock; undulating to hummocky.
Includes Baseline Units: ***M/Ruh; M/Ruh-B; M/Ruh-BN; M/Ruh-N; M/Ruh-R-B; M/Ruh-R; M/Ruhr-B***

Fen
Fen Dominated; planar.
Includes Baseline Units: ***N; N-Lv/Rd***

Exposed Bedrock
Bedrock; variable topography
Includes Baseline Units: ***R***

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Terrain Units in the Local Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:60,000 (1 0.5 0 1 Kilometers)		
FILE No: E-Soils-001-GIS		DATE: October 19, 2010
JOB NO: 09-1365-1004	REVISION NO: 5	**Figure 11.7.I-3**
OFFICE: GOLD-SAS	DRAWN: MK / CHECK: JV	

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Table 11.7.I-6 Terrain Units in the Local Study Area

Terrain Unit	Surficial Material	Landform	Area (ha)	% of LSA
B	bog peat	polygonal peat plateau, northern peat plateau, lowland polygon	83	0.43
B-Fv/Ri	bog, with sub-dominant glaciofluvial veneer on bedrock	bog forms with gently inclined fluvial areas	12	0.06
B-M/Ru	bog dominant, with sub-dominant morainal veneer over bedrock	bog forms with undulating morainal areas	16	0.08
B-M/Ruh	bog dominant, with sub-dominant morainal veneer over bedrock	bog forms with undulating to hummocky morainal areas	91	0.47
BN	mixed bog and fen peat	bog (B) and fen (N) forms	2,268	11.63
BN-Fv/Ri	mixed bog and fen dominant, with fluvial veneers or moraine over bedrock	bog and fen forms with gently inclined fluvial areas	100	0.51
BN-M/Ru	mixed bog and fen with sub-dominant morainal veneer over bedrock	bog and fen forms with undulating morainal areas	264	1.36
BN-M/Ruh	mixed bog and fen with sub-dominant morainal veneer over bedrock	bog and fen forms with undulating to hummocky morainal areas	58	0.30
FGr	glaciofluvial	ridged forms of eskers	65	0.33
Fv/Ri	fluvial veneer overlying bedrock	gently inclined (shallow channels)	167	0.86
M/Ru	morainal veneer overlying bedrock, with some areas of blanket	undulating	552	2.83
M/Ruh	morainal veneer overlying bedrock, with some areas of blanket	undulating to hummocky; rolling and whaleback forms in places	80	0.41
M/Ruhr-B	morainal veneer (as in M/Ruh), with sub-dominant Bog	undulating to hummocky and rolling; minor esker ridges	18	0.09
M/Ru-B	morainal veneer (as in M/Ru), with sub-dominant bog	undulating with bog forms	1,381	7.08
M/Ruh-B	morainal veneer (as in M/Ruh), with sub-dominant bog	undulating to hummocky and rolling, with bog forms	6,193	31.76
M/Ruh-B-R	morainal veneer (as in M/Ruh), with sub-dominant bog and bedrock outcrops	undulating to hummocky and rolling, with bog forms	168	0.86
M/Ru-BN	morainal veneer (as in M/Ru), with sub-dominant bog and fen complex	undulating, with bog and fen forms	1,173	6.01
M/Ruh-BN	morainal veneer (as in M/Ruh), with sub-dominant bog and fen complex	undulating to hummocky and rolling, with bog and fen forms	784	4.02
M/Ru-B-Fv/Ri	morainal veneer (as in M/Ru), with sub-dominant Bog and Fluvial veneer	undulating, with bog and gently inclined fluvial forms	16	0.08
M/Ru-N	morainal veneer (as in M/Ru), with sub-dominant Fen	undulating with Fen forms	8	0.04
M/Ruh-N	morainal veneer (as in M/Ruh), with sub-dominant Fen	undulating to hummocky and rolling, with fen forms	53	0.27
M/Ruh-R	morainal veneer (as in M/Ruh), with sub-dominant Bedrock outcrop	undulating to hummocky, with bedrock exposures	117	0.60
N	fen peat	lowland polygon and horizontal	35	0.18
N/Lv/Rd	fen, with sub-dominant Lacustrine veneer over Bedrock	horizontal to depressional, lake and pond shore areas	19	0.10
R	bedrock	bedrock exposures	11	0.05
Water	open water		5,768	29.58
Total			**19,500**	**100%**

ha = hectares; % = percent; LSA = Local Study Area.

11.7.I.2.2.5 Existing Soil Conditions

11.7.I.2.2.5.1 Classification and Description of Soils

The surficial and bedrock geology, along with freeze-thaw processes, have a major influence on soil types found within the LSA. Soil development on the local parent materials mainly involves podzolization, cryogenic, paludification, and terrestrialization processes that are limited by cold weather and low precipitation. Therefore, the Brunisolic, Cryosolic, Organic, and Regosolic soil orders predominate (soil classification according to Soil Classification Working Group 1998). Soil type associations vary according to specific site characteristics and conditions, but can be generally categorized according to parent material type.

Small areas of non-soils, consisting of exposed bedrock and boulder fields, occur in the LSA, and are more extensive in the northern part of the RSA. Soils associated with the bedrock and boulder fields are formed on shallow till deposits and are mainly classified as Regosols, which are relatively undeveloped soils showing little or no distinct soil profile development. In many instances poor drainage conditions exist, resulting in the accumulation of an organic veneer (less than 1 m). Depending on the depth and influence of the active layer, Organic Cryosols may develop (Bradley et al. 1982).

Soil types associated with the deposition of glacial till include Eluviated and Orthic Dystric Brunisols, often in the wetter cryoturbated phase (Cryoturbated Gleyed Dystric Brunisol or Gleysolic Turbic Cryosols) (Bradley et al. 1982). The variability of the till mantle over bedrock (0.2 to more than 2 m) and the influence of drainage characteristics are governing controls on soil formation processes (Bradley et al. 1982). Dystric Brunisols are commonly found in well-drained upland sites. The imperfectly to poorly drained lower slope positions, characterized by dull colour and mottling, are dominated by Gleyed Dystric Brunisols or Gleysolic Turbic Cryosols (Bradley et al. 1982). The presence and influence of ground ice, in the form of sorted and unsorted circles or nets, directly affects the development of soil and subsequent classification (Bradley et al. 1982).

Glaciofluvial and ice-contact deposits were also mapped in the LSA. According to Bradley et al. (1982), Eluviated and Orthic Dystric Brunisols, and Orthic Regosols, are commonly associated with eskers and glaciofluvial outwash plains. The extent of soil development is variable, with Brunisols associated with well-drained portions of the landscape, and Regosols associated with the actively eroding, rapidly drained upper slopes and ridge tops.

The extensive accumulation of organic deposits, comprising bog and fen peat accumulations of variable thickness, which are commonly underlain by permafrost, are classified mainly as Terric subgroups of Organic Cryosol soils (Bradley et al. 1982). The presence or absence of mineral sediment within 1 m of the surface controls the classification of the permafrost-rich, organic soils. The shallow nature of the active layer in these Organic Cryosols tends to be directly related to the formation of patterned organic ground (Bradley et al. 1982).

Along watercourses, annual flooding may deposit fine-grained mineral and organic material that is nutrient-rich and promotes relatively vigorous vegetation growth. Shallow peat deposits develop in these areas as well. Soils on these parent materials include Cumulic, Gleyed, and Humic subgroups of Regosols; peaty phase Gleysolic and Regosolic subgroups of Cryosols; and Terric subgroups of Organic and Organic Cryosolic great groups. Cryoturbated phases of non-permafrost soils also frequently occur.

Soils have been grouped into six distinct soil associations based on their classification and relationship to surficial sediments within the LSA (Table 11.7.I-7). A soil association is a group of associated soil series developed from similar parent material and occurring under essentially similar climatic conditions. Three of these soil associations are based on earlier work completed by Bradley et al. (1982), and include the Wolverine, Hoarfrost, and Sled Lake Associations. The remaining associations should be considered Project-specific and have been named based on the local and regional features, and are used here for reference purposes only.

Soils of the LSA were mapped by assigning a map unit to distinctive landscape portions delineated on a map. A map unit consists of a single soil association, or where the landscape is complex, of a combination of two soil associations. The map units and the area of each in the LSA are presented in Table 11.7.I-8. The soil map is presented in Figure 11.7.I-4.

Table 11.7.I-7 Summary of Soil Associations and Surficial Materials in the Local Study Area

Surficial Material	Association	Dominant Soil Great Group(s)
Soils Developed on Coarse to Moderately Coarse Textured, Non-calcareous Glacial Till		
Moraine veneer - Till <1 m thick	Wolverine Lake	Dystric Brunisol
Soils Developed on Glaciofluvial Deposits		
Ice-contact (esker)	Hoarfrost River	Regosol
Soils Developed on Organic Deposits		
Shallow to deep fen peat	Dragon Lake	Organic Cryosol
Shallow to deep bog and mixed fen and bog peat	Sled Lake	Organic Cryosol
Soils Developed in Actively Flooded Areas		
Shallow peat and mineral soil deposits	Goodspeed Lake	Fibrisol or Mesisol Humic Regosol
Bedrock	Bedrock	n/a

n/a = not applicable; < = less than; > = more than.

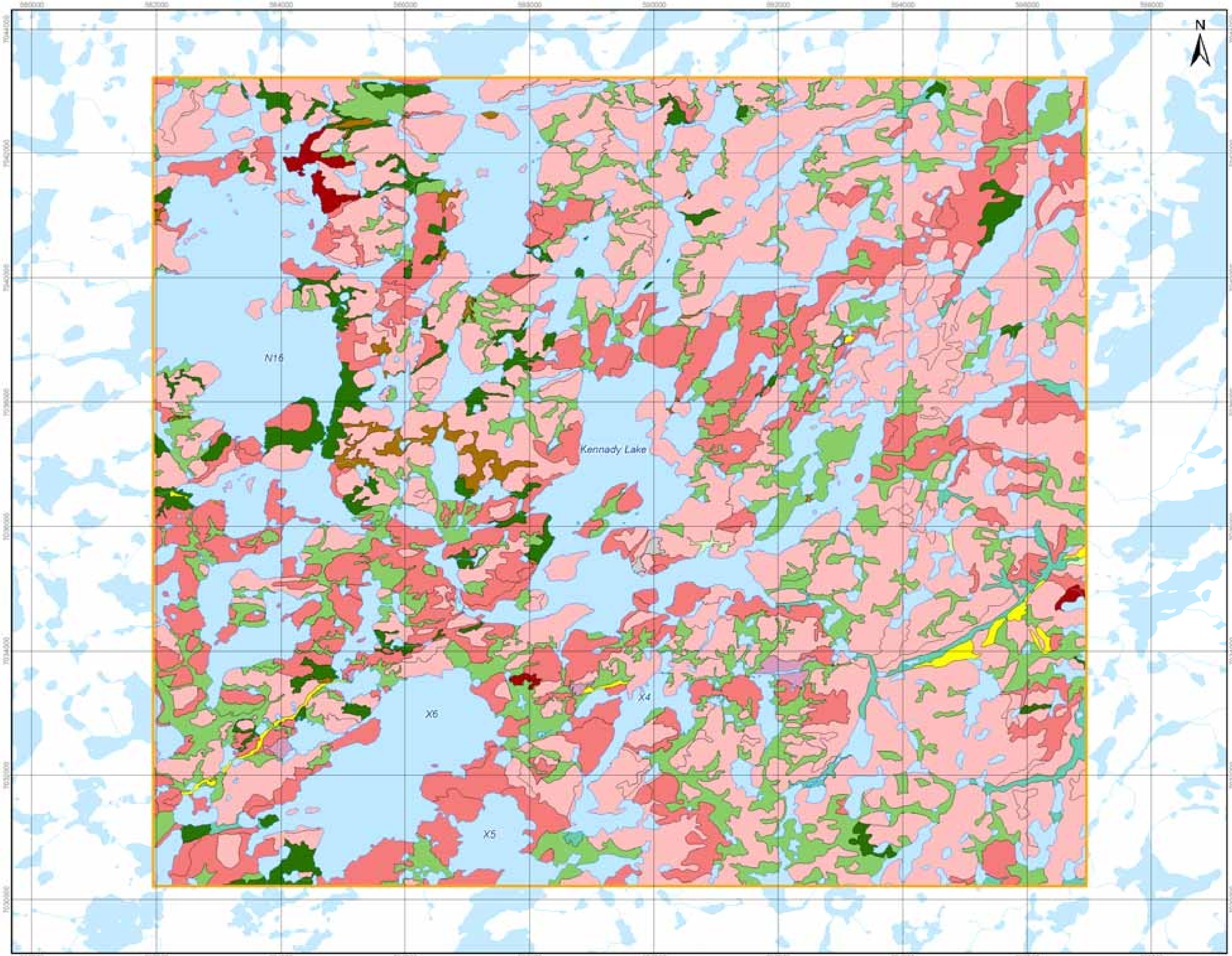
Table 11.7.I-8 Soil Map Unit Composition and Extent in the Local Study Area

Soil Map Unit	Terrain Unit	Dominant Soil Association(s)	Subdominant Soil Association(s)	Area (ha)	% of LSA
D1	N	Dragon Lake	none	29	0.15
D2	N	Dragon Lake	Wolverine Lake	5	0.03
D3	BN	Dragon Lake	Sled Lake	65	0.33
D4	N/Lv/Md	Dragon Lake	Goodspeed Lake	19	0.10
G1	Fv/Ri	Goodspeed Lake	Sled Lake, Dragon Lake, and Wolverine Lake	168	0.86
H1	FGr	Hoarfrost River	none	65	0.33
LAKE	Open Water	None	none	5,768	29.58
R	R	Bedrock	none	11	0.05
S1	B	Sled Lake	none	9	0.05
S2	B-M/Ruh	Sled Lake	Wolverine Lake	91	0.47
S2u	B-M/Ru	Sled Lake	Wolverine Lake	16	0.08
S3	B	Sled Lake	Dragon Lake and Wolverine Lake	58	0.30
S3u	BN-M/Ru	Sled Lake	Dragon Lake and Wolverine Lake	157	0.81
S4i	BN-Fv/Ri	Sled Lake	Dragon Lake and Goodspeed Lake	100	0.51
S5	B	Sled Lake	Dragon Lake	74	0.38
SD1	BN	Sled Lake Dragon Lake	none	2,067	10.60
SD2	BN	Sled Lake Dragon Lake	Wolverine Lake	104	0.53
SD2u	BN-M/Ru	Sled Lake Dragon Lake	Wolverine Lake	107	0.55
SD4	BN	Sled Lake Dragon Lake	Goodspeed Lake	33	0.17
SG1	B-Fv/Ri	Sled Lake Goodspeed Lake	none	12	0.06

Table 11.7.I-8 Soil Map Unit Composition and Extent in the Local Study Area (continued)

Soil Map Unit	Terrain Unit	Dominant Soil Association(s)	Subdominant Soil Association(s)	Area (ha)	% of LSA
W1	M/Ruh	Wolverine Lake	none	80	0.41
W1u	M/Ru	Wolverine Lake	none	552	2.83
W2	M/Ruh-B	Wolverine Lake	Sled Lake	5,315	27.26
W2u	M/Ru -B	Wolverine Lake	Sled Lake	812	4.16
W3	M/Ruh-BN	Wolverine Lake	Dragon Lake and Sled Lake	297	1.52
W4u	M/Ru-BN-R	Wolverine Lake	Bedrock, Dragon Lake, and Sled Lake	143	0.74
W5	M/Ruh-R	Wolverine Lake	Bedrock	78	0.40
WD1	M/Ruh-N	Wolverine Lake Dragon Lake	none	53	0.27
WD1u	M/Ru-N	Wolverine Lake Dragon Lake	none	8	0.04
WR1	M/Ruh-R	Wolverine Lake Bedrock	none	39	0.20
WS1	M/Ruh-B	Wolverine Lake Sled Lake	none	895	4.59
WS1u	M/Ru-B	Wolverine Lake Sled Lake	none	569	2.92
WS2	M/Ruh-BN	Wolverine Lake Sled Lake	Dragon Lake	491	2.52
WS2u	M/Ru-BN	Wolverine Lake Sled Lake	Dragon Lake	1,169	6.00
WS3	M/Ruh-B-R	Wolverine Lake Sled Lake	Bedrock	25	0.13
WS4ui	M/Ru-B-Fv/Ri	Wolverine Lake Sled Lake	Goodspeed Lake	16	0.08
Total				**19,500**	**100.00**

ha = hectares; % = percent; LSA = Local Study Area.



LEGEND

- Watercourse
- Waterbody
- Local Study Area

Soil Unit

- Dragon Lake Association
  Includes Baseline Units: ***D1; D2; D3; D4***
- Goodspeed Lake Association
  Includes Baseline Units: ***G1***
- Hoarfrost River Association
  Includes Baseline Units: ***H1***
- Exposed Bedrock
  Includes Baseline Units: ***R***
- Sled Lake Association
  Includes Baseline Units: ***S1; S2; S2u; S3; S3u; S4i; S5***
- Sled Lake/Dragon Lake Co-dominant
  Includes Baseline Units: ***SD1; SD2; SD2u; SD4***
- Sled Lake/Goodspeed Lake Co-dominant
  Includes Baseline Units: ***SG1***
- Wolverine Lake Association
  Includes Baseline Units: ***W1; W1u; W2; W2u/r; W3; W4U; W5***
- Wolverine Lake/Dragon Lake Co-dominant
  Includes Baseline Units: ***WD1; WD1u***
- Wolverine Lake/Bedrock Co-dominant
  Includes Baseline Units: ***WR1***
- Wolverine Lake/Sled Lake Co-dominant
  Includes Baseline Units: ***WS1; WS1u; WS2; WS2u; WS3; WS4ul***

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Soil Map Units in the Local Study Area

PROJECTION: UTM Zone 12
DATUM: NAD83
Scale: 1:60,000
1 0.5 0 1
Kilometers

DE BEERS CANADA

FILE No: E-Soils-002-GIS
DATE: October 19, 2010
JOB NO: 09-1365-1004
REVISION NO: 5
OFFICE: GOLD-SAS
DRAWN: MK
CHECK: JV

Figure 11.7.I-4

11.7.I.2.2.6 Soil Quality in the Local Study Area

11.7.I.2.2.6.1 Overview of Soil Quality

Soil quality attributes described for soils of the LSA consist of erosion susceptibility, acidification sensitivity, and reclamation suitability. The ratings for each of these are presented in Table 11.7.I-9. The information in Table 11.7.I-9 was used to derive summaries of soil quality categories and their distributions in the LSA, which are discussed in the following sections.

Table 11.7.I-9 Soil Map Units and Interpretations for Erosion Risk, Acidification Sensitivity, and Reclamation Suitability in the Local Study Area

Soil Map Unit[(a)]	Water Erosion Risk	Wind Erosion Risk	Acidification Sensitivity	Reclamation Suitability Upper Lift	Reclamation Suitability Lower Lift	Area (ha)	% of LSA
D1	L	L (H) [(b)]	M	O	P	29	0.15
D2	L (M)	M	M (S)	O (P)	P	5	0.03
D3	L	L (H)	M	O	P	65	0.33
D4	L	L (H)	M	O (P)	P (U)	19	0.10
G1	L (M)	L (H)	M	P (U)	U	168	0.86
H1	H	H	S	P	P	65	0.33
LAKE	n/a	n/a	n/a	n/a	n/a	5,768	29.58
R	L	L	S	U	U	11	0.05
S1	L	L (H)	M	O	P	9	0.05
S2	L (M)	M	M (S)	O (P)	P	91	0.47
S2u	L (M)	M	M (S)	O (P)	P	16	0.08
S3	L (M)	M	M (S)	O (P)	P	58	0.30
S3u	L (M)	M	M (S)	O (P)	P	157	0.81
S4i	L	L (H)	M	O (P)	P (U)	100	0.51
S5	L	L (H)	M	O	P	74	0.38
SD1	L	L (H)	M	O	P	2,067	10.60
SD2	L (M)	M	M (S)	O	P	104	0.53
SD2u	L (M)	M	M (S)	O (P)	P	107	0.55
SD4	L	L (H)	M	O (P)	P (U)	33	0.17
SG1	L	L (H)	M	O (P)	P (U)	12	0.06
W1	H	M	S	P	P (U)	80	0.41
W1u	M	M	S	P	P (U)	552	2.83
W2	L (H)	M	S (M)	P (O)	P (U)	5,315	27.26
W2u	L (M)	M	S (M)	P (O)	P (U)	812	4.16
W3	L (H)	M	S (M)	P (O)	P (U)	297	1.52
W4u	L (M)	M	S (M)	P (U)	P (U)	143	0.74
W5	L (H)	M	S	P (U)	P (U)	78	0.40
WD1	L (H)	M	S (M)	P (O)	P (U)	53	0.27
WD1u	L (M)	M	M (S)	P (O)	P (U)	8	0.04

Table 11.7.I-9 Soil Map Units and Interpretations for Erosion Risk, Acidification Sensitivity, and Reclamation Suitability in the Local Study Area (continued)

Soil Map Unit[(a)]	Water Erosion Risk	Wind Erosion Risk	Acidification Sensitivity	Reclamation Suitability Upper Lift	Reclamation Suitability Lower Lift	Area (ha)	% of LSA
WR1	L (H)	M	S	P (U)	P (U)	39	0.20
WS1	L (M)	M	S (M)	P (O)	P (U)	895	4.59
WS1u	L (M)	M	S (M)	P (O)	P (U)	569	2.92
WS2	L (H)	M	M (S)	P (O)	P (U)	491	2.52
WS2u	L (M)	M	M (S)	P (O)	P (U)	1,169	6.00
WS3	L (H)	M	S (M)	P (U)	P (U)	25	0.13
WS4ui	L (M)	M	M (S)	P (O)	P (U)	16	0.08
Total						**19,500**	**100**

(a) See Tables 11.7.I-7 and 11.7.I-8 for explanation of soil map units.

(b) Brackets () = a subdominant rating associated with the dominant rating.

L = low; M = medium; H = high; ha = hectare; LSA = Local Study Area; % = percent; n/a = not applicable.

11.7.I.2.2.6.2 Soil Chemistry

Analytical data were obtained for soil samples collected from 28 sites in the LSA and from the Lobster Association within the RSA. Soil pH values are mainly acidic. The LFH horizons (duff layers) of mineral soils are extremely acidic, with pH values generally less than 4.6. The surface peat layers of Organic and Organic Cryosol soils are likewise extremely acidic. Subsoil layers of mineral soils fall into very strongly acidic (pH 4.6 to 5.0), strongly acidic (pH 5.1 to 5.5), and medium acidic (pH 5.6 to 6.0) categories. One Lobster Lake profile had a pH of 8.1 at a depth below 21 cm. Subsurface layers of Organic Cryosols and Organics have very strongly acid to strongly acid pH values. These very low soil pH values reflect the acidic rock origin of the parent materials. Acidic soils are generally associated with low nutrient status, and some elements such as aluminum can be present in soils at levels that are toxic to vegetation. Native vegetation is adapted to these conditions, but the pH conditions represent a somewhat harsh chemical environment for plant growth.

The cation exchange capacity (CEC) of a soil is a measure of its ability to retain base cations, especially calcium, magnesium, potassium, and sodium, which are essential plant nutrients. Organic materials generally have high CEC values as compared to mineral soils. This is reflected in the CEC data for LFH horizons and peat layers, which have values up to about 80 centimoles elemental charge per kilogram (kg) of soil.

The base saturation percentage (BSat) represents the proportion of the CEC that is actually occupied by base cations, and this value is commonly about 50% in organic soils. When the low bulk density of organic soils is considered, these CEC and BSat values reflect low levels of base cations available for plant growth. The CEC and BSat values of mineral soils are very low, due to their high sand content. These properties therefore also indicate low base cation levels available to plants. Sandy soils have very low levels of base cations as well as other major nutrients such as nitrogen and phosphorous, because they are unable to absorb and retain nutrient elements. Soil samples from the LSA were not analyzed for nutrients; however, nutrient regimes of almost all soils in the area can be regarded as low because of their predominantly sandy composition.

Trace metals contents were measured in eight surface soil layers (LFH or peat materials) and in one subsurface layer (Table 11.7.I-10). Arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, thallium, vanadium and zinc contents at all sites are considerably lower than the maximum allowable contents for soil in the Canadian Council of Ministers of the Environment Soil Quality Guidelines (Environment Canada 2007, internet site). No environmental quality guidelines exist for the trace elements aluminum, iron, manganese, and selenium. Calcium, magnesium, phosphorus, potassium, and sodium contents, which are considered essential for plant growth, also do not have environmental quality guidelines.

Table 11.7.I-10 Total Elemental Analysis of Selected Soil Horizons

Analytical Parameter	Unit	Guideline[a]	T2F-01 LF 5.5 to 0 cm	T2F-06 LFH 20 to 0 cm	T2-F-07 Cz 47 to 55 cm	T2F-10 Of 0 to 20 cm	T2F-11 LFH 6 to 0 cm
Soil Association	**-**	**-**	**Wolverine Lake**	**Wolverine Lake**	**Sled Lake**	**Dragon Lake**	**Lobster Lake**
pH_w[b]	-	6 to 8	4.8	3.9	-	4.1	4.3
Trace Elements							
Aluminum	mg/kg	-	4,270	10,500	4,710	2,840	4,560
Arsenic	mg/kg	12	1.3	1.9	1.3	1.4	1.5
Barium	mg/kg	500 to 2,000	37	86	33	36	81
Cadmium	mg/kg	1.4 to 22	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	mg/kg	64 to 87	6.8	22.6	10.2	1.8	8.3
Cobalt	mg/kg	40 to 300	1.4	6.8	1.8	1.8	3.0
Copper	mg/kg	63 to 91	5.3	17.1	8.3	18.6	13.8
Iron	mg/kg	-	4,330	10,750	5,060	1,660	5,900
Lead	mg/kg	70 to 600	0.9	2.2	0.9	<0.5	1.5
Manganese	mg/kg	-	16.4	96.3	35.4	<0.5	76.6
Mercury	mg/kg	6.6 to 50	<0.5	<0.5	<0.5	<0.5	<0.5
Molybdenum	mg/kg	5 to 40	<0.5	0.7	<0.5	<0.5	<0.5
Nickel	mg/kg	50	3.2	12.2	4.5	2.9	6.0
Selenium	mg/kg	-	<0.5	<0.5	<0.5	<0.5	<0.5

Table 11.7.I-10 Total Elemental Analysis of Selected Soil Horizons (continued)

Analytical Parameter	Unit	Guideline[(a)]	T2F-01 LF 5.5 to 0 cm	T2F-06 LFH 20 to 0 cm	T2-F-07 Cz 47 to 55 cm	T2F-10 Of 0 to 20 cm	T2F-11 LFH 6 to 0 cm
Thallium	mg/kg	1	<0.5	<0.5	<0.5	<0.5	<0.5
Vanadium	mg/kg	130	9.6	23.5	10.4	6.5	8.2
Zinc	mg/kg	200 to 360	6.1	32.9	7.8	7.1	19.3
Other Elements							
Calcium	mg/kg	-	594	1,575	986	2,290	1,730
Magnesium	mg/kg	-	895	3,975	1,790	465	1,180
Phosphorus	mg/kg	-	153	376	255	413	766
Potassium	mg/kg	-	413	1,335	840	66	1,090
Sodium	mg/kg	-	40	104	69	50	50
Soil Association	**-**	**-**	**Lobster Lake**	**Wolverine Lake**	**Sled Lake**	**Average**	**Range**
pH_w	-	6 to 8	4.5	4.1	4.3	4.3	3.9 to 4.8
Trace Elements							
Aluminum	mg/kg	-	3,530	8,760	2,660	5,198	2,660 to 10,500
Arsenic	mg/kg	12	0.8	1.5	1.0	1.3	0.8 to 1.9
Barium	mg/kg	500 to 2,000	29	45	84	54	29 to 86
Cadmium	mg/kg	1.4 to 22	<0.2	<0.2	0.2	<0.2	<0.2 to 0.2
Chromium	mg/kg	64 to 87	5.1	19	<0.5	10.5	<0.5 to 22.6
Cobalt	mg/kg	40 to 300	1.0	3.7	1.5	2.6	1.0 to 7.0
Copper	mg/kg	63 to 91	2.2	16.0	6.9	11.0	2.2 to 18.6
Iron	mg/kg	-	4,020	7,570	2,030	5,165	1,660 to 11,000
Lead	mg/kg	70 to 600	1.0	1.0	0.6	1	<0.5 to 2.2
Manganese	mg/kg	-	11.1	61.7	9.5	43.9	<0.5 to 98.8
Mercury	mg/kg	6.6 to 50	<0.5	<0.5	<0.5	<0.5	0
Molybdenum	mg/kg	5 to 40	<0.5	0.5	<0.5	<0.5	<0.5 to 0.7
Nickel	mg/kg	50	1.9	8.7	1.8	5.2	1.8 to 12.5
Selenium	mg/kg	-	<0.5	<0.5	<0.5	<0.5	0
Thallium	mg/kg	1	<0.5	<0.5	<0.5	<0.5	0
Vanadium	mg/kg	130	9.8	16.4	0.9	10.7	0.9 to 24.0
Zinc	mg/kg	200 to 360	5.9	16.2	32.3	16.0	6.1 to 33.9
Other Elements							
Calcium	mg/kg	-	603	772	3,130	1,460	594 to 3,130
Magnesium	mg/kg	-	684	3,210	682	1,610	465 to 4,070
Phosphorus	mg/kg	-	153	301	532	369	153 to 766
Potassium	mg/kg	-	293	1,390	754	773	66 to 1,390
Sodium	mg/kg	-	40	70	67	61	40 to 106

(a) Guideline is based on the 2007 Canadian Environmental Quality Guidelines. The range reported encompasses guidelines for agricultural, residential/park, commercial and industrial areas.

(b) pH_w = pH determined in soil-water mixture.

cm = centimetre; < = less than; mg/kg = milligram per kilogram; - = no guideline exists for the element.

11.7.I.2.2.6.3 Wind and Water Erosion

Most of the LSA has a Low water erosion rating, although some areas of Medium and High susceptibility occur (Table 11.7.I-11). The ratings Low (Medium) and Low (High) indicate that there are some areas of soil complexes in which one of the soil components has a rating of either Medium or High. Generally, the Medium and High ratings apply to Wolverine Lake soils that occur on hummocky topography with slopes in the 6 to 15% or higher slope categories.

Table 11.7.I-11 Summary of Water and Wind Erosion Ratings for Soils in the Local Study Area

Water Erosion Rating	Area (ha)	% of LSA	Wind Erosion Rating	Area (ha)	% of LSA
High	145	0.74	High	65	0.33
Moderate	552	2.83	Moderate	11,080	56.82
Low (high)[(a)]	6,298	32.30	Low (high)	2,575	13.21
Low (moderate)	4,317	22.14	Low (moderate)	n/a[(b)]	n/a
Low	2,419	12.41	Low	11	0.06
Open water	5,768	29.58	Open water	5,768	29.58
Total				**19,500**	**100**

(a) first rating is dominant, and rating in brackets is subdominant.

(b) n/a =not applicable (does not occur).

ha = hectares; % = percent; LSA = Local Study Area.

Most of the area (57% of the LSA), which represents almost all of the non-water area, is rated as having moderate susceptibility to wind erosion (Table 11.7.I-11). The erosion ratings pertain to soils if they are stripped of vegetation and then undergo drying. Most of the upland soils are coarse textured and readily moved by wind due to absence of aggregation among the sand particles. The lowland soils of bogs and fens would also be erodible under conditions of surface disturbance and desiccation.

11.7.I.2.2.6.4 Acidification Sensitivity

All of the soils in the LSA were categorized as being Sensitive or of Moderate sensitivity in terms of acid deposition. The areas and percentages of different sensitivity acidification categories are shown in Table 11.7.I-12. The Sensitive class pertains mainly to upland soils, especially the Wolverine Association, which is characterized by low buffering capacity due to low clay content and low cation exchange capacity. Organic and Organic Cryosol soils were categorized as moderately sensitive.

Table 11.7.I-12 Acidification Sensitivity of Soils in the Local Study Area

Acidification Sensitivity	Area (ha)	% of LSA
Sensitive	825	4.23
Sensitive (moderate)[(a)]	8,109	41.58
Moderate (sensitive)	2,222	11.40
Moderate	2,575	13.21
Open water	5,768	29.58
Total	**19,500**	**100**

(a) First rating is dominant, and rating in brackets is subdominant.

ha = hectare; LSA = Local Study Area; %=percent.

Wiens et al. (1987) characterized mineral soils in the Northwest Territories according to their potential to reduce the acidity of atmospheric deposition. Soil depth, soil carbonate content, and bedrock type were considered in addition to chemical properties to assign a soil buffering potential of high, moderate, or low. According to this study, the non-calcareous surficial deposits overlying granite bedrock that are typical of the LSA were assigned a low potential to reduce acidity at all soil depths.

11.7.I.2.2.6.5 Reclamation Suitability

Reclamation suitability categories of soils in the LSA are summarized in Table 11.7.I-13. Topsoils in the LSA generally have poor suitability for reclamation in the case of mineral soils. Organic materials such as peat and the duff layer of soils have not been differentiated in the reclamation suitability rating system. The extensive Organic soils and Organic Cryosols in the area are, therefore, classed simply as an Organic category. Organic material can be valuable in reclamation because of its nutrient content and ability to improve the soil moisture holding capacity. The major limitation for topsoil suitability for reclamation is the coarse texture of most surface soils in the LSA, which is associated with low pH, low nutrient status, and low moisture holding capacity. The high stone and boulder content of the soils also limits the suitability for reclamation.

Subsoils were predominantly categorized as Poor and Unsuitable for reclamation. This rating arises mainly from the high stone and boulder content of the glacial till soils, and the presence of bedrock close to the soil surface. Furthermore, many of the subsoils have coarse textures and associated low pH, nutrient status, and water holding capacity, similar to the surface soils.

Table 11.7.I-13 Reclamation Suitability Categories of Soils in the Local Study Area

Soil Rating	Upper Lift		Lower Lift	
	Area (ha)	% of LSA	Area (ha)	% of LSA
Organic	2,348	12.04	n/a	n/a
Organic (Poor)	599	3.07	n/a	n/a
Poor	697	3.57	2,847	14.60
Poor (Organic)	9,625	49.36	n/a	n/a
Poor (Unsuitable)	452	2.32	10,707	54.91
Unsuitable	11	0.06	178	0.91
Open water	5,768	29.58	5,768	29.58
Total	**19,500**	**100.00**	**19,500**	**100.00**

ha= hectare; %=percent; LSA = Local Study Area; n/a = not applicable; brackets () = rating for a subdominant soil associated with a dominant soil.

Some areas of soils developed on glacial till may have relatively low stone contents, and they could therefore have higher soil suitabilities for reclamation. Generally, areas with mud and frost boils develop in relatively non stony till, and the content of fines may be higher than normal (Bradley et al. 1982). These soils, however, may have unique physical limitations. Thixotropic soil materials were observed in the field in many places. This property refers to the tendency to puddle and flow upon disturbance, due to high moisture content. Such soils may therefore be difficult to handle in soil salvage and reclamation activities.

11.7.I.2.2.6.6 Permafrost Assessment

The Project site is located near the tree line and the southern limit of continuous permafrost (Heginbottom and Dubreuil 1995). The study area supports tundra heath with isolated spots of stunted spruce, willow, high polar birch and peat bogs.

Permafrost extends over approximately 90 to 95% of the on-land area of the LSA. Based on the results of the field reconnaissance, it was concluded that shallow taliks (i.e., areas up to several metres deep that remain unfrozen year-round) could be encountered withuffiin isolated areas of glaciolacustrine plains, fluvial-glaciofluvial valleys and channels treed with spruce, willow and high polar birch. Rough calculations indicate also that taliks may be encountered beneath small lakes deeper than 0.6 m. Depending on the size and age of the lake, taliks may be shallow or penetrate through the entire permafrost thickness.

Fifteen terrain units and subunits were identified on the permafrost map as a result of the aerial photograph interpretation, field reconnaissance and field drilling program. Each unit or subunit identified is characterized by an individual collection of topographic conditions, as well as soil and permafrost parameters. These include: landscape (topography) description, soil composition, overburden thickness, moisture content, mean annual soil temperature, thickness of active layer or seasonal frost penetration, and earth/permafrost processes.

Weathered bedrock had the thickest active layer and was estimated to be approximately 3.7 m to 4.0 m. Deep seasonal thaw is explained by the low moisture content of the bedrock. A deep active layer was also predicted for the eskers. Depending on the mean annual esker temperature, the thickness of the active layer is estimated to be approximately 3.0 to 3.35 m. The deep thaw in eskers is also explained by low moisture content. The thickness of the active layer within the moraine veneer and blanket is estimated to be 2.6 m to 3.2 m and 1.6 m to 2.5 m, respectively. This range of thickness corresponds to differences in moisture contents. Glaciofluvial sand and silt was predicted to have an active layer thickness of 1.0 to 2.0 m. Organic soils were estimated to have the shallowest active layers (0.40 to 0.85 m).

Due to the stony composition of mineral soils within the study area, it was impossible to verify the thickness of the active layer by hand-auger drilling during the field reconnaissance. However, hand-auger drilling was used to determine the active layer thickness in organic soils. The field measurements of the active layer in organic soils were from 0.2 to 1.0 m (average 0.45 m).

In general, mineral soils within the LSA have low ice content. No visible ice has been found in the majority of the boreholes that were advanced at the moraine blanket and glaciolacustrine plain. The moisture content in glaciolacustrine plain ranged from 3 to 20%. The soil texture was silt and silty sand with gravel up to 20%. Single thin ice layers, horizontal and vertical, were encountered below a depth of 6.1 m, near the contact with bedrock. In the moraine blanket, several thin ice layers were recorded in the interval from 0.7 to 0.95 m. Glaciofluvial deposits have higher ice content. Ice layers, up to 10 mm thick were encountered in an interval from 1.75 to 2.9 m. The soil consisted of fine-grained sand and silt with some fine gravel. The moisture content of that soil was about 35%.

Organic deposits were found to be ice rich. It was estimated that volumetric ice content of the peat could be about 40% to 50%. Ice layers were observed to be up to 3 mm in thickness, horizontal or wavy in shape. The ice layers alternated with thin peat layers. Numerous lenses and pockets of ice were also observed in organic samples. The field reconnaissance confirmed the high ice content of the peat.

Various permafrost processes were observed during the field reconnaissance. Several places within the study area were observed to be affected by frost cracks and heaving of the active layer. These occurred in materials of a finer texture, higher moisture content, and fewer coarse fragments (i.e., cobbles, boulders, and rocks). Ice wedges were observed in bogs and areas of organic veneers. Thermokarst (thaw subsidence) features were also observed, and were only observed in organic soils. Thermoerosion slumps have developed at the banks of deep thermokarst depressions. Pingos were also observed within the study area, although these features were very infrequent.

11.7.I.2.3 TRADITIONAL KNOWLEDGE

The integration of traditional knowledge (TK) as it relates to the disciplines of geology, terrain, soils, and permafrost was achieved through a review of publicly available TK reports. This review focused on the importance of terrain conditions and the linkages that exist between other terrestrial disciplines and traditional land uses. In general, the review also focused on traditional knowledge related to the use of eskers as an aggregate source. Relevant TK and traditional land use (TLU) information collected as a part of this program has been used in the terrain, soils, and geology assessment process. However, little TK or TLU information specifically related to terrain, soils, and geology was identified.

The nature of esker ridges has been defined in previous sections of the EIS (e.g., Section 11.7.I.2.2.4), in terms of their sedimentological and ecological value. The review of TK also indicated that these features had substantial importance to the local communities and their traditional practices (Annex M).

There was some available TK and TLU information about the importance of eskers. The reviewed information suggests that eskers are important because they provide relatively easy land to travel upon. Also, they support animals such as white fox, wolves, grizzly bears, and wolverines, and are therefore, good hunting and trapping locations.

> *The people followed the eskers to direct them when travelling on the barrenlands. Near the big eskers there are little narrow eskers which are sand only and no rocks. This is where the white foxes raise their pups in their dens. This is where I will set my traps. White foxes mate near rough terrain on the tundra around boulders and rocks. They make dens under snow—they might even have a wife under there. But this is not their regular den site—it's like a rough cliff with broken*-up rocks (ND in LKDFN 2001:27).

While no contemporary or historical cultural sites were identified within the area of the Project, archaeological surveys of the area have defined important linkages between traditional land use and esker deposits.

Traditional knowledge will also be considered during Project closure. The closure and reclamation of roads will be completed in accordance with best practices, taking into account the information provided by traditional sources (LKDFN 2003, internet site).

> *I went to the mines this summer to check out the caribou. They don't like those mine roads. They're too high for them to get across, and they have sharp boulders on the sides where caribou can get hurt from falling or getting stuck. We even drove in a truck on the road, and saw the caribou having trouble going up and down the sides of the road. It's no good, and it's no good for us Dene people. Those mines should do something about this, or maybe soon our caribou will be all gone* (LKDFN 2003:70, internet site).

It is the goal of the closure and reclamation plan to return parts of the environment affected by the Project to a state that is similar to environmental conditions not influenced by the Project. This includes the levelling and recontouring of roads to match the surrounding landscape so that caribou, and other animals, can move easily through the area.

11.7.I.3 PATHWAY ANALYSIS

11.7.I.3.1 METHODS

Pathway analysis identifies and assesses the issues and linkages between the Project components and activities, and the correspondent potential residual effects on geology, terrain, and soils. Pathway analysis is a three-step process for determining linkages between Project activities and effects on terrain and soils. Potential pathways through which the Project could influence the geology, terrain, and soils were identified from a number of sources including:

- the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Gahcho Kué Panel 2007) and the Report of Environmental Assessment (MVEIRB 2006);
- a review of the Project Description and scoping of potential effects by the environmental assessment and Project engineering teams for the Project; and
- consideration of potential effects identified for the other diamond mines in the NWT and Nunavut.

The first part of the analysis is to produce a list of all potential effects pathways for the Project. Each pathway is initially considered to have a linkage to potential effects on geology, terrain, and soils. This step is followed by the development of environmental design features and mitigation that can be incorporated into the Project to remove the pathway or limit (mitigate) the effects on geology, terrain, and soils. Environmental design features and mitigation include Project designs and environmental best practices, and management policies and procedures. Environmental design features were developed through an iterative process between the Project's engineering and environmental teams to avoid or mitigate effects.

Knowledge of the ecological system and environmental design features and mitigation is then applied to each of the pathways to determine the expected amount of Project-related changes to the environment and the associated residual effects (i.e., after mitigation) on geology, terrain, and soils. For an effect to occur, there has to be a source (Project component or activity) that causes a change in the environment and a correspondent effect on geology, terrain, and soils.

Pathway analysis is a screening step that is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the

Project. This screening step is largely a qualitative assessment, and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects on geology, terrain, and soils. Pathways are determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features. Each potential pathway is assessed and described as follows:

- no linkage – pathway is removed by environmental design features and mitigation so that the Project results in no detectable environmental change and, therefore, no residual effects to terrain and soils relative to baseline or guideline values;
- secondary - pathway could result in a measurable and minor environmental change, but would have a negligible residual effect on terrain and soils relative to baseline or guideline values; or
- primary - pathway is likely to result in a measurable environmental change that could contribute to residual effects on terrain and soils relative to baseline or guideline values.

Primary pathways for geology, terrain, and soils require further effects analysis to determine the magnitude, duration, and spatial extent of effects from the Project. Pathways with no linkage to geology, terrain, and soils or that are considered minor (secondary) are not analyzed further because environmental design features and mitigation will remove the pathway (no linkage) or residual effects can be determined to be negligible through a simple qualitative evaluation of the pathway. Primary pathways are analyzed in more detail in Section 11.7.I.5.

11.7.I.3.2 RESULTS

Pathways potentially leading to effects on geology, terrain, and soils include direct and indirect effects (Table 11.7.I-14). These changes may ultimately affect the persistence of plant populations and communities, listed plant species, and continued opportunity for traditional and non-traditional use of plants. Evaluation of effects on geology, terrain, and soils also considers changes to permafrost, hydrogeology, hydrology, water quality, and air quality during the construction, operation, and closure of the Project, as well as effects remaining after closure. The following sections discuss the potential pathways relevant to geology, terrain, and soils.

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Project Footprint (e.g., pits, Fine PKC Facility, Coarse PK Pile, mine rock piles, Winter Access Road and Tibbitt-to-Contwoyto Winter Road)	• loss or alteration of soil and terrain features from the Project footprint	• backfilling the mined-out pits with PK and mine rock will decrease the on-land Project footprint • compact layout of the surface facilities will limit the area disturbed at construction and increase site operations efficiency • some of the mine rock from the mine rock piles will be used for construction, and therefore, will reduce the amount stored in the piles • mine rock will be used as the source of aggregate production, thereby, reducing the need for separate quarries • pit wall stability is a priority safety issue and the focus of specific geotechnical engineering design requirements • soil, overburden, and lakebed sediments from areas of disturbance will be salvaged and stockpiled during the pit and mine rock pile development for use at closure to the extent practical • where practical, natural drainage patterns will be used to reduce the use of ditches or diversion berms • plant site infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave where possible • road design will use coarser materials to reduce frost effects • progressive closure of the major waste containment facilities, including the capping, and final cover and grading of the Fine PKC Facility and the Coarse PK Pile, as well as final grading of the mine rock piles • at closure, the entire site area will be stabilized and contoured to blend with the surrounding landscape • culverts or stream-crossing structures will be removed and natural drainage re-established • conditions will be monitored over time to evaluate the success of the Closure and Reclamation Plan and, using adaptive management and newer proven methods as available, adjust the Plan, if necessary • De Beers will actively liaise with other mine operators in the Canadian Arctic to understand the challenges and successes they have encountered with respect to reclamation • reclamation trials will be completed throughout the Project life to determine which prescriptions may be most effective for reclamation	Primary
	• site clearing, contouring and excavation can cause slides, rock falls and slumping in Quaternary sediments and bedrock resulting in redistributed materials and geologic hazards		Secondary
	• physical loss or alteration of permafrost from the Project footprint can cause changes to terrain and soil		Secondary

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Project Footprint (e.g., pits, Fine PKC Facility, Coarse PK Pile, mine rock piles, Winter Access Road and Tibbitt-to-Contwoyto Winter Road) (continued)	• site clearing, contouring and excavation can cause admixing, compaction, and increase erosion potential (soil and sediment), and change terrain	• erosion will be controlled primarily by keeping slope angles of constructed facilities at less than the angle of repose or by rock armouring, as appropriate • erosion protection materials will be placed over the downstream natural channels (or engineered channel when required) to limit erosion along the flow paths to the mined-out Tuzo Pit • where erosion is a concern during closure, the surface will be re-contoured, and culverts or stream-crossing structures will be removed, and natural drainage re-established • the Coarse PK Pile will be shaped and covered with a layer of mine rock of a minimum 1 m to limit surface erosion • alternative reclamation methods, such as rock armouring may be used to allow for the long-term stability of rock slopes or other site features that may not be suitable for revegetation • at the plant site, airstrip, roads and on dykes, long-term sediment control will be achieved by re-vegetation. Rock armouring will be done where re-vegetation is not feasible. Rock for the rock armouring will be obtained by screening suitably sized inert material from the mine rock pile • reduce admixing of topsoil with subsoil during salvage and reclamation • obtain direction of qualified reclamation specialists • apply appropriate lift techniques to preserve organic materials • avoid work in wet conditions in areas with finer textured soil	Primary
	• soil salvage, stockpiling and transport can change physical, biological, and or chemical properties of soil and sediment, and increase erosion potential		Primary

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction and operations (e.g., equipment operation, aircraft/vehicles, airstrip, processing and storage facilities) Winter Access Road and Tibbitt-to-Contwoyto Winter Road	• dust deposition and air emissions (including NOx and PAI deposition) may change the chemical content of soil	• personnel arriving at or leaving the site will be transported by bus therefore reducing the amount of traffic between the airstrip and the accommodation complex • compact layout of the surface facilities will reduce traffic, and therefore dust and air emissions, around the site • watering of roads, airstrip, and laydown areas will facilitate dust suppression • enforcing speed limits will assist in reducing production of dust	Primary
	• chemical spills (including de-icing fluid run off) may cause changes to soil quality	• processing of the kimberlite ore will be mechanical, with limited use of chemicals • hazardous, non-combustible waste and contaminated materials will be temporarily stored in the waste storage transfer area in sealed steel or plastic, wildlife-resistant drums, and shipped off-site for disposal or recycling • chemicals such as de-icing fluid, acids, solvents, battery acids, and laboratory agents will be collected in lined trays and drums, and stored in suitable sealed containers in the waste transfer area • the waste transfer storage area will include a lined and enclosed pad for the collection and subsequent return of hazardous waste to suppliers or to a hazardous waste disposal facility • emulsion materials will be stored at the emulsion plant where spills would be 100% contained within the building • all fuel storage tanks will be designed and constructed according to the American Petroleum Institute 650 standard and placed in a lined and dyked containment area to contain any potential fuel spills • aviation fuel will be stored in self-contained, Underwriters Laboratories Canada-rated envirotanks mounted on an elevated pad at the air terminal shelter • aviation fuel for helicopters will be stored in sealed drums inside a lined berm area near the airstrip • to prevent accumulation and/or runoff of de-icing fluid at the airstrip from aircraft de-icing operations, aircraft will be sprayed in a specific area that will be equipped with swales to collect excess fluids as necessary • puddles of de-icing fluid in the swales will be removed by vacuum truck and deposited into waste de-icing fluid drums for shipment to recycling facilities • an Emergency Response and Contingency Plan has been developed • spill containment supplies will be in designated areas • any spills will be isolated and immediately cleaned up by a trained spill response team consisting of on-site personnel will be available at all times	No Linkage

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Site Water Management	• release of seepage and surface water runoff from the PK and mine rock piles can change soil quality	• the performance of the dykes will be monitored throughout their construction and operating life. Instrumentation monitoring together with systematic visual inspection will provide early warning of many conditions that can contribute to dyke failures and incidents. Additional mitigation will be applied, if required • a system of ditches and sumps will be constructed, maintained, and upgraded throughout the operation phase of the Project to manage groundwater from the open pits • site runoff will flow naturally to the dewatered areas of Kennady Lake that will act as a control basin for storage of water. Within this basin, water flows can be managed. Where practical, natural drainage patterns will be used to reduce the use of ditches or diversion berms • no substantial runoff and seepage from the mine rock piles is • a soil-bentonite slurry cutoff wall through a till fill zone placed over the overburden and the overburden to the bedrock surface has been adopted as the main seepage control for the diversion dyke separating Areas 7 and 8 • the cut-off wall for the dyke separating Areas 7 and 8 will be protected by a downstream filter zone and mine rock shell zone • for the retention dyke that separates Areas 3 and 4, Areas 5 and 6, and Areas 4 and 6, a wide till core has been selected as the main seepage control • the water retention dyke separating Area 2 and Lake N7, as well as diversion dykes dealing with Lakes A3, A4, B1, N13, D2, E1, and E3 will have a liner keyed into the competent frozen ground or bedrock to control seepage • the curved filter dyke to retain the particles in the fine PK placed in Areas 1 and 2 will be construction material and will be free of roots, organics, and other materials not suitable for construction	No Linkage

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Mine Rock Management	• leaching of PAG mine rock can change soil quality	• mine rock used to construct the dykes will be non-acid generating (NAG) • any mine rock containing kimberlite will be separated from the tundra by at least 2 m of inert and kimberlite-free rock to prevent drainage with low pH • any PAG mine rock, as well as any barren kimberlite, will be sequestered within the interior of the mine rock piles in areas that will allow permafrost to develop or will be underwater when Kennady Lake is refilled • till from ongoing pit stripping will be used to cover PAG rock placed within the interior of the structure to keep water from penetrating into the portion of the repository • the PAG rock will be enclosed within enough NAG rock that the active frost zone (typically two metres) will not extend into the enclosed material and water runoff will occur on the NAG rock cover areas • to confirm the lower levels remain frozen, temperature monitoring systems will be placed in the mine rock piles as they are being constructed • minimal water is expected to penetrate to the PAG rock areas • only non-reactive mine rock will be placed on the upper and outer surfaces of the mine rock piles. The thickness of the cover layer is predicted to be sufficient so that the active freeze-thaw layer remains within the non-reactive mine rock • thermistors will be installed within the mine rock piles to monitor the progression of permafrost development. The upper portion of the thick cover of mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are expected to remain permanently frozen	No Linkage
Dewatering of Kennady Lake	• changes in downstream flows (e.g., isolation and diversion, altered drainage patterns) and water levels from dewatering of Kennady Lake may cause soil erosion of stream floodplains and stream/lake banks	• Lake N11 is capable of accepting water at the rate of 500,000 m^3/d without erosion damage to downstream watercourses • as a contingency scenario, the Project is capable of operating without discharge beyond the controlled areas of the Kennady Lake watershed after initial lake dewatering is completed • discharge from Area 3 will be monitored so that the lake surface remains at a level that will minimize wave action on exposed shorelines and reduce the suspension of lake bottom sediment as the water level in Kennady Lake is lowered.	Secondary
Tibbitt-to-Contwoyto and Winter Access Road (traffic)	• road footprint and vehicle traffic can cause soil compaction and increase potential for erosion	• use of proven best practices for winter road construction • road preparation involves building the road base with snow and ice • additional snow placed at the slope breaks of hills and lake edges may reduce soil compaction	No Linkage
	• dust deposition may change the chemical content of soil along the Winter Access Road and Tibbitt-to-Contwoyto Winter Road		No Linkage

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Closure and Reclamation	• changes in downstream flows and water levels from the refilling of Kennady Lake during closure may cause soil erosion of stream floodplains and stream/lake banks	• mined-out pits will be backfilled with PK and mine rock to reduce the time required for filling these portions of Kennady Lake because less water is required to refill the partially backfilled pits • Kennady Lake will be refilled using natural runoff and supplemental waters drawn from Lake N11 • while fine PK is being discharged in the mined-out pits (primarily Hearne, but potentially 5034), process water will not be reclaimed from the pits Instead the slurry discharge water will be used to accelerate the infill of the mined-out pits; the process will facilitate a more rapid re-filling and progressive reclamation of Area 6 within Kennady Lake • the 5034 Pit will be backfilled to the extent possible with mine rock and the remaining space will be eventually filled with water once mining in the Tuzo Pit is complete • the Tuzo Pit will be allowed to flood following the completion of the operations phase; natural watershed inflows will be supplemented by pumping water from Lake N11 • the pumping rates are anticipated to be managed such that the total outflow from Lake N11 does not drop below the 1 in 5-year dry conditions	Secondary
	• residual ground disturbance from portions of the Project footprint can cause permanent loss or alteration to soils	• backfilling the mined-out pits with PK and mine rock will decrease the on-land Project footprint • compact layout of the surface facilities will limit the area disturbed at construction • mine rock will be used as the source of aggregate production, thereby, reducing the need for quarries • soil, overburden, and lakebed sediments from areas of disturbance will be salvaged and stockpiled during the pit and mine rock pile development for use at closure • progressive closure and reclamation of the major containment facilities, with the capping, and final cover and grading of the Fine PKC Facility, the Coarse PK Pile, as well as final grading of the mine rock piles • at closure, transportation corridors the airstrip will be scarified and loosened to encourage natural revegetation, and re-contoured where required • monitor conditions over time to evaluate the success of the Closure and Reclamation Plan and, using adaptive management and newer proven methods as available, adjust the Plan, if necessary • De Beers will actively liaise with other mine operators in the Canadian Arctic to understand the challenges and successes they have encountered with respect to reclamation • reclamation trials will be completed throughout the Project life to determine which prescriptions may be most effective for reclamation	Primary

Table 11.7.I-14 Potential Pathways for Effects to Geology, Terrain, and Soils (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Closure and Reclamation (continued)	• long-term seepage from the Coarse PK Pile and mine rock piles may cause local changes to soil quality	• no substantial runoff and seepage from the mine rock piles is expected • a soil-bentonite slurry cutoff wall through a till fill zone placed over the overburden and the overburden to the bedrock surface has been adopted as the main seepage control for the diversion dyke separating Area 7 and Area 8 • the water retention dyke separating Area 2 and Lake N7, as well as diversion dykes dealing with Lakes A3, A4, B1, N13, D2, E1, and E3 will have a liner keyed into the competent frozen ground or bedrock to control seepage • the curved filter dyke to retain the particles in the fine PK placed in Areas 1 and 2 will be construction material free of roots, organics and other materials not suitable for construction	No Linkage

CCME = Canadian Council of Ministers of the Environment; m = metre; NAG = non-acid generating; NO_X = nitrogen oxide; PK = processed kimberlite; PKC = processed kimberlite containment; PAG = potentially acid generating; PAI = potential acid input; STP = sewage treatment plant

11.7.I.3.3 NO LINKAGE PATHWAYS

A pathway may have no linkage if the activity does not occur (e.g., effluent is not released), or if the pathway is removed by environmental design features so that the Project results in no detectable (measurable) environmental change and no residual effects to geology, terrain, and soils. The following pathways are anticipated to have no linkage to geology, terrain, and soils, and will not be carried through the effects assessment.

11.7.I.3.3.1 Changes to Soil Quality

The following bullets describe pathways that have no linkage to soil quality.

- Chemical spills (including glycol and de-icing fluid runoff) may cause changes to soil quality.

Chemical spills are usually localized, and are quickly reported and managed. Mitigation practices identified in the Emergency Response and Contingency Plan (Section 3, Appendix 3.I, Attachment 3.I.1), and environmental design features will be in place to limit the frequency and extent of chemical spills at the Project, and along the winter access roads (Table 11.7.I-14). The following are examples of environmental design features and mitigation that will be used to reduce the risk from chemical spills:

  - Hazardous, non-combustible waste, and contaminated materials will be temporarily stored in the waste storage transfer area in sealed steel or plastic, wildlife-resistent drums, and shipped off-site for disposal or recycling.
  - Chemicals such as waste oil, glycol, acids, solvents, battery acids, and laboratory agents will be collected in lined trays and drums and stored in suitable sealed containers in the waste transfer area.
  - The waste transfer storage are will include a lined and enclosed pad for the collection and subsequent return of hazardous waste to suppliers or to a hazardous waste disposal facility.
  - Emulsion materials will be stored at the emulsion plant where spills would be 100% contained within the building.
  - Spill containment supplies will be available in designated areas where fuel and chemicals are stored.
  - All fuel storage tanks will be designed and constructed according to the American Petroleum Institute 650 standard.

- The tanks will be placed in a lined and dyked containment area.
- The design of the containment area for tanks will be based on the requirements of the Canadian Council of Ministers of the Environment (CCME) Environmental Code of Practice for Above-Ground Storage Tanks Systems Containing Petroleum Products (2003), the National Fire Code of Canada, and any other standards that are required.
- Spill containment supplies will be in designated areas.
- Any spills will be isolated and immediately cleaned up by a trained spill response team consisting of on-site personnel who will be available at all times.

The implementation of the Emergency Response and Contingency Plan, environmental design features, mitigation, and monitoring programs is expected to result in no detectable change to soil quality. Subsequently, this pathway was determined to have no linkage to effects on soil.

- Release of seepage and surface water runoff from the processed kimberlite (PK) and mine rock piles can change soil quality.
- Long-term seepage from the Coarse PK Pile and mine rock piles may cause local changes to soil quality.

Water-borne chemicals can adversely affect soil quality through surface water runoff and seepage. Environmental design features have been incorporated into the Project to eliminate or reduce potential effects from surface water runoff and seepage (Table 11.7.I-14). Runoff and seepage from the Fine PKC Facility, Coarse PK Pile, and mine rock piles will not be released to the environment outside of the Project footprint during construction and operations, with the exception of a monitored discharge to Lake N11. Runoff from the coarse PK and mine rock piles will be contained in the affected basins and drain to either Area 3 or to one of the mined-out pits using natural drainage channels. Natural drainage channels will provide opportunities for monitoring runoff quality, and additional mitigation will be applied if required to limit changes to the existing environment (Table 11.7.I-14).

The Coarse PK Pile will not be designed to have a single point of release for seepage and runoff. Any runoff will flow through natural channels within the watershed and be retained in the controlled basin associated with Area 4, which in later years represents the Tuzo Pit area. Groundwater entering the open pits during mining will be routed by ditches to a series of sumps (Table 11.7.I-14). Groundwater inflows collected in the pit dewatering systems will be discharged to either Area 5 or the process plant where groundwater will be incorporated in the fine PK and pumped to the Fine PKC Facility.

As part of reclamation, the Fine PKC Facility will be covered with a 1 m to 2 m thick layer of non-acid generating (NAG) mine rock. The facility will be graded so that surface runoff will flow towards Area 3. The final geometry of the cover layer will be graded to limit ponding of water over the mine rock covered fine PK in Areas 1 and 2 of the Fine PKC Facility. Permafrost development in the Fine PKC Facility and underlying talik is expected to occur over time. Thermistors will be installed in the Fine PKC Facility to monitor the formation of permafrost in the solids (Table 11.7.I-14). The Coarse PK Pile will also be shaped and covered with a layer of mine rock of approximately 1 m to limit surface erosion. Runoff will be directed to Area 4.

Overall, release of seepage and surface water runoff from the PK and mine rock piles, and long-term seepage from the Coarse PK Pile and mine rock piles is not expected to result in a detectable change to soil quality relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects to soil.

- Leaching of potentially-acid generating (PAG) mine rock can change soil quality.

Any PAG mine rock, as well as any barren kimberlite, will be sequestered within the interior of the mine rock piles in areas that will allow permafrost to develop or will be underwater when Kennady Lake is refilled. Overburden, including lakebed sediments, will be used to cover any areas in the core of the mine rock piles where potentially reactive mine rock is sequestered (Table 11.7.I-14). The overburden (including sediments), which consist mainly of till, will provide a low permeability barrier that will limit infiltration and encourage water to flow over the surface of the mine rock pile, rather than through it. Water quality will be monitored on site, and additional mitigation will be applied if required to limit changes to the environment.

Further, the PAG rock will be enclosed with enough non-acid generating (NAG) rock that the active zone (typically 2 m) will not extend into the enclosed material, and water runoff will occur on the NAG rock cover areas (Table 11.7.I-14). While all water will not be stopped completely from penetrating a till and NAG rock envelop, the amounts that may penetrate deeper into the pile are expected to be trapped in void spaces and likely freeze. Minimal water is expected to penetrate to the PAG rock areas. To confirm the lower levels remain frozen, temperature monitoring systems will be placed in the mine rock piles as they are being constructed (Table 11.7.I-14).

Experience at the Ekati Diamond Mine suggests that coarse kimberlite in direct contact with the naturally acidic tundra soils can lead to drainage with low pH. Therefore, barren kimberlite or mine rock mixed with kimberlite will not be placed directly on the tundra soils, and will be separated from the tundra by at least 2 m of inert and kimberlite-free clean rock (Table 11.7.I-14).

Progressive closure and reclamation of the mine rock piles will involve contouring and re-grading. The piles will not be seeded for revegetation, consistent with the approaches in place at the Ekati Diamond Mine and Diavik Diamond Mine. Thermistors will be installed within the mine rock piles to monitor the progression of permafrost development (Table 11.7.I-14). The upper portion of the thick cover of clean mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are predicted to remain permanently frozen.

Overall, leaching of PAG mine rock is not expected to result in a detectable change to soil quality relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects to soil and has not been evaluated further.

- Road footprint and vehicle traffic can cause soil compaction and increase potential for erosion.

Construction and operation of the Winter Access Road connecting the Project with the Tibbitt-to-Contwoyto Winter Road will follow best practices (e.g., use of snow or ice pads of sufficient thickness to limit damage to overland portages between lakes, and discontinued use of the road when the ground surface becomes too soft). These are practices that are implemented in the design, construction, and operation of the Tibbitt-to-Contwoyto Winter Road that have proven to be successful in limiting effects to vegetation, and consequently, soil compaction and potential for erosion (EBA 2001) (Section 11.7). Therefore, this pathway was determined to have no linkage to effects on soil.

- Dust deposition may change the chemical content of soil along the Winter Access Road and Tibbitt-to-Contwoyto Winter Road.

Haul trucks travelling on the Winter Access Road have the potential to transfer dust from vehicles and loads during the winter months (e.g., dust deposited on wheels and undercarriage while at mine sites and in Yellowknife). However, the relative contribution of these loads to the overall dust accumulation in the area along the roads is considered to be negligible. Air emissions and TSP deposition from the Winter Access Road were modelled assuming the road was in operation for 63 days (Section 11.4). In general, emissions from the Winter Access Road are small, and if extended over whole year, a non-measurable change in annual depositions was predicted (Section 11.4). During the winter, dust that accumulates on snow may settle on vegetation during the spring melt. Although snow melting does not result in “washing away” of dust, the dust that has accumulated on snow during the winter may be diluted during snow melt and spring freshet, and eventually removed by rain (Section 11.7). Therefore, dust deposition along the Winter Access Road is not expected to result in a detectable change to soil quality relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects to soil.

11.7.I.3.4 SECONDARY PATHWAYS

In some cases, both a source and a pathway exist, but the Project is anticipated to result in a minor environmental change, and would have a negligible residual effect on geology, terrain, and soil relative to baseline or guideline values (e.g., a slight increase in a chemical parameter above CCME guidelines, but would not affect soil quality). The following pathways are anticipated to be secondary, and will not be carried through the effects analysis.

11.7.I.3.4.1 Changes to Terrain and Geology

The following bullet describes the pathway that is expected to result in a minor change to terrain and geology.

- Site clearing, contouring and excavation can cause slides, rock falls and slumping in Quaternary sediments and bedrock resulting in redistributed materials and geologic hazards.

Ground stability conditions, including rock fall and slumping, resulting from the development of the mine pits are directly influenced by Project activities during the construction and operation phases. Specifically, the potential for effects is possible during site preparation and infrastructure development, dyke construction and diversions, and mining and quarrying phases of the Project.

Geological processes can include shallow translational landslides, rockfalls and slides, mud flows, and debris flows. Some of these can be considered to be hazardous processes that can affect both Project operations and safety. The quarrying and infrastructure development (including Project site and roads) pose the greatest risk for generating geologic hazards. The geological hazards are divided into bedrock and surficial sediment hazards.

Ground stability hazards were assessed qualitatively due to the localized nature of the effect. The baseline conditions were assessed at a resolution that does not permit quantitative analysis of stability concerns. During the construction and operations phases of the Project, specific localized conditions may be encountered in which ground stability may be compromised. These effects are most accurately assessed on-site, during the construction phase and during the operations.

Geological hazards related to bedrock disturbance will result from the blasting of the bedrock during the development of each of the kimberlite quarries. This hazard is expected to remain throughout the development of the Project as blasting and over-steepened rock walls will exist until mine closure. The effect of blasting is also associated with the construction of roads and infrastructure. The grading of bedrock to suitable slope gradients for road development presents a limited potential for geological hazards. In general, the bedrock structure of the LSA is stable and not prone to instability, except in the specific disturbance situations described above.

Geological hazards associated with the disturbance of surficial sediment are generally limited to the development of shallow translational slides. These effects are generally associated with the disturbance of the permafrost layer and correspondent melting of ground ice, and the over-steepening of sediment-controlled slopes. Much of the area is characterized by gentle slopes; however, areas of steeper terrain do occur. During initial site preparation and infrastructure development, the potential for ground disturbance is high. Natural and artificial disturbance of the permafrost may induce instability, especially in the higher relief terrain. Evidence from baseline conditions indicates that slight over-steepening and exposure of ground ice can lead to accelerated slumping and earth movement (Section 11.6). At closure, the goal is to re-establish similar permafrost patterns in distributed areas to aid in the terrain stability.

Geologic hazards are serious in terms of safety and effects on normal mining operations; however, in terms of effects on the natural bedrock and surficial sediment, only the mine component of the footprint, specifically a very small portion of the mine area characterized by relatively steep parts of the mine, will be affected. Overall, development of the Project is anticipated to result in minor changes to ground stability relative to baseline conditions (secondary; Table 11.7.I-14). Therefore, the residual effects to geology and terrain are predicted to be negligible.

11.7.I.3.4.2 Changes to Permafrost and Terrain

The following bullet describes the pathway that is expected to result in a minor change to permafrost and terrain.

- Physical loss or alteration of permafrost from the Project footprint can cause changes to terrain and soil.

The Project occurs at the southern extent of the continuous permafrost zone (NRC 1993). Freeze induced displacement of soil (i.e., frost jacking) and thaw induced displacement (i.e., subsidence) of soil are the main issues related to permafrost degradation (i.e., loss or alteration). Changes to thaw penetration and thickness of the active layer can influence surface stability through thaw settlement, frost heave and bearing capacity, as well as slope stability (Tarnocai et al. 2004). Changes can also affect hydrology, soil moisture, and nutrient availability, thereby influencing ecology of an area by affecting vegetation.

The ice content of the upper 10 to 20 m of the ground within the Project footprint is described as having low ice content with sparse areas that contain ice wedges (i.e. ice-rich permafrost) (NRC 1993). The amount of ground ice present within the permafrost is important for assessing the response of permafrost to clearing, construction, and subsequent recovery of ice conditions following disturbance (Jorgenson et al. 2010). The magnitude of changes to permafrost thermal regimes and potential thaw settlement is directly related to the nature and abundance of ground ice and the type and severity of disturbance at the surface (Lawson 1986; Pullman et al. 2007). Knowledge of the potential magnitude of thaw settlement is important for assessing placement and construction of Project components, the long term recovery of disturbed areas, and for developing reclamation and rehabilitation plans. Clearing of an area and subsequent construction activities are anticipated to cause permafrost to slowly degrade due to ground thermal changes resulting from removal and disturbance of vegetation. Once permafrost degrades, it can result in changes to surface relief, and subsequently influence the surface drainage of an area (Lawson 1986). Areas with high ground ice content (i.e., terrain with abundant ice wedges) should be avoided where possible. These areas are more sensitive to thaw-settlement and can result in longer-term changes in terrain, soils, and surface hydrology (Jorgenson et al. 2010). Conversely, areas with small volumes of ground ice are not as sensitive to thaw-settlement (Lawson 1986).

Numerous factors affect the magnitude of changes to permafrost areas and influence recovery of an area following disturbance, and include: type of construction activities, site infrastructure, vegetation, soil type, soil texture, density, water content and snow depth (Lawson 1986; Nolte et al. 1998; Jorgenson et al. 2010). For example, soil type influences the thermal regime of permafrost because heat loss tends to be more rapid from mineral soils as the thermal conductivity of a mineral soil is usually higher than in organic soil (Woo and Winter 1993). Thaw settlement caused by disturbance and subsequent melting of permafrost can initially lead to water impoundment, decreased albedo, and an increase in heat flux, which in turn causes more thaw settlement

(Jorgenson et al. 2010). This can result in a change in surface hydrology that shifts recovery patterns towards new plant communities, further influencing permafrost. The depth of the active layer may continue to increase as a result of disturbance (Burgess and Harry 1990; Burn and Smith 1993; Hayhoe and Tarnocai 1994). Jorgenson et al. (2010) found that the thaw depth continued to increase for 3 to 8 years after disturbance prior to stabilizing and recovering. Stabilization or re-establishment of equilibrium between climate and permafrost will eventually occur, but may take decades depending on the severity of the disturbance (Nolte et al. 1998; Jorgenson et al. 2010).

Where possible, Project components such as the access road will be located on well-drained granular soils. Areas underlain by finer grained, imperfectly- to poorly-drained, ice rich permafrost, may require substantial ground treatment prior to construction to maintain surface integrity for Project components. Areas of ice-rich permafrost could be stripped and insulated with materials such as wood chips to maintain permafrost, thus surface integrity. Changes to the thermal regime of soils can be minimized through the timing of construction (i.e., construction while the ground is frozen) (Hayhoe and Tarnocai 1994). Sufficient snow cover is important to minimize vehicle damage and Jorgenson et al. (2010) found that at least 25 cm of a packed snow surface was required to reduce construction related impacts to permafrost areas. Disturbed areas should be re-seeded as soon as possible during the growing season following construction to speed up permafrost recovery; Nolte et al. (1998) found that permafrost equilibrium began to recover within 5 years following re-seeding of disturbed areas.

Mitigation to reduce the potential for permafrost melting, and subsequent subsidence of areas include:

- Manage drainage around infrastructure to reduce pooling of water at the surface.
- Limit the mine footprint disturbance area.
- Limit the road footprint disturbance area, while maintaining safe construction and operation practices.
- Use coarser materials for road construction to minimize frost effects.
- Manage drainage around infrastructure.
- Insulate infrastructure, where possible.
- Building foundations will be built on bedrock not susceptible to frost heave to minimize thawing of permafrost in sensitive areas.
- Organic and/or topsoil horizons will not be stripped in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence.

- Additional field inspection may be necessary to assess specific poorly drained areas to assess local variations in permafrost conditions prior to construction.

By implementing these mitigation practices and using permafrost design features, the change to terrain and soil from the physical loss or alteration of permafrost is anticipated to be minor relative to baseline conditions (secondary; Table 11.7.I-14). Therefore, the residual effects to soil are predicted to be negligible.

11.7.I.3.4.3 Changes to Soil Quantity and Distribution

The following bullets describe pathways that are expected to result in minor change to soil quantity and distribution.

- Changes in downstream flows and water levels from dewatering of Kennady Lake may cause soil erosion of stream floodplains and stream/lake banks.
- Changes in downstream flows and water levels from the refilling of Kennady Lake during closure may cause soil erosion of stream floodplains and stream/lake banks.

Environmental design features have been included in the Project to limit erosion during construction, operation, and closure (Table 11.7.I-14). For example, discharges will be limited so that pumping will not increase discharges above the baseline 2-year flood levels in downstream lakes and channels. These levels were selected to reduce potential channel and bank erosion that could occur during dewatering.

Construction of dykes will cause changes to drainage flow patterns and surface water elevations in some lakes. For example, the construction of Dykes E and D will divert drainage flows from Lake B1 to N6 (Section 3). Construction of Dykes F and G divert water from Lakes D3, D2, E1, and N14 through Lake N17. The construction of Dyke C will divert water from Lake A3 through Lake N9. In addition to diversion of drainage flows, the construction of these dykes will also raise baseline surface water elevations in Lakes D2, D3, E1, and A3. For example, it is anticipated that surface water elevations in Lakes D2 and D3 will increase from approximately 424.2 m and 425.4 m at baseline, respectively, to 427.0 m throughout the construction and operational phases (Section 3). Surface water elevation in Lake E1 is anticipated to increase from 425.2 m to 426.0 m. The greatest increase in lake levels is predicted to be in Lake A3 where surface water elevations will increase from 423.0 m to 426.5 m after the construction of Dyke C (Section 3).

The progressive reclamation strategy will be extended to the water management of Kennady Lake, where portions of the lake will be isolated and brought back to preconstruction water levels and quality as quickly as possible (Table 11.7.I-14). The closure Water Management Plan requires annually pumping water from Lake N11 to Area 3 to reduce the overall time for the closure phase. The pumping rates are anticipated to be managed such that the total outflow from Lake N11 does not drop below the 1 in 5-year dry conditions (Table 11.7.I-14).

At closure, some dykes will be breached to return drainage flows and water levels to baseline conditions. While most changes are predicted to revert back to natural conditions, it is anticipated that the surface water elevation in Lake A3 will remain above baseline conditions (Section 3). Overall, the increase in drainage flows and surface water elevations associated with the dewatering and refilling of Kennady Lake is localized and is expected to have a minor influence on soil distribution relative to baseline conditions. Therefore, the residual effects to soil are predicted to be negligible.

11.7.I.3.5 PRIMARY PATHWAYS

The following pathways were determined to be primary for effects to terrain and soil, and will be carried through the effects assessment.

Changes to Terrain

- Loss or alteration of terrain features from the Project footprint.

Changes to Soil Quantity

- Loss or alteration of soil from the Project footprint.
- Residual ground disturbance from portions of the Project footprint can cause permanent loss or alteration to soils.

Changes to Soil Quality

- Soil salvage, stockpiling, and transport can change physical, biological, and/or chemical properties of soil, and increase erosion potential.
- Dust deposition and air emissions (including NO_X and PAI deposition) may change the chemical content of soil.

Changes to Soil Distribution

- Site clearing, contouring, and excavation can cause admixing, compaction, and increase erosion potential (soil and sediment).

11.7.I.4 EFFECTS TO TERRAIN AND SOILS

11.7.I.4.1 CHANGES TO TERRAIN

11.7.I.4.1.1 Methods

The effects of the Project on the surficial material distribution are partly presented quantitatively, based on Geographic Information System (GIS) analysis of areas of different surficial geological types disturbed by the Project. The terrain map was overlain by the Project footprint to calculate the areas of different terrain types affected by the Project. Some components are discussed qualitatively because some effects analyses are based only on a sensitivity rating.

11.7.I.4.1.2 Results

The proposed construction and operations plan for the Project involves the removal of overburden, and the re-contouring of the landscape. This modification of the landscape will result in both temporary and permanent changes in the distribution of surficial sediments from the pre-disturbed baseline conditions (Table 11.7.I-15). A temporary increase in the exposure of subaquatic sediment will occur as a result of Kennady Lake dewatering (Figure 11.7.I-5). A permanent increase of coarse-textured anthropogenic materials will be associated with the stockpiling of mine rock and the development of the Coarse PK Pile and Fine PKC Facility.

During the construction and operation phases of the Project, the local till overburden will have the greatest loss in area. This loss of area is considered to be a negative effect; however, the till parent material comprises the majority of the surficial sediments in the LSA. The total disturbance area of both low and high relief till within the LSA is 279.15 hectares (ha), (or 1.63% of low-relief till and 3.07% of high-relief till). Part of the loss is due to small lakes that will be flooded upon construction of saddle dykes. This will be regained upon closure, and the closure net change will be -0.74% and -2.6% respectively, for the low and high relief tills. The change is -1.1% in terms of the LSA.

The majority of the change to till material will be related to the development of the mine rock piles, Coarse PK Pile and Fine PKC Facility, because these features will partially occupy till areas. Operations and facilities will also affect the distribution of this parent material; however, the till can be reclaimed in those areas limited to surface stripping.

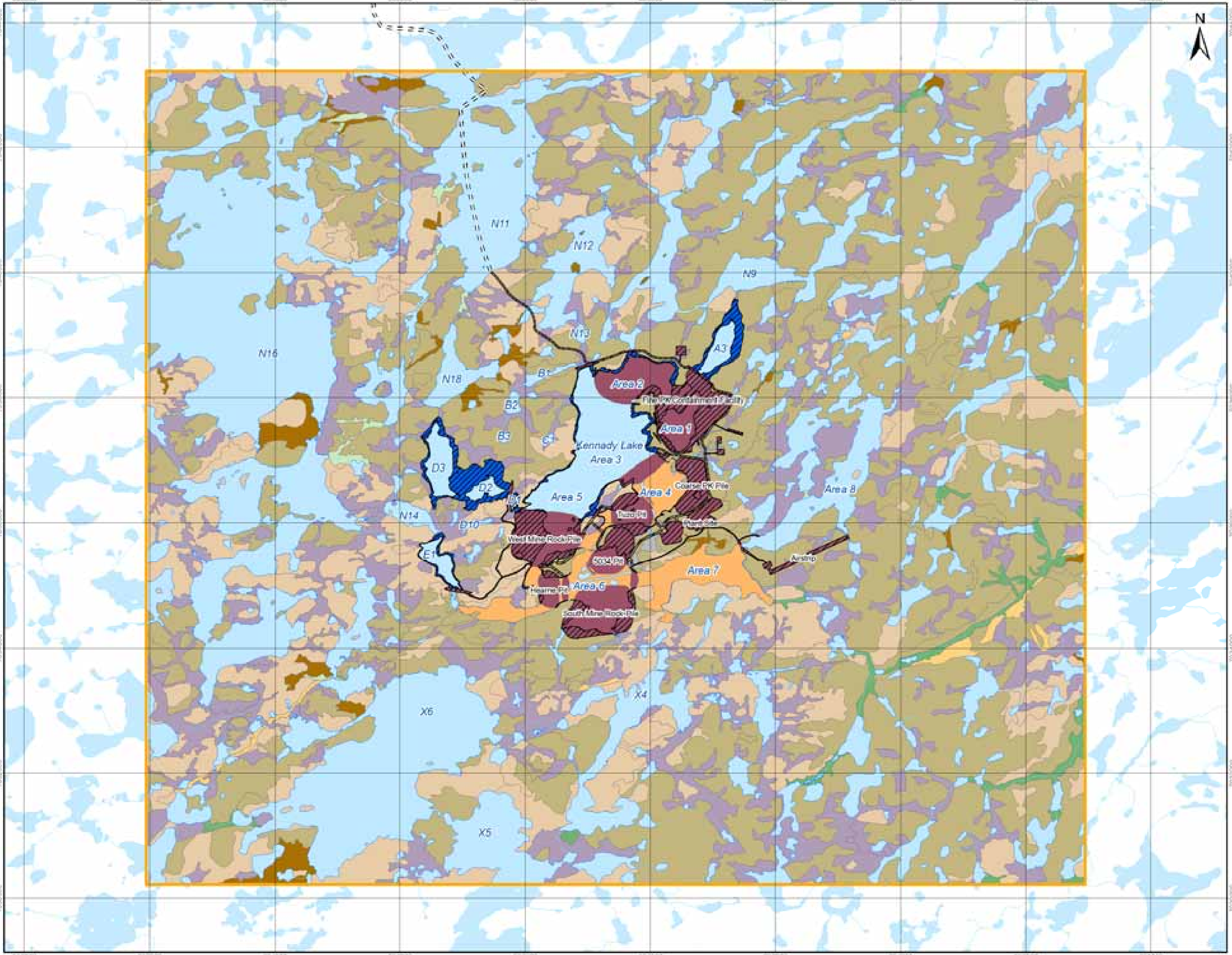
Table 11.7.I-15 Net Change in Surficial Material in the Local Study Area

Terrain Unit	Baseline		Area Affected by Project Footprint		Closure		
	Area (ha)	% of LSA	Area (ha)	Area at Maximum Disturbance (ha)	Area at Closure (ha)	Closure Net Change (ha)	Closure Net Change (%)
Lake	5,768	29.58	841.74	4,926.26	5,602.32	-165.68	-2.87
Bog	202	1.04	0.03	201.97	201.97	-0.03	-0.01
Bog/fen	2,690	13.79	112.05	2,577.95	2,614.16	-75.84	-2.82
Fen	54	0.28	1.88	52.12	52.12	-1.88	-3.48
Glaciofluvial	65	0.33	0.0	65	65	0.0	0.0
Fluvial	167	0.86	0.0	167	167	0.0	0.0
Low relief till	3,130	16.05	51.02	3,078.98	3,106.74	-23.26	-0.74
High relief till	7,413	38.01	228.13	7,184.87	7,220.32	-192.68	-2.60
Exposed bedrock	11	0.06	1.08	9.92	9.95	-1.05	-9.55
Mine Pits[(a)]	n/a	n/a	n/a	87.54	0.0	n/a	n/a
Other Disturbance[(b)]	n/a	n/a	n/a	965.48	0.0	n/a	n/a
Dewatered[(c)]	n/a	n/a	n/a	78.73	0.0	n/a	n/a
Flooded	n/a	n/a	n/a	104.18	22.94	n/a	n/a
Reclaimed	n/a	n/a	0	0	85.41	85.41	n/a
Non-reclaimed[(d)]	n/a	n/a	0	0	352.07	352.07	n/a
Total	**19,500**	**100**	**394.19**[(e)]	**19,500**	**19,500**	**0.0**	n/a

(a) Mine pits include Tuzo, Hearne and 5034.
(b) All disturbances, excluding the mine pits, dewatered and flooded areas.
(c) New land area resulting from dewatering of Kennady Lake.
(d) Non-reclaimed areas include the mine rock piles, Coarse PK Pile and the Fine PKC Facility.
(e) Terrain units only; excludes Lake area disturbances.
n/a = not applicable; ha = hectares; % = percent; LSA = Local Study Area.

The dewatering of Kennady Lake will directly affect the sediments currently occupying Kennady Lake. Based on the sampling program conducted as part of the permafrost study, the surficial sediments are generally less than 3 m deep and consist of a mixture of glacial till and recent lacustrine accumulations. These materials are finer textured than those of the surrounding area because of slope wash and surface runoff processes. It is anticipated, based on the proposed water management pond area, that 78.73 ha of subaquatic sediment will be exposed as a result of the dewatering (Table 11.7.I-15; Figure 11.7.I-5).

The water levels of Kennady Lake are scheduled to be re-established during closure. However, Lake A3 will remain elevated. The removal of on-land dykes for water management systems is expected to return inundated areas to baseline conditions (Figure 11.7.I-6). The resulting shoreline will be different than the pre-disturbed shoreline, mainly due to pit development. It is expected that a net loss of terrain will occur at the locations of pit development because the overall area and perimeter of the reclaimed lake will exceed the original lake margins.



LEGEND

- Proposed Winter Access Road
- Watercourse
- Waterbody
- Terrestrial Footprint
- Flooded Area
- De-watered Lake Bed
- Project Development Feature
- Local Study Area

Terrain Unit

- Bog
  Bog Dominated; peat plateau
  Includes Baseline Units: ***B; B-M/Ru; B-M/Ruh; B-Fv/Ri***
- Bog and Fen
  Bog and Fen Dominated; planar
  Includes Baseline Units: ***BN; BN-Fv/Ri; BN-M/Ru; BN-M/Ruh***
- Glaciofluvial
  Glaciofluvial; esker ridges
  Includes Baseline Units: ***FGr***
- Fluvial
  Fluvial veneer over Bedrock
  Includes Baseline Units: ***Fv/Ri***
- Moraine (Low Relief)
  Morainal veneer and blankets over Bedrock; undulating
  Includes Baseline Units: ***M/Ru; M/Ru-B; M/Ru-B-Fv/Ri; M/Ru-BN; M/Ru-N***
- Moraine (High Relief)
  Morainal veneer and blankets over Bedrock; undulating to hummocky
  Includes Baseline Units: ***M/Ruh; M/Ruh-B; M/Ruh-BN; M/Ruh-N; M/Ruh-R-B; M/Ruh-R; M/Ruhr-B***
- Fen
  Fen Dominated; planar
  Includes Baseline Units: ***N; N-Lv/Rd***
- Exposed Bedrock
  Bedrock; variable topography
  Includes Baseline Units: ***R***

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

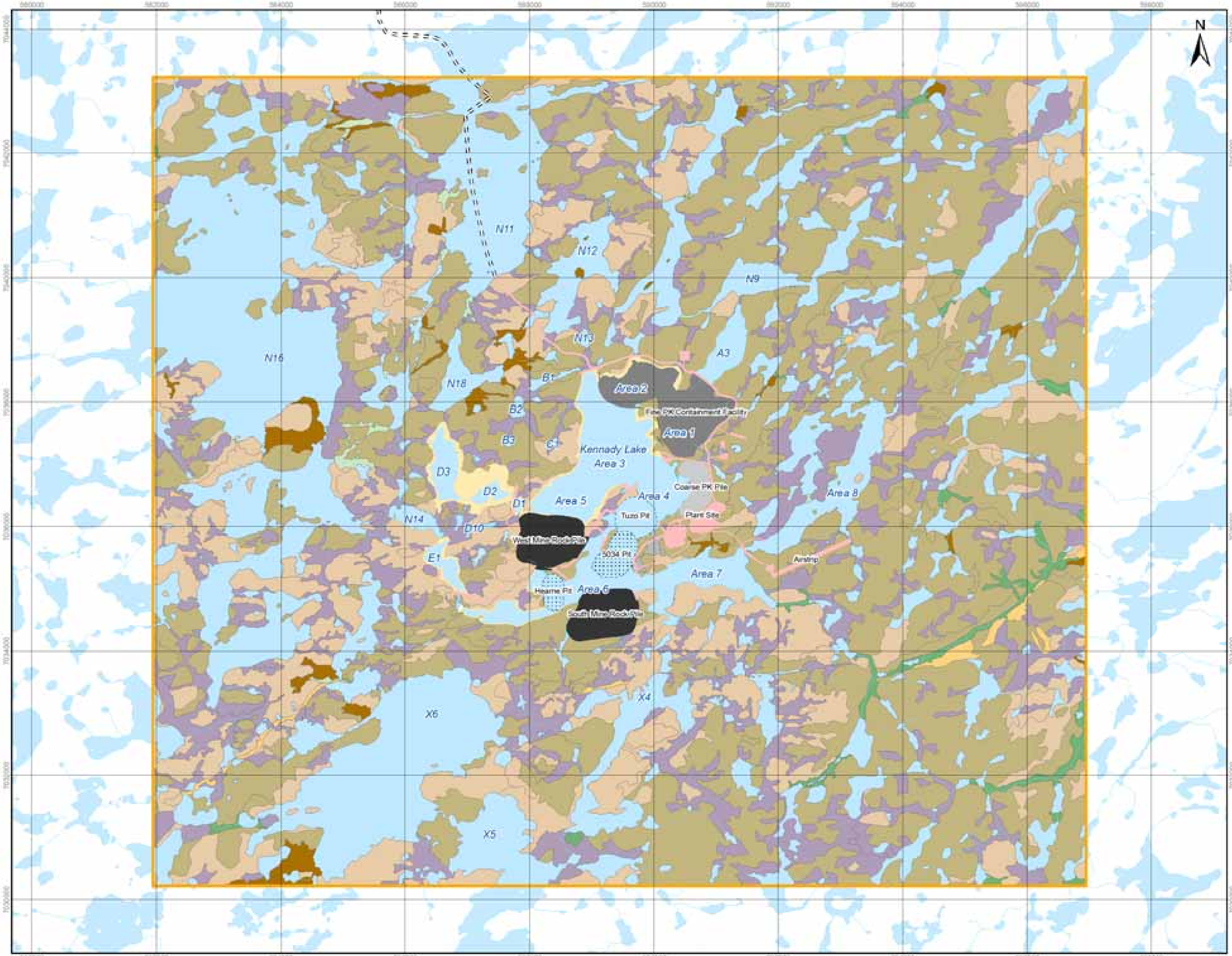
Terrain Distribution at Maximum Development of the Project

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:60,000 (1 0.5 0 1 Kilometers)	
FILE No: E-Soils-003-GIS	DATE: October 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 4
OFFICE: GOLD-SAS	DRAWN: MK CHECK: JV

DE BEERS CANADA

Figure 11.7.I-5

G:\2009\1365\09-1365-1004 De Beers Gahcho Kue EA Support\GIS\maps\05_terrain-geology-soils\EIA\E-Soils-003-GIS.mxd



LEGEND

- Proposed Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Closure Footprint

- Disturbance - Infrastructure (Reclaimed)
- Disturbance - Flooded Area
- Submerged Backfilled Mine Pit
- Submerged Mine Pit
- Waste Rock Covered Coarse PK
- Waste Rock Covered Fine PK/Coarse PK
- Waste Rock Pile

Terrain Unit

- Bog
  Bog Dominated; peat plateau.
  Includes Baseline Units: ***B; B-M/Ru; B-M/Ruh; B-Fv/Ri***
- Bog and Fen
  Bog and Fen Dominated; planar.
  Includes Baseline Units: ***BN; BN-Fv/Ri; BN-M/Ru; BN-M/Ruh***
- Glaciofluvial
  Glaciofluvial; esker ridges.
  Includes Baseline Units: ***FGr***
- Fluvial
  Fluvial veneer over Bedrock
  Includes Baseline Units: ***Fv/Ri***
- Moraine (Low Relief)
  Morainal veneer and blankets over Bedrock; undulating
  Includes Baseline Units: ***M/Ru; M/Ru-B; M/Ru-B-Fv/Ri; M/Ru-BN; M/Ru-N***
- Moraine (High Relief)
  Morainal veneer and blankets over Bedrock; undulating to hummocky
  Includes Baseline Units: ***M/Ruh; M/Ruh-B; M/Ruh-BN; M/Ruh-N; M/Ruh-R-B; M/Ruh-R; M/Ruhr-B***
- Fen
  Fen Dominated; planar.
  Includes Baseline Units: ***N; N-Lv/Rd***
- Exposed Bedrock
  Bedrock; variable topography
  Includes Baseline Units: ***R***

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Terrain Distribution After Closure

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:60,000 (1 0.5 0 1 Kilometers)	
FILE No: E-Soils-004-GIS	DATE: October 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 5
OFFICE: GOLD-SAS	DRAWN: ANK; CHECK: JV

De Beers Canada

Figure 11.7.I-6

A net loss of organic (i.e., peat) deposits is also expected as a result of Project development. These organic accumulations are important features in the landscape and are directly linked to the ecological and biological activity in the LSA. The effects of Project development on bog, fen, and bog/fen combinations will be 113.96 ha, with all of this parent material being removed. The net change in these materials is only 2.6% because of their widespread distribution within the LSA. The net effect of the Project on this parent material type will be negative. The material from organic deposits will be salvaged and used in reclamation to the extent practical (specified as an environmental design feature, Table 11.7.I-14).

The effect from the Project on exposed bedrock is estimated at a loss of 1.05 ha, or a net change of 9.55% of the original area. This change in distribution is calculated from baseline mapping, which identified the proposed Project site as one of very few exposed bedrock units in the LSA. However, small bedrock outcrops in association with other surficial materials also occur commonly. The Mu/Ruh-B-R (168 ha) and the M/Ruh-R (117 ha) terrain units (Section 11.7.I.2.2.4, Table 11.7.I-6) are estimated to consist of about 70 ha of the R (exposed bedrock) component in the LSA. Small inclusions of bedrock are also characteristic of various other terrain map units, and the 1.08 ha change in this unit is considered to represent less than 10% of this unit. No esker material will be used for construction of the Project.

11.7.I.4.2 CHANGES TO SOIL QUANTITY

11.7.I.4.2.1 Methods

Soil loss is discussed qualitatively, based on general soil conservation and reclamation practices. The extent of losses of soils by burial and erosion is determined by the success of preventative practices.

11.7.I.4.2.2 Results

11.7.I.4.2.2.1 Construction and Operation

During the processes of soil salvage and stockpiling, and storage of topsoils and subsoils over a number of years, the quantity of soils available for site reclamation may be reduced due to wind and water erosion. The potential and extent of wind and water erosion beyond the Project footprint is not expected to change because there will be no physical disturbance of the native soils. Erosion is a concern within the Project site at the time of soil salvage and stockpiling due to removal of the surface protective vegetation. Also, stockpiles maintained through the operation phase may be susceptible to erosion due to factors such as steep slopes and surface desiccation.

The effect of water erosion on soil associations within the Project site is determined by the potential of precipitation and surface water to cause erosion of exposed soils. Most of the LSA has been rated as low in terms of potential for surface water erosion, although some localized areas of medium and high susceptibility occur. Some land areas have mixed erodibility ratings. For example, areas of low susceptibility with a component of medium or high susceptibility are common. This diversity is generally associated with hummocky topography where some slopes range from 6 to 15% (medium erosion susceptibility) and more than 15% (high susceptibility).

The effect of wind erosion on soils within the Project site is determined by the removal of exposed surface material by wind processes. Most of the soils are rated as medium in terms of the potential for surface wind erosion. This rating represents the maximum effect potential based on the disturbance of the soil profile and no mitigation to control soil loss. Most of the upland soils are coarse textured and are potentially eroded by wind due to absence of aggregation among the sand particles. Thus, soils will be most susceptible to wind erosion at the time of salvage and during storage. The lowland soil associations containing organic sediments also are potentially sensitive under conditions in which they are disturbed and allowed to desiccate.

Because erosion is a concern mainly with respect to disturbed soils, the effect will be confined to the Project footprint. Areas include soil stockpiles, sloped areas such as road ditches and backslopes, and any areas with a fine to medium sand surface. Various practices are available for control of wind and water erosion. Specific design practices and procedures for minimizing soil loss are presented in Table 11.7.I-14. These environmental design features range from maintaining low profiles on soil stockpiles, to use of erosion control materials such as vegetation and surface mats. Given the availability of these practices, along with the development and implementation of erosion and sedimentation control structures, the potential loss of soil materials from wind and water is expected to be within the range of baseline conditions.

The expected effect of development also considers the dewatering of Kennady Lake in the analysis of wind erosion susceptibility. Loose-textured subaquatic sediment could be susceptible to wind erosion. Anecdotal evidence from the Diavik Diamond Mine suggests that the lakebed will develop a hard, caked or crusted surface upon desiccation, and wind erosion is predicted to not exceed baseline conditions.

11.7.I.4.2.2.2 Residual Disturbance

The establishment of the mine rock piles, Coarse PK Pile and Fine PKC Facility will result in a net increase in human-produced materials in the LSA. The non-reclaimed portion of the Project footprint is anticipated to be 352.1 ha. The largest portion of this area occurs on upland, while a small portion occurs in an area that was previously part of Kennady Lake. The Project Description indicates that two mine rock piles (South and West) are planned with the backfilling of additional mine rock into 5034 Pit (and potentially, Hearne Pit).

11.7.I.4.3 CHANGES TO SOIL QUALITY

11.7.I.4.3.1 Methods

The effects on soil quality by soil admixing, soil compaction, and storage processes are examined qualitatively, and are based on general soil conservation and reclamation practices. Some information is based on studies reported in the literature.

Acid deposition effects were assessed by reference to the soil map and to acidification sensitivity of soils in the LSA (Section 11.7.I.2.2.6.4). Soils were assigned to one of three sensitivity classes: low, moderate or sensitive. The potential effects of acid deposition were then addressed in terms of whether or not emissions would result in deposition levels that exceed critical loads of acidity.

Critical loads were assigned to soils as follows: sensitive – 0.25 kiloequivalents hydrogen per hectare per year (keq H^+/ha/y); moderate sensitivity – 0.5 keq H^+/ha/y; and low sensitivity – 1.0 keq H^+/ha/y. These are based on recommendations for management of acid deposition on soils in Alberta by the Clean Air Strategic Alliance (CASA) and Alberta Environment (AENV) (1999).

This sensitivity class and critical load relationship was adopted because it is the only one developed in Canada, and is appropriate for soils in boreal regions. Isopleths of potential acid input (PAI) (Section 11.4) corresponding to the critical loads for the three soil sensitivity classes were derived by modelling methods for the Project during the operations phase. Using GIS methods, the isopleths were overlain on the soil sensitivity map of the LSA, and areas of exceedance of soil critical loads were calculated.

11.7.I.4.3.2 Results

11.7.I.4.3.2.1 Changes to Soil Physical, Biological, and Chemical Properties

Factors that can affect soil quality as a consequence of the salvaging, stockpiling and storage process include admixing of topsoil with subsoil due to overstripping, compaction, erosion, and physical-chemical changes during storage.

11.7.I.4.3.2.1.1 Soil Admixing

Admixing of surface soil and subsoil components during soil lift and salvage operations may cause soil profile (particularly in the A horizon) integrity to be compromised, especially if clear distinctions cannot be maintained between the topsoil and subsoil. This is often the case when topsoil thickness is highly irregular over the area of the lift. The depth of the surface layer that will be salvaged from mineral soils will vary according to landscape position and soil drainage conditions.

Turbic Cryosols occur commonly in the LSA as inclusions within the upland soil types such as the Wolverine association. These soils are characterized by mixing of the topsoil into the subsoil below, and they are already admixed in their natural condition. The turbic soil condition was observed to depths of 30 to 40 cm in some of the soil profiles examined in the field, although it extended to greater depths at some sites.

The primary concern of soil profile admixing are changes in texture and structure, which can directly affect soil physical and chemical characteristics. Admixing may occur where topsoil (i.e., A horizon) thickness is less than the average depth specified for the soil type, such that subsoil components (e.g., B horizon) would then be incorporated into the surface lift. This may lead to textural discontinuities, dilution of nutrient status, and reduction in the content of organic matter in A horizon materials.

Changes in soil texture could arise from admixing, particularly in those soils with large textural differences between A and B horizons. However, in the LSA, differences in texture among the soil horizons do not occur, except in some localities. Differences in texture between soil A and B horizons typically have not been noted within the Project footprint. Consequently, the main concern regarding admixing is the dilution of nutrients and organic matter of the topsoil.

In some cases, the incorporation of clayey textured subsoil with silty or sandy topsoils may serve to improve soil quality. Incorporating a clayey material can contribute to particle aggregation and improved water holding capacity, thereby reducing susceptibility to wind and water erosion. Admixing of peat materials with mineral soil material that is deficient in organic matter may also result in a positive change to soil quality. During soil salvage, peat materials can be admixed with topsoil materials, with a net positive change due to increased organic matter and nutrient content. Overall, the admixing of soil is likely to have little influence on soil quantity.

11.7.I.4.3.2.2 Soil Compaction

Compaction of soil influences drainage, structure, porosity, aeration, and potential susceptibility to erosion, all of which ultimately affect soil quality. Compaction by heavy equipment or by repeated passes of lighter equipment compresses the soil mass and breaks down soil aggregates, thereby decreasing macro-pore volume and increasing the volume proportion of solids.

The susceptibility of soils to compaction depends on several factors including soil texture, organic matter content, and moisture status. In general, the higher the clay content, the higher the susceptibility to compaction, especially when soils are moist. Conversely, the higher the organic matter content, the less susceptible soils are to permanent compaction. Variability in soil particle size tends to offset compaction, such that soils with homogenous texture (i.e., clay, silt) are more prone to compaction than are soils of mixed particle size (Pritchett and Fisher 1987).

Soils developed on coarse to moderately coarse-textured glacial till, commonly overlying bedrock at shallow depths (less than 1 m), characterize the Project site. Sandy soils are less prone to compaction than silty or clay soils, and soils with a high content of coarse fragments are less susceptible to compaction than stone-free soils (Archibald et al. 1997). Conversely, where compaction has occurred, these soils are relatively easily de-compacted. Small areas prone to compaction are limited to low-lying, poorly drained areas where the clay content of soils might be slightly higher than in upland soils. Compaction is therefore considered to have little influence on soil quality and suitability for reclamation.

11.7.I.4.3.2.3 Erosion

Soil quality can be affected if erosion preferentially removes finer particles and organic materials from bulk soil. Removal of organic particles and clays from soil can reduce its overall nutrient content and water holding capacity. This may be a concern mainly in the case of soil stockpiles. Appropriate mitigation such as providing vegetation cover or other means such as erosion control mats can reduce this effect.

During the processes of soil salvage and stockpiling, and storage of topsoils and subsoils over a number of years, the quality of soils available for site reclamation may be reduced due to wind and water erosion. The potential and extent of wind and water erosion beyond the Project footprint is not expected to change because there will be no physical disturbance of the native soils. Erosion is a concern within the Project site at the time of soil salvage and stockpiling, due to removal of the surface protective vegetation. Also, stockpiles maintained through the operation phase may be susceptible to erosion due to factors such as steep slopes and surface desiccation.

The effect of water erosion on soil associations within the Project site is determined by the potential of precipitation and surface water to cause erosion of exposed soils. Most of the LSA has been rated as low in terms of potential for surface water erosion. The effect of wind erosion on soils within the Project site is determined by the removal of exposed surface material by wind processes. Most of the soils are rated as medium in terms of the potential for surface wind erosion. This rating represents the maximum effect potential based on the disturbance of the soil profile and no mitigation to control soil loss. Soils will be most susceptible to wind erosion at the time of salvage and during storage.

The effect on soil quality from erosion will be confined to the Project footprint. Areas of particular concern are soil stockpiles, sloped areas such as road ditches and backslopes. Environmental design features (e.g., rock armouring, working in wet conditions in areas with fine textured soil) along with the development and implementation of an erosion and sedimentation control plan, are expected to result in limited changes to soil quality.

11.7.I.4.3.2.4 Soil Reclamation Suitability

Soil reclamation suitability is discussed as an integrator of various soil quality parameters. Reclamation suitability is defined by a set of soil quality parameters that define a soil’s capability to support ecosystems. Criteria to determine soil suitability for reclamation, developed in Alberta (Alberta Soils Advisory Committee 1987), were applied to the baseline soil data. The criteria were developed for the prairie and forest regions. These were considered generally applicable to the LSA. The capability ratings are presented in the existing soil conditions section (Section 11.7.I.2.2.6.5).

According to the criteria for forest soils, the upper lift (UL) of soils should consist of a mixture of the organic (litter, fibric, humic [LFH]) and A horizons of the soils, and a portion of the B horizon to a depth of 30 cm, depending on site-specific conditions. Salvage of a lower lift (LL) may be carried out to develop adequate soil depth for rooting of vegetation.

Based on the criteria for UL (topsoil), the topsoils of the mineral soil associations in the LSA generally have poor suitability for reclamation. The limiting factor in topsoil suitability for reclamation is the coarse texture of the mineral soils in the LSA. This coarse-textured material is associated with low pH, low nutrient status, and low moisture holding capacity. The moderate to high coarse fragment content of the soils also limits suitability for reclamation.

The Organic soil associations, including deep Organics and Organic Cryosols, are not rated for reclamation suitability but rather are classed simply as an organic category. This distinguishes the Organic soils from the poor suitability of the mineral associations. Organic materials can be a valued material in reclamation because of their nutrient content and ability to improve the soil moisture holding capacity of the reclaimed mineral soils.

Based on the criteria for LL (subsoil) reclamation suitability, subsoils were predominantly categorized as poor to unsuitable for reclamation. This rating is based primarily on the high coarse fragment content of the soils developed on the glacial till and the presence of bedrock close to the soil surface. These coarse-textured subsoils also have low pH values, low nutrient status, and limited water holding capacity. All of these factors contribute to the poor reclamation suitability of the soil associations in the LSA.

The reclamation suitability ratings of soils in the LSA and the Project footprint are presented in Table 11.7.I-18. The ratings show that the soils to be salvaged in the Project footprint area have predominantly poor upper lift and lower lift suitability, and some soils are rated as unsuitable. It also shows that there is about 90 ha of peat that could be salvaged (to help with reclamation and revegetation), with additional areas in mixed Organic (poor) and poor (Organic) suitability categories (Table 11.7.I-16). This peat material will be useful as an amendment for reclamation of the soils.

Table 11.7.I-16 Reclamation Suitability Ratings of Soils in the Local Study Area

Reclamation Suitability Upper Lift	Area (ha)	% of LSA	Disturbed Area (ha)	Disturbed Area (%)	Reclamation Suitability Lower Lift	Area (ha)	% of LSA	Disturbed Area (ha)	Disturbed Area (%)
Organic	2,348	12.0	89.51	22.7	Organic	-	-	-	-
Organic (Poor)	599	3.1	24.45	6.2	Organic (Poor)	-	-	-	-
Poor	697	3.6	0.73	0.2	Poor	2,847	14.6	113.89	28.9
Poor (Organic)	9,625	49.4	277.84	70.5	Poor (Organic)	-	-	-	-
Poor (Unsuitable)	452	2.3	0.58	0.1	Poor (Unsuitable)	10,707	54.9	279.22	70.8
Unsuitable	11	<0.1	1.08	0.3	Unsuitable	178	0.9	1.08	0.3
Water	5,768	29.6	0.0	0	Water	5,768	29.6	0.0	0.0
Total	**19,500**	**100.0**	**394.19**	**100.0**	**Total**	**19,500**	**100.0**	**394.19**	**100.0**

Note: - implies not present in Lower Lift soils.

ha = hectares; % = percent; LSA = Local Study Area.

Given the general poor quality of existing soils, soil materials in the LSA cannot diminish greatly in quality. The change to soil quality from admixing of topsoil with subsoil, compaction, erosion, and storage is predicted to be within the range of baseline conditions. Soil quality can be improved to some extent by addition of organic material from salvaged peat.

11.7.I.4.3.2.5 Dust Deposition

Accumulation of dust (i.e., total suspended particulate [TSP] deposition) and concentrations of air emissions produced from the Project may result in changes to the chemical content of soil within the LSA. Changes to the chemical content of soil can alter soil pH and affect the soils ability to support vegetation. Changes to soil flora influences soil organic matter decomposition and nutrient cycling. The change to the chemical content of the soils is applicable only to undisturbed soils, and considers only the rooting zone. Therefore, disturbed soil areas from the Project footprint were excluded from the calculations.

Air quality modelling (Section 11.4, Appendix 11.4.III) was completed to predict the maximum spatial extent of dust deposition and air emissions from the Project. Air quality modeling was completed for the baseline case, the construction case, and the application case. The baseline case includes background concentrations from SO_2, NO_2, and PM, as well as background PAI depositions from the regional modelling network. The baseline case also includes air emissions from the Snap Lake Mine.

As per the Terms of Reference, a construction case was modeled for the Project. Typically, the construction phase will have lower emissions that the operations phase of a project. As expected, the construction case emissions are much lower that the application case emissions, and therefore, result in lower predictions than those for the application case. The assessment of the application case is anticipated to capture the maximum effects resulting from the Project.

Sources of dust deposition and air emissions modelled in the application case include blasting activities, haul roads, the processing plant, activities at the mine pits and other ancillary facilities (e.g., mine rock disposal areas, PK disposal areas), and vehicle traffic along the Winter Access Road. Environmental design features have been incorporated into the Project to reduce potential effects from dust deposition. For example, the watering of roads, airstrip, and laydown areas will facilitate dust suppression. In addition, De Beers will review power and heat use at the mine to reduce energy use. Although these environmental design features will be implemented to reduce dust deposition and air emissions, assumptions incorporated into the model (e.g., deposition velocity, and particle size) are expected to contribute to conservative estimates of emission concentrations and deposition rates (Section 11.4).

The results of the air quality modelling predicted the maximum annual dust deposition resulting from the Project is 6,292 kg/ha/y within the Project development area boundary and 5,520 kg/ha/y outside of the Project development area boundary. The maximum deposition that occurs is mostly associated with the mine pits and haul roads. The maximum deposition rate for dust is predicted to occur within 100 m of the Project footprint. (Section 11.4). The strongest effects from dust are generally confined to the immediate area adjacent to the dust source, such as roads (Walker and Everett 1987). Walker and Everett (1987) and Everett (1980) reported that effects were confined to a 50-m buffer on either side of a road. Moreover, Meininger and Spatt (1988) found that most of effects occurred within 5 to 50 m of a road, with less obvious effects observed between 50 m and 500 m from a road.

The largest component of dust emissions is expected to be mine transport related (Section 11.4). The elemental profile of dust was therefore estimated by assuming that the dust would originate from the various rock types in the Project site. The elemental concentrations obtained from the geochemical investigations (Section 11.5) are presented in Table 11.7.I-17, along with a calculation of the average concentrations among the rock types. This was a simple arithmetic average obtained without weighting of proportions of rock types.

The total deposition of elements was determined using a worst case emission scenario during which all three mining pits will be in operation. The total dust amount was then added to the total amounts of element concentrations in surface layers of a soil sampled during baseline studies in the LSA

(Table 11.7.I-18). This soil was selected from 8 sites that were sampled because it had the thinnest surface LFH (duff) layer, and would show the highest increase in concentration upon input of dust.

To convert the concentration of elements in the dust to concentration in litter material, the mass of litter was calculated by assuming a dry bulk density of 0.1 mega grams per cubic metre (Mg/m^3). The concentrations of elements in the baseline LFH soil layer and in the layer after deposition of elemental addition were compared with CCME (2007) soil quality guidelines.

Table 11.7.I-18 shows the CCME guidelines for the elements (guidelines do not exist for some elements). Although there is an addition to many of the elements, the soil concentrations do not exceed the guidelines for any of the elements during periods of greatest deposition.

A number of assumptions were made to estimate a worst-case scenario of dust deposition effects. The main assumptions entailed consistent composition of dust as indicated above, uniformity of dust deposition, and accumulation of all dust when all three mining pits are in production. In addition, these calculations estimate a worst-case scenario because accumulation is assumed to occur in a thin duff layer. Concentrations would be somewhat lower in thicker layers, or in layers with higher bulk density. Consequently, although elemental addition to soil is likely, the magnitude is such that CCME guidelines would not be exceeded.

Table 11.7.I-17 Rock Elemental Composition by Lithology at the Project Site

Element	Altered Granite	Gneissic Granite	Granite	Hypabyssal Kimberlite	Hypabyssal Transitional Kimberlite	Kimberlite	Tuffisitic Kimberlite	Tuffisitic Kimberlite Breccia	Tuffisitic Transitional Kimberlite	Average
(%)										
Aluminum	1.39	0.73	0.65	1.57	1.61	1.76	2.64	2.13	1.96	1.60
Calcium	0.59	0.23	0.26	1.89	3.19	1.48	0.66	0.97	0.56	1.09
Iron	2.4	1.4	1.4	4.5	5.3	3.7	3.1	2.8	3.5	3.12
Potassium	0.743	0.385	0.298	1.09	1.44	0.765	0.587	0.406	0.49	0.69
Magnesium	4.2	0.7	0.7	14.7	14.3	11.7	11.2	8.1	12.9	8.7
Phosphorous	0.101	0.053	0.05	0.133	0.177	0.112	0.073	0.108	0.09	0.10
Sodium	0.048	0.022	0.023	0.174	0.243	0.181	0.079	0.078	0.06	0.10
Titanium	0.1	0.094	0.075	0.085	0.096	0.076	0.054	0.036	0.05	0.07
(mg/kg)										
Silver	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	1.5	0.4	0.9	2.3	2	1.6	0.6	1	1.7	1.3
Gold	0.55	0.61	0.77	1.26	0.98	0.83	0.82	1.17	1.27	0.92
Boron	12	5	4.9	167.3	154	104.9	29.9	14.1	70.7	62.5
Barium	405	101	60	795	1072	628	366	228	452	456
Bismuth	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	29.5	6.3	5.1	70.3	78.5	55.2	44.2	36.5	51.5	41.9
Chromium	115	50	64	406	413	285	257	145	319	228
Copper	17.83	6.68	9.15	48.52	56.93	38.03	34.98	22.11	38.33	30.28
Gallium	6.3	4.3	5.1	4.8	5	5.8	7.7	7.7	6.7	5.9
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
Lanthanum	47	30	45	44	32	49	61	60	67	48
Manganese	329	223	192	883	1157	621	315	184	456	484
Molybdenum	1.6	3.3	4.73	0.44	0.30	0.68	0.14	1.14	0.08	1.38
Nickel	318	13.3	16	1113.6	1282.08	885.9	693.7	581.6	787.4	632.4
Lead	1.87	3.43	11.85	6.32	10.65	6.64	2.11	6.11	0.9	5.54
Antimony	<0.1	0.17	0.76	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	0.35

Table 11.7.I-17 Rock Elemental Composition by Lithology at the Project Site (continued)

Element	Altered Granite	Gneissic Granite	Granite	Hypabyssal Kimberlite	Hypabyssal Transitional Kimberlite	Kimberlite	Tuffisitic Kimberlite	Tuffisitic Kimberlite Breccia	Tuffisitic Transitional Kimberlite	Average
Scandium	3.33	1.77	1.7	7.03	8.63	5.35	4.86	3.75	5.8	4.69
Selenium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Strontium	110.7	11	12.4	353.2	546.5	429.4	227.8	178.8	308.7	242.1
Thorium	8.1	7.7	20.2	4.6	2.9	8.4	11	13	8.6	9.4
Thallium	0.17	0.14	0.16	0.16	0.14	0.13	0.06	0.09	0.05	0.12
Uranium	1	0.53	1.1	1.15	1.48	1.12	1.12	1.06	1.2	1.08
Vanadium	47	23	18	51	65	45	36	36	41	40
Tungsten	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	44	50	56	47	49	37	27	19	25	39

% = percent; mg/kg = milligrams per kilogram; < = less than.

Table 11.7.I-18 Elemental Concentration Change in a Soil Duff Layer Due to Dust Deposition

Element	Guideline[a] (mg/kg)	Baseline Concentration in Litter Layer[b] (mg/kg)	Deposition in Litter Layer (mg/kg)	Concentration in Soil after Deposition (mg/kg)[c]
Aluminum	-	8,760	322.9	9,082.9
Antimony	20[d]	ND	0.01	ND
Arsenic	12	1.5	0.03	1.53
Barium	500	45.0	6.61	51.61
Bismuth	-	ND	0.00	ND
Boron	-	ND	0.26	ND
Cadmium	1.4	0.20	0.4	0.6
Chromium	64	19.0	2.75	21.75
Cobalt	50[d]	3.7	0.55	4.25
Copper	63	16.0	0.46	16.46
Gallium	-	ND	0.25	ND
Gold	-	ND	0.02	ND
Iron	-	7,570	605.74	8,175.74
Lanthanum	-	ND	1.42	ND
Lead	140	1.0	0.26	1.26
Manganese	-	61.7	8.73	70.43
Mercury	6.6	0.25	0.02	0.27
Molybdenum	10[d]	0.50	0.11	0.66
Nickel	50	8.7	4.12	12.82
Scandium	-	ND	0.08	ND
Selenium	1	0.25	0.02	0.27
Silver	20[d]	ND	0.07	ND
Vanadium	130	16.4	1.02	17.42
Zinc	200	16.2	0.86	17.06
Uranium	-	ND	0.03	ND
Other Elements				
Calcium	-	772	126.57	198.57
Magnesium	-	3,210	662.2	3,872.2
Phosphorus	-	301	23.77	324.77
Potassium	-	1,390	165.7	1,555.7
Sodium	-	70	10.91	80.91
Titanium	-	ND	31.15	ND

Note: ND = not determined; some elements were not determined in the soil samples.
(a) CCME Guideline for Residential/Parkland Soils (CCME 2007).
(b) Surface 4 cm litter layer in a Wolverine Soil sample site; pH 4.1.
(c) Calculation: [deposition mg/ha / soil weight (100 kg/m^3, assuming bulk density of 0.1) * volume (400 m^3/ha)].
(d) No guideline for soil. Value indicated is the remediation guideline for soil.
mg/kg = milligrams per kilogram

11.7.I.4.3.2.6 Acid Deposition on Soils

Nitrogen oxides (NO_X) and sulphur dioxide (SO_2) are acidifying compounds and can adversely affect soil quality. Possible effects of acidic inputs to soils include changes in chemical properties such as pH, nutrient levels, and concentrations of soluble aluminum and other elements in soils. The lowering of pH and increase in soluble aluminum beyond threshold levels are associated with plant growth effects due to toxicity or to inability to take up plant nutrients.

The possible effect of acidic deposition on soils was assessed using the concept of soil acidification sensitivity, which is defined as the potential for soil pH conditions to become reduced as a result of environmental inputs mainly associated with atmospheric deposition. This rating is based on the background atmospheric acid conditions and an analysis of the potential change as a result of the Project.

All soils in the LSA were categorized as sensitive or moderately sensitive to soil acidification (Section 11.7.I.2.2.6.4), using criteria developed for western and northern Canada (Wiens et al. 1987). The sensitive class pertains mainly to upland soils, especially the Wolverine Lake Association, which is characterized by low buffering capacity due to low clay content and low cation exchange capacity. Organic and Organic Cryosol soils were categorized as moderately sensitive. No soil associations within the LSA were assigned a low sensitivity rating.

The background annual soil acid input is 0.10 keq H^+/ha/y, which is well below the critical load for sensitive soils. At PAI levels below 0.25 keq H^+/ha/y, it is predicted that sensitive soils would likely not be affected by acid deposition relative to baseline conditions.

Soils that are sensitive or moderately sensitive to acid deposition occur in areas where the PAI exceeds 0.25 keq H^+/ha/y, while soils of low sensitivity do not occur. Sensitive soils that occur where the PAI is greater than 0.25 keq H^+/ha/y occupy an area of 13.1 ha (Table 11.7.I-19). The Sensitive (Moderate) category consists of intermixed soils falling into both these sensitivity classes, and these occupy an area of 187.2 ha in this zone. Together, these two most sensitive categories occupy 200 ha (about 1%) of the LSA. That is, 200 ha of sensitive soils receive PAI greater than their critical load. A small area of soils adjacent to the Project site is in a zone with PAI greater than 0.5 keq H^+/ha/y. In this zone, Moderate and mixed Moderate (Sensitive) soils can be affected by acid deposition (in addition to sensitive soils), and these occupy 9 ha (0.05%) of the LSA. In total, the critical load of acid deposition on soils is exceeded in 209 ha of the LSA.

Table 11.7.I-19 Extent of Local Study Area Soils within Potential Acid Input Ranges

Acidification Sensitivity Rating	PAI Range (keq H+/ha/y)	Area in LSA (ha)	Proportion of LSA (%)
Sensitive	0.25 to 0.5	4.97	0.03
	0.5 to 1.0	7.81	0.04
	>1.0	0.35	<0.01
Total Area		**13.13**	**0.07**
Sensitive (Moderate)	0.25 to 0.5	149.78	0.77
	0.5 to 1.0	37.22	0.19
	>1.0	0.23	<0.01
Total Area		**187.23**	**0.96**
Moderate (Sensitive)	0.5 to 1.0	6.95	0.04
	>1.0	0.0	0.0
Total Area		**6.95**	**0.04**
Moderate	0.5 to 1.0	1.56	0.01
	>1.0	0.0	0.0
Total Area		**1.56**	**0.01**
Total		**208.87**	**1.07**

ha = hectare; > = greater than; % = percent; LSA = Local Study Area; keg H^+/ha/y = kiloequivalents hydrogen per hectare per year; PAI = potential acid input.

While critical load exceedances were indicated by the PAI modelling and soil sensitivity analysis, acidification is a concern only if the deposition occurs over a number of years. Studies of critical loads of acid deposition on soils have been carried out in Alberta using a dynamic modelling approach (Abboud et al. 2002). Small changes in soil chemistry, such as pH reduction, could not be detected in sensitive soils at their critical load level of (0.25 keq H^+/ha/y). Based on this study, it is not likely that soil acidification effects would be observed within the span of the Project during which acidic and acid forming substances will be emitted (about 11 years).

11.7.I.4.4 CHANGES TO SOIL DISTRIBUTION

Site clearing and construction of the Project, particularly through the process of soil stripping, will result in changes to soil distribution. Soil distribution refers to two aspects of soils, namely the types of soil cover that will be affected, and the area or extent of the change. Soil removal will occur mainly during the construction phase of the Project, and to a small extent during the operational phase.

11.7.I.4.4.1 Methods

The effects of the Project on the soil distribution are partly presented quantitatively, based on GIS analysis of areas of different soil types disturbed by the Project. The soil map was overlain by the Project footprint to calculate the areas of different soil types affected by the Project. Some components are discussed qualitatively because some effects analyses are based only on a sensitivity rating.

11.7.I.4.4.2 Results

The maximum effect from the Project on soil distribution is presented in Table 11.7.I-20 and Figure 11.7.I-7. This table presents the expected effects during the active phases of construction and operation, as well as a summary of the net change in each major group of soil associations following closure. The total area of disturbed upland soils at closure is 352.1 ha.

The effect of development on the local soil associations is variable, but most of the associations within the LSA will be affected to some extent. The distribution of soils during the operations phase is shown in Figure 11.7.I-7, and soil associations following closure are shown in Figure 11.7.I-8.

Similar to the effect on terrain distribution, the greatest effect on soil associations will occur in the Wolverine Lake Association. This soil forms on glacial till parent material and comprises the majority of the soils on the upland sites. The Project will remove 158.1 ha of the Wolverine Lake Association, representing a net loss of 2.17% of this unit.

The loss of complex soil associations (areas with a mix of more than one soil association) will also occur as a result of the Project. Those soils associated with complex till (Wolverine Lake soils) and other soil materials will have a 121.05 ha loss, equivalent to a net change of 3.8% of the baseline area. The loss of soil associations related to bog and fen parent materials (Sled Lake/Dragon Lake Associations) is expected to be 113.9 ha, which represents a net loss of 3.87% of the baseline area.

Table 11.7.I-20 Summary of Operations and Closure Effects on Soil Associations in the Local Study Area

Soil Unit	Baseline		Area Affected by Project Footprint		Closure		
	(ha)	(%) of LSA	(ha)	Area at Maximum Disturbance (ha)	Area at Closure (ha)	Closure Net Change (ha)	Closure Net Change (% Unit)
Lake	5,768	29.58	841.74	4,926.26	5,602.32	-165.68	-2.87
Dragon Lake Association	118	0.60	21.48	96.52	116.12	-1.88	-1.59
Goodspeed Lake Association	168	0.86	0.0	168.00	168	0.0	0.0
Hoarfrost Lake Association	65	0.33	0.0	65.00	65	0.0	0.0
Sled Lake Association	505	2.59	22.95	482.05	490.03	-14.97	-2.96
Sled Lake/Dragon Lake Co-dominant	2,311	11.85	69.5	2,241.50	2,250.73	-60.27	-2.61
Sled Lake/Goodspeed Lake Co-dominant	12	0.06	0.03	11.97	11.97	-0.03	-0.25
Wolverine Lake Association	7,277	37.32	158.1	7,118.90	7,156.50	-120.50	-1.66
Wolverine Lake/Dragon Lake Co-dominant	61	0.32	0.0	61.00	61	0.0	0.0
Wolverine Lake/Bedrock Co-dominant	39	0.20	0.0	39.00	39	0.0	0.0
Wolverine Lake/Sled Lake Co-dominant	3,165	16.23	121.05	3,043.95	3,068.42	-96.58	-3.05
Exposed bedrock	11	0.06	1.08	9.92	9.95	-1.05	-9.55
Mining pits[(a)]	n/a	n/a	n/a	87.54	0.0	n/a	n/a
Other Disturbances [(b)]	n/a	n/a	n/a	965.48	0.0	n/a	n/a
Dewatered[(c)]	n/a	n/a	n/a	78.73	0.0	n/a	n/a
Flooded	n/a	n/a	n/a	104.18	22.94	n/a	n/a
Reclaimed	n/a	n/a	n/a	n/a	85.95	85.95	n/a
Non-reclaimed[(d)]	n/a	n/a	n/a	n/a	352.07	352.07	n/a
Total	**19,500**	**100**	**394.19[(e)]**	**19,500**	**19,500**	**0.0**	**n/a**

(a) Mine pits include Tuzo, Hearne and 5034.

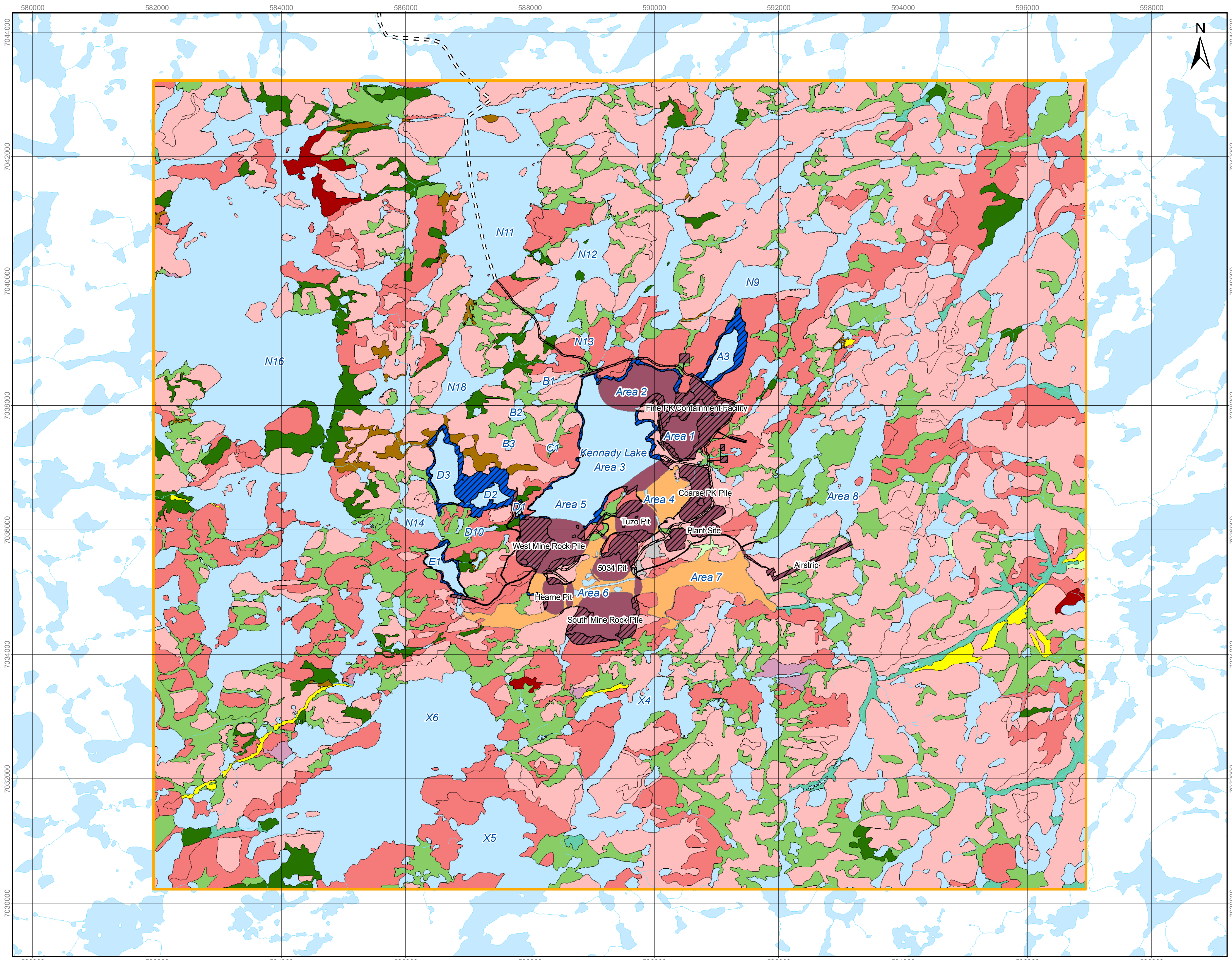
(b) All disturbances, excluding the mine pits, dewatered and flooded areas.

(c) New land area resulting from Dewatering of Kennady lake.

(d) Non-reclaimed areas include the mine rock piles, Coarse PK Pile and Fine PKC Facility.

(e) Terrain units only; excludes ‘Lake’ area disturbances.

n/a = not applicable; ha = hectares; % = percent; LSA = Local Study Area.



LEGEND

- Proposed Winter Access Road
- Watercourse
- Waterbody
- Terrestrial Footprint
- Flooded Area
- De-watered Lake Bed
- Project Development Feature
- Local Study Area

Soil Unit

- Dragon Lake Association
  *Includes Baseline Units: **D1; D2; D3; D4**.*
- Goodspeed Lake Association
  *Includes Baseline Units: **G1**.*
- Hoarfrost River Association
  *Includes Baseline Units: **H1**.*
- Exposed Bedrock
  *Includes Baseline Units: **R**.*
- Sled Lake Association
  *Includes Baseline Units: **S1; S2; S2u; S3; S3u; S4i; S5**.*
- Sled Lake/Dragon Lake Co-dominant
  *Includes Baseline Units: **SD1; SD2; SD2u; SD4**.*
- Sled Lake/Goodspeed Lake Co-dominant
  *Includes Baseline Units: **SG1**.*
- Wolverine Lake Association
  *Includes Baseline Units: **W1; W1u; W2; W2u/r; W3; W4U; W5**.*
- Wolverine Lake/Dragon Lake Co-dominant
  *Includes Baseline Units: **WD1; WD1u**.*
- Wolverine Lake/Bedrock Co-dominant
  *Includes Baseline Units: **WR1**.*
- Wolverine Lake/Sled Lake Co-dominant
  *Includes Baseline Units: **WS1; WS1u; WS2; WS2u; WS3; WS4ui**.*

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Soil Distribution at Maximum Development of the Project

PROJECTION: UTM Zone 12
DATUM: NAD83
Scale: 1:60,000
1 0.5 0 1
Kilometers

DE BEERS CANADA

FILE No: E-Soils-006-GIS
DATE: October 20, 2010
JOB NO: 09-1365-1004
REVISION NO: 4
OFFICE: GOLD-SAS
DRAWN: ANK
CHECK: JV

Figure 11.7.I-7

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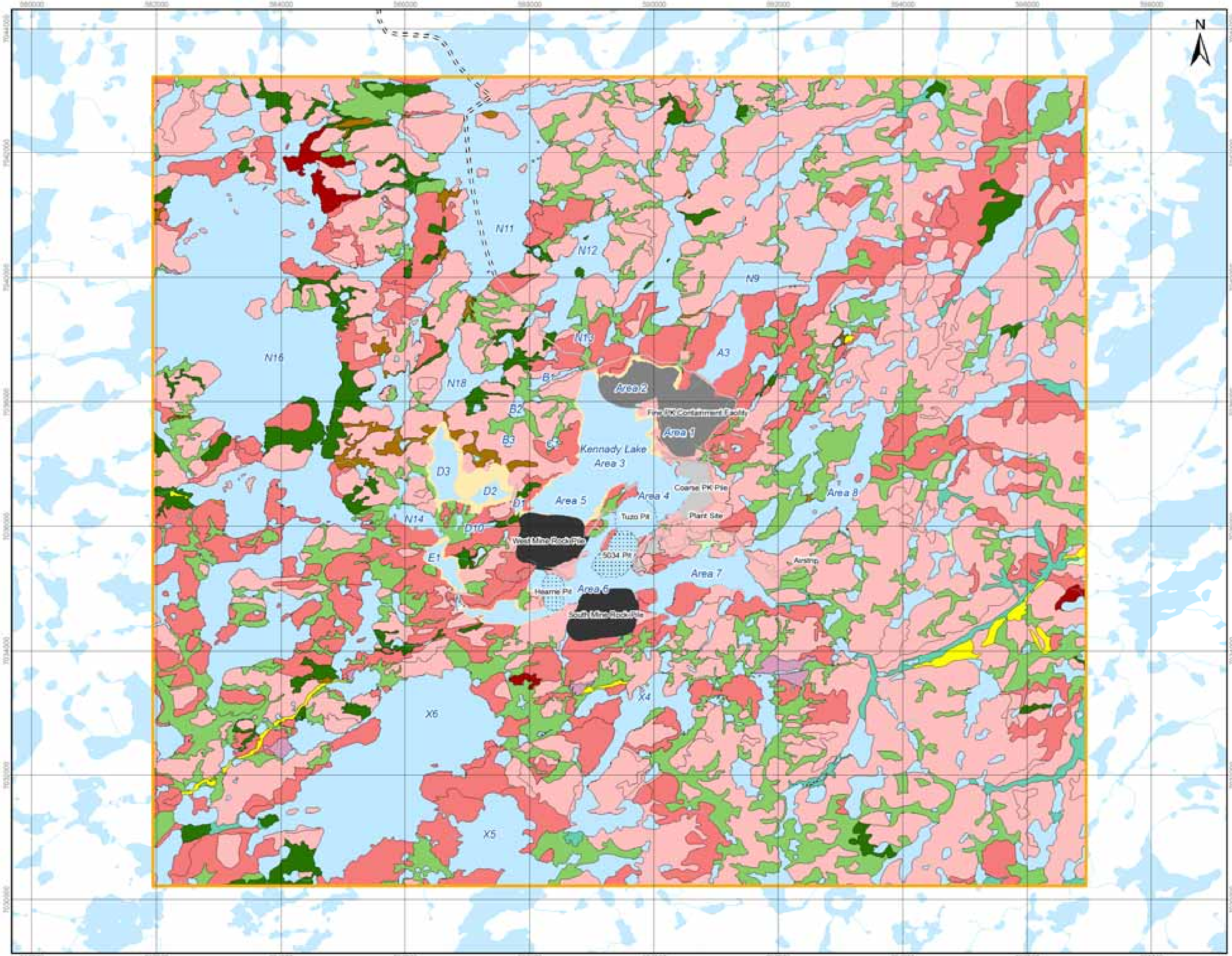

LEGEND

- Proposed Winter Access Road
- Watercourse
- Waterbody
- Local Study Area

Closure Footprint

- Disturbance - Infrastructure (Reclaimed)
- Disturbance - Flooded Area
- Submerged Backfilled Mine Pit
- Submerged Mine Pit
- Waste Rock Covered Coarse PK
- Waste Rock Covered Fine PK/Coarse PK
- Waste Rock Pile

Soil Unit

- Dragon Lake Association
  Includes Baseline Units: D1; D2; D3; D4
- Goodspeed Lake Association
  Includes Baseline Units: G1
- Hoarfrost River Association
  Includes Baseline Units: H1
- Exposed Bedrock
  Includes Baseline Units: R
- Sled Lake Association
  Includes Baseline Units: S1; S2; S2u; S3; S3u; S4i; S5
- Sled Lake/Dragon Lake Co-dominant
  Includes Baseline Units: SD1; SD2; SD2u; SD4
- Sled Lake/Goodspeed Lake Co-dominant
  Includes Baseline Units: SG1
- Wolverine Lake Association
  Includes Baseline Units: W1; W1u; W2; W2u/r; W3; W4U; W5
- Wolverine Lake/Dragon Lake Co-dominant
  Includes Baseline Units: WD1; WD1u
- Wolverine Lake/Bedrock Co-dominant
  Includes Baseline Units: WR1
- Wolverine Lake/Sled Lake Co-dominant
  Includes Baseline Units: WS1; WS1u; WS2; WS2u; WS3; WS4ui

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Soil Distribution After Closure

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:60,000 (1 0.5 0 1 Kilometers)	DE BEERS CANADA
FILE No: E-Soils-005-GIS	DATE: October 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 5
OFFICE: GOLD-SAS	DRAWN: ANK; CHECK: JV

Figure 11.7.I-8

The effect of the Project on exposed bedrock area will be the same as described for terrain. About 9.8% of the mappable bedrock area (1.08 ha) in the LSA will be disturbed. However, bedrock outcrops do occur as inclusions with other soil associations, and the actual loss of exposed bedrock area is estimated to be less than 10%.

The dewatering of Kennady Lake will expose 78.7 ha (0.4% of the LSA) of previously unexposed subaquatic sediment. This sediment generally has no soil association designation, but upon exposure would be categorized initially as a Gleysolic soil and then as a Cryosolic soil once permafrost develops. The processes of desiccation and permafrost development will alter the existing soil conditions during operations. The proposed re-filling of Kennady Lake at closure would likely reverse any soil-related changes, such as temperature changes and chemical changes due to aeration, that may occur during exposure. It is expected that all of the sediment that is exposed during the dewatering would be reclaimed to baseline aquatic conditions following Project closure.

Upon Project closure, there will be a marginal recovery of area in certain soil associations. This will generally be associated with the removal of on-land dykes and the localized lowering of waterbodies to baseline levels. These gains will be relatively small and will generally be associated with the more widespread associations (Figure 11.7.I-8). An area of 85.9 ha within the Project footprint may be reclaimable land through mitigation and reclamation processes. The mine rock piles, Coarse PK Pile and Fine PKC Facility will occupy 352.1 ha (1.81% of the LSA), which is considered to be non-reclaimed land in the Project closure plan. Lake A3 will have elevated levels when compared to baseline, and 22.9 ha of soils will be permanently lost to flooded areas.

11.7.I.5 RESIDUAL EFFECTS SUMMARY

11.7.I.5.1 EFFECTS TO TERRAIN

The effect from the Project on surficial material distribution will be confined to the Project footprint. Most of this effect will occur during the construction phase, although activities through the life of the Project will continue to change the landscape. The type and degree of change consists of three attributes, the spatial extent of change, integrity of the material, and the shape of the landscape.

The terrestrial area that will be disturbed during construction and operation is 394.2 ha. At closure, the extent of the effect will consist of 86.0 ha of reclaimed land and 352.1 ha of non-reclaimed land associated with the mine rock piles, Coarse PK Pile and Fine PKC Facility. The difference between the original area disturbed and the area at closure results from some land segments being either lost to or gained from Kennady Lake, and to land gained from burial of small upland waterbodies. The total disturbance represents 1.8% of the LSA.

The integrity of the disturbed materials will be compromised. That is, the disturbed materials cannot be replaced exactly in their original positions and sequences. The material will nevertheless have the same or similar composition as it had previous to disturbance, and the terrain will appear similar to that of the surrounding landscape upon re-contouring at reclamation. The reclaimed landscape will have an undulating surface with slopes up to about 10%, and could include some steeper areas with slopes up to about 15%.

The surficial material distribution effect is considered to be permanent. That is, once the disturbed material is re-contoured to match the pre-existing and surrounding land surface, it is expected the land will remain that way permanently.

The height of the mine rock piles are predicted to be up to 90 m, while the Coarse PK Pile and Fine PKC Facility will be somewhat lower. In terms of the surrounding landscape, these features will be considerably higher and steeper, and they will not be seeded. Other high hills and areas of high relief occur in the LSA, although the mine rock piles, Coarse PK Pile, and Fine PKC Facility would be relatively isolated by comparison. Once constructed, the mine rock piles, Coarse PK Pile, and Fine PKC Facility will be permanent features of the landscape.

11.7.I.5.2 EFFECTS TO SOIL QUANTITY

Soil loss by water and wind erosion is of concern at the time of soil salvage and stockpiling, and during storage. Various erosion control techniques are available, and it is expected that the loss would be less than 10% of the total salvageable soil, which is considered be meet an acceptable standard of practice for soil erosion protection. The effect will occur only within the Project footprint. The duration of the effect would likely occur over decades or hundreds of years.

11.7.I.5.3 EFFECTS TO SOIL QUALITY

Effects attributed to the core Project activities include admixing of topsoil with subsoil materials, compaction, physical-chemical changes that could occur during storage in stockpiles, and soil erosion. The geographic extent of the effect from these activities will be limited to the Project footprint. The soils are very sandy and therefore have low water capacity and low nutrient content. Due to the coarse texture of the soils, processes such as compaction will result in changes to these materials relative to baseline conditions, and erosion is expected to be controlled. Chemical changes during storage are also predicted to be within the range of baseline conditions. Undisturbed soils are considered to be mainly of poor quality in terms of reclamation suitability, and the suitability ratings are expected to generally remain unchanged after disturbance. Evidence from the literature suggests that storage changes are minimal (Thurber Consultants Ltd. et al. 1990).

Soil loss by water and wind erosion is of concern at the time of soil salvage and stockpiling, and during storage. Various erosion control practices are available, and it is expected that the loss would be less than 10% of the total salvageable soil, which is considered be meet an acceptable standard of practice for soil erosion protection. The effect will occur only within the Project footprint. The duration of the effect would likely occur over decades or hundreds of years.

Effects to physical and chemical properties of stockpiled soil are expected to be reversible in the order of a few years to a few decades following closure. Recovery will be assisted by mitigation techniques that are available to maintain or improve soil quality. Salvaged organic-rich materials such as peat and lakebed sediments will likely enable topsoil amendment, thus maintaining or possibly improving the quality of surface soil. Consequently, once soils are reclaimed, it is expected that the overall quality will be such that the soils will support vegetation growth in the same way as native soils.

Acid deposition effects on soil chemical properties were assessed for soils beyond the Project footprint only. Soils within the footprint will be disturbed, and as such, any chemical changes would be modified upon reclamation. Effects from acid deposition are expected to be at or slightly exceed the limits of baseline values, with only a small area receiving deposition rates of potential acid input (PAI) that exceed guideline levels. Air quality modelling results estimate that 200 ha (1.0%) of the LSA will receive PAI greater than the critical load (0.25 keq H^+/ha/y) for sensitive soils, and 9 ha (0.05%) will receive PAI greater than the critical load (0.50 keq H^+/ha/y) for moderately sensitive soils.

Changes in soil chemistry are generally not observed at low acid input levels until about many years of deposition, potentially decades. Because the Project will have an operational lifespan of 11 years, the above areas are not likely to exhibit measurable changes in soil chemical properties such as pH, exchangeable cation levels, and soil solution aluminum. After acid deposition ends, soil buffering mechanisms are expected to return any chemical changes in the soils to baseline conditions, although this could require several years to decades.

11.7.I.5.4 EFFECTS TO SOIL DISTRIBUTION

Effects from the Project on soil distribution will be confined to the Project footprint. Most of this change will occur during the construction phase, although activities through the life of the Project will continue to change soil distribution. The disturbance area of soils is predicted to be 394.2 ha (2.0% of the LSA). Of this area, 86 ha is expected to be reclaimed. The remainder of the original area will be affected by loss to Lake A3, gain from burial of small upland waterbodies, and loss to the development of the mine rock piles, Coarse PK Pile and Fine PKC Facility.

Terrain and soils share a closely linked interaction, resulting in comparable changes from development. The changes in terrain features result in a small net loss in the spatial extent of some terrain types, as well as the correspondent soil associations.

The soil type that will be affected to the greatest extent is the Wolverine Association, in which 158.1 ha (2.2%) of the original 7,277 ha in the LSA will be disturbed. Exposed Bedrock will have disturbance of 1.1 ha (10%) of the original 11 ha within the Project footprint. Bedrock does occur elsewhere within the LSA as inclusions within other soil types, and the overall proportion disturbed is estimated to be less than 5%. Overall, the magnitude of the local effect to soil distribution from the Project is predicted to approach or slightly exceed baseline conditions. The effect is restricted to the Project footprint, and represents 2% to 5% of a particular soil type in the LSA.

11.7.I.6 UNCERTAINTY

11.7.I.6.1 EFFECTS TO TERRAIN

There is certainty that surficial materials will be moved, excavated, and re-contoured, and that a new land surface will temporarily occur as a result of dewatering of Kennady Lake. The areas affected have been determined with good precision. The landscape will change especially due to the construction of the mine rock piles, Coarse PK Pile and Fine PKC Facility.

11.7.I.6.2 EFFECTS TO SOIL QUANTITY

Soil quantity was assessed in terms of effects from burial and admixing on soil loss, and from wind and water erosion, especially with regard to soil stockpiles. Erosion will occur without using environmental design features. Mitigation practices are available and are commonly used and shown to be effective. Thus, with appropriate application of mitigation, the evaluation of soil loss is considered to be of high certainty.

11.7.I.6.3 EFFECTS TO SOIL QUALITY

Several aspects of soil quality were examined. The effects from soil removal and storage, traffic, and other activities on chemical and physical properties were assessed. The main processes are soil admixing, compaction, and chemical reactions during storage in stockpiles. Minor changes in quality due to these processes are predicted with moderate certainty. Admixing and compaction effects are expected to be low. Storage effects are not well known, especially for soils in northern climates. Prediction of a low effect is based on the storage being mainly under frozen conditions; however, there is little background information to support this assumption.

The effects of acid deposition on soils can be predicted only with low confidence. The state of the science is such that acidification is predicted from theoretical principles, but demonstration of acidification having occurred is rare, especially in northern regions. Furthermore, critical load and potential acid input predictions are both based on modelling with several inherent assumptions (Section 11.4). There is also uncertainty about the predicted effects of dust deposition on soils. Trace metals from dust can be removed by water in the soil profile, or they can be adsorbed onto soil particles, and chemical forms can change. Acidification can lead to mobilization of some trace metals. Therefore, predicted changes to soil quality were overestimated so that effects were not underestimated.

11.7.I.6.4 EFFECTS TO SOIL DISTRIBUTION

As with surficial material, there is certainty that soils will be stripped, stored, and eventually replaced during reclamation. The types of soils affected as well as their spatial extents have been determined in detail. There will be loss of soil to the mine rock piles, Coarse PK Pile and Fine PKC Facility, Lake A3 and to Kennady Lake. The effect is considered to be irreversible because the soils would require a considerable period of time to develop horizonation, chemical properties, and other attributes similar to undisturbed soils. This prediction is made with high certainty, based on well-established principles of soil formation.

11.7.I.7 MONITORING AND FOLLOW-UP

Programs implemented during the life of the Project may be a combination of environmental monitoring to track conditions and implement further mitigation as required, and follow-up monitoring to verify the accuracy of impact predictions and adaptively manage and implement further mitigation as required.

Soil quality and quantity conditions would be monitored during the construction and operations phases of the Project, as well during closure and post closure as part of reclamation monitoring. Soil conditions will be assessed in conjunction with the implementation of the vegetation management plan (VMP) (Section 11.7.10.1.1), to monitor reclamation success and effects from dust deposition and physical disturbance. Other soil quality issues such as erosion, admixing and compaction will be visually assessed as part of this task.

Results from this monitoring program could be used to support adjustments to the overall reclamation plan and incorporated into the ongoing reclamation activities.

11.7.I.8 REFERENCES

11.7.I.8.1 LITERATURE CITED

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11.7.I.9 ACRONYMS AND GLOSSARY

11.7.I.9.1 ACRONYMS AND ABBREVIATIONS

AENV	Alberta Environment
C	Clay
CASA	Clean Air Strategic Alliance
CCME	Canadian Council of Ministers of the Environment
CEC	Cation Exchange Capacity
CL	Clay Loam
De Beers	De Beers Canada Inc.
EBA	EBA Engineering Consultants Ltd.
EIS	Environmental Impact Statement
EC	Electrical Conductivity
ELC	Ecological Landscape Classification
F	Fair
G	Good
GIS	Geographic Information System
HC	Heavy Clay
HS	High Subarctic
KLOI	Key Line of Inquiry
L	Loam
LFH	Litter, Fibric, Humic
LL	Lower Lift
LS	Loamy Sand
LSA	Local Study Area
n/a	Not Applicable
ND	Not determined
Non-AG	Non-acid generating
NO_X	Nitrogen oxide
P	Poor
PAG	Potentially-acid generating
PAI	Potential acid input
Panel	Gahcho Kué Panel
PK	Processed kimberlite
PKC	Processed tkimberlie containment
Project	Gahcho Kué Project
RSA	Regional Study Area
S	Sand
SAR	sodium adsorption ratio
SCL	Sandy Clay Loam
SGP	Slave Geological Province
SiCL	Silty Clay Loam
SiL	Silt Loam
SL	Sandy Loam

SO_2	sulphur dioxide
SON	Subject of Note
STP	Sewage treatment plant
SW	Southwest
Terms of Reference	Terms of Reference for the Gahcho Kué Environmental Impact Statement
TK	Traditional Knowledge
TLU	Traditional Land Use
TSP	Total suspended particulate
UL	Upper Lift
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
VCs	Valued compounds

11.7.I.9.2 UNITS OF MEASURE

>	more than
<	less than
°C	degrees Celsius
%	percent
$CaCO_3$	Calcium Carbonate equivalent
cm	centimetre
cmol	centimole
dS m-1	deciSiemens per metre
H_2O pH Range	the pH of surface water (H_2O) in a peatland.
Ha	hectares
keq H^+/ha/y	kiloequivalents hydrogen per hectare per year
kg/ha/y	kilograms per hectare per year
kg	kilogram
km^2	square kilometres
m	metre
mm	millimetre
masl	metres above sea level
mg/kg	milligram per kilogram
Mg/m^3	mega grams per cubic metre
pH_w	pH determined in soil-water mixture
t/ha/y	tonne per hectare per year
µS/cm	microSiemens per centimetre

11.7.I.9.3 GLOSSARY

Ablation moraine	Morainal material deposited from stagnant glacial ice.
Acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, caused by natural or anthropogenic processes. Acidification is exhibited as the lowering of pH.
Acidity	Amount of both weak and strong acids expressed as milliequivalents of a strong base necessary to neutralize those acids.
Active layer	A surface layer of soil above the permafrost that is alternately thawed each summer and completely frozen each winter. It represents the seasonally frozen ground on permafrost.
Admixing	The dilution of topsoil with subsoil, spoil or waste material, with the result that topsoil quality is reduced. Admixing can result in adverse changes in topsoil texture, poor soil aggregation and structure, loss of organic matter and decrease in friability.
Aeolian	Pertaining to the wind. Suspension, transport and deposition of particles, particularly sand and silt, by the wind.
Aeration, soil	The process by which air in the soil is replaced by air from the atmosphere. The rate of aeration depends largely on the volume and continuity of pores in the soil.
Aggregate	A group of soil particles cohering so as to behave mechanically as a unit.
Alkaline soil	A soil having a pH greater than 7.0.
Anthropogenic	Pertaining to the influence of human activities.
Archaean (also Archaeozoic)	The early part of the Precambrian time, about 2,500 to 3,800 million years before present. Also, rocks of this eon.
Bedding planes	The surfaces between consecutive layers of rock.
Bedrock	The solid rock (harder than 3 on Moh's scale of hardness) underlying soils and the regolith in depths ranging from zero (where exposed to erosion) to several hundred meters.
Blanket	A mantle of unconsolidated materials thick enough to mask minor irregularities in the underlying unit but which still conforms to the general underlying topography. As used in this report, a blanket is generally greater than 100 cm thick and has a surface form similar to a particular material's genesis.
Bog	A peat-covered area or peat-filled wetland. The water table is at or near the surface. The surface is often raised, or level with the surrounding wetlands, and is virtually unaffected by the nutrient-rich groundwaters from the surrounding mineral soils. Hence, the groundwater of the bog is generally acid and low in nutrients. The dominant peat materials are sphagnum and forest peat underlain, at times, by fen peat. The associated soils are Fibrisols, Mesisols and Organic Cryosols. Bogs may be treed or treeless and they are usually covered with *Sphagnum* and feather mosses, and ericaceous shrubs.
Boulders	Coarse fragments greater than 60 cm in diameter.
Brunisolic	A soil order consisting of immature soils, but of sufficient development to exclude it from the Regosolic order, but without sufficient development to include it in any other order. These soils develop under various climates and vegetation, and are frequently characterized by a reddish colour.
Calcareous	Soil containing sufficient calcium carbonate, often with magnesium carbonate, to effervesce visibly when treated with cold 0.1M hydrochloric acid.

Calcareous classes	Six classes that represent the amount of carbonates, expressed as percent calcium carbonate ($CaCO_3$) equivalent, present in the soil or parent material. The classes are noncalcareous (less than 1), weakly calcareous (1 to 5), moderately calcareous (6 to 15), strongly calcareous (16 to 25), very strongly calcareous (26 to 40), and extremely calcareous (more than 40). At the family level of soil taxonomy, strongly calcareous means 5 to 40 $CaCO_3$ equivalent.
Cation Exchange Capacity	The sum total of exchangeable cations that a soil can absorb. It is usually expressed in milliequivalents per 100 grams of soil.
CCME	Canadian Council of Ministers of the Environment; body of Environment Canada that sets ambient guidelines for air, water, soil and contaminants
Cenozoic	The latest of the four eras into which geologic time is divided.
Classification, soil	The systematic arrangement of soils into categories according to their inherent characteristics, or on some interpretation of those properties for various uses. Broad groupings are made on the basis of general characteristics, and subdivisions according to more detailed differences in specific properties.
Clay	(i) As a particle size term: a size fraction less than 0.002 mm equivalent diameter, or some other limit (geology or engineering). (ii) As a rock term: a natural, earthy, fine grained material that develops plasticity with a small amount of water. (iii) As a soil term: a textural class. See also texture, soil. (iv) As a soil separate: a material usually consisting largely of clay minerals but commonly also of amorphous free oxides (sesquioxides) and primary minerals.
Clay mineral	Finely crystalline hydrous aluminum silicates and hydrous magnesium silicates with a phyllosilicate (platy) structure.
Consistence	(i) The resistance of a material to deformation or rupture. (ii) The degree of cohesion or adhesion of the soil mass.
Consolidated	Firm and coherent materials.
Craton	A portion of the earth's crust that has been tectonically stable and not substantially deformed for a long period.
Cretaceous	Period of geologic time beginning 135 million years before present and ending 65 million years before present.
Critical Loads	A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. For waterbody acidification, the critical load represents an estimate of the amount of acidic deposition below which significant adverse changes are not expected to occur in a lake's ecosystem.
Cryogenesis	The combination of thermophysical, physico-chemical, and physico-mechanical processes occurring in freezing, frozen, and thawing earth materials. Specific processes of cryogenesis include water migration during freezing and thawing of the ground, frost heave, heat and mass (moisture) exchange, regulation, and gelifluction.
Cryosolic	An order of soils in the Canadian taxonomic system. Cryosolic soils are mineral or organic soils that have perennially frozen material within 1 m of the surface in some part of the soil body, or pedon. The mean annual soil temperature is less than 0°C (32°F). Their maximum development occurs in organic and poorly drained, fine textured materials. The active layer of these soils is frequently saturated with water, especially near the frozen layers, and colours associated with gleying are therefore common in mineral soils, even those that occur on well drained portions of the landscape. They may or may not be markedly affected by cryoturbation. The order has three great groups: Turbic Cryosol, Static Cryosol, and Organo Cryosol (q.v.)
Cryoturbation	Frost action that causes churning, heaving, and considerable structural modification of the soil and subsoil.

Deformation	Term for the processes of folding, faulting, shearing, compression or extension of rocks as a result of various earth forces.
Deglaciation	The uncovering of an area from beneath glacier ice as a result of melting.
Deposition, deposit	The accumulation of material left in a new position by a natural transporting agent such as water, wind, ice or gravity; or by the activity of man.
Depressional	Describing an area with elevation lower than that of the surrounding area; any hollow, basin, or flat, low-lying area in the landscape.
Disturbed land	Area where vegetation, topsoil, or overburden is removed, or where topsoil, spoil, and processed waste is placed (as in mining). Also called disturbed area.
Dominant	In natural resources mapping, the feature (soil type, terrain, or other feature) that constitutes the majority of a mapping unit (generally 40% or more, and usually 50% or more).
Drainage	The removal of excess surface water or groundwater from land by natural runoff and percolation, or by means of surface or subsurface drains.
Duff	
Dyke	A tabular body of igneous rock that cuts across the bedding or foliation of the rock it intrudes.
Dyke swarm	A large group of parallel, linear, or radially oriented dykes
Ecoregion	Relatively homogeneous subregions within an ecozone; an area characterized by distinctive regional climate as expressed by vegetation.
Ecozone	An area of the earth's surface that is representative of a broad-scale ecological unit characterized by particular abiotic (non-living) and biotic (living) factors, e.g. taiga forest, tundra.
ELC	Ecological Land Classification; an ecological mapping process that involves the integration of site, soil, and vegetation information
Eluvial horizon	A soil horizon that has been formed by the process of eluviation.
Eluviation	The transportation of soil material in suspension or in solution within the soil by the downward or lateral movement of water.
Eolian	Well sorted materials, predominantly sand and silt, deposited by wind.
Eon	The largest subdivision of time on the geologic time scale.
Ericaceous	Of or relating to the heath family.
Erosion	(i) The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. (ii) Detachment and movement of soil or rock by water, wind, ice, or gravity.
Esker	A long narrow often sinuous ridge of sand and gravel and boulders deposited by a stream flowing on, within or beneath a glacier
Eutrophic	Term referring to peatlands that are relatively nutrient-rich; also refers to soils and waters with high nutrient content and high biological activity.
Exposure	An area of a rock formation that is visible at the land surface
Feather moss	A collective term for three primary moss species: Schreber's moss (*Pleurozium schreberi*), stair-step moss (*Hylocomium splendens)*, and knight's plume moss (*Ptilium crista-castrensis*).
Feldspar	A group of abundant rock-forming minerals of the general formula, $M\text{-}Al(Al,Si)_3O_8$, where M can be K, Na, Ca, Ba, Rb, Sr, or Fe. Feldspars are the most widespread of any mineral group and constitute 60% of the earth's crust; they occur in all types of rock.
Fen	A wetland, covered or filled with fen peat, having a high water table which is usually at or above the surface.

Fen peat	Peat material constituting fens, derived primarily from sedges and brown mosses with inclusions of partially decayed stems of shrubs formed in an eutrophic environment due to the close association of the material with mineral-rich waters.
Fibre, rubbed or unrubbed	The organic (peat) material retained on a 100-mesh sieve (0.15 mm) either with or without rubbing, except for wood fragments that cannot be crushed in the hand and are larger than 2 mm in the smallest dimension.
Floodplain	The land bordering a stream, comprising sediments from overflow of the stream and subject to inundation when the stream is at flood stage.
Fluvial (alluvial) material	All sediments, past and present, deposited by flowing water, including glaciofluvial deposits.
Fluvial/eolian	Originally deposited from moving water, subsequently transported by wind.
Forest peat	Peat materials derived mainly from trees such as black spruce, from ericaceous shrubs, and from feathermosses.
Frost action	The process of alternate freezing and thawing of moisture in soil, rock, and other materials, and the resulting effects on materials and on structures placed on, or in, the ground.
Frost heave	The upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice in the soil.
Genesis, soil	The mode of origin of soil, especially the processes or soil forming factors responsible for development of the soil profile from unconsolidated parent material.
Geothermal gradient	An increase of soil temperature with depth due to the heat flux of the Earth core. An average geothermal gradient is approximately 2^{o}C per 100 m.
Glacial	(i) Of or relating to the presence and activities of ice or glaciers, such as glacial erosion. (ii) Pertaining to distinctive features and materials produced by or derived from glaciers and ice sheets, such as glacial lakes. (iii) Pertaining to an ice age or region of glaciation.
Glaciofluvial	Material moved by glaciers and subsequently deposited by streams flowing from the melting ice. The deposits may be unsorted or sorted. Sorted deposits are stratified and may be in the form of outwash plains, deltas, kames, eskers, and kame terraces.
Gley, gleying	A chemical reduction process that takes place in soils that are saturated with water for long periods of time. The horizon of most intense reduction is characterized by a gray, commonly mottled appearance, which on drying shows numerous rusty brown iron stains or streaks.
Gleysolic soil	Soil developed under wet conditions resulting in reduction of iron (i.e., rust) and other elements and in gray colours and mottles.
Gneiss	A coarse crystalline metamorphic rock in which there are bands of light and dark minerals of widely varying origin and mineralogy.
Gneissic	Pertaining to texture or structure typical of gneisses.
Granite	A coarsely crystalline igneous intrusive rock composed of quartz, potassium feldspar, mica and/or hornblende.
Gravel	(i) As a deposit term: glaciofluvial or fluvial materials with 60 or more coarse fragments, usually subrounded to rounded and of variable size. (ii) As a particle size term: a size fraction between 2 and 75 mm diameter with rounded, subrounded, angular, or irregular shapes.
Great group	A category in the Canadian system of soil classification. A subdivision of a soil order, it is a taxonomic grouping of soils having certain morphological features in common and a similar pedogenic environment.
Greywacke	A hard, poorly sorted impure sandstone that is typically grey to greenish grey.

Ground ice A general term referring to all types of ice contained in freezing and frozen ground. Ground ice occurs in pores, cavities, voids or other openings in soil or rock and includes massive ice. It may occur as lenses, wedges, veins, sheets, seams, irregular masses, or as individual crystals or coatings on mineral or organic particles. Perennial ground ice can only occur within permafrost bodies.

Groundwater Water that is passing through or standing in the soil and the underlying strata in the zone of saturation. It is free to move by gravity.

Holocene The geologic time period since deglaciation (about 10,000 years).

Horizon, soil A layer of soil or soil material approximately parallel to the land surface. It differs from adjacent genetically related layers in properties such as colour, structure, texture, consistence, and chemical, biological, and mineralogical composition. A list of the designations and some of the properties of soil horizons and layers follows.

Mineral horizons and layers

Mineral horizons and layers contain less than 17% organic carbon. Four main horizons are recognized:

A - Mineral horizon formed at or near the surface in the zone of removal of materials in solution and suspension, or maximum in-situ accumulation of organic carbon, or both.

B - A mineral horizon characterized by one or more of the following:

(i) An enrichment in silicate clay, iron, aluminum, or humus.

(ii) A prismatic or columnar structure that exhibits pronounced coatings or stainings associated with plentiful amounts of exchangeable solutions.

(iii) An alteration of hydrolysis, reduction, or oxidation to give a change in colour or structure from the horizons above or below, or both.

C - A mineral horizon comparatively unaffected by the pedogenic processes operative in A and B, except gleying, and the accumulation of carbonates and more soluble salts.

R - Underlying consolidated bedrock that is too hard to break with the hands or to dig when moist.

Roman numerals are prefixed to horizon designations to indicate unconsolidated lithologic discontinuities in the profile. Roman numeral I is understood for the uppermost material and usually is not written. Subsequent contrasting materials are numbered consecutively in the order in which they are encountered downward, that is, II, III, and so on.

Lowercase Suffixes

e - A horizon characterized by removal of clay, iron, aluminum, or organic matter alone or in combination and higher in colour value by one or more units when dry than an underlying B horizon. It is used with A (Ae).

g - A horizon characterized by gray colours, or prominent mottling indicative of permanent or periodic intense reduction, or both; for example, Aeg, Btg, Bg or Cg.

h - A horizon enriched with organic matter.

Ah - An A horizon of organic matter accumulation. It contains less than 17 organic carbon. It is one Munsell unit of colour value darker than the layer immediately below, or it has at least 0.5 more organic carbon than the IC, or both.

Ahe - This horizon has been degraded, as evidenced by streaks and splotches of light and dark gray material and often by platy structure.

j - This is used as a modifier of suffixes e, g, n, and t to denote an expression of, but failure to meet, the specified limits of the suffix it modifies. For example, Aej is an eluvial horizon that is thin, discontinuous, or faintly discernible.

k - Presence of carbonate.

m - A horizon slightly altered by hydrolysis, oxidation, or solution, or all three, to give a change in colour, or structure, or both.

t - A horizon enriched with silicate clay, as indicated by a higher clay content (by specified amounts) than the overlying eluvial horizon, a thickness of at least 5 cm, oriented clay in some pores, or on ped surfaces, or both, and usually a higher ratio of fine (less than 0.2 μm) to total clay than in the IC horizon.

z - A perennially frozen layer.

c horizons

Organic layers contain 17% or more organic carbon. Two groups of these layers are recognized:

O - An organic layer developed mainly from mosses, rushes and woody materials.

Of - The least decomposed organic layer, containing large amounts of well-preserved fibre, and called the fibric layer.

Om - An intermediately decomposed organic layer containing less fibre than an Of layer and called the mesic layer.

Oh - The most decomposed organic layer, containing only small amounts of raw fibre and called the humic layer.

L,F,H - Organic layers developed primarily from leaves, twigs, an woody materials, with a minor component of mosses.

L - The original structures of the organic material are easily recognized.

F - The accumulated organic material is partly decomposed.

H - The original structures of the organic material are unrecognizable.

Horizontal A type of surface expression of peatland terrain consisting of a flat peat surface not broken by any marked elevations or depressions.

Hornblende Dark green to black crystals that are minerals of the amphibole group; common in various types of metamorphic and igneous rocks. The general formula is $Ca_2(Mg, Fe^{+2})_4Al(Si_7Al)O_{22}(OH,F)_2$.

Humic Organic material, such as peat, that is at an advanced stage of decomposition. It has the lowest amount of fibre, the highest bulk density, and the lowest saturated water-holding capacity of the organic materials. It is physically and chemically stable over time, unless it is drained. The rubbed fibre content is less than 10% by volume and the material usually is classified in the von Post scale of decomposition as class 7 or higher. See also Horizon, soil.

Hummocky A very complex sequence of slopes extending from somewhat rounded depressions or kettles of various sizes to irregular to conical knolls or knobs. There is a lack of concordance between knolls and depressions. Slopes are generally 9 to 70.

Immature soil A soil with indistinct or only slightly developed horizons.

Inclined A sloping, unidirectional surface of at least 300 metres in length and not broken by marked irregularities. Slopes can be 2 to 70.

Inclusion In natural resources mapping, a soil, terrain or other feature that constitutes up to 15 % or 20 %of a unit. Some map units contain several inclusions that together add up to a substantial percentage.

Infiltration The downward entry of water into the soil.

Intrusive Pertaining to the process of emplacement of magma in pre-existing rock.

Isopleths A line on a map connecting places sharing the same feature (e.g., ground-level concentrations).

Kettle	A steep-sided bowl or basin-shaped hole or depression in glacial drift deposits, especially outwash or kame, and believed to have formed by the melting of a large, detached block of stagnant ice (left behind by a retreating glacier) that had been wholly or partly buried in the glacial drift. Kettles commonly lack surface drainage and some may contain a lake or swamp.
Key line of inquiry	The topic of the greatest concern that requires the most attention during the environmental impact review and the most rigorous analysis and detail in the environmental impact statement.
Kimberlite	Igneous rocks that originate deep in the mantle and intrude the earth's crust. These rocks typically form narrow pipelike deposits that sometimes contain diamonds.
Lithology	The systematic description of sediment and rocks, in terms of composition and texture.
Litter	Accumulation of leaves, needles, trigs and other woody materials on the surface of a site. The LFH horizon of soils.
Lower lift	A soil layer below the upper lift, and of specified thickness, that is selectively removed, stored, and replaced as subsoil in the reclamation process.
Lowland	Land that is saturated with water long enough to promote wetland or aquatic processes, indicated by poorly drained soils and hydrophytic vegetation.
Mafic	A term to describe minerals that contain in iron and magnesium.
Map unit	A combination of kinds of soil, terrain, or other feature that can be shown at a specified scale of mapping for the defined purpose and objectives of a particular survey.
Massive ice	A comprehensive term used to describe large masses of ground ice, including ice wedges, pingo ice, buried ice and large ice lenses.
Matrix, soil	The main soil constituent or material that encloses other soil features such as gravels or concretions embedded in a fine-grained matrix.
Mean annual soil temperature	Soil temperature, measured at a specified depth, averaged over a period of a year.
Mesic	Organic materials at a stage of decomposition between that of fibric and humic materials; peat soil material with >10 % and less than 40 % rubbed fibres; mesic peat usually is classified in the von Post scale as class 5 or 6. See also Horizon, soil.
Mesoarchaean	A geologic era within the Archean, spanning 3,200 to 2,800 million years ago.
Basement	Any rock below sedimentary rocks or sedimentary basins that are metamorphic or igneous in origin
Metasediments	Sedimentary rocks that have been modified by metamorphic processes.
Metavolcanics	Volcanic rocks that have been modified by metamorphic processes.
Mineral soil	A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter.
Morainal	Of or pertaining to moraine.
Moraine	A mound, ridge, or other distinct accumulation of unsorted, unstratified drift, predominantly till, deposited chiefly by direct action of glacier ice in a variety of topographic landforms that are independent of control by the surface on which the drift lies. It is now commonly used as a geomorphologic name for a landform composed mainly of till that has been deposited by a glacier.
Mottles, mottling	Spots or blotches of different colour or shades of colour interspersed with the dominant colour; formed mainly by the affects of impeded drainage.
Mudstone	A sedimentary rock composed of silt and clay sized particles that breaks along bedding planes much less easily than siltstone or shale.

Order, soil	The highest category in the Canadian system of soil classification. All the soils within an order have one or more characteristics in common.
Organic carbon, soil	The percent by weight of soil carbon in organic forms determined by the difference between total carbon (determined by dry combustion) and inorganic carbon (determined by acid dissolution).
Organic Cryosol	An organic soil having a surface layer containing more than 17 % organic carbon by weight, with permafrost within 1 m below the surface. In the Canadian System of Soil Classification, Organic Cryosol is more than 40 cm thick, or more than 10 cm thick over a lithic contact, or more than 10 cm thick over an ice layer that is at least 30 cm thick. Organic cryosols have mean annual ground temperatures below 0°C.
Organic matter, soil	The organic fraction of the soil; included are plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. It is estimated by multiplying the soil organic carbon content by 1.724.
Organic soil	An order of soils that have developed dominantly from organic deposits. The majority of Organic soils are saturated for most of the year, unless artificially drained, but some of them are not usually saturated for more than a few days. They contain 17 % or more organic carbon, and must extend to a minimum depth of 40 cm, or to 10 cm if overlying bedrock.
Orthic	A subgroup referring to the modal or central concept of various great groups in the Brunisolic, Chernozemic, Cryosolic, Gleysolic, Luvisolic, Podzolic and Regosolic orders of the Canadian system of soil classification.
Outcrop	That part of a geologic formation or structure that appears at the surface of the earth.
Outwash	Stratified sediments (chiefly sand and gravel) deposited by meltwater streams in front of the end moraine or the margin of an active glacier.
Overburden	Materials of any nature, consolidated or unconsolidated, that overlie a deposit of useful materials. In the present situation, overburden refers to the soil and rock strata which overlie kimberlite deposits.
Paludification	The process of peat accumulation leading to peatland formation over previously forested land, grassland or bare rock.
Parent material	The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil has developed by pedogenic processes.
Particle size	The effective diameter (grain size) of a particle measured by sedimentation, sieving, or micrometric methods.
Particle-size analysis	The determination of the various amounts of the different separates in a soil sample, usually by sedimentation, sieving, micrometry, or combinations of these methods. Has been called grain-size analysis or mechanical analysis.
Patterned (ribbed)	A type of surface expression associated with fen peatlands and consisting of a pattern of parallel or reticulate low ridges.
Patterned ground	A general term for any ground surface exhibiting a discernibly ordered, more or less symmetrical, morphological pattern of ground and, where present, vegetation. Some patterned ground features are not confined to permafrost regions but they are best developed in regions of present or past intensive frost action. A descriptive classification of patterned ground includes such features as nonsorted and sorted circles, nets, polygons, steps and stripes, and solifluction features. In permafrost regions, the most ubiquitous macro-form is the ice-wedge polygon, and a common micro-form is the nonsorted circle. The latter includes mud boils, mud hummocks, frost boils, stony earth circles, earth hummocks, turf hummocks, thufa and tundra hummocks. Patterned ground also occurs in peatlands in the form of string fens and other peatland features.

Peat	A deposit consisting of decayed or partially decayed humified plant remains. Peat is commonly formed by the slow decay of successive layers of aquatic and semi-aquatic plants in swampy or water-logged areas, where oxygen is absent.
Peat plateau	A generally flat-topped expanse of peat, elevated above the general surface of a peatland, and containing segregated ice that may or may not extend downward into the underlying mineral soil.
Peatland	Peat-covered terrain. There is no minimum thickness of peat required for the terrain to be classified as "peatland". In Canada, peatland is defined as a type of wetland formed by the accumulation of plant remains with limited decomposition.
Pedogenic	Pertaining to the mode of origin of the soil, especially the processes or soil forming factors responsible for the development of the solum.
Peneplain	An area which has been reduced by erosion to a low, gently rolling surface resembling a plain.
Percolation	The downward movement of water through saturated or nearly saturated soil.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years. Permafrost is defined on the basis of temperature. It is not necessarily frozen, because the freezing point of the included water may be depressed several degrees below 0°C; moisture in the form of water or ice may or may not be present.
Permafrost region	A region in which the temperature of some or all of the ground below the seasonally freezing and thawing layer remains continuously at or below 0°C for at least two consecutive years. The permafrost region is commonly subdivided into permafrost zones.
Permeability, soil	The ease with which gases and liquids penetrate or pass through a bulk mass of soil or a layer of soil. Because different soil horizons vary in permeability, the specific horizon should be designated.
Perviousness	The potential of a soil to transmit water internally, as inferred from soil characteristics such as structure, texture, porosity, cracks, and shrink-swell properties.
pH, soil	The negative logarithm of the hydrogen-ion activity of a soil solution (q.v.). The degree of acidity or alkalinity of a soil as determined by means of a suitable electrode or indicator at a specified moisture content or soil-water (or $CaCl_2$ solution) ratio, and expressed in terms of the pH scale.
Phase, soil	A subdivision of a soil type or other unit of classification having characteristics that affect the use and management of the soil but which do not vary sufficiently to differentiate it as a separate type. A variation in a property or characteristic such as depth of lime, degree of erosion, and content of stones.
Physiography	The physical nature of the land; it includes topography (the relief and contours of the land), elevation, aspect, slope, surface pattern of landforms, and drainage.
Plain	An extensive tract of flat land or an undulating terrain without prominent hills or depressions.
Podzolization	A process of soil formation in which Fe (iron) and/or Al (aluminum) complexes with organic matter are moved downward into the B horizon from the A horizon, resulting in concentration of Si (silica) in the A horizon.
Polygon	A map delineation that represents a tract of land with certain landform, soil, hydrologic, and vegetation features. The smallest polygon on a 1:50,000 scale map is about 0.5 cm^2 and represents a tract of about 12.5 ha.
Polygonal peat plateau	A peat plateau with ice-wedge polygons. Polygonal peat plateaus are commonly found near the boundary between the zones of discontinuous and continuous permafrost.
Pore	A void or space in a soil or rock not occupied by solid mineral material.
Porosity, soil	The volume percentage of the total bulk not occupied by solid particles.

Potential Acid Input (PAI)	A composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.
Precambrian	All geologic time, and its corresponding rocks, before the beginning of the Palaeozoic; it is equivalent to about 90 % of geologic time.
Profile, soil	A vertical section of the soil through all its horizon and extending into the parent material.
Proterozoic	The latest of two great divisions of the Precambrian.
Quartz	Crystalline silica, an important rock-forming mineral, SiO_2. It is next to feldspar, the commonest mineral, occurring wither in transparent hexagonal crystals or in crystalline or cryptocrystalline masses.
Quaternary	The second period of the Cenozoic era; also, the corresponding system of rocks.
Recent	Deposits of late post-glacial age, i.e. within the last few hundred to few thousand years. Soils have had insufficient time to develop "normal" profiles.
Reclamation	The process of reconverting disturbed land to its former or other productive uses.
Regosolic	An order of soils having no horizon development or development of the A and B horizons insufficient to meet the requirements of the other orders.
Relief	The elevations or inequalities of the land surface when considered collectively.
Ridged	A type of surface expression of mineral landforms, characterized by a long, narrow elevation of the surface, usually sharp crested with steep sides. Ridges may be parallel, subparallel or intersecting.
Rock	Any naturally formed, consolidated or unconsolidated material, other than soil, composed of two or more minerals or occasionally of one mineral, and having some degree of chemical and mineralogical constancy.
Rolling	Long, regular or smooth, often convex slopes with a cycle distance of about 0.5 to 1 km.
Saddle dyke	A barrier constructed across a waterway to control the flow or raise the level of water.
Sand	(i) As a particle size term: a size fraction between 0.05 and 2.0 mm equivalent diameter, or some other limit (geology or engineering). (ii) As a soil term: a textural class with abundant sand sized particles.
Sandstone	A sedimentary rock formed largely of sand-sized particles.
Seasonally frozen ground	Ground that freezes and thaws annually.
Sediment	Solid particles of material that have been derived from rock weathering. They are transported and deposited from water, ice or air as layers at the earth's surface.
Seep	An area, generally small, where water percolates slowly to the land surface. Synonymous with spring where the flow of water is substantial but includes flows that are very small.
Seismicity	The phenomenon of Earth movement, mainly due to earthquakes.
Separates, soil	Mineral particles, less than 2.0 mm in equivalent diameter, ranging between specified size limits. The names and size limits of separates recognized by soil pedologists in Canada and the United States are: very coarse sand, 2.0 to 1.0 mm; coarse sand, 1.0 to 0.5 mm; medium sand, 0.5 to 0.25 mm; fine sand, 0.25 to 0.10 mm; very fine sand, 0.10 to 0.05 mm; silt, 0.05 to 0.002 mm; clay, less than 0.002 mm; and fine clay, less than 0.0002 mm.
Series, soil	A category (or level) in the Canadian system of soil classification. This is the basic unit of soil classification, and consists of soils that are essentially alike in all major profile characteristics except the surface texture.
Sesquioxides	A general term for oxides and hydroxides of iron and aluminum.

Shale A sedimentary rock composed of clay and silt sized particles that splits readily along bedding planes.

Sialic A term to describe rock that contains relatively high proportions of silica and aluminum.

Subdominant A major soil (or other feature) that is clearly subordinate to the dominant. The typical range of proportions of a subdominant soil is 15 to 40.

Silt (i) As a particle size term: a size fraction between 0.002 and 0.05 mm equivalent diameter, or some other limit (geology or engineering). (ii) As a soil term: a textural class with abundant silt sized particles.

Siltstone A sedimentary rock with at least two thirds silt-sized particles

Slope The degree of deviation of a surface from horizontal, measured in a numerical ratio, percent and degree.

Slope classes The description of an area or region in terms of the steepness of slopes. The slope classes, class limits (in percent slope), and descriptive terminology are:

Slope Class	Slope	Terminology
1	0-0.5	level
2	0.5-2	nearly level
3	2-5	very gentle slopes
4	5-9	gentle slopes
5	9-15	moderate slopes
6	15-30	strong slopes
7	30-45	very strong slopes
8	45-75	extreme slopes
9	70-100	steep slopes
10	>100	very steep slopes

Soil The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick that occurs at the earth's surface and is capable of supporting plant growth. Soil extends from the earth's surface through the genetic horizons, if present, into the underlying material, normally about 1 to 2 m. Soil development involves climatic factors and organisms, conditioned by relief and water regime, acting through time on geological materials.

Soil horizon A layer of mineral or organic soil material approximately parallel to the land surface that has characteristics altered by processes of soil formation. A soil mineral horizon is a horizon with 17% or less total organic carbon by weight. A soil organic horizon is a horizon with more than 17% organic carbon by weight.

Soil map A map showing the distribution of soil types, classes, or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

Soil survey The systematic examination of an area having the purpose of describing, classifying and mapping its soils. Soil surveys are classified according to the kind and intensity of the field examination.

Solifluction Slow downslope flow of saturated unfrozen earth materials, resulting in development of topographic features such as lobes, aprons, sheets, terraces, and stripes.

Solum, soil (plural sola) The upper horizons of a soil in which the parent material has been modified and in which most plant roots are contained. It usually consists of the A and B horizons.

Steep A type of surface expression of mineral landforms, consisting of erosional slopes, greater than 70 (35°), occurring on both consolidated and unconsolidated materials.

Stones	Rock fragments greater than 25 cm in diameter if rounded and greater than 38 cm along the greater axis if flat.
Structure, soil	The combination or arrangement of primary soil particles into secondary particles, units, or peds. These peds may be, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristic pattern. The peds are characterized and classified based on size, shape, and degree of distinctness into classes, types, and grades. The soil structure classes are described below.
Subglacial	Formed or accumulated in, or by the bottom parts of a glacier or ice sheet.
Subgroup, soil	A category in the Canadian system of soil classification. These soils are subdivisions of the great groups, and therefore are defined more specifically.
Subject of note	An issue that requires serious consideration and a substantive analysis, although it does not have the same priority as a key line of inquiry.
Subsoil	The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow.
Surface expression	The form (assemblage of slopes) and pattern of forms of parent genetic materials
Swamp	A peat-filled area or a mineral wetland with standing or gently flowing, nutrient-rich waters occurring in pools and channels. The water table is usually at or near the surface. If peat is present, it is mainly well decomposed forest peat. Associated soils are Mesisols, Humisols, and Gleysols. The vegetation is characterized by a dense cover of coniferous or deciduous trees, tall shrubs, herbs, and some mosses.
Tectonic	Pertaining to the internal forces involved in deforming the earth's crust.
Thermokarst	Pock-marked topography in northern regions caused by the collapse of permafrost features.
Terrain	The landscape, or lay of the land. The term comprises specific aspects of the landscape, namely genetic material, material composition, landform (or surface expression), active and inactive processes (e.g. permafrost, erosion) that modify material and form, slope, aspect, and drainage conditions.
	any part of the environment that is considered important by the proponent, members of the public, scientists and government involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concerns.

Texture, soil — **The relative proportions of the various soil separates in a soil as described by the classes of soil texture. The limits of the various classes and subclasses are given below:**

sand (S) Soil material that contains 85% or more sand.

loamy sand (LS) Soil material that usually contains 70% to 85% sand but may contain as much as 90% sand depending upon the amount of clay present. Also loamy very fine sand (LVFS), loamy fine sand (LFS), loamy coarse sand (LCS).

sandy loam (SL) Soil material that usually contains 52% to 70% sand but may contain as much as 85% and as little as 43% sand depending upon the content of clay. Also very fine sandy loam (VL), fine sandy loam (FL), coarse sandy loam (CSL).

loam (L) Soil material that contains 7% to 27% clay, 28% to 50% silt, and less than 52% sand.

silt loam (SiL) Soil material that contains 50% or more silt and 12% to 27% clay, or 50% to 80% silt and less than 12% clay.

silt (Si) Soil material that contains 80% or more silt and less than 12% clay.

sandy clay loam (SCL) Soil material than contains 20% to 35% clay, less than 28% silt, and 45% or more sand.

clay loam (CL) Soil material that contains 27% to 40% clay and 20% to 45% sand.

silty clay loam (SCL) Soil material that contains 27% to 40% clay and less than 20% sand.

sandy clay (SC) Soil material that contains 35% or more clay and 45% or more sand.

silty clay (SiC) Soil material that contains 40% or more clay and 40% or more silt.

clay (C) Soil material that contains 40% or more clay, less than 45% sand, and less than 40% silt.

heavy clay (HC) Soil material that contains more than 60% clay.

Till — Unsorted and unstratified drift (morainal material), consisting of clay, silt, sand, gravel and boulders intermingled in any proportion, deposited by and underneath a glacier without subsequent reworking by glacial meltwater.

Topography — The physical features of a district or region, such as those represented on a map, taken collectively; especially the relief and contours of the land. On most soil maps topography may also mean topography classes that describe slopes according to standard ranges of percent gradient.

Topsoil — (i) The layer of soil moved in cultivation. (ii) The A horizon. (iii) The Ah horizon. (iv) Presumably fertile soil material used to topdress road banks, gardens and lawns.

Total Suspended Particulate (TSP) — A measure of the total particulate matter suspended in the air. This represents all airborne particles with a mean diameter less than 30 µm (microns) in diameter.

Tundra — Treeless terrain, with a continuous cover of vegetation, found at both high latitudes and high altitudes. Tundra vegetation comprises lichens, mosses, sedges, grasses, forbs and low shrubs, including heaths, and dwarf willows and birches. The term is used to refer to both the region and the vegetation growing in the region.

Translational slide — A type of slide in which a mass of earth on a slope moves along a roughly planar surface with little rotation or backward tilting

Turbic Cryosol — A mineral soil showing marked evidence of cryoturbation, as indicated by broken horizons and displaced material. Turbic Cryosols generally occur on patterned ground. They have mean annual ground temperatures below 0°C, with permafrost within 2 m below the surface.

Undulating — A wave-like pattern of very gentle slopes with low local relief. Slope length is generally less than 0.5 km and slope gradients are commonly 2 to 5.

Upper lift	A surface soil layer of specified thickness that is selectively removed, stored, and replaced as topsoil in the reclamation process.
Valued Component	Any part of the environment that is considered important by the proponent, members of the public, scientists and government involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concerns
Veneer	A mantle of unconsolidated materials too thin to mask the minor topographic irregularities of the underlying material. As used in this report, a veneer is generally less than 100 cm thick and lacks a surface form typical of a particular material's genesis.
Von Post	Humification scale describing peat moss in varying stages of decomposition ranging from H1, which is completely unconverted, to H10, which is completely converted. It is determined by squeezing a peat sample in the hand; criteria are described below.
Water table	(i) The upper surface of groundwater or that level below which the soil is saturated with water. (ii) groundwater surface or elevation at which the pressure in the water is zero with respect to atmospheric pressure.
Weathering	The physical and chemical disintegration, alteration and decomposition of rocks and minerals at or near the earth's surface by atmospheric agents.
Wetland	Land having the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation and various kinds of biological activity which are adapted to the wet environment.
Whaleback	A rock formation shaped like the back of a whale.