ANNEX V

SOILS BASELINE REPORT FOR THE JAY PROJECT

SOILS BASELINE REPORT FOR THE JAY PROJECT

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September 2014

Table of Contents

Maps

Tables

Appendices

Abbreviations

Abbreviation	Definition
BSA	baseline study area
$CaCO_3$	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
CEC	cation exchange capacity
CSQG	Canadian Soil Quality Guideline
Dominion Diamond	Dominion Diamond Ekati Corporation
E1	Esker Complex
EDIS	Existing Disturbance
Ekati Mine	Ekati Diamond Mine
e.g.,	for example
ELC	Ecological Landscape Classification
et al.	and more than one additional author
GPS	global positioning system
i.e.,	that is
LiDAR	Light Detection and Ranging
M1	Mineral-1
M2	Mineral-2
M3	Mineral-3
M4	Mineral-4
n/a	not applicable
NWT	Northwest Territories
Project	Jay Project
SAR	sodium adsorption ratio

Units of Measure

Unit	Definition
%	percent
°C	degrees Celsius
<	less than
>	greater than
cm	centimetre
dS/m	decisiemens per metre
ha	hectare
km	kilometre
km^2	square kilometre
m	metre
meq	milliequivalent
mg/kg	milligrams/kilogram
mg/kg dw	milligrams/kilogram dry weight
pH	potential of hydrogen; a quantitative measure of the acidity or basicity

1 INTRODUCTION

1.1 Background and Scope

Dominion Diamond Ekati Corporation (Dominion Diamond) is a Canadian-owned and Northwest Territories (NWT) based mining company that mines, processes, and markets Canadian diamonds from its Ekati Diamond Mine (Ekati Mine). The existing Ekati Mine is located approximately 200 kilometres (km) south of the Arctic Circle and 300 km northeast of Yellowknife, NWT (Map 1.1-1).

Dominion Diamond is proposing to develop the Jay kimberlite pipe (Jay pipe) located beneath Lac du Sauvage. The proposed Jay Project (Project) will be an extension of the Ekati Mine, which is a large, stable, and successful mining operation that has been operating for 16 years. Most of the facilities required to support the development of the Jay pipe and to process the kimberlite currently exist at the Ekati Mine. The Project is located in the southeastern portion of the Ekati claim block approximately 25 km from the main facilities and approximately 7 km to the northeast of the Misery Pit, in the Lac de Gras watershed (Map 1.1-2).

This Soils Baseline Report is one component of a comprehensive environmental and socio-economic baseline program to collect information about the natural and socio-economic environment near the Project. This report describes characteristics and existing conditions of soils in the baseline study area (BSA). The BSA was selected to encompass both the existing mine site and the area that contains the potential new development. This boundary was defined so that baseline information for both existing and potential development areas is presented in this report. Baseline soil data are required to provide an evaluation of reclamation suitability of soils in undisturbed areas, permafrost potential, and soil susceptibility to erosion. Soil data and information are also used to determine the sensitivity of soils to acid deposition (e.g., from oxides of sulphur and oxides of nitrogen emissions). This baseline report also provides supporting information for other baseline components, such as vegetation, wildlife, and traditional and non-traditional land use. The following sections include data and information collected during the 2013 baseline survey and a review of current literature.

1.2 Objectives

The objectives of the soils baseline were:

- to classify soils at representative locations the BSA;
- to develop a reconnaissance soil map to describe soil distribution within the BSA;
- to describe existing soil properties, quality, and quantity within the BSA;
- to determine baseline soil chemistry and metal concentrations;
- to evaluate soil sensitivities and reclamation suitability; and,
- to evaluate the potential for the occurrence of permafrost in the BSA.

LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- ALL-SEASON ROAD
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- TREELINE
- WATERCOURSE
- WATERBODY

150 0 150

SCALE 1:6,000,000 KILOMETRES

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
PROJECTION: CANADA LAMBERT CONFORMAL CONIC

DOCUMENT

SOILS BASELINE REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF THE JAY PROJECT

Golder Associates

PROJECT		13-1328-0041	FILE No. B_JC_Soils_004_GIS	
DESIGN	ANK	29/01/14	SCALE AS SHOWN	REV. 0
GIS	NS	10/09/14	MAP 1.1-1	
CHECK	CG	10/09/14		
REVIEW	SM	10/09/14		

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LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- KIMBERLITE PIPE
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

SOILS BASELINE REPORT

3 0 3
SCALE 1:150,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

EKATI PROPERTY MAP

Golder Associates

PROJECT		13-1328-0041	FILE No. B_JC_Soils_005_GIS	
DESIGN	SM	12/08/14	SCALE AS SHOWN	REV 0
GIS	ANK	10/09/14	MAP 1.1-2	
CHECK	CG	10/09/14		
REVIEW	SM	10/09/14		

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To meet these objectives, the Soils Baseline Report has been organized into the sections described below:

- **Section 1.4** provides the rationale for selecting the BSA spatial boundary and a description the BSA.
- **Section 2** provides detailed descriptions of the sampling methods for collecting baseline soil data including soil chemistry (i.e., soil quality); soil classification and mapping processes; and criteria for determining soil sensitivities, including erosion, acidification, and compaction.
- **Section 3** provides qualitative and quantitative information on general soil conditions in the BSA, as well as a discussion on the extent of permafrost. A discussion on soil erosion sensitivity, acidification sensitivity, permafrost potential, compaction sensitivity, soil metal chemistry, and reclamation suitability in the BSA is also provided.
- **Section 4** provides a summary of the results presented in the Soils Baseline Report.

1.3 Summary of Reclamation Studies

Numerous reclamation studies have been completed at the Ekati Mine (Table 1.3-1). The revegetation research programs have been completed to support the reclamation goals in the Reclamation and Closure Plan.

Table 1.3-1 Summary of Recent Reclamation Studies Applicable to Soils

Report	Description	Reference
Ekati Diamond Mine Revegetation Research Projects - 2004	• Processed kimberlite tailings reclamation research program, results of 2004 research. The first field studies were initiated in 2000. • Progressive reclamation sites were evaluated and included the Airstrip Esker, Fred's Channel, Culvert Camp, the topsoil stockpiles, and the till/lake sediment storage areas. • Chemical and physical properties of the stockpiled topsoil in Koala, Misery, and Beartooth stockpiles presented. • Preliminary results of the revegetation of salvaged glacial till/lake sediment mixtures show that materials high in glacial till appear to be more suitable for site reclamation. Surface compaction appears to be a major factor limiting plant establishment and growth in mixtures containing a high proportion of lake sediment. • Growth materials, including surface tundra soils, glacial till and lake sediment have been salvaged and stockpiled for future use in site reclamation. Site contouring, landscaping techniques and different methods of enhancing plant establishment are being assessed on an operational basis.	Martens (2005)
Ekati Diamond Mine Revegetation Research Projects - 2008	• Monitoring of progressive reclamation sites in 2008 included three topsoil stockpiles (Koala, Beartooth and Misery), Panda lake sediment storage area, Old Camp road, Fred's Channel, Culvert Camp and South Airport Esker. All sites were stable. • Establishment of plant cover on lake sediment has proved difficult and results have been poor, due in large to the poor physical characteristics of this material. • Construction Rock Pad Reclamation Study in 2008. Discussion of soil properties from growth media in reclamation areas at Old Camp Road and Culvert Camp.	Martens (2009)

Table 1.3-1 Summary of Recent Reclamation Studies Applicable to Soils

Report	Description	Reference
Ekati Diamond Mine Revegetation Research Projects - 2009	• Rock Pad Reclamation Study continued in 2009. Soil characteristics of topdressing obtained from stockpiles for Rock Pad Reclamation research before application of fertilizer and seed. • Study assessed methods and procedures that optimize benefits from the salvaged growth materials that include best equipment to use and placement techniques. The study goals were to assess plant establishment and growth on different growth materials applied as a top dressing or in pockets.	Martens (2010)
Ekati Diamond Mine Revegetation Research Projects - 2010	• Monitoring of the progressive reclamation sites in 2010 included three topsoil stockpiles (Beartooth, Fox and Misery), Paul Lake and Tercon Laydown areas, Culvert Camp. All sites were stable. • Rock Pad Reclamation Study continued in 2010. Beartooth, Fox, and Misery stockpile soil analyses results compared with 2004 to 2010 results.	Martens (2011)
Ekati Diamond Mine Revegetation Research Projects - 2011	• Monitoring of the progressive reclamation sites in 2011 included the Airstrip, South Airstrip Esker, Fred's Channel, the Panda/Koala Waste Rock Storage Area and the Fox Portal reclamation study site. • The Fay Bay overflow was stable with no evidence of surface erosion. • The benefits of surface roughening, produced by deep-ripping, were evaluated in the topdressings with lower soil moisture holding ability (i.e., lake sediment and glacial till).	Martens (2012)
Ekati Diamond Mine Revegetation Research Projects - 2012	• Amelioration work at Culvert Camp, Fred's Channel, and Esker South to provide more favourable site conditions for establishment and growth of plant cover on sites with coarse grained substrate. • The Culvert Camp portion of the site was deep ripped to increase surface roughness to improve soil moisture conditions and provide more favourable microsites. • At Fred's Channel and Esker South, organic material that had been stockpiled was spread out adjacent to the stockpile and incorporated in the sand and gravel substrate to enhance site conditions for revegetation. • Monitoring of soil characteristics at progressive reclamation sites (Old Camp Road, Culvert Camp, Misery Topsoil Stockpile, Koala Topsoil Stockpile and Fay Bay). • A Substrate Materials Assessment was undertaken as part of the Rock Pad Reclamation Study. – Topdressing ▪ Coarse kimberlite was found to be unsuitable as a growth material. ▪ Surface-roughened glacial till topdressing supported the greatest grass and legume cover followed closely by the topsoil topdressing. ▪ Mixing of lake sediment with topsoil during construction of the topsoil-over-lake-sediment topdressing treatment has reduced quality as a growth medium. – Surface Treatment ▪ Surface roughening generally increased seedling survival and annual growth. ▪ Greatest benefits of surface roughening were realized in the lake sediment and glacial till topdressings, where soil moisture is most limiting because of low organic matter content.	Martens (2013)

1.4 Regional Setting and Study Area

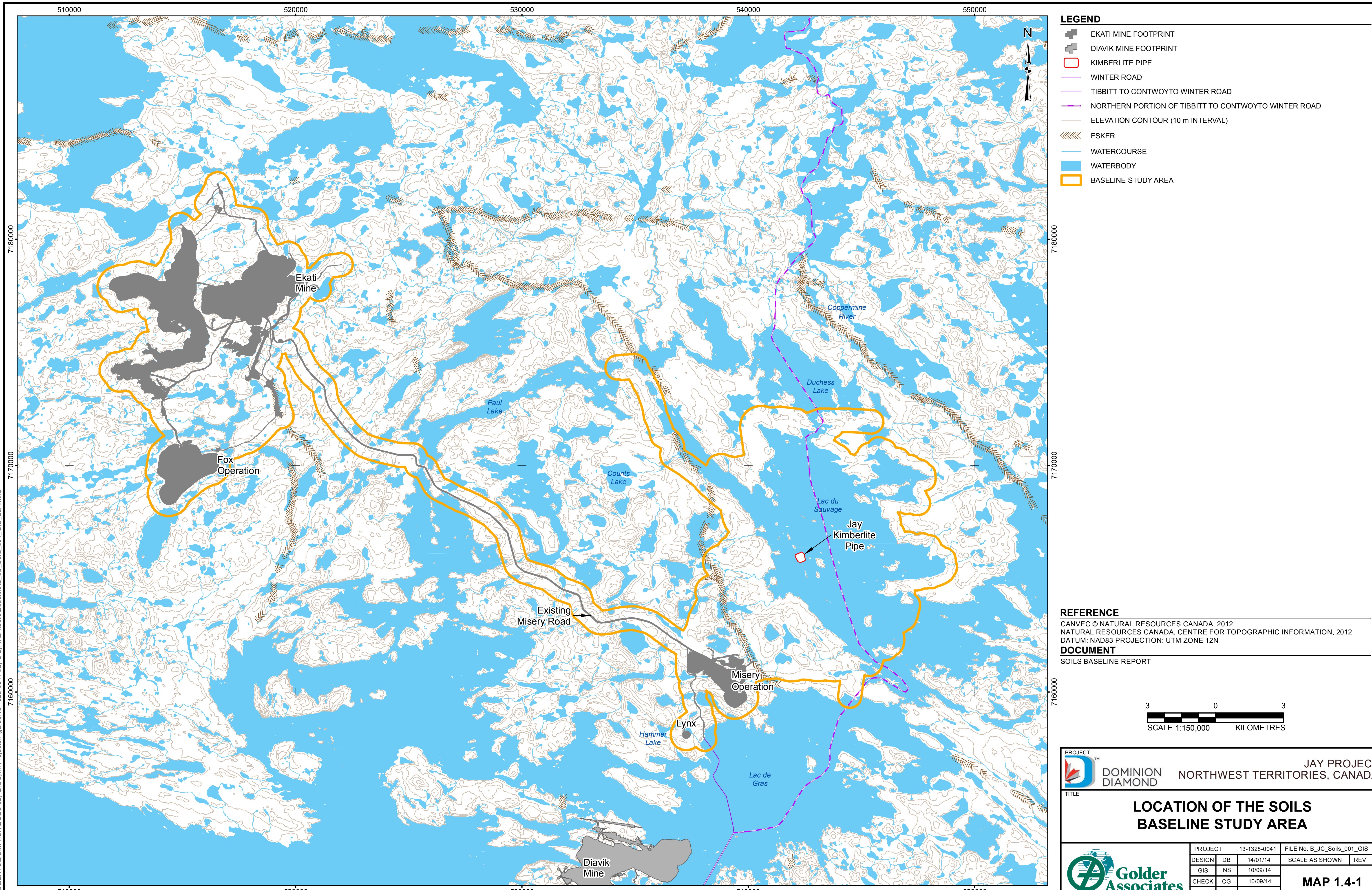
1.4.1 Regional Terrain and Eskers

The Project lies within the northwestern Canadian Shield physiographic region, which is characterized by rolling hills and low-relief terrain controlled by the abundant, near-surface, resistant Precambrian rock. The region is dominated by rolling terrain, with terrain elevations rising up to 100 metres (m). The regional terrain has been strongly influenced by glaciations, with glaciers flowing in a variety of directions during the Quaternary period. Deglaciation involved a general east-northeasterly retreat of glacial ice and abundant supply of meltwater that influenced the resulting regional terrain through deposition and erosion.

Esker and kame terrain features are common in the region, and were formed by glaciofluvial processes associated with the transport and deposition of coarse material by glacial meltwater. These landforms are composed of well-sorted sand and gravel. Areas of rolling terrain with ridges and hills that compose much of the region are associated with glacial till/morainal deposition. Glacial till deposits are typically shallow, and consist of heterogeneous, sandy texture material that has been deposited directly by the glacier by mechanical processes or melt-out. Lacustrine plains are gently sloping areas associated with lakes and comprise a small portion of the region. Lacustrine terrain features are composed of silty and gravelly sands.

1.4.2 Study Area Selection

To quantify baseline conditions, a BSA was defined for soils. The BSA is approximately 236 square kilometres (km^2) (23,578 hectares [ha]) and includes the existing Ekati Mine plus the Project footprint and a 500 m buffer (Map 1.4-1). The BSA was selected to encompass both the existing mine site and the area that contains the potential new development so that this information can be used in support of the assessment of potential Project effects on soils.



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The BSA is within the headwaters of the Coppermine River drainage basin and is entirely within the Tundra Shield Low Arctic (south) Level III Ecoregion of the Tundra Shield Level II Ecoregion in the Northwest Territories (ECG 2012). The BSA is characterized by undulating to rolling terrain, exposed bedrock outcrops, and northwest to southeast trending ridge features, known as eskers. Brunisolic, Gleysolic, and Regosolic soils have developed on the extensive till and outwash deposits, with Cryosolic soils dominating the region. Peat polygons, non-sorted circles, frost-shattered bedrock, and heaving of the active layer are evidence of continuous permafrost, reflecting the influence of a mean annual temperature of approximately -9 degrees Celsius (°C) (ECG 2012).

The BSA is situated on a transitional area between the boundaries of the Level IV Point Upland Ecoregion and the Level IV Contwoyto Upland Ecoregion contained within the Tundra Shield Low Arctic (south) Level III Ecoregion (ECG 2012). Elevations within these two ecoregions range from approximately 400 to 500 m above sea level (ECG 2012). The boundary between the Point Upland Ecoregion and the Contwoyto Upland Ecoregion separates the BSA into eastern and western sections along the western edge of Lac du Sauvage.

The western portion of the BSA occurs within the Point Upland Ecoregion that is characterized by a rugged landscape dominated by exposed bedrock with extensive boulder tills and patches of dwarf-shrub and rock lichen communities. Frost-shattered boulder till plains occur among the large exposed areas of fractured and ice-scoured bedrock. Bare bedrock exposures that dominate the ecoregion do not have soil development. Permafrost is continuous, and Turbic and Static Cryosolic soils have developed on the till veneers that overlie the bedrock. Organic Cryosol areas associated with the wetlands and high-centre peat polygons occur in low-lying areas (ECG 2012).

The Contwoyto Upland Ecoregion encompasses the eastern portion of the BSA. The ecoregion includes deposits of level to hummocky bouldery till with nearly continuous shrub cover. The underlying Precambrian bedrock outcrops are overlain with till hummocks and bouldery till veneers and blankets. The bedrock outcrops exist as scattered ice-scoured and frost-shattered knobs and hills (ECG 2012). Small eskers and kame deposits are scattered throughout the region. Permafrost is continuous; non-sorted circles are the most prominent evidence of permafrost. Turbic and Static Cryosolic soils have developed on the till hummocks, veneers and blankets, and glaciofluvial influenced eskers and kames. Cryosolic soils are characteristic of deep, well-drained, coarse textured landforms, while Organic Cryosolic soils are associated with low-lying wetlands (ECG 2012).

2 METHODS

2.1 Field Program

A review of existing soil information for the BSA was undertaken in both the pre-planning and interpretation stages of this baseline. As no previous soil mapping had been established for the BSA, reconnaissance level surveys were necessary to identify common soil subgroups and terrain features that could be used to delineate map units in the area.

Within the BSA, soil surveys were completed at survey intensity level four (broad reconnaissance level; one survey location per 100 to 1,000 ha). Representative soil survey inspection sites were located primarily along or adjacent to the location of the proposed Jay Pit Haul Road, proposed Project infrastructure (e.g., Jay Waste Rock Storage Area) and along the perimeter of Lac du Sauvage.

Field inspections were conducted from August 28 through September 1, 2013, using helicopter and foot access. Soil characteristics were documented at representative locations using the methods outlined by the Expert Committee on Soil Survey (Agriculture Canada 1982) and the Mapping System Working Group (Agriculture Canada 1981) to support the classification and mapping of soils in the BSA (Section 2.2). Final selection of inspection sites in the field was based on perceived changes in drainage and vegetation that reflected soil conditions. Locations of soil inspection sites were recorded with a Global Positioning System (GPS) unit.

Mineral soil test pits were excavated using a shovel and Dutch auger up to a maximum depth of 1 m, or to “auger refusal” if ground ice or gravelly or stony contacts were encountered. Organic soils were examined using a Dutch auger to the depth of peat plus 0.2 m into the underlying mineral material to a maximum depth of 2.2 m. Data collected at each site included horizon designation, colour, texture, structure, consistency, drainage class, surface stoniness, volume of coarse fragments, parent material, landform, slope position, slope class, slope length, and vegetation cover (Agriculture Canada 1981, 1982).

Soil samples of representative soil profiles identified in the BSA were collected from 28 sites during the 2013 field program and analyzed to determine baseline soil quality. Samples were collected from each discrete soil horizon. Samples were not collected from soil horizons that were less than 5 centimetres (cm) thick, had excessive stones or boulders, or were frozen, as it was impractical to obtain an adequate quantity of soil sample in these circumstances. Once collected, soil samples were placed in labelled, resealable plastic bags and kept cool until submission to the ALS Laboratory Group in Saskatoon, Saskatchewan. Soil samples were analyzed for all or some of the following chemical parameters:

- potential of hydrogen (pH) and electrical conductivity;
- plant available chloride, calcium, potassium, magnesium, and sodium;
- sodium adsorption ratio;
- cation exchange capacity (CEC);
- percent saturation;
- inorganic carbon; and,
- calcium carbonate equivalent.

Soil was also collected from the upper soil layer to measure baseline soil metal concentrations at the 28 sample locations. Where soils were classified as upland mineral soils (e.g., Brunisolic soils), a sample of the upper mineral horizon was collected for metal analysis. In soils with surface peat layers greater than 30 cm thick (e.g., peaty Cryosols and Organic soils), the peat layer was collected and analyzed for metals (including metalloids and non-metals).

A quality assurance/quality control program was carried out to maintain confidence in data collection, data entry, and data analysis. Each datasheet was checked in the field to confirm that all data fields were completed. Data entry was evaluated for errors or omissions by reviewing all the datasheets to confirm that the electronic database accurately reflected field observations. All results tables for chemical analyses were checked for transcription errors. All calculations were reviewed to check that the correct formulae, procedures, and data sources were used.

2.2 Soil Classification and Mapping

Soils were classified to the subgroup level according to *The Canadian System of Soil Classification* (SCWG 1998). Soil mapping was completed at a survey intensity level four following the guidelines outlined in *A Soil Mapping System for Canada: Revised* (Agriculture Canada 1981). Soil mapping was undertaken by correlating vegetation polygons with soil and landform types. Soil mapping initially involved the correlation of field soil classification observations with mapped Ecological Landscape Classification (ELC) map units. Vegetation mapping used Landsat Thematic Mapper satellite imagery (25 m by 25 m resolution) and air photo interpretation (Golder 1998) to classify vegetation units for the ELC map for the BSA (Vegetation Baseline Report [Annex VI], Section 2.1). Information obtained from Light Detection and Ranging (LiDAR) imagery was also used to identify general relief and changes in terrain within the vegetation map units. Final soil map units were derived by applying the principles of geomorphology and surficial geology in combination with vegetation patterns.

Soils were grouped into seven soil map units based on landscape features, topography, relief, drainage, amount and extent of bedrock and boulder, and soil types (soil subgroups) associated with these features. The primary characteristics used to group soil types into map units were dominant soil texture and parent material, site drainage, soil subgroup, and terrain (slope and surface expression). No published soil surveys exist for the BSA; therefore, soil map unit names were assigned based on the dominant parent material (e.g., mineral), or dominant landform (e.g., esker) within the map unit area.

Due to the coarse resolution of the ELC data, the extent of the BSA and the reconnaissance level soil survey, many soil map units include both mineral and organic soils. Soil subgroups within map units are defined as dominant, co-dominant, or sub-dominant. All map units may contain inclusions of soil types not described in the map unit, as inclusions do not represent the dominant soil type.

Existing Disturbance was mapped based on visual identification of areas modified by human activity and included the infrastructure associated with the existing Ekati Mine. Existing water management areas and small sections of undisturbed soil within the mine footprint were also mapped as disturbances.

2.3 Permafrost Potential

Permafrost is defined as permanently frozen soil or rock and incorporated ice and organic material (peat) that remains at or below 0°C for a minimum of two years due to natural climatic factors (van Everdingen 2005). The distribution and thickness of permafrost is influenced by factors including climate, topography, peat thickness, winter snow accumulation, hydrology, and subsurface geology. Peat thickness, vegetation cover, micro-topography (i.e., presence of hummocks), and moisture content are important variables in predicting the presence of permafrost (Williams and Burn 1996).

Permafrost soils are sensitive to ground disturbances as changes to surface materials can alter the soil thermal regime, which can result in soil warming to a greater depth, and cause persistent ice to melt (Hayhoe and Tarnocai 1993). The melting of permafrost can result in differential thaw settling, slumping, and increased wind and water erosion potential (Burgess and Harry 1990; Hayhoe and Tarnocai 1993). The potential effects of disturbance on permafrost soil depends on soil ice content, soil type, drainage, and vegetative cover. Organic soils in wetlands are particularly sensitive to disturbance and melting of ice because of their low bulk densities and potentially high ice content (Magnusson and Stewart 1987). However, depressional topography, high moisture content, dense vegetation cover, thickness of snow cover, and thickness of surface organic matter can have an insulating effect on permafrost (i.e., keep it frozen) (Judge 1973; Tarnocai 1984; Zoltai 1995; Williams and Burn 1996).

Permafrost potential was assigned to the soil types within the BSA. Permafrost potential ratings for each soil type were assigned based on soil texture and drainage observed during the field program (Table 2.3-1). Location of the Project with respect to the permafrost zone in which it occurs was also considered. In addition, permafrost conditions within the Ekati Mine footprint were examined through a number of geotechnical investigations carried out since 1998. These results are discussed in the Permafrost Baseline Report (Annex IV), which confirms that permafrost is present in the BSA. Additional investigations of permafrost conditions for the Project will be carried out in 2014 (Annex IV).

Table 2.3-1 Criteria for Determining Permafrost Potential

Soil Texture	Drainage	Permafrost Potential
Coarse - sand, loamy sand, sandy loam	Very Rapid	Low
	Rapid	Low
	Well	Low
	Moderately Well	Low
	Imperfect	Moderate
	Poor	Moderate
	Very Poor	High
Medium - loam, sandy clay loam, sandy clay	Very Rapid	Low
	Rapid	Low
Medium - loam, sandy clay loam, sandy clay	Well	Moderate
	Moderately Well	Moderate
	Imperfect	High
	Poor	High
	Very Poor	High

Table 2.3-1 Criteria for Determining Permafrost Potential

Soil Texture	Drainage	Permafrost Potential
Fine - clay loam, clay, silty clay, silty clay loam, silty loam, silt	Very Rapid	Low
	Rapid	Moderate
	Well	Moderate
	Moderately Well	High
	Imperfect	High
	Poor	High
	Very Poor	High

Sources: Adapted from Williams and Burn (1996) and Johnson et al. (2013).

2.4 Soil Sensitivities and Quality Ratings

The definition of soil quality encompasses physical, chemical, and biological characteristics used to determine overall soil health. Many indicators can be used to describe soil quality, including properties related to organic matter content (e.g., the carbon to nitrogen ratio) and soil texture. Changes to soil quality can be a result of soil erosion, compaction, admixing, changes to permafrost, and changes to soil chemistry. The extent of changes to soil quality varies depending on existing soil conditions and the sensitivity of a soil to change; methods for determining existing soil sensitivities are outlined in the following sub-sections.

2.4.1 Erosion Sensitivities

Soil erosion is one of the primary concerns for disturbed soils because the removal of vegetation cover exposes soil materials to wind and water. Depending on terrain and soil characteristics, with continuous exposure of soil to wind or rain, soil materials may be eroded, washed, or blown away, which may result in the loss of surface soil and a reduction in soil quality and the ability for soil to support vegetation.

Soil sensitivity to water and wind erosion were assigned to soil subgroups within the BSA. The approaches for determining water and wind erosion sensitivities are described in more detail in the following subsections.

2.4.1.1 Water Erosion

The sensitivity of soil to erosion by water is affected by soil texture, organic matter content, cohesiveness, rates of infiltration, topography, slope gradient, and vegetation cover (Cruse et al. 2001; Kuhn and Bryan 2004; Li et al. 2007). Finer textured clayey soils tend to be less prone to erosion by water than silty soils (TAC 2005), especially when the soil has been disturbed by freeze-thaw or human activity (Cruse et al. 2001). The higher permeability of sandy textured soils contributes to a lower potential for overland flow of water, thus decreasing the potential for soil erosion. Water erosion sensitivity can vary seasonally due to changes in infiltration potential from the presence or absence of frozen layers, residue cover, and extreme weather events. In areas where slope gradient and slope length increase, so too does the potential for soil erosion regardless of soil texture.

Determining soil erosion potential by water is based on methods described by the Transportation Association of Canada (TAC 2005). Water erosion ratings and potentials were assigned to soil subgroups within the BSA based on characteristics of soils and terrain (i.e., topsoil texture, slope length, and gradient) recorded during the field programs. The uppermost mineral soil horizon textures of soil subgroups identified were used to determine the water erosion rating (Table 2.4-1) as the first step in determining water erosion potential. Water erosion potential was then determined based on the water erosion rating, dominant slope class, and dominant slope length (Table 2.4-2). Water erosion potentials were then assigned to each soil subgroup within the BSA. Water erosion potentials are based on soils that have been disturbed and have not had mitigation applied.

Table 2.4-1 Criteria for Determining Water Erosion Rating

Soil Texture	Water Erosion Rating
Silt, silt loam, loam	High
Sandy loam, silty clay loam, sandy clay loam, silty clay, clay loam	Medium
Sandy clay, clay, heavy clay, loamy sand, sand	Low

Source: TAC (2005).

Table 2.4-2 Criteria for Determining Water Erosion Sensitivity

Slope Gradient	Water Erosion Rating[a]	Water Erosion Sensitivity	
		Slope Length	
		<70 m	>70 m
0% to 10%	Low	Low	Low
	Medium	Low	Moderate
	High	Moderate	High
10% to 20%	Low	Low	Moderate
	Medium	Moderate	High
	High	High	High
>20%	Low	Moderate	Moderate
	Medium	High	High
	High	High	High

Source: TAC (2005).

a) Determined from Table 2.4-1.

m = metre; % = percent; < = less than; > = greater than.

2.4.1.2 Wind Erosion

Soil sensitivity to erosion by wind is affected by soil properties, including texture, cohesiveness, moisture, and organic matter content (Dickinson et al. 1985; Campbell et al. 2002). Site characteristics that affect soil sensitivity to wind erosion include surface roughness, slope, topography, and plant cover. In general, coarse textured soils are more prone to wind erosion than finer textured soils because sandy textured soils typically do not have a well-developed soil structure (Coote and Pettapiece 1989). The lack of soil structure is due to limited soil aggregation or adhesion of the soil particles, which does not allow for the formation of larger and more stable soil aggregates that are less likely to be moved by wind. Dry sites with loose, coarse textured soils and smooth surfaces void of plant residues are most susceptible to wind erosion. Organic soils are typically less prone to wind erosion, unless they have dried out or are disturbed (Campbell et al. 2002). Wind erosion of organic soils is a function of the degree of peat decomposition; thus, the more highly decomposed (humic) the organic material is, the greater the risk for wind erosion when dry.

Wind erosion ratings were assigned to the soil subgroups identified in map units in the BSA. Mineral soil sensitivity was based on the uppermost mineral soil horizon texture and a dimensionless index described by Coote and Pettapiece (1989) (Table 2.4-3). Wind erosion ratings for peaty phase and Organic soils were assigned based on degree of peat decomposition based on criteria described by Campbell et al. (2002) (Table 2.4-3).

Table 2.4-3 Criteria for Determining Wind Erosion Sensitivity

Soil Texture	Wind Erosion Rating
Very fine sand, sand, coarse sand, loamy sand, gravelly sand, humic	High
Sandy loam, loam, silty loam, sandy clay loam, sandy clay, mesic/folic	Medium
Silt, silty clay loam, clay loam, silty clay, clay, heavy clay, fibric	Low

Sources: Adapted from Coote and Pettapiece (1989) and Campbell et al. (2002).

2.4.2 Sensitivity to Acidification

The sensitivity of a soil to acid inputs is a measure of the decrease in soil pH that a soil would likely experience from a given addition of acid. Soils can have High, Medium, or Low sensitivity ratings. The ratings are based on the sensitivity to loss of basic cations (primarily calcium, magnesium, and potassium), sensitivity to acidification, and sensitivity to solubilization of aluminum.

The sensitivity of mineral soils to acid deposition was evaluated using the chemical criteria published by Holowaychuk and Fessenden (1987) (Table 2.4-4). In general, neutral to alkaline soils (pH values greater than 6.0) have a lower sensitivity to acidification because of an increased buffering capacity (Holowaychuk and Fessenden 1987).

Upland soil types, including Brunisolic, Regosolic, and Cryosolic soils, were rated for sensitivity to acidification based on the pH and CEC values from samples obtained from the top 20 cm of mineral soil and the criteria in Table 2.4-4. When two discrete soil horizons were identified within the top 20 cm, the pH and CEC values for each horizon within this depth were averaged for the location and used for determining the acidification sensitivity. Where the uppermost soil horizon was thicker than 20 cm, the pH and CEC values for this horizon was used for determining the rating.

Table 2.4-4 Criteria for Rating the Sensitivity of Mineral Soils to Acidic Inputs

Cation Exchange Capacity (meq/100 g)	pH	Overall Sensitivity Rating
<6	<4.6 to 6.5	High
	>6.5	Low
6 to 15	<4.6	High
	4.6 to 6.0	Medium
	>6.0	Low
>15	<4.6	High
	4.6 to 5.5	Medium
	5.6 to >6.0	Low

Source: Adapted from Holowaychuk and Fessenden (1987).

meq/100 g = milliequivalents of ammonium cation (NH_4^+) adsorbed by 100 grams of dry soil; pH = potential of hydrogen, a quantitative measure of the aciditiy or basicity; < = less than; > = greater than.

The sensitivity rating for wetland soils, including Gleysolic, Organic, and peaty phase wetland soils (e.g., peaty Gleysolic Static Cryosols) is based on the type of wetland (i.e., bog, poor fen, moderate rich fen, or extreme rich fen) (Turchenek et al. 1998). These criteria are based on the pH, CEC, and percent base saturation of the surface layer of organic soil in each wetland type, as well as the pH and base cation content of the associated pore water (Turchenek et al. 1998).

In general, moderate rich and extreme rich fens (moderate to high nutrient status and neutral pH or higher [greater than pH 6]) tend to be least susceptible to acidification (Table 2.4-5). In moderate and extreme rich fens, water supply is from surface water or groundwater, which is typically mineral rich and neutral in pH. Fens are not hydrologically isolated, and therefore receive mineral-rich surface water or groundwater, which influences their pH and nutrient content. Due to the incoming water, the acid buffering capacity is replenished and water is eventually discharged from the wetland through lateral flow. Organic soils that occur in moderate and extreme rich fens are least susceptible to acidification and, therefore have a Low sensitivity rating (Table 2.4-5).

Table 2.4-5 Criteria for Rating the Sensitivity of Wetland Soils to Acidic Inputs

Wetland Type	Sensitivity to: Base Loss	Sensitivity to: Acidification	Overall Sensitivity Rating
Extreme rich fen	Low	Low	Low
Moderate rich fen	Low to Medium	Low	Low
Bog and poor fen	Medium to High	Medium	Medium

Source: Turchenek et al. (1998).

Bogs are hydrologically isolated; therefore, these wetlands mainly get their water from precipitation and are very low in nutrients and are acidic. In addition, a larger volume of peat material is present at the surface of bogs that can react with incoming acidity. Poor fens, although slightly higher in nutrient status and pH than bogs, represent an intermediate between bogs and rich fens. Peat accumulation in poor fens is ongoing, and the influence of underlying mineral material is reduced compared to richer fen types. In poor fens, there is less material available to react with incoming acidity, and buffering capacity may not be replenished as quickly through water inputs. Organic soils that occur in bogs and in poor fens are most susceptible to acidification, and therefore have a Medium sensitivity rating (Table 2.4-5).

Wetland soil types, which include Gleysolic, peaty phase Crysolic, and Organic soils, were rated for acidification sensitivity based on the wetland type that they were associated with. Mineral soil properties of Gleysolic soils were considered.

2.4.3 Compaction Sensitivity

Soil capability to support vegetation can be reduced if soil becomes compacted. Soil compaction can also influence plant establishment and subsequent plant growth. Compaction of topsoil and subsoil can lead to a decrease in long-term productivity because of an increase in soil bulk density and soil strength, reductions in soil aeration (i.e., soil oxygen), reduced water infiltration and available soil water, restricted root growth, reductions in soil microbiological activity, and lowered nutrient uptake by vegetation (Blouin et al. 2008; Heuer et al. 2008).

Generally, well-drained, coarse and medium textured soils (loams, sandy loam, loamy sand, loam) are less prone to compaction than fine textured soils (silty clay loam, silty clay, clay loam, and clay). However, sensitivity to compaction can change based on soil moisture conditions (Lewis et al. 1989). For example, loamy-textured soils under wet conditions are more prone to compaction than the same soil texture under dry conditions. In finer textured soil (i.e., clay), saturated conditions may exist due to poor drainage (i.e., the smaller soil pore sizes related to these textures can reduce water movement through the soil), and as soil moisture increases, so too does soil sensitivity to compaction.

Compaction ratings for the soil types in the BSA were determined using the criteria outlined in Table 2.4-6, using textures observed during the field program and prevailing moisture conditions. The majority of soils were rated using moist conditions. Soils occurring at toe slopes and in depressions (wetlands) were assigned compaction ratings based on soil texture under wet (saturated) soil conditions. Organic soils and bedrock were not assigned compaction ratings: however, the depth of surface organic material can affect the rating because it can cushion the surface mineral horizon.

Table 2.4-6 Criteria for Determining Compaction Sensitivity

Soil Texture	Compaction Rating[a]		
	Dry	Moist	Wet
Sandy (sand; loamy sand)	Low	Low	Moderate
Loamy (sandy loam; loam)	Low	Moderate	High
Silty (silt; silty loam)	Moderate	High	Very High
Clayey (sandy clay; silty clay loam; sandy clay loam; clay loam; silty clay; clay; heavy clay)	High	Very High	Very High

Source: Adapted from Lewis et al. (1989).

a) Based on a coarse fragment content of less than 35 percent (%) (if coarse fragment content is between 35% and 70%, loamy and silty are grouped together and compaction rating is Moderate, and clayey is High).

2.4.4 Soil Metal Chemistry

Chemical constituents of underlying bedrock and associated rock leachate have the potential to be present in the upper soil strata because of soil formation from bedrock parent material as well as upward leaching of metals from rock (Turk et al. 2012). Soil metal concentrations were measured to provide baseline soil metal concentrations for the soils in the BSA and to identify areas of naturally high metal concentrations, if present. Metals, metalloids, and non-metals analyzed were aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, uranium, vanadium, and zinc.

Measured metal concentrations were compared to the Canadian Council of Ministers of the Environment (CCME) Canadian Soil Quality Guideline (CSQG) for the Protection of Environmental and Human Health (CCME 2013). The CSQGs provide benchmarks for substances that, in the event they exceed the guidelines, may pose a risk to ecological or environmental health (including vegetation and wildlife). The CSQGs for residential/parkland areas were used as they are conservative and most appropriate for the area based on the current land use in the BSA.

Mean metal, metalloid, and non-metal concentrations, ranges, and standard deviations were calculated for the Cryosolic, Brunisolic, Regosolic, Gleysolic, and Organic soil orders in the BSA. For calculations of mean and standard deviations, where 50 percent (%) or less of the data were below detection limits, half of the detection limit value was used in calculations of mean and standard deviation. Where more than 50% were below the detection limits, calculations of mean and standard deviation were not completed. Results from one identified peaty Gleysolic Static Cryosol were included in the Organic group for mean calculations due to the thick peat layer (i.e., 38 cm).

2.4.5 Reclamation Suitability

The reclamation suitability of undisturbed soils in the BSA was evaluated to support salvage and reclamation planning, as construction activities will disturb new areas of soil and may include the removal and salvage of soil materials for use in subsequent reclamation activities. Undisturbed soil reclamation suitability ratings were determined by evaluating soil properties, including texture, coarse fragment content, and select soil chemistry parameters (Alberta Agriculture 1987).

Soils occurring in tundra habitat tend to be very thin and weakly developed. The Alberta Agriculture (1987) criteria reflect generic soil suitability for plant growth and soil handling characteristics. The eastern slopes region criteria were used as these were considered most applicable to soils in the BSA. The criteria for the eastern slopes consider the thin, sandy, and stony soils that occur in montane, sub-alpine, and alpine areas of the Rocky Mountains and are similar to soils occurring in the BSA (i.e., they support similar plant species). In addition, soil handling in the eastern slopes region is to salvage and replace one lift of material, which is the same approach as that used in Arctic environments and at the Ekati Mine. Currently at the Ekati Mine, substrates removed during site development, salvaged, and stockpiled include the upper most layers of tundra soils, which includes both mineral and organic materials.

Individual soil subgroups within the BSA were rated according to the suitability criteria outlined by Alberta Agriculture (1987). Soils in the BSA were rated as Good, Fair, Poor, or Unsuitable based on the criteria in Table 2.4-7. The pH values, salinity, sodicity, and saturation limits may vary depending on the plant species used for revegetation. These soil quality criteria do not include Organic soils; therefore, the rating “Organic” was used to designate these soils.

Reclamation suitability ratings for the undisturbed rooting zone material were determined from the soil characteristics of the uppermost mineral soil horizons in Brunisolic, Regosolic, Cryosolic, and Gleysolic soils. The thick organic layer associated with peaty Cryosolic soils and Organic soils identified in wetlands was rated as Organic. Mineral soil underlying peaty Cryosolic soil was considered, although mineral materials were generally deeper than the rooting zone. Mineral soil underlying Organic soils was not rated. The most limiting property of soil chemical or physical parameter was used to determine the final overall rating (Alberta Agriculture 1987).

Table 2.4-7 Criteria for Evaluating the Reclamation Suitability of Root Zone Material

Property	Good	Fair	Poor	Unsuitable
pH	5.0 to 6.5	4.0 to 5.0, 6.5 to 7.5	3.5 to 4.0, 7.5 to 9.0	<3.5 and >9.0
Salinity (dS/m)[(a,b)]	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[(b)]	<4	4 to 8	8 to 12	>12[(c)]
Saturation (%)[(b)]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Coarse fragments (% volume) where modal matrix texture is finer than sandy loam	<30	30 to 50	50 to 70	>70
Coarse fragments (% volume) where modal matrix texture is sandy loam or coarser	<15	15 to 30	30 to 50	>50
Texture	Loam, silty clay loam, sandy clay loam, sandy loam, fine sandy loam	clay loam, silty loam, very fine sandy loam, sandy clay, silty clay	loamy sand, sand, silt, clay, heavy clay	consolidated bedrock
Moist consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaCO_3$ equivalent (%)	<2	2 to 20	20 to 70	>70

Source: Alberta Agriculture (1987).

a) Measured as electrical conductivity.

b) Limits may vary depending on plant species to be used.

c) Materials characterized by a SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation is less than 100%.

pH = potential of hydrogen, a quantitative measure of the acidity or basicity; < = less than; > = greater than; dS/m = decisiemens per metre; SAR = sodium adsorption ratio; % = percent; $CaCO_3$ = calcium carbonate.

3 RESULTS

3.1 Field Program

During the baseline field program, 49 sites were surveyed in and adjacent to the BSA. Of the 49 sites surveyed, 32 sites were upland mineral soils, 2 were mineral soils found along the margins of wetlands (i.e., transitional areas), 3 were mineral soils found in wetlands, 8 were peaty phase soils in wetlands, and 4 were Organic soils (Map 3.1-1). Soils information for each survey site is available in Appendix A, Soils Data (Tables A-1 and A-2a).

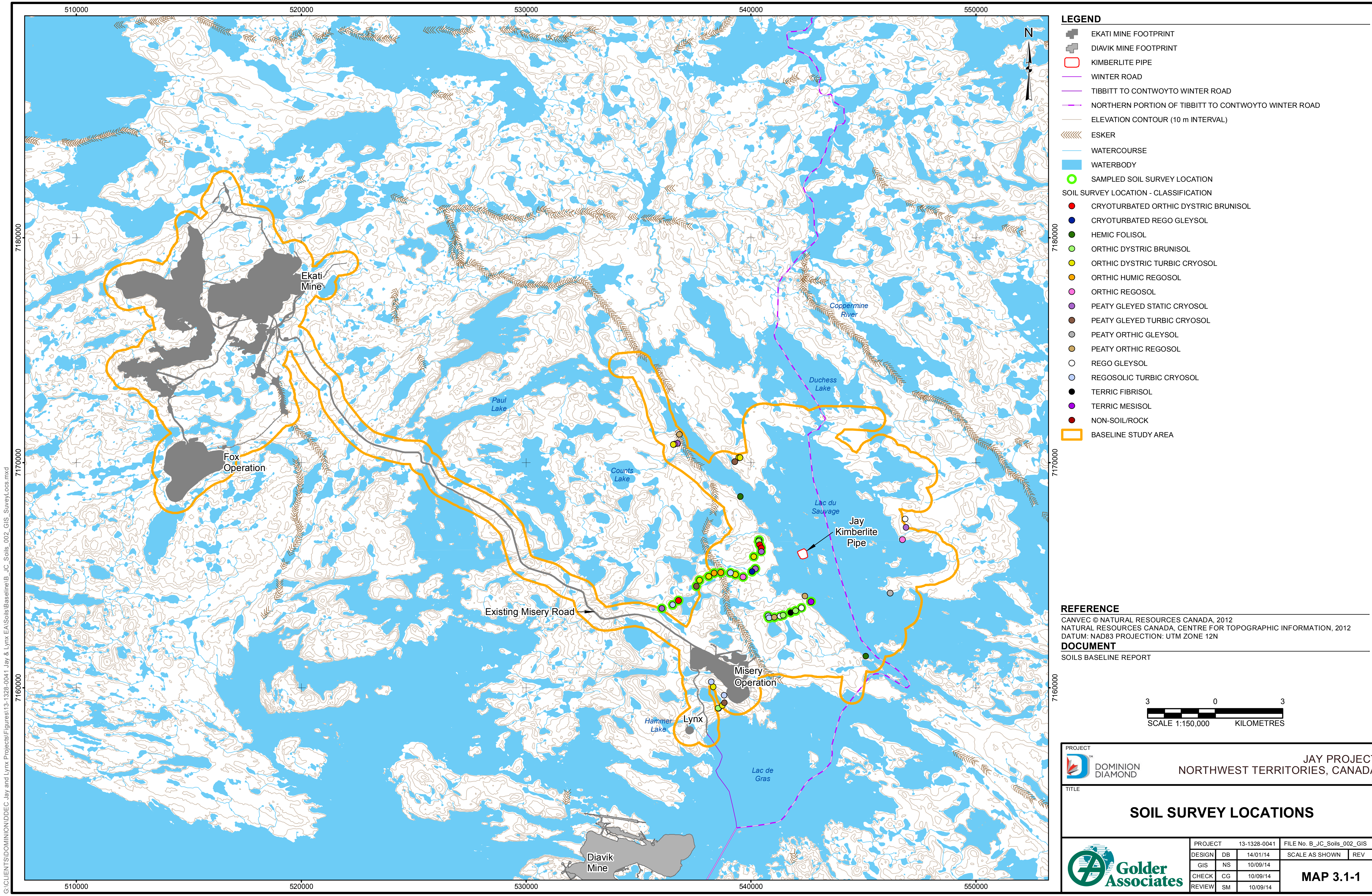
3.2 Soil Classification and Mapping

3.2.1 Soil Classification

Mineral soils identified during the baseline field program included Cryosolic, Brunisolic, Gleysolic, and Regosolic soils (Table 3.2-1; Map 3.1.1). Organic soils identified included subgroups within the Fibrisol, Mesisol, and Folisol great groups. One site was identified as bedrock (classified as a non-soil). Turbic Cryosolic soils were generally found at upland landscape positions, while peaty Static Cryosolic and peaty Turbic Cryosolic soils were generally found in wetlands. Brunisolic and Regosolic soils were found at upland landscape positions. Gleysolic soils were found in transition areas between upland and depressional landscape positions (i.e., wetlands) and in wetlands. Organic soils were found in wetlands.

Table 3.2-1 Summary of Soils Classified Within the Baseline Study Area

Soil Order	Soil Subgroup	Number of Locations
Cryosolic	Orthic Dystric Turbic Cryosol	9
	Regosolic Turbic Cryosol	6
	peaty Gleysolic Turbic Cryosol	5
	peaty Gleysolic Static Cryosol	3
Brunisolic	Orthic Dystric Brunisol	5
	cryoturbated Orthic Dystric Brunisol	3
Regosolic	Orthic Humic Regosol	2
	Orthic Regosol	3
	peaty Orthic Regosol	3
Gleysolic	cryoturbated Rego Gleysol	1
	Rego Gleysol	3
	peaty Orthic Gleysol	1
Organic	Hemic Folisol	2
	Terric Fibrisol	1
	Terric Mesisol	1
Non-soil	Bedrock	1
	Total	**49**



LEGEND
EKATI MINE FOOTPRINT
DIAVIK MINE FOOTPRINT
KIMBERLITE PIPE
WINTER ROAD
TIBBITT TO CONTWOYTO WINTER ROAD
NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
ELEVATION CONTOUR (10 m INTERVAL)
ESKER
WATERCOURSE
WATERBODY
SAMPLED SOIL SURVEY LOCATION
SOIL SURVEY LOCATION - CLASSIFICATION
CRYOTURBATED ORTHIC DYSTRIC BRUNISOL
CRYOTURBATED REGO GLEYSOL
HEMIC FOLISOL
ORTHIC DYSTRIC BRUNISOL
ORTHIC DYSTRIC TURBIC CRYOSOL
ORTHIC HUMIC REGOSOL
ORTHIC REGOSOL
PEATY GLEYED STATIC CRYOSOL
PEATY GLEYED TURBIC CRYOSOL
PEATY ORTHIC GLEYSOL
PEATY ORTHIC REGOSOL
REGO GLEYSOL
REGOSOLIC TURBIC CRYOSOL
TERRIC FIBRISOL
TERRIC MESISOL
NON-SOIL/ROCK
BASELINE STUDY AREA
N
510000
520000
530000
540000
550000
7180000
7170000
7160000
Ekati Mine
Fox Operation
Paul Lake
Counts Lake
Coppermine River
Duchess Lake
Lac du Sauvage
Jay Kimberlite Pipe
Existing Misery Road
Misery Operation
Lynx
Hammer Lake
Lac de Gras
Diavik Mine
REFERENCE
CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N
DOCUMENT
SOILS BASELINE REPORT
3 0 3
SCALE 1:150,000 KILOMETRES
PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA
TITLE
SOIL SURVEY LOCATIONS
Golder Associates
PROJECT 13-1328-0041 FILE No. B_JC_Soils_002_GIS
DESIGN DB 14/01/14 SCALE AS SHOWN REV 0
GIS NS 10/09/14
CHECK CG 10/09/14
REVIEW SM 10/09/14
MAP 3.1-1
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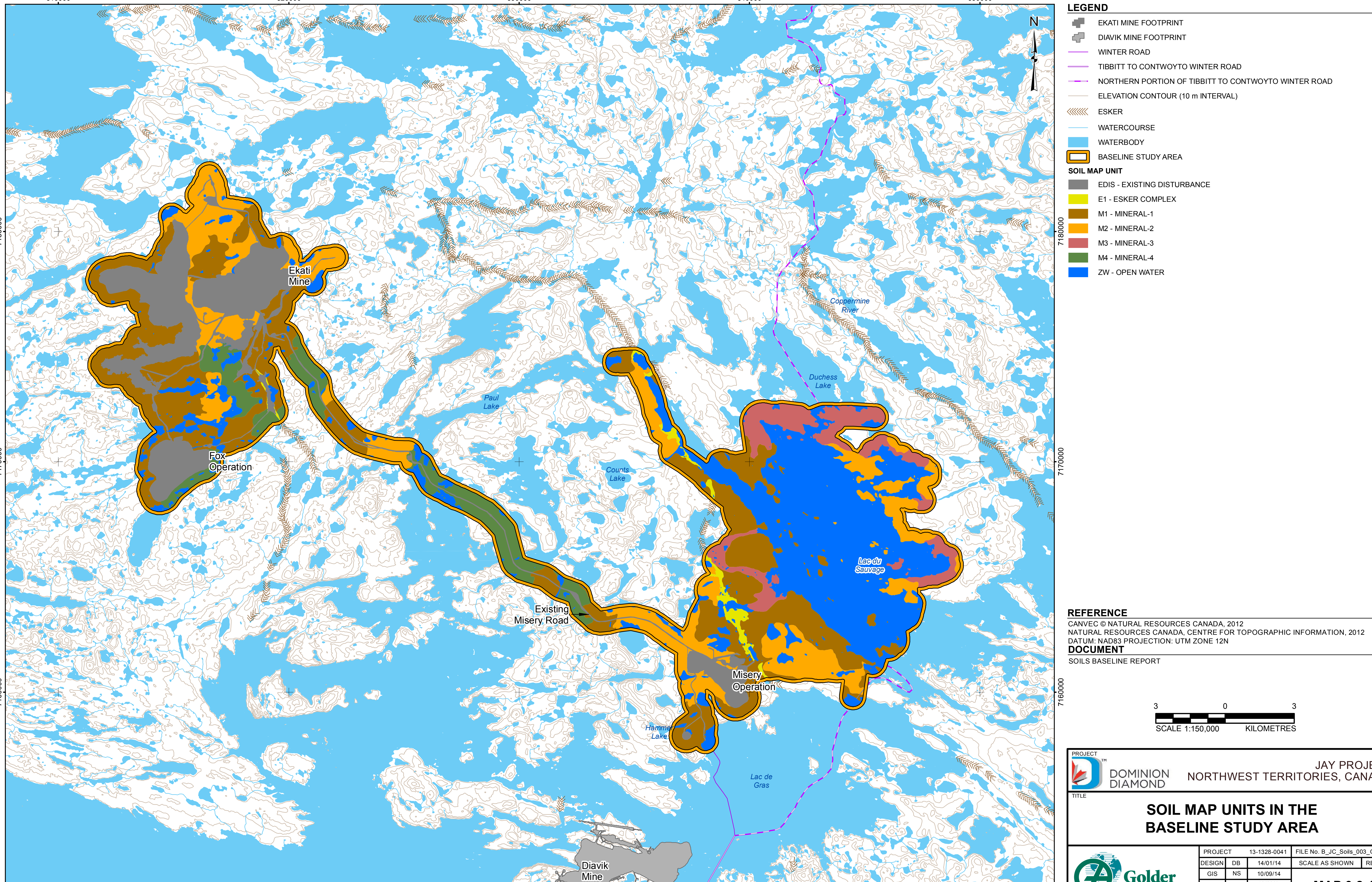
3.2.2 Soil Mapping

The BSA covers an area of approximately 23,578 ha. Seven map units have been defined and mapped for the BSA based on correlations of soil classification information collected at the representative soil survey locations with the ELC vegetation classes, aerial photographs, and landscape characteristics. The distribution and extent of each soil map unit within the BSA is illustrated in Map 3.2-1 and provided in Table 3.2-2.

The seven map units include five mineral soil map units (Esker Complex [E1], Mineral-1 [M1], Mineral-2 [M2], Mineral-3 [M3], and Mineral-4 [M4]), all of which capture the range of variability in soil subgroups and terrain present in the BSA. The Existing Disturbance (EDIS) map unit represents existing anthropogenic features, such as haul roads and mine facilities, and the Open Water map unit delineates areas of open or flowing water within the BSA. The soil map units included upland landscapes with varying degrees of bedrock exposure for well drained soils, low relief hummocky, depressional landscapes associated with wetlands with poorly drained peaty phase or Organic soils, and ridged landscapes for coarse, poorly developed soils.

The majority of the BSA comprises mineral soil map units; all map units may contain inclusions of wetland soils. The Open Water map unit encompasses the largest proportion of the BSA and covers 29% (Table 3.2-2). The M1 map unit encompasses the second largest proportion of the BSA and covers approximately 26%. The Esker Complex map unit covers the smallest area of the BSA (approximately 1% of the BSA). The EDIS map unit, which includes the existing Ekati Mine footprint, covers 15% of the BSA. Detailed descriptions of each map unit presented in Map 3.2-1 are provided below.

The resulting soil map should be viewed as a predictive model of possible soil distribution because soil map unit delineations are largely inferred from the interpretation of landscape features and ELC map units (Map 3.2-1). This information should not be applied for predicting site-specific characteristics without collecting additional field information.



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CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

SOILS BASELINE REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

SOIL MAP UNITS IN THE BASELINE STUDY AREA

Golder Associates

PROJECT		13-1328-0041	FILE No. B_JC_Soils_003_GIS
DESIGN	DB	14/01/14	SCALE AS SHOWN REV 0
GIS	NS	10/09/14	MAP 3.2-1
CHECK	CG	10/09/14	
REVIEW	SM	10/09/14	

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Table 3.2-2 Soil Map Units Within the Baseline Study Area

Map Unit Name	Map Unit Symbol	Area (ha)	Proportion of BSA (%)	Dominant, Co-dominant, and Sub-dominant Soil Subgroups in Map Unit
Esker Complex	E1	246	1	dominantly Orthic Regosols and Orthic Humic Regosols
Mineral-1	M1	6,104	26	co-dominantly Turbic Cryosols (Orthic Dystric and Regosolic) and cryoturbated Orthic Dystric Brunisols
				sub-dominant exposed bedrock and frost-shattered boulders
Mineral-2	M2	3,978	17	dominantly Turbic Cryosols (Orthic Dystric and Regosolic)
				sub-dominant exposed bedrock and frost-shattered boulders
Mineral-3	M3	1,376	6	co-dominantly peaty Gleysolic Static Cryosols, Rego Gleysols, and peaty Orthic Gleysols
				sub-dominant peaty Gleysolic Turbic Cryosols, Rego Gleysols, and Orthic Gleysols (peaty phase)
Mineral-4	M4	1,584	7	co-dominantly Turbic Cryosols (Orthic Dystric and Regosolic), cryoturbated Orthic Dystric Brunisols, and exposed bedrock or frost-shattered boulders
Existing Disturbance	EDIS	3,548	15	n/a
Open Water	**ZW**	6,741	29	n/a
Total	**n/a**	**23,578**	**100**	**n/a**

Note: Numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.

ha = hectare; % = percent; BSA = baseline study area; n/a = not applicable.

3.2.2.1 Mineral Map Units

3.2.2.1.1 Esker Complex

The E1 soil map unit covers approximately 246 ha (1%) of the BSA. The E1 soil map unit consists of excessively stony, rapidly drained Orthic and Orthic Humic Regosols developed on inclined and ridged (slopes 0% to 45%), and coarse textured (fine sand to gravelly sand) glaciofluvial material. Exposed mineral soil is common on crest, upper, and midslope positions. Minor amounts of Orthic Dystric Brunisols and cryoturbated Orthic Dystric Brunisols may occur in areas of gradual or nearly level slope. Peaty Orthic Regosols and gleyed variants occur sporadically at lower and toe slope positions.

3.2.2.1.2 Mineral-1

The M1 soil map unit covers approximately 6,104 ha (26%) of the BSA. The M1 soil map unit is co-dominated by very stony to excessively stony (3% to greater than 50% of ground surface covered) well-to-rapidly drained Turbic Cryosols (Orthic Dystric Turbic Cryosols and Regosolic Turbic Cryosols), and cryoturbated Orthic Dystric Brunisols developed on undulating (slopes 0% to 10%, locally up to 15%) coarse to moderately fine (sand to sandy loam) textured glacial till. Substantial amounts of the unit are occupied by exposed bedrock outcrops and boulders. Minor amounts of Orthic Dystric Brunisols and Orthic Regosols occur on shallow glacial till veneers at upper slope positions and in upper, mid, and lower positions on slopes greater than 5%. Shallow Organic soil (Terric Fibrisols, and Terric Mesisols) and Rego Gleysols, peaty Gleysolic Static Cryosols, and peaty Gleysolic Turbic Cryosols developed on coarse textured (loamy sand) glacial till and moderately fine and fine textured (sandy loam to silt) fluvial material occur sporadically in low and depressed drainage areas associated with patterned ground or drainage channels associated with boulders.

3.2.2.1.3 Mineral-2

The M2 soil map unit covers approximately 3,978 ha (17%) of the BSA. The M2 soil map unit consists dominantly of very to exceedingly stony (3% to 50% of ground surface covered), well-to-rapidly drained Orthic Dystric Turbic Cryosols and Regosolic Turbic Cryosols developed on undulating (slopes 0% to 10%, locally up to 30%), coarse to moderately fine (sand to sandy loam) textured glacial till. Substantial amounts of the unit are occupied by exposed bedrock outcrops and frost-shattered fragmental materials. Minor amounts of cryoturbated Orthic Dystric Brunisols and Orthic Regosols occur on shallow glacial till veneers at upper slope positions or in upper, mid, and lower positions on slopes greater typically than 5%. Non-stony, poor to imperfectly drained shallow Organic soils (Terric Fibrisols, Hemic Folisols), Gleysols (Rego Gleysol and peaty Orthic Gleysol), peaty Gleysolic Static Cryosols, and peaty Turbic Cryosols occur sporadically in low and depressed drainage areas associated with patterned ground or drainage channels associated with frost-shattered bedrock.

3.2.2.1.4 Mineral-3

The M3 soil map unit covers approximately 1,376 ha (6%) of the BSA. The M3 soil map unit consists dominantly of non-stony to moderately stony (0% to 3% of ground surface covered), very poor to poorly drained Gleysols and Static Cryosols (peaty Gleysolic Static Cryosols) developed on depressed to undulating (slopes 0% to 5%), moderately coarse to moderately fine (sandy loam to loam) textured glacial till. Substantial amounts of the unit consist of peaty Gleysolic Turbic Cryosols and Gleysols developed on moderately coarse to fine (loamy sand to silt) textured fluvial deposits occurring in low and depressed drainage areas associated with patterned ground and shallow Organic soils (Terric Fibrisols, Terric Mesisols, and Hemic Folisols) developed on sedge dominated wetlands and riparian areas. Peaty phases are common within this soil map unit, and exposed bedrock outcrops and boulders compose approximately 20% of the unit. Gleyed variant Turbic Cryosols, Orthic Regosols, and Orthic Dystric Brunisols occur sporadically in less moist areas, on high hummocks, or in areas transitioning from higher elevation.

3.2.2.1.5 Mineral-4

The M4 soil map unit covers approximately 1,584 ha (7%) of the BSA. The M4 soil map unit is co-dominated by exposed bedrock outcrops and frost-shattered fragmental materials and very stony to excessively stony (3% to greater than 50% of ground surface covered) well to rapidly drained Turbic Cryosols (Orthic Dystric Turbic Cryosols and Regosolic Turbic Cryosols) and cryoturbated Orthic Dystric Brunisols developed on undulating (slopes 0% to 10%, locally up to 30%), coarse to moderately fine (sand to sandy loam) textured glacial till. Minor amounts of Orthic Dystric Brunisols and Orthic Regosols occur on very shallow glacial till veneers at upper slope positions or in upper, mid, and lower positions on slopes typically greater than 5%. Shallow Organic soil (Terric Fibrisols and Terric Mesisols), Rego Gleysols, peaty Gleysolic Static Cryosols, and peaty Gleysolic Turbic Cryosols developed on coarse textured (loamy sand) glacial till and moderately fine and fine textured (sandy loam to silt) fluvial material occur sporadically in low and depressed drainage areas between bedrock undulations or drainage channels associated with frost-shattered bedrock.

3.2.2.2 Other Map Units

3.2.2.2.1 Existing Disturbance

The EDIS soil map unit covers approximately 3,548 ha (15%) of the BSA and consists of areas of soil disturbance from roads and the existing infrastructure associated with the Ekati Mine operations.

3.2.2.2.2 Open Water

The Open Water soil map unit covers approximately 6,741 ha (29%) of the BSA and consists of standing or moving waterbody basins which may be filled or partly filled with water.

3.3 Permafrost Potential

The BSA is within the continuous permafrost zone, where permafrost may occupy approximately 90% to 100% of the area (Natural Resources Canada 1995). In general, permafrost in this area is characterized by having low ice content, indicating the ground ice content in the upper 10 to 20 m of the ground has less than 10% ice content by volume of visible ice (i.e., dry permafrost) (Natural Resources Canada 1995; Annex IV). Ice lenses (small bodies of ice in frozen soils) and ice wedges are likely locally present, as indicated by ground conductivity and by permafrost features such as palsas (mounds of alternating layers of ice and or mineral soils).

In general, imperfectly to very poorly drained soils in the continuous permafrost zone have Moderate to High permafrost potential, whereas rapidly drained soils have Low potential for permafrost (Table 3.3-1). Brunisolic and Regosolic soils in the BSA have Low permafrost potential. Cryoturbated Brunisolic soils have Moderate permafrost potential. Gleysolic soils and Hemic Folisols with imperfect to poor drainage have Moderate permafrost potential. Cryosolic soils in the BSA have High potential for permafrost. Imperfectly to poorly drained shallow Organic soils have Moderate to High permafrost potential based on their drainage class, peat and vegetation cover, and potential for increased water content. The permafrost potential of Organic soils can also be influenced by the insulating quality of a thick peat layer, which could increase the potential for permafrost (Zoltai 1995; Johnson et al. 2013).

Table 3.3-1 Permafrost Potential for Soil Types Within the Baseline Study Area

Soil Order	Soil Subgroup	Soil Texture	Dominant Soil Drainage Class	Permafrost Potential
Upland				
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	loamy sand and sandy loam	Rapid	High
Brunisolic	Orthic Dystric Brunisol	loamy sand	Rapid	Low
Brunisolic	cryoturbated Orthic Dystric Brunisol	loamy sand	Rapid	Moderate
Regosolic	Orthic Regosol, peaty Orthic Regosol, and Orthic Humic Regosol	loamy sand and coarse sand	Rapid	Low
Wetland				
Gleysolic	Rego Gleysol, cryoturbated Rego Gleysol, and peaty Orthic Gleysol	loamy sand, sandy loam and organic/loamy sand	Poor	Moderate
Cryosolic	peaty Gleysolic Static Cryosol and peaty Gleysolic Turbic Cryosol	organic/silt, organic/loam, organic/sandy loam, organic/loamy sand, and organic/fine sandy loam	Poor	High
Organic	Terric Mesisol	organic	Imperfect	High
	Terric Fibrisol	organic	Very Poor	High
	Hemic Folisol	organic	Imperfect	Moderate

3.4 Soil Sensitivities and Quality Ratings

3.4.1 Erosion Sensitivities

Soil erosion risk is one of the primary concerns for disturbed soils because the limited amount of vegetation cover exposes soil materials to the elements (e.g., wind and water). With continuous exposure to wind or rain, the uppermost portions of the soil profile may be eroded, washed, or blown away, depending on soil and terrain characteristics, resulting in loss of topsoil and subsequent soil quality. Soil erosion risk ratings were not assigned to water or EDIS map units, or to exposed bedrock and boulders within the map units, as these units are considered non-soils.

3.4.1.1 Water Erosion

Water erosion potentials were assigned to each soil subgroup classified during the field program and described in map units within the BSA. A summary of the water erosion ratings and potentials for each soil subgroup is presented in Table 3.4-1. Water erosion potential for soils in the BSA was Low, based on the loamy sand texture associated with upper mineral soil horizons and low relief topography in the BSA (i.e., low percent slope). Soils with Moderate water erosion potential were associated with loam, and with sandy loam textured upper mineral soil horizons and high dominant slope class or dominant slope length greater than 70 m. Soils with High water erosion potential were associated with silt texture of the uppermost mineral soil horizons and a dominant slope length greater than 70 m (Table 3.4-1).

In the BSA, the upland Cryosols and Brunisols that dominate the M1, M2, and M4 soil map units have Low sensitivity to water erosion. The coarse sandy Regosolic soils associated with esker complexes (E1 soil map unit) have Low sensitivity to water erosion. The erosion potential increases to Moderate on locations along the eskers' steep side slopes. Gleysolic soils occurring at transition and depressional landscape positions have Low sensitivity to water erosion. At transition and depressional landscape positions, if the organic layer is removed and underlying mineral soil horizons are exposed, peaty Cryosols and Organic soils have Low to Moderate sensitivity to water erosion. Regardless of soil type, if slope percentage or slope length increases, the water erosion potential for soils will also increase.

Table 3.4-1 Water Erosion for Soil Types Within the Baseline Study Area

Soil Order	Soil Subgroup	Uppermost Mineral Soil Horizon Texture(s)	Water Erosion Rating	Dominant Slope Class (%)	Dominant Slope Length (m)	Water Erosion Potential
Upland						
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	loamy sand and sandy loam	Low to Medium	>2 to 10	<70	Low
Brunisolic	Orthic Dystric Brunisol and cryoturbated Orthic Dystric Brunisol	loamy sand	Low	>2 to 5	<70	Low
Regosolic	Orthic Regosol, peaty Orthic Regosol, and Orthic Humic Regosol	loamy sand and coarse sand	Low	>5 to 10	<70	Low
Wetland						
Gleysolic	Rego Gleysol, cryoturbated Rego Gleysol, and peaty Orthic Gleysol	loamy sand and sandy loam	Low to Medium	0 to 0.5	<70	Low
Cryosolic	peaty Gleysolic Static Cryosol and peaty Gleysolic Turbic Cryosol	loamy sand, sandy loam, fine sandy loam, loam, and silt,	Low to High	0 to 0.5	<70	Low to Moderate
Organic	Terric Fibrisol, Terric Mesisol, and Hemic Folisol	loamy sand and bedrock[(a)]	Low	0 to 0.5	<70	Low

a) Exposed bedrock and frost-shattered boulders are non-soils and therefore have no texture and no water erosion potential.

% = percent; m = metre; > = greater than; < = less than.

3.4.1.2 Wind Erosion

Wind erosion ratings assigned to each soil subgroup classified during the field program and described in map units within the BSA are presented in Table 3.4-2. Generally, wind erosion ratings for the majority of soil types were High, based on the sandy textured mineral upper soil horizons present. Soils with Low to Medium wind erosion ratings potential were associated with medium to moderately fine textured (sandy loam, loam, and silt) upper mineral soil horizons and medium to moderately textured upper mineral soil horizons overlain with a fibric organic (Low rating) peat layer (Table 3.4-2).

Soils most sensitive to wind erosion were sandy upland Cryosolic, Brunisolic, and Regosolic soils (Table 3.4-2). Areas containing wetland peaty Cryosolic and Organic soils with fibric organic peat layers have a Low sensitivity to wind erosion if they become dry and disturbed. Those with mesic or folic organic peat layers have a Medium sensitivity. In the event organic surface materials are removed and underlying mineral soil horizons are exposed, the wind erosion ratings will vary according to the upper mineral soil horizon textures. For example, locations containing a silt texture in the underlying horizon would have a Low wind erosion rating, whereas those containing loamy sand would be rated as High.

Table 3.4-2 Wind Erosion Ratings for Soil Types Within the Baseline Study Area

Soil Order	Soil Subgroup	Uppermost Soil Horizon Texture	Wind Erosion Rating
Upland			
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	sandy loam and loamy sand	Medium to High
Brunisolic	Orthic Dystric Brunisol and cryoturbated Orthic Dystric Brunisol	loamy sand	High
Regosolic	Orthic Regosol, peaty Orthic Regosol, and Orthic Humic Regosol	loamy sand and coarse sand	High
Wetland			
Gleysolic	Rego Gleysol, cryoturbated Rego Gleysol, and peaty Orthic Gleysol	loamy sand, sandy loam, and organic/loamy sand	Medium to High
Cryosolic	peaty Gleysolic Static Cryosol and peaty Gleysolic Turbic Cryosol	fibric and mesic	Low to Medium
Organic	Terric Fibrisol, Terric Mesisol, and Hemic Folisol	fibric, mesic, and folic	Low to Medium

3.4.2 Sensitivity to Acidification

Acidification sensitivity ratings were assigned to each soil subgroup classified during the field program and described in map units within the BSA, and are listed in Table 3.4-3. Brunisolic and Regosolic soils have acidic or low pH and low CEC and therefore have a High sensitivity to acidification. Upland Cryosolic soils have a low pH and moderate CEC and have a Medium sensitivity to acidification.

Table 3.4-3 Acidification Ratings for Upland Soil Types Within the Baseline Study Area

Soil Order	Soil Subgroup	Average pH[(a)]	Average CEC (meq/100 g)[(a)]	Acidification Sensitivity Rating[(b)]
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	4.78	6	Medium
Brunisolic	Orthic Dystric Brunisol and cryoturbated Orthic Dystric Brunisol	5.10	5	High
Regosolic	Orthic Regosol, peaty Orthic Regosol, and Orthic Humic Regosol	5.57	3	High

a) For complete chemistry results, refer to Appendix A (Tables A.3 to A.7).

b) Derived from soil criteria presented in Holowaychuk and Fessenden (1987).

pH = potential of hydrogen, a quantitative measure of the acidity or basicity; CEC = cation exchange capacity; meq/100 g = milliequivalents of ammonium cation (NH_4^+) adsorbed by 100 grams of dry soil.

The sensitivity ratings for Organic, Gleysolic, and peaty phase wetland soils (e.g., peaty Gleysolic Static Cryosols) were based on the type of wetland (Turchenek et al. 1998). Soils associated with wetlands have Low to Medium sensitivity to acidification depending on the associated wetland type. Peaty Crysolic soils and Folisols were predominantly identified in areas of tussock hummock wetlands, which are considered equivalent to poor fen (Annex VI, Section 3.1). Therefore, peaty Cryosolic soils and Folisols have a Medium sensitivity to acidification. Terric Mesisol and Terric Fibrisol soils were generally identified in sedge wetlands, that are considered equivalent to moderate rich fens (Annex VI, Section 3.1), and were rated as Low in sensitivity to acidification.

Gleysolic soils generally occur in transitional areas adjacent to wetlands and in riparian shoreline areas, and in some cases, within wetlands; therefore, their pH would also be influenced by water associated with the wetland type. In general, these soils would be considered to have a Medium sensitivity to acidification. The mineral materials present in Gleysols may influence this rating because of their low pH (mean pH of 5.2; Appendix A, Table A-7) and low CEC (mean CEC of 3.1; Appendix A, Table A-7), which may increase this sensitivity to High.

3.4.3 Compaction Sensitivity

Soil compaction ratings were assigned to soil types within the BSA based on soil texture under moist conditions. Gleysolic and wetland Cryosolic soils were assigned compaction ratings based on soil texture under wet (saturated) soil conditions. Organic soils should be treated with special management practices (e.g., rig matting) or avoided during construction. Upper organic horizons were not assigned compaction ratings; however, if enough material is present, it can decrease the compaction rating of the lower mineral horizons. Fibrous organic materials can have high bearing strength and provide protection for the underlying mineral soil (Lewis et al. 1989). Bedrock was not assigned a compaction rating for obvious reasons.

Compaction ratings for soil map units in the BSA are listed in Table 3.4-4. Sandy loam and loamy sand textured upland soils (Cryosols, Brunisols, and Regosols) had a Low sensitivity to compaction under moist soil conditions. Gleysolic soils generally had sandy loam and loamy sand textures in the upper and lower mineral soil horizons, indicating Moderate to High sensitivity to compaction under wet soil conditions. Imperfect to poorly drained peaty phase Cryosolic soils associated with wetlands generally had silt, loam, sandy loam, and loamy sand textured mineral soil horizons, indicating Moderate to Very High sensitivity to compaction under wet soil conditions. However, the organic layer present on these soils is sometimes fibric, which can reduce the compaction sensitivity by one class.

Table 3.4-4 Compaction Ratings for Soil Types Within the Baseline Study Area

Soil Order	Soil Subgroup	Uppermost Mineral Soil Horizon Texture	Average Depth of Organic Layer (cm)	Prevailing Moisture Condition	Soil Compaction Rating
Upland					
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	loamy sand and sandy loam	5	moist	Low to Moderate
Brunisolic	Orthic Dystric Brunisol and cryoturbated Orthic Dystric Brunisol	loamy sand	6	moist	Low
Regosolic	Orthic Regosol and Orthic Humic Regosol	loamy sand and coarse sand	4	moist	Low
	peaty Orthic Regosol	loamy sand and coarse sand	26	moist	Low
Wetland					
Gleysolic	Rego Gleysol and cryoturbated Rego Gleysol	loamy sand and sandy loam	7	wet	Moderate to High
	peaty Orthic Gleysol	loamy sand and coarse sandy loam	16	wet	Moderate to High[(a)]
Cryosolic	peaty Gleysolic Static Cryosol and peaty Gleysolic Turbic Cryosol	loamy sand, sandy loam, fine sandy loam, loam, and silt	29	wet	Moderate to Very High[(b)]

a) Where upper organic horizons are fibric and greater than 20 centimetres, this rating can decrease by one class.

b) Where upper organic horizons are fibric, this rating can decrease by one class. Areas containing an upper organic layer that is mesic should be treated with special management practices (e.g., rig matting) or avoided during construction to avoid disturbance of the surface organic layer if the organic materials are not salvaged during construction.

3.4.4 Soil Metal Chemistry

Soil metal concentrations were measured to provide baseline metal chemistry in the BSA. Results of the metal analyses for the baseline metal chemistry of soil types can be found in Appendix A (Tables A-8 to A-12).

Evaluation of the soil metal concentrations identified one location where the measured arsenic concentration was over the CSQG value of 12 milligrams per kilogram (mg/kg dry weight [dw]). The elevated arsenic concentration (13.6 mg/kg dw) was observed in the B horizon of a shallow Orthic Dystric Brunisol (30 cm total depth) overlying bedrock. This relatively shallow soil occurred in an upper slope position of an exposed bedrock hilltop.

Arsenic naturally occurs in the aquatic and terrestrial environments of the Northwest Territories. A number of arsenic-bearing minerals exist, and the weathering of these rocks provides natural sources of arsenic to the environment (Drahota and Filippi 2009). Other natural sources of environmental arsenic are windblown or eroded soils derived from these rocks, and volcanic eruptions. Releases of arsenic from anthropogenic sources greatly exceed releases from natural sources. Anthropogenic sources of arsenic include gold and copper mining and smelting, pesticide application, coal combustion, and waste incineration (ATSDR 1993).

The elevated arsenic concentration observed during the soil field program is likely a result of naturally occurring arsenic contained within the bedrock. The dominant rock type where this soil was observed is metasedimentary schists (metasediments). Sulphide minerals can be present at trace concentrations in metasediments. The mineral sulphides class found in these rocks includes arsenides, which are made up of arsenic compounds (Dominion Diamond 2013). A shallow, poorly developed soil, such as that present at the location of the soil sample, was most likely influenced by the parent material (metasediments) on which it has developed. Therefore, the parent material is the likely source of the naturally elevated arsenic levels. Measured arsenic concentrations of a similar adjacent soil (Orthic Dystric Brunisol) were also slightly elevated (9.77 mg/kg); however, this was not over CSQG values. Other shallow Orthic Dystric Brunisols in other areas in the BSA typically had arsenic concentrations ranging from 4.2 to 5.5 mg/kg dw (Appendix A, Table A-8).

3.4.5 Reclamation Suitability

The reclamation suitability of soils in the BSA was evaluated to support salvage and reclamation planning. Soil reclamation suitability ratings for each undisturbed soil type in the BSA are provided in Table 3.4-5. Complete chemistry and physical parameters for determining the reclamation suitability for each soil type are provided in Appendix A (Tables A-3 to A-7).

Undisturbed surface material in the BSA generally has Poor suitability for reclamation (Table 3.4-5). All locations were non-saline and non-sodic, and pH was considered good. The surface soil horizons of Upland Cryosolic, Brunisolic, and Regosolic soils are rated as Poor for reclamation due to their sandy textures. Reclamation suitability of Gleysolic soils is rated as Fair to Poor with constraints of sandy texture and a non-coherent, loose consistency. Areas containing finer soil textures (e.g., sandy loam) would be rated as Fair. The Organic soil and peaty Cryosolic soils in the BSA are not given a rating and are classified simply as Organic and can be added to sandy materials as an amendment.

Table 3.4-5 Reclamation Suitability of Root Zone Material Within the Baseline Study Area

Soil Order	Soil Subgroup	Reclamation Suitability[a]	
		Rating	Constraints
Upland			
Cryosolic	Orthic Dystric Turbic Cryosol and Regosolic Turbic Cryosol	Poor	texture
Brunisolic	Orthic Dystric Brunisol and cryoturbated Orthic Dystric Brunisol	Poor	texture
Regosolic	Orthic Regosol, peaty Orthic Regosol, and Orthic Humic Regosol	Poor	texture
Wetland			
Gleysolic	Rego Gleysol, cryoturbated Rego Gleysol, and peaty Orthic Gleysol	Fair to Poor	consistency and texture
Cryosol	peaty Gleysolic Static Cryosol and peaty Gleysolic Turbic Cryosol	Organic	n/a
Organic	Terric Fibrisol, Terric Mesisol, and Hemic Folisol	Organic	n/a

a) Reclamation suitability ratings are based on criteria in Table 2.4-7. These are criteria for the Eastern Slopes Region based on a rooting zone of approximately 15 centimetres; however, the ratings in the above table indicated for surface material are based on soil horizon, not depth. The ratings are based on laboratory analyses and physical characteristics of soils (Appendix A [Tables A-3 to A-7]) sampled in the baseline study area.

n/a = not applicable.

Although undisturbed soil materials are rated as Poor, they currently support the local vegetation populations in the BSA and, as such, would be considered appropriate for use as reclamation material. In addition, reclamation research has been completed annually to evaluate soil and other salvaged materials for their ability support a self-sustaining vegetation cover. Research results have been provided in reclamation reports (Kidd and Max 2002; Martens 2003, 2005, 2006, 2009, 2010, 2011, 2012). The results from the reclamation research can be used to further refine salvage techniques in undisturbed soils, and also to refine the methods for using salvaged materials during reclamation. Reclamation strategies that have been developed from reclamation research and that could be implemented to improve salvaged material for use during reclamation (Ekati Diamond Mine Interim Closure and Reclamation Plan 2001) include:

- deep ripping to alleviate compaction, increase surface roughness to improve soil moisture conditions, and provide favourable microsites for plant growth;
- application of fertilizer to supplement soil nutrients;
- scattering of large boulders over reclaimed surfaces to create surface roughness and a more natural landscape; and,
- construction of islands of salvaged soil materials to improve soil quality and act as a seed source during revegetation.

In addition, incorporation of salvaged Organic material may be completed to improve the suitability of lake sediment and glacial till material for use during reclamation (Martens 2013).

4 SUMMARY

This Soils Baseline Report presents a review and interpretation of qualitative and quantitative information from the literature and from data collected during the 2013 field program. The key objective of this report is to describe existing soil resources, associated soil quality and sensitivities, and the potential for occurrence of permafrost within the BSA.

The BSA was selected as the study area based on the predicted spatial extent of the immediate direct and indirect effects on soil from the Project. The BSA is approximately 236 km^2 (23,578 ha) and includes the existing Ekati Mine and the Project footprint. The BSA was selected to encompass both the existing mine site and the area that contains the potential new development so that this information can be used in support of the assessment of potential Project effects on soils.

A field program was completed in 2013 and was designed as a level four intensity (one survey location per 100 to 1,000 ha), broad reconnaissance survey that identified common soil subgroups used to delineate soil map units and map unit descriptions, and to collect baseline physical and chemical characteristics of representative soils in the BSA.

Mineral soils identified included Cryosolic (containing permafrost), Brunisolic (having brownish-coloured B-horizons), Gleysolic (affected by periodic or sustained saturation), and Regosolic (poorly developed) soils. Some Brunisolic soils were identified to be cryoturbated phase, which means they are mixed by the action of freeze and thaw but do not contain permafrost. Organic (composed of peat and typically water saturated) and peaty (organic material deeper than 15 cm but not deeper than 40 cm) soils were also identified. Turbic Cryosols (characterized by lateral mixing of soil horizons in the active layer) were generally found at upland landscape positions, while peaty Cryosolic soils were found in wetlands. Brunisolic and Regosolic soils were found at upland landscape positions. Gleysolic soils were found at transition areas between upland and depressional landscape positions (i.e., wetlands) and in wetlands. Organic soils were found in wetlands.

The seven units mapped in the BSA include five soil map units (E1, M1, M2, M3, and M4), which capture the range of variability in soil subgroups and terrain present in the BSA. All of these map units contain inclusions of Organic soils. The EDIS map unit covers 3,548 ha (15%) of the BSA, and the Open Water map unit covers 6,741 ha (29%). The M1 map covers the second largest proportion (26%) of the BSA and is co-dominated by Turbic Cryosols and cryoturbated Brunisolic soils. The E1 map unit covers the smallest area of the BSA (approximately 235 ha or 1% of the BSA) and is dominated by Regosolic soils.

The BSA is within the continuous permafrost zone, where permafrost may occupy approximately 90% to 100% of the area (Natural Resources Canada 1995). In general, permafrost in this area is characterized by having low ice content, indicating the ground ice content in the upper 10 to 20 m of the ground has less than 10% ice content by volume of visible ice (i.e., dry permafrost) (Natural Resources Canada 1995; Annex IV). Ice lenses (small bodies of ice in frozen soils) and ice wedges are likely locally present, as indicated by ground conductivity and by permafrost features such as palsas (mounds of alternating layers of ice and or mineral soils).

Brunisolic and Regosolic soils in the BSA have Low potential to contain permafrost. Cryoturbated Brunisolic soils have Moderate potential to contain permafrost. Gleysolic soils with imperfect to poor drainage have Moderate permafrost potential. Cryosolic soils in the BSA have High potential for permafrost. Imperfectly to poorly drained Organic soils have Moderate to High permafrost potential based on their drainage class, peat depth, and vegetation cover.

Water erosion potential for soil types in the BSA was generally Low, based on the dominantly sandy texture associated with upper mineral soil horizons, low percent slope, and a dominant slope length less than 70 m. The Cryosols, Brunisols, and Regosols occurring at upland locations in the BSA have Low sensitivity to water erosion. Gleysolic soils occurring at transition and depressional landscape positions have Low sensitivity to water erosion. At transition and depressional landscape positions, peaty Cryosols and Organic soils have Low to Moderate sensitivity to water erosion if the organic layer is removed and underlying mineral soil horizons are exposed. Regardless of soil type, if slope percentage or slope length increases, the water erosion potential for soils will also increase.

Generally, wind erosion ratings for soils in the BSA were High based on sandy textured mineral upper soil horizons. Soils most sensitive to wind erosion were upland Cryosolic, Brunisolic, and Regosolic soils. Areas containing wetland peaty Cryosolic and Organic soils with fibric (i.e., least decomposed) organic peat layers have Low sensitivity to wind erosion if they become dry and disturbed. Those with mesic or folic (i.e., medium decomposition) organic peat layers have a Medium sensitivity. In the event organic surface materials are removed and underlying mineral soil horizons are exposed, the wind erosion ratings will depend on the upper mineral soil horizon textures.

Soils are categorized as having High, Medium, or Low sensitivity ratings to acid deposition. The sensitivity of mineral soils to acid deposition was evaluated using the chemical criteria published by Holowaychuk and Fessenden (1987). Analyzed CEC and pH values from soils sampled during the baseline field program were used to estimate the sensitivities of soils to acidification. The sensitivity rating for wetland soil types (Gleysolic, peaty Cryosolic, and Organic soils) is based on the type of wetland (i.e., bog, poor fen, moderate rich fen, and extreme rich fen) (Turchenek et al. 1998). Mineral soil properties of Gleysolic soils were considered.

Brunisolic and Regosolic upland mineral soils in the BSA have a High sensitivity to acidification. Upland Cryosolic soils have a Medium sensitivity to acidification. Soils associated with wetlands have Low to Medium sensitivity to acidification depending on the associated wetland type. Organic soils identified in tussock hummock wetlands were rated as having a Medium sensitivity to acidification. Organic soils occurring in sedge wetlands were rated as Low in sensitivity to acidification.

Gleysolic soils generally occur in transitional areas adjacent to wetlands, and in some cases within wetlands; therefore, their pH is influenced by water associated with the wetland type. In general, these soils would be considered to have a Medium sensitivity to acidification. The mineral materials present in Gleysolic soils could influence this rating and increase this sensitivity to High.

Compaction ratings for soil types in the BSA were determined using the criteria outlined in Lewis et al. (1989) using the prevailing moisture conditions. Soils occurring at toe slopes and in depressions (wetlands) were assigned compaction ratings based on soil texture under wet (saturated) soil conditions. Organic soils and bedrock were not assigned compaction ratings.

Sandy loam and loamy sand textured upland soils (Cryosols, Brunisols, and Regosols) have a Low sensitivity to compaction under moist soil conditions. Gleysolic soils generally had sandy loam and loamy sand textures in the upper and lower mineral soil horizons, indicating Moderate to High sensitivity to compaction under wet soil conditions. Imperfect to poorly drained peaty phase Cryosolic soils associated with wetlands generally had silt, loam, sandy loam, and loamy sand textured mineral soil horizons, indicating Moderate to Very High sensitivity to compaction under wet soil conditions.

Chemical constituents of underlying bedrock and associated rock leachate have the potential to be present in the upper soil strata because of soil formation from bedrock parent material as well as upward leaching of metals from rock (Turk et al. 2012). Soil metal concentrations were measured during the 2013 field program to provide baseline soil metal concentrations for the soils in the BSA.

The evaluation of the soil metal concentrations identified one location where the baseline concentration of arsenic was 13.6 mg/kg dw and is over the CSQG value of 12 mg/kg dw. This elevated arsenic concentration was observed in the B horizon of a shallow Brunisol (30 cm total depth) overlying bedrock and is likely a result of naturally occurring arsenic contained within the bedrock.

All locations were non-saline and non-sodic, and pH was considered good. The surface soil horizons of Upland Cryosolic, Brunisolic, and Regosolic soils are rated as Poor for reclamation due to their sandy textures. Reclamation suitability of Gleysolic soils is rated as Fair to Poor with constraints of sandy texture and loose consistency. The Organic soil and peaty Cryosolic soils in the BSA were not given a rating and are classified simply as Organic. Although soil materials were generally rated as poor, they are able to sustain the local vegetation populations and, as such, should be considered appropriate as reclamation material.

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6 GLOSSARY

Term	Description
Acidification	The process of becoming acid or being converted into an acid.
Active layer	In permafrost environments, it is the top layer of soil that thaws in the summer and freezes again in the fall.
Admixing	Mixing of the upper soil materials (e.g., topsoil) with the generally nutrient deficient lower soil materials (e.g., subsoil, parent material, C horizon) cause a dilution of texture, nutrients, and/or organic matter found in the upper lift.
Baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
Baseline study area (BSA)	The area where direct effects and small-scale indirect effects from the Project are expected to occur.
Bedrock	The body of rock that underlies gravel, soil or other material.
Blanket	Unconsolidated soil material thick enough to cover/mask minor irregularities in the underlying material but still integrating the generally underlying topography.
Bog	A peatland with weakly to moderately decomposed sphagnum and forest peat material formed in oligotrophic environments. The bog surface is acidic and low in nutrients due to the slightly raised peat surfaces disassociating it from underlying and surrounding mineral rich soil waters.
Brunisolic soil	Boreal forest soils that primarily develop in sandy glacial sediments. These soils have undergone very limited soil formation.
Buffering capacity	The ability of a soil to resist changes in pH.
Cation	An ion carrying a positive charge of electricity. The common soil cations are calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and hydrogen (H).
Cation exchange capacity	The maximum quantity of total cations that a soil is capable of holding, at a given pH value, for exchanging with the soil solution. Cation exchange capacity is used as a measure of fertility and nutrient retention capacity.
Canadian Council of Ministers of the Environment (CCME)	Body of Environment Canada that sets ambient guidelines for air, water, soil, and contaminants.
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.
Climate	The prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.
Compaction	An increase in soil density and a loss of soil pore space because of weight or pressure being placed on soil.
Consistence	Soils degree of cohesion and adhesion and a soil’s resistance to deformation or rupture.
Cryosolic soil	Cryosolic soils have horizons with permafrost. In some soils the frost action causes considerable mixing of soil horizons, which is termed cryoturbation. In these soils the permafrost layer must be within 2 m of the surface. If no strong cryoturbation has occurred the permafrost layer must be within 1 m of the surface.
Cryoturbated phase, soil	Any non-permafrost soil having one or more cryoturbated (mixed) horizons.
Disturbed soils	Soil that has experienced disturbance, usually as a result of human activity or natural processes such as erosion or annual freeze and thaw cycles.
Ecological Landscape Classification (ELC)	An ecological mapping process that involves the integration of site, soil, and vegetation information.
Ecoregion	Relatively homogeneous subdivisions of an ecozone, which are characterized by distinctive climatic zones or regional landforms.
Ecosystem	A relatively homogeneous area of organisms interacting with their environment

Term	Description
Electrical conductivity	The ability of soil to conduct electrical current as expressed in decisiemens per metre (dS/m) and typically used to measure soil salinity.
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.
Fen	A fen is a peat-covered or peat-filled wetland with a high water table, which is not hydrologically isolated and receives water from streams and/or groundwater.
Fen, poor	An ecosite that is transitional between the fen and bog. A poor fen is intermediate in nutrient regime and has a similar floristic composition to fen and bog. Sedges and peat moss, golden and brown mosses compose the majority of the organic matter content.
Fen, rich	A peatland with moderate to well-decomposed sedge, grass, and reed peat material from eutrophic environments. Mineral-rich waters are at or are just above the fen surface.
Fibric material	Materials (primarily mosses, rushes, and woody materials) that are readily identifiable as to botanical origin. A fibric horizon (Of) has 40% or more of rubbed fiber by volume.
Folisolic soil	Composed of upland organic (folic) materials, generally of forest origin that are either 40 cm or more in thickness, or are at least 10 cm thick if overlying bedrock or fragmental material.
Glaciofluvial	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.
Gleysolic soil	Gleysolic soils are associated with prolonged water saturation of the soil profile. Water saturation leads to depletion of oxygen and the development of soil features associated with oxygen-depleted conditions: blue-gray colours and reddish specks (called mottles) within the soil profile. These features are the diagnostic criteria for Gleysolic soils and occur within 50 cm of the soil surface.
Habitat	The physical location or type of environment in which an organism or biological population lives or occurs.
Infiltration	The process by which water on the ground surface enters the soil.
Landform	A particular type of land formation.
Landscape	A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout. From a wildlife perspective, a landscape is an area of land containing a mosaic of habitat patches within which a particular “focal” or “target” habitat patch is embedded.
LiDAR	A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.
Map unit	A combination of kinds of soil, terrain, or other features that can be shown at a specified scale of mapping for the defined purpose and objectives of a particular survey.
Mesisolic soil	Mesisolic soils are at a stage of decomposition intermediate between Fibrisols and Humisols and are dominantly composed of mesic organic materials.
Non-sorted circles	A type of patterned ground where alternating freeze and thaw of soils develop geometric circular patterns surrounded by a circular margin of vegetation. Consists of unsorted mineral material.
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Organic matter	Plant and animal materials that are in various stages of decomposition.
Organic soil	Organic soils are composed of organic materials. They include most of the soils commonly known as peat, or bog/fen soils. Most Organic soils are saturated with water for prolonged periods. These soils occur widely in poorly and very poorly drained depressions and level areas and are derived from vegetation that grows in such sites. The organic layer is greater than 60-cm thick (if fibric) or 40-cm thick (if mesic or humic).
Outwash deposit	Deposits of sand and gravel by running water from the melting ice of a glacier.
Parameter	A particular physical, chemical, or biological property that is being measured.
Parent material	Underlying bedrock or drift deposit on which soil horizons form and are made up of consolidated or unconsolidated mineral material that has undergone some degree of physical or chemical weathering.
Peaty phase, soil	Any mineral soil having a surface horizon of 15 to 60 cm of fibric and 15 to 40 cm of mesic or humic organic material.

Term	Description
Peat polygon (polygonal peat plateau)	A perennially frozen bog, rising about 1 m above the surrounding fen. The surface is relatively flat, scored by a polygonal pattern of trenches that developed over ice wedges. The permafrost and ice wedges developed in peat originally deposited in a non-permafrost environment. Polygonal peat plateaus are commonly found near the boundary between the zones of discontinuous and continuous permafrost.
Permafrost	Permanently frozen soil or rock and incorporated ice and organic material that remain at or below 0°C for a minimum of two years due to natural climatic factors (van Everdingen 2005). The occurrence of permafrost increases with latitude (i.e., more northern areas permafrost is continuous, and more southern areas patches of permafrost alternate with unfrozen ground).
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.
Reclamation	The process of reconverting disturbed land to its former or other productive uses.
Regosolic soil	Regosolic soils lack significant soil formation and occur on very young surfaces (e.g., sand dunes or river floodplains) or unstable surfaces (e.g., upper slope positions that experience high rates of soil erosion).
Riparian	(i) The interface between an upland area and a river or stream. (ii) The floodplain portion of a river or stream corridor.
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.
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 to the depth of the control section (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, and thus modifying the properties of the parent material.
Soil great group	Used in the classification of soil and is the next division of the soil order. These are differentiated based on characteristics that reflect the differences in the strengths of the dominant processes or a major contribution of an additional process.
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. It differs from adjacent horizons in properties such as colour, structure, texture, and consistence and in chemical, biological, or mineralogical composition.
Soil macro-organisms	Invertebrates that live in the soil and are generally visible to the naked eye. Many benefit the soil by helping to break down minerals, soil particles, and nutrients. Examples include beetles, earthworms, and some nematodes.
Soil micro-organisms	Any organism in soil, which requires a microscope to observe. These organisms include bacteria, fungi, algae, and protozoa. Soil micro-organisms are responsible for the breakdown of organic matter, conversion of inorganic compounds from one form to another, and the production of humus.
Soil order	Used in the classification of soil and include Brunisolic, Regosolic, Organic, Cryosolic, and Gleysolic Orders. At this level, soils are differentiated on the basis of characteristics of the soils that reflect the nature of the total soil environment and the effects of the dominant soil forming processes.
Soil structure	Refers to the accumulation of soil particles into compound particles that are classified in terms of grade (weak, moderate, strong), class or size (fine, medium, coarse), and type (platy, granular, prismatic, blocky).
Soil subgroup	The third level of classification of soils formed by subdividing each larger grouping. Subgroups are differentiated on the basis of the kind and arrangement of horizons that reflect 1) similarity to the central concept of the larger group, 2) intergrading towards soils of another order, 3) additional features within the control section. A control section is the vertical section of soil upon which classification is based.
Soil texture	A soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil.
Subsoil material	The layer of soil under the topsoil on the surface of the ground, the layer of soil under the topsoil on the surface of the ground.

Term	Description
Terrain	The landscape or lay of the land. This term is considered to comprise specific aspects of the landscape, namely genetic material, material composition, landform (or surface expression), active and inactive processes that modify material and form, slope, aspect, and drainage conditions. Terrain analysis is the identification of the above land surface features, to a more or less defined depth and determining their areal extent. The identification of special features such as permafrost, erosion, and landforms indicating subsurface structures is included in such analyses.
Till	An unstratified, unconsolidated mass of boulders, pebbles, sand, and mud deposited by the movement or melting of a glacier.
Topography	The surface features of a region, such as hills, valleys, or rivers
Topsoil	Uppermost layer of soil, usually the top 5 to 20 cm. It has the highest concentration of organic matter and microorganisms and is where most of the biological activity occurs. Plants generally concentrate their roots in and obtain most of their nutrients from this layer.
Tundra	An area between the polar ice cap and taiga that is characterized by a lack of trees and permanently frozen subsoil.
Upland	Areas that have typical ground slopes of 1% to 3%, have better drainage, and are not wetlands.
Veneer	Unconsolidated soil material too thin to cover the minor irregularities of the underlying material. Ranges from 10 to 100 cm in thickness.
Vegetation	A term to describe all of the plants or plant life of an area.
Wetlands	Areas with ground slopes of less than 0.5% or depressions and typically poorly drained.
Wildlife	A term to describe all undomesticated animals living in the wild.