Appendix V4-8A

Hope Bay Belt Project:
2010 Ecosystems and Vegetation Baseline Report

Hope Bay Mining Limited

HOPE BAY BELT PROJECT
2010 Ecosystems and Vegetation Baseline Report

NEWMONT NORTH AMERICA




Rescan Engineers & Scientists

Rescan™ Environmental Services Ltd.
Rescan Building, Sixth Floor - 1111 West Hastings Street
Vancouver, BC Canada V6E 2J3
Tel: (604) 689-9460 Fax: (604) 687-4277

April 2011

HOPE BAY BELT PROJECT

2010 ECOSYSTEMS AND VEGETATION BASELINE REPORT

April 2011
Project #1009-002-12

Citation:

Rescan. 2011. *Hope Bay Belt Project: 2010 Ecosystems and Vegetation Baseline Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, British Columbia.

Prepared for:

NEWMONT™ NORTH AMERICA

Hope Bay Mining Limited

Prepared by:

Rescan™ Engineers and Scientists

Rescan™ Environmental Services Ltd.
Vancouver, British Columbia

Executive Summary

Executive Summary

This report presents the ecosystem and vegetation baseline study undertaken by Rescan Environmental Services Ltd. on behalf of Hope Bay Mining Limited (HBML) for the Hope Bay Belt Project. The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound. The property consists of a greenstone belt 80 km in length and oriented in a north/south direction, with 3 main gold deposit areas. HBML plans to develop Phase 2 of the Project, which includes an expansion of additional deposits in the belt.

In 2010, ecosystem baseline studies were initiated to address information gaps in support of permitting for the Phase 2 Project. This report describes the distribution and characteristics of the ecosystems and vegetation types found within the expanded Project area, which includes the all- weather access road connecting the North and South areas of the belt. Data collected in 2010 builds on existing work conducted in 1996 and 1997, and provides presence/absence information on rare species and invasive species. Plant tissue samples were collected from the Project area to establish baseline metal concentrations in sampled vegetation.

Terrestrial and wetland ecosystems in the Hope Bay Belt Project area were characterized at the regional and local scales. The Regional Study Area (RSA), covering 770,000 ha, was adapted using project data from the 2001 Vegetation Classification for the West Kitikmeot/Slave Study Region. Terrestrial Ecosystem Mapping (TEM), completed in 1997 and 2010, was used to assess the 56,138 ha Local Study Area (LSA). A total of 13 unique ecosystem units were mapped in the LSA, along with 13 non-vegetated map units. Three ecosystem units and one non-vegetated map unit comprised 66% of the mapped area; Eriophorum Tussock Meadow (27.9%), Lakes and Ponds (14.3%), Betula-Ledum-Lichen (12.6%), and Wet Meadow (11.1%).

A system for the identification of sensitive or at risk ecosystems does not currently exist in Nunavut. In the absence of a territorial system for identifying sensitive ecosystems, the ecosystem units mapped in the LSA were assessed for rarity within a regional context. Based on the analysis of mapped ecosystem occurrences in the RSA and LSA, it was determined that the LSA contains a significant amount of wet, lowland ecosystems relative to the RSA. Lowland ecosystems, as described in this report, are considered susceptible to disturbance.

No species of conservation concern were identified during the 2010 field surveys; however, three species considered vulnerable or at risk were identified in previous baseline studies for the Project. Three species were identified as being rare, including the bryophyte *Sphagnum orientale,* considered vulnerable with a global ranking status of Globally Imperilled to Apparently Secure (G2G4), as well as *Cinclidium latifolium* and *Frullania tamarisci*. One exotic species, common dandelion (*Taraxacum officinale*), was identified during field surveys.

Plant tissue samples were collected from the study area in 2010 to establish baseline metal concentrations in sampled vegetation. A total of 18 lichen tissue samples from two different species were collected for metals analysis. Results are presented that summarize the metal levels that naturally occur in vegetation growing within the study area.

Acknowledgements

Engineers and Scientists

Acknowledgements

This report was prepared for Hope Bay Mining Limited (HBML) by Rescan Environmental Services Ltd. (Rescan). The 2010 Ecosystems and Vegetation fieldwork was conducted by Ryan Durand (B.Sc., R.P.Bio), Natasha Bush (B.Sc., P.Ag), Shanley Thompson (M.Sc.), Dean Jansen, Damian Power (R.P.Bio.) and Ron Meister (R.P.F., P.Ag.). The report was prepared and written by Natasha Bush and Ryan Durand and technically reviewed by Greg Sharam (Ph.D., M.Sc.). GIS support was provided by Luke Powell (M.Sc.) and Andy Pettersson (B.Sc., M.C.S.E.), and report production was conducted by Lloyd Majeau. The project was managed by Deborah Muggli (Ph.D., M.Sc., R.P.Bio.).

Rescan staff were assisted in the field by Chelsea Adjun, Darcy Kanayok, Johnny Avalak, Brenden Greenley, David Ayalik, Irvin Kuptana, Henry Eyegetok, Wayne Greene, Sarah Chang, and Brock Stables.

Field and logistical support was provided by the HBML Environmental and Social Responsibility Department (ESR), Health, Safety and Loss Prevention Department (HSLP), Great Slave Helicopters, Braden Burry Expediting and Nuna Logistics.

Table of Contents

HOPE BAY BELT PROJECT
2010 ECOSYSTEMS AND VEGETATION BASELINE REPORT

Table of Contents

List of Figures

List of Tables

List of Plates

List of Appendices

Glossary, Acronyms and Abbreviations

Glossary, Acronyms and Abbreviations

Acronyms and abbreviations used in this document are defined where they are first used. The following list of abbreviations will assist readers who may choose to review only portions of the document.

Alluvial	Pertaining to the loose, unconsolidated sediments that have been eroded, deposited, and reshaped by water in some form in a non-marine setting. Generally not applied to deposits when the particular mode of deposition via water is identifiable.
Attribute	Any feature of a vegetation association that is not represented by the site series/vegetation association, site modifier or structural stage. Attributes may either be recorded from fieldwork or inferred by extrapolating features from similar vegetation associations.
COSEWIC (Committee on the Status of Endangered Wildlife in Canada)	A committee that produces the official list of Canada's endangered species.
Ecological amplitude	The limits of environmental conditions within which an organism can live and function.
Ecosystem (terrestrial)	A volume of earth-space that is composed of non-living parts (climate, geologic materials, groundwater, and soils) and living or biotic parts, which are all constantly in a state of motion, transformation, and development. No size or scale is inferred.
Edaphic	Pertaining to soil characteristics, and specifically how these affect living organisms.
ELC	Ecosystem Land Classification
FCIR	False-Colour Infrared
Floodplain	Area of unconsolidated, river-borne sediment in a river valley; subject to periodic flooding.
Fen	Peatlands where groundwater inflow maintains relatively high mineral content within the rooting zone. They are dominated by non-ericaceous shrubs, sedges, grasses, reeds, and brown mosses.
Fibric	Poorly decomposed peat with large amounts of well-preserved fibre readily identifiable as to botanical origin.
Forb	Non-graminoid herbaceous plants.
Habitat	Land and water surface used by wildlife. This may include biotic and abiotic aspects such as vegetation, exposed bedrock, water and topography.
HBML	Hope Bay Mining Limited
HDI	Hydrodynamic Index
Hectare	10,000 m^2 or 0.01 km^2 or 2.47 acres.

Herb	A plant - annual, biennial or perennial - with stems that die back to the ground at the end of the growing season.
Hydric	A qualitative measure of soil moisture that indicates water being removed so slowly that a water table is at or above soil surface during the entire growing season. Organic and gleyed mineral soils are present.
Hydrophilic	Substances that have an affinity for water often because of the formation of hydrogen bonds.
Hygric	A qualitative measure of soil moisture regime that indicates wetter than mesic conditions. Saturation of the soil is limited so that anaerobic soil conditions are transient in the rooting zone.
Hydrodynamic index	And index measuring the magnitude of water vertical fluctuation and lateral flow.
LSA	Local Study Area
Marsh	A shallowly flooded mineral wetland dominated by emergent grass-like vegetation.
Mesic	1. Organic material in an intermediate stage of decomposition where some fibers can be identified as to botanical origin. 2. Medium soil moisture regime where a site has neither excess soil moisture nor a moisture deficit.
Moisture Regime	Indicates the available moisture for plant growth in terms of the soil's ability to hold, lose, or receive water. Described as moisture classes from Very Xeric (0) to Hydric (8)(BC Ministry of Environment Lands and Parks and BC Ministry of Forests Research Branch 1998).
NGSWG	National General Status Working Group (NGSWG)
Nutrient Regime	Indicates the available nutrient supply for plant growth. Nutrient regime is based on a number of environmental and biotic factors, and is described as classes from Oligotrophic (A) to Hypereutrophic (F) (BC Ministry of Environment Lands and Parks and BC Ministry of Forests Research Branch 1998).
NWT GSRP	Northwest Territories General Status Ranking Program. The program that integrates knowledge from relevant agencies regarding statue of species within the NWT.
Palsa	Palsas are low, often oval, frost heaves occurring in polar and subpolar climates, which contain permanently frozen ice lenses.
Peatland	Organic wetlands containing at least 40 cm of peat accumulation on which organic soils (excluding folisols) develop (Warner and Rubec 1997).
Periglacial process	Freezing and thawing processes that drastically modify the ground surface.
Physiognomy	General appearance of an object without reference to its implied characteristics.

Polygon	Delineations that represent discrete areas on a map, bounded by a line on all sides.
Presence/absence surveys	Surveys which rely on visual observations to confirm the presence of the target. These cannot be used in isolation from other statistical techniques to determine the size or absence of a population. They can only be used to confirm the presence of a target species.
Rescan	Rescan Environmental Services Ltd.
Riparian Ecosystem	Ecosystems whose structure and species composition is strongly influenced by regular flooding.
RSA	Regional Study Area
SARA	Species At Risk Act
SMR	Soil Moisture Regime
SNR	Soil Nutrient Regime
Structural Stage	Describes the existing dominant stand appearance or physiognomy for a land area. Structural stages range from non-vegetated to old forest.
Submesic	A qualitative measure of soil moisture regime that indicates soil conditions drier than mesic. Water is removed from the soil at a faster rate than supply.
Topography	The configuration of a surface, including its relief and the position of its natural and man-made features.
TRIM	Terrain Resource Information Management
Tundra	An area with permafrost soils which causes trees to be excluded from the landscape due to the edaphic conditions of the rooting zone within the soil.
UTM	Universal Transverse Mercator
Vegetation association	Defines all sites capable of supporting similar plant communities.
VM	Very Moist SNR
VW	Very Wet SNR
Wetland	Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrotrophic vegetation and various kinds of biological activity which are adapted to a wetland environment (National Wetlands Working Group 1988).
W	Wet SNR
WKSS	West Kitikmeot/Slave Study

1. Introduction

1. Introduction

The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound (Figure 1-1). The nearest communities are Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The property consists of a greenstone belt approximately 80 km in length oriented in a north/south direction, with three main gold deposit areas. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is located in the southern end. The northern portion of the property consists of several watershed systems that drain into Roberts Bay, and a large river (Koignuk River) that drains into Hope Bay. Watersheds in the southern portion of the belt ultimately drain into the upper Koignuk, which drains into Hope Bay.

Hope Bay Mining Limited (HBML) is proceeding with the development of the Doris North Project. Required licences and permits are in place for the development of the Doris North Gold Mine, and construction of the project commenced in 2010.

HBML plans to develop additional deposits in the belt, and planning for this Phase 2 Project development has commenced. Required baseline studies to support the permitting of the Phase 2 Project were carried out in 2009, and were continued in 2010. The environmental baseline program conducted in 2010 was intended to fill information gaps in order to support the permitting of the Phase 2 Project. The site layout options considered for the 2010 Phase 2 environmental baseline program are presented in Figure 1-2.

Results from the 2010 Phase 2 Project environmental baseline program are being reported in a series of reports, as follows:

- 2010 Hydrology Baseline Report;
- 2010 Freshwater Baseline Report;
- 2010 Freshwater Fish and Fish Habitat Baseline Report;
- 2010 Marine Baseline Report;
- 2010 Marine Fish and Fish Habitat Baseline Report;
- 2010 Terrain and Soil Baseline Report;
- 2010 Country Foods Baseline Report;
- 2010 Ecosystems and Vegetation Baseline Report; and
- 2010 Marine Wildlife Baseline Report.

In addition, numerous reports are being produced as part of the Doris North Project compliance requirements, and many of these reports cover the geographical areas of the proposed Phase 2 Project. Examples of Doris North Project compliance reports generated in 2010 that are relevant to the proposed Phase 2 Project include:

- 2010 Meteorology Compliance Report, Doris North Project;

PROJECT # 1009-002-29 ILLUSTRATION # a23708w-CR November 17, 2010

Figure 1-1

NEWMONT NORTH AMERICA

Hope Bay Belt Project Location

Rescan Engineers & Scientists

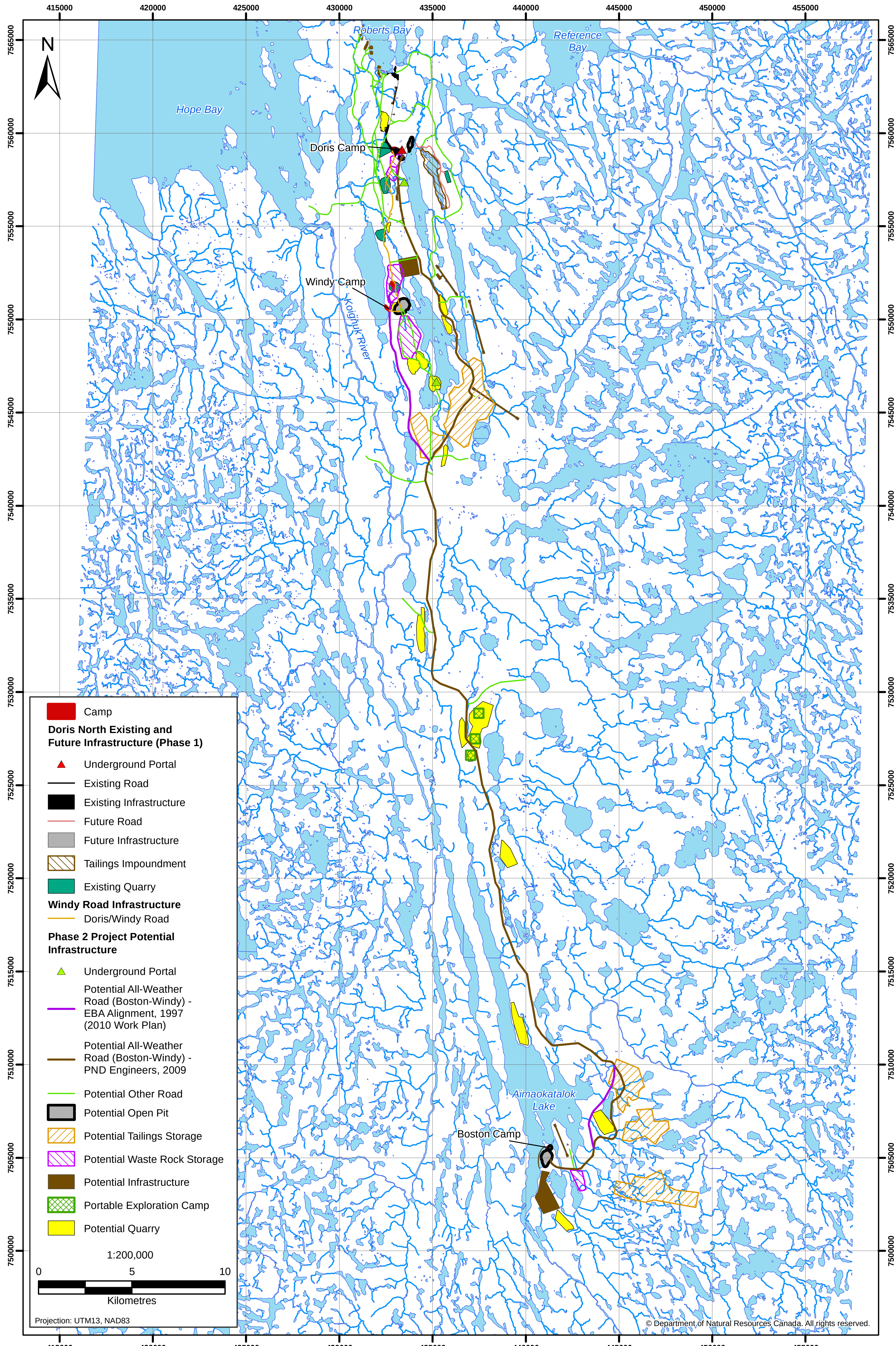


Figure 1-2

NEWMONT NORTH AMERICA

Site Layout Options Considered for Phase 2 Baseline Program, 2010

Rescan Engineers & Scientists

- 2010 Hydrology Compliance Report, Doris North Project;
- 2010 Wildlife Mitigation and Monitoring Report, Doris North Project;
- 2010 Wildlife DNA Study, Doris North Project;
- 2010 Wildlife Habitat Suitability Mapping Report, Doris North Project;
- 2010 Air Quality Compliance Reports, Doris North Project; and
- 2010 Aquatic Effects Monitoring Program Report, Doris North Project.

Archaeology work was also conducted in 2010 and is being reported separately.

This report presents the results from the Terrestrial Ecosystems and Wetlands portion of the 2010 Phase 2 environmental baseline program. Results from the 2010 field surveys and ecosystem mapping compliment information collected in 1997, as well as several other local and regional studies. Descriptions of all mapped ecosystem units are provided, as well as wetlands identified during field surveys. It also includes the results of rare and invasive species inventories, baseline metal analyses of plant samples, and a discussion on the value and importance of identified vegetation and ecosystems.

The specific objectives of this report are to:

- Describe the terrestrial and wetland ecosystems and their distribution within the expanded Project area to cover the potential Phase 2 Project infrastructure, including the all-weather access road to Boston;
- Identify and describe the plants tracked by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the Northwest Territories General Status Ranking Program (GSRP), and the Species At Risk Act (SARA) that may occur in the Local Study Area (LSA);
- Identify the presence, location and potential occurrence of invasive plants tracked by the GSRP;
- Describe baseline metal concentrations in plant collections from the Project area;
- Describe the functions of identified ecosystems; and
- Provide land cover and vegetation data for the wildlife habitat suitability modelling.

2. Methods and Background

2. Methods and Background

2.1 STUDY AREA

The ecosystems and vegetation Project area is divided into a Regional Study Area (RSA) and a Local Study Area (LSA) (Figure 2.1-1). The regional study area covers 770,000 ha and was mapped over a four year period (1997 to 2000) using Landsat Thematic Mapper satellite images from 1989 to 1997 (Matthews & Epp 2001). The ecosystems RSA is based on the areas surveyed for ungulates, carnivores, waterfowl, upland breeding birds, and raptors. This boundary provides a regional ecological context for ecosystems and also takes into account the area that provides habitat for wildlife species that may come into contact with proposed Project infrastructure during the course of a season or a lifetime. The 56,138 ha LSA includes the proposed Phase 2 Project infrastructure including proposed access roads and marine infrastructure sites.

2.2 ECOSYSTEM CLASSIFICATION

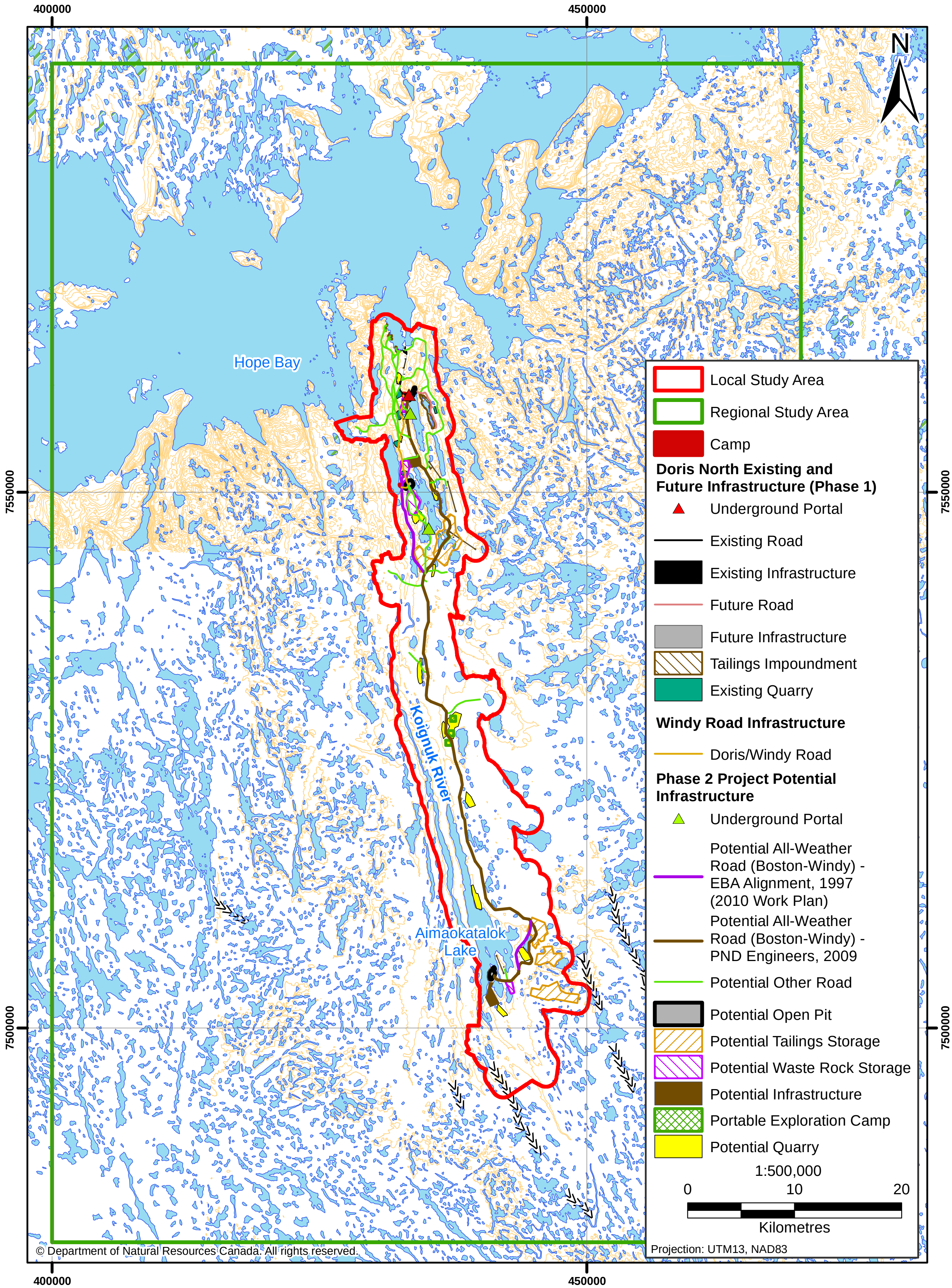
2.2.1 Regional Ecological Context

The National Ecological Framework is a hierarchal system of ecological classification that provides a framework for describing the distribution of ecological patterns across Canada. At its broadest level, this system recognizes 2 Ecozones across Nunavut, the Northern Arctic and the Southern Arctic (Natural Resources Canada 2003). The project lies within the Southern Arctic Ecozone (Figure 2.2-1). The Southern Arctic Ecozone extends across central Nunavut. It is bordered by the tree line to the south and by the Northern Arctic ecosystem to the north. Summers are cool and short with a mean temperature of 5ºC. Winters are long and cold with an average temperature ranging from -28ºC near the MacKenzie Delta to -18 ºC in Northern Quebec. Precipitation is limited to about 200 mm per year.

The terrain is comprised of flat and rolling bedrock covered by thin veneers of till, lacustrine and fluvial deposits. Exposed bedrock is common, as repeated glacial advance and recession has removed much of the surficial material. Permafrost is found throughout the region. Although annual precipitation is low, many low-lying areas (as well as low-gradient hillsides) remain permanently saturated. This is due to very low rates of evaporation and transpiration as well as the continual supply of moisture from within the soil profile due to seasonal permafrost melting.

Wetlands are common throughout the region. The occurrence and development of Arctic wetlands is closely connected to the freezing and thawing of soil. The freeze-thaw action results in a number of wetland types depending on the amount of dynamism in the active layer (the mobile layer of soil above the permafrost, which is subject to periodic thawing), the depth of the surficial organic material, landscape position, and the properties of the subsurface mineral parent material. Many Arctic wetlands are located in depressions caused by glacial scour, and subsequently filled with water from snowmelt. Kettle and kame topography also promotes wetland development (Gracz 2007).

The southern border of the Southern Arctic Ecozone is defined by a lack of full-size trees along its southern edge. Stunted forms of certain tree species, such as dwarf birch (*Betula nana*), green alder (*Alnus viridis* spp. *crispa*), willow species (*Salix* spp.), and less commonly, white and black spruce (*Picea glauca* and *mariana*), grow throughout the Ecozone. Much of the area is dominated by sedge meadows, tussock tundra, and heath tundra. Sparsely vegetated areas, such as the wind-swept crests of eskers, are also common.



NEWMONT NORTH AMERICA

Figure 2.1-1

Hope Bay Project Ecosystem Study Area Boundaries

Rescan Engineers & Scientists

Figure 2.2-1

NEWMONT NORTH AMERICA

Arctic Ecozones and Ecoregions

Rescan Engineers & Scientists

Figure 2.2-1

2.2.2 Background Information

A comprehensive site level ecological classification system has not been developed for Nunavut or the Northwest Territories. A coarse level vegetation classification system was developed for the West Kitikmeot/Slave Study (WKSS) region (RWED 2000; and Matthews and Epp 2001), which includes the Project area (Golder 2009). Multiple local ecosystem classification projects have been completed for the Project area (Rescan 1997; Burt 2003) from which Golder (2009) created a preliminary regional Ecosystem Land Classification (ELC). The ELC was developed to compare local ecosystems with the broad level WKSS classification system, and to enable the assessment of environmental impacts at both local and regional levels (Golder 2009). The ELC correlation to local ecosystem classifications did not include marine influenced ecosystems, with the exception of a beach (dune) vegetation type, because the WKSS classification does not contain equivalent units. These types are also generally considered to be too small to map at a regional level (Golder 2009). Furthermore, it was unclear in Golder (2009) whether the Marine Intertidal and Marine Backshore ecosystem units were included in the Beach (Dune) ELC unit. The Dry Willow (DW), Low Bench Floodplain (FP), and Polygonal Ground (PG) ecosystem units found in Rescan (1997) were not included in the Golder (2009) classification.

Table 2.2-1 was adapted from Golder (2009) to show the correlation between the WKSS ELC units and local ecosystem mapping units. The table was simplified by removing the Golder ELC associated plant community type and associated plant community subtype columns. The Burt (2003) Classification Column was converted to the Rescan 1997 ecosystem types that this report is largely based upon. Figure 2.2-2 presents the RSA with the WKSS ELC units and the LSA boundary.

Table 2.2-1. Modified Correlation of Regional ELC Units with the WKSS and Rescan 1997 Classification

ELC Code	WKSS ELC Unit	Local Ecosystem Unit(s)	Area (ha)	% of RSA
0	Unclassified	NA	7,674	1
1	Lichen Veneer	Carex-Lichen (CL)	10,507	1.4
2	Deep Water	Lakes (LA) and Salt Water (SW)	108,899	14.1
3	Esker Complex	Carex-Lichen (CL) and Dwarf Shrub-Heath (SH)	1,533	0.2
4	Wetland (Sedge Meadow)	Wet Meadow (WM), Polygonal Ground (PG) and Emergent Marsh (EM)	37,192	4.8
5	Shallow Water	Ponds (PD) and Shallow Open Water (OW)	150,709	19.6
6	Tussock/Hummock	Eriophorum Tussock Meadow (TM)	60,898	7.9
7	Heath Tundra	Dryas Herb Mat (DH) and Betula-Ledum-Lichen (BL)	127,670	16.6
10	Bedrock Association	Rock Outcrop (RO) and Carex-Lichen (CL)	31,086	4
11	Riparian Tall Shrub	Riparian Willow (RW)	18,649	2.4
13	Heath/Boulder	Carex-Lichen (CL) and Dwarf Shrub-Heath (SH)	11,943	1.6
14	Heath/Bedrock	Dryas Herb Mat (DH) and Carex-Lichen (CL)	128,042	16.6
15	Boulder Association	Blockfield (BI)	4,790	0.6
16	Bare Ground	Barren (BA) and Exposed Soil (ES)	5,972	0.8
17	Low Shrub	Dry Willow (DW) and Betula-Moss (BM	38,936	5.1
18	Gravel Deposit	Barren (BA) and Exposed Soil (ES)	25,500	3.3
TOTAL			**770,000**	**100**

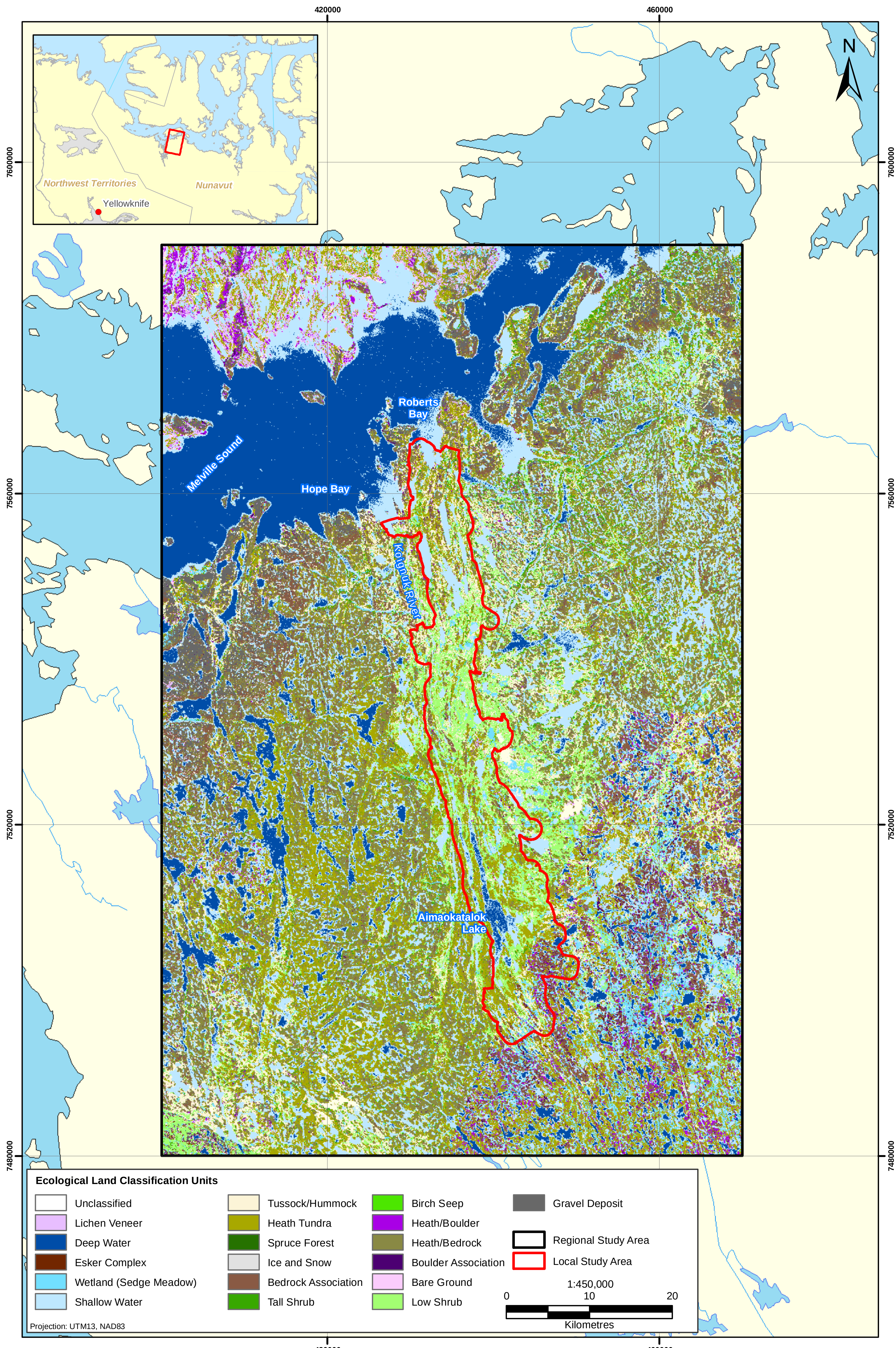


Figure 2.2-2

NEWMONT NORTH AMERICA

Regional Study Area WKSS Ecosystem Land Classification

Rescan Engineers & Scientists

2.2.3 Local Study Area Ecological Classification

As described above, a comprehensive site level ecological classification system has not been developed for Nunavut or the Northwest Territories. Over a period of two years (1996 and 1997) Rescan created a preliminary local ecosystem classification system for the Project area (Appendix 1). The system used a variety of multivariate statistical analyses of 412 field plots to develop 13 unique ecosystem units. Each unit is defined by distinct assemblages of plant species and environmental conditions (soil moisture and nutrients, parent material, drainage, etc.; Rescan 1997). These ecosystem units are defined at a scale that can be distinguished at the scale of mapping. Finer-scale differences in plant associations also occur in the area, many of which are wetland associations that were documented during the wetland field surveys (See Wetlands section in the Results chapter).

Table 2.2-2 provides a brief summary of the mapped ecosystem units adapted from the 1997 Rescan report. Detailed descriptions of the ecosystem units are provided in Chapter 3 of this report. The descriptions have been modified to reflect the larger study area and additional sample plot data. In addition to mapped ecosystem types, 11 non-vegetated map codes were used to describe other features such as lakes, rivers and rock outcrop (Table 2.2-3). The non-vegetated map codes and descriptions are adapted from the *Standard for Terrestrial Ecosystem Mapping in British Columbia* (RIC 1998).

Table 2.2-2. General Ecosystem Units

General Ecosystem Unit	Map Code	Description
Dry Carex-Lichen	CL	Dry, nutrient poor community restricted to exposed bedrock outcrops characterized by a sparse cover of sedges, lichens and dwarf shrubs.
Riparian Willow	RW	Wet to very wet, medium to rich nutrient community restricted to active floodplains and seasonally fluctuating water tables with a thick cover of willow species and variable (often extensive) cover of sedges, cotton-grass, and moss species.
Dryas-Herb Mat	DH	Dry to mesic, poor to medium nutrient community occurring on very thin, poorly developed soils on bedrock outcrops and moirainal deposits dominated by Arctic avens and a high diversity of dwarf shrubs and herbs.
Wet Meadow	WM	Wet to very wet, medium to rich nutrient community occurring on plains and gentle lower slopes with constant water seepage dominated by thick covers of cotton-grass and sedges, few shrubs and lichens, and limited moss cover.
Betula-Ledum-Lichen	BL	Dry to mesic, poor to medium nutrient community occurring on hillslopes of glacial till containing thick covers of low dwarf birch, Labrador tea and a variety of dwarf shrubs, sedges, herbs and lichens.
Emergent Marsh	EM	Permanently saturated rich to very rich communities which are rarely extensive and dominated by sedges, some hydrophilic herbs, and no shrubs of lichens, typically occurring along watercourses and ponds.
Dwarf Shrub-Heath	SH	Mesic, poor to medium nutrient community restricted to moderate to steep slopes of glacial till over bedrock (often containing frost mounds) containing arctic heather and a highly variable assemblage of dwarf shrubs, herbs, moss and lichen in response to microtopography and aspect.
Low Bench Floodplain	FP	Permanently wet, medium to rich community restricted to active floodplains of rivers, streams and lake outlets lacking shrub and lichen cover and containing hydrophilic herbs and water tolerant mosses.
Betula-Moss	BM	Mesic to moist, poor to medium nutrient community located in depressions or gently sloping fluvial and lacustrine plains typified by a high cover of dwarf birch (and often willow) and a thick moss layer, with few herbs or lichens present.
Marine Intertidal	MI	Wet, medium nutrient marine community strictly limited to intertidal flats and shorelines containing low floral diversity of salt-tolerant herbs, with no shrubs, mosses or lichens.

(continued)

Table 2.2-2. General Ecosystem Units (completed)

General Ecosystem Unit	Map Code	Description
Eriophorum Tussock Meadow	TM	Moist to wet, medium to rich nutrient, widespread community type characterized by deep tussocks of sheathed cotton-grass and a variety of dwarf shrubs (on drier tussock tops), herbs, and mosses found in low lying plain of organic material overlying fine textures marine and lacustrine materials (permafrost almost always occurs at the organic – mineral transition).
Marine Backshore	MB	Dry, nutrient poor community occurring directly upslope of marine backshore communities characterized by extensive deposits of washed marine sands with highly variable (but generally sparse) herb layer and few shrub, moss or lichen species.
Dry Willow	DW	Mesic, medium nutrient community occurring on steep slopes (typically fluvial, marine or lacustrine) with a thick cover of willow (occasionally dwarf birch) and few other species.
Polygonal Ground	PG	Mosaic of disjunct communities comprised of drier communities (raised palsa mounds with communities similar to birch-ledum-lichen or birch-moss) and wet depressions (normally wet meadows) which typically occur in depressions and valley bottoms near lakes and ponds.

Table 2.2-3. Non-vegetated Map Units

Non-Vegetated Map Unit Names	Code	Description
Barren	BA	Land devoid of vegetation due to extreme climatic or edaphic conditions.
Beach	BE	The area that expresses sorted sediments reworked in recent time by wave action. It may be formed at the edge of fresh or salt water bodies.
Blockfield	BI	Level or gently sloping areas that are covered with moderately sized or large, angular blocks of rock derived from the underlying bedrock or drift by weathering and/or frost heave, and that have not undergone any significant downslope movement.
Exposed soil	ES	Any area of exposed soil that is not included in any of the other definitions. It includes areas of recent disturbance, such as mud slides, debris torrents, avalanches, and human-made disturbances (e.g., pipeline rights-of-way) where vegetation cover is less than 5%.
Lake	LA	A naturally occurring static body of water, greater than 2 m deep in some portion. The boundary for the lake is the natural high water mark.
Mine spoils	MS	Discarded overburden or waste rock moved so that ore can be extracted in a mining operation.
Shallow open water	OW	A wetland composed of permanent shallow open water and lacking extensive emergent plant cover. The water is less than 2 m deep.
Pond	PD	A naturally occurring static body of water, greater than 2 m deep in some portion. The boundary for the pond is the natural high water mark.
River	RI	A watercourse formed when water flows between continuous, definable banks. The flow may be intermittent or perennial. An area that has an ephemeral flow and no channel with definable banks is not considered a river.
Rock outcrop	RO	A gentle to steep, bedrock escarpment or outcropping, with little soil development and sparse vegetative cover.
Rubble	RU	Rubble is common on the ground surface in and adjacent to alpine areas, on ridgetops, gentle slopes and flat areas due to the effects of frost heaving.
Salt water	SW	Any body of water that contains salt or is considered to be salty.

2.3 FIELD GUIDE AND REFERENCE DATA

The following guide books and reference data were used for field inventories and ecosystem descriptions:

- Burt, P. 2000. Barren Land Beauties: Showy Plants of the Canadian Arctic. Outcrop Ltd. Yellowknife, NWT.
- MacKinnon, A., J. Pojar, R. Coupé (eds.). 1992. Plants of Northern British Columbia. B.C. Ministry of Forests and Lone Pine Publishing. Canada.
- Mallory, C. and S. Aiken. 2004. Common Plants of Nunavut. Department of Education, Iqaluit, Nunavut.
- Porsild, A. E. and W. J. Cody. 1980. Vascular Plants of Continental Northwest Territories. National Museums of Canada. Ottawa, ON, Canada.

In addition to the field guides, previous studies were used to generate lists of species known to occur in the Project area, and for general ecological information. Numerous online data sources were also used for identification (such as Flora of the Canadian Arctic Archipelago).

2.4 ECOSYSTEM MAPPING

Ecosystem mapping is the process of using ecological features such as terrain, soil, and vegetation to delineate meaningful units on a map. Terrestrial Ecosystem Mapping (TEM) requires mapping specialists to interpret ecosystem boundaries and attributes from aerial photographs or digital stereo images. The first step involves the identification of permanent terrain units based on surficial material, geomorphology and slope. The second involves the identification of ecosystems, which are mapped within the terrain polygons. Each ecosystem within a polygon is recorded as a decile on a scale from one to ten, which represents its proportional area within the polygon (e.g., 70% Wet Meadow, 20% Emergent Marsh and 10% Betula-Moss) (RIC 1998). There are a maximum of three deciles per polygon. Decile 1 contains the most dominant ecosystem unit. Decile 2 and 3 contain the second and third most dominant ecosystem units, respectively.

2.4.1 Local Study Area Mapping

Preliminary mapping of 16,115 ha of the Project area was completed in 1997 (Rescan 1997). An additional 40,023 ha were mapped in 2010 to characterize the ecosystems within an expanded Project area, which includes the potential Phase 2 Project infrastructure (Figure 2.4-1). The total area mapped was 56,138 ha. Ecosystems mapped were those defined by the local study area ecological classification.

The 1997 mapping was completed using 1:15,000 aerial photos and digitized via mono restitution (Rescan 1997). Detailed methodology for the preliminary mapping can be found in the Rescan (1997) Environmental Data Report. The expanded Project area was mapped in 2010 using 0.6 m QuickBird anaglyph satellite images from 2008. Anaglyph images create a stereoscopic 3D effect with the use of specialized anaglyph glasses (chromatically opposite lens of red and cyan). The images utilize two colour layers that are offset to provide a depth (3D) effect when viewed with the anaglyphic glasses. While the resolution of the anaglyph images is of lower quality than hard copy aerial photos, it allows for the interpretation of topological and bioterrain features. Terrain features were digitized in ArcGIS 9.3 directly on the anaglyph images. Terrain classification, and subsequent ecosystem delineation and classification, was completed on the matching 2008 2D QuickBird satellite imagery using both Natural Colour and False-Colour Infrared (FCIR) coverage.

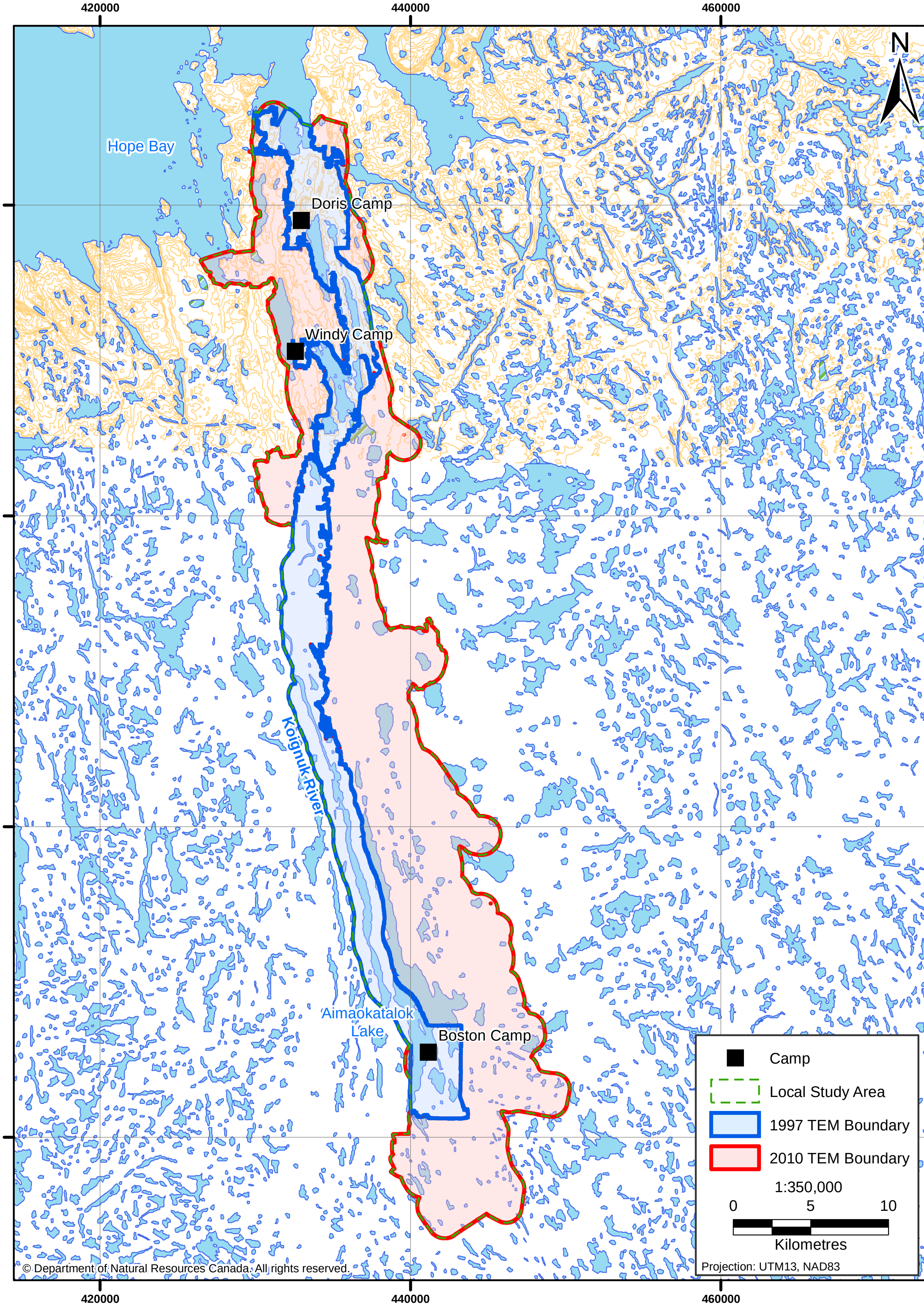


Figure 2.4-1

NEWMONT NORTH AMERICA

Local Study Area Mapped Boundaries

Rescan Engineers & Scientists

The 2010 mapping was matched where possible with the boundaries of the 1997 terrain and ecosystem polygons; however, in many areas the difference in mapping techniques (and resolution of the imagery that was used) resulted in discontinuous polygon boundaries. As well, the 2010 imagery contained areas of cloud and cloud shadow (particularly in the southeast) where interpretation was difficult. These areas were focused on during field surveys to ensure polygon delineation and classification was correct.

2.5 FIELD SURVEYS

Terrestrial and wetland field studies were conducted by Rescan in July and August, 2010. Terrestrial field teams consisted of a plant ecologist, a wildlife biologist, a soil scientist and a local Inuit assistant. The wetland field teams consisted of a plant ecologist and a local Inuit assistant.

The objective of the field studies was to identify the ecosystems and vegetation types, and map their distribution within the expanded Project area. The study area covered the potential Phase 2 Project infrastructure, including the all-whether access road to Boston. Data collected in 2010 builds on the existing work conducted in 1996 and 1997 by Westroad Resource Consultants Ltd. (Rescan 1997), and provides presence/absence information for rare species and invasive species.

General site and vegetation characteristics were assessed in plots measuring 20 m x 20 m (variable plot dimensions were used to capture linear ecosystems). Site locations were selected based on pre-existing mapping information as well as representative landform types, soil texture, soil drainage, species composition, and physiognomy according to RIC standards (RIC 1998). Field surveys were timed to optimize plant identification (e.g., during flowering and/or fruiting).

In addition to the ground inspections, numerous visual observations were taken to document the ecosystems traversed between formal survey locations. Both types of information are used to refine the ecosystem mapping. Detailed surficial material and soils information was also recorded and is discussed in the *2010 Terrain and Soil Baseline Report* (Rescan 2010).

2.5.1 Terrestrial Ecosystems

Field data was collected according to the prepared Field Data Collection Forms (Appendix 2). At each location, the following attributes were recorded:

- Project ID;
- Surveyor;
- Date;
- Photograph Numbers;
- GPS coordinates in Universal Transverse Mercator (UTM);
- Aspect (slope direction);
- Dominant/indicator plant species;
- Percent composition (terrestrial plots)/cover (wetland plots) of vegetation layers and species;
- Plant species and vegetation communities at risk and invasive plants;
- Soil texture;
- Soil Moisture Regime (Table 2.5-1); and
- Soil Nutrient Regime (Table 2.5-2).

Additional soils and terrain information was also collected as indicated on the Field Data Collection Form and in the *2010 Terrain and Soil Baseline Report* (Rescan 2010).

Table 2.5-1. Soil Moisture Regime (SMR) from the Standard for Terrestrial Ecosystem Mapping in British Columbia.

Code	Class	Description	Primary water source
0	Very xeric	Water removed extremely rapidly in relation to supply; soil is moist for a negligible time after precipitation	precipitation
1	Xeric	Water removed very rapidly in relation to supply; soil is moist for brief periods following precipitation	precipitation
2	Subxeric	Water removed rapidly in relation to supply; soil is moist for short periods following precipitation	precipitation
3	Submesic	Water removed readily in relation to supply; water available for moderately short periods following precipitation	precipitation
4	Mesic	Water removed somewhat slowly in relation to supply; soil may remain moist for a significant, but sometimes short period of the year. Available soil moisture reflects climatic inputs	precipitation in moderate- to fine-textured soils and limited seepage in coarse- textured soils
5	Subhygric	Water removed slowly enough to keep soil wet for a significant part of growing season; some temporary seepage and possibly mottling below 20 cm	precipitation and seepage
6	Hygric	Water removed slowly enough to keep soil wet for most of growing season; permanent seepage and mottling; gleyed colours common	seepage
7	Subhydric	Water removed slowly enough to keep water table at or near surface for most of year; gleyed mineral or organic soils; permanent seepage < 30 cm below surface	seepage or permanent water table
8	Hydric	Water removed so slowly that water table is at or above soil surface all year; gleyed mineral or organic soils	permanent water table

Table 2.5-2. Soil Nutrient Regime (SNR) from the Standard for Terrestrial Ecosystem Mapping in British Columbia.

Code	Soil Nutrient Regime
A	Very poor
B	Poor
C	Medium
D	Rich
E	Very Rich

**adapted from Standard for Terrestrial Ecosystem Mapping in British Columbia (RIC. 1998).*

2.5.2 Wetland Ecosystems

In addition to the local ecosystem classification used for mapping the LSA, the Federal Wetland Class (Table 2.5-3) was used to classify wetlands during ground field surveys. Wetland class cannot be distinguished from satellite imagery.

Table 2.5-3. Description of Federal Wetland Classes

Federal Wetland Class	Description
Bog	Nutrient poor peatland, receiving water exclusively from precipitation.
Fen	Nutrient medium peatland, receiving water from groundwater and precipitation.
Marsh	Nutrient rich mineral wetland; vegetation dominated by graminoids, forbs, shrubs and emergent plants.
Swamp	Nutrient rich mineral wetland; vegetation dominated by woody plants > 1 m in height.
Shallow open water	Wetland with free surface water up to 2 m depth; less than 25% of surface area occluded by emergent or woody plants.

Source: (Warner and Rubec 1997)

Wetland sites were classified to the class and form level according to the Canadian Wetland Classification System (Warner and Rubec 1997). Wetland class is based on general site characteristics, such as soil type and the extent and quality of predominant vegetation cover. Wetland classes are further subdivided into forms. Form classification is based upon surface morphology, surface pattern, water type, and characteristics of the soil (Warner and Rubec 1997).

Field data was collected using the field data sheets provided in Appendix 3. Sampling sites were selected based on the National Topographic Database (NTDB) mapping and proximity to proposed infrastructure features. A Wetland Habitat Inspection Form (WHIF) was used to collect the above-mentioned field information, as well as the following:

- Wetland class and form;
- Plant species present;
- Hydrodynamic index;
- Soil types;
- pH/conductivity;
- Site diagram; and
- Wildlife sightings.

Survey plots measured 400 m^2 in large wetlands. In smaller wetlands, the boundary of the plot extended to the outer edge of the wetland vegetation. A series of soil cores were taken throughout each plot to determine the representative soil type for each wetland. A GPS coordinate was recorded at the centre of each plot, and photos were taken in each direction covering a full 360 degrees. Other significant features, such as landforms, unique vegetation, rare plants, invasive plants and wildlife, were also noted.

2.6 ECOSYSTEMS AND PLANTS OF INTEREST

There is little information available for vegetation communities at risk in Nunavut or the Northwest Territories because there is no formal site level ecological classification system in use. Without an established taxonomic methodology available, it is difficult to identify communities at risk (since these communities have not yet been defined within Nunavut).

2.6.1 Sensitive or At Risk Ecosystems

Sensitive ecosystems are easily degraded by disturbance (McPhee et al. 2000), and are often remnants of the natural ecosystems that once occupied a much larger area (BC Ministry of Environment 2007).

Sensitive ecosystems are dependent on specialized habitats and/or complex ecological processes (Farmer 1993; McPhee et al. 2000).

In the absence of a Territorial system for identifying sensitive ecosystems, the ecosystem units mapped in the Project area have been assessed for local sensitivity and rarity. The analyses have been generalised into three groups of ecosystem units based on landscape position: marine, lowland, and upland. The rarity assessment was based on the occurrence of ecosystem units in the LSA compared to the much larger RSA. Although the mapping techniques and classification differ, generalized conclusions can be made regarding the regional occurrence of the mapped ecosystem units.

2.6.2 At Risk Plant Species

A formal ranking system for identification or status determination for plant species potentially at risk has not been established in Nunavut. Thus, The NWT Department of Environmental and Natural Resources database was used to create a list of species at risk known to occur within Nunavut (Appendix 4).

The resultant plant list was used to identify potential habitat that may support rare species. The locations of individual plants of interest cannot be predicted using the available satellite imagery; however, rare plant habitat is often associated with fine-scale and uncommon landscape features (Williston et al., 2004; Alberta Native Plant Council 2000) that can be targeted during field surveys.

Field surveys for rare/at risk plants were conducted in conjunction with general field surveys. A list of dominant plants in each field plot was recorded and evaluated for the presence of rare/at risk plants according to the Northwest Territories General Status Ranking Program or NWT GSRP (NWT Department of Environment and Natural Resources 2010). Systematic rare plant surveys were not conducted during the 2010 field season.

2.6.3 Invasive Plant Species

Invasive plants or weeds generally refer to species (native or non-native) that have the ability to out-compete native species when introduced into natural settings (Haber 1997). Typically, invasive plants aggressively establish in disturbed areas, thereby decreasing biodiversity (Polster 2005).

An invasive plant council or other formal means of determining the status of potentially invasive plants has not been established in Nunavut. Thus, the NWT GSRP invasive plant risk levels have been adopted for use in this report.

The NWT GSRP has been collecting information on plant species that are present within the NWT since 1999. Its purpose is to create a knowledge base that can be used to determine the status of any particular plant species. The NWT GSRP online database allows users to query information regarding the likelihood of a plant species occurring in a defined area. The online database also identifies plant status (prevalence, rare, alien etc.). The NWT GSRP identifies four levels of risk to the environment associated with invasive plants (NWT Department of Environment and Natural Resources 2010):

> **High** - Typically invades natural and disturbed habitats quickly, and is hard to eradicate. These plants can have severe ecological impacts on physical processes, plant or animal communities, and vegetation structure. Reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. They usually have very broad ecological amplitude (i.e. range of tolerance).
>
> **Moderate** - Usually invades anthropogenic disturbed habitats and invades some natural habitats. These species are invasive but their ecological impacts are usually moderate. They may be locally persistent and problematic, but distribution is usually limited.

Low - Tends to invades anthropogenic disturbed habitats and some natural habitats with natural disturbances. These species are invasive but their ecological impacts are low or there was not enough information to justify a higher score. Ecological amplitude and distribution are generally very limited, but these species may be locally persistent.

Potential - These plants can invade disturbed habitats if conditions are correct. These species can be invasive but there was not enough information to justify a higher score. Ecological amplitude and distribution are generally very limited, but these species may be locally persistent.

Field surveys for invasive plants were conducted in conjunction with general field surveys. The list of plants in each field plot was recorded and evaluated for the presence of invasive plants according to the NWT Environment and Natural Resources databases (Northwest Territories Environment and Natural Resources 2010).

2.7 BASELINE METAL CONCENTRATIONS IN PLANT TISSUES

The objective of the metals analysis was to quantify background tissue metal concentrations in plants that grow within the study area. Results from the baseline metals analysis may be used for country foods assessments and/or future monitoring programs.

Two lichen species, *Flavocetraria cucullata* and *Flavocetraria nivalis,* were targeted for collection. These species were selected for metals sampling based on the following criteria:

- known bioaccumulator of metals;
- likelihood of being a food source for animals, particularly caribou; and
- frequency of occurrence and ease of collection.

In total, 18 plant tissue samples were collected from 18 sites within the LSA during field surveys in July and August, 2010 ((*F. cucullata* (n = 8) and *F. nivalis* (n=10)). Aggregate samples of one species per site were sampled. The above-ground tissue was collected and any debris present on the tissue was removed before samples were placed into a plastic sampling bag.

Samples were sent to ALS Laboratory Group in Burnaby, BC, for analysis. Parameters analysed include percent moisture and metals (Table 2.7-1; Appendix 5). Variation in detection limits (Table 2.7-1; Appendix 5) was due to calibration differences in the test equipment.

Results were summarized by location (i.e., South or North end of the Belt; Figure 2.7-1).

In the South end of the belt, the following samples were collected and summarized together:

- *F. nivalis*: D65, D62, D63, D89, D93, D97, D86, D114, D116, and D125;
- *F. cucullata*: D82, D114, D73, 010, and 011.

In the North end of the belt, the following samples were collected and summarized together:

- *F. cucullata*: 021, 023, and 024.

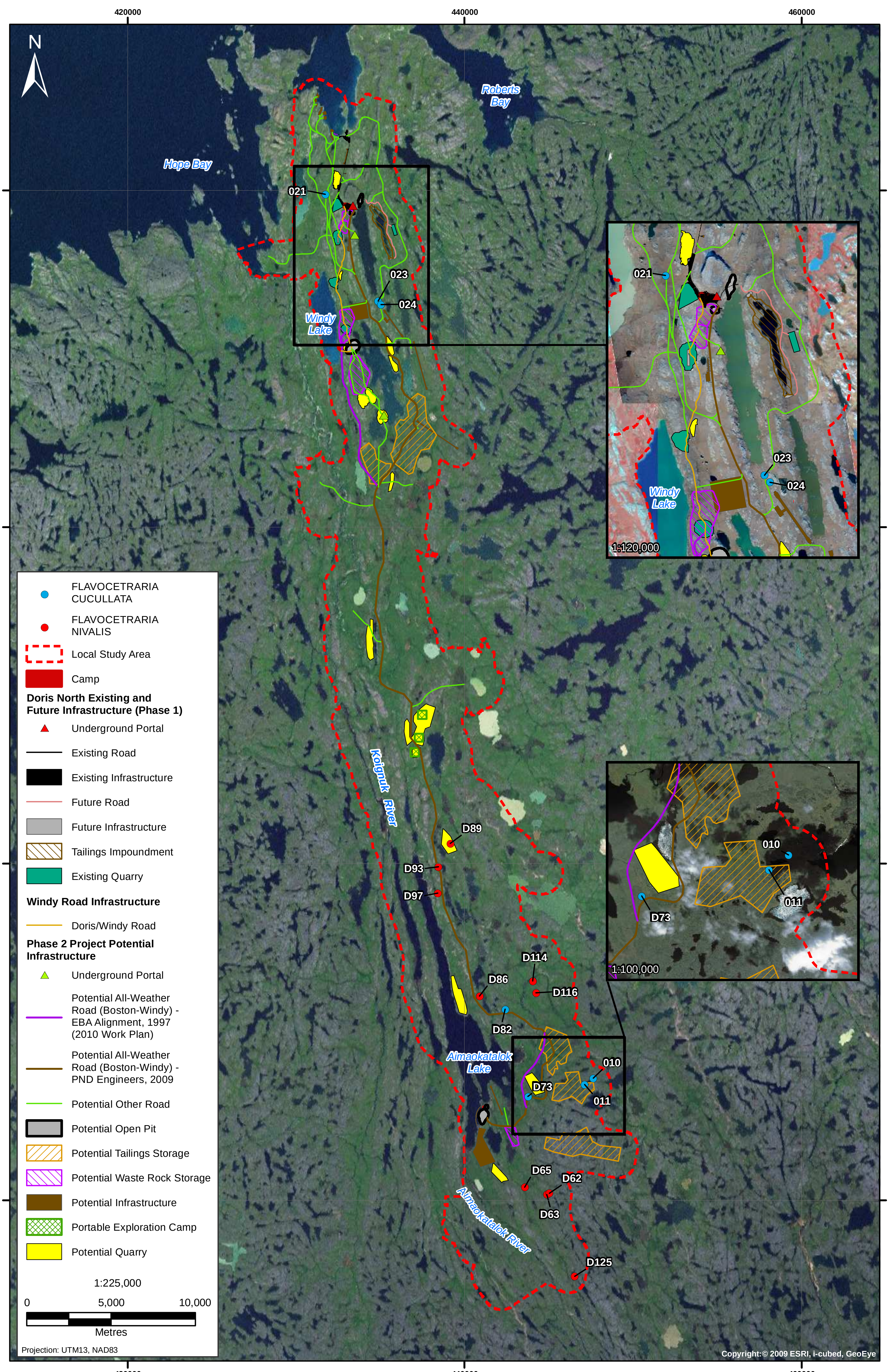
Table 2.7-1. Plant Tissue Metals Analyzed and their Realized Detection Limits

Parameter	Unit	Detection Limit (Range) (mg/kg wwt)	Parameter	Unit	Detection Limit (Range) (mg/kg wwt)
Physical Tests					
Moisture	%				
Metals			**Metals (cont'd)**		
Aluminum (Al)	mg/kg wwt	0.4	Molybdenum (Mo)	mg/kg wwt	0.004
Antimony (Sb)	mg/kg wwt	0.002	Nickel (Ni)	mg/kg wwt	0.02
Arsenic (As)	mg/kg wwt	0.004	Phosphorus (P)	mg/kg wwt	100 - 225
Barium (Ba)	mg/kg wwt	0.01	Potassium (K)	mg/kg wwt	400 - 900
Beryllium (Be)	mg/kg wwt	0.002	Rhenium (Re)	mg/kg wwt	0.002
Bismuth (Bi)	mg/kg wwt	0.002	Rubidium (Rb)	mg/kg wwt	0.01
Boron (B)	mg/kg wwt	0.2	Selenium (Se)	mg/kg wwt	0.02
Cadmium (Cd)	mg/kg wwt	0.002	Silver (Ag)	mg/kg wwt	0.001
Calcium (Ca)	mg/kg wwt	10 - 23	Sodium (Na)	mg/kg wwt	400 - 900
Cesium (Cs)	mg/kg wwt	0.001	Strontium (Sr)	mg/kg wwt	0.01
Chromium (Cr)	mg/kg wwt	0.04	Tellurium (Te)	mg/kg wwt	0.004
Cobalt (Co)	mg/kg wwt	0.004	Thallium (Tl)	mg/kg wwt	0.0004
Copper (Cu)	mg/kg wwt	0.02	Thorium (Th)	mg/kg wwt	0.002
Gallium (Ga)	mg/kg wwt	0.004	Tin (Sn)	mg/kg wwt	0.004
Iron (Fe)	mg/kg wwt	0.2	Titanium (Ti)	mg/kg wwt	0.01
Lead (Pb)	mg/kg wwt	0.004	Uranium (U)	mg/kg wwt	0.0004
Lithium (Li)	mg/kg wwt	0.02	Vanadium (V)	mg/kg wwt	0.004
Magnesium (Mg)	mg/kg wwt	20 - 45	Yttrium (Y)	mg/kg wwt	0.002
Manganese (Mn)	mg/kg wwt	0.004	Zinc (Zn)	mg/kg wwt	0.1
Mercury (Hg)	mg/kg wwt	0.001	Zirconium (Zr)	mg/kg wwt	0.04

Summaries are based on total wet weight, which represent *in situ* conditions under which wildlife might consume these plants. Results were summarized separately by species because uptake, allocation, and concentration of various metals differ by species (Garty 2001; Pugh, Dick, and Fredeen 2002; Naeth and Wilkinson 2008).

Metal concentrations below the detection limit were replaced by half the value of the detection limit for summary calculations. Although this methodology for addressing missing values does not capture the true frequency distribution of concentrations (Nosal, Legge, and Krupa 2000), assigning values to undetectable concentrations in this manner is common practice. It is assumed that the values are not zero, but the level of risk (i.e., with regards to human health) is low enough not to warrant additional statistical analyses.

Control sites were not identified for this summary, but can be established for future monitoring based on these analyses and once the locations of infrastructure have been confirmed. The majority of fugitive dust created during the lifetime of the Project is expected to settle within 500 m, which can further be used as a guide for selecting future monitoring sites (US EPA 1995; Auerbach, Walker, and Walker 1997).



NEWMONT NORTH AMERICA

Figure 2.7-1

Lichen Tissue Sampling Locations for Metal Analyses

Rescan Engineers & Scientists

3. Results and Discussion

3. Results and Discussion

This chapter describes the results of local ecosystem mapping (Section 3.1), field surveys (Section 3.2), ecosystems and plants of interest (Section 3.3) and metal concentrations of plant tissues (Section 3.4). The collected field data is reported in Appendix 6.

Results of the local ecosystem mapping are grouped into three categories. Each category shares similar characteristics in terms of vegetation and parent materials. Marine ecosystem units are strictly limited to the edge of the active marine environment. Upland ecosystem units are generally associated with bedrock outcrops and till or colluvial deposits found on the lower slopes of the outcrops. Lowland ecosystem units encompass the extensive lower slopes and plains, and generally occur on lacustrine, marine and fluvial deposits. Non-vegetated map units are not described in additional detail.

- Marine Ecosystems
  - Marine intertidal (MI)
  - Marine backshore (MB)
- Upland Ecosystems
  - Dry Carex-Lichen (CL)
  - Dryas Herb Mat (DH)
  - Betula-Ledum-Lichen (BL)
  - Dwarf Shrub Heath (SH)
- Lowland Ecosystems
  - Eriophorum Tussock Meadow (TM)
  - Dry Willow (DW)
  - Riparian Willow (RW)
  - Low Bench Floodplain (FP)
  - Wet Meadow (WM)
  - Emergent Marsh (EM)
  - Polygonal Ground (PG)
  - Betula-Moss (BM)

Many of the lowland ecosystem units are described at two levels. At the local ecosystem mapping level they are described as single ecosystem units based on attributes and boundaries discernable on the satellite imagery. Most of these wet ecosystems (including the EM, WM, OW and PG), however, are more accurately described as wetland complexes based on characteristics not readily identified by satellite image interpretation. Therefore, they are described in greater detail in the wetland section of this chapter.

Table 3-1 presents a summary of the local ecosystem mapping from 1997 and 2010 and the area of each ecosystem unit mapped (excluding the more detailed wetland classifications). A total of 1,069 ecosystem polygons were mapped in 1997 and 1,993 ecosystem polygons were mapped in 2010. Due to different mapping methodologies (aerial photos vs. satellite imagery) and study area boundaries, four mapping units used in 1997 were not used in 2010, and one new unit was added in 2010. Refer to Rescan (1997) for additional ecosystem unit descriptions and the methodology used to develop the classifications. The labelled TEM map is provided in Appendix 7 and the descriptions of the corresponding TEM map codes are provided in the TEM legend (Appendix 8).

Table 3-1. Local Ecosystem Mapping Summary

Map Code	Description	1997 TEM (ha)	2010 TEM (ha)	Total LSA (ha)	Percent of LSA
BA	Barren	5.78	0.00	5.78	0.01
BE	Beach	12.44	74.73	87.17	0.15
BI	Blockfield	0.00	345.72	346	0.61
BL	Betula-Ledum-Lichen	1280.27	7494.43	8,775	15.59
BM	Betula-Moss	339.96	1677.33	2,017	3.58
CL	Dry Carex-Lichen	86.91	580.21	667	1.19
DH	Dryas Herb Mat	1713.07	3179.09	4,892	8.69
DW	Dry Willow	946.33	743.20	1,690	3
EM	Emergent Marsh	1.65	1342.43	1,344	2.39
ES	Exposed Soil	1.79	101.60	103	0.18
FP	Low Bench Floodplain	90.84	36.95	128	0.23
LA & PD	Lakes and Ponds	2875.72	2983.40	5,859	8.01
MB	Marine Backshore	12.31	55.94	68.25	0.12
MI	Marine Intertidal	3.34	0.00	3.34	0.01
MS	Mine Spoils	5.71	10.07	15.78	0.03
OW	Shallow Open Water	10.56	0.00	10.56	0.02
PG	Polygonal Ground	218.17	1651.81	1,870	3.32
RI	River	568.81	210.55	779	1.38
RO	Rock Outcrop	1270.87	3761.58	5,032	8.94
RU	Rubble	19.62	0.00	19.62	0.03
RW	Riparian Willow	258.33	1839.86	2,098	3.73
SH	Dwarf Shrub-Heath	391.72	719.30	1,111	1.97
SW	Salt Water	392.74	58.39	451	0.8
TM	Eriophorum Tussock Meadow	4457.09	7171.10	11,628	20.66
WM	Wet Meadow	1147.70	6127.57	7,275	12.93
TOTAL		16,112	40,165	56,277	100

Wetlands within the LSA are widely distributed and comprise approximately 19 % of the mapped area. Some wetlands occur at too fine of a scale to be mapped (e.g. bogs) and thus the total distribution of wetlands in the LSA is likely underestimated. Common wetlands in the north of the LSA are fens and bogs, and large, shallow water bodies that are thought to have formed from the heaving and melting of ground ice under periglacial conditions (Rescan 1997). In the east of the LSA, many shallow ponds are formed in troughs behind what were once offshore sandbars now exposed above sea level due to isostatic rebound (Rescan 1997).

3.1 LOCAL ECOSYSTEM CLASSIFICATION AND MAPPING

3.1.1 Marine Ecosystems

3.1.1.1 Marine Backshore (MB)

Marine Backshore (MB) areas were mapped and surveyed in 1997 (Rescan 1997). Further surveying of the MB ecosystem unit was not required in 2010 because its occurrence was largely limited to areas surveyed in 1997.

The MB ecosystem unit occurs upslope of the Marine Intertidal (MI) unit. It is characterized by thick deposits of marine sands and is similar in appearance to a sand dune (Plate 3.1-1). Occurrences of this ecosystem unit are restricted to small protected bays and inlets with shallow slopes along a coastline that is dominated by steep, rocky shores. MB ecosystems comprise 0.12% (68 ha) of the LSA, while the non-vegetated Beach (BE) map unit that occurs in similar locations covers an additional 0.15% (87 ha) of the LSA.

Plate 3.1-1. Typical Marine Backshore (MB) ecosystem unit.

The MB unit is very dry (Soil Moisture Regime, SMR, of 1) and nutrient poor (Soil Nutrient Regime, SNR, of A) with poorly developed coarse textured soils. Organic inputs are limited due to sparse vegetation cover. Vegetation is limited to salt tolerant species such as lyme-grass (*Elymus arenarius* ssp. *mollis*), seabeach sandwort (*Honckenya peploides*), seaside plantain (*Plantago juncoides* var. *glauca*), and northern sweet-vetch (*Hedysarum mackenzii*). Cover is generally less than 50% with shrubs, moss, and lichens generally absent.

3.1.1.2 Marine Intertidal (MI)

Marine Intertidal (MI) areas were mapped and surveyed in 1997 (Rescan 1997). No additional surveying or mapping of the MI ecosystem unit was required in 2010 as the 1997 surveys provided sufficient coverage.

The MI unit is limited to intertidal flats and gently sloping shorelines in northern portions of the LSA and comprises less than 0.01% (3 ha) of the mapped area. It occurs on veneers of marine sand often overlaying marine clays that often have buried organic layers (Plate 3.1-2). These areas are frequently inundated with saltwater, often from wave action, which largely preclude soil development. MI units are very wet (SMR of 7 or 8) and medium to rich (SNR C to D).

Plate 3.1-2. Typical MI ecosystem unit (left) and upslope MB (right).

Vegetation is variable, ranging from 50 to 90% cover. Shrubs, mosses and lichens are generally absent. The MI unit is characterized by a simple community of salt tolerant species dominated by creeping alkaligrass (*Puccinelia phryganodes*) and Hoppner sedge (*Carex subspathacea*), while Pacific silverweed (*Potentilla egedii*), scurvygrass (*Cochlearia officinalis*), *Carex amblyorhyncha*, and low chickweed (*Stellaria humifusa*) occurs in variable amounts upslope of the ocean where the MI often transitions into the MB unit.

3.1.2 Upland Ecosystems

3.1.2.1 Dry Carex – Lichen (CL)

The Dry Carex-Lichen (CL) unit is the driest and most nutrient-limited unit in the study area. It occurs in small to large patches (generally discontinuous) on crests and upper slopes underlain by coarse washed till, glaciofluvial materials, or weathered bedrock (Plate 3.1-3). Slopes typically range from zero to fifteen percent and are water shedding. Sands comprise the typical soil matrix, although coarse loamy sands and silt loams occasionally occur. Soil development is minimal and generally restricted to thin layers over bedrock or weathered bedrock. High coarse fragment content (35 to > 70%) is typical.

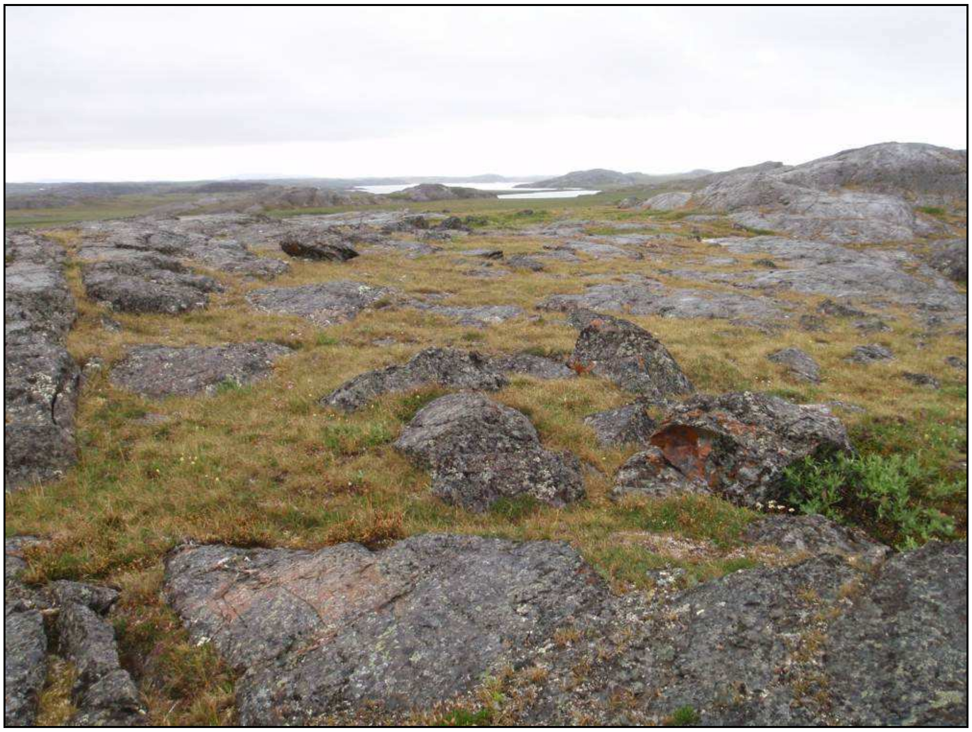


Plate 3.1-3. Typical Dry Carex-Lichen (CL) ecosystem unit interspersed with bedrock outcrops.

Communities with characteristics intermediate between the CL and Dryas Herb Mat (DH) ecosystems are common but the transition between the two is typically rapid. CL typically occurs in small patches (often 25% or less vegetated) on bedrock outcrops where thin soils accumulate, and in association with DH, and non-vegetated types including rock outcrops (RO) and exposed soil (ES). CL ecosystems comprise just over one percent (667 ha) of the LSA. The type is likely under-represented in the ecosystem mapping due to its generally sparse cover that often does not extend to 10% of an ecosystem polygon (the smallest mappable component of a polygon).

Harsh environmental conditions limit the number and type of plant species that occur in the CL. Total vegetation cover is strongly influenced by microsites (generally small depressions) which allow for greater soil development, water retention, and reduced wind exposure. This microtopographical affinity results in highly variable cover. For example, dwarf shrubs may range from 1 to 78% cover, herbs from 1 to 45% cover, and moss and lichens from 0.1 to 85% cover.

Thin and poorly developed soils, limited soil moisture and nutrients, and severe wind exposure limit the extent and diversity of vegetation cover in the CL. Common dwarf shrub species include Arctic willow (*Salix arctica*) and Arctic avens (*Dryas integrifolia*). Herbaceous cover is typically dominated by curly sedge (*Carex rupestris*) with variable occurrence of alpine sweetgrass or holy grass (*Hierochloe alpina*), moss campion (*Silene acaulis* var. *exscapa*), prickly saxifrage (*Saxifraga tricuspidata*), purple saxifrage (*S. oppositifolia*), and Arctic oxytrope (*Oxytropis arctica*). Crustose and foliose (*Cetraria* spp.) lichens are typically abundant, while moss cover is highly variable (Rescan 1997).

3.1.2.2 Dryas Herb Mat (DH)

The Dryas Herb Mat (DH) unit occurs on well drained sites with limited or no seepage. It often occurs on mid to upper slopes (2 to 25% slope) of bedrock outcrops in conjunction with CL and non-vegetated bedrock or weathered bedrock (Plate 3.1-4). In southern regions it also occurs on flat and gently sloped areas in conjunction with block fields and on shallow soils over bedrock. It is the fifth most common ecosystem unit in the LSA, comprising 8.7% (4,892 ha) of the total mapped area. DH typically occurs on shallow veneers and mantles of sandy till, and occasionally on glacial fluvial, aeolian, or weathered bedrock with high coarse fragment contents (35 to 70%). Frost boils and solifluction are relatively common. Relative soil moisture is typically xeric (1) or subxeric (2), and occasionally submesic (3) or mesic (4). Soil development is variable, but generally limited and highly active. Relative soil nutrients range from poor (B) to medium (C).

Plate 3.1-4. Typical Dryas Herb Mat (DH) ecosystem unit.

Arctic avens (*Dryas integrifolia*) is typically the dominant species in the DH unit. Dwarf shrubs such as alpine bilberry (*Vaccinium uliginosum* var. *alpinum*), Arctic willow (*Salix arctica*), and net-veined willow (*Salix reticulata*) occur in variable amounts. Curly sedge (*Carex rupestris*) is the most common herbaceous species. Other herbs that commonly occur include Liquoriceroot (*Hedysarum alpinum*), Maydell's oxytrope (*Oxytropis maydelliana*), Arctic heather *(Cassiope tetragona*), Lapland rosebay (*Rhododendron lapponicum*), Arctic oxytrope (*Oxytropis arctica*), woolly and capitate louseworts (*Pedicularis lanata*, *P. capitata*), and single-spike sedge (*Carex scirpodea*). The diversity and abundance of herbaceous cover is highly variable and associated with microsites that provide deeper soils, increased water availability, and shelter from wind exposure.

Plant species characteristic of the DH unit commonly persist downslope, resulting in transitional communities with characteristics intermediate between DH and SH ecosystems (Rescan 1997). The DH unit typically occurs in similar locations as CL, and is immediately upslope of SH, and occasionally BL and DW.

3.1.2.3 Betula Ledum Lichen (BL)

The Betula Ledum Lichen (BL) unit occurs almost exclusively on level-to-gentle hillslopes overlain by washed till of variable thickness. It occasionally occurs on glaciofluvial outwash, sandy marine sediments, fine colluvium and alluvial slopes. BL is the second most common vegetation type in the LSA, comprising 15% (11,628 ha) of the mapped area. It typically occurs in extensive areas upslope of TM (and occasionally BM) where glacial lacustrine and glacial marine lower slopes and plain turn to organic veneers over till, and below bedrock outcrops containing SH, DH, and CL (Plate 3.1-5). BL occurs on 0 to 18% slopes, are slightly to strongly water shedding, and often contain frost boils and evidence of solifluction. In flatter terrain, mainly in southern portions of the LSA, the BL ecosystem units contain a substantial exposed boulder component and are typically associated with patches of DH, TM, WM, and extensive block fields (Plate 3.1-6).

Plate 3.1-5. Fine textured Betula Ledum Lichen (BL) ecosystem unit typical of northern portions of the LSA.

Plate 3.1-6. Bouldery Betula Ledum Lichen (BL) ecosystem unit typical of southern portions of the LSA.

Soil textures are predominantly sands and loamy sands, with occasional occurrences of silts and clays. Coarse fragments range from 0 to 65% and are predominantly gravels and cobbles. Relative soil moisture regime is subxeric (2) to subhygric (5), and rarely xeric (1). Relative soil nutrient regime is very poor (A) to medium (C). Coarse, well-drained and often nutrient-deficient soils limit the diversity and abundance of herbs and mosses, which results in low total ground cover (range: 80-100% including shrubs, herbs, mosses and lichens), relative to more productive ecosystems (which often have a total ground cover of greater than 100%).

Dwarf birch and northern Labrador tea (*Ledum decumbens*) are typically the dominant shrubs, although several willow species occur. Alpine bilberry and lingonberry (*Vaccinium vitis-idaea* var. *minus*) are typically present and occasionally abundant. Alpine bearberry (*Arctostaphylos alpina*) and crowberry (*Empetrum nigrum*) are usually present at low cover, while several *Carex* and *Eriophorum* species occur in variable amounts. Arctic heather, Maydell's oxytrope, and alpine sweet-grass are typically present in trace amounts.

Occurrences of the BL that contain high boulder cover are frequent in the north and south ends of the study area. Based on the initial 1997 field data this boulder association was believed to represent a distinct unit; however, the analysis did not support such a distinction, as vegetation and environmental conditions overlap significantly with the typical BL unit. This condition is typically found on slopes and crests of rock outcrops and occasionally on glaciofluvial deposits (*i.e.* eskers and outwash). The unit is characterized by less northern Labrador tea (0-15%) and generally higher cover of lichens, crowberry, and alpine bearberry than the typical BL unit (Rescan 1997).

3.1.2.4 Dwarf Shrub Heath (SH)

The Dwarf Shrub Heath (SH) ecosystem unit occurs on moderate to steep rocky slopes of till or colluvium (Plate 3.1-7). It generally occurs at the base of rock outcrops with extensive solifluction, cryoturbated soils, and frost boils (Plate 3.1-8). It is relatively uncommon in the LSA, accounting for 2.0% (1,111 ha) of the mapped area. Soil texture is variable and ranges from silty loam to sand. It is generally well drained with coarse fragments ranging from 20 to 70%. Relative soil moisture is subxeric (2) to mesic (4), with a single plot indicating subhygric (5) conditions. Relative soil nutrients are generally poor (B) to occasionally medium (C).

This ecosystem unit is highly variable, but always contains a component of Arctic heather (*Cassiope tetragona*). It contains variable microtopography in the form of boulder and rock outcrops and often forms an uneven, stepped slope. The variable microtopography and active, variable soils result in a diverse, somewhat unpredictable assemblage of species. Aspect is also an important factor in species occurrence. Western slopes generally contain drier species, while eastern slopes have late snow packs resulting in high moisture adapted species and a higher moss cover. Common species include dwarf birch (*Betula nana*), (*Vaccinium vitis-idaea* var. *minus*), crowberry (*Empetrum nigrum*), and several *Salix* and *Saxifraga* species. Moss and lichen cover is variable and often diverse.

The SH unit typically occurs in distinct communities with abrupt transitions to adjacent ecosystem units. TM and BL often occur immediately downslope from SH units, with occasional occurrences of DW. Upslope communities are generally CL and non-vegetated units such as RO and ES.

Plate 3.1-7. Typical Dwarf Shrub-Heath (SH) ecosystem unit.

Plate 3.1-8. Frost boils in the Dwarf Shrub-Heath (SH) ecosystem unit.

3.1.3 Lowland Ecosystems

3.1.3.1 Betula-Moss (BM)

The Betula-Moss (BM) ecosystem unit occurs on level to slightly sloped (0-5%) sandy or silty clay, lacustrine and fluvial sediments, and occasionally on fine tills. BM comprises just under 4% (2,017 ha) of the LSA, generally in valley bottom positions adjacent to flowing or standing water. Relative soil moisture regime is mesic (4) to hygric (6), and rarely submesic (3) or subhydric (7). Soil moisture is variable based on specific soil pit locations as BM is often complexed with wet depressions containing EM or WM. Relative soil nutrient regime is generally medium (C), but occasional poor (B) or very poor (A). Coarse fragments are generally absent or less than 20%. Permafrost is common and typically occurs 25 to 60 cm from the surface.

Vegetation in the BM is relatively simplistic. It is dominated by a high cover of dwarf birch (*Betula nana*), and occasionally *Salix* species (particularly *S. pulchra* and *Vaccinium* species; Plate 3.1-9). Herbaceous and lichen cover is largely absent, while mosses (typically *Sphagnum, Aulacomnium* and *Dicranium* spp.) often form thick mats under the shrub layer.

Plate 3.1-9. Typical Betula-Moss (BM) ecosystem unit with wet depressions containing EM.

The BM has distinct boundaries to adjacent ecosystem units. It typically contains EM or WM in wet depressions between palsa mounds. Adjacent communities are varied, with TM, WM, and RW often occurring.

3.1.3.2 Dry Willow (DW)

The Dry Willow (DW) unit has been modified from the Rescan 1997 description. It was previously limited to fluvial and marine slopes on upper river banks and lakeshores. This description has been expanded to include willow dominated communities found on fine textured morainal and lacustrine slopes. DW is relatively common in the LSA, comprising 3.0% (1,690 ha) of the mapped area. It is generally found upslope of RW in typical conditions, and occasionally on the lower slopes of bedrock outcrops with BL or TM below and SH above. Relative moisture is generally mesic (4) and occasionally submesic (3) at upper slope positions, and occasionally subhygric (5) at mid slope positions (Rescan 1997). Permafrost is common, particularly in the lower slope positions, occurring at 30 to 50 cm below the surface. Relative soil nutrients are generally medium (C), and occasionally poor (B) or rich (D).

Gray-leaved willow (*Salix glauca*) is the characteristic species of the DW (Plate 3.1-10). Dwarf birch (*Betula nana*) is also common and often extensive, but limited to surfaces of freeze-thaw mounds, along with occasional occurrences of crowberry (*Empetrum nigrum*) and *Vaccinium* species. Large-flowered wintergreen (*Pyrola grandiflora*), alpine arnica (*Arnica alpina* ssp. *angustifolia*), alpine milk-vetch (*Astragalus alpinus*), and Maydell's oxytrope are also common.

Plate 3.1-10. Typical Dry Willow (DW) ecosystem unit.

3.1.3.3 Emergent Marsh (EM)

The Emergent Marsh (EM) is the wettest ecosystem unit described in the LSA. It occurs on level organic plains along lakes, ponds and low-gradient streams (Plate 3.1-11 and 3.1-12). The EM is rarely wide-spread, often complexed with other ecosystem units, and not extensive enough to map. It comprises 2.4% (1, 344 ha) of the LSA, although this value is likely an underestimate of the true proportion. The EM occurs in areas where the water table is at the surface year-round, and surface and subsurface flows are continuous. Soil moisture is hydric (8) and soil nutrients are generally rich (D).

Water sedge (*Carex aquatalis*) is the characteristic species for the EM unit. Additional *Carex* species, along with marsh cinquefoil (*Potentilla palustris*), mare's tail (*Hippurus vulgaris*), marsh marigold (*Caltha palustris* var. *arctica*), Pallas's buttercup (*Ranunculus pallasii*), and giant water moss (*Calliergon giganticum*) are also common.

Plate 3.1-11. Typical Emergent Marsh (EM) ecosystem unit in southern portions of the LSA.

Plate 3.1-12. Typical Emergent Marsh (EM) ecosystem unit in northern portions of the LSA.

The EM unit typically forms narrow communities along lakes, ponds, and streams. It occurs in complexes with WM, PG and TM, and in narrow linear depressions with moving water in BM ecosystems. The EM is described in greater detail in the wetland field survey section of this report.

3.1.3.4 Low Bench Floodplain (FP)

The Low Bench Floodplain (FP) unit is an uncommon ecosystem type in the LSA (mapped in 0.2% - 128 ha – of the total area) that is restricted to narrow bands along active floodplains of rivers, streams and lakes (Plate 3.1-13). The FP unit was primarily field mapped in 2010 because the unit was less discernible on the satellite imagery used to complete local ecosystem mapping compared to the aerial photographs used for mapping in 1997. The FP occurs on saturated soils with relative moisture ranging from hygric (6) to hydric (8) with nutrients ranging from moderate (C) to rich (D). It typically occurs on active sandy fluvial plains and silty lacustrine slopes. The FP typically occurs in narrow strips between upslope RW communities and lakes, ponds or streams downslope.

Plate 3.1-13. Typical Low Bench Floodplain (FP) ecosystem unit (left) and RW (right).

Vegetation cover is typically moderate to high, but limited to species that are tolerant of seasonal inundation. Common species include *Equisetum* goose-grass (*Dupontia Fischeri* ssp. *psilosantha*), yellow water crowfoot (*Ranunculus gmelini*), marsh cinquefoil (*Potentilla palustris*), and mare's tail (*Hippurus vulgaris*). Moss cover is variable with no dominant species, although *Sphagnum* often occurs in thick blankets. In many areas, extensive scouring and/or sediment deposition have created disclimax communities.

3.1.3.5 Polygonal Ground (PG)

The Polygonal Ground (PG) ecosystem unit is defined by periglacial processes (i.e. freeze-thaw processes) rather than dominant vegetation or environmental conditions. It is characterized by disjunct communities due to abrupt microtopographical changes. Two types of PG occur in the LSA. High-centre polygons are described as a matrix of palsas surrounded by WM depressions (Plate 3.1-14). Low-centre types have a matrix of linear ridges underlain by ice-wedges (Plate 3.1-15). Palsa and ridge tops are generally dry and support communities similar to BL or BM. Wet depressions are typically similar to the WM unit, although EM also frequently occurs. PG units are common in the LSA, accounting for 3.3% (1,870 ha) of the mapped area.

Plate 3.1-14. Aerial view of a typical Polygonal Ground (PG) ecosystem unit.

Plate 3.1-15. Polygonal Ground (PG) ecosystem unit showing low-centered ice-wedge ridges with the Wet Meadow (WM) ecosystem on either side.

3.1.3.6 Riparian Willow (RW)

The Riparian Willow (RW) unit occurs in areas that experience fluctuating water tables; predominantly active floodplains of streams and rivers, lake and pond edges, and occasionally upslope seepage sites (Plate 3.1-16 and 3.1-17). It occurs on fine fluvial sediments, and occasionally on lacustrine plains. RW was mapped on 3.7% (2,098 ha) of the LSA. Soils generally have a sandy or silty texture, although several plots occurred on fibric organic veneers. Relative soil moisture ranges from subhygric (5) to sub hydric (7). Relative soil nutrients are variable in response to organic inputs and range from poor (B) to rich (D).

Plate 3.1-16. Aerial view of a typical Riparian Willow (RW) ecosystem unit (dark green) with the Emergent Marsh (EM) ecosystem unit along a stream (bright green).

Plate 3.1-17. Typical Riparian Willow (RW) ecosystem unit in autumn.

RW ecosystems are readily discernable from other shrub dominated units by the high willow cover and landscape position. Several species of willow are common (*Salix planifolia*, *S. lanata* and *S. pulchra*). The RW, especially in protected seepage sites, contain the tallest willows in the LSA, with thickets often exceeding one meter in height. Other common species include sedges (including *C. aquatilis)*, *Eriophorum*, *Equisetium*, *Festuca* and *Calamagrostis* species, and coltsfoot (*Petasites frigidus*).

The RW unit rarely grades into other ecosystem units, but rather, boundaries are typically distinct, particularly downslope where it transitions to FP and EM. Ecosystem units upslope of RW are variable and include TM and WM in valley bottoms, and BL, DW, and SH along seepage site communities.

3.1.3.7 Eriophorum Tussock Meadow (TM)

The Eriphorum Tussock Meadow (TM) ecosystem unit is the most common and widespread unit in the LSA. It comprises 20.6% (11,628 ha) of the total mapped area. It occurs in a variety of lowland landscape positions on marine and lacustrine plains and gentle slopes (0 to 15%), and occasionally on fine textured fluvial and till. Significant surface seepages are typically present, but standing water is uncommon. Relative soil moisture is mesic (4) to subhydric (7) depending on landscape position. Relative soil nutrients are typically medium (C), but range from poor to medium (B-C) in drier locations dominated by dwarf birch, and occasionally medium to rich (C-D) in wet, willow dominated areas. Soil textures are typically organic veneers overlying silty loams and silty clays. Permafrost is ubiquitous at the organic/mineral soil transition, generally 30 to 65 cm from the surface, and frost boils occasionally occur.

The TM is characterized by the presence of distinct sheathed cotton-grass (*Eriophorum vaginatum*) tussocks (Plate 3.1-18). Other ecosystem units may have sporadic tussocks, but the TM is distinguished by a continuous occurrence of well formed, distinct tussocks (Plate 3.1-19). While *E. vaginatum* tussocks are known to vary in terms of topography, hydrology, soils, and pH, it is considered a common vegetation type across most of the Arctic (Walker et al. 1994). Mark et al. (1985) suggest that tussocks can be up to 187 years when mature. Within the TM, plant species favouring dry conditions, such as Arctic avens, alpine bilberry, Arctic heather and lichens, are found on the top and upper sides of the tussocks. Conditions are wetter in inter-tussock troughs, and these areas may be dominated by tall cotton-grass (*Eriophorum angustifolium*) and various species of *Carex* and mosses. Several species of willows (including *Salix lanata* ssp. *richardsonii* and *S. pulchra*) and to a lesser extent dwarf birch (*Betula nana*) occur sporadically or extensively on small to large mounds within the tussocks.

Transitions from TM to other ecosystem units are generally gradual and somewhat difficult to detect. The TM typically occurs in ecosystem polygons that also include, but not limited to, WM, BL, PG and EM.

3.1.3.8 Wet Meadow (WM)

The Wet Meadow (WM) ecosystem unit is a wet community that typically occurs on water-receiving lacustrine and marine lower slopes (0 to 5%) and plains (Plate 3.1-20). It is the third most common unit in the LSA, comprising 12.9% (7,275 ha) of the mapped area. WM is predominantly found on fibric and mesic organic veneers over fine textured (<20% coarse fragments) silty clays and silty loams, and occasionally coarser material. Permafrost generally occurs at the organic to mineral soil boundary at a depth of 20 to 50 cm. Relative moisture regime is generally hygric to subhydric (6-7). Relative soil nutrients range from medium (C) to rich (D) and occasionally poor (B). Ice wedges and low transverse wedges of organic or mineral soils are common.

Plate 3.1-18. Typical Eriophorum Tussock Meadow (TM) ecosystem unit.

Plate 3.1-19. Close-up of typical E. vaginatum tussocks.

One or more vegetation associations comprise the WM in any given area. These associations are specific plant communities that develop within a particular range of conditions (SMR, SNR, hydrodynamism, and pH) that define the WM. Two sedge associations, water sedge and tall cottongrass, were identified during field surveys by Rescan (1997) and one additional association, chordroot sedge, was identified in 2010. The ecosystem mapping does not distinguish among the vegetation associations within the WM because these fine-scale differences cannot be detected on the satellite imagery. The association types are described in greater detail in the wetland section of this report and in Rescan (1997).

Plate 3.1-20. Typical Wet Meadow (WM) ecosystem unit.

Water sedge (*Carex aquatilis)* and tall cottongrass (*Eriophorum angustifolium*) are the most characteristic species of the WM. Other frequently occurring species include *Carex membranacea, C. atrofusca*, *C. misandra*, *C. vaginata*, *C. capillaris*, and *C. rariflora*. Sudetan lousewort (*Pedicularis sudetica*), an indicator of saturated organic soils, is typically present, although in trace amounts.

The WM unit typically occurs in lower landscape positions in combination with TM, EM, BL and BM. Transition to other ecosystem units is generally rapid and marked by reduced *Carex* diversity, and increased shrub cover or tussocks. WM commonly forms small portions of large TM ecosystem polygons along seepage channels, and extensive pure communities in low positions. It is also typically complexed in PG units.

3.1.4 Local Ecosystems within a Regional Context

Direct comparisons between the occurrence of ecosystem units at the local and regional scales could not be made due to differences in classification methods. The regional WKSS ELC system is more generalised and results in multiple local ecosystem units correlating with one or more ELC units (Table 3.1-1). In addition, the ELC contains an unclassified ELC unit, while the LSA mapping contains multiple non-vegetated codes. Therefore, a generalised comparison was made by grouping the LSA and ELC results by landscape position (Table 3.1-1 and 3.1-2). This comparison indicates that upland ecosystems are more prevalent in the RSA (40.4% in RSA vs. 27.5% in the LSA) and lowland ecosystems are more common in the LSA (49.8% in the LSA vs. 39.8% in the RSA). The difference in the lowland comparison is actually larger as 19.6% of the RSA is classified as shallow water, which includes ponds, shallow open water, and ecosystems dominated by emergent vegetation.

Ponds are considered to be non-vegetated units in the LSA mapping, and grouped in the 'other' category (other includes non-vegetated units and the ELC unclassified unit, with the RSA containing 19.8% and the LSA containing 20.1%). The exact amount of ponds mapped in the RSA is not known, but it is reasonable to suggest that half or more of the 19.8% is ponds. Therefore, it is assumed that lowland ecosystems are roughly twice as common in the LSA compared to the RSA, and perhaps five times as common if the shallow water unit is removed entirely. In particular, Eriophorum Tussock Meadow (TM) occurs on 20.6% of the LSA, while the similar WKSS Tussock/Hummock ELC unit only comprises 7.9% of the RSA. Marine ecosystems were not included in the WKSS ELC and have been excluded from this comparison.

Table 3.1-1. WKSS ELC Summary and Landscape Position

ELC Code	WKSS ELC Unit	Local Ecosystem Unit(s)	Landscape Position	Area (ha)	% of RSA
4	Wetland (Sedge Meadow)	Wet Meadow (WM), Polygonal Ground (PG) and Emergent Marsh (EM)	Lowland	37,192	4.8
6	Tussock/Hummock	Eriophorum Tussock Meadow (TM)	Lowland	60,898	7.9
11	Riparian Tall Shrub	Riparian Willow (RW)	Lowland	18,649	2.4
17	Low Shrub	Dry Willow (DW) and Betula-Moss (BM	Lowland	38,936	5.1
5	Shallow Water	Ponds (PD) and Shallow Open Water (OW)	Lowland	150,709	19.6
0	Unclassified	NA	Other	7,674	1.0
2	Deep Water	Lakes (LA) and Salt Water (SW)	Other	108,899	14.1
15	Boulder Association	Blockfield (BI)	Other	4,790	0.6
16	Bare Ground	Barren (BA) and Exposed Soil (ES)	Other	5,972	0.8
18	Gravel Deposit	Barren (BA) and Exposed Soil (ES)	Other	25,500	3.3
1	Lichen Veneer	Carex-Lichen (CL)	Upland	10,507	1.4
3	Esker Complex	Carex-Lichen (CL) and Dwarf Shrub-Heath (SH)	Upland	1,533	0.2
7	Heath Tundra	Dryas Herb Mat (DH) and Betula-Ledum-Lichen (BL)	Upland	127,670	16.6
10	Bedrock Association	Rock Outcrop (RO) and Carex-Lichen (CL)	Upland	31,086	4.0
13	Heath/Boulder	Carex-Lichen (CL) and Dwarf Shrub-Heath (SH)	Upland	11,943	1.6
14	Heath/Bedrock	Dryas Herb Mat (DH) and Carex-Lichen (CL)	Upland	128,042	16.6
TOTAL				**770,000**	**100.0**

Table 3.1-2. LSA Ecosystem Unit Summary and Landscape Position

Map Code	Description	Landscape Position	Total LSA (ha)	Percent of LSA
BM	Betula-Moss	Lowland	2,017	3.58
DW	Dry Willow	Lowland	1,690	3.00
EM	Emergent Marsh	Lowland	1,344	2.39
FP	Low Bench Floodplain	Lowland	128	0.23
OW	Shallow Open Water	Lowland	11	0.02
PG	Polygonal Ground	Lowland	1,870	3.32
RI	River	Lowland	779	1.38
RW	Riparian Willow	Lowland	2,098	3.73
TM	Eriophorum Tussock Meadow	Lowland	11,628	20.66
WM	Wet Meadow	Lowland	7,275	12.93
BE	Beach	Marine	87	0.15
MB	Marine Backshore	Marine	68	0.12
MI	Marine Intertidal	Marine	3	0.01
BA	Barren	Other	6	0.01
BI	Blockfield	Other	346	0.61

(continued)

Table 3.1-2. LSA Ecosystem Unit Summary and Landscape Position (completed)

Map Code	Description	Landscape Position	Total LSA (ha)	Percent of LSA
ES	Exposed Soil	Other	103	0.18
LA & PD	Lakes and Ponds	Other	5,859	8.01
MS	Mine Spoils	Other	16	0.03
SW	Salt Water	Other	451	0.80
BL	Betula-Ledum-Lichen	Upland	8,775	15.59
CL	Dry Carex-Lichen	Upland	667	1.19
DH	Dryas Herb Mat	Upland	4,892	8.69
RO	Rock Outcrop	Upland	5,032	8.94
RU	Rubble	Upland	20	0.03
SH	Dwarf Shrub-Heath	Upland	1,111	1.97
TOTAL			**56,277**	**100.00**

3.2 FIELD SURVEYS

The following sections describe the number and type of local ecosystem sample plots established during the 2010 field season. Terrestrial survey plots are described first and wetland survey plots are described separately as different methodologies were used for data collection. However, there is overlap between the wetter terrestrial ecosystem units and multiple wetland types as the ecosystem units are much more generalized (e.g., the emergent marsh ecosystem unit can be further classified into wetland form types such as lacustrine marsh, slope marsh, or basin marsh).

3.2.1 Terrestrial Field Surveys

A total of 166 sample plots and 166 visual plots were surveyed within the LSA in 2010 to characterize the local ecosystem units (Figures 3.2-1a-c). TM, BL and DH were the most commonly sampled ecosystem units, accounting for 28%, 20%, and 13% of sample plots respectively (Table 3.2-1). The field data is reported in Appendix 10. In addition to the 12 ecosystem units that were sampled, three plots were established in two non-vegetated units (block field and rock outcrops). Visual plots were quick assessments recorded while traversing between sample plots. In visual plots, limited data beyond the ecosystem unit were recorded, and they typically described multiple ecosystem units observed in the larger polygon for mapping purposes.

Data from the terrestrial field plots were used to modify some of the Rescan (1997) ecosystem unit descriptions. The data were also used to confirm ecosystem mapping classification and polygon boundaries.

3.2.2 Wetland Field Surveys

The water, soils, and vegetation information collected during the field surveys was used to classify the wetlands to federal class and form (B.G. Warner and C.D.A Rubec 1997). Four of the five classes (fen, bog, marsh, and open water) were identified during field surveys (Table 2.5-3). Within the wetland classes, nine types of wetland forms were differentiated based upon surface morphology, surface pattern, water type, and soil characteristics.

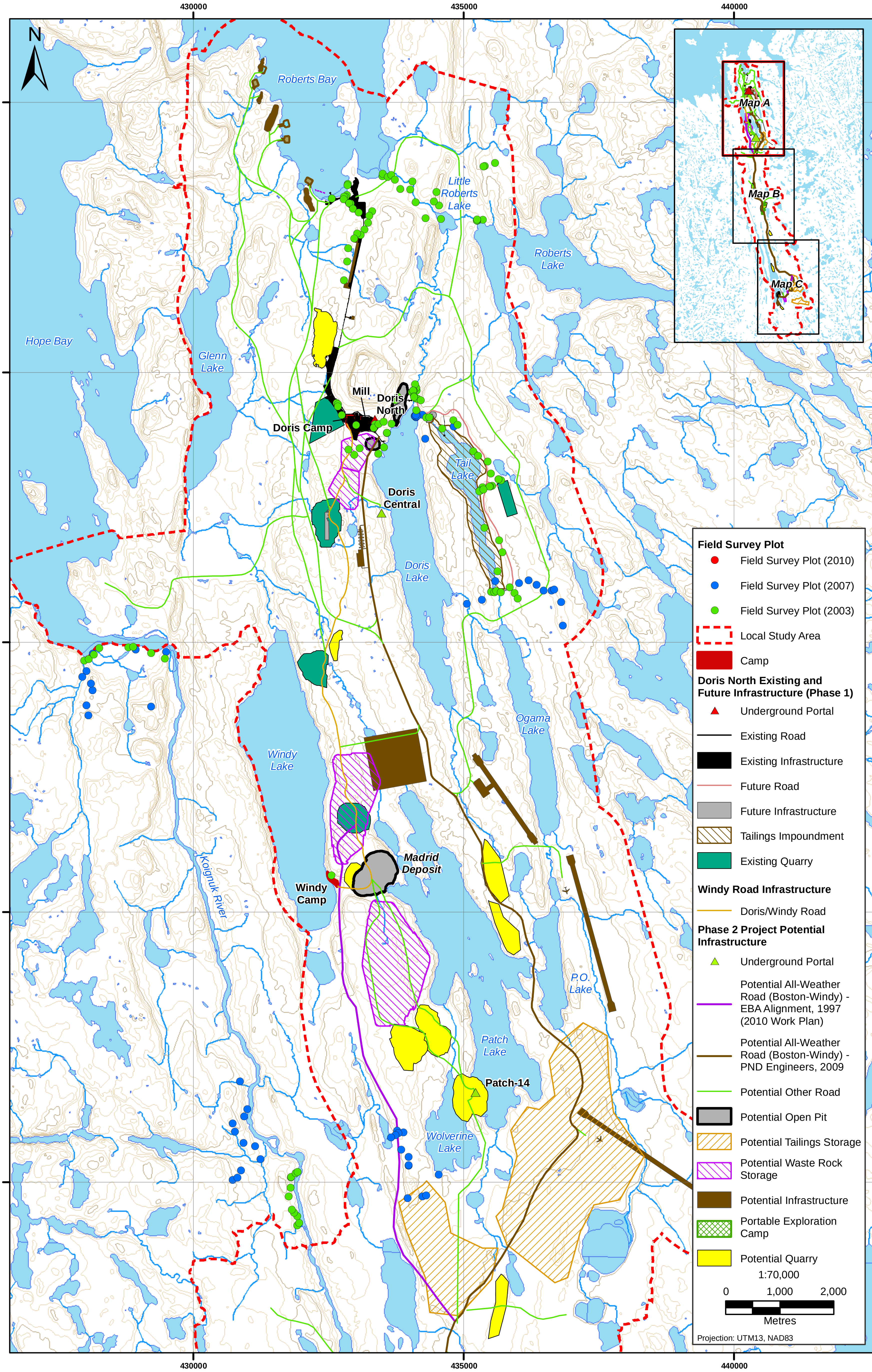


Figure 3.2-1a

NEWMONT NORTH AMERICA

Ecosystem Mapping Field Survey Locations - North End of Belt

Rescan Engineers & Scientists

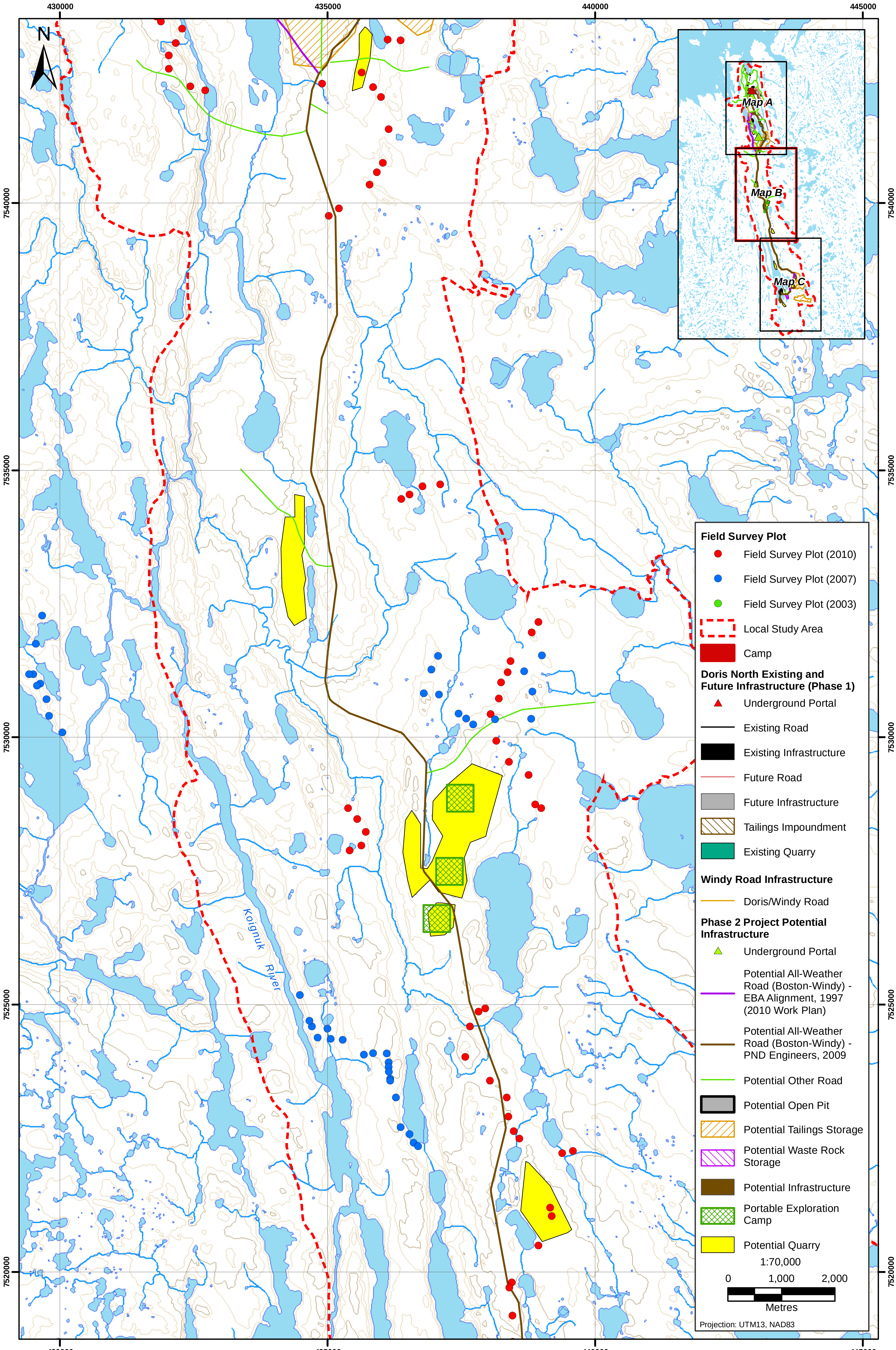


Figure 3.2-1b

NEWMONT NORTH AMERICA

Ecosystem Mapping Field Survey Locations - Mid Belt

Rescan Engineers & Scientists

PROJECT # 1009-002-12 GIS # HB-20-007c March 01 2011

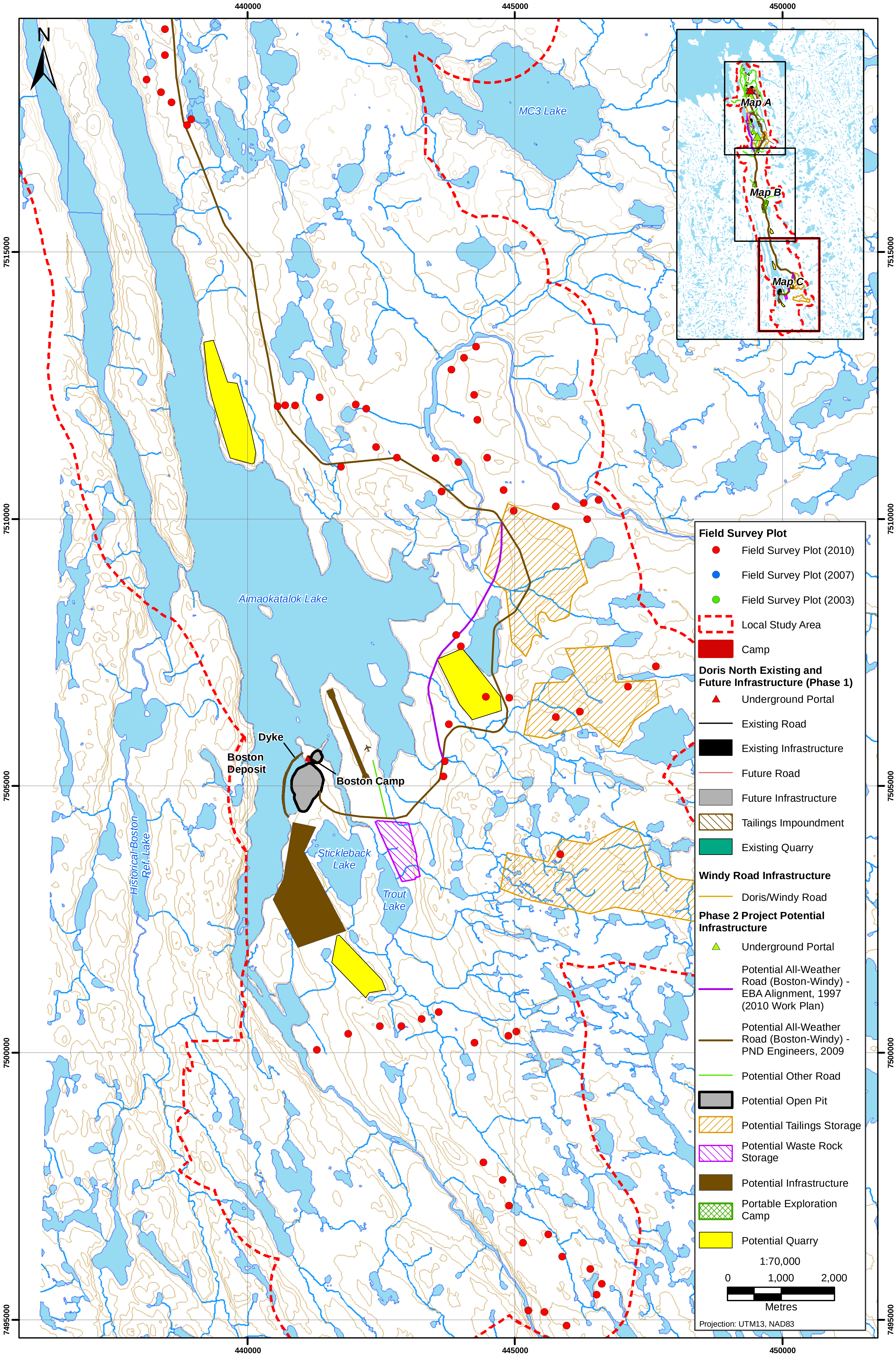


Figure 3.2-1c

NEWMONT NORTH AMERICA

Ecosystem Mapping Field Survey Locations - South End of Belt

Figure 3.2-1c

Rescan Engineers & Scientists

Table 3.2-1. Distribution of Terrestrial Field Plots by General Ecosystem Unit

General Ecosystem Unit	Number of Field Plots	Proportion of Field Plots
Blockfield	1	0.6
Betula-Ledum-Lichen	33	19.9
Betula-Moss	9	5.4
Dry Carex-Lichen	11	6.6
Dryas Herb Mat	22	13.2
Dry Willow	5	3.0
Emergent Marsh	2	1.2
Low Bench Floodplain	3	1.8
Polygonal Ground	3	1.8
Rock Outcrop	2	1.2
Riparian Willow	7	4.2
Dwarf Shrub-Heath	11	6.6
Eriophorum Tussock Meadow	46	27.7
Wet Meadow	11	6.6
Total	**166**	**100.0**

A total of 52 ground surveys (using the Wetland Habitat Identification Form, WHIF) and 40 visual surveys were conducted within the LSA in 2010 (Figures 3.2-1a-c). The majority (75%) of the surveyed wetlands occurred as complexes. Table 3.2-2 summarizes the distribution of the primary wetland class and form type identified at each ground plot. The distribution of secondary and tertiary classes and forms within wetland complexes are summarized in Appendix 9.

Table 3.2-2. Distribution of Ground Wetland Plots by Class and Form Type

Class	Primary Wetland Form[1]	Number of Wetland Field Plots	Percent of Total Wetland Plots
Fen	horizontal fen	11	21.2
	lowland polygon fen	19	36.5
Bog	lowland polygon bog	8	15.4
	peat mound bog	3	5.8
	palsa bog	0[2]	0.0
Marsh	lacustrine marsh	4	7.7
	slope marsh	1	1.9
	basin marsh	1	1.9
Open Water	shallow open water	n/a[2]	0.0
Terrestrial sites		5	9.6
Total		**52**	**100**

[1] *This field represents the primary wetland type identified at the field plot*
[2] *Present as sub-dominant community only. See Appendix 9*

Over half (58%) of the wetlands surveyed were characterized as fens (Table 3.2-2). Bogs were the next most common wetland types surveyed, accounting for 23% of field plots. Of the form types, lowland polygon fens were surveyed most frequently (36.5%), followed by horizontal fens (21.2%) and lowland polygon bogs (15.4%). The ecological characteristics and typical vegetation communities for each of these ecosystems are summarized in the following text.

Eight wetland plots were established in the North end of the belt. Considering all wetland forms (i.e. those identified as primary, secondary, and tertiary forms), the most common forms observed near Doris Camp were horizontal fens (n=5) and peat mound bogs (n=3; Appendix 9; Figure 3.2-2a). Other wetland forms that were identified in the north end of the belt were tussock tundra (n=1), slope marshes (n=2), lowland polygon fens (n=2), and lowland polygon bogs (n=2).

Twenty-three wetland plots were sampled in the Mid Belt (Table 3.2-2; Figure 3.2-2b). The most common forms observed in this area were lowland polygon fens (n=17), lowland polygon bogs (n=10), and lacustrine marshes (n=9). When observed, lowland polygon fens were most often the primary wetland form and were often associated with bog wetland forms. Other wetland forms that were identified in the Mid-Belt were shallow open water (n=4), horizontal fens (n=5), basin marsh (n=1), palsa bog (n=1), and peat mound bogs (n=4).

Twenty-one wetland plots were sampled in the South end of the belt (Table 3.2-2; Figure 3.2-2c). This area had the widest range of wetland units observed in the LSA. The most common form observed in this area was the lowland polygon fen (n=11). Lowland polygon fens were almost always observed in wetland complexes with bog wetland forms. Horizontal fens (n=4), tussock meadow (n=1), tussock tundra (n=2), peat mound bogs (n=5), dwarf birch-Labrador tea-lichen (n=1), slope marshes (n=1), seepage marsh (n=1), palsa bog (n=2), and lacustrine marshes (n=3) were all observed in lesser amounts in the South end of the belt.

3.2.3 Fens

Fens are nutrient-medium peatland ecosystems dominated by sedges and brown mosses. Mineral-bearing groundwater is within the rooting zone, and minerotrophic plant species are common (MacKenzie and Moran 2004). Fens can have fluctuating water tables, and as a result they are often rich in dissolved minerals. Surface water flow can be direct, either through channels, pools, or other open features that can often form characteristic surface patterns. The vegetation in fens is closely related to the depth and chemistry of groundwater. Shrubs occupy drier sites and minerotrophic graminoids (narrow-leaved vegetation) are typically found in wetter sites (Warner and Rubec 1997).

Fens are widespread throughout the LSA on level to slightly sloping terrain that receive surface runoff and/or groundwater. Saturated soils are common throughout the growing season due to very low rates of evapotranspiration, as well as a continual supply of moisture from within the soil profile due to seasonal permafrost melting. Fens occur on a number of substrates but most commonly as sedge peat veneers over fine-textured mineral soils. Other substrates include medium textured soils. Permafrost varies in extent depending on the thickness of the organic layer that acts as an insulator (Black 1976). Organic matter reduces the soil diurnal damping depth during the warmer months of the year which mitigates seasonal permafrost melting (Hinkel 1997).

Two wetland fen form types (horizontal fens and lowland polygon fens) were identified during field surveys. Table 3.2-3 presents a summary of the site characteristics at fen sites within the LSA.

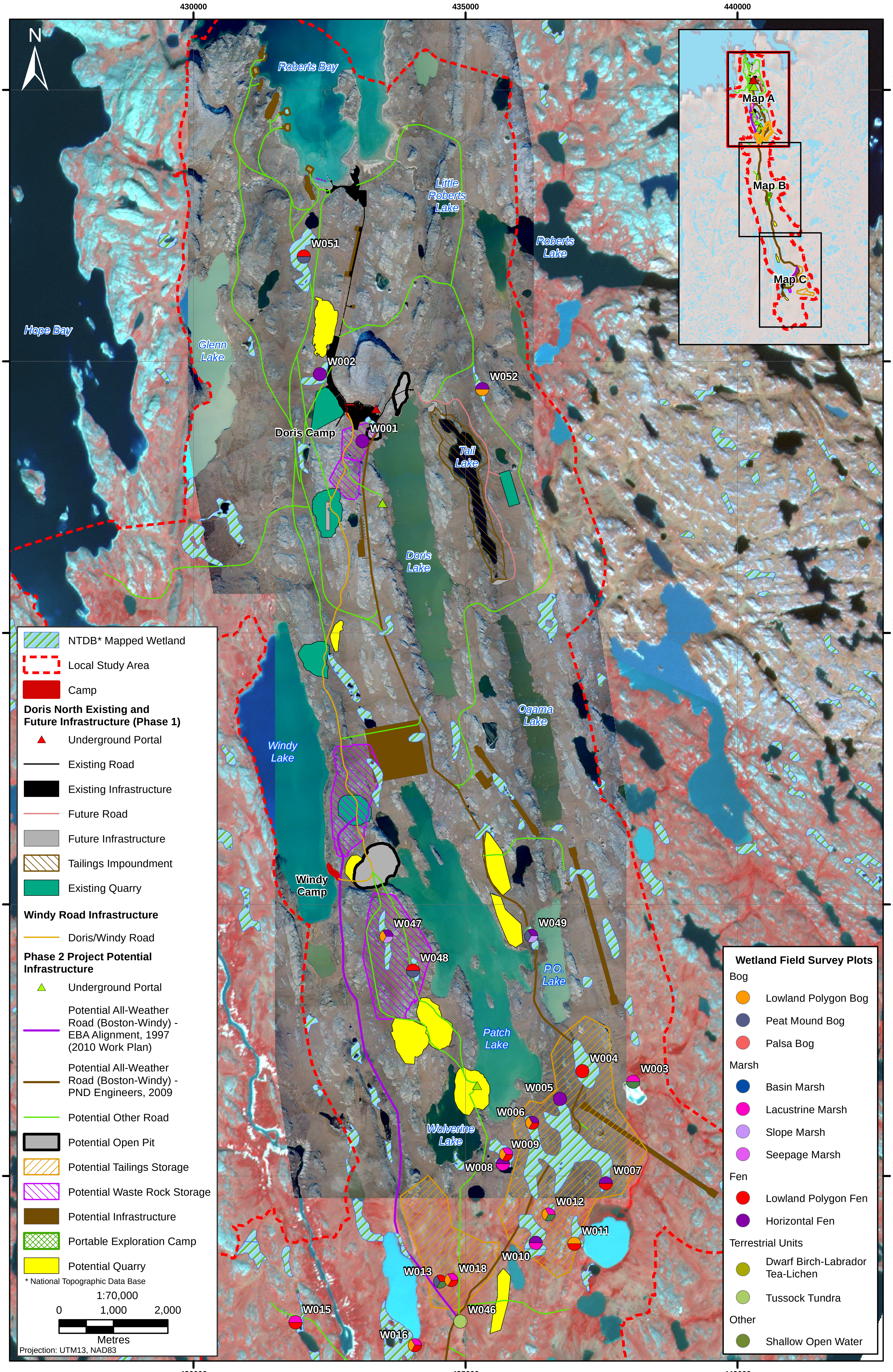


Figure 3.2-2a

NEWMONT NORTH AMERICA

Wetland Field Survey Plots and Wetland Classification; North End of Belt

Rescan Engineers & Scientists

Figure 3.2-2a

PROJECT # **1009-002-16** *GIS #* **HB-22-004b** *March 01 2011*

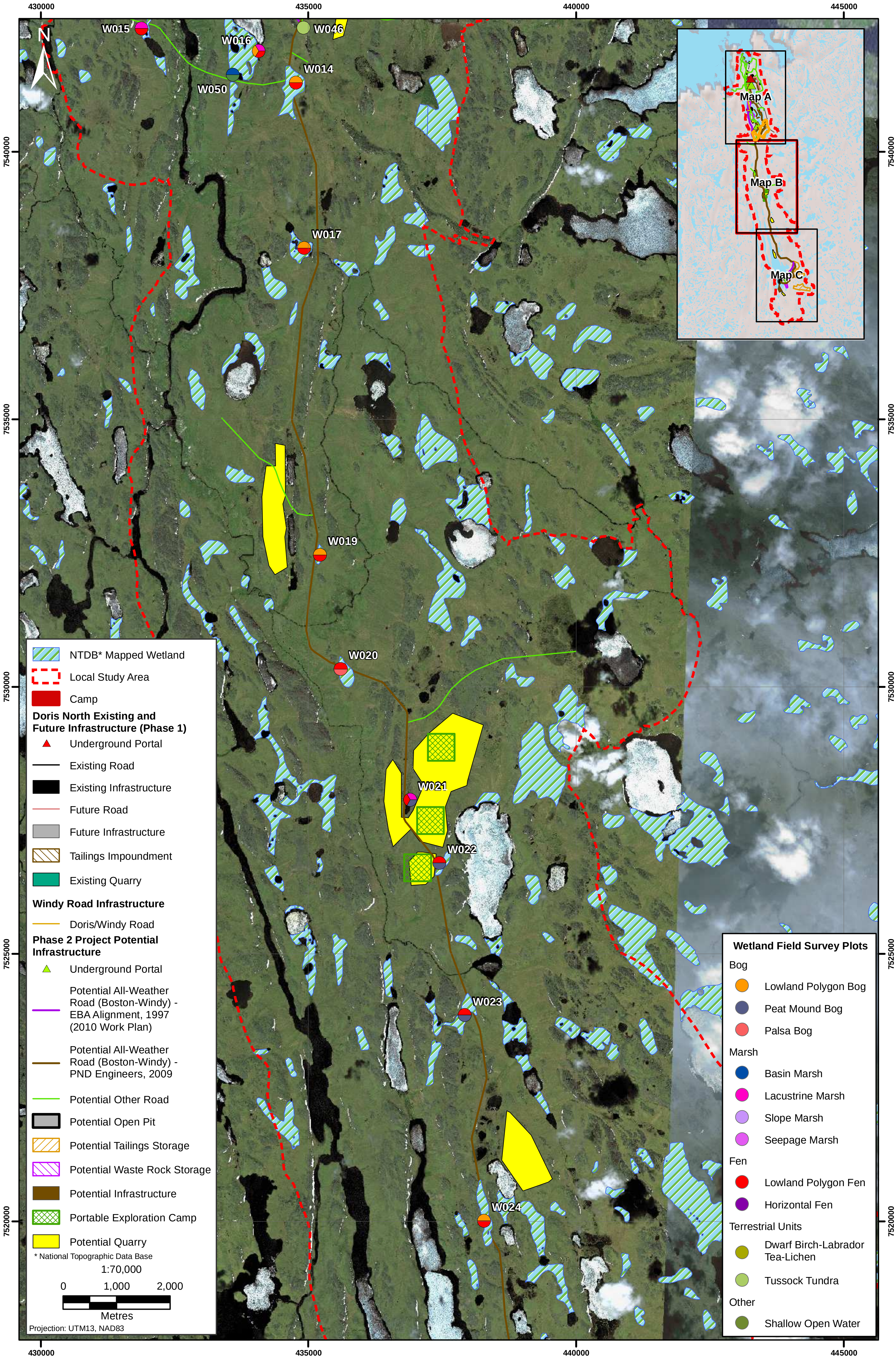


Figure 3.2-2b

NEWMONT NORTH AMERICA

Wetland Field Survey Plots and Wetland Classification; Mid Belt

Rescan Engineers & Scientists

Figure 3.2-2b

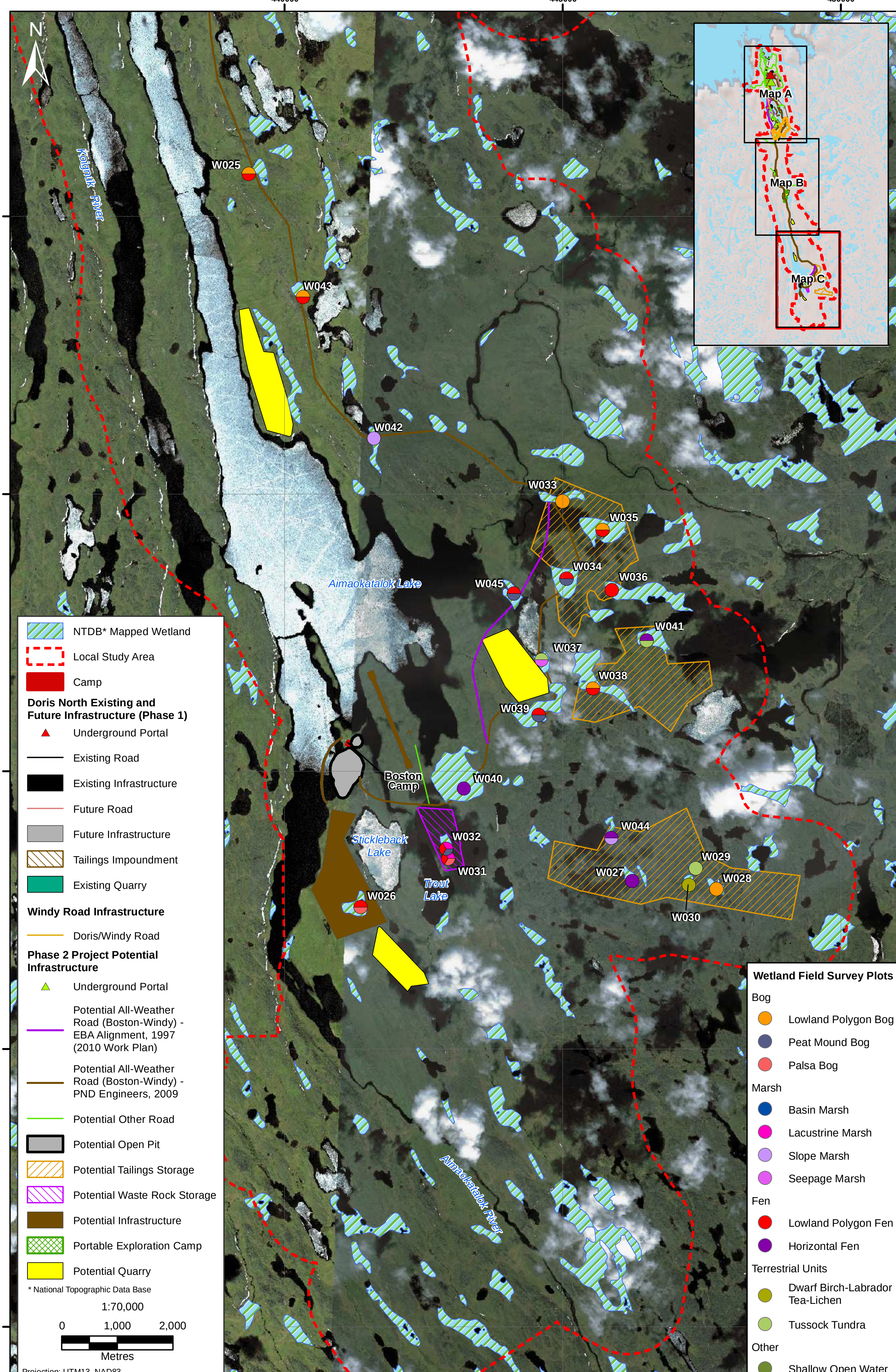


Figure 3.2-2c

NEWMONT NORTH AMERICA

Wetland Field Survey Plots and Wetland Classification; South End of Belt

Rescan Engineers & Scientists

Table 3.2-3. Characteristics of Fen Wetlands Observed during 2010 Field Surveys

Survey Parameter	Range
Soil Moisture Regime	very wet (VW) to wet (W)
Soil Nutrient Regime	poor (B) to medium (C)
Hydrodynamic Index	stagnant (ST) to mobile (Mo)
Von Post (scale of decomposition)	3 to 7
depth to permafrost (cm)	10 to 42
pH (pH units)	5 to 7
Conductivity (μS/cm)	63 to 406

3.2.3.1 Horizontal Fen

Three plant communities occur as horizontal fens within the study area and include the following: water sedge (*Carex aquatilis*), cotton grass (*Eriophorum angustifolium*) and chordroot sedge (*Carex chordorrhiza)*. The water sedge community occupies wet depressions subject to extended flooding and is most common near the margins of ponds and lakes (Rescan 1997). The tall cottongrass community occurs on sloping sites and is often associated with the water sedge community (Plate 3.2-1). The chordroot sedge community occupies level areas with poor drainage near the margins of marshes or shallow open water (Plate 3.2-2). Other common species include water sedge (*Carex aquatilis),* fragile sedge *(Carex membranacea),* short-leaved sedge *Carex fulginosa* spp. *misandra,* sheathed sedge *Carex vaginata,* round sedge *(Carex rotundata) and* looseflower alpine sedge *Carex rariflora*. Lousewort (*Pedicularis spp*.) is also often present in trace amounts.

Plate 3.2-1. A mixed water sedge and tall cottongrass fen located at plot W024.

Plate 3.2-2. A cordroot sedge community near the margin of an open water feature (W017).

3.2.3.2 Lowland Polygon Fen

Lowland polygon fens form when the active layer within the soil directly influences surface landscape morphology. They are characterised by repeating variations of wet depressions (flarks) and dry linear hillocks (ribs) resulting from the displacement of soil due to freeze thaw cycles and permafrost dynamics (Plate 3.2-3). The wet soil conditions within the depressions support predominantly *Carex* species, including *C. aquatilis* (Plate 3.2-4), *C. membranacea, C. rotundata and C. atrofusca,* as well as *Eriophorum Angustifolium (*Plate 3.2-5). The drier hillocks support plant species assemblages characteristic of Arctic bog ecosystems, such as bog blueberry (*Vaccinium uliginosum*), lingonberry (*Vaccinium vitis idaea)* and to a lesser extent bearberry (*Arctostaphylos* spp).

3.2.4 Bogs

Bogs are nutrient-poor, *Sphagnum* or brown moss-dominated peatland ecosystems in which the rooting zone is isolated from mineral-enriched groundwater. Precipitation, fog, snowmelt, and seasonal melt of permafrost are the primary water sources. Precipitation does not usually contain dissolved minerals and is mildly acidic, therefore bog waters are low in dissolved minerals and acidic in nature. Bog water acidity is enhanced because of organic acids formed during the decomposition of peat (Warner and Rubec 1997). Due to the acidity, few minerotrophic plant species occur (MacKenzie and Moran 2004).

Bogs are numerous in occurrence but limited in extent throughout the LSA. Three types of bog forms were identified: lowland polygon bogs, peat mound bogs, and palsa bogs, all of which occurred in association with fen forms. Table 3.2-4 presents a summary of the typical site characteristics observed at bog sites during the field surveys.

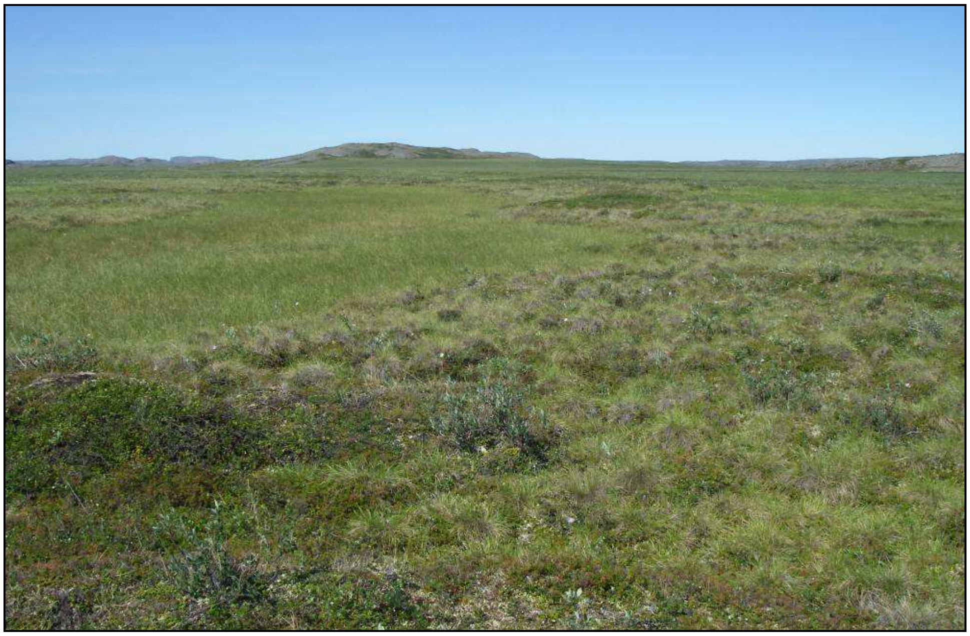


Plate 3.2-3. A lowland polygon fen and bog complex resulting from freeze thaw cycles.

*Plate 3.2-4. Macroview of the inflorescence of water sedge (*Carex aquatilis*), a common fen and marsh sedge.*

*Plate 3.2-5. Macroview of the inflorescence of tall cottongrass (*Eriophorum angustifolium*), a dominant sedge in fens throughout the Local Study Area.*

Table 3.2-4. Characteristics of Bog Wetlands Observed during 2010 Field Surveys

Survey Parameter	Range
Soil Moisture Regime	mesic (M) to wet (W)
Soil Nutrient Regime	poor (B) to medium (C)
Hydrodynamic Index	n/a[1]
Von Post (scale of decomposition)	2 to 5
depth to permafrost (cm)	20 to 29
pH (pH units)	4 to 5.5
Conductivity (μS/cm)	n/a[2]

[1] The Hydrodynamic Index was not recorded because of the presence of permafrost at approximately 30 cm below the soil surface and a lack of surface water. These features combined to eliminate HDI indicators such as channels, rivulets, ponding, and seepage.
[2] The measurements not taken because there was no surface water available to sample in the bog.

3.2.4.1 Lowland Polygon Bog

Lowland polygonal bogs are perennially frozen peatlands characterized by linear ridges underlain by ice-wedges (Plate 3.2-6). This ecosystem occurs in conjunction with the lowland polygon fen and represents the raised drier portions of the wetland complex. Lowland polygon bogs occur most commonly near estuaries, along river floodplains, and in depressions (Routledge 2004).

Plate 3.2-6. Typical linear ridges of lowland polygon bogs within the Local Study Area (W017).

3.2.4.2 Peat Mound Bog

Peat mound bogs are characterized by small hummocks (>3 m in diameter) of peat which have been raised by frost action (Plate 3.2-7). They occur most commonly adjacent to or surrounded by fen wetlands.

Plate 3.2-7. Raised hummocks within a peat mound bog at W021.

3.2.4.3 Palsa Bog

Palsa bogs are convex, uneven mounds of perennially frozen peat and mineral soil usually raised up to one metre above the adjacent ground due to ice wedge activity and frost heave (Warner and Rubec 1997; Plate 3.2-8). They typically occur in complexes with lowland polygon, basin, and horizontal fens. They support species more common in the terrestrial units BL and BM such as dwarf birch, Labrador tea and bog blueberry. Within the study area, palsas most commonly have relatively thin veneers of peat overlying frozen mineral soil horizons.

3.2.5 Marshes

Marshes are permanently to seasonally flooded non-tidal mineral wetlands dominated by emergent graminoid vegetation (W.H. MacKenzie and J.R. Moran 2004). Marshes are strongly influenced by groundwater or surface water and have relatively high hydrodynamic indices. The water table is above the soil surface for the entire growing season, which limits species richness to those few plants that can tolerate prolonged anoxic conditions. The soil nutrient regime is relatively rich compared to other wetland types as a result of nutrient inputs associated with high plant productivity and relatively rapid organic decomposition (Rescan 1997). Soils are typically mineral but can also have a well decomposed organic surface tier (B.G. Warner and C.D.A. Rubec 1997; W.H. MacKenzie and J.R. Moran 2004).

Three wetland marsh form types (lacustrine marsh, slope marsh, and basin marsh) were identified during field surveys. Table 3.2-5 presents a summary of the site characteristics at marsh sites within the LSA.

3.2.5.1 Lacustrine Marsh

Lacustrine marshes occur along lake margins or, less commonly, along unconfined low-gradient streams in microsites protected from erosional flows and ice and wave scour (Rescan 1997; Plate 3.2-9). Water sources are a combination of inputs from adjacent lakes, rivers and streams flowing into the lake, as well as surface runoff from adjacent catchment areas.

Plate 3.2-8. Typical palsa bog mound feature in association with a lowland polygon fen at W20.

Table 3.2-5. Characteristics of Marsh Wetlands Observed during 2010 Field Surveys

Survey Parameter	Range
Soil Moisture Regime	very wet (VW)
Soil Nutrient Regime	medium (C) to rich (D)
Hydrodynamic Index	sluggish (SL) to stagnant (ST)
Von Post (scale of decomposition)	3 to 5
depth to permafrost (cm)	10 to 34
pH (pH units)	5 to 7.5
Conductivity (µS/cm)	73 to 242

3.2.5.2 Slope Marsh

Slope marshes occupy the lower portions of seepage slopes in areas of groundwater discharge and are characterized by hummocky terrain (Warner and Rubec 1997; Plate 3.2-10).

3.2.5.3 Basin Marsh

Basin marshes occupy the well defined depressions in inland areas that are not influenced by salt water (Plate 3.2-11 and 3.2-12).

Plate 3.2-9. A lacustrine marsh located at W016.

Plate 3.2-10. A typical slope marsh (far left) surrounding an open water feature. Hummocky terrain in the foreground is a characteristic feature of slope marsh sites.

*Plate 3.2-11. A basin marsh dominated by marsh cinquefoil (*Caltha palustris*) and sedges (*Carex *spp.) surrounds the open water feature at Plot W050.*

Plate 3.2-12. Aerial view of a basin marsh (centre of the photo) located south of the open water feature at Plot W050.

3.2.6 Open Water

3.2.6.1 Shallow Open Water

Shallow open water wetland ecosystems are permanently flooded by still or slow-moving water and dominated by submerged and floating-leaved aquatic plants. Shallow open water wetlands can represent the transitional unit from permanent deep water bodies (i.e., sluggish streams and lakes) to fens and marshes (B.G. Warner and C.D.A. Rubec 1997; W. H. MacKenzie and J. R. Moran 2004). They are among the most important habitat for wildlife and fish for providing cover and high prey densities (W. H. MacKenzie and J. R. Moran 2004). Sedimentation and nutrient loading are the biggest concern for these wetlands because changes in turbidity block light penetration that influences where submerged rooted aquatic vegetation can grow (W. H. MacKenzie and J. R. Moran 2004). A variety of shallow open water features were observed throughout the study area, most commonly in association with emergent marshes or larger water bodies (Plate 3.2-13 to Plate 3.2-15).

Plate 3.2-13. Shallow open water surrounded by Carex aquatilis *at W012.*

3.3 ECOSYSTEMS AND PLANTS OF INTEREST

3.3.1 Sensitive or At Risk Vegetation Communities

Arctic ecosystems are well known for their sensitivity to anthropogenic disturbance. Even small, low intensity disturbances, such as vehicle use on Arctic tundra, often create immediate and persistent effects on vegetation and soils (Forbes, Ebersole, and Strandberg 2001). In particular, disturbances to wetter areas may affect soil thaw characteristics that define many ecosystems. Although many Arctic species are adapted to rapid re-colonization of disturbed sites, the altered vegetation communities may no longer provide pre-disturbance ecosystem functions or habitat values (Forbes et al. 2001).

Plate 3.2-14. A shallow open water and marsh wetland complex surrounded by lowland polygon bogs and fens, near plot W025.

Plate 3.2-15. A shallow open water and peat mound bog wetland complex at W034.

Lowland ecosystem units with high water tables and relatively shallow active layers are sensitive to disturbances that result in soil compression, partly because disturbance can cause ground thawing and changes to hydrology (Jorgenson, Ver Hoef, and Jogenson 2010). However, if the disturbance is not too severe, the vegetation in these areas (primarily graminoids) may recover relatively quickly following disturbance. Upland ecosystems are generally dryer and water shedding, so physical disturbances may have a limited affect on water movement relative to lowland ecosystems. However, the vegetation species growing in dryer areas are often slower to recover following disturbance (Kemper and Macdonald 2009; Jorgenson, Ver Hoef, and Jogenson 2010). The marine ecosystem units are generally sparsely vegetated and characterized by unstable substrates that are constantly or erratically disturbed by tides, ice scouring and wave action. Vegetation that occurs in these ecosystem units should have a greater ability to re-colonize after disturbance, but literature reviews of Arctic marine foreshores indicate that knowledge in this area is limited.

3.3.2 At Risk Plant Species

There are documented occurrences of five at risk plant species within Nunavut, which include hairy rockcress (*Braya pilosa*), Drummond bluebell (*Mertensia drummondii*), Banks Island alkali grass (*Puccinellia banksiensis*), Raup's willow (*Salix raupii*), and Nahanni aster (*Symphyotrichum nahanniense*) (R. Gau, pers. comm. 2010). The National General Status Working Group (NGSWG) also tracks 121 plant species that may be at risk in the NWT and may also occur in Nunavut (Appendix 4).

Field plots surveyed in 2010 identified 102 plants by genus and species, and 24 by genus alone (Appendix 8). Of these plants, none are considered at risk.

Golder (2009) identified three bryophyte species that were considered to be at risk globally. *Sphagnum orientale* is ranked by NatureServe as G2G4, indicating that it is globally imperilled to apparently secure. *Cinclidium latifoliumi* is ranked as G3G5, indicating it is globally vulnerable to secure, while *Frullania tamarisci* is ranked G5T4 (globally secure, but subspecies apparently secure). All three species rankings are provided as ranges, which indicate that data deficiencies limit more accurate assessments of their global status (NatureServe 2010). The status of these three species in the NWT and Nunavut has not been assessed. None of these species were identified during the 2010 field surveys.

3.3.3 Invasive Plant Species

There is limited information available for invasive plant species in Nunavut. Information regarding invasive plants was compiled from the NWT Department of Environment and Natural Resources 2010, the Invasive Species Specialist Group (ISSG) Global Invasive Species Database, and the Evergreen Native Plant Database and compared with field data collected in 2010 (Appendix 5). Field surveys found one potentially invasive plant, common dandelion (*Taraxacum officiniale*) at plot 006. There are two subspecies of common dandelion (*Taraxacum officinale*), one of which is native (formerly known as *Taraxacum lacerum)* and the other is invasive (*T. officinale* ssp. *officinale*). Plant species were generally not identified to the subspecies level and thus field personnel were unable to determine the status of the plant in question.

3.4 METAL CONCENTRATIONS IN PLANT TISSUES

Twelve metals of interest were summarized and are discussed in this section. These do not include metals for which over 50% of the tissue samples had concentrations that were below detection limits. The raw analytical results for metal concentrations in the lichen tissue samples (both wet and dry weights) are presented in Appendix 10. There are no territorial or federal guidelines for metal limits in vegetation.

Metal concentrations for *Flavoceraria cucullata* samples are summarized by location, based on their occurrence within the North or South end of the belt (Table 3.4-1; Figure 3.4-1).

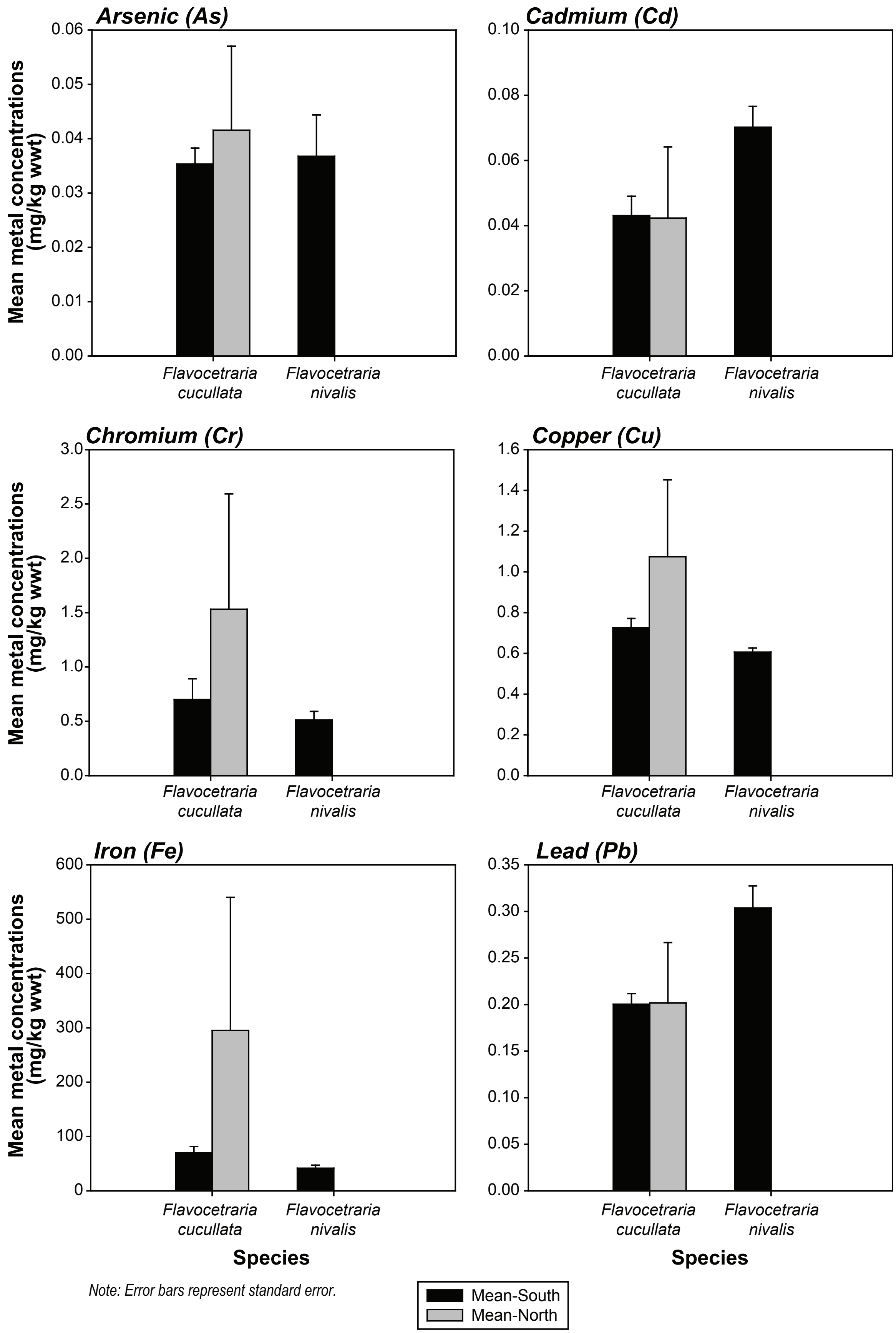


Figure 3.4-1a

2010 Mean Metal Concentrations in Sampled Lichen Tissue

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

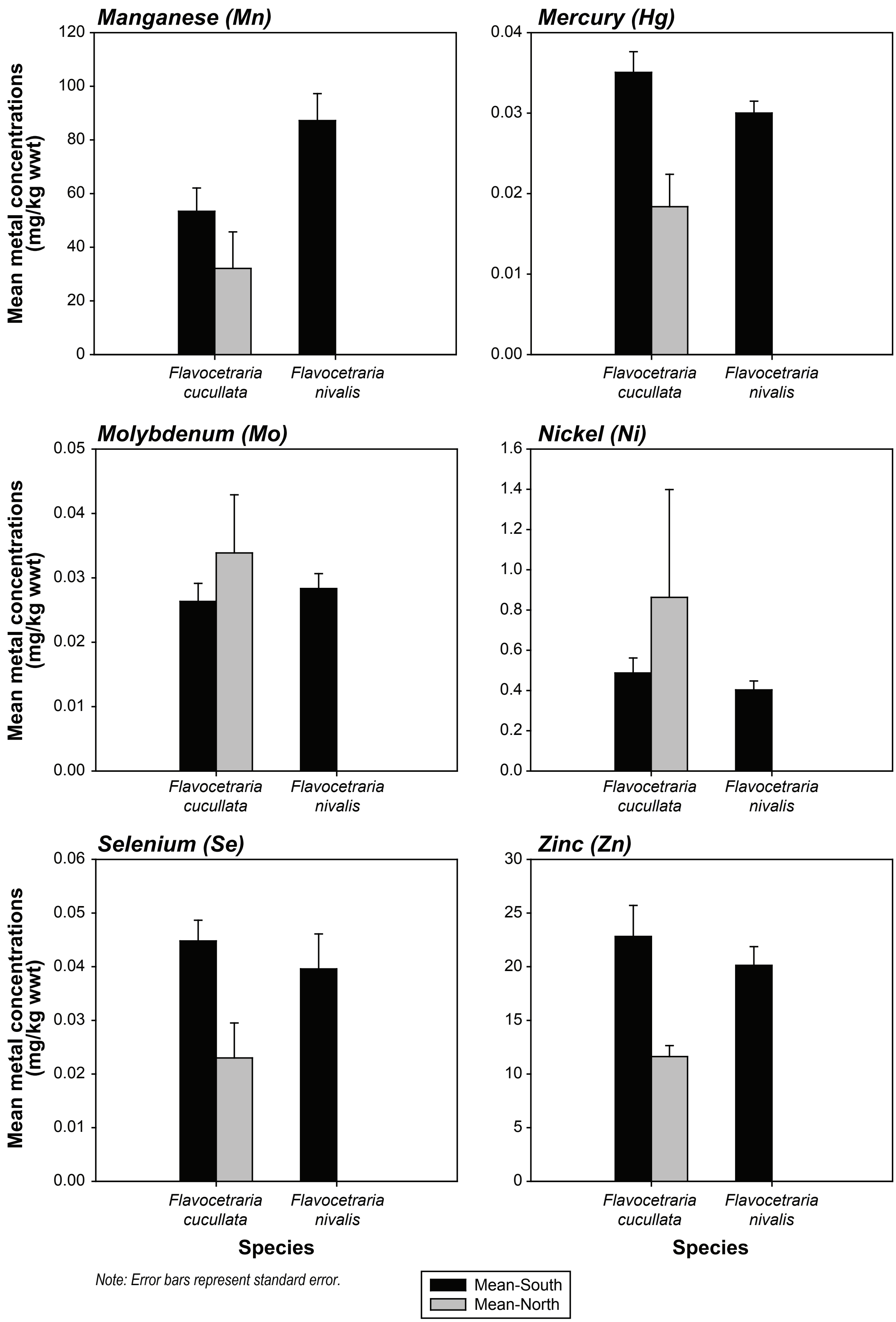


Figure 3.4-1b

2010 Mean Metal Concentrations in Sampled Lichen Tissue

NEWMONT NORTH AMERICA

Rescan Engineers & Scientists

Table 3.4-1. Summary Metal Concentration Results for Collected Samples of *Flavocetraria cucullata*

		F. cucullata South Summary n=5				*F. cucullata* North Summary n=3			
	Units	Mean	Standard Error	Minimum	Maximum	Mean	Standard Error	Minimum	Maximum
Physical Tests									
% Moisture	%	18	5.0	8.1	36	48	8.7	31	61
Metals									
Arsenic (As)	mg/kg wwt	0.04	0.003	0.02	0.04	0.04	0.02	0.02	0.07
Cadmium (Cd)	mg/kg wwt	0.04	0.006	0.03	0.07	0.04	0.02	0.02	0.09
Chromium (Cr)	mg/kg wwt	0.70	0.19	0.36	1.4	1.5	1.1	0.36	3.6
Copper (Cu)	mg/kg wwt	0.7	0.04	0.6	0.8	1.1	0.4	0.4	1.6
Iron (Fe)	mg/kg wwt	70.0	11.4	39.9	110	295	245	40.6	785
Lead (Pb)	mg/kg wwt	0.20	0.011	0.17	0.24	0.2	0.06	0.07	0.3
Manganese (Mn)	mg/kg wwt	53	8.7	34	84	32	14	6.1	52
Mercury (Hg)	mg/kg wwt	0.04	0.003	0.03	0.04	0.02	0.004	0.01	0.02
Molybdenum (Mo)	mg/kg wwt	0.03	0.003	0.02	0.04	0.03	0.01	0.02	0.05
Nickel (Ni)	mg/kg wwt	0.5	0.08	0.4	0.8	0.86	0.54	0.25	1.9
Selenium (Se)	mg/kg wwt	0.05	0.004	0.04	0.06	0.02	0.01	0.01	0.03
Zinc (Zn)	mg/kg wwt	23	2.9	14	29	12	1.0	9.8	13

Metal concentrations for *Flavoceraria nivalis* samples are summarized for the South end of the belt as no *F. nivalis* samples were collected in the North end of the belt (Table 3.4-2; Figure 3.4-1).

Table 3.4-2. Summary Metal Concentration Results for Collected Samples of *Flavocetraria nivalis*.

		F. nivalis South Summary n=10			
	Units	Mean	Standard Error	Minimum	Maximum
Physical Tests					
% Moisture	%	19	3.1	9.5	36
Metals					
Arsenic (As)	mg/kg wwt	0.04	0.008	0.02	0.1
Cadmium (Cd)	mg/kg wwt	0.07	0.006	0.05	0.1
Chromium (Cr)	mg/kg wwt	0.5	0.08	0.2	1.1
Copper (Cu)	mg/kg wwt	0.6	0.02	0.5	0.7
Iron (Fe)	mg/kg wwt	42	5.7	27	88
Lead (Pb)	mg/kg wwt	0.3	0.02	0.2	0.4
Manganese (Mn)	mg/kg wwt	87	10	42	145
Mercury (Hg)	mg/kg wwt	0.03	0.001	0.02	0.04
Molybdenum (Mo)	mg/kg wwt	0.03	0.002	0.02	0.05
Nickel (Ni)	mg/kg wwt	0.4	0.04	0.2	0.6
Selenium (Se)	mg/kg wwt	0.04	0.006	0.01	0.08
Zinc (Zn)	mg/kg wwt	20	1.7	14	31

Mercury, selenium and zinc had higher mean values in plant tissues from the South end of the belt than in the North end of the belt. No further conclusions about differences between species or metals can be made due to limited sample sizes and high variability among the samples.

3.5 OVERVIEW OF ECOSYSTEM FUNCTIONS

This section provides a brief overview of the overall function of terrestrial ecosystems in the Project LSA.

3.5.1 Terrestrial Ecosystem Functions

For this discussion, terrestrial ecosystems include local ecosystem units grouped in the upland category. These include ecosystem units that are generally water shedding, situated in mid, upper, and crest landscape positions, and generally located on morainal, colluvial, or weathered bedrock parent materials, often overlaying bedrock outcrops. Upland ecosystems comprise 28.5% of the LSA and 40.4% of the RSA.

With the exception of the BL unit, upland ecosystems generally have lower primary productivity. They are typically dominated by slower growing vegetation and are generally nutrient poor. These ecosystems function much differently than the more common lowlands. They include a significant cover of dwarf shrubs (mainly prostrate *Betula nana*, *Salix* spp., and *Vaccinium* spp.) in comparison to lowland areas that are largely dominated by a mix of similar shrub species and extensive cover of herbaceous species, namely *Carex* spp. and *Eriophorum* spp. Higher shrub cover results in important wildlife habitat opportunities, and also increases the depth and duration of snow cover relative to lowland areas (Liston et al. 2002). With the exception of dry, wind-blown crests, the ability of upland ecosystems to retain deeper snow cover for a longer duration provides meltwater later in to the growing season. This extended meltwater production may beneficially affect downslope communities that are dependent on continuous water flows, and by providing nutrients (Liston et al. 2002; Callaghan et al. 2004). Increased snow cover also increases winter soil temperature, improving soil biochemical cycling and Nitrogen uptake during snowmelt (Callaghan et al. 2004; Bilbrough et al. 2000). The timing of snowmelt, combined with air temperature, is also known to affect carbon cycling (Groendahl, Friborg, and Soegaard 2007).

Upland ecosystems, particularly dry rocky crests, provide a multitude of early season wildlife habitat values (further described in Section 4.3.4). These areas have low snow cover due to wind exposure and albedo, providing wildlife such as muskox and caribou opportunities to forage on important lichen communities (Joly, Jandt and Klein 2009).

Terrestrial ecosystems in the Project LSA also provide numerous habitat functions. In particular, dry crests of bedrock outcrops and eskers provide important habitat for much of the region's ungulate species (Rescan 2011). These areas are wind swept during the winter resulting in limited snow cover and easy access to lichens and other browse. During the spring, as lowland areas are still frozen and snow covered, ridges melt early and expose important food, such as the previous years' overwintered berries. They also serve as movement corridors for many species as the ground remains relatively solid year round relative to lowlands that are largely wet and dominated by tussocks, making travel more difficult. Eskers in particular are valuable denning sites for grizzly bears, wolves, foxes, and wolverines. Eskers often have deeper active layers and deeper mineral soils that provide good digging substrate. Other upland ecosystems provide a wide variety of food and shelter opportunities.

3.5.2 Wetland Functions

This section provides a brief overview of the overall function of the wetland ecosystems in the Project LSA.

3.5.2.1 Wetland Ecosystem Functions

Wetland function is defined as a process or series of processes that occur within a wetland (United States Geological Survey Water 1997). Wetlands perform a wide variety of functions due to their physical, chemical, and biological attributes. Wetland function is separated into four primary categories: hydrological, biochemical, ecological, and habitat (Environment Canada 2003). Wetland ecosystems comprise 58 % of the LSA and 32% of the RSA.

3.5.2.2 Hydrological Functions

The hydrological function of a wetland is defined as the wetland's ability to regulate water contributions to and from surface and groundwater reserves. Hydrological function in Arctic wetlands depends greatly on spring snowmelt and the summer thaw period (NSF-ARCSS 2000; Woe and Thomas 1993). The freezing and thawing of frozen soil dictates the presence or absence of wetlands and drives the timing of plant growth, as well as evaporation, infiltration, and runoff (NSF-ARCSS 2000). Most wetland runoff occurs during snowmelt in the spring and may cease entirely in late summer, even if wetland soils remain near saturation (Roulet and Woo 1986). As spring transitions to summer, peat thaws and is able to retain more water, limiting the discharge of wetland drainages (Ryden 1977). Changes in wetland hydrology due to warming temperatures also have implications for biochemical functions.

3.5.2.3 Biochemical Functions

Biochemical function is defined as the wetland's influence on the quality of surface water and groundwater. This function is particularly difficult to quantify given the number of specific interactions within and between the different soil, water, and vegetation systems in a wetland.

The pH and conductivity of wetlands were measured to aid in wetland classification (MacKenzie and Moran 2004) and provide baseline data on these aspects of biochemical function. The status of peat decomposition and permafrost depth were assessed in order to characterize rate of decomposition within the wetland (an important consideration for carbon dynamics).

An important function of high latitude wetland ecosystems is their role in the carbon cycle. This role has recently received more attention from the scientific community due to the potential release of large amounts of methane (CH_4) and smaller amounts of carbon dioxide (CO_2) from Arctic wetlands in response to warming temperatures (Bubier et al 1995; Juutinen et al 2010).

The functional and structural responses of carbon storage by wetland ecosystems at high latitudes have important implications for the amount and rate of CO_2 accumulation in the atmosphere (Smith and Shugart 1993; McGuire and Hobbie 1997). Globally, while high latitude wetlands cover only 4 to 5% of the terrestrial surface, they may contain up to 450 Gt C[1]. This is approximately 20% of the carbon in the terrestrial biosphere (Gorham 1991, Maltby and Immirzi 1993), and 40% of the world's soil carbon inventory (McGuire and Hobbie 1997).

Under current conditions, high latitude wetlands are a small, persistent sink for CO_2 (Gorham 1995) and a large source of CH_4 (Fung et al 1991). Functional and structural changes, caused by Arctic temperature increases, have the potential to influence the current balance between terrestrial and atmospheric carbon (Smith and Shugart, 1993; McGuire and Hobbie 1997). In many areas of the Arctic, peat accumulation has been extensive due to production exceeding decomposition. As warming occurs, however, it is predicted that large reservoirs of soil carbon may become available for decomposition.

[1] 1Gt C is a gigatonne of carbon or one petagram, Pg, or 1015 g C

This is particularly the case with frozen peat, as decomposition occurs rapidly once the thaw cycle has been initiated (Bubier et al 1995).

The methane storage function of Arctic wetlands is of particular importance because methane is a potent greenhouse gas (Christensen et al 2004). Permafrost has stored methane since the end of the last ice age. During the last glacial advance, organic and mineral Arctic soils became saturated and frozen. Under these conditions, decomposition of organic compounds occurs anaerobically, resulting in a build-up and storage of CH_4.

There is mounting evidence from a variety of sources that permafrost is degrading (Adams et al 2001; Burn 1992; Camill and Clark 2000; French and Egorov 1998; Halsey et al 1995; Kershaw 2003; Osterkamp 2003; Vitt et al 1994). As permafrost melts, the release of CH_4 is accelerated due to the release of stored methane as well as increased anaerobic respiration via methanogenesis (Christensen et al 2004). The rate of release is related to the type of vegetation cover. Christensen et al (2004) reported that the release of CH_4 in discontinuous environments was positively correlated with sedge meadows and treed areas in the northern boreal forest. Vegetation communities dominated by shrubs were found to release methane at much lower rates.

3.5.2.4 Habitat Functions

Wetlands provide key habitats for both terrestrial and avian wildlife (Environment Canada 2003; UNESCO 2009). In Arctic environments, wetlands have been identified as one of the top rated habitats for all mammalian and avian valued ecosystem components (Rescan 2007). Functional wetland habitats host a high diversity of avian and small mammal species, which in turn provide prey for raptors, wolves, foxes, and other predators. In addition, wetlands provide forage habitat for caribou, muskox (Thorpe et al. 2001), and waterfowl, which are important game species for Inuit in the Project area. Many wildlife species that require wetlands for foraging and/or nesting habitat are afforded special protection through the Migratory Bird Convention Act, the Wildlife Act, and the Species at Risk Act. Two species assessed by COSEWIC, the peregrine falcon (*Falco perigrinus tundrius*) and short-eared owl (*Asio flammeus*), choose nest sites adjacent to or in close proximity to wetlands and riparian areas where a reliable source of prey can be found (Sinclair et al. 2003; COSEWIC 2007, 2008). Various other species nesting in wetland habitats have been ranked as sensitive by NWT ranking categories, including American golden plover (*Pluvialis dominica*), red-necked phalarope (*Phalaropus lobatus*), northern pintail (*Anas acuta*), and long-tailed jaeger (*Stercorarius longicaudus*) (DOENR 2010). The presence of waterfowl and shorebirds is used as an indicator of the availability of functional wetland habitat in an area.

References

References

Adams J.B., P., Camill, J.S. Clark, B. Jordan, and J.A. Lynch. 2001. Changes in Biomass, Aboveground Net Primary Production, and Peat Accumulation Following Permafrost Thaw in the Boreal Peatlands of Manitoba, Canada. *Ecosystems* 4:461-474.

Alberta Native Plant Council. 2000. *A Rogue's Gallery of Invasive Non-native Plants*. http://www.anpc.ab.ca/wiki/index.php/Main_Page (accessed February 2011).

Auerbach, N. A., M. D. Walker, and D. A. Walker. 1997. Effects of Roadside Disturbance on Substrate and Vegetation Properties in Arctic Tundra. *Ecological Applications* 7 (1): 218-35.

BC Ministry of Environment. 2007. *Sensitive ecosystems inventory*. http://www.env.gov.bc.ca/sei/ (accessed November 2010).

BC Ministry of Environment Lands and Parks and BC Ministry of Forests Research Branch. 1998. *Field Manual for Describing Terrestrial Ecosystems*. Victoria, BC: Land Management Handbook No. 25.

Bilbrough, Carol J., Jeffrey M. Welker and William D. Bowman. 2000. Early Spring Nitrogen Uptake by Snow-Covered Plants: A Comparison of Arctic and Alpine Plant Function under the Snowpack. *Arctic, Antarctic, and Alpine Research*. Vol. 32, No. 4 (Nov., 2000), pp. 404-411

Black, R. F. 1976. Periglacial features indicative of permafrost: Ice and soil wedges. *Quaternary Research* 6 (1): 3-26.

Bubier, J., T. Moore, and S. Juggins. 1995. Predicting methane emissions from bryophyte distribution in northern Canadian peatlands. *Ecology* 76:677-693.

Burn C.R. 1992. Recent Ground Warming Inferred from the Temperature in Permafrost near Mayo, Yukon Territory. In: J.C. Dixon, A.D. Abrahams eds. *Periglacial geomorphology: proceedings of the 22nd annual Binghamton Symposium in Geomorphology*. Buffalo: John Wiley & Sons, 1992:327-350.

Burt, P. 2003. *Summary of Vegetation Baseline Studies, 2003, for the Miramar Hope Bay Ltd., Doris North Project Kitikmeot Region, Nunavut*. Outcrop Ltd., October 2003, Yellowknife, NT.

Burt, P. 2000. Barren Land Beauties: Showy Plants of the Canadian Arctic. Outcrop Ltd. Yellowknife, NWT.

Callaghan, Terry V., Lars Olof Björn, Yuri Chernov, Terry Chapin, Torben R. Christensen, Brian Huntley, Rolf A. Ims, Margareta Johansson, Dyanna Jolly, Sven Jonasson, Nadya Matveyeva, Nicolai Panikov, Walter Oechel, Gus Shaver (2004) Effects on the Function of Arctic Ecosystems in the Short- and Long-term Perspectives. *AMBIO: A Journal of the Human Environment*: November 2004, Vol. 33, No. 7, pp. 448-458.

Camill P., and J. S. Clark. 2000. Long-Term Perspectives on Lagged Ecosystem Responses to Climate Change: Permafrost in Boreal Peatlands and the Grassland/Woodland Boundary. *Ecosystems* 3:534-544.

COSEWIC. 2007. *COSEWIC assessment and update status report on the Peregrine Falcon Falco peregrinus (pealei subspecies – Falco peregrinus and pealei anatum/tundrius – Falco peregrinus anatum/tundrius) in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 45 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2008. *COSEWIC assessment and update status report on the Short-eared Owl Asio flammeus in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 24 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Christensen, T. R., T. Johansson, H. J. Åkerman, M. Mastepanov, N. Malmer, T. Friborg, P. Crill, and B. H. Svensson (2004), Thawing sub-arctic permafrost: Effects on vegetation and methane emissions, *Geophysical Research Letters* 31:L04501.

DOENR. 2010. *Species at Risk in the Northwest Territories: A guide to species in the Northwest Territories currently listed, or considered for listing, under federal and territorial species at risk legislation*. Government of the Northwest Territories, Department of Environment and Natural Resources.

Environment Canada. 2003. Wetland Environmental Assessment Guideline. Government of Canada. Accessed from: http://www.cws-scf.ec.gc.ca/publications/eval/wetl/index_e.cfm.

Farmer, A. M. 1993. The effects of dust on vegetation - a review. *Environ Pollut* 79:63–75.

Forbes, B. C., J. J. Ebersole, and B. Strandberg. 2001. Anthropogenic Disturbance and Patch Dynamics in Circumpolar Arctic Ecosystems. *Conservation Biology* 15 (4): 954-969.

French H. M., and I. E. Egorov. 1998. 20th Century Variations in the Sourthern Limit of Permafrost near Thompson, Northern Manitoba, Canada. In: A.G. Lewkowicz, M. Allard eds. *Permafrost Seventh International Conference*. Yellowknife, Canada: Centre d'études nordiques, Université Laval, pp. 297-304.

Fung, I. Y., J. J. Lerner, E. Matthews, M. Prather, L. P. Steele, and P. J. Fraser. 1991. Three-dimensional model synthesis of global methane cycle. *Journal of Geophysical Research* 96:13033–13065.

Garty, J. 2001. Biomonitoring Atmospheric Heavy Metals with Lichens: Theory and Application. *Critical Reviews in Plant Sciences* 20 (4) : 309-371.

Gau, R. 2010. Wildlife Biologist (Species at Risk), Wildlife Division, Department of Environment & Natural Resources, Government of the Northwest Territories, Yellowknife; June 28, 2010.

Gorham, E. 1995. The biogeochemistry of northern peatlands and its possible responses to global warming. p. 169–187. In G. M. Woodwell and F. T. Mackenzie (eds.) *Biotic Feedbacks in the Global Climate System: Will the Warming Feed the Warming?* Oxford University Press, New York, NY, USA.

Golder Associates, 2009. *Preliminary Regional Ecological Land Classification, Hope Bay Belt, Nunavut*. Submitted to Hope Bay Mining Ltd. North Vancouver, BC.

Gracz, M. 2007. *Wetland Classification and Mapping of the Kenai Lowland, Alaska KETTLE ECOSYSTEM*. Kenai Watershed Forum. http://www.kenaiwetlands.net/EcosystemDescriptions/Kettle.htm (accessed December 2010).

Groendahl, L., Friborg, T., and Soegaard, H. 2007. Temperature and snow-melt controls on interannual variability in carbon exchange in the high Arctic. *Theor. Appl. Climatol*. 88:111–125

Haber, E. 1997. *Guide to Monitoring Exotic and Invasive Plants*. Ontario: Prepared for Ecological Monitoring and Assessment Network Environment Canada by National Botanical Services, Ontario.

Halsey, L.A., D. H.,Vitt, and S. C. Zoltai. 1995. Disequilibrium Response of Permafrost in Boreal Continental Western Canada to Climate Change. *Climate Change* 30:57-73.

Hinkel, K. M. 1997. Estimating seasonal values of thermal diffusivity in thawed and frozen soils using temperature time series. *Cold Regions Science and Technology* 26 (1): 1-15.

Joly, K., Jandt, R. R. and Klein, D. R. (2009), Decrease of lichens in Arctic ecosystems: the role of wildfire, caribou, reindeer, competition and climate in north-western Alaska. *Polar Research*, 28: 433–442

Jorgenson, J. C., J. M. Ver Hoef, and M. T. Jogenson. 2010. Long-term recovery patterns of arctic tundra after winter seismic exploration. *Ecological Applications* 20 (1): 205-21.

Juutinen, S., J. L. Bubier, and T. R. Moore. 2010. Responses of Vegetation and Ecosystem CO2 Exchange to 9 Years of Nutrient Addition at Mer Bleue Bog. *Ecosystems* 13 (6): 874-887.

Kemper, J. T. and S. E. Macdonald. 2009. Effects of Contemporary Winter Seismic Exploration on Low Arctic Plant Communities and Permafrost. *Arctic, Antarctic, and Alpine Research* 41 (2): 228–37.

Kershaw, G. P. 2003. Permafrost Landform Degradation over More Than Half a Century. Macmillan Pass/Caribou Pass Region, Nwt/Yukon, Canada. In: M. Phillips, S.M. Springman, L.U. Arenson eds. *Proceedings of the Eighth International Conference on Permafrost*. Zurich: Swets & Zeitlinger Publishers, pp. 543-548.

Liston, G. E., Mcfadden, J. P., Sturm, M. and Pielke, R. A. (2002), Modelled changes in arctic tundra snow, energy and moisture fluxes due to increased shrubs. *Global Change Biology*, 8: 17–32

MacKenzie, W. H. and J. R. Moran. 2004. *Wetlands of British Columbia: A Guide to Identification*. Victoria, B.C.: Ministry of Forest Research Program: Land Management Handbook 52.

MacKinnon, A., J. Pojar, R. Coupé (eds.). 1992. Plants of Northern British Columbia. B.C. Ministry of Forests and Lone Pine Publishing. Canada.

Maltby, E., and P. Immirzi. 1993. Carbon dynamics in peatlands and other wetland soils: regional and global perspectives. *Chemosphere* 27:999–1023.

Mallory, C. and S. Aiken. 2004. Common Plants of Nunavut. Department of Education, Iqaluit, Nunavut.

Mark, A. F., N. Fetcher, G. R. Shaver, and F. S. Chapin III. 1985. Estimated Ages of Mature Tussocks of Eriophorum vaginatum along a Latitudinal Gradient in Central Alaska, U.S.A. *Arctic and Alpine Research* 17 (1) :1-5.

Matthews, S., Epp, H., and G. Smith. 2001. *Vegetation classification for the West Kitikmeot/Slave study region*. Final report to the West Kitikmeot/Slave Study. Yellowknife, NT.

McGuire, A. D. and J. E. Hobbie. 1997. Global climate change and the equilibrium responses of carbon storage in arctic and subarctic regions. In: *Modeling the Arctic system: A workshop report on the state of modeling in the Arctic System Science program*, pp. 53-54, The Arctic Research Consortium of the United States, Fairbanks, AK.

McPhee, M., P. Ward, J. Kirkby, L. Wolfe, N. Page, K. Dunster, N. Dawe, and I. Nykwist. 2000. *Sensitive ecosystems inventory: East Vancouver Island and Gulf Islands, 1993–1997*. Vol. 2 Of *Conservation manual*. Pacific and Yukon Region: Canadian Wildlife Service, Environmental Conservation Branch, Technical Report Series No. 345.

Naeth, M. A. and S. R. Wilkinson. 2008. Lichens as Biomonitors of Air Quality around a Diamond Mine, Northwest Territories, Canada. *J Environ Qual* 37: 675-1684

Natural Resources Canada. 2003. *The Atlas of Canada. Terrestrial Ecozones (Nunavut)*. http://atlas.nrcan.gc.ca/site/english/maps/peopleandsociety/nunavut/land/terrestrialecozones (accessed December 2010).

NatureServe. 2010. *NatureServe Explorer*. NatureServe, Arlington Virginia, USA. Available: http://www.natureserve.org/explorer (accessed December 12, 2010).

Northwest Territories Environment and Natural Resources. 2010.NWT Species Monitoring Infobase http://www.enr.gov.nt.ca/_live/pages/wpPages/Infobase.aspx (accessed December 2010).

Nosal, M., A. H. Legge, and S. V. Krupa. 2000. Application of a stochastic, Weibull probability generator for replacing missing data on ambient concentrations of gaseous pollutants. *Environmental Pollution* 108: 439-446.

NSF-ARCSS Hydrology Workshop Steering Committee. 2000. *The Hydrologic Cycle and its Role in Arctic and Global Environmental Change: A Rationale and Strategy for Synthesis Study*. Scientific Community to the National Science Foundation Arctic System Science Program NSF-ARCSS Hydrology Workshop Steering Committee http://arcticchamp.sr.unh.edu/pdffiles /report1.pdf (accessed December 2010).

NWT Department of Environment and Natural Resources. 2010. *State of the Environment Report* Northwest Territories. http://www.enr.gov.nt.ca/_live/pages/wpPages/SOE_Welcome.aspx (accessed October 20, 2010).

Osterkamp, T. E. 2003. A Thermal History of Permafrost in Alaska. In: M. Phillips, S.M. Springman, L.U. Arenson eds. *Proceedings of the Eighth International Conference on Permafrost*. Zurich: Swets & Zeitlinger Publishers, pp. 863-868.

Polster, D. F. 2005. The role of invasive plant species management in mined land reclamation. *Canadian Reclamation* Summer/Fall 2005:24–32.

Porsild, A. E. and W. J. Cody. 1980. Vascular Plants of Continental Northwest Territories. National Museums of Canada. Ottawa, ON, Canada.

Pugh, R. E., D. G. Dick, and A. L. Fredeen. 2002. Heavy Metal (Pb, Zn, Cd, Fe and Cu) contents of plant foliage near the Anvil Range lead/zinc mine, Faro, Yukon Territory. *Ecotoxicoloy and Environmental Safety* 52:273-79.

Rescan. 1997. *BHP World Minerals Hope Bay Belt Project, 1997 Environmental Data Report*. Rescan Environmental Services Ltd., Vancouver, BC. (1005.13.01.003 Hope Bay Reg., Technical Reports-Environmental General. 1997 Environmental Data Report Vol. 1 & 2, Rescan, 1998.).

Rescan. 2007. *BIPR Wildlife Habitat Suitability Baseline Report*. Prepared for the BIPR Project by Rescan Environmental Services Ltd. October 2007.

Rescan. 2010. *Hope Bay Belt Project: Terrain and Soil Baseline Report*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, British Columbia.

Rescan. 2011. *Hope Bay Belt Project: Wildlife Habitat Suitability Baseline Report*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, British Columbia.

RIC. 1998. *Standard for Terrestrial Ecosystem Mapping in British Columbia*. Victoria, BC: Terrestrial Ecosystems Taskforce, Ecosystems Working Group, Resources Inventory Committee.

Roulet, N.T. and Woo, M.K. 1986. Hydrology of a wetland in the continuous permafrost region. *Journal of Hydrology* 89:73-91.

RWED. 2000. *Vegetation Classification for the West Kitikmeot/Slave Study Region*. 1999/2000 Annual Report Submitted to the West Kitikmeot/Slave Study Society by: The Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories, Yellowknife, NWT.

Routledge Taylor and Francis Group. 2004. *The Encyclopedia of the Arctic*. http://cw.routledge.com/ref/arctic/sedge.html (accessed December 2010)

Ryden, B. E., 1977. Hydrology of Truelove Lowland. In: L.C. Bliss (Editor), *Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem*. Univ. of Alberta Press, Edmonton, Alta., pp. 107-136.

Sinclair, P. H., W. A. Nixon, C. D. Eckert, and N. L. Hughes. 2003. *Birds of the Yukon Territory*. University of British Columbia Press, Vancouver, BC. 595 pp.

Smith, T.M. and H. H. Shugart. 1993. The transient response of terrestrial carbon storage to a perturbed climate. *Nature* 361:523-526.

Thorpe, N.L., N. Eyegetok, N. Hakongak and Qitirmuit Elders. 2001. The Tuktu and Nogak Project: a caribou chronicle. *Final Report of the West Kitikmeot Slave/Study Society*, Yellowknife, NWT.

UNESCO. 2009. *Atlas of Transboundary Aquifers: Global maps, regional cooperation, and local inventories*. United Nations Educational, Scientific, and Cultural Organization, Paris.

US EPA. 1995. *Compilation of Air Pollutant Emission Factors*. Vol. 1 Of *Stationary Point and Area Sources*. N.p.: AP 42, Fifth Edition. US EPA.

US EPA. 2000. *Assigning Values to Non-Detected/Non-Quantified Pesticide Residues*. Washington, DC: Office of Pesticide Programs.

Vitt D. H., L. A. Halsey, and S. C. Zoltai. The Bog Landforms of Continental Western Canada in Relation to Climate and Permafrost Patterns. *Arctic and Alpine Research* 26:1-13.

Walker, M. D., D. A. Walker, and N. A. Auerbach. 1994. Plant communities of a tussock tundra landscape in the Brooks Range Foothills, Alaska. *Journal of Vegetation Science* 5:843-866.

Warner, B. G. and C. D. A. Rubec, eds. 1997. *The Canadian Wetland Classification System: The National Wetlands Working Group*. University of Waterloo, Waterloo, Ontario: Wetlands Research Centre.

Williston, P., P. Bartemucci1 and J. Pojar. 2004. Eskers and Outwash Plains: Skeins of Connectivity in the Liard Basin. Gentian Botanical Research and Canadian Parks and Wilderness Society, Yukon Chapter.

Appendix 1

Preliminary Local Ecosystem Classification System for the Project Area (Rescan 1997)

Engineers and Scientists

EXECUTIVE SUMMARY

Mapping of bioterrain and terrestrial ecosystem units within the Hope Bay Belt study area (N.W.T., Canada) was completed in accordance with protocol developed in British Columbia. Thirteen typic ecosystem units were identified through analysis of vegetation and environmental data collected at 412 sampling sites. Three broad ecosystem-bioterrain associations occur within the study area. The moist-to-wet 'Lacustrine, Fluvial and Fine Marine Substrates Association' comprises approximately 65% of the terrestrial landbase and supports the most prevalent ecosystem unit, Eriophorum Tussock Meadow, on fine marine deposits. On drier upland sites, the 'Rock-Outcrop and Coarse, Dry Substrates Association' supports the common Dryas Herb Mat ecosystem unit; however, wide and gradual slopes extending into the wetter lowlands commonly support transitional occurrences of this ecosystem unit as well. The 'Ocean Shoreline Association comprises a very small portion of the study area and is located only along the coastal margin in Roberts Bay. Here the Marine Intertidal and Backshore ecosystem units occur in linear arrangement in close association with unvegetated beach sands.

This report is accompanied by four map sets (1:20,000 scale) which identify, by way of detailed labels and generalized colour theming, the surficial materials and ecosystem units in the Hope Bay Belt study area.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 OBJECTIVES

Terrestrial Ecosystem Mapping (TEM) is a protocol for stratifying the landscape into polygons that delineate ecosystem units. Within the context of the multi-disciplinary study of the Hope Bay Belt, the overall objective of employing TEM is to provide baseline maps and a database of ecosystem and terrain data for use in:

- guiding resource management decisions,
- monitoring changes to ecosystems over time,
- interpreting wildlife values at landscape and site-specific levels,
- developing mitigation or compensation strategies for proposed developments, and
- aiding in the identification of sensitive and/or rare ecosystems.

Specific objectives of this TEM project are:

- to identify and describe terrain types and ecosystem units,
- to identify any broad vegetation and terrain differences within the study area,
- to produce maps and supporting databases for terrain and ecosystem units, and
- to produce an accompanying report to the maps and databases

2.0 STUDY AREA

2.1 Location

The Hope Bay Volcanic Belt (the Belt) is situated approximately 65-km to the east of Bathurst Inlet on the northern mainland coast of the Northwest Territories, Canada (Figure 1). It measures 90-km in length and approximately 15 to 20 km in width. The study area, which lies entirely within the Belt at its north end, is 17,624 ha and stretches south from Roberts Bay to Spyder Lake, a distance of 65.2-km. The boundaries of the study area were delineated to produce a 2-km wide corridor centered on the proposed winter road alignment, and to connect three principle sites of interest - a) the proposed barge landing facility in Roberts Bay (550 ha), b) the Doris Lake Property at the north tip of Doris Lake (1,650 ha), and c) the Boston Property on Spyder Lake (1,970 ha). As changes to the proposed road alignment were made during the course of the study, the mapped width of the road corridor exceeds 2-km in some areas.

2.2 Ecological Land Classification

The Northwest Territories (N.W.T.) have been classified within a national classification system that provides a framework for describing ecological patterns across the country. At its broadest level, this hierarchical system recognizes fifteen terrestrial Ecozones, nine of which occur in the Northwest Territories (Ecological Stratification Working Group 1996). The Belt is situated within the Southern Arctic Ecozone (SAE), a broad zone characterized by a vegetative transition from southern taiga forest to northern treeless arctic tundra (Ecological

Stratification Working Group, 1996). Being situated along the northern boundary of the SAE, the Belt supports vegetation more characteristic of treeless arctic tundra.

Ecozones are divided into Ecoregions, which represent characteristic landforms, climates, vegetation, soils, water and human activity. Seventeen ecoregions comprise the SAE; the study area straddles two of these - Queen Maud Gulf Lowlands (QMGL) and Bathurst Hills (BH). The following excerpt describing vegetation characteristics for the QMGL Ecoregion is taken from a report of the National Land Use Information Series (Wiken *et al.*, 1987):

> Species diversity and biomass production and accumulation are due to the cold climate, short growing season, edaphic conditions and consequent low soil temperatures. Soil conditions are generally sufficient to support continuous (>60%) cover of sedge tussocks along with herbs, mosses, and trailing shrubs. Typical lowland flats and concavities are characterized by poorly drained peaty soil materials containing medium to high ice content and permafrost.
>
> The dominant sedge is *Carex aquatilis* and occasionally (*C. rupestris, C. nardina, C. misandra, C. scirpoidea, C. chordorrhiza and C. membranacea*). Dominant graminoids include cotton grass (*Eriophorum angustifolium* spp. *triste, E. vaginatum* spp. *spissum*) and grasses (*Poa arctica, P. alpigena, Arctagrostis latifolia*). [Cotton grasses (*Eriophorum* spp.) actually belong to the sedge (Cyperacaea) family not the graminoid family.] Among the forbs and herbs *Saxifraga* spp. (saxifrage varieties), *Pedicularis* spp. (lousewort varieties) and *Dryas* spp. (aven varieties) are common. Mosses cover up to 50% of the surface. In the shallow pools of low-center polygons (a common feature in poorly drained lowlands) *Drepanocladus* spp., *Scorpidium* spp. and *Aulacomnium* spp. mosses are common among the sedges. *Salix arctica* and *S. glauca* are usually present on better drained polygon shoulders or small mounds and occasionally *S. alaxensis* and *S. alba* (forms of arctic willow). Other shrubs may include *Vaccinium Vitis-idaea* var. *minus, Ledum decumbens, Arctostaphylos rubra*, and herb *Dryas integrifolia*. *Sphagnum* spp. moss may occur on some polygon shoulders and lichens are generally absent.

Ecoregions are further subdivided into ecodistricts representing areas of "distinctive assemblages of landform, relief, surficial geological material, soil, water bodies, vegetation and land uses" (Ecological Stratification Working Group 1996). The study area straddles two ecodistricts – '157' within the BH Ecoregion and '159' within the QMGL Ecoregion. Most of the Belt lies within Ecodistrict 159; only the most northern portion of the area, the coastal margin, lies within Ecodistrict 157 (see accompanying map set). Due to the small scale (1:2,000,000) at which this boundary has been mapped by the federal government, its actual position on the accompanying map set (1:20,000) is somewhat arbitrary. Its position was based on topographical features which serve to separate contiguous coastal lands from those protected and partially isolated by rock outcrops. Descriptions of Ecodistricts are stored in a federal database currently being developed for general release (Marshall, pers. comm.). Differences in vegetation and soils, at least within the study area boundaries, relate to the saltwater influence on plant communities, active marine washing of soils, and possibly the influence of a maritime climate regime. Attributes that serve to distinguish the two ecodistricts, as identified within the federal database, may or may not be apparent from the results of this study due to the minimal size of the Belt relative to the total areas of the two ecodistricts.

The national classification system provides for three more levels of classification (ecosection, ecosite and ecoelement), however public mapping at these successively finer scales has not been conducted.

2.3 General Landscape Features

Over the past 10,000 years, three large-scale geological processes have shaped the Belt's landscape to its modern condition - glaciation, marine transgression (invasion of the land by the sea), and marine washing of surface deposits. Combined, they have created a relatively subdued landscape. Recent deposits and periglacial processes continue to modify the landscape on a smaller scale. All are discussed in section 4.0.

The topography of the Belt is best described as gently rolling valleys with a roughly parallel drainage pattern resulting from parallel rock outcroppings and valleys. The Koignuk River is the major watercourse in the region; it flows into the study area from the south where it feeds Spyder Lake. North of the lake, the Koignuk River flows north-by-northwest and empties into Hope Bay. It has downcut sharply through partially consolidated marine and till deposits and is characterized in many places by relatively steep cutbanks. Three sets of falls and rapids within the study area occur in association with constrictions at rock outcroppings. As well as the Koignuk River, there are numerous unnamed streams that flow through the study area. Thaw lakes are numerous.

Generally, the Belt is characterized by gentle, north-by-northwest tending valleys filled with silty-clay marine deposits. The valleys are typically separated by discontinuous, gently sloping, oblong or linear rock outcrops, predominantly of Archean-aged mafic volcanic and intrusive origin. Occasionally, particularly in the north, younger Franklin diabase sills and Mackenzie diabase dykes rise sharply and steeply. Over most of the landscape the mafic outcrops which are most easily weathered rise to elevations of no more than 50-m while the more resistant sills and dykes protrude as high as 160-m. The Belt is bordered by the regionally dominant felsic rocks (predominantly granodiorites, granites and gneisses) that form the Canadian Shield (Gebert, 1995).

At the extreme southern end of the study area, the landscape is a gently rolling plain overlain by complexes of washed till and fine marine deposits. North of Doris Lake to the coast, bedrock outcrops are characterized by marine and till mantles of variable thickness. High boulder exposure and coarse sandy textures characterize portions of rock outcrops that have undergone energetic washing. The differences in topography and surficial materials between the north and south portions of the study area appear to correspond closely with differences described by Bird (1961) between the two local physiographic regions - 'Buchan Upland' and the 'Elu Rock Plain'. The 'Buchan Upland' in the south is described as consisting of convex-sided rock-knob hills, which are generally drift-free, and valleys filled with washed glacial till. In contrast, the 'Elu Rock Plain' region is described as a region dominated by silt plains of marine origin interrupted by a high proportion of rock ridges.

3.0 METHODOLOGY

For the purposes of this study, the term "ecosystem" is defined as "a segment of land relatively uniform in its biotic and abiotic components, structure, and function" (Sukachev and Dylis 1964) - a restrictive but practical definition suited to management-oriented land classification.

Abiotic and biotic components of ecosystems are numerous and variable, making data collection a potentially complicated and exhaustive process. Ecosystem classification therefore generally concentrates on identifying and characterizing those components which integrate other components, reflect ecosystem function best, and which are most conveniently studied (Meidinger and Pojar 1991) - components such as plant species, soils and terrain conditions on which the plants persist.

Ecosystems of the N.W.T. have only been described over limited areas and usually in association with specific development projects (for example Oikos Ecological Services Ltd., 1995) or for academic research (for example Bliss, 1977). Sub-regional descriptions have not been attempted, nor has a protocol for mapping them been developed. Consequently, we developed sampling and analysis strategies based on a protocol developed and widely used in British Columbia (Resources Inventory Committee, 1995, 1996a). This protocol allowed us to formally describe the ecosystems of the Belt and produce ecosystem and terrain maps.

3.1 Modifications to Standard TEM Methodology

3.1.1 Ecosystem Description

Lands of the Northwest Territories have only been classified to a broad ecological level called the Ecodistrict using a national system of classification (Ecological Stratification Working Group 1996). In contrast, much of B.C. has been classified to the ecosystem unit level (termed site series and site series modifiers) using two provincial systems – the Ecoregional Classification System (Demarchi 1988 and Demarchi *et al.* 1990) and the Biogeoclimatic Ecosystem Classification (BEC) system (Meidinger and Pojar, 1991).

The broadest level of classification utilized in B.C.'s terrestrial ecosystem mapping is the Ecosection, which represents areas of minor physiographic and macroclimatic variations (Demarchi 1988 and Demarchi *et al.* 1990) and is roughly equivalent to the national Ecodistrict level (Ecological Stratification Working Group 1996). The BEC site series units are appropriate to develop site-specific prescriptions and are roughly equivalent to the ecosystem unit used in this study.

Table 1 compares ecological land classification hierarchies associated with each major classification system described here Mapping the study area incorporates two-levels of classification hierarchy, the *Ecoregion Units* and *Ecosystem Units*. The national classification system provides the broad level classification in *Ecoregion Units* (Ecozone, Ecoregions and Ecodistricts – see table below), while the present study, through sampling, analysis and description, provides the detailed classification in *Ecosystem Units* (Ecosystem Units and Ecosystem Modifiers). Modifiers are attached to ecosystems to account for variation in the proportions of plant species associated with variation in edaphic and terrain characteristics between sites. The modifiers used have been largely developed from those used in B.C (Resources Inventory Committee 1996a).

TABLE 1: COMPARISON OF ECOLOGICAL LAND CLASSIFICATION HIERARCHIES BY JURISDICTION/AREA

BRITISH COLUMBIA	CANADA AND N.W.T.	HOPE BAY AREA
ECOREGION UNIT ECOREGION--------------- ECOSECTION--------------	*ECOREGION UNIT* ---ECOREGION------------------- ---ECODISTRICT----------------- ECOSECTION ECOSITE	*ECOREGION UNIT* ----ECOREGION ----ECODISTRICT
BIOGEOCLIMATIC UNIT SUBZONE	*-no equivalent*	*-no equivalent*
ECOSYSTEM UNIT SITE SERIES----------- SITE MODIFIER-------	*ECOSYSTEM UNIT* ---ECOELEMENT------------ ------------------------------------	*ECOSYSTEM UNIT* ----ECOSYSTEM UNIT ----ECOSYSTEM MODIFIER

3.1.2 Aerial Photography

Large-scale aerial photos were not available until after the 1996 field season. Small-scale (1:60,000) photos do not provide adequate resolution of terrain and vegetation necessary for mapping ecosystems but were used during the first field season for navigation, to identify gross terrain features, and to permanently record sample plot locations.

3.2 Phototyping

Ecosystem mapping normally begins with the delineation of terrain map units (or polygons) on large-scale aerial photos, a process known as phototyping. Terrain polygons represent areas that are relatively uniform in landform and surficial materials. TEM takes a bioterrain approach to phototyping in that terrain polygons are further subdivided according to biologically significant attributes that control the expression of distinct ecosystems. In this way, a terrain unit of bedrock uniformly overlain by a veneer of glacial till may be subdivided to reflect that the crest is drier than the side slopes. Similarly, if slopes are significant enough, opposite aspects of the unit may be separated to reflect that different ecosystems will be found on opposing aspects due to differences in insolation and/or duration and depth of snow cover.

Bioterrain polygons were delineated on 1:15,000 aerial photos following the first field season when the photos became available. Sample data already collected was used to strengthen initial phototyping while data from the second season served to confirm and/or refine designations.

Apart from the necessary departures from standard methodology (as discussed in Sections 3.1.1 and 3.1.2) phototyping closely followed the protocol outlined by the Resources Inventory Committee (1995, 1996a). According to this protocol, polygons may contain up to three bioterrain and ecosystem unit components, which are identified in polygon labels along with their proportional decile occurrences. Terrain phototyping adopted the symbology of Howes and Kenk (1988, 1997) except for minor differences, including the substitution of 'T' for 'M' to represent glacial till, and 'M' for 'W' to represent marine deposits. This was done so symbols correspond more closely with those used by federal (Geological Survey of Canada) and territorial agencies.

3.3 Field Sampling

At regional levels, climate determines the general type of vegetation in an area (i.e. tundra vs. forest). Distinct plant species assemblages however, are determined by factors such as topography, surficial geology, and soil properties through their influence on soil moisture and nutrients. These factors together with the plant community are used to describe ecosystem units. Sample plots were located systematically across the study area, on all terrain types and at different slope positions, according to an initial plan refined following reconnaissance of the study area.

Sample plots (10-m x 10-m) were established in areas uniform in vegetation, terrain and soils. Transitional areas were sampled in the second field season in order to improve the accuracy of phototyping and refine community descriptions. Plot locations were permanently recorded onto 1:60,000 photos and subsequently transferred to large-scale photos once they came available.

TEM recognizes two types of sampling plots: detailed and visual plots. Detailed plots are the most comprehensive and are the type required for statistical analysis to identify and describe ecosystems units. Visual plots are less detailed and are used to confirm terrain phototyping and ecosystem assignment. Sampling in 1996 concentrated on the establishment of detailed plots. Six or more plots per ecosystem unit are preferred in order to strengthen the reliability of ecosystem descriptions; however, uncommon units may be described using fewer plots. Field crews attempted to obtain at least six samples for each ecosystem unit encountered. Visual plots established in 1997 included the collection of complete plant lists so that a greater number of plots could be used in the analysis.

Sampling was consistent with the methods of Luttmerding *et al.* (1990), the Resources Inventory Committee (1995, 1996a) and Mitchell *et al.* (1989). Standard ecosystem field forms were filled out at each sampling location. Site-specific information recorded onto field cards included slope, aspect, mesoslope position, surface shape, moisture and nutrient regimes, terrain type and surface substrate composition. Soils were classified according to the Canadian system of soil classification (Agriculture Canada Expert Committee on Soil Survey 1987). Soils data included soil profile descriptions, numerous genetic horizon characteristics, drainage class, rooting depth, presence or absence of seepage water, depth to (and type of) root restricting layer, and humus form type.

Plant species were identified and given a unique seven-letter code. Percent cover and physiognomic form (herb, shrub, moss or lichen) were also recorded. Voucher specimens of all plant species were collected. Species that could not be positively identified on site were identified later with the aid of taxonomic keys (Hulten 1968, Porsild and Cody 1980, Vitt *et al.* 1988). A collection of mosses encountered was sent to a specialist for identification (LaFarge-England 1996). Representative photographs of the soil pit and vegetation community were taken at each sampling location. Common plant names, if available, were taken from Hulten (1969), Porsild and Cody (1981), Trelawny (1988), Vitt *et al.* (1988), Schofield (1992).

3.4 Analysis

3.4.1 Overview

The objective of ecosystem analysis is to reveal the relationship of sample plots by grouping them into ecosystem units on the basis of their floristic composition and environmental attributes (i.e. soils, terrain, soils moisture and nutrients). When the effective range of environmental attributes is initially uncertain, a common approach to classifying ecosystems is to analyze vegetation data independently of environmental data (Kent and Coker 1996); this is known as indirect analysis.

SYN-TAX 5.0 (Podani 1994) is a package of multivariate statistical procedures chosen for its powerful analysis capabilities and its flexibility in meeting specific study requirements. This flexibility is reflected in its capacity to perform numerous indirect classification procedures useful in mathematically and graphically demonstrating the relationships between sample plots. Four indirect procedures were used to group plots into tentative ecosystem units based on the vegetation data. The four procedures used were; hierarchical classification, non-hierarchical classification, fuzzy clustering, and ordination; they are outlined below. Once this was done, the relationship between environmental variables and vegetation was examined.

3.4.2 Analytical Procedures

The grouping or separation of plots is based on mathematical distances between them as represented by statistically determined similarity or dissimilarity coefficients. All analysis is based on the calculation of these distances, which are commonly referred to as distance scores (Podani 1994). Syntax 5.0 provides no less than fourteen distance score coefficients, however Kent and Coker (1996) indicate that the **Euclidean distance coefficient** is commonly and reliably used in analyzing quantitative vegetation data. This coefficient was used in all procedures.

Hierarchical Classification

Hierarchical classification is probably the most widely used procedure for showing similarities (or dissimilarities) among plots at successive levels of grouping. Hierarchical classification begins by segregating one large group containing all plots into successively smaller groups at successive levels of analysis. This continues until all plots are shown as separate groups. It is up to the discretion of the analyst to determine the most practical level at which groupings should be halted. Two methods of hierarchical clustering were explored: minimization of sums of squares in new clusters and global optimization. In the first approach, successive segregations occur if the sum of squares of distance scores of the newly obtained groups is the minimum for a given level in the hierarchy. In the second approach, segregations are made if the ratio of distance scores within clusters and between clusters is minimized for a given hierarchy.

Non-Hierarchical Classification

The second procedure, non-hierarchical clustering (by global optimization), requires that the user specify the number of groups in advance. Plots are then assigned to groups based on an optimal solution which minimizes the ratio of average within cluster distances and the average between-cluster distances (the G-Ratio). Several trials are run, each time specifying a different number of groups.

Fuzzy Clustering

A third procedure, known as fuzzy clustering, calculates the affinity of each plot to one of the prespecified number of clusters (groups). The optimal solution is obtained through the minimization of the so called fuzzy sum of squares of clusters calculation.

Ordination

The fourth procedure, ordination, is a graphical technique that depicts the relationships of plots to each other in a two or three-dimensional space as a scattergram. Non-metric multidimensional scaling ordination arranges the plots along two or three axes using distance scores converted to rank order. This reduces clumping of plots and helps remove distortion when distance scores are far apart. The rank distances between any two plots or groups of plots reflects their degree of similarity in floristic composition - the further apart they are the more dissimilar they are. This procedure, as well as fuzzy clustering helped assign specific plots to the most appropriate units where hierarchical and non-hierarchical procedures were unable to do so definitively.

SYNTAX 5.0 is limited in the size of the dataset that certain procedures can handle. Hierarchical and non-hierarchical procedures were able to analyze our full dataset and provided an unbiased and appropriate guide for separating the plots into two or three subgroups which then became the input datasets for size restricted procedures (fuzzy clustering and ordination). Reference to these subgroups [A, (A1, A2) and B] is made in Section 4.3.

An initial analysis was conducted after the first field season prior to final identification of all species, namely bryophyte and willow (*Salix)* spp. The ecosystem units developed from that analysis were used as a guide during the 1997 sampling season to collect visual plot data having full species lists and with the intention of reanalyzing the data. The final analysis was conducted late 1997.

3.5 Digital Mapping and Database

Maps-3D Digital Mapping Solutions™[1] is a suite of software tools used to digitally capture data for further use by a GIS software package. The software utilizes Microstation PC ®[2] as the graphics engine to achieve the data capture. Raw linework (polygon lines delineating ecosystem units) was digitized directly from large-scale aerial photos using the Mono Restitution module (MONO-3D) within the Maps-3D package. This module utilizes ground control points, a Triangulated Irregular Network (TIN) surface and a mathematical model

[1] Maps-3D Digital Mapping Solutions™ is a suite of software tools produced by Pacific International Mapping Corp. (Victoria B.C., Canada.)

[2] Microstation PC is a product of Bentley Systems Inc. (Exton Pennsylvania, U.S.A)

that allows the user to transfer photo coordinates into X, Y and Z ground coordinates. Ground control points within the study area were provided by Land Data Technologies Inc. (Edmonton Alberta, Canada). The TIN surface was created from a Digital Elevation Model (DEM) of the study area, also provided by Land Data Technologies. Once captured, the digitized linework was vector cleaned using various modules within the Maps-3D software. This resulted in a topologically correct digital model of the ecosystem polygons within the study area.

Data entry as well as format and content validation programs were designed to transcribe ecosystem and bioterrain labels into a Microsoft Access Database. Standards for data entry as established by the Resources Inventory Committee (1996b,c) were followed. Map labels for each polygon were created using an in-house label generator. These labels were then imported into the Geographics database and annotated to the maps using Microstation Geographics ®[3]

It should be noted that a small section (480 ha) of the study area to the southeast of Spyder Lake was not digitized because aerial photo coverage and a digital elevation model were lacking. This is the reason for a number of sampling plots being located outside the mapped area.

4.0 RESULTS AND DISCUSSION:

4.1 Surficial Geology and Major Landforms

The late Wisconsinan Glaciation was responsible for the transportation and deposition of till into the area. This till chiefly comprises a sandy matrix with a low coarse fragment content (0-25%). During the period of glacier recession (approximately 8800 to 3500 ± 1000 years ago - see Ryder and Associates, 1992) the region became entirely submerged (marine transgression) and marine sediments were deposited over most, if not all, of the landscape (Bird and Bird, 1961). The marine sediments within the study area are predominantly composed of silts and clays and form the dominant surficial deposit.

Since the end of the Wisconsinan Glaciation the land formerly inundated has emerged from the sea through isostatic rebound. As it emerges, surface sediments are exposed to washing regimes that vary as a consequence of local differences in topography, exposure and nearshore currents.

Erratic boulders found scattered across the landscape identify where finer fractions of till and glaciofluvial materials have mostly been washed away or moved downslope by solifluction[4]. Although washed till occurs throughout the study area, it is most prevalent in the south, at times complexed with marine sediments. Near Spyder Lake, washed till predominantly occurs as wide, gently undulating plains, as typified by three drumlinoids located just south of Boston Camp. North of Spyder Lake, along the Koignuk River corridor, till overlies bedrock and forms smaller and discrete complexes of till, rock and marine sediments.

[3] Microstation Geographics ® CAD software is a product of Bentley Systems Inc. (Exton Pennsylvania, U.S.A)

[4] Solifluction is the *slow* gravitational downslope movement of saturated soils overlying permafrost.

The distribution of surficial sediments resulting from glacial and marine processes is characterized by relatively thick marine deposits in valleys, and thinner marine, till, and glaciofluvial deposits at higher elevations. Areas exposed to high energy washing have either had the fine marine sediments washed away completely exposing the underlying till and/or bedrock, or have had larger, coarse marine sediments (predominantly sands and gravels) deposited and preserved as strandlines (isolated beaches), predominantly in the northern portion of the study area.

4.2 Recent Deposits and Periglacial Processes

Numerous erosional, depositional, and periglacial[5] processes have been modifying the Hope Bay landscape since its emergence from the ocean. Photo-typing and soils data collected during the study were used to identify and characterize the landforms and surficial deposits resulting from these processes.

4.2.1 Erosional and Depositional Processes

Fluvial deposits result from suspended sediments settling out of flowing water. Within the study area they are relatively common but limited in area. Along rivers and streams they occur as level or slightly sloped terraces, benches or plains overlying marine and till deposits. In landscape positions remote from present watercourses, their association with lacustrine deposits suggests they have been deposited during rapid drainage stages of thaw lakes (see Section 4.2.2).

Solifluction is prevalent in the study area on all sloped terrain. It occurs in any saturated soil types but is most common in fine-textured soils. On shallow slopes (3-5%) evidence of solifluction is difficult to detect because slope materials move very slowly and in a sheet-like manner, leaving little surface disturbance. On steeper slopes it occurs more quickly, often creating surface deformities in the shape of lobes. Such lobes were observed in a few instances while phototyping and field sampling.

Saturated soils can also undergo *rapid* downslope movement where slopes and high moisture content combine to weaken soil structure. Upon thawing, the slope fails and the eroded sediments are deposited downslope as colluvium. Within the study area, these thaw flow slides (also known as earth- or mudflows) are most common in marine sediments along the steep banks of the Koignuk River (Figure 2). They also occur on the steep banks of smaller streams and within shallower seepage tracks. The trigger for slope failure in seepage tracks is high soil moisture, which weakens soil strength. Adjacent to rivers, the trigger is fluvial erosion of the lower bank. When an initial failure takes place, ice-rich, subsurface soils are exposed. These subsequently thaw and become susceptible to failure. An initial failure typically begins a cycle of successive slope failures producing a semicircular backwall that continues eroding further back into the slope until the gradient is decreased by collapsing sidewalls. The deposition of collapsed materials buries underlying substrates and thawing ceases.

Colluvial deposits also originate in non-saturated coarse-textured materials (where slopes are steep enough) as well as in rock that fractures when interstitial water freezes - a process

[5] The term ‘periglacial processes’ refers to those processes that occur in association with permafrost and freeze-thaw cycles in cold climates (Howes and Kenk 1997).

known as frost-wedging (Washburn, 1980). Aprons of rubble (large angular rock fragments) are found throughout the study area at the base of rock outcrops, particularly diabase outcrops (PLATE 6)

Figure not Available

FIGURE 2: Thaw flow slides along the cutbanks of the Koignuk River

4.2.2 Periglacial Processes

Periglacial processes produce several recognizable features across the landscape including thaw lakes, patterned ground (ice-wedge polygons), beaded streams, and frost mounds.

Thaw lake cycles are variable and depend highly on local terrain features and soil texture. They are most common in fine-textured substrates. When the active layer[6] and near-surface permafrost thaw at the lake margins, shorelines erode, and sediments are sorted and transported within the water column. Over time, shorelines advance outward and adjacent lakes may coalesce. When outlet drainage channels develop, lake levels fall exposing lacustrine and fluvial sediments along valley-bottom positions (Bird, 1967; Britton, 1967).

Thaw lakes are numerous in the study area and are often associated with polygonal (or patterned) ground. Britton (1967) explains this association as a direct result of the thaw lake cycle. As a thaw lake enlarges, it melts ice-wedges and erodes patterns. Britton hypothesizes that after a lake drains and patterned ground begins to form again, it does so by differential thawing along existing pattern lines preserved beneath the lacustrine and fluvial deposits. Thaw lake margins lacking patterned ground may have deposits too thick to allow the expression of buried patterns. Surface soils in the drained basins are also generally composed of some organic materials. Productive wet meadows form a major component of the plant communities in these basins. The annual dieback of above-ground biomass tends to

[6] 'Active layer' refers to the upper portion of the soil column that undergoes seasonal freezing and thawing and which is underlain by permafrost. The depth of the active layer varies from year to year and is highly dependent on soil texture. It is deepest in well-drained coarse-textured soils and remains very shallow (0-40 cm) when the surface is blanketed by wet organic soils.

accumulate while the rate of accumulation and thickness of the resulting organic layers depend on factors such as degree of seasonal flushing and time since the thaw lake cycle was last completed

Within the study area, two types of patterned ground are recognized: high-centered polygons and low-centered polygons[7]. Low-centered polygons are dominated by flat, wet-to-moist basins, separated by raised, linear ice-wedges. Description of these formations as ‘polygons’ reflects the distinct angles at which the ice-wedges intersect. In contrast, high-centre polygons are dominated by palsas (mounds domed-up by a growing lens of ice). Each mound is typically encircled by wet meadow where runoff and seepage are concentrated. Patterned ground is found most commonly on level, poorly drained valley bottoms overlain by fine marine or sandy lacustrine and fluvial sediments. In such situations, patterned ground occurs in elongated low-lying areas between thaw-lakes. Patterned ground occasionally occurs in depressional areas along streams, rivers, and at upper elevations remote from any water bodies. In all situations however, the patterns occur on poorly drained, level to slightly sloped (approximately 0-1.5%) fine substrates.

Beaded streams are another permafrost-related phenomenon found within the study area. The beads (or pools) are believed to form in the stream channel at ice-wedge intersection points (Tedrow 1977). As stream-water flows over these wedges, they melt to depths greater than the channel bed and result in the formation of deep, round or oval pools. Beaded streams typically occur on gently sloped terrain overlain by fine marine deposits.

Frost mounds, also known as non-sorted circles (Washburn, 1973), earth hummocks (Tarnocai and Zoltai, 1978), mud circles (Bird, 1967) and frost boils occur throughout the arctic (Tedrow, 1977) and are common within the Hope Bay Belt area. According to the polygenetic classification scheme of Washburn (1970) frost mounds are one of many forms of patterned ground; however we restrict the usage of patterned ground to low-centre and high-centre polygons which are easily distinguishable on air photos. Consistent with Zoltai and Tarnocai (1974), the term “frost mound” is used here to describe features with the general shape of a low dome, or mound, where frost is the driving force behind its formation. In the Hope Bay Belt area, mounds most commonly form in fine-textured soils in gently sloped terrain, and infrequently on coarse-textured soils. Strong cryoturbation within frost mounds is evidenced by distinct organic intrusions, buried organic layers, and discontinuous soil horizons, which indicate that cryogenic (freeze-thaw) processes above the permafrost table are responsible for mound formation. The proportion of unvegetated mineral soils is often an indication of the degree of cryogenic activity within the mounds. In the study area, active mounds are typically 0.5 to 1.5 metres in diameter and 0.3 to 0.5 m in height. Vegetated inter-mound distances vary highly depending on the degree of activity. Active mounds are typically only partially vegetated, while inactive mounds are often completely vegetated and sustain shrubs.

The occurrence and distribution of major plant community types is strongly influenced by major landforms, surficial sediments and permafrost-related processes, which are featured in the description of ecosystem units throughout Section 4.4. Bioterrain theme maps have been developed to present, in a more generalized and visually effective manner, the detailed

[7] Usage of the word polygon in this context should not be confused with its usage as a mapping unit that delineates an area similar in ecosystems or bioterrain, as the case may be.

information contained in the bioterrain maps. Colour theming is based on the dominant surficial material with a map polygon. In this way, a polygon with a complex of surficial materials such as 70% glacial till and 30% marine sands is coloured as a glacial till polygon.

4.3 Analysis

A total of 412 sample plots were established over the course of two field seasons: 127 detailed plots and 49 visual plots in 1996 (July 28 - August 16) and 236 visual plots (with full vegetation species lists) in 1997 (July 5 - July 23). The locations of all plots are identified on the accompanying mapset. Ecosystem analysis was based on the data from 113 of the 127 detailed plots and 121 of the 236 visual plots established in 1997.

One hundred and seventy eight (178) plots were not included in the analysis for the following reasons:

- A preliminary analysis of all detailed plots established in 1996 determined that six plots were outliers and eight plots represented transitional situations. These fourteen plots were thus not included in the final analysis.
- The 49 visual plots established in 1996 incorporated only dominant vegetation species, terrain descriptions, and abbreviated soil descriptions. As such they were not intended for use in the analysis but rather as sources for confirming and refining terrain and ecosystem designations.
- Visual plots established in 1997 initially represented typic (unmodified) ecosystems (121 plots) and atypic (transitional and/or modified) ecosystems (115 plots). Only those representing typic units were intended for inclusion in the analysis.

The results of the analysis are presented in Appendices B-1 to B-8 and are summarized below.

4.3.1 Hierarchical Classification

Two dendrograms (Appendices B-1 and B-2) depict the results of hierarchical classification (by minimization of sums of squares in new clusters and by global optimization). Comparison of the figures shows that the two techniques produce similar results in that plots tend to be grouped into the same clusters. Notable differences do exist. The technique that produced results most similar to preliminary field groupings was global optimization. At this stage of analysis the number of distinct groups remained undefined.

4.3.2 Non-hierarchical Classification

Non-hierarchical classification by global optimization requires prior specification of the number of groupings to run the analyses. Several runs were processed with number of groups specified at 12, 13, 14, 15 and 16. The best results are defined by a combination of minimizing the global optimization ratio, or G-ratio, maximizing the frequency of a particular G-ratio, as well as subjectively assessing the appropriateness of plots in each group. The best results were obtained when fifteen groups were prespecified. The results are presented in Appendix B-3. Examination of the results showed that differences between G-ratios for each of the twenty runs is minimal. This means that placement of some plots into different groups produces minimal differences. This is why utilizing other techniques, such as fuzzy clustering and ordination, is important to strengthen groupings.

4.3.3 Fuzzy Clustering

The third technique, fuzzy clustering, is limited by the number of groups (maximum 10) that can be pre-specified. The sample plots were therefore separated into two subgroups based on the hierarchical classification already conducted. In this way it was assured that placement of plots into each subgroup did not bias or confound results. Fuzzy clustering results are presented in Appendices B-4 and B-5 for subgroups A and B respectively. The output of fuzzy clustering is a list of all plots and respective membership weights (or affinities) that each plot has for each of the pre-specified number of groups. Using an arbitrary value of 0.65 as a lower limit to define membership to one of the groups, those plots with no membership weights exceeding this limit (all plots in bold) were subjectively assigned to a group or treated as outliers.

4.3.4 Ordination

The fourth technique, non-metric multi-dimensional scaling ordination, required that the data be grouped into three subgroups (A1, A2, and B). The same criteria for grouping plots into subgroups were used as those employed for the purposes of fuzzy clustering. The results of the outputs are presented in Appendices B-6, B-7 and B-8.

4.3.5 Examination of Environmental Data

In the final stage of analysis, environmental (abiotic) variables were examined for each community developed through indirect analysis. The effect of this procedure was the definition of final ecosystem units that include the typical ranges of environmental variables as well as the typical plant species assemblages. Each ecosystem unit identified is described below in Section 4.4.

4.4 Ecosystem Unit Descriptions

In summary, the analysis produced the following notable results:

1. Thirteen unique terrestrial ecosystem units were identified within the Hope Bay Belt study area:

Dry Carex-Lichen (12)	*Riparian Willow (19)*
Dryas-Herb Mat (20)	*Wet Meadow (28)*
Betula-Ledum-Lichen (33)	*Emergent Marsh (1)*
Dwarf Shrub-Heath (19)	*Low Bench Floodplain (4)*
Betula-Moss (15)	*Marine Intertidal (4)*
Eriophorum Tussock Meadow (68)	*Marine Backshore (4)*
Dry Willow (7)	

Note: Numbers in brackets indicate the number of sample plots established in each ecosystem unit identified as typic prior to analysis

2. Each of these units is defined by a distinct (typic) plant species assemblage and a finite range of environmental conditions (edaphic, topographic and terrain). Often, transitional communities occur where site conditions are intermediate between those which define

typic ecosystem units. In such cases, plant species assemblages exhibit characteristics of two or more of these units. Where site conditions change gradually along shallow slopes, transitional communities can be extensive.

3. Where typic plant species assemblages occur but individual species proportions and site conditions vary from those defining the typic unit, modifiers (topographic and edaphic) are applied to account for the variation (i.e. x – drier, m – mounded, s – steeper). Several recurrent modified ecosystem units were found to occur, the most prevalent are identified and described in further sections. The analysis identified two specific modified types that were initially identified in the field as distinct groups (potential ecosystem units). As discussed below in Sections 4.4.1 and 4.4.2, they are the nutrient-poor Tussock Meadow type (TMp) and the bouldery Betula Ledum type (BLb):

4. The Eriophorum Tussock Meadow (TM) ecosystem unit is the most widespread and dominant unit within the study area. Although three types of TM communities were initially identified in the field, the analysis distinguished only one typic community (TM and one modified unit (TMp, as mentioned above).

5. Although two wet meadow plant assemblages are represented in the field data, one dominated by water sedge (*Carex aquatilis* var. *stans*) and the other by tall cotton-grass (*Eriophorum angustifolium*), the environmental conditions are not reliably distinct between the two. As both communities are largely ecological equivalents and are not reliably distinguishable by phototyping, they collectively represent the Wet Meadow ecosystem unit.

6. The preliminary segregation of willow-dominated riparian communities into lake-margins, seepage zones, and medium and high bench floodplains was not supported by the field data, largely due to significant overlap in floristic composition. Consequently they were grouped to form one ecosystem unit called Riparian Willow.

7. Three broad Ecosystem-Bioterrain associations occur within the study area (Figure 3):

   i. The 'Rock Outcrop and Coarse, Dry Substrates Association' includes four ecosystem units, which occur under the dry to mesic conditions of coarse glacial till overlying bedrock, or well-drained coarse glaciofluvial and marine deposits.

   ii. The 'Lacustrine, Fluvial and Fine Marine Substrates Association' includes seven typic ecosystem units. These units occur under mesic to wet conditions attributable to fine soil textures, shallow active layers, or seepage receiving landscape position.

   iii. The 'Ocean Shoreline Association' contains the Marine Intertidal and Marine Backshore ecosystem units.

Figure not Available

FIGURE 3: Northwest view of Roberts Bay coastline; i) 'Rock Outcrop and Coarse, Dry Substrates Association' supporting bare rock and a bouldery Betula-Ledum-Lichen community (foreground), ii) 'Lacustrine, Fluvial and Fine Marine Substrate Association' supporting a hummocky wet meadow community (centre-left), and iii) 'Ocean Shoreline Association' supporting unvegetated beach sands and marine intertidal and backshore communities (centre-right).

Sections 4.4.1, 4.4.2 and 4.4.3 detail the environmental conditions and floristic composition of each ecosystem unit identified. Environmental conditions discussed include relative soil moisture and nutrient regimes, topography, percent slope, soil classification, texture, terrain classification and presence or absence of a water table. These are then summarized in an environmental characteristics table. Discussion of floristic composition includes typical plant species assemblages and the environmental conditions which support them. Common modified and/or transitional units are also discussed in relation to the topographic and edaphic conditions producing them. Definitions of relative soil moisture and nutrient regimes are presented as Appendix A. All plants identified from the study area are listed in Appendix C along with a citation for the source of the botanical names and the species descriptions. A key to the identification of ecosystem units within the Hope Bay study area has been included as Appendix D.

4.4.1 Ecosystem Units Associated with Rock Outcrops and Coarse, Dry Substrates

Dry Carex - Lichen (CL)
(PLATE 1)

Environmental Conditions

The CL unit is the driest and most nutrient-limited unit in the study area. It occurs on crests and upper slopes underlain by coarse washed till, glaciofluvial materials, or sandy marine deposits. Sands comprise the typical soil matrix, although loamy sands (LS) and coarser skeletal materials are occasionally dominant. A deep permafrost boundary, (usually deeper than 100 cm of the surface), coarse soil textures, and convex slope shape are all contributing factors to the moisture and nutrient-deficient conditions typical of this unit. Slopes typically range from zero to seven percent. Soil development is minimal, typically being Regosolic, occasionally Brunisolic and rarely Cryosolic.

Environmental Characteristics – Typic Dry Carex-Lichen (CL)	
SMR:	1 - 2 - (3)
SNR:	B - A (- C)
Percent Slope:	0 – 7
Soil Classif.:	typically Regosol (R), occasionally Brunisol (B), rarely Static Cryosol (GL.SC, BR.SC)
Soil Texture:	typically sand (S), occasionally loamy sand (LS)
Terrain Classification:	washed till, glaciofluvial outwash and sandy marine deposits
Water Table:	may be present immediately after rain events and at beginning of growing season at interface with frozen soil
Common Modifiers:	x, c, z

Vegetation Characteristics

Harsh environmental conditions limit the number and type of plant species that occur here. Drought conditions and wind abrasion almost preclude the occurrence of shrubs, although Arctic willow (*Salix arctica*) is favoured due to its prostrate growth-form and drought-resistance, and may be up to 10% of the ground cover. Curly sedge (*Carex rupestris*), a pronounced calciphile and drought-resistant dwarf sedge, forms the loose matrix of this community. Arctic avens (*Dryas integrifolia*), another calciphile, is typically present but its abundance is limited by shallow rooting depth, low nutrients and drought conditions. Other common plant species scattered at low abundance include alpine sweetgrass or holy grass (*Hierochloe alpina*), moss campion (*Silene acaulis* var. *exscapa*), prickly saxifrage (*Saxifraga tricuspidata*), purple saxifrage (*S. oppositifolia*) and arctic oxytrope (*Oxytropis arctica*). Crustose lichens occur on exposed rock and dead moss throughout. Unvegetated mineral soil (usually fine gravels and coarse sand) is typically present and reflects the harsh conditions for most plants. The diagnostic plant species assemblage that characterizes the CL unit is recurrent throughout the Arctic on sites where comparable environmental conditions exist.

Vegetation Characteristics – Typic Dry Carex-Lichen (CL)	
Layer (%)	**Species (%)**
Shrubs (<10)	no dominant species
Herbs (45-80)	*Carex rupestris* (35-60) *Dryas integrifolia* (<30)
Moss (0-10)	no dominant species
Lichen (15-40)	crustose lichens

Typical modifiers applied to the CL ecosystem unit include x (dry), c (coarse), and z (steep). These modifiers are related in that they infer faster drainage and drier soils. Lower total plant cover and fewer plant species characterize these modified communities.

Communities with characteristics intermediate between the CL and DH ecosystems are common but the transition between the two is typically rapid.

Dryas Herb Mat (DH)
(PLATE 2)

Environmental Conditions

The DH unit occurs on moderately well to well-drained substrates at landscape positions that receive minor or no seepage inputs. This includes sandy/gravelly marine deposits and more typically, mantles of washed till in complex with rock outcroppings. On rare occasions the soil matrix develops from weathered bedrock. Soil textures are moderate (SiL) to coarse (S and gravelly S). Relative soil nutrient regime is moderate (C) to poor (B) and relative moisture is most commonly subxeric (2), occasionally submesic (3), and rarely xeric (1) or mesic (4). Soil development is variable (Brunisolic Cryosols, both Static and Turbic, Regosols, and Brunisols) reflecting degree of soil churning and the variable depths of active layers.

Environmental Characteristics – Typic Dryas Herb Mat (DH)	
SMR:	(1 -) 2 – 3 (-4)
SNR:	C – B
Percent Slope:	0 – 7
Soil Classification:	Brunisolic Static and Turbic Cryosols (BR.SC, BR.TC), Regosol (R), and Brunisol (B)
Soil Texture:	Variable – moderate to very coarse (LS)
Terrain Classification:	washed till and sandy/gravelly marine deposits occasionally weathered bedrock
Water Table:	may be present immediately after rain events and at beginning of growing season at interface with frozen soil
Common Modifiers:	x, y, f, m, s

Vegetation Characteristics

This ecosystem unit is distinguished by high cover of Arctic avens, a ubiquitous pioneer species that flourishes in dry, gravelly calcareous soils where it roots very deeply. Dwarf shrubs, primarily alpine bilberry (*Vaccinium uliginosum* var. *alpinum*), Arctic willow and net-veined willow (*Salix reticulata*), are usually present at low cover. Curly sedge is nearly always present and often relatively abundant. This community contains a diverse assemblage of herbaceous species, each typically present at low cover. The high diversity is attributable to the moderate availability of nutrients, lack of competition from shrubs (limited by low moisture and wind abrasion), and microsite variation associated with variable conditions on rock outcrops, where the DH unit is most often found. Liquorice-root (*Hedysarum alpinum*), Maydell's oxytrope (*Oxytropis maydelliana*), arctic heather (*Cassiope tetragona*) and Lapland rosebay (*Rhododendron lapponicum*) are typically present in amounts of < 5%. Less frequently occurring species include arctic oxytrope (*Oxytropis arctica*), woolly and capitate louseworts (*Pedicularis lanata*, *P. capitata*), and single-spike sedge (*Carex scirpodea*). Mosses usually occur in trace amounts within frost cracks. Crustose and foliose (*Cetraria* sp.) lichens are typically present and often relatively abundant.

Vegetation Characteristics – Typic Dryas Herb Mat (DH)	
Layer (%)	**Species (%)**
Shrubs (2-20)	*Vaccinium uliginosum* var. *alpinum* (0-15) *Salix arctica, S. arctophila* and *S. reticulata*
Herbs (60-90)	*Dryas integrifolia* (45-70) *Carex rupestris* (<30) Hedysarum alpinum
Moss (0-5)	Dicranum elongatum
Lichens (5-25)	crustose and foliose lichens

The DH unit is widespread and several recurrent modifiers have been applied in association with atypic conditions; the more common ones include (x-drier, y-wetter), finer soil textures (f-fine), steeper slopes (z-steep) and mounding (m-mounded). Drier (x) and steeper (z) types typically sustain lower cover of arctic avens and higher cover of curly sedge. Wetter types (y) also have lower arctic avens cover and typically have increasing amounts of mosses, *Carex* sedges, and other generally uncommon herbaceous species such as the northern bog orchid (*Habenaria obtusata*), which was found only near the coast. Plant species characteristic of DH communities also occur on fine-textured soils (f) where crumbly, granular surface layers on raised mounds (m) provide suitable rooting conditions for arctic avens and other species generally associated with coarse-textured soils.

Plant species characteristic of the DH ecosystem commonly persist downslope and result in significant transitional occurrences. Communities with characteristics intermediate between DH and Dwarf Shrub–Heath (SH) ecosystems are common on rock outcrops but typically small in area.

Betula-Ledum-Lichen (BL)
(PLATE 3)

Environmental Conditions

This unit occurs almost exclusively on level-to-gentle hillslopes overlain by washed till of variable thickness. It rarely occurs on glaciofluvial outwash and sandy marine sediments. It is most prevalent in the southern half of the study area where washed till is most common. In the vicinity of Spyder Lake, where till terrain occurs as gentle undulating plains, this unit is quite uniform and expansive. Along the Koignuk River corridor, just North of Spyder Lake, till overlies rock and forms discreet complexes of till, bedrock and marine sediments. In these situations the BL unit is generally less expansive, is complexed with DH, CL, and the Dwarf Shrub-Heath (SH) units and occasionally occurs on slopes up to eighteen percent. Soil textures are sands and loamy sands. Coarse fragments range from 0 to 65 percent and are predominantly gravels and cobbles. Relative soil moisture regime is subxeric (2) to submesic (3), occasionally mesic (4) and rarely xeric (1). Relative soil nutrient regime is poor (B) to very poor (A). Soils are Brunisols (B), Regosols (R) and Brunisolic Static Cryosols (BR.SC) depending on the depth to permafrost and degree of soil development. Occasionally, the unit occurs on Regosolic Static Cryosols (R.SC).

Environmental Characteristics – Typic Betula-Ledum-Lichen (BL)	
SMR:	(1-) 2 - 3 (- 4)
SNR:	B - A
Percent Slope:	0 to 7 (- 18)
Soil Classif.:	Brunisol (B), Regosol (R), Brunisolic Static Cryosol BR.SC; rarely Regosolic Static Cryosol (R.SC)
Soil Texture:	S and LS
Terrain Classification:	almost exclusively glacial till; rarely glaciofluvial or marine deposits
Water Table:	may or may not be present; present at active layer interface; may be present for two or three days following precipitation; may be present at the beginning of growing season
Common Modifiers:	b

Vegetation Characteristics

Coarse, well-drained and nutrient-deficient soils limit the diversity and abundance of herbs and mosses, which results in low total ground cover (range: 90-100% including shrubs, herbs, mosses and lichens), relative to more productive ecosystems. Shallow frost wedges, exposed rock (<5%) and mineral soil (<2%) are typically present and provide low to moderate variation in microtopography. Dwarf birch and northern Labrador tea (*Ledum decumbens*) are typically the dominant shrubs. Alpine bilberry and lingonberry (*Vaccinium Vitis-idaea* var. *minus*) are typically present and occasionally abundant. Alpine bearberry (*Arctostaphylos alpina*) and crowberry (*Empetrum nigrum*) are usually present at low cover. Arctic heather, Maydell's oxytrope and alpine sweet-grass are typically present in trace amounts.

Vegetation Characteristics – Typic Betula-Ledum-Lichen (BL)	
Layer (%)	**Species (%)**
Shrubs (50-75)	*Betula glandulosa* (10-30) *Ledum decumbens* (10-30) *Vaccinium uliginosum* var. *alpinum* (2-25) *Vaccinium Vitis-idaea* var. *minus* (2-10) *Empetrum nigrum* *Arctostaphylos alpina*
Herbs (1-10)	*Cassiope tetragona* *Oxytropis maydelliana* *Hierochloe alpina*
Mosses (0-20)	*Dicranum elongatum* *Dicranum groenlandicum* *Aulacomnium turgidum*
Lichens (10-40)	crustose, foliose and fructicose lichens

Occurrences of the Betula-Ledum-Lichen (BL) ecosystem unit that are modified by high boulder cover (BLb) are frequent in the north and south ends of the study area. Based on initial field data this bouldery condition was believed to represent a distinct unit; however the analysis did not support such a distinction, as vegetation and environmental conditions overlap significantly with the typic BL unit. High boulder cover is generally found where an energetic marine environment has washed away the finer soil matrix leaving behind coarse fragments. This condition is typically found on slopes and crests of rock outcrops and occasionally on glaciofluvial deposits (i.e. eskers and outwash). The unit is characterized by less northern Labrador tea (0-15%) and, generally higher cover of lichens, crowberry and alpine bearberry than the typic BL unit. The distinction between BL and BLb units by aerial phototyping is unreliable, as species assemblages are very similar. Known occurrences (from plot data) of the BLb and BL units are labeled as such on the ecosystem maps; however all BL units not tied to plots represent the potential range of plant species assemblages encompassed by both the typic (BL) and modified (BLb) units.

The transition to downslope communities is often gradual and results in significant transitional communities. Transitions to the Betula-Moss (BM) unit occur at lower slope positions in relation to decreasing coarse fragment content and increasing sand fraction. The greater occurrence of dwarf birch and mosses distinguishes the BM from the BL community.

Dwarf Shrub-Heath (SH)
(PLATE 4)

Environmental Conditions

The Dwarf Shrub Heath unit occurs on moderate to moderately steep slopes of rock outcrop terrain overlain by glacial till as well as on gentle to moderate slopes at the base of rock outcrops. On slopes greater than approximately ten-percent solifluction is evident, as are strongly cryoturbated soils. Where permafrost lies within two meters of the surface soils are typically Brunisolic Turbic Cryosols (BR.TC), otherwise Regosols predominate. Soil textures range from moderately fine to coarse (silty loam to sand). Coarse fragment content is variable depending on the origin of material and may include colluvial fragments from exposed outcrops above. Relative soil nutrient regime is moderate to poor and relative moisture regime is mesic (4) to submesic (3).

Environmental Characteristics – Typic Dwarf Shrub-Heath (SH)	
SMR:	4 – 3
SNR:	C – B
Percent Slope:	commonly 10 to 40 (rarely < 10 and 40 - 60)
Soil Classif.:	commonly Brunisolic Turbic Cryosol (BR.TC); occasionally Brunisolic Static Cryosol (BR.SC), Regosol (R) and Brunisol (B);
Soil Texture:	variable SiL – S; most commonly SL
Terrain Classification:	predominantly glacial till; rarely marine deposits
Water Table:	may or may not be present
Common Modifiers	m

Vegetation Characteristics

This typic community is characterized by the prevalence of arctic heather and moderate to high variation in microtopography as a result of the influence of rock outcrops and boulders. A relatively diverse assemblage of herbs, mosses and lichens results from the microsite variation associated with the uneven distribution of coarse substrates, "stepped" or uneven slopes, soil mixing, presence of rock crevices and variation in moisture availability. Predictable differences in plant species assemblages occur in relation to aspect. West-facing slopes are typically drier and sustain higher cover of alpine bilberry and arctic avens. East-facing aspects are often late snow-lie areas, which sustain high cover of arctic heather and mosses. Some of the more rarely observed species within the project area were found in this community, including: northern anemone (*Anemone parviflora*), heart-leaved saxifrage (*Saxifraga punctata* ssp. *Porsiliana*), alpine saxifrage (*S. nivalis*) and fir clubmoss (*Lycopodium selago*).

Vegetation Characteristics – Typic Dwarf Shrub-Heath (SH)	
Layer (%)	**Species (%)**
Shrubs (10-60)	*Betula glandulosa* *Vaccinium uliginosum* var. *alpinum* *Salix species* *Ledum decumbens* *Arctostaphylos rubra*
Herbs (60-90)	*Cassiope tetragona* (20-50) *Dryas integrifolia* (0-25)
Moss (7-30)	*Dicranum groenlandicum* *Aulacomnium turgidum*
Lichen (1-10)	crustose, foliose and fruticose lichens

The occurrence of frost mounds (m-mounding) is common in the transitional zones to downslope ecosystem units where soil textures are at the finer end of the range considered typical for this unit. Herb and grass species associated with drier conditions are common on the raised mounds.

The boundaries with upslope and adjacent ecosystem units (i.e. DH) are generally distinct, while the transition to downslope units (i.e. Tussock Meadow) is often broad due to gradually changing soil properties.

4.4.2 Ecosystem Units Associated with Lacustrine, Fluvial and Fine Marine Substrates

Betula-Moss (BM)
(PLATES 5 & 6)

Environmental Conditions
The Betula-Moss unit occurs on level to slightly sloped (1-4%) sandy lacustrine and fluvial sediments. Typically these deposits have been laid down at different stages of thaw lake cycles but they also occur as stream and river terraces. Numerous typical examples are found adjacent to thaw lakes, the Koignuk River and its tributaries. Although soil textures are moderate to coarse (SL to S), relative soil moisture regime is typically mesic due to a) the level topography, b) level-plain or toe-of-slope landscape position and c) presence of a relatively shallow permafrost boundary (typically 25 to 60 cm from the surface). Soils are typically Brunisolic Static Cryosols (rarely Gleysolic) and occasionally Brunisolic Turbic Cryosols.

Environmental Characteristics – Typic Betula-Moss (BM)	
SMR:	(3 -) 4 (- 5)
SNR:	C – B
Percent Slope:	0 – 4
Soil Classif.:	Brunisolic Static Cryosols (BR.SC), occasionally Brunisolic Turbic Cryosols (BR.TC), rarely Gleysolic Static Cryosols (GL.SC)
Soil Texture:	moderate to coarse (SL, LS, S)
Terrain Classification:	fluvial and lacustrine
Water Table:	Usually present (depth dependent on depth to permafrost)
Common Modifiers	m, y

Vegetation Characteristics
High cover of dwarf birch and mosses are the main distinguishing features of the Betula-Moss ecosystem unit. In general, and relative to other communities, plant species diversity is low in the BM community. Dwarf birch thrives in the moist, sandy and somewhat nutrient-deficient soils that are typical of this ecosystem unit. Willows, particularly *S. pulchra*, are commonly present in minor amounts, generally along frost cracks where the moisture regime is wetter due to the accumulation of organic materials. Moss cover increases and dwarf birch cover decreases with increasing size and influence of frost cracks. Herbs are typically present in minor quantities.

Vegetation Characteristics – Typic Betula-Moss (BM)	
Layer (%)	**Species (%)**
Shrubs (50-85)	*Betula glandulosa* (40-70) *Salix lanata* ssp. *Richardsonii* and *S. pulchra* *Vaccinium uliginosum* var. *alpinum* and *V. Vitis-idaea* var. *minus*
Herbs (<10)	*Arctagrostis latifolia*
Moss (20-90)	*Aulacomnium turgidum* (5-50) *Dicranum groenlandicum* (0-30)
Lichen (1-20)	crustose, foliose and fruticose lichens

The transition to adjacent ecosystem units (e.g. Tussock Meadow) is typically abrupt, although strong mounding will allow the BM community to persist. The BM ecosystem is maintained, but becomes stagnant through the development of strongly mounded palsas.

Eriophorum Tussock Meadow (TM)
(PLATE 7)

Environmental Conditions:
The TM ecosystem unit is the most widespread unit within the study area. It occurs on marine silts and clays in a variety of landscape positions where seepage or active-layer meltwater inputs are nearly balanced by outputs through lateral drainage. Relative soil moisture regime, therefore, is typically subygric (5) to mesic (4). Relative soil nutrient regime is; typically moderate (C), commonly poor to moderate (B-C) where birch and Labrador tea are the dominant shrubs, and slightly richer (C-D) where prostrate willow spp. are the dominant shrubs. Slopes are generally less than five percent but occasionally reach ten percent. Soils are of the Cryosolic order; most commonly Gleysolic Static Cryosol (GL.SC) but others include Brunisolic and Regosolic Static Cryosols (BR.SC and R.SC respectively), as well as Gleysolic, Brunisolic and Regosilic Turbic Cryosols (GL.TC, BR.TC and R.TC). The Turbic Cryosol great group is predominantly found within ecosystem units modified by mounding.

Environmental Characteristics – Typic Eriophorum Tussock Meadow (TM)	
SMR:	4 - 5 (- 6)
SNR:	(B) C - D
Percent Slope:	0 to 5 (- 10)
Soil Classif.:	Gleysolic Static Cryosol (GL.SC); less commonly Brunisolic and Regosolic Static Cryosols (BR.SC, R.SC), and Gleysolic Brunisolic and Regosolic Turbic Cryosols (GL.TC, BR.TC, R.TC)
Soil Texture:	fine (predominantly SiCL; occasionally SiL) occasionally medium to coarse (CL, fSL, L, and SC)
Terrain Classification:	almost exclusively marine occasionally fluvial, lacustrine or organic veneers overlying marine
Water Table:	May or may not be present; present at the beginning of growing season while snow is melting and permafrost interface is nearest the surface, and for short periods of time following precipitation.
Common Modifiers:	z, x, y, m, p, s

Vegetation Characteristics

High cover of the tussock-forming sheathed cotton-grass (*Eriophorum vaginatum*) distinguishes this community from all others. It has been reported (Mark et al. 1985) that minimum ages of mature *E. vaginatum* tussocks ranged from 122 to 187 years across several sites in Alaska. Where the average heights and diameters of mature tussocks in the Alaskan study are comparable to those in this study area, it is likely that these are mature communities. The tussock-forming habit of *E. vaginatum* provides elevated microsites suitable for some plant species that are characteristically found in dry communities (i.e. arctic avens and alpine bilberry). In addition to tussocks, low to moderate degrees of mounding are typically present; mound size ranges between 0.5-1.2 m in diameter and 0.15-0.3 m in height. Mosses (several species) comprise the dominant cover in the mesic inter-tussock troughs, and tall cotton-grass (*Eriophorum angustifolium*) is often dominant over mosses in the deeper, wetter troughs. The accumulation of organics in the troughs, and the dense blocky soils comprising the mounds create microsite variation that promotes diversity in plant species. Woolly willow (*Salix lanata* ssp. *richardsonii*) and *Salix pulchra* are characteristically present and typically relatively tall (~0.75 m).

Vegetation Characteristics – Typic Eriophorum Tussock Meadow (TM)	
Layer (%)	**Species (%)**
Shrubs (25-50)	*Salix lanata* ssp. *Richardsonii* and *S. pulchr*a (10-30) *Betula glandulosa* (<30) *Ledum decumbens* (<10) *Vaccinium uliginosum* var. *alpinum* and *V. Vitis-idaea* var. *minus* (2-8)
Herbs (40-75)	*Eriophorum vaginatum* (35-65) *Eriophorum angustifolium* (0-10)
Moss (5-25)	*Dicranum groenlandicum* *Aulacomnium palustre and A. turgidum* *Tomenthypnum nitens* *Hylocomium splendens*
Lichen (trace)	foliose and fruticose lichens

Three preliminary field groups dominated by *Eriophorum vaginatum* were recognized in the field. Two have been amalgamated to form the typic Tussock Meadow Ecosystem Unit while the third group has been classified as a modified type (TMp) on the basis of its poorer nutrient regime. Distinguishing between the typic and modified types by aerial photo interpretation was not possible and consequently all have been labeled as typic TM. Relative to the typic unit, nutrient poor (SNR: B) sites sustain low willow cover (<10%), high northern Labrador tea cover (10-25%), and higher dwarf birch and *Sphagnum* moss (up to 25%). The occurrences of TMp in relation to landscape position is uncertain; however it seemed to be encountered most often (but not predictably) adjacent to diabase dykes and on rock outcrop saddles overlain by marine silts and clays.

Plant species indicative of wet conditions such as giant water moss (*Calliergon giganticum*), sweet coltsfoot (*Petasites frigidus*) and marsh marigold (*Caltha palustris*) are sustained in trace quantities where shallow standing water is maintained throughout most of the growing season in the deepest troughs in wetter sites (‘y’ for wetter). Occasionally, wetter tussock meadow communities (TMy) are characterized by high cover of sheathed cotton-grass and tall cottongrass or *Carex* sedges with very low shrub and moss cover.

A common modifier applied to the TM unit describes strong mounding (m). Although very common in fine-textured marine soils, mounds also occur in coarse soils and consequently the edaphic conditions that promote frost mounding are not clearly understood. Within the study area, it appears that frost mounds are most common on crests and gentle valley slopes near rock outcrops. In the latter situation it may be that differential heaving of the soil column is promoted by locally variable moisture conditions, which arise from different seepage and runoff regimes from the outcrops. Mounded communities typically sustain greater proportions of species indicative of drier communities such as alpine bilberry, Arctic avens and Maydell’s oxytrope.

Other common modifiers applied to the TM community include ‘x’ for drier soil moisture regime, ‘z’ for steeper slopes, and ‘s’ for shallow soils. These types commonly occur along with strong mounding but are also related to slope concavity, crest landscape positions and thin marine mantles over till or bedrock.

Upslope transitions are usually gradual and are marked by a sharp decrease in the proportion of sheathed cotton-grass. Typical upslope transitions include DH or SH units. Downslope transitions, typically to WM ecosystems, are generally more abrupt and are marked by a sharp decrease in shrub cover.

Dry Willow (DW)
(PLATE 8)

Environmental Conditions

The DW unit occurs on gentle to steeply-sloped river banks and lakeshores that have been affected by significant post-marine washing. The unit is most common within the study area along the mid-portion of the Koignuk River and its major tributary. Along these watercourses it typically occurs where the rivers have downcut and made the soils prone to thaw flow-slides. Although uncommon (at least within the study area) the unit also occurs along some lakeshores where historical lake levels wave-washed the shorelines and induced sheet erosion. It occurs on fine (SiL to SiCL) marine sediments from upper slope breaks to mid-slope positions. This unit grades at lower slope positions into the Riparian Willow unit. Relative soil moisture regime is predominantly mesic (4), occasionally submesic (3) at upper slope positions and occasionally subhygric (5)at mid slope positions. Permafrost depth ranges from 35 to 55 cm. Relative soil nutrient regime is moderate (C) to poor (B). Soils are generally Brunisolic Turbic or Static Cryosols.

Environmental Characteristics – Typic Dry Willow (DW)	
SMR:	4 (range: 3 - 5)
SNR:	C - B
Percent Slope:	variable (5 – 55)
Soil Classification:	Brunisolic Static and Turbic Cryosols (BR.SC, BR.TC)
Soil Texture:	fine (typically SiL to SiCL)
Terrain Classification:	marine
Water Table:	amy or may not be present
Common Modifiers:	j, m, y

Vegetation Characteristics

The high cover of gray-leaved willow (*Salix glauca*) distinguishes this community from all others. The microtopography is usually slightly mounded as a result of freeze-thaw processes. As mounds form, subsurface horizons are compacted and roots are only able to penetrate surface horizons. The result is a thick, crumbly layer (a poorly developed B horizon) on the surface of the mounds, which provides a suitable microsite for dwarf birch, which typically thrives on sandy coarse-textured soils. Large-flowered wintergreen (*Pyrola grandiflora*) is typically present where leaf litter accumulates beneath the canopy of gray-leaved willow. Trace amounts of alpine arnica (*Arnica alpina* ssp. *angustifolia*), alpine milk-vetch (*Astragalus alpinus*) and Maydell's oxytrope are also common.

Vegetation Characteristics – Typic Dry Willow (DW)	
Layer (%)	**Species (%)**
Shrubs (80-95)	*Salix glauca* (50-80) *Betula glandulosa* (0-15) *Salix lanata* ssp. *Richardsonii* and *S. pulchra*
Herbs (3-15)	*Pyrola grandiflora* *Arnica alpina* ssp. *angustifolia*
Moss (0-5)	*Hypnum plicatulum* *Dicranum groenlandicum* *Aulacomnium turgidum*
Lichen (0-2)	crustose, foliose and fructicose lichens

A commonly occurring modified DW community occurs on strongly mounded (m), shallowly-sloped (j-shallow slope) sites. Distinctive features of DWjm communities include: 1) higher cover (up to 45%) of dwarf birch, 2) greater proportion of exposed mineral soils, and 3) wider range of moisture conditions.

Riparian Willow (RW)
(PLATES 8, 9 &10)

Environmental Conditions

The RW unit occurs in landscape positions that are strongly influenced by a seasonally fluctuating water table such as active floodplains along rivers and streams, and within the eulittoral zone of lakes and ponds. It also occurs where significant seepage inputs occur (seepage tracks and toe-of-slope positions). Along streams, rivers, lakes and ponds, soils typically have sandy and/or silty textures (reflecting their fluvial or lacustrine origin) while in seepage tracks, soils may have any genesis. Relative soil moisture regime is typically subhygric (5) to hygric (6) and occasionally wetter in low-gradient seepage tracks. Relative soil nutrient regime is predominantly rich (D) due to the influx of nutrients by flowing water but can be moderate (C) where inputs are minimal.

Environmental Characteristics – Typic Riparian Willow (RW)	
SMR:	5 - 6 (-7)
SNR:	C – D
Percent Slope:	0 - 7 (occasionally higher to 20)
Soil Classification:	Gleysolic Static Cryosol (GL.SC); occasionally Brunisolic Static Cryosol (BR.SC), Gleysolic Turbic Cryosol (GL.TC), or Organic Cryosol (OC)
Soil Texture:	variable; fine to coarse (SiCL to S); occasionally fibric or humic
Terrain Classification:	generally fluvial veneer overlying marine; occasionally organic veneer overlying fluvial or marine occasionally organic plain
Water Table:	may or may not be present; always present in seepage tracks.
Common Modifiers	b,

Vegetation Characteristics

High willow (*Salix lanata* and *S. pulchra*) cover distinguishes this unit from all others. Variation in soil texture and nutrient availability associated with the mode of soil deposition (fluvial vs lacustrine) and seepage effects result in variation in understorey plant species assemblages. Although both willow species can be dominant and are often intermixed, *Salix pulchra* tends to be more abundant in fluvial communities. Seepage tracks tend to sustain an abundance of water sedge (*Carex aquatilis* var. *stans*) and tall cotton-grass and have high overall plant cover. Soils along larger streams and rivers support lower cover of water sedge and low to moderate cover of tall cotton-grass. The understorey along lakeshores is typically characterized by higher moss cover, low to moderate sedge (*Carex* and *Eriophorum*) cover, and coltsfoot (*Petasites frigidus*).

Vegetation Characteristics – Typic Riparian Willow (RW)	
Layer (%)	**Species (%)**
Shrubs (50-90)	*Salix lanata* and *S. pulchra* (50-90) *Betula glandulosa* (0-15)
Herbs (20-90)	*Carex* species (0-50) *Eriophorum angustifolium* (0-40)
Mosses (5-40)	*Aulacomnium turgidum* (0-15) *Sphagnum* species
Lichens (0)	

The combined action of ice, wind, waves and boulders along various lake shorelines and portions of the Koignuk River produces a modified RW community characterized by the prevalence of boulders. The plant community typically has lower shrub and herb covers and lower species diversity where channels are kept unvegetated or sparsely-vegetated by scouring. This modified unit has been designated as RWb on accompanying maps.

Low Bench Floodplain (FP)
(PLATES 9 & 10)

Environmental Conditions
The FP unit is found on the active floodplains of rivers and streams as well as at outlets of lakes under hydrologic conditions that favor significant flushing of decaying plant matter during spring floods. It is most prevalent on the Koignuk River, particularly in reaches upstream of main channel constrictions, where slower flows deposit a significant bedload of fluvial sediments and produce shallowly-sloped shorelines. Soils are typically composed of layered organic and mineral deposits or pure layered mineral deposits reflecting annual inundation regimes. Soil textures range from silt loam (SiL) to pure sand (S) depending on the prevailing hydrologic regime. Relative soil nutrient regime is moderate (C) to rich (D) depending on the amount of organic input from decaying plant matter and waterfowl inputs. Relative moisture regime is subhydric (7) to hygric (6). Soil development (typically Gleysolic Static Cryosols) reflects the duration of seasonal inundation and /or the presence of a near surface fluctuating water table..

Environmental Characteristics – Typic Low Bench Floodplain	
SMR:	7 (- 6)
SNR:	C – D
Percent Slope:	0 to 2
Soil Classification:	Gleysolic Static Cryosol (GL.SC)
Soil Texture:	bedded sands and silts (occasionally clays) overlying clay loams
Terrain Classification:	active fluvial veneer overlying marine
Water Table:	present at or near the surface; annual or periodic inundation
Common Modifiers:	b

Vegetation Characteristics
Prolonged flooding and seasonal deposition of fine sediments precludes the occurrence of many plant species and limits annual production within this community, which typically sustains diminutive plant species with low overall plant cover (~80%). High cover of goose-grass (*Dupontia Fischeri* ssp. *psilosantha*) and a lack of shrubs and lichens distinguish the Low Bench Floodplain (FP) community from all others. Mare's tail typically occurs in nearshore and shoreline areas where it usually occurs in association with yellow water crowfoot (*Ranunculus gmelini*) and trace quantities of marsh marigold, particularly in the transition to *goose-grass*, which is typically the dominant species in the upslope portion of the FP community. The contribution of nutrients from goose droppings is significant in FP communities along the Koignuk River as a result of extensive grazing of goose-grass by Canada geese.

Vegetation Characteristics – Typic Low Bench Floodplain (FP)	
Layer (%)	**Species (%)**
Shrubs (0)	
Herbs (50-85)	*Dupontia fischeri* ssp. *Psilosantha* (5-50) *Hippurus vulgaris* (5-30) *Ranunculus gmelini*
Mosses (15-50)	no dominant species
Lichens (0)	

Portions of the Spyder Lake and lower Koignuk River shorelines are characterized by fine-to-medium textured soils with significant boulder cover. These areas are typically sparsely-vegetated or possess highly variable or patchy herb mat and/or moss cover due to the combined scouring action of ice, boulders and waves. This scouring disturbance regime maintains such sites at disclimax states of succession. They are labeled on the ecosystem maps as Low Bench Floodplain ecosystem units modified by boulder cover with a structural stage of 1 (FPb 1 label on ecosystem maps).

<u>Wet Meadow (WM)</u>
(PLATES 11 & 12)

Two types of wet meadow communities are represented in the field data with respect to vegetation; one dominated by water sedge (*Carex aquatilis* var. *stans*) and the other by tall cotton-grass (*Eriophorum angustifolium*). Analysis did not support such a distinction since landscape position and environmental (edaphic) conditions often overlap. In addition, intermediate communities are common. As both communities are largely ecological equivalents, they were grouped to collectively represent the Wet Meadow ecosystem unit.

Environmental Conditions
The WM unit occurs on wet, level-to-gently sloped terrain with slopes typically below seven percent. Relative moisture regime is generally hygric to subhydric (6-7) however hydric (8) sites are not uncommon. Soils are predominantly Gleysolic Static Cryosols (GL.SC) but occasionally are Turbic (TC) or Organic (OC). Wet meadows occur on fine to coarse-textured deposits of variable origin (marine, lacustrine, fluvial or organic). Invariably however, a water table is present at or near the surface and where slopes exceed two percent, there is constant runoff from upslope. Typically, wet meadows are found in three types of landscape positions: toe-of-slope, level plain, and valley slopes. They occur at toe-of-slope and level plain positions where seepage and active layer-meltwater collect. On valley slope positions they occur where seepage inputs are significant (such as in depressional seepage tracks) or downslope of perched lakes and ponds. In general, the *Carex* phase is the slightly wetter of the two phases and is found where surface and sub-surface run-off is impeded to a greater degree than in situations where the *Eriophorum* phase is found. Relative nutrient regime is characteristically moderate (C) to rich (D) due to the influx of nutrients by seepage and meltwater. Generally, wet meadows occur on level to only slightly-sloped terrain (0 - 1.5%) but on occasion also occur on slopes up to seven percent

Environmental Characteristics – Typic Wet Meadow (WM)	
SMR:	6-7 (8)
SNR:	C-D (- E)
Percent Slope:	0 to 1.5 (<7)
Soil Classification:	Gleysolic Static Cryosol (GL.SC); occasionally Organic Cryosol (OC), Brunisolic Static Cryosol (BR.SC), or Turbic Cryosol
Soil Texture:	organic (fibric to humic), or fine to moderate (SiCL to SCL)
Terrain Classification:	marine deposits or organic veneer overlying variable (marine, lacustrine, or fluvial) deposits,
Water Table:	present throughout the growing season at or near the surface
Common Modifiers:	i, r, x

Vegetation Characteristics

The high cover of hydrophilic sedges and general lack of shrubs and lichens distinguishes this unit from all others. The prevalence of water sedge or less frequently yellow bog sedge (*Carex gynocrates*) characterize wet depressions in areas subject to prolonged flooding (i.e. margins of ponds and lakes). The latter species is typically associated with persistent shallow standing water and a contiguous algae mat. Tall cotton-grass becomes more prevalent with increasing slope angle, although it is also common in wet depressions in association with water sedge. A mixed *Carex* and *Eriophorum* association is prevalent in upper slope positions and slightly drier transitional areas. Extensive WM occurrences are often a mosaic of *Carex* and/or *Eriophorum*-dominated communities. A total of 15 species of *Carex* sedges were found within the WM sites sampled. Some of the more frequently occurring species include: *Carex membranacea*, *C. atrofusca*, *C. misandra*, *C. vaginata*, *C. capillaris*, *C. rariflora*. Occasional species include *C. physocarpa* and *C. bigelowii*. Uncommon occurrences include *C. microglochin*, *C. amblyorhyncha* and *C. holostoma*, the last species is a range extension. Sudetan lousewort (*Pedicularis sudetica*), an indicator of saturated organic soils, is typically present, although in trace amounts.

Vegetation Characteristics – Typic Wet Meadow	
Layer (%)	**Species (%)**
Shrubs (<5)	no dominant species
Herbs (80-99)	*Eriophorum angustifolium* (5-95) *Carex* species (5-90) *Carex aquatilis* var. *stans* (1-65) *Pedicularis sudetica*
Mosses (0-25)	*Drepanocladus revolvens* *Hypnum pratense*
Lichens (0-t)	no dominant species

Modified WM communities are frequently associated with drier (x-drier) soil conditions (SMR: 5-6) and are typically characterized by higher species richness and evenness of *Carex* sedges than the typic community. WM communities are also modified by the presence of ice wedges (i-ice wedges) or low, transverse ridges (r-ridges) of organic or mineral materials; however the typic species assemblage is little affected by either.

Transitional communities are often extensive and may extend into or occur on upper slope positions in association with DH or BL communities, particularly where runoff and seepage from upslope is concentrated or localized. Transitional communities in upslope areas are typically dominated by *Carex* spp. indicative of mesic conditions such as C. misandra, C. bigelowii. Transitional communities between WM and TM ecosystems are also common but small in area and feature species assemblages that are intermediate between them.

<u>Polygonal Ground</u>
<u>(PLATES 16, 17 & 18)</u>

Polygonal ground is typically characterized by disjunct communities that are a product of the spacially rapid and repeating variation in microtopography. The two common types of polygonal ground within the study area are the high-centre type in which a matrix of palsas are encircled by wet meadow depressions, and the low-centre type, in which a matrix of flat wet basins are delineated by linear ridges underlain by ice-wedges. The relatively dry soil conditions on palsas and along the crests of the ridges typically support plant species assemblages characteristic of BL or BM units (see PLATES 16, 17, and 18). As the ice lens in a palsa grows, relative soil moisture drops and plant productivity stagnates. This change is accompanied by a transition in vegetation from a wet meadow community through a BM communityunit to a BL community. Patterned ground in which palsa formations are distinct are labeled on the accompanying ecosystem maps as B*q. This label reflects the invariable presence of dwarf birch (B__), the variable assemblages of other species typically found in BM and/or BL units (_*_), and the presence of an underlying ice lens (__q) which modifies the palsa community from that of a typic BM or BL unit. Within the study area, palsas most commonly have relatively thin veneers of peat overlying frozen mineral soil horizons, indicating that the wet meadow basins within which they typically develop also have relatively thin organic accumulations.

<u>Emergent Marsh (EM)</u>
(PLATE 13)

Environmental Conditions
The EM unit is the wettest unit mapped. It occurs on level organic plains along lake margins or less commonly along unconfined low-gradient streams in microsites protected from erosional flows and ice and wave scour. The water table is above the surface the entire growing season (SMR 8) and relative soil nutrient regime is rich (D) to very rich (E) as a result of nutrient inputs associated with high plant productivity and relatively rapid organic decomposition in the warmer shallow waters.

Environmental Characteristics – Typic Emergent Marsh (EM)	
SMR:	8
SNR:	D – E
Percent Slope:	0
Soil Classif.:	Organic Cryosol (OC)
Soil Texture:	organic
Terrain Classification:	organic plain
Water Table:	present throughout the growing season at or above the soil surface
Common Modifiers:	none

Vegetation Characteristics

Occurrences of this ecosystem unit are rare within the study area and are generally too small to map. This is largely due to the limited occurrence of suitable conditions; primarily stable water table (5–30 cm. above the ground surface) throughout the growing season and organic sediments for rooting. In most areas the development of EM communities is prevented due to the combined scouring of rocks, ice and waves. The Emergent Marsh (EM) community typically occurs along or within Wet Meadow communities in low lying areas immediately adjacent to large ponds or lakes, or less frequently along flooded areas bordering low-gradient streams. The prevalence of aquatic and semi-aquatic plant species including marsh cinquefoil (*Potentilla palustris*), mare's tail (*Hippurus vulgaris*), marsh marigold (*Caltha palustris* var. *arctica*), Pallas's buttercup (*Ranunculus pallasii*), and giant water moss (*Calliergon giganticum*) distinguish the EM community from all others.

Vegetation Characteristics – Typic Emergent Marsh (EM)	
Layer (%)	**Species (%)**
Shrubs (0)	
Herbs (50-95)	*Carex aquatilis* var. *stans* (5-50) *Hippurus vulgaris* (0-25) *Caltha palustris* *Potentilla palustris*
Mosses (10-25)	*Calliergon giganticum* *Drepanocladus revolvens* *Hypnum pratense*
Lichens (0)	

4.4.3 Ecosystem Units Associated with the Ocean Shoreline

The Marine Intertidal and Backshore Units are generally found in association with unvegetated beach sands (BE label on maps). Due to the linear nature of all three units they are often too small to map separately and, even when combined, they frequently occur as inclusions within map polygons dominated by more expansive neighbouring upland units.

Marine Intertidal (MI)
(PLATE 14)

Environmental Conditions

Occurrences of this ecosytem unit are strictly limited to intertidal flats and shallowly sloped (0-2%) shorelines, which are uncommon in Roberts Bay. This unit occurs on veneers of marine sands overlying gleyed, structureless or weakly-structured marine clays. Frequent inundation with saltwater precludes the occurrence of most plant species. Buried organic materials (primarily marine algae and seaweed) are strongly oxidized and appear as black planes in the soil profile. Soils are typically gleysolic or regosolic reflecting the fluctuating water table and constant disruptive forces, which preclude even minor soil development.

Environmental Characteristics – Typic Marine Intertidal (MI)	
SMR:	7 (8)
SNR:	C (D)
Percent Slope:	0 to 2
Soil Classif.:	Gleysol or Regosol (generally lacking soil structure)
Soil Texture:	Structureless silty clay over massive marine clays and heavy clays
Terrain Classification:	marine (intertidal) blanket
Water Table:	frequently inundated and persistently saturated, at low tide the water table may occur at depths between of 20-30 cm.
Common Modifiers:	none

Vegetation Characteristics

Frequent inundation with saltwater precludes the occurrence of most plant species. This simple community is characterized by the prevalence of only two plant species, creeping alkaligrass (*Puccinelia phryganodes*) is dominant in the lower, most frequently inundated portion and Hoppner sedge (*Carex subspathacea*) extends to the strand line where Pacific silverweed (*Potentilla egedii*), scurvy-grass (*Cochlearia officinalis*) and *Carex amblyorhyncha* are typically found. Another salt-tolerant species, low chickweed (*Stellaria humifusa*) occurs in greatest abundance in association with Hoppner sedge but often extends into the alkaligrass-dominated portion.

Vegetation Characteristics – Typic Marine Intertidal (MI)	
Layer (%)	**Species (%)**
Shrubs (0)	
Herbs (50-90)	*Carex subspatheca* (15-70) *Puccinelia phyrganodes* (10-30)
Moss (0)	
Lichen (0)	

Marine Backshore (MB)
(PLATE 15)

Environmental Conditions

The Marine Backshore ecosytem unit occurs immediately upslope of the intertidal community on thick deposits of washed marine sands and is essentially equivalent to a sand dune. Where rocky headlands comprise much of the coastline, occurrences of the MB community are limited to protected or partially protected bays and inlets with shallowly-sloped shorelines. The unit is very dry and nutrient poor as a result of the coarse soil texture, lack of soil development and organic input, and limited vegetation cover.

Environmental Characteristics – Typic Marine Intertidal (MB)	
SMR:	1 (2)
SNR:	A
Percent Slope:	0-10 (variable where this community often resembles a sand dune)
Soil Classif.:	Regosol, Brunisol (weak)
Soil Texture:	S with weak structure
Terrain Classification:	Marine beach ridge
Water Table:	>1 m
Common Modifiers:	none

Vegetation Characteristics

The occurrence of seashore plant species such as lyme-grass (*Elymus arenarius* ssp. *mollis*), seabeach sandwort (*Honckenya peploides*) and seaside plantain (*Plantago juncoides* var. *glauca*) distinguish the MB community from all others. Up to 50% of the ground is typically unvegetated and plant cover is typically sparse, except around arctic ground squirrel burrows, which are common in this community. Low moisture and nutrients as well as the wind-blown sands preclude the establishment of most plant species. Northern sweet-vetch (*Hedysarum mackenzii*) is typically present in MB communities but was rarely observed inland. Scattered grasses and clumps of prickly saxifrage and arctic oxytrope are characteristically present.

Vegetation Characteristics – Typic Marine Backshore (MB)	
Layer (%)	**Species (%)**
Shrubs (t)	*Salix arctica*
Herbs (40-60)	*Elymus arenarius* ssp. *mollis (10-30)* *Oxytropis arctica (1-15)* *Hedysarum Mackenzii (1-10)* *Saxifraga tricuspidata*
Mosses (0-4)	
Lichens (0-10)	

5.0 CONCLUSIONS

The application of Terrestrial Ecosystem Mapping (TEM) protocols developed in British Columbia to the tundra landscape of the Hope Bay Belt proved to be effective in identifying and describing the ecosystem units and terrain of the study area.

Thirteen unique ecosystem units were identified. Eriophorum Tussock Meadow (TM), the dominant unit, along with six others (Betula-Moss, Riparian Willow, Dry-Willow, Low Bench Floodplain, Wet Meadow, and Emergent Marsh) are all ecosystems associated with moist to wet substrates overlying level to gently sloped terrain. Four ecosystem units (Dry Carex Lichen, Dryas Herb Mat, Betula-Ledum-Lichen, and Dwarf-Shrub Heath) found typically on drier soils, occur in close association with outcrops and coarse-to-medium textured substrates. The Dryas Herb Mat unit is the most common of these although this is largely due to the prevalence of calcium-rich soils. A third association, although very limited in extent is the ‘Ocean Shoreline Association which supports the Marine Intertidal and Marine Backshore ecosystem units, which usually occur in close association with unvegetated beach sands.

The application of ecosystem modifiers and the recognition of transitional community occurrences, further refine ecosystem classification and description to a level appropriate for developing prescriptions and identifying ecological values or environmental sensitivities.

6.0 REFERENCES

Agriculture Canada Expert Committee on Soil Survey. 1987. The Canadian System of Soil Classification. 2nd edition. Agric. Can. Publ. 1646. 164 pp.

Banner, A., D.V. Meidinger, E.C. Lea, R.E. Maxwell, and B.C. von Sacken. 1996. Ecosystem Mapping Methods for British Columbia. Environmental Monitoring and Assessment 39:97-117

Bird, J.B. 1967. The Physiography of Arctic Canada. The Johns Hopkins Press, Baltimore, Maryland.

Bird, J.B. and Bird, M.B. 1961. Bathurst Inlet, Northwest Territories. Geographical Branch, Mines and Technical Surveys, Ottawa, Memoir 7. 63 pp.

Bliss, L.C. (editor). 1977. Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem. University of Alberta Press. 714 pp.

Brayshaw, C. 1996. Catkin-bearing plants of British Columbia. Royal British Columbia Museum, Victoria, BC. 213 pp.

Britton, M.E. 1967. Vegetation of the Arctic Tundra. *In:* (ed. Hansen, H.P.) Arctic Biology. Oregon State University Press. 318 pp.

Demarchi, D.A. 1993. Ecoregions of British Columbia (Third Edition). 1:2,000,000 Map. B.C. Min. Environment Lands and Parks. Victoria, B.C.

Demarchi, D.A., E.C. Lea, M.A. Fenger, and A.P. Harcombe. 1990. Biophysical Habitat Mapping Methodology (unpublished draft). B.C. Min. Env., Lands and Parks, Wildlife Branch, Victoria, B.C.

Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. Report and national map at 1:7 500 00 scale.

French, H.M. 1976. The Periglacial Environment. Longman Inc., New York. 309 pp.

Gebert, J. 1995. TOK 1-4 Concessions Assessment Report (Section 3). Contract Report for the Nunavut Government.

Howes, D.E. and E. Kenk. 1988. Terrain Classification System for British Columbia (Version 1). Min. of Env. (Recr. Fish. Branch) and Min. of Crown Lands (Surveys and Res. Map. Branch). Victoria, B.C. 90 pp.

Howes, D.E. and E. Kenk. 1997. Terrain Classification System for British Columbia (Version 2). Min. of Env. (Recr. Fish. Branch) and Min. of Crown Lands (Surveys and Res. Map. Branch). Victoria, B.C. 102 pp.

Hulten, E. 1968. Flora of Alaska and Neighboring Territories. Stanford University Press. Stanford, California.

La Farge-England, C. 1996. Cryptogramic Herbarium, Department of Biological Sciences, University of Alberta, Edmonton, AB. T6G 2E9

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold (editors). 1990. Describing Ecosystems in the Field. Second edition. B.C. Min. Environ. MOE Man. 11. Victoria, B.C.

Mark, A.F., Ned Fetcher, G.R. Shaver and F.S. Chapin III. 1985. Estimated Ages of Mature Tussocks of *Eriophorum vaginatum* along a Latitudinal Gradient in Central Alaska, U.S.A. Arctic and Alpine Research 17(1):1-5.

Marshall, I.A. 1998, Feb. 02. Indicators and Assessment Office, Ecosystem Science Directorate. Environment Canada, Hull, Quebec.

Mitchell, W.R., R.N. Green, G.D. Hope, and K. Klinka. 1989. Methods for Biogeoclimatic Ecosystem Mapping. B.C. Min. For., Res. Rep. 89002-KL. Victoria, B.C.

Meidinger, D. and J. Pojar (compilers and editors). 1991. Ecosystems of British Columbia. Research Branch, B.C. Min. For. Special Report Series, no. 6. 330 pp.

Oikos Ecological Services Ltd. 1995. Ecosystem Mapping of a Tundra Landscape, Lac de Gras area, N.W.T. Contract Report to BHP Diamet Vancouver.

Porsild, A.E. and W.J. Cody. 1980. Vascular Plants of the Continental Northwest Territories, Canada. National Museum of Natural Sciences. Natural Museums of Canada, Ottawa, Canada.

Resources Inventory Committee. 1995. Standards for Terrestrial Ecosystems Mapping in British Columbia – Review Draft. Ecosystems Working Group, Resources Inventory Committee (RIC) Secretariat, Victoria, B.C. 222 pp.

Resources Inventory Committee. 1996a. Addenda to Terrestrial Ecosystems Mapping Standards - May 1996. Ecosystems Working Group, Resources Inventory Committee (RIC) Secretariat, Victoria, B.C. 85 pp.

Resources Inventory Committee. 1996b. Data Standards for Terrestrial Ecosystem Mapping in British Columbia. Ecological Data Committee/Ecosystems Working Group/Terrestrial Ecosystems Task Force, Resources Inventory Committee (RIC) Secretariat, Victoria, B.C. 30 pp.

Resources Inventory Committee. 1996c. Terrain Database Manual: Standards for Digital Terrain Data Capture in British Columbia. Terrain Data Working Committee/Surficial Geology Task Group/Earth Science Task Force, Resources Inventory Committee (RIC) Secretariat, Victoria, B.C. 93 pp.

Ryder, J.M. and Associates. 1992. Spyder Lake Area (Hope Bay Greenstone Belt): Terrain Analysis and Surficial Geology. Unpublished report prepared for University of British Columbia and B.H.P. Utah Mines, Ltd., Vancouver, B.C. 20 pp.

Schofield, W.B. 1992. Some common mosses of British Columbia, Royal British Columbia Museum, Victoria, B.C. 394 pp.

Sukachev, V. and N. Dylis. 1964. Fundamentals of forest biogeocoenology. Oliver and Boyd, London, England.

Tarnocai, C. and S.C. Zoltai. 1978. Earth Hummocks of the Canadian Arctic and Subarctic. Arctic and Alpine Research 10:581-594.

Tedrow, J.C.F. 1977. Soils of the Polar Landscapes. Rutgers University Press, New Brunswick, New Jersey.

Trelawny, J.G. 1988. Wildflowers of the Yukon, Alaska and northwestern Canada. Sono Nis Press., Victoria, BC. 214 pp.

Vitt, D.H., J.E. Marsh and R.B. Bovey. 1988. Mosses, lichens and ferns of northwest North America. Lone Pine Publishing, Edmonton, A.B. 296 pp.

Washburn, A.L. 1973. Periglacial Processes and Environments. St. Martin's Press, New York, N.Y. 320 pp.

Washburn, A.L. 1980. Geocryology: A Survey of Periglacial Processes and Environments. John Wiley & Sons, New York.

Zoltai, S.C. and C. Tarnocai. 1974. Soils and Vegetaion of Hummocky Terrain. Environmental-Social Committee, Task Force on Northern Oil Development, Government of Canada Report No. 74-5. 86 pp.

Appendix 2

2010 Ecosystem Mapping Field Survey Plot Card

Rescan™
Engineers and Scientists

Date:			**Plot #:**		**Project:**		
Surveyors:					**Photos:**		
UTM zone:		**Northing:**			**Easting:**		
SITE INFO:							
Slope:		**Aspect:**		**Elevation:**			
Slope Position:							
crest	upper	mid-slope	toe	level	depression		
Surficial Material:							
Terrain:				**Microtopography:**			
beach		alluv fan		hummocky		frost fiss.	
terrace		floodplain		frost boils		flat	
plateau		ridge crest		solifluct		br. outcrop	
valley bottom		cliff		circles		boulders	
slope		stream		bould strm		bould field	
delta		esker		polygon		shattered br.	
Mineral soil texture:				**Organic soil texture:**			
Sandy				Fibric			
Loamy				Mesic			
Silty				Humic			
Clayey							
Surface substrate (%) :							
bedrock (consolidated):				rock (> 0.75 cm):			
boulder (> 25 cm):				water:			
Permafrost? (Y/N)			**Permafrost depth:**				
Coarse Fragment Content							
<20%	20-35%	35-70%	>70%				
Soil Moisture Regime (0 = very xeric, 4 = mesic, 8 =hydric):							
Soil Nutrient Regime (A = very poor, C = medium, E = very rich):							
Notes / Site Diagram:							

VEGETATION							
% Cover by layer:							
Shrub:		**Herb:**			**Moss/Lichen:**		
Shrubs:	%	**Forbs**	%	**Forbs**	%	**Grasses**	%
ANDRPOL		ACHILLE		SAXICER		ARCTLAT	
ARCTALP		ANEMPAR		SAXIFOL		CALAMAG	
ARCTRUB		ANEMRIC		SAXIHIR		Dupontia	
BETUNAN		Antennaria		SAXINEL		Festuca	
CASSTET		Arabis sp.		SAXINIV		HIERALP	
DRYAINT		armemari		SAXIOPP		Poa	
EMPENIG		ARNIANG		SAXIRIV		Trisetum	
LEDUPAL		Artemisia		SAXITRI		CINNLAT	
RHODLAP		Aster		SILEACA			
SALIARC		Astragalus		TARAOFF			
SALIGLA		CERAALP		TEPHATR			
SALIPLA		CHRYTET		TOFICOC			
SALIRET		COCHGRO		TOFIPUS			
SALIRIC		COMAPAU				**Lichens:**	**%**
VACCULI		DRABALP				ALECTORIA	
VACCVIT		DRABGLA				ALECNIG	
		EPILANG				ALECOCH	
		Erigeron				CETRNIV	
		ERYSPAL		**Sedges:**	%	CETRCUC	
		HIPPVUL		CAREAQU		CLADINA	
		LUPIARC		CAREATR		CLADONIA	
		MERTMAR		CAREBIG		OPHILAP	
Fern/horsetail/clubmoss:	%	MINURUB		CARECAP		THAMVER	
		ORTHSEC		CAREMEM		XANTELE	
CYSTFRA		OXYRDIG		CARENAR		map	
DRYOFRA		OXYTARC		CARERUP		rock tripe	
EQUIARV		OXYTMAY		CARESCI		blk crustose	
HUPESEL		PAPARAD		ERIOANG			
LYCOANN		PEDIARC		ERIOSCH			
		PEDICAP		ERIOVAG			
		PEDILAB					
		PEDILAN					
		PEDILAP				**Mosses**	**%**
		PEDISUD				AULAPAL	
		PETAFRI				DICRELO	
		PETASAG		**Rushes**	%	HYLOSPL	
		POLYVIV		Juncus		RACOLAN	
		POTENIV		LUZUCON		SPHAGNU	
		PYROGRA		LUZUWAH		TOMENIT	
		RANUGME					
		RANUNIV					
		RANUPAL					
		RUBUCHA					

Appendix 3

2010 Wetland Habitat Information Form

Engineers and Scientists

WETLANDS:

Rescan Wetlands Ecosystem Survey Methodology

Table of Contents

List of Figures

List of Tables

List of Plates

1. Introduction

Wetlands are dynamic, low-lying or slightly sloping areas on the landscape that are saturated with water for a significant period of time during the growing season. Wetlands can range from sites that contain small, shallow areas of water that are present for only a few weeks after snow melt, to sites that comprise large, permanent open water zones (Stewart and Kantrud 1971) and peatland ecosystems. Wetland ecosystems fulfill a wide range of ecological, hydrological, biochemical and habitat functions (Environment Canada 2003; Environment Canada 2008). They maintain water quality, regulate water flow on the landscape and provide erosion control. They also provide habitat for a wide variety of wildlife, including many economically important game species (Natural Resources Canada 2009).

Wetlands are included in environmental baseline studies for a variety of large infrastructure and resource projects because guidance documents for environmental assessments in Canada and a number of provinces have identified wetlands as an ecosystem of special importance. Wetlands, in Canada, are managed and conserved through the Federal Policy of Wetland Conservation which states that there shall be "no net loss of wetland functions on all federal lands and waters". The Policy also states that the functions and values derived from wetlands will be maintained and wetlands will be enhanced and rehabilitated in areas of continuing loss and degradation (Environment Canada 1991). Generally wetland studies are planned to meet the requirements of the federal policy, however, exceptions are often made as this is a policy that is largely not applicable to non-federal projects.

Wetland studies are developed in consultation with hydrologists, aquatic biologists, and ecosystem mapping/wildlife scientists with the goal of identifying and, where possible quantifying wetland function. Wetland function is defined as the process or series of processes a wetland carries out such as its ability to regulate the local climate, filter surface water, recharge groundwater reserves, increase an areas ecosystem integrity, and provide wildlife habitat. Environment Canada (2003) has identified four primary functions which are typically the focus of wetland studies and consideration of wetland function is integral to wetland inventory methodology (Cox and Cullington 2009). Table 1 describes the primary functions and identifies which aspect of the wetland study data is collected to address a given function.

The following text presents the methodology for completing the ecosystem survey component of wetland studies. This is the largest aspect of wetland studies and provides valuable information for use in identifying, describing, and quantifying wetland function. This information also supports identification of wetland classes and associations, levels of permanence, and forms/subforms. It can be tailored to specific regions to meet specific delineation requirements or regional classification frameworks. The methodology presented below represents a general over and provides a solid base for incorporating regional specific data. This document describes the wetland classes of Canada (Warner and Rubec 1997), pre-fieldwork planning and equipment, vegetation/soil/water wetland data collection requirements, general study methodologies, and the wetland habitat information form (WHIF)

Table 1 Wetland Functions and Supporting Data

Wetland Function	Description	Supporting Data
Hydrological	Contribution of the wetland to the quantity of surface water and groundwater	Hydrology survey – Static and continuous data Ecosystem survey – Hydrodynamic indicators
Biogeochemical	Contribution of the wetland to the quality of surface water and groundwater	Ecosystem survey – Wetland classification, Aquatic biology survey – sediment and water chemistry Vegetation sampling – Tissue metal concentrations
Habitat	Relative abundance of terrestrial and aquatic habitat and connectivity to surrounding ecosystem	Ecosystem survey – Wetland classification Ecosystem survey – Wildlife observations
Ecological	Role of the wetland in the surrounding ecosystem	Ecosystem survey – Wetland classification Wetland classification – Red and blue listed ecosystems Wetland classification – Wetland complexes

2. Wetlands in Canada

Wetlands in Canada are classified according to the Canadian System of Wetland Classification (CSWC). All wetland baseline studies, environmental assessments, and surveys done on projects in Canada use the "Class" Description of wetlands presented in the CSWC. There are 5 classes (bog, fen, marsh, swamp, shallow open water). A description of each class, basic classification tools, and a representative site photo are provided below.

2.1 BOG CLASS

Description A bog is a nutrient-poor, *Sphagnum*-dominated peatland ecosystem in which the rooting zone is isolated from mineral-enriched groundwater, soils are acidic, and few minerotrophic plant species occur (MacKenzie and Moran, 2004).

Key Features Most bogs are treed; however, some can look similar to fens (open meadow like). The soil is less decomposed then fens and the pH is quite low (bogs have the lowest pH of any wetland). Trees are always conifers and there is always sphagnum moss.

pH < 5.5, Water movement is stagnant to sluggish, soil colour is often reddish brown and the soil is usually pretty spongy with visible bits of poorly decomposed sphagnum moss.

Photo

Plate 2.1-1 Treeless Bog – Northwest British Columbia

Plate 2.1-2 Treed Bog/Shallow Open Water Complex Northwest Territories

2.2 FEN CLASS

Description A fen is a nutrient-medium peatland ecosystem dominated by sedges and brown mosses, where mineral-bearing groundwater is within the rooting zone and minerotrophic plant species are common (MacKenzie and Moran, 2004).

Key Features Generally these are open "meadow like" ecosystem. There are not usually treed but occasionally trees can be present usually covering < 10% of an area (20 m by 20 m); at higher elevations dwarf tree species may be present in small clusters and are < 5 m tall. The dominant plants are sedges, mosses, and cotton grasses.

pH ~ 5.5 – 7.5, Water movement is stagnant to sluggish, soil colour is often reddish brown with visible bits of poorly decomposed moss and sedge.

Photo

Plate 2.2-1 Fen Complex Northwest British Columbia

Plate 2.2-2 Patterned Fen Northwest British Columbia

2.3 MARSH CLASS

Description: A marsh is a permanent or seasonally flooded non-tidal mineral wetland, dominated by emergent grass-like vegetation. Marshes may experience drawdown, which will result in portions drying up. They can typically recover from mechanical disturbance, provided their hydrology is maintained (MacKenzie and Moran, 2004).

Key Features Marshes are sedge dominated (though cattail and bulrush wetlands are also marshes) sites associated with open water. The ground is almost always covered by standing water. Soils are usually mineral and mucky; they have lots of nutrients so soils are dark. These sites never have trees and only occasionally have dwarf shrubs < 5% in a 20 m by 20 m area.

pH ~ > 7.0, Water movement is mobile to very dynamic,

Photo

Plate 2.3-1 Bulrush marsh/Shallow Open Water Complex Southern Interior British Columbia

Plate 2.3-2 Sedge Marsh Northwest British Columbia

2.4 SWAMP CLASS

Description

A swamp is a nutrient-rich wetland where significant groundwater inflow, periodic surface aeration, and elevated microsites support the growth of trees and tall shrubs (MacKenzie and Moran, 2004). Generally there is more than 30% tree cover and soils are often of the gleyed mineral group and can have a surface layer of anaerobically decomposed woody peat. There are three general physically different swamp communities (shrub-thicket, coniferous forest, and hardwood (deciduous) swamps) (Warner and Rubec, 1997).

Key Features

Swamps are mineral wetlands with lots of tree or tall shrub cover. Mineral wetland means their soil is black or very dark brown and feels slimy; they can also be gleyed which can look bluish-green sometimes with orange flecks. Shrubs are usually alder or willow and trees can be spruce, fir, or cedar. Tree/shrub cover is almost always > 5 m tall. Swamps can have a rolling micro-topography with trees growing on mounds and water filling the hollows.

pH ~ 5.5 – 7.5, Water movement is mobile to very dynamic, and soil is usually dark woody peat

Photo

Plate 2.4-1 Spruce/Horsetail Swamp Northwest British Columbia

2.5 SHALLOW OPEN WATER CLASS

Description

Shallow open-water wetlands are ecosystems permanently flooded by still or slow-moving water and dominated by rooted and floating leaved aquatic plants. Shallow open water wetlands are often the transition from bogs, fens, marshes, and swamps to permanent deep waterbodies (*i.e.*, sluggish streams and lakes) (Warner and Rubec, 1997; MacKenzie and Moran, 2004).

Key Features

These are basically ponds, or other areas of open water with emergent and submergeent vegetation < 2 m deep. They usually form a complex with other wetlands such as marshes but can also appear in fens and bogs where they have steep sides, very little vegetation and overhanging mats of peat. They usually have pond lily or pond weed.

Photo

Plate 2.5-1 Yellow Pond Lily Shallow Open Water Northwest British Columbia

Plate 2.5-2 Cattail Marsh Shallow Open Water Complex in Saskatchewan

3. Pre-fieldwork Planning and Equipment

As with any scientific study there are a number of considerations prior to field data collection that must be considered. The following is a condensed list of pre-field considerations.

- Check the work plan and budget to know specific studies being conducted and estimated field times.
- Review the kinds of wetlands that are expected from local, regional, and national wetland classification documents, Ducks Unlimited Canada, Natural Resources Canada, and/or RAMSAR
- Don't go into the field without large scale maps of the study area (1:5000 to 1:15000)
    - The wetland study area is usually the local development area which is often the TEM area.
- Organize your field equipment (see Table 2)
- Spend some time doing a pre-field reconnaissance to identify wetland/water features from the air. If you can see any wetlands focus on other aquatic features particularly in areas where development is expected.

Table 2 Suggested Wetland Field Equipment List

50 m eslon tape	Batteries	Flagging tape
Compass	Vegetation field guide(s)	Gumboots
Clinometer	Latex gloves	Waders
GPS	Ziploc bags	Rescan field safety manual
Range finder	pH Meter	VHF Radio
Field maps	Conductivity Meter	Sat-phone
Field notebook and data forms	Hand trowel	First aid kit
Pens, pencils, and sharpies	Soil auger	Bear bangers and spray
Digital Camera	Construction Tape Measure	

4. General Wetland Study Methodology

Once on site conduct an aerial or ground based reconnaissance level survey. This will help identify wetlands within the study area that need to be surveyed. At each survey site complete a wetland habitat information form (WHIF); some sites that are surveyed my not be wetlands but flood associations or shrub-carrs, or unclassified aquatic systems. Data on all of these ecosystems is important but wetlands are the focus of the survey. The following text describes information collected on the WHIF.

Before field surveys, equipment and field clothing should be cleaned using a 1% Virkon solution to prevent the spread of *Batrachochytrium dendrobatidis* between wetland sites. *B. dendrobatidis* is a pathogen for amphibians.

Establish a wetland plot center. Plots are 20 m×20 m and established in large uniform wetlands or at the centre of wetlands smaller than 400 m^2. The edges of wetlands smaller than 400 m^2 were used as the survey plot boundary. The wetland plot may include different associations or classes of wetlands.

Record the project ID, names of survey personnel, map sheet information, plot number, and survey date. This information should be collected as soon as a wetland survey plot is established. At the centre of the plot a GPS coordinate must be taken and photographs of the wetland, in each cardinal direction (starting at North) of the soil surface and of other significant features such as landforms, unique vegetation, and wildlife must also be collected. Record the GPS coordinates, elevation, and digital photo file number on the WHIF. Use a compass and clinometer to determine the average aspect and slope of the site. An aspect of 0 and slope of -1 indicates level ground.

Record the meso-slope position; which is the position of the plot relative to the local catchment area (Table 4.1).

Table 4.1 Meso-slope position descriptions

Meso-slope position	**Definition**
Crest	Upper most portion of a hill, convex in all directions, no distinct aspect.
Upper Slope	Generally the convex upper portion of the slope immediately below the crest of a hill; has a specific aspect.
Mid Slope	Area between the upper and lower slope has a straight or somewhat sigmoid surface profile with a specific aspect.
Lower Slope	The area toward the base of a slope; generally has a concave surface profile with a specific aspect.
Toe	The area demarcated from the lower slope by an abrupt decrease in slope gradient; seepage is typically present.
Depression	Any area concave in all directions; may be at the base of a meso-scale slope or in a generally level area
Level	Any level meso-scale area

Adapted from MOF 1998

Record the hydrogeomorphic; which describes the topographic position and hydrology of a site (Table 4.2).

Table 4.2 Hydrogeomorphic position descriptions

Hydrogeomorphic position	Definition
Estuarine	Sites at the confluence of fluvial and marine environments
Fluvial	Sites associated with flowing water, subject to flooding, erosion, and sedimentation
Lacustrine	Sites at lakeside
Basins and Hollows	Sites in depressions or topographic low points, receive water from groundwater or precipitation
Ponds and Potholes	Sites associated with Small water-bodies
Seepage slopes	Sloping sites with near surface groundwater seepage

Adapted from MacKenzie and Moran 2004

Identify vegetation within the survey plot; separately recording the tree/shrub species, forbs, and bryophytes. Estimate the percent cover of the species within each layer and estimate the percent ground cover by each layer. Each layer can add up to 100% but the sum of all layers can exceed 100%. Indicate if the vegetation list was complete or partial.

Establish a series of soil cores around the wetland; these can exceed the plot boundary but not the wetland boundary, though they may exceed the wetland boundary if confirmation of a wetland is needed. Look at all the soil cores within the wetland and describe soil properties on the WHIF using a representative core.

Determine the soil moisture regime (SMR) (Table 4.3).

Table 4.3 SMR descriptions

Soil Moisture Regime	Code	Definition
Moist	M	No water deficit (demand doesn't exceed supply), temporary groundwater table may be present. Generally supports forest.
Very Moist	VM	Rooting zone groundwater present during growing season. Groundwater table > 30 cm below ground surface. Unless otherwise limited supports forest
Wet	W	Sites at lakeside
Very Wet	VW	Sites in depressions or topographic low points, receive water from groundwater or precipitation

Adapted from MacKenzie and Moran 2004

Determine the Hydrodynamic Index (HDI) (Table 4.4).

Table 4.4 HDI descriptions

Hydrodynamic Index	Code	Definition/Indicators
Stagnant	St	Stagnant to very slow moving soil water, vertical fluctuations minimal, no evidence of flooding; lots of organic matter and high bryophyte cover
Sluggish	Sl	Gradual groundwater movement; patterned fens; brief periods of surface aeration
Mobile	Mo	Distinct flooding; open water tracks such as rivulets/ponds/potholes; well decomposed peat; patchy bryophyte cover.
Dynamic	Dy	Significant lateral flow and/or strong vertical fluctuations; pothole wetlands in arid climates; riparian/oxbow sites; little organic accumulation
Very Dynamic	VD	Highly dynamic surface water; exposed tidal sites; shallow potholes that dry completely; no organic matter accumulation or bryophytes.

Adapted from MacKenzie and Moran 2004

Determine the soil nutrient regime (SNR) (Table 4.5).

Table 4.5 SNR descriptions

Soil Nutrient Regime	Code	Indicators
Very Poor	A	HDI St, von post 1-3, tea coloured or yellowish water, pH < 5
Poor	B	HDI St-Sl, von post 3-6, tea coloured or yellowish water, possibly green-brown or clear, pH 4.5 - 6
Medium	C	HDI St-Mo, von post 4-7, tea coloured, yellowish, green-brown, or clear water, pH 5-6.5
Rich	D	HDI Sl-Dy, von post 7-10, green-brown and turbid water, pH 6-7.4
Very Rich	E	HDI Mo-Dy, von post 8-10, green-brown and turbid water, pH 6.5-8
Hyper	F	Excess salt accumulation, pH > 8, high conductivity

Adapted from MacKenzie and Moran 2004

Determine if mineral soils are present (silt, sand, or clay) and identify drainage (Table 4.6).

Table 4.6 Drainage Class for Mineral Soils

Drainage Class	Description
Very Rapid	Water is removed from the soil very rapidly in relation to supply. Water source is precipitation and available water storage capacity following precipitation is essentially nil. Soils are typically fragmental or skeletal, shallow, or both.
Rapid	Water is removed from the soil rapidly in relation to supply. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Water source is precipitation. Soils are generally coarse textured.
Well	Water is removed from the soil readily, but not rapidly. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. Water source is precipitation. On slopes, subsurface flow may occur for short durations, but additions are equaled by losses. Soils are generally intermediate in texture and lack restricting layers.
Mod. Well	Water is removed from the soil somewhat slowly in relation to supply because of imperviousness or lack of gradient. Precipitation is the dominant water source in medium- to fine-textured soils; precipitation and significant additions by subsurface flow are necessary in coarse-textured soils.
Imperfectly	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major source. If subsurface water or groundwater (or both) is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season. Precipitation is the main source if available water storage capacity is high; contribution by subsurface or groundwater flow (or both) increases as available water storage capacity decreases. Soils generally have a wide range of texture, and some mottling is common.
Poorly	Water is removed so slowly in relation to supply that the soil remains wet for much of the time that it is not frozen. Excess water is evident in the soil for a large part of the time. Subsurface or groundwater flow (or both), in addition to precipitation, are the main water sources. A perched water table may be present. Soils are generally mottled and/or gleyed.
Level	Water is removed from the soil so slowly that the water table remains at or near the surface for most of the time the soil is not frozen. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important, except where there is a perched water table with precipitation exceeding evapotranspiration. Typically associated with wetlands. For organic wetlands, also evaluate the soil moisture subclass, and when entering on the form, separate from drainage by a slash. For example, v/ac.

Adapted from MOF 1998

Determine if mineral soils are present (silt, sand, or clay) and mineral soil texture (Figure 4.1).

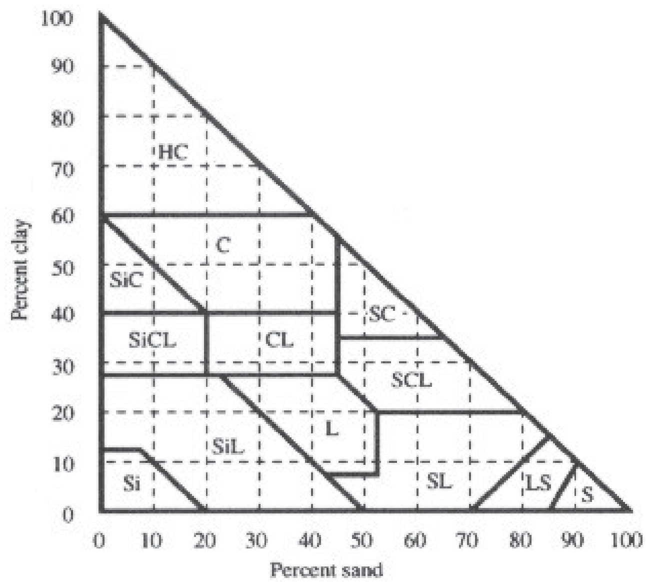


Figure 4.1 Soil Texture Triangle (MOF 1998)

Determine if Organic soils are present and identify moisture subclass (Table 4.7).

Table 4.7 Moisture Sub-class of Organic Soils

Moisture Sub-class	Description	Saturation period (mo.)
Aqueous	Free surface water	11.5-12
Peraquic	Soils saturated for very long periods	>10
Aquic	Soils saturated for moderately long periods	4-10
Subaquic	Soils saturated for short periods	<4
Perhumid	No significant water deficits in growing season	<2
Humid	Very slight deficit in growing season water availability	<0.5

Adapted from MOF 1998

Determine if Organic soils are present and identify the von post (Table 4.8).

Table 4.8 Von Posts

Von Post	Description
1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amorphous material present.
2	Almost entirely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.
3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but from which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present.
4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.
5	Moderately decomposed peat which, when squeezed, releases very "muddy" water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty.
6	Moderately highly decomposed peat with a very indistict plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is very pasty but shows the plant structure more distinctly than before squeezing.
7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
8	Very highly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is a fairly uniform paste.
10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

Adapted from Ekono 1981

Determine if Organic soils are present and identify texture (Table 4.9).

Table 4.9 Organic Soil Texture

Texture	Description	Corresponding von post
Fibric	Visible and identifiable plant part, soil water clear	1-3
Mesic	Some visible plant parts, soil water slightly coloured	4-7
Humic	Muck!	8-10

Complete the soil and water descriptions by estimating the percentage of coarse fragments, measuring the depth of soil horizons (depth of organic layer, depth of mineral layer, depth to water, rooting depth, anything that looks interesting). Draw the soil profile, indicate the depth to all features, record the pH, conductivity, and estimate the percentage of open water. The pH and conductivity should be measured within the soil matrix and in open water features within the wetland as well. The colour of main open water feature should also be identified.

Identify vegetation species and record in the appropriate section of the field form. Ensure that shrubs (woody plants) are recorded in the appropriate area. Estimate the percent cover of each individual species, estimate the percent cover of species guilds, and indicate if the vegetation identification was complete or partial.

Complete the remainder of the WHIF by recording all wildlife observations, drawing the wetland, attempting wetland classification, and identifying wetland communities within a continuous ecosystem unit.

5. Wetland Habitat Information Form (WHIF)

The following form is the Wetland Habitat Information Form (WHIF). It was developed in 2010 and builds heavily off the Ground Inspection Form (GIF). Filed methods were developed for completing the Ground Inspection Form in wetland ecosystems (MacKenzie 1999); however, there were a number of data requirements not included in the GIF that have been added to the WHIF, such as a space for the hydrodynamic index, hydrogeomorphic position, and von post. Please provide any comments or suggestions to Wade Brunham regarding the layout and content of the WHIF.

WETLAND HABITAT INFORMATION FORM

Rescan Engineers & Scientists

W ☐ T ☐	PHOTO	X:	Y:	DATE
PROJECT ID		SURV.		
MAPSHEET		PLOT #		
UTM ZONE	NORTH	EAST		
ASPECT		ELEVATION		
SLOPE %	SMR	HDI	SNR	

MESO SLOPE POSITION	☐ Crest ☐ Upper slope	☐ Mid slope ☐ Lower slope ☐ Toe	☐ Depression ☐ Level
HYDROGEO-MORPHIC POSITION	☐ Estuarine ☐ Fluvial	☐ Lacustrine ☐ Ponds & Potholes	☐ Basins & Hollows ☐ Seepage Slopes
DRAINAGE - MINERAL SOILS	☐ Very rapidly ☐ Rapidly	☐ Well ☐ Mod. well ☐ Imperfectly	☐ Poorly ☐ Very poorly
MINERAL SOIL TEXTURE	☐ Sandy (LS,S) ☐ Loamy (SL,L,SCL,FSL)	☐ Silty (SiL,Si) ☐ Clayey (SiCL,CL,SC,SiC,C)	
MOISTURE SUBCLASSES ORGANIC SOIL	☐ Aqueous ☐ Peraquic	☐ Aquic ☐ Subaquic	☐ Perhumid ☐ Humid

ORGANIC SOIL TEXTURE	SURF. ORGANIC HORIZON THICKNESS
☐ Fibric ☐ Mesic ☐ Humic	___________ cm
HUMUS FORM	ROOTING DEPTH
☐ Mor ☐ Moder ☐ Mull	Depth ______ cm Type ____________

VON POST

1 2 3 4 5 6 7 8 9 10

COARSE FRAGMENT CONTENT

☐ < 20% ☐ 20-35% ☐ 35-70% ☐ > 70%

ECOSYSTEM COMPONENT: ☐ WL1 ☐ WL2 ☐ WL3

BGC UNIT	WETLAND CLASS
SITE SERIES	ASSOCIATION
STRUCTURAL STAGE	MODIFIER

WETLAND POLYGON SUMMARY

	%	CLASS	ASSOCIATION
WL1			
WL2			
WL3			

WB-RES10-01 100510

WETLAND MAP

Features to include: North arrow, wildlife features, open water, slope, vegetation communities, wetland boundary, direction of water flow, soil core locations.

NOTES

DOMINANT / INDICATOR PLANT SPECIES

TOTAL %	TALL TREE	TREE / SHRUB	FORB	BRYOP.

TREE / SHRUB	%	FORB	%	FORB cont'd	%
				BRYOP.	%

☐ COMPLETE ☐ PARTIAL

WATER COLOUR		
	☐ Tea Coloured	☐ Green-Brown Turbid
	☐ Yellow-Deep Brown Turbid	☐ Blue-Green Clear
	☐ Green-Brown Clear	

pH	CONDUCTIVITY	% OPEN WATER	DEPTH TO WATER

SOIL PROFILE	WILDLIFE OBSERVATIONS	
	SPECIES	FEATURE

Adapted from Ground Inspection Form: FS FS212-2(1) HRE 98/5-7610000694

6. References and Extra Information

Links

Canadian Wildlife Service. 2006. Conservation Atlas of Wetlands.
http://www.qc.ec.gc.ca/faune/atlasterreshumides/html/AtlasTerresHumides_e.htm

Cox, R. and J. Cullington. 2009. Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in British Columbia.
http://www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/Wetland%20Ways%20Ch%201%20Introduction.pdf

Ducks Unlimited. 2007. Top Ten Wetland Facts.
http://www.ducks.ca/resource/general/wetland/facts.html#disappear

MacKenzie and Moran. 2004. Wetlands of British Columbia: a Guide to Identification.
http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh52.htm.

Warner and Rubec, Eds. 1997. The Canadian Wetland Classification System:
http://www.uwwrc.net/web/wetlandsrc/cat/books/books-1053313151236

WetKit. Tools of for working with Wetlands in Canada. http://www.wetkit.net/modules/1/

WetlandRule. Follow Wade on Twitter at http://twitter.com/WetlandsRule

Books

Mitsch, W. J., and J. G. Gosselink. 2000. Wetlands. 3rd ed. New York, NY: John Wiley and Sons Inc.

Tiner, R. 1999. Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping. CRC Press LLC. Boca Raton.

References

Cox, R. and J. Cullington. 2009. Wetland Ways: Interim Guidelines for Wetland Protection and Conservation in British Columbia. Wetland Stewardship Partnership. Accessed from: http://www.env.gov.bc.ca/wld/documents/bmp/wetlandways2009/Wetland%20Ways%20Ch%201%20Introduction.pdf (accessed April 28, 2010).

Ekono. 1981. *Report on energy use of peat.* Contribution to U.N. Conference on New and Renewable Sources of Energy, Nairobi.

Environment Canada. 2003. Wetland Environmental Assessment Guideline. Government of Canada. Accessed from: http://www.cws-scf.ec.gc.ca/publications/eval/wetl/index_e.cfm.

Environment Canada. 2008. Wetland Ecological Functions Assessment: and Overview of Approaches. Technical Report 497. Government of Canada.

Ministry of Forests (MOF). 1998. Field Manual for *Describing Terrestrial Ecosystems*. B.C. Min. Env., Lands and Parks and B.C. Min. of For., Land Manage. Handb. No. 25.. Victoria, B.C.

MacKenzie, W.H. 1999. *Field Description of Wetlands and Related Ecosystems in British Columbia*. Ministry of Forest Research Program. Victoria, B.C.

MacKenzie, W. H., and J. R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 52.

Natural Resources Canada. 2009. Atlas of Canada – Wetlands. http://atlas.nrcan.gc.ca/site/english/learningresources/theme_modules/wetlands/index.html (accessed March 18, 2010)

Stewart, R.E., and H. A. Kantrud. 1971. *Classification of natural ponds and lakes in the glaciated prairie region.* Resource Publication 92, Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/wetlands/pondlake/index.htm (Version 16APR1998). (accessed March 18, 2010).

Warner, B. G., and C. D. A. Rubec, Eds. 1997. The Canadian Wetland Classification System: The National Wetlands Working Group. Waterloo, Ontario: Wetlands Research Centre, University of Waterloo.

Appendix 4

Potentially Occurring At Risk or Sensitive Plant Species

Engineers and Scientists

Appendix 4. Potentially Occurring At Risk or Sensitive Plant Species

Common Name	Scientific Name	Group	Family	NWT GSRank	COSEWIC Status	Ecozones
Yukon Fleabane	*Erigeron yukonensis*	Plant	Asteraceae	May Be At Risk	-	Southen Arctic, Taiga Plains, Boreal Cordillera
Pygmy Wood Aster	*Eurybia pygmaea (Lindl.) Nesom. (Aster pygmaeus Lindl. ; Aster sibiricus var. pygmaeus (Lindl.) Cody)*	Plant	Asteraceae	May Be At Risk	-	Northern Arctic, Southen Arctic
Saltwater Cress	*Arabidopsis salsuginea (Thellungiella salsuginea)*	Plant	Brassicaceae	May Be At Risk	-	Southen Arctic, Boreal Plains
Hairy Rockcress (Pilose Braya)	*Braya pilosa*	Plant	Brassicaceae	May Be At Risk	-	Southen Arctic
Yellowstone Whitlow-grass	*Draba incerta*	Plant	Brassicaceae	May Be At Risk	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Persistent-sepal Yellowcress	*Rorippa calycina*	Plant	Brassicaceae	May Be At Risk	-	Southen Arctic
Gmelin's Orache	*Atriplex gmelinii*	Plant	Chenopodiaceae	May Be At Risk	-	Southen Arctic
Mackenzie Sedge	*Carex mackenziei (Carex norvegica Willdenow ex Schkuhr, Besch. Riedgrä)*	Plant	Cyperaceae	May Be At Risk	-	Taiga Plains, Southen Arctic
Moss Heather	*Harrimanella hypnoides (Cassiope hypnoides)*	Plant	Ericaceae	May Be At Risk	-	Arctic Cordillera, Northern Arctic, Southen Arctic
Beach Pea	*Lathyrus japonicus*	Plant	Fabaceae	May Be At Risk	-	Southen Arctic, Taiga Plains
Slender Rock-brake	*Cryptogramma stelleri*	Plant	Pteridaceae	May Be At Risk	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Dane's Gentian	*Gentianella tenella*	Plant	Gentianaceae	May Be At Risk	-	Northern Arctic, Southen Arctic
Alternate-flower Water Milfoil	*Myriophyllum alterniflorum*	Plant	Haloragaceae	May Be At Risk	-	Southen Arctic, Taiga Plains
Drummond Bluebell	*Mertensia drummondii*	Plant	Boraginaceae	May Be At Risk	-	Northern Arctic, Southen Arctic
Mingan Moonwort	*Botrychium minganense*	Plant	Ophioglossaceae	May Be At Risk	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Seaside Plantain	*Plantago maritima (Plantago juncoides)*	Plant	Plantaginaceae	May Be At Risk	-	Northern Arctic, Southen Arctic, Taiga Plains
Arctic Seashore Willow	*Salix ovalifolia (S. ovalifolia var. arctolitoralis)*	Plant	Salicaceae	May Be At Risk	-	Southen Arctic, Taiga Plains
Wedgeleaf Willow	*Salix sphenophylla*	Plant	Salicaceae	May Be At Risk	-	Southen Arctic
Northern Mudwort	*Limosella aquatica*	Plant	Scrophulariaceae	May Be At Risk	-	Southen Arctic, Taiga Plains, Taiga Shield
Muskeg Lousewort	*Pedicularis macrodonta (syn Pedicularis parviflora var. macrodonta (Richards.)*	Plant	Scrophulariaceae	May Be At Risk	-	Southen Arctic, Taiga Plains
Pale False Dandelion	*Agoseris glauca*	Plant	Asteraceae	Sensitive	-	Southen Arctic, Taiga Plains, Taiga Shield
Three-fork Sagebrush	*Artemisia furcata (Artemisia hyperborea)*	Plant	Asteraceae	Sensitive	-	Southen Arctic, Taiga Plains
Arctic Daisy	*Dendranthema arcticum (Chrysanthemum arcticum)*	Plant	Asteraceae	Sensitive	-	Southen Arctic, Taiga Plains
Four-leaved Marestail	*Hippuris tetraphylla*	Plant	Hippuridaceae	Sensitive	-	Southen Arctic, Taiga Plains
Arctic Rockcress	*Arabis arenicola*	Plant	Brassicaceae	Sensitive	-	Northern Arctic, Southen Arctic, Taiga Shield
Boreal Whitlow-grass	*Draba borealis*	Plant	Brassicaceae	Sensitive	-	Southen Arctic, Taiga Plains
Snowbed Whitlow-grass	*Draba crassifolia*	Plant	Brassicaceae	Sensitive	-	Southen Arctic
Yukon Stitchwort	*Minuartia yukonensis (Arenaria laricifolia)*	Plant	Caryophyllaceae	Sensitive	-	Taiga Plains, Southen Arctic
Creeping Campion	*Silene repens*	Plant	Caryophyllaceae	Sensitive	-	Southen Arctic, Taiga Plains
Sorensen's Campion	*Silene sorensenis*	Plant	Caryophyllaceae	Sensitive	-	Northern Arctic, Southen Arctic
Rocky Mountain Goosefoot	*Chenopodium salinum (Chenopodim gaucum var. salinum)*	Plant	Chenopodiaceae	Sensitive	-	Southen Arctic, Taiga Plains
Horned Sea-blite	*Suaeda calceoliformis*	Plant	Chenopodiaceae	Sensitive	-	Southen Arctic, Taiga Plains, Boreal Plains
White Sea-blite	*Suaeda maritima*	Plant	Chenopodiaceae	Sensitive	-	Southen Arctic
Water Blinks	*Montia fontana (syn Montia lamprosperma, Claytonia fontana)*	Plant	Portulacaceae	Sensitive	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Circumpolar Sedge	*Carex adelostoma (Carex morrisseyi)*	Plant	Cyperaceae	Sensitive	-	Southen Arctic, Taiga Shield
Gravel Sedge	*Carex glareosa (Carex glareosa Wahlenberg subsp. glareosa ;Carex amphigena (Fernald) Mackenzie; C. cryptantha T. Holm; C. glareosa var. amphigena Fernald))*	Plant	Cyperaceae	Sensitive	-	Northern Arctic, Southen Arctic

Appendix 4. Potentially Occurring At Risk or Sensitive Plant Species

Common Name	Scientific Name	Group	Family	NWT GSRank	COSEWIC Status	Ecozones
Circumpolar Reed Grass	*Calamagrostis deschampsioides*	Plant	Poaceae	Sensitive	-	Southen Arctic
Anderson's Alkali Grass	*Puccinellia andersonii*	Plant	Poaceae	Sensitive	-	Northern Arctic, Southen Arctic
Prince Patrick Alkali Grass (Goose Grass)	*Puccinellia bruggemannii*	Plant	Poaceae	Sensitive	-	Northern Arctic, Southen Arctic
Polar Nuttall's Alkali Grass	*Puccinellia nuttalliana (Puccinellia deschampsioides, Puccinillia borealis?, and incl Puccinellia interior)*	Plant	Poaceae	Sensitive	-	Southen Arctic, Taiga Plains, Taiga Shield
Arctic Tussock Alkali Grass	*Puccinellia vaginata*	Plant	Poaceae	Sensitive	-	Southen Arctic
Purple Mountain Heather	*Phyllodoce caerulea*	Plant	Ericaceae	Sensitive	-	Northern Arctic, Southen Arctic, Taiga Shield
Alpine Cliff-fern (Northern Woodsia)	*Woodsia alpina*	Plant	Dryopteridaceae	Sensitive	-	Arctic Cordillera, Northern Arctic, Southen Arctic, Taiga Cordillera, Taiga Plains
Northern Beech Fern	*Phegopteris connectilis (Dryopteris phegopteris, Thelypteris phegopteris)*	Plant	Thelypteridaceae	Sensitive	-	Taiga Cordillera, Southen Arctic, Taiga Shield
Sea Bluebell	*Mertensia martitima*	Plant	Boraginaceae	Sensitive	-	Northern Arctic, Southen Arctic, Taiga Plains
Arctic Willowherb	*Epilobium arcticum*	Plant	Onagraceae	Sensitive	-	Arctic Cordillera, Northern Arctic, Southen Arctic, Taiga Plains
Dauria Willowherb	*Epilobium davuricum*	Plant	Onagraceae	Sensitive	-	Southen Arctic, Taiga Plains, Taiga Shield
Blunt-leaf Pondweed	*Potamogeton obtusifolius*	Plant	Potamogetonaceae	Sensitive	-	Southen Arctic, Taiga Shield
Yenisei River Pondweed	*Potamogeton subsibiricus (Potamogeton porsildiorum)*	Plant	Potamogetonaceae	Sensitive	-	Southen Arctic, Taiga Plains
Iceland Purslane	*Koenigia islandica*	Plant	Polygonaceae	Sensitive	-	Northern Arctic, Southen Arctic, Boreal Cordillera
Alaska Knotweed	*Polygonum humifusum ssp caurianum (Polygonum caurianum)*	Plant	Polygonaceae	Sensitive	-	Southen Arctic, Taiga Plains
Slender Primrose	*Primula borealis*	Plant	Primulaceae	Sensitive	-	Southen Arctic, Taiga Plains
Floating Marsh Marigold	*Caltha natans*	Plant	Ranunculaceae	Sensitive	-	Southen Arctic, Taiga Plains, Taiga Shield
Pallas' Buttercup	*Ranunculus pallasii*	Plant	Ranunculaceae	Sensitive	-	Southen Arctic, Taiga Plains
Sardinain Buttercup	*Ranunculus sabinei (Ranunculus pygmaeus ssp.sabinei)*	Plant	Ranunculaceae	Sensitive	-	Northern Arctic, Southen Arctic
Egede Cinquefoil	*Argentina egedii (Potentilla egedii)*	Plant	Rosaceae	Sensitive	-	Southen Arctic, Taiga Plains
Arizona Cinquefoil	*Sibbaldia procumbens*	Plant	Rosaceae	Sensitive	-	Southen Arctic, Taiga Cordillera, Taiga Plains, Taiga Shield, Boreal Cordillera
Halberd Willow	*Salix hastata (syn Salix farriae var. walpolei)*	Plant	Salicaceae	Sensitive	-	Southen Arctic, Taiga Plains
Northern Indian Paintbrush	*Castilleja hyperborea*	Plant	Scrophulariaceae	Sensitive	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Red-tip Lousewort	*Pedicularis flammea*	Plant	Scrophulariaceae	Sensitive	-	Northern Arctic, Southen Arctic, Taiga Plains, Taiga Shield
Richarson's Phlox	*Phlox richardsonii (incl. spp alaskensis, syn P. alaskensis (P. richardsonii ssp alaskensis), P. sibirica ssp alaskensis)*	Plant	Polemoniaceae	Sensitive	-	Northern Arctic, Southen Arctic, Taiga Plains
Showy Jacob's Ladder	*Polemonium pulcherrimum*	Plant	Polemoniaceae	Sensitive	-	Southen Arctic, Taiga Cordillera, Taiga Plains
Smooth White Violet	*Viola macloskeyi (Viola pallens)*	Plant	Violaceae	Sensitive	-	Southen Arctic, Taiga Plains, Taiga Shield
Alpine Marsh Violet	*Viola palustris*	Plant	Violaceae	Sensitive	-	Southen Arctic, Taiga Shield

Source:Northwest Territories Environment and Natural Resources. 2010.NWT Species Monitoring Infobase http://www.enr.gov.nt.ca/_live/pages/wpPages/Infobase.aspx (accessed December 2010).
Gau, R. 2010. Wildlife Biologist (Species at Risk), Wildlife Division, Department of Environment & Natural Resources, Government of the Northwest Territories, Yellowknife; June 28, 2010.

Appendix 5

Invasive Plant Species Known to Occur in Nunavut or the Northwest Territories

Rescan™
Engineers and Scientists

Appendix 5. Invasive Plant Species Known to Occur in Nunavut or the Northwest Territories

Scientific Name	Common Name	Predicted Invasiveness
Bromus inermis	awnless brome	moderate/low
Caragana arborescens	caragana	low
Cirsium arvense	creeping thistle	moderate/low
Medicago sativa	alfalfa	low
Phalaris arundinacea	reed canary grass	moderate/low
Poa compressa	flat-stem blue grass	minor
Agropyron cristatum spp pectinatum	crested wheat grass	low/potential
Poa pratensis	Kentucky blue grass	minor
Tanacetum vulgare	common tansy	potential
Atriplex patula	spear saltbush	not rated
Berteoa incana	hoary false-alyssum	low
Leucanthemum vulgare	oxeye daisy	not rated
Matricaria discoidea	pineapple chamomile	not rated
Melilotus alba	sweet white clover	moderate
Melilotus officinalis	yellow sweet clover	moderate
Puccinellia distans	spreading alkaligrass	not rated
Ranunculus acris var. acris	tall buttercup	not rated
Taraxacum officinale officinale	common dandelion	not rated
Tripleurospermum maritima	scentless chamomile	not rated
Vicia cracca	tufted vetch	not rated

Additional invasive species have been documented to occur in the Northwest Territories (See Oldham, M., 2006, 2006 Survey of Exotic Plants along Northwest Territories Highways, Report to the GNWT).

The invasive plant list was compiled from the following resources:

Northwest Territories Environment and Natural Resources. 2010.NWT Species Monitoring Infobase http://www.enr.gov.nt.ca/_live/pages/wpPages/Infobase.aspx (accessed December 2010).

The Invasive Species Specialist Group (ISSG) Global Invasive Species Database. http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&sn=&rn=Nunavut&hci=-1&ei=-1&lang=EN (accessed December 2010)

Evergreen Native Plant Database. http://nativeplants.evergreen.ca/search/search-results.php?mode=guided&province=NU&type=invasive (accessed December 2010)

Appendix 6

Detection Limits for Metals Analysis

Engineers and Scientists

Appendix 6. Detection Limits for Metals Analysis

Sample ID	Measurement Units	D73 FLAVOCETRARIA CUCULLATA	D82 FLAVOCETRARIA CUCULLATA	D114 FLAVOCETRARIA CUCULLATA	023 FLAVOCETRARIA CUCULLATA	021 FLAVOCETRARIA CUCULLATA	010 FLAVOCETRARIA CUCULLATA	011 FLAVOCETRARIA CUCULLATA	024 FLAVOCETRARIA CUCULLATA	D63 FLAVOCETRARIA NIVALIS
Physical Tests										
% Moisture	%	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Metals										
Aluminum (Al)	mg/kg	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Aluminum (Al)	mg/kg wwt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Antimony (Sb)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Antimony (Sb)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Arsenic (As)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Arsenic (As)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Barium (Ba)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Barium (Ba)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Beryllium (Be)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Beryllium (Be)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Bismuth (Bi)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bismuth (Bi)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Boron (B)	mg/kg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Boron (B)	mg/kg wwt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Cadmium (Cd)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Cadmium (Cd)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Calcium (Ca)	mg/kg	30	30	30	30	30	30	30	30	30
Calcium (Ca)	mg/kg wwt	23	18	15	10	13	18	20	18	18
Cesium (Cs)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Cesium (Cs)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Chromium (Cr)	mg/kg	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chromium (Cr)	mg/kg wwt	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Cobalt (Co)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Cobalt (Co)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Copper (Cu)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Copper (Cu)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Gallium (Ga)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Gallium (Ga)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Iron (Fe)	mg/kg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Iron (Fe)	mg/kg wwt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lead (Pb)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Lead (Pb)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Lithium (Li)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Lithium (Li)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Magnesium (Mg)	mg/kg	50	50	50	50	50	50	50	50	50
Magnesium (Mg)	mg/kg wwt	45	35	30	20	25	35	40	35	35
Manganese (Mn)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Manganese (Mn)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Mercury (Hg)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Mercury (Hg)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Molybdenum (Mo)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Molybdenum (Mo)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Nickel (Ni)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Nickel (Ni)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Phosphorus (P)	mg/kg	200	200	200	200	200	200	200	200	200
Phosphorus (P)	mg/kg wwt	225	175	150	100	125	175	200	175	175
Potassium (K)	mg/kg	1000	1000	1000	1000	1000	1000	1000	1000	1000
Potassium (K)	mg/kg wwt	900	700	600	400	500	700	800	700	700
Rhenium (Re)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Rhenium (Re)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Rubidium (Rb)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Rubidium (Rb)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Selenium (Se)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Selenium (Se)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Silver (Ag)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Silver (Ag)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Sodium (Na)	mg/kg	1000	1000	1000	1000	1000	1000	1000	1000	1000
Sodium (Na)	mg/kg wwt	900	700	600	400	500	700	800	700	700
Strontium (Sr)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Strontium (Sr)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Tellurium (Te)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Tellurium (Te)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Thallium (Tl)	mg/kg	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Thallium (Tl)	mg/kg wwt	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040
Thorium (Th)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Thorium (Th)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Tin (Sn)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Tin (Sn)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Titanium (Ti)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Titanium (Ti)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Uranium (U)	mg/kg	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Uranium (U)	mg/kg wwt	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040
Vanadium (V)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Vanadium (V)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Yttrium (Y)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Yttrium (Y)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Zinc (Zn)	mg/kg	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Zinc (Zn)	mg/kg wwt	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Zirconium (Zr)	mg/kg	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Zirconium (Zr)	mg/kg wwt	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

Appendix 6. Detection Limits for Metals Analysis

Sample ID	Measurement Units	D65 FLAVOCETRARIA NIVALIS	D62 FLAVOCETRARIA NIVALIS	D89 FLAVOCETRARIA NIVALIS	D97 FLAVOCETRARIA NIVALIS	D93 FLAVOCETRARIA NIVALIS	D116 FLAVOCETRARIA NIVALIS	D86 FLAVOCETRARIA NIVALIS	D114 FLAVOCETRARIA NIVALIS	D125 FLAVOCETRARIA NIVALIS
Physical Tests										
% Moisture	%	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Metals										
Aluminum (Al)	mg/kg	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Aluminum (Al)	mg/kg wwt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Antimony (Sb)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Antimony (Sb)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Arsenic (As)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Arsenic (As)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Barium (Ba)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Barium (Ba)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Beryllium (Be)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Beryllium (Be)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Bismuth (Bi)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Bismuth (Bi)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Boron (B)	mg/kg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Boron (B)	mg/kg wwt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Cadmium (Cd)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Cadmium (Cd)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Calcium (Ca)	mg/kg	30	30	30	30	30	30	30	30	30
Calcium (Ca)	mg/kg wwt	23	15	18	23	20	20	20	18	20
Cesium (Cs)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Cesium (Cs)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Chromium (Cr)	mg/kg	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chromium (Cr)	mg/kg wwt	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Cobalt (Co)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Cobalt (Co)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Copper (Cu)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Copper (Cu)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Gallium (Ga)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Gallium (Ga)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Iron (Fe)	mg/kg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Iron (Fe)	mg/kg wwt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lead (Pb)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Lead (Pb)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Lithium (Li)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Lithium (Li)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Magnesium (Mg)	mg/kg	50	50	50	50	50	50	50	50	50
Magnesium (Mg)	mg/kg wwt	45	30	35	45	40	40	40	35	40
Manganese (Mn)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Manganese (Mn)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Mercury (Hg)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Mercury (Hg)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Molybdenum (Mo)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Molybdenum (Mo)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Nickel (Ni)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Nickel (Ni)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Phosphorus (P)	mg/kg	200	200	200	200	200	200	200	200	200
Phosphorus (P)	mg/kg wwt	225	150	175	225	200	200	200	175	200
Potassium (K)	mg/kg	1000	1000	1000	1000	1000	1000	1000	1000	1000
Potassium (K)	mg/kg wwt	900	600	700	900	800	800	800	700	800
Rhenium (Re)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Rhenium (Re)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Rubidium (Rb)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Rubidium (Rb)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Selenium (Se)	mg/kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Selenium (Se)	mg/kg wwt	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Silver (Ag)	mg/kg	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Silver (Ag)	mg/kg wwt	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Sodium (Na)	mg/kg	1000	1000	1000	1000	1000	1000	1000	1000	1000
Sodium (Na)	mg/kg wwt	900	600	700	900	800	800	800	700	800
Strontium (Sr)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Strontium (Sr)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Tellurium (Te)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Tellurium (Te)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Thallium (Tl)	mg/kg	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Thallium (Tl)	mg/kg wwt	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040
Thorium (Th)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Thorium (Th)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Tin (Sn)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Tin (Sn)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Titanium (Ti)	mg/kg	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Titanium (Ti)	mg/kg wwt	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Uranium (U)	mg/kg	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Uranium (U)	mg/kg wwt	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040
Vanadium (V)	mg/kg	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Vanadium (V)	mg/kg wwt	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Yttrium (Y)	mg/kg	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Yttrium (Y)	mg/kg wwt	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Zinc (Zn)	mg/kg	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Zinc (Zn)	mg/kg wwt	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Zirconium (Zr)	mg/kg	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Zirconium (Zr)	mg/kg wwt	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

Appendix 7

Hope Bay Belt Project Ecosystem Maps

N
Wetland Field Plot
Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
1:20,000
0 500 1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012a
Projection: UTM 13, NAD83
NEWMONT NORTH AMERICA
Rescan Engineers & Scientists
Map A
Map B
Map C
Map D
Map E
Map F
427000
428000
429000
430000
431000
432000
433000
434000
435000
436000
437000
7550000
7551000
7552000
7553000
7554000
7555000
7556000
7557000
7558000
7559000
7560000
7561000
7562000
7563000
7564000
7565000
7566000


Wetland Field Plot
Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
1:20,000
0 500 1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012b
Projection: UTM 13, NAD83
NEWMONT NORTH AMERICA
Rescan Engineers & Scientists
Map A
Map B
Map C
Map D
Map E


N
Wetland Field Plot
Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
1:20,000
0 500 1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012c
Projection: UTM 13, NAD83
NEWMONT NORTH AMERICA
Rescan Engineers & Scientists
Map A
Map B
Map C
Map D
Map E
Map F
432000
433000
434000
435000
436000
437000
438000
439000
440000
441000
442000


Terrestrial Field Plot
Wetland Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
1:20,000
0
500
1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012d
Projection: UTM 13, NAD83
NEWMONT
NORTH AMERICA
Rescan
Engineers & Scientists
Map A
Map B
Map C
Map D
Map E
Map F
N


Wetland Field Plot
Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
1:20,000
0 500 1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012e
Projection: UTM 13, NAD83
NEWMONT NORTH AMERICA
Rescan Engineers & Scientists
Map A
Map B
Map C
Map D
Map E
Map F
440000
441000
442000
443000
444000
445000
446000
447000
448000
449000
450000


N
Wetland Field Plot
Field Plot
BL Betula-Ledum-Lichen
BM Betula-Moss
CL Dry Carex-Lichen
DH Dryas Herb Mat
DW Dry Willow
EM Emergent Marsh
FP Low Bench Floodplain
MB Marine Backshore
MI Marine Intertidal
PG Polygonal Ground
RW Riparian Willow
SH Dwarf Shrub-Heath
TM Eriophorum Tussock Meadow
WM Wet Meadow
Unvegetated (BA BE BI ES MS RO)
Water (LA OW PD RI)
SW Salt Water
Camp
Doris North Existing and Future Infrastructure (Phase 1)
Underground Portal
Existing Road
Existing Infrastructure
Future Road
Future Infrastructure
Future Tailings Impoundment
Existing Quarry
Windy Road Infrastructure
Doris/Windy Road
Phase 2 Project Potential Infrastructure
Potential Underground Portal
Potential All-Weather Road (Boston-Windy) - EBA Alignment, 1997 (2010 Work Plan)
Potential All-Weather Road (Boston-Windy) - PND Engineers, 2009
Potential Other Road
Potential Open Pit
Potential Tailings Storage
Potential Waste Rock Storage
Potential Infrastructure
Portable Exploration Camp
Potential Quarry
Map A
Map B
Map C
Map D
Map E
1:20,000
0 500 1,000
Metres
Date: December 10, 2010
File Reference: HB-20-012f
Projection: UTM 13, NAD83
NEWMONT NORTH AMERICA
Rescan Engineers & Scientists

Appendix 8

2010 Terrestrial and Wetland Field Data

Engineers and Scientists

Appendix 8a. 2010 Terrestrial Field Data

Project Name	Plot #	Date	Surveyors	Photos	UTM zone	Northing	Easting	Slope	Aspect	Elevation	Slope Position	Surficial Material	Terrain	Microtopography	Mineral Soil Texture	Organic Soil Texture	Surface Sub Bedrock	Surface Sub Boulder	Surface Sub Rock	Surface Sub Mineral Soil	Surface Sub Water	Surface Sub Organic Soil	Permafrost Present	Permafrost Depth	Fragment Content	Soil Moisture Regime	Soil Nutrient Regime	ShrubTotal Cover (%)	Herb Total Cover (%)	Moss Total Cover (%)	Polygon Summary	Map Unit
Hope Bay Belt	001	11-Jul-10	ST, RD, BS, DK	40 - 54	13	7562225	431795	0	999		water receiving	moraine		hummocky	Silty Clay		0	0					TRUE	30	<20%	wet	medium	65	65	40		TM
Hope Bay Belt	002	11-Jul-10	ST, RD, BS, DK	68 - 83	13	7562513	431501	25	NE		water shedding	moraine	slope		Silty Loam	N/A	0	0			N/A	N/A	FALSE		35-70%	mesic-dry	poor	65	45	10		DH
Hope Bay Belt	003 - V	11-Jul-10	ST, RD, BS, DK	84 - 92	13			0	999		water shedding	rock	ridge crest	br. outcrop		N/A	95	0	0	5	0	0	FALSE			dry	very poor					CL
Hope Bay Belt	004	12-Jul-10	ST, RD, BS, TP	121 - 126	13	7557681	431600	2.5	SE		mid-slope-water shedding	moraine	slope	hummocky	Clayey		0	0	0		0	N/A	TRUE	36	<20%	mesic	rich - medium	80	25	35		BL
Hope Bay Belt	005	12-Jul-10	ST, RD, BS, TP	127 - 134	13	7557566	431712	0	999		level	lacustrine	valley bottom		Silty Clay Loam	Mesic	0	0	0		0		TRUE	28	<20%	moist	medium	90		25		BM
Hope Bay Belt	006	12-Jul-10	ST, RD, BS, TP	137 - 142	13	7557078	431717	0	999		crest-water shedding	rock	ridge crest	br. outcrop	N/A	N/A	100				0	0	FALSE			dry	very poor	1	5			CL
Hope Bay Belt	007	12-Jul-10	ST, RD, BS, TP	159 - 167	13	7556703	431919	10	N			moraine	slope	bould field	Sandy Loam	N/A	0	15	20		0		FALSE		35-70%	mesic	medium	70	10	10		SH
Hope Bay Belt	008	12-Jul-10	ST, RD, BS, TP	168 - 174	13	7556490	431889	8	W		water shedding	lacustrine		hummocky	Silty Clay	Mesic	0	0	0		0		TRUE	32	<20%	moist	medium	75	30	30		TM
Hope Bay Belt	009	14-Jul-10	ST, RD, BS, TP	197 - 202	13	7507188	448193	2.5	S	111	neither shedding nor receiving	organic				Fibric	0	0	0		0		TRUE	20	<20%	moist	medium	64	50	30		TM
Hope Bay Belt	010	14-Jul-10	ST, RD, BS, TP	203 - 207	13	7507247	447631	0	999	122	water shedding	moraine	ridge crest	br. outcrop	Loamy	N/A	50	5	40		0	0	FALSE		35-70%	mesic-dry	medium	65	0.1	15		BL
Hope Bay Belt	011	14-Jul-10	ST, RD, BS, TP	208 -213	13	7506863	447111	0	999	116	level- neither receiving or shedding	moraine		br. outcrop	Loamy	Fibric	0	10	50		0		FALSE		20-35%	mesic-mesic-dry	medium	70	0.1	20		BL
Hope Bay Belt	012	14-Jul-10	ST, RD, BS, TP	214 - 219	13	7506395	446209	0	999	113	level-water receiving	moraine			Sandy Loam	Fibric - Humic	0	0	0		0		TRUE	41	35-70%	wet-moist	medium	45	55	40		TM
Hope Bay Belt	013	14-Jul-10	ST, RD, BS, TP	220 - 223	13	7506296	445764	8	N	94	upper slope-water shedding	moraine	slope		Sandy Loam	N/A	40	0	35		0	0	FALSE		20-35%	moist-mesic	medium	50	0.1	24		BL
Hope Bay Belt	014	14-Jul-10	ST, RD, BS, TP	224 - 230	13	7547927	437081	5	W	45	mid-slope	glacial lacustrine	slope		Clay Loam	Mesic	0	0	0		0		TRUE	42	<20%	moist	medium	65	35	35		TM
Hope Bay Belt	015	15-Jul-10	ST, RD, BS, TP	231 - 236	13	7547734	437131	10	N	57	upper slope-water shedding	moraine		br. outcrop	Sandy Loam	N/A	50	5	20	40	0	0	FALSE		35-70%	dry	medium	35		35		DH
Hope Bay Belt	016	15-Jul-10	ST, RD, BS, TP	254 - 264	13	7547392	437606	10	S	53	upper slope	moraine	slope	br. outcrop	Loamy	Humic					0		TRUE	50	<20%	moist	medium	42	40	31		SH
Hope Bay Belt	017	15-Jul-10	ST, RD, BS, TP	281 - 291	13	7547059	437790	0	999	38	water receiving	organic			N/A	Fibric - Mesic	0	0	0		0		TRUE	18	<20%	wet	very poor	75	15	45		RW
Hope Bay Belt	018	15-Jul-10	ST, RD, BS, TP	292 - 298	13	7546759	437685	2.5	E	41	mid-slope-water shedding	glacial lacustrine		hummocky	Clay Loam	Mesic	0	0	0		0		TRUE	45	<20%	moist	medium	50	20	40		DW
Hope Bay Belt	019	15-Jul-10	ST, RD, BS, TP	299 - 306	13	7546321	437579	10	NE	65	crest - upper slope-water shedding	moraine	ridge crest	br. outcrop	N/A	Mesic	10	20	10		0	0	FALSE		>70%	dry	poor	55	5	25		SH
Hope Bay Belt	020	15-Jul-10	ST, RD, BS, TP		13	7546263	437459	10	NW	47	mid-slope	moraine			Silty Loam	N/A		50			0		TRUE	51	35-70%	moist	medium	40	35			SH
Hope Bay Belt	021	16-Jul-10	ST, RD, BS, TP	307 - 313	13	7559766	431742	0	999	19	neither shedding nor receiving	glacial lacustrine	plain		Clay Loam	N/A	0	0	0.1		0		TRUE	52	<20%	moist	medium	35	50	55		TM
Hope Bay Belt	022	16-Jul-10	ST, RD, BS, TP	314 - 318	13	7559736	431495	2.5	S	41	water receiving	glaciomarine		br. outcrop	Silty Clay Loam	N/A	0	5	0		0		TRUE	68	<20%	moist	rich	65	25	25		SH
Hope Bay Belt	023	16-Jul-10	ST, RD, BS, TP	319 - 325	13	7553440	434866	5	W	27	midslope	glaciomarine			Clay Loam	N/A	0	0	0		1		TRUE	43	<20%	wet-moist	rich	65	60	35		TM
Hope Bay Belt	024	16-Jul-10	ST, RD, BS, TP	326 - 334	13	7553215	435038	67	W	65	water shedding	moraine	slope		Sandy Clay Loam	Fibric	0	20	5		0		FALSE		20-35%	mesic	rich	75	20	10		DW
Hope Bay Belt	025	16-Jul-10	ST, RD, BS, TP	335 - 339	13	7552926	435165	5	NW	61		weathered bedrock	ridge crest	br. outcrop	N/A	N/A	50	60	10		0	0	FALSE					20	15	7		CL
Hope Bay Belt	026	16-Jul-10	ST, RD, BS, TP	340 - 345	13	7552562	435184	0	999	47		lacustrine			Silty Clay Loam	N/A	0	0					TRUE	30	<20%		rich	50	30			TM
Hope Bay Belt	027	16-Jul-10	ST, RD, BS, TP	345 - 350	13	7552176	435154	2.5	NW	46		lacustrine			Silty	Fibric - Mesic	0	1			4		TRUE	35	<20%	wet-moist	medium	45	40	30		TM
Hope Bay Belt	028	18-Jul-10	ST, RD, BS, TP	357 - 366	13	7557943	436537				water receiving	lacustrine	valley bottom				0	0	0		0		FALSE					85	10	40		BM
Hope Bay Belt	029	18-Jul-10	ST, RD, BS, TP	367 - 376	13	7557974	436397		E		midslope	lacustrine					0	1	0		0		FALSE					70	22			DW
Hope Bay Belt	030	18-Jul-10	ST, RD, BS, TP	384 - 389	13	7557597	436232		NE		midslope	moraine					0	25	0		0		FALSE					53	0.1	20		BL
Hope Bay Belt	1	18-Aug-10	DP, RM, DI	145	13	7559191	434101	3		22	toe	see soils field data	lake	tussocks/hummocky		Fibric					20		TRUE	55	0	7	B	85	95	5		RW
Hope Bay Belt	2	18-Aug-10	DP, RM, DJ	149	13	7559178	434125	2		22	lower	organic veneer over floodplain	slope	hummocky		Fibric					5		FALSE		0	7	B	65	95	7		RW
Hope Bay Belt	3	18-Aug-10	DP, RM, DJ	150	13	7559186	434133	3		22	mid-slope	organic veneer over floodplain	slope	hummocky		Fibric							TRUE	45		7	B	55	85	20		RW
Hope Bay Belt	D01	14-Aug-10	DP, RM, DJ	16, 19, 20	13	7553678	433669	10	254	67	mid-slope	see soils field data	slope	hummocky	Silty								TRUE	30	<20%	4	C	95	90	7		TM
Hope Bay Belt	D02	14-Aug-10	DP, RM, DJ	21, 22	13	7553305	433492	15	250	44	toe	see soils field data	slope	hummocky	Silty	Fibric							TRUE	35	<20%	6	C	76	90	1		TM
Hope Bay Belt	D03	15-Aug-10	DP, RM, DJ	30, 31	13	7546977	433336	15	276	51	lower	moraine	slope	hummocky	Clayey								TRUE	35	<20%	6	C	55	90	1		BL
Hope Bay Belt	D04	15-Aug-10	DP, RM, DJ	33, 34	13	7547382	432972	3	999	48	level	glacial lacustrine	plain	flat	Silty	Fibric					1		TRUE	22	<20%	7	C	35	85	0.1		WM
Hope Bay Belt	D05	15-Aug-10	DP, RM, DJ	36, 37	13	7547427	432899	20	120	54	upper	moraine		br. outcrop	Sandy Loam	Fibric	45	5	5				FALSE		>70%	2	B	45	0.1	1.01		SH
Hope Bay Belt	D06	15-Aug-10	DP, RM, DJ	39, 40	13	7547704	433211	5	27	60	mid-slope	moraine		hummocky/frost boils	Loamy								TRUE	47	<20%	4	C	65	76	5		BL
Hope Bay Belt	D07	15-Aug-10	DP, RM, DJ	42, 43	13	7548125	432919	9	260	53	level	morainal	blalnket	hummocky	Clay Loam	Fibric							TRUE	50	<20%	7	C	50	95	10		BL
Hope Bay Belt	D08	15-Aug-10	DP, RM, DJ	46, 47	13	7548660	433060	2	999	69	depression	moraine	plateau	frost boils	Sandy			1					TRUE	70	<20%	4	C	60	22	10		BL
Hope Bay Belt	D09	15-Aug-10	DP, RM, DJ	50, 51	13	7548585	432591	0	990	19	level	glacial lacustrine	valley bottom	hummocky	Silty Clay								TRUE	50	<20%	6	C	75	98	0.1		RW
Hope Bay Belt	D10	15-Aug-10	DP, RM, DJ	53, 54	13	7548235	432471	3	160	42	toe	moraine	slope	hummocky	Sandy		15	5					FALSE		<20%	3	B	91	11	0.3		DH
Hope Bay Belt	D100	26-Aug-10	DP, RM, DJ	373, 374	13	7517384	438867	10	360	105	mid-slope	glacial lacustrial	slope	hummocky/frost boils	Silty Clay Loam								TRUE	55	0	5	C	87	55	40		TM
Hope Bay Belt	D101	26-Aug-10	DP, RM, DJ	376, 377	13	7517496	438947	0	999	97	level	organic	floodplain	flat		Fibric					4		TRUE	45	0	8	B	2	100	60	EM and FP	FP
Hope Bay Belt	D102	27-Aug-10	DP, RM, DJ	379, 380	13	7524930	437940	5	010	93	lower	morainal	slope	frost boils/solifluct	Loamy Sand								FALSE		0	4	C	95	5	3		BL
Hope Bay Belt	D103	27-Aug-10	DP, RM, DJ	382, 383	13	7524875	437813	5	220	90	lower	glacial moraine	slope	hummocky	Silty Clay								TRUE	55	0	6	C	57	32	50		TM
Hope Bay Belt	D104	27-Aug-10	DP, RM, DJ	385, 386	13	7524593	437654		999	79		lacustrine	stream	hummocky	Silty Clay								FALSE		0	8	C	70	100	0		EM
Hope Bay Belt	D105	27-Aug-10	DP, RM, DJ	388, 389	13	7524024	437567	20	variable	109	crest	weathered bedrock	ridge crest		Loamy Sand								FALSE		35-70%	0	B	2	1	0	RO and CL	RO
Hope Bay Belt	D106	27-Aug-10	DP, RM, DJ	391, 392	13	7523579	438028	5	010	97	upper	moraine	slope	br. outcrop	Sandy Loam			30					FALSE		20-35%	3	B	70	1	0.2	BL and DH	BL
Hope Bay Belt	D107	27-Aug-10	DP, RM, DJ	394, 395	13	7523270	438343	5	100	92		glacial marine	slope	hummocky	Silty Clay	Mesic					1		TRUE	32	0	6	B	90	100	20		TM
Hope Bay Belt	D108	27-Aug-10	DP, RM, DJ	397, 398	13	7522911	438371	7	180	104		aeolian	slope	br. outcrop	Sandy Loam		40						FALSE		20-35%	1	B	46	10	16		DH
Hope Bay Belt	D109	27-Aug-10	DP, RM, DJ	400, 401	13	7522631	438474			91	level	organic	raised polygon	humocky/solifluct/polygon	Silt Loam	Humic							TRUE	30	0	4	D	76	38	5		BL
Hope Bay Belt	D11	15-Aug-10	DP, RM, DJ	56, 57	13	7547796	432284	0	999	32	level	glacial lacustrine	valley bottom	flat	Silty	Fibric							TRUE	30	<20%	6	C	75	98	0	WM and RW	WM
Hope Bay Belt	D110	27-Aug-10	DP, RM, DJ	403, 404	13	7522493	438577		999	96	level	glacial marine	plain	hummocky	Silty Clay Loam	Mesic							TRUE	26	0	7	C	41	99	5		WM
Hope Bay Belt	D111	27-Aug-10	DP, RM, DJ	406, 407	13	7522219	439381		999	84	level	organic	plain	polygon	Clayey	Mesic					5		TRUE	55	0	8	C	8	95	15		PG
Hope Bay Belt	D112	27-Aug-10	DP, RM, DJ	410, 411	13	7522261	439582	5	260	95	mid-slope	moraine	slope	solifluct	Loamy								TRUE	46	0	4	C	100	16	40		BL
Hope Bay Belt	D113	28-Aug-10	DP, RM, DJ	413, 414	13	7513228	444265	7	344	86	lower	glacial marine	slope	hummocky	Silty Clay Loam						2		TRUE	55	0	8	C	100	98	40		TM
Hope Bay Belt	D114	28-Aug-10	DP, RM, DJ	417, 418	13	7513021	444040	5	350	100	mid-slope	moraine	slope	frost boils	Loamy Sand			1					FALSE		20-35%	3	B	47	0.2	50		BL
Hope Bay Belt	D115	28-Aug-10	DP, RM, DJ	420, 421	13	7512800	443803	2		90	lower	glacial marine	plain	hummocky	Silty Clay						3		TRUE	72	0	7	B	75	95	15		TM
Hope Bay Belt	D116	28-Aug-10	DP, RM, DJ	424, 425	13	7512327	444233	10	170	108	toe	moraine	slope	frost boils/solifluct	Loamy Sand								FALSE		20-35%	3	B	83	5	50		BL
Hope Bay Belt	D117	28-Aug-10	DP, RM, DJ	427, 428	13	7511860	444289	2	999	101	toe	glacial marine	slope	hummocky/frost boils/ solifluct	Silty Clay Loam								TRUE	45	0	6	C	80	71	20		TM
Hope Bay Belt	D118	28-Aug-10	DP, RM, DJ	430, 431	13	7511149	444473	10	310	103	mid-slope	moraine	slope	frost boils/solifluct	Loamy Sand								FALSE		20-35%	4	B	100	2	32		BL
Hope Bay Belt	D119	28-Aug-10	DP, RM, DJ	433, 434	13	7510544	444785	12	330	91	lower	moraine	slope	solifluct	Loamy Sand								FALSE		<20%	3	B	25	10	65		DH
Hope Bay Belt	D12	15-Aug-10	DP, RM, DJ	61, 62	13	7539768	435015	10	360	68	toe	moraine	slope	frost boils/br. Outcrop	Sandy		2	5					FALSE		35-70%	2	B	65	20	5	DH and SH	DH
Hope Bay Belt	D120	28-Aug-10	DP, RM, DJ	436, 437	13	7510157	444973	5	75	97	mid-slope	moraine	slope	solifluct/boulders	Sandy Loam								FALSE		20-35%	5	C	76	7	38		BL
Hope Bay Belt	D121	28-Aug-10	DP, RM, DJ	439, 440	13	7510237	445760	12	030	92	lower	moraine	slope	solifluct	Sandy Loam								FALSE		<20%	4	C	90	20	98		BM
Hope Bay Belt	D122	28-Aug-10	DP, RM, DJ	443, 444	13	7510305	446280		999	78		fluvial	floodplain	flat	Sand Loam								FALSE		0	8	D	0	10	100	FP and RW	FP
Hope Bay Belt	D123	28-Aug-10	DP, RM, DJ	446, 447	13	7510365	446560	5	060	88		lacustrine	slope	polygon	Silt Loam								TRUE	45	0	4	C	100	60	30		BM
Hope Bay Belt	D124	28-Aug-10	DP, RM, DJ	449, 450	13	7510003	446345	5	080	100	crest	morainal	ridge crest	frost boils	Loamy Sand								FALSE		20-35%	2	B	87	6	25		BL
Hope Bay Belt	D125	29-Aug-10	DP, RM, DJ	453, 454	13	7495476	446527	5	variable	132	depression	bedrock	slope	frost boils/boulders	Sandy Loam		35		5				FALSE		20-35%	1	B	60	0	51		BL
Hope Bay Belt	D126	29-Aug-10	DP, RM, DJ	456, 457	13	7495678	446619	2	310	131	lower	morainal	slope	hummocky	Sandy Loam								FALSE		<20%	6	C	40	60	40		TM
Hope Bay Belt	D127	29-Aug-10	DP, RM, DJ	459, 460	13	7495957	446406	10	variable	136		bedrock	ridge crest	br. outcrop	Sandy Loam								FALSE		>70%	0	B	4	1	56		CL
Hope Bay Belt	D128	29-Aug-10	DP, RM, DJ	462, 463	13	7496184	445880	3	variable	127	lower	bedrock	ridge crest	br. outcrop/boulders	Sandy Loam		10						FALSE		35-70%	1	B	85	21	35		DH
Hope Bay Belt	D129	29-Aug-10	DP, RM, DJ	466, 467	13	7496602	445620	0	999	121		glacial lacustrine	slope	hummocky	Silt Loam						1		TRUE	38	0	7	C	80	22	60		BM
Hope Bay Belt	D13	16-Aug-10	DP, RM, DJ	64, 65	13	7539903	435207	0	999	58	level	glacial lacustrine	plateau	flat	Silty Clay	Fibric					2		TRUE	43	<20%	7	C	50	99	0	WM and RW	WM
Hope Bay Belt	D130	29-Aug-10	DP, RM, DJ	469, 470	13	7496448	445145	7	130	126	toe	weathered bedrock	slope	br. outcrop	Silt Loam		5						FALSE		>70%	1	B	90	7	6		DH
Hope Bay Belt	D131	29-Aug-10	DP, RM, DJ	472, 473	13	7497142	444882	0	999	108	level	organic	plain	flat		Mesic					50		TRUE	40		8	B	0	100	40		EM
Hope Bay Belt	D132	29-Aug-10	DP, RM, DJ	475, 476	13	7497620	444763	10	050	101	lower	moraine	slope	frost boils/solifluct									FALSE		20-35%	5	C	89	5	5		BL
Hope Bay Belt	D133	29-Aug-10	DP, RM, DJ	479, 480	13	7497952	444403	3	035	102	depression	glacial marine		hummocky									TRUE	72	0	6	C	70	100	25		TM
Hope Bay Belt	D14	16-Aug-10	DP, RM, DJ	67, 68	13	7540346	435779	10	316	75	toe	moraine	ridge crest	br. outcrop	Sandy		40						FALSE		>70%	1	B	42	1	3	DH and RO	DH
Hope Bay Belt	D15	16-Aug-10	DP, RM, DJ	71, 72	13	7540580	435918	0	999	63	level	glacial lacustrine	flat	hummocky	Sandy Loam	Fibric							TRUE	43	<20%	7	C	30	98	15		TM
Hope Bay Belt	D16	16-Aug-10	DP, RM, DJ	74, 75, 76	13	7540759	436028	10	120	81	mid-slope	moraine	slope	rolling	Sandy			1	1				FALSE		35-70%	3	B	55	25	2	DH and RO	DH
Hope Bay Belt	D17	16-Aug-10	DP, RM, DJ	78, 79	13	7541383	436139	0	999	55	level	organic veneer over glacial lacustrine	flat	flat	Silty Clay	Fibric					10		FALSE		0	7	B	20	85	15	WM and PG	WM
Hope Bay Belt	D18	16-Aug-10	DP, RM, DJ	81, 82	13	7541992	435993	0	999	54	level	glacial lacustrine	plain	hummocky/flat	Silty	Fibric					5		TRUE	15	0	6	C	31	65	10		BL
Hope Bay Belt	D19	16-Aug-10	DP, RM, DJ	85, 86	13	7542173	435844	10	140	62	toe	glacial lacustrine	slope	hummocky	Silty						1		TRUE	60	0	5	C	75	45	30		BL
Hope Bay Belt	D20	16-Aug-10	DP, RM, DJ	88, 89	13	7542445	435631	10	110	79	crest	moraine	ridge crest	br. outcrop	Sandy		45	5					FALSE		35-70%	2	B	38	45	0.1	CL and RO	CL
Hope Bay Belt	D21	16-Aug-10	DP, RM, DJ	91, 92	13	7543060	436121	3		50	toe	glacial lacustrine	slope	frost boils	Clayey								TRUE	55	0	5	C	75	20	2		BL
Hope Bay Belt	D22	16-Aug-10	DP, RM, DJ	95, 96, 97	13	7543053	436364	5	240	59	lower	moraine	slope	frost boils	Sandy				1				FALSE		20-35%	3	B	80	7	2		SH
Hope Bay Belt	D23	16-Aug-10	DP, RM, DJ	99, 100	13	7543950	431418	5	variable	54	crest	moraine	ridge crest	br. outcrop	Sandy		75						FALSE		>70%	1	B	16	10	0.5	RO and CL	CL
Hope Bay Belt	D24	17-Aug-10	DP, RM, DJ	102, 103	13	7543713	431617	0	999	47	level	glacial lacustrine	plain	flat	SiCL	Fibric							TRUE	50	<20%	5	C	65	100	25		TM
Hope Bay Belt	D25	17-Aug-10	DP, RM, DJ	105, 106	13	7543493	431797	0	999	45	level	glacial lacustrine	plain	frost boils	Silty Clay	Fibric							TRUE	58	0	5	C	68	99	25		TM
Hope Bay Belt	D26	17-Aug-10	DP, RM, DJ	108, 109	13	7543400	431884		variable	57	crest	moraine	ridge crest	br. outcrop	Sandy		80						FALSE		35-70%	1	B	7	10	60	RO and CL	CL
Hope Bay Belt	D27	17-Aug-10	DP, RM, DJ	111, 112	13	7543266	432280	10	070	11	toe	fluvial over marine	valley bottom	frost boils/solifluct	Clayey								FALSE		0	6	D	50	10	85		RW

Appendix 8a. 2010 Terrestrial Field Data

Project Name	Plot #	Date	Surveyors	Photos	UTM zone	Northing	Easting	Slope	Aspect	Elevation	Slope Position	Surficial Material	Terrain	Microtopography	Mineral Soil Texture	Organic Soil Texture	Surface Sub Bedrock	Surface Sub Boulder	Surface Sub Rock	Surface Sub Mineral Soil	Surface Sub Water	Surface Sub Organic Soil	Permafrost Present	Permafrost Depth	Fragment Content	Soil Moisture Regime	Soil Nutrient Regime	ShrubTotal Cover (%)	Herb Total Cover (%)	Moss Total Cover (%)	Polygon Summary	Map Unit
Hope Bay Belt	D28	17-Aug-10	DP, RM, DJ	114, 115, 116	13	7543000	432157	10	040	28	mid-slope	glacial lacustrine	slope	solifluct	Silty Clay								TRUE	30	0	4	C	86	14	75		DW
Hope Bay Belt	D29	17-Aug-10	DP, RM, DJ	118, 119	13	7542768	432032	15	290	50	mid-slope	moraine	slope	hummocky	Silty Clay			1	1				TRUE	40	<20%	5	D	44	54	20		SH
Hope Bay Belt	D30	17-Aug-10	DP, RM, DJ	121, 122	13	7542518	432030	0	999	50	level	glacial lacustrine	plain	flat	Silty Clay	Mesic							TRUE	20	0	7	C	30	100	40		WM
Hope Bay Belt	D31	17-Aug-10	DP, RM, DJ	124, 125	13	7542187	432430	5	080	47	mid-slope	glacial lacustrine	slope	frost boils	Silty								TRUE	28		5	B	96	77	65		BL
Hope Bay Belt	D32	17-Aug-10	DP, RM, DJ	127, 128, 129	13	7542115	432709	5	140	9	toe	fluvial	floodplain	flat	Loamy						2		TRUE	44	20-35%	7	C	15	2	95		RW
Hope Bay Belt	D33	19-Aug-10	DP, RM, DJ	152, 153	13	7532162	438933	0	999	84	level	glacial lacustrine	plain	hummocky	Silty Clay	Fibric							FALSE		0	6	B	60	100	10		TM
Hope Bay Belt	D34	19-Aug-10	DP, RM, DJ	155, 156	13	7531965	438812	10	340	96	upper	moraine	ridge crest	br. outcrop	Silt Loam		70						FALSE		35-70%	1	B	20	20	85	RO and CL	CL
Hope Bay Belt	D35	19-Aug-10	DP, RM, DJ	158, 159	13	7531427	438414	0	999	82	level	glacial lacustrine	plain	hummocky	Silty Clay	Fibric							TRUE	25		6	B	52	100	2		TM
Hope Bay Belt	D36	19-Aug-10	DP, RM, DJ	163, 164	13	7531221	438361	10	020	93		moraine	slope	solifluct	Sandy Loam								TRUE	80	<20%	4	B	90	65	10		SH
Hope Bay Belt	D37	19-Aug-10	DP, RM, DJ	166, 167	13	7531031	438235	5	320	83	lower	glacial lacustrine	plain	flat	Silt Loam	Mesic					2		TRUE	20	0	7	C	1	99	0		WM
Hope Bay Belt	D38	19-Aug-10	DP, RM, DJ	169, 170	13	7530727	438196	10	316	88	lower	moraine	slope	flat	Sandy				2				FALSE		20-35%	3	B	64	5	36		BL
Hope Bay Belt	D39	19-Aug-10	DP, RM, DJ	173, 174	13	7530438	438041	10	variable	97	upper	moraine	plateau	polygon	Sandy								FALSE		35-70%	2	B	75	42	15		DH
Hope Bay Belt	D40	19-Aug-10	DP, RM, DJ	176, 177	13	7520942	438143	5	variable	115	crest	bedrock	plateau	br. outcrop			80						FALSE			0	B	78	2	46	RO and CL	CL
Hope Bay Belt	D41	19-Aug-10	DP, RM, DJ	179, 180	13	7529543	438384	0	999	99	level	moraine	plain	hummocky	Loamy								TRUE	50	<20%	6	B	18	98	23		TM
Hope Bay Belt	D42	19-Aug-10	DP, RM, DJ	182, 183	13	7529300	438752	3	-	100	level	glacial fluvial	esker	flat	Sandy								FALSE		<20%	2	B	40	0	5	ES and DH	DH
Hope Bay Belt	D43	19-Aug-10	DP, RM, DJ	185, 186	13	7528747	438876	3	variable	98	upper	moraine	esker	frost boils									TRUE	46	<20%	4	C	100	0.2	5		DH
Hope Bay Belt	D44	19-Aug-10	DP, RM, DJ	189, 190	13	7528680	438986	5	variable	89	level	glacial lacustrine	plain	hummocky/frost boils	Silty Clay	Mesic							TRUE	20	0	6	C	17	98	32		TM
Hope Bay Belt	D45	19-Aug-10	DP, RM, DJ	192, 193	13	7556183	429353	3	200	48	lower	moraine	slope	hummocky	Loamy								TRUE	80	20-35%	5	C	100	40	15		BL
Hope Bay Belt	D46	20-Aug-10	DP, RM, DJ	195, 196, 198	13	7556138	429748	60	050	38	mid-slope	colluvial	cliff	br. outcrop	Silt Loam								FALSE		<20%	2	B	70	40	10	SH and RO	SH
Hope Bay Belt	D47	20-Aug-10	DP, RM, DJ	203, 204	13	7556269	430074	0	999	20	level	glacial lacustrine	plain	flat	Silty Clay								TRUE	42	0	6	C	85	10	50		BM
Hope Bay Belt	D48	20-Aug-10	DP, RM, DJ	206, 207	13	7556611	430304	0	999	14	level	glacial lacustrine	plain	flat	Silty Clay								TRUE	31	0	6	C	65	28	40		BM
Hope Bay Belt	D49	20-Aug-10	DP, RM, DJ	209, 210	13	7557321	430856	3	250	19	toe	glacial lacustrine	slope	solifluct	Silty Clay								TRUE	58	0	4	C	80	60	15	BL and DH	BL
Hope Bay Belt	D50	20-Aug-10	DP, RM, DJ	212, 213	13	7528679	435378	7	050	82	mid-slope	glacial lacustrine	slope	hummocky	Silt Loam								TRUE	55	0	6	C	66	89	30		TM
Hope Bay Belt	D51	20-Aug-10	DP, RM, DJ	215, 216	13	7528476	435550	3	070	84	lower	moraine	slope	frost boils/solifluct	Sandy								FALSE		35-70%	2	B	50	1	2		DH
Hope Bay Belt	D52	20-Aug-10	DP, RM, DJ	218, 219	13	7528231	435710	2	variable	77	lower	glacial lacustrine	plain	hummocky	Silty Clay								TRUE	65	0	6	C	66	95	40		TM
Hope Bay Belt	D53	20-Aug-10	DP, RM, DJ	221, 222	13	7527977	435625	2	-	91	depression	bedrock	ridge crest	br. outcrop	Loamy Sand		80	5					FALSE		35-70%	1	B	28	60	14	RO and CL	CL
Hope Bay Belt	D54	20-Aug-10	DP, RM, DJ	224, 225	13	7527892	435410		999	83	level	glacial lacustrine	plain	frost boils/polygon		Mesic					5		FALSE		0	7	B	15	72	10		PG
Hope Bay Belt	D55	21-Aug-10	DP, RM, DJ	227, 228	13	7534463	436373	5	-	78	depression	bedrock	ridge crest	br. outcrop		Humic	30		10				FALSE		0	2	C	92	1	8	DH and RO	DH
Hope Bay Belt	D56	21-Aug-10	DP, RM, DJ	230, 231	13	7534544	436530	0	999	60	level	glacial lacustrine	plain	mounded	Silty Clay								TRUE	33	0	7	B	40	100	1		WM
Hope Bay Belt	D57	21-Aug-10	DP, RM, DJ	233, 234	13	7534702	436768	10	190	70	toe	glacial lacustrine	slope	frost boils	Silty Clay								TRUE	55	0	6	C	88	50	20		TM
Hope Bay Belt	D58	21-Aug-10	DP, RM, DJ	236, 237	13	7534736	437104	0	999	75	level	glacial lacutrine	plain	flat	Silty Clay	Fibric							TRUE	50	0	7	C	60	99	50		WM
Hope Bay Belt	D59	22-Aug-10	DP, RM, DJ	239, 240	13	7494897	445959	5	236	136		moraine	slope	frost boils	Sandy			5					FALSE		20-35%	2	B	72	37	10		SH
Hope Bay Belt	D60	22-Aug-10	DP, RM, DJ	243, 244	13	7495148	445545	30	260	118	upper	colluvium	slope	br. outcrop	Silt Loam								FALSE		0	5	D	96	45	1		DW
Hope Bay Belt	D61	22-Aug-10	DP, RM, DJ	246, 247	13	7495180	445242	10	250	93	lower	glacial lacustrine	slope/stream	hummocky/solifluct	Silt Loam								FALSE		0	6	C	97	95	15	TM and RW	TM
Hope Bay Belt	D62	23-Aug-10	DP, RM, DJ	249, 250	13	7500407	445021	5	variable	125	depression	moraine	slope	frost boils	Sandy			20					FALSE		35-70%	3	B	71	3	30		BL
Hope Bay Belt	D63	23-Aug-10	DP, RM, DJ	252, 253	13	7500331	444873	5	variable	125		weathered bedrock	ridge crest	br. outcrop	Silt Loam		100						FALSE		20-35%	0	B	10	1	60		BF
Hope Bay Belt	D64	23-Aug-10	DP, RM, DJ	255, 256	13	7500198	444237	0	-	111	level	moraine	plain	frost boils	Sandy Loam								FALSE		20-35%	3	B	92	11	25		BL
Hope Bay Belt	D65	23-Aug-10	DP, RM, DJ	258, 259	13	7500774	443575	10	250	95	lower	colluvial	slope	frost boils/solifluct	Sandy Loam			25					FALSE		20-35%	5	C	70	1	51		BL
Hope Bay Belt	D66	23-Aug-10	DP, RM, DJ	261, 262	13	7500640	443251	10	050	88	lower	colluvial	slope	solifluct	Sandy Loam								TRUE	85	<20%	5	C	88	10	40		BL
Hope Bay Belt	D67	23-Aug-10	DP, RM, DJ	264, 265	13	7500507	442872	10	variable	113	toe	glacial lacustrine	slope	hummocky	Silt Loam								TRUE	67	0	4	C	18	75	5		TM
Hope Bay Belt	D68	23-Aug-10	DP, RM, DJ	267, 268	13	7500507	442470	5	variable	113	depression	moraine	slope	hummocky	Loamy Sand						2		TRUE	75	<20%	6	C	53	75	60		BL
Hope Bay Belt	D69	23-Aug-10	DP, RM, DJ	270, 271	13	7500369	441878	5	270	85	lower	moraine	slope	hummocky/solifluct	Sandy Loam								FALSE			4	C	85	55	2		BL
Hope Bay Belt	D70	23-Aug-10	DP, RM, DJ	275, 276	13	7500063	441289	2	W	72	level	moraine	plain	hummocky	Sandy Loam								TRUE	60	0	4	C	85	5	70		BM
Hope Bay Belt	D71	24-Aug-10	DP, RM, DJ	278, 279	13	7505185	443663	5	276	82	toe	moraine	slope	hummocky/frost boils/boulders	Loamy Sand			2					FALSE		20-35%	4	C	100	2	6		BL
Hope Bay Belt	D72	24-Aug-10	DP, RM, DJ	281, 282	13	7505467	443686	5	variable	68	level	glacial lacustrine	slope	hummocky/frost boils	Silt Loam								TRUE	60	0	4	C	90	80	15		TM
Hope Bay Belt	D73	24-Aug-10	DP, RM, DJ	284, 285	13	7506162	443756	10	variable	88	crest	aeolian	plateau/ridge crest	br. Outcrop/boulders	Silt Loam		5	35					FALSE		35-70%	1	B	36	55	5		DH
Hope Bay Belt	D74	24-Aug-10	DP, RM, DJ	287, 288	13	7506660	444891	10	270	104	lower	moraine	slope	frost boils/br. Outcrop	Loamy Sand		2						FALSE		35-70%	2	B	87	0	20		DH
Hope Bay Belt	D75	24-Aug-10	DP, RM, DJ	290, 291	13	7506676	444448	3	variable	102	mid-slope	moraine	slope	solifluct	Loamy Sand								FALSE		<20%	5	C	51	22	25		BL
Hope Bay Belt	D76	24-Aug-10	DP, RM, DJ	293, 294	13	7507620	443987	5	340	84	toe	glacial fluvial	slope	hummocky	Sandy Loam								FALSE		<20%	5	C	55	65	50		TM
Hope Bay Belt	D77	24-Aug-10	DP, RM, DJ	297, 298	13	7507831	443891	0	999	81	level	glacial lacustrine	plain	flat	Silty Clay						1		TRUE	55	0	6	C	85	60	60		TM
Hope Bay Belt	D78	25-Aug-10	DP, RM, DJ	301, 302	13	7510516	443627	15	310	101	crest	glacial fluvial	esker	mounded	Sandy								FALSE		>70%	1	B	6	20	2	CL and ES	CL
Hope Bay Belt	D79	25-Aug-10	DP, RM, DJ	304, 305	13	7511068	443938	0	999	82	level	glacial lacustrine	stream	flat	Silty Clay	Mesic							FALSE		0	6	D	0	50	100	FP and RW	FP
Hope Bay Belt	D80	25-Aug-10	DP, RM, DJ	307, 308	13	7511146	443514	2	-	86	level	glacial lacustrine	plain	hummocky	Silty Clay						1		TRUE	80	0	6	C	60	100	20		TM
Hope Bay Belt	D81	25-Aug-10	DP, RM, DJ	310, 311	13	7511148	442790	2	020	88	mid-slope	glacial lacustrine	slope	hummocky	Silty Clay								FALSE		0	4	C	100	3	70		BM
Hope Bay Belt	D82	25-Aug-10	DP, RM, DJ	313, 314	13	7511352	442400	7	010	99		moraine	ridge crest	frost boils	Loamy Sand								FALSE		20-35%	3	B	86	1	22		BL
Hope Bay Belt	D83	25-Aug-10	DP, RM, DJ	316, 317	13	7512071	442215	5	360	87	toe	glacial lacustrine	slope/plain	solifluct	Silt Loam	Mesic					1		FALSE		0	7	B	0.1	100	0		WM
Hope Bay Belt	D84	25-Aug-10	DP, RM, DJ	319, 320	13	7512149	442020		999	93	depression	moraine	slope	solifluct	Sandy Loam								FALSE		20-35%	4	C	100	10	33		BL
Hope Bay Belt	D85	25-Aug-10	DP, RM, DJ	322, 323	13	7512282	441343	5	240	86	mid-slope	glacial lacustrine	slope	hummocky	Silty Clay								TRUE	30	0	5	B	56	40	60		TM
Hope Bay Belt	D86	25-Aug-10	DP, RM, DJ	325, 326	13	7512126	440881	5	270	94	mid-slope	aeolian	slope	boulders	Sandy Loam			10	30				FALSE		20-35%	1	B	66	0.0001	22		DH
Hope Bay Belt	D87	25-Aug-10	DP, RM, DJ	328, 329	13	7512135	440699		999	95		glacial lacustrine	plain	hummocky	Silty Clay Loam								TRUE	40	0	5	C	36	96	40		TM
Hope Bay Belt	D88	25-Aug-10	DP, RM, DJ	331, 332	13	7512115	440559	3	variable	103		moraine	plateau	frost boils	Loamy Sand								FALSE		20-35%	3	B	97	0.5	5		BL
Hope Bay Belt	D89	26-Aug-10	DP, RM, DJ	334, 335	13	7521197	439153	5	150	105	upper	aeolian	ridge crest	br. outcrop/solifluct	Sandy Loam		10						FALSE		<20%	1	B	80	16	25		DH
Hope Bay Belt	D90	26-Aug-10	DP, RM, DJ	337, 338	13	7521045	439184	2	999	100	lower	glacial lacustrial	slope/plain	hummocky	Silty Clay				1		2		TRUE	55	0	7	B	53	80	20		TM
Hope Bay Belt	D91	26-Aug-10	DP, RM, DJ	341, 342	13	7520494	438937	3	250	104	toe	glacial lacustrine	slope	hummocky/frost boils	Silty Clay Loam								TRUE	35	0	6	B	70	55	40		TM
Hope Bay Belt	D92	26-Aug-10	DP, RM, DJ	344, 345	13	7520069	438700	2	999	98	depression	lacustrine	plain	hummocky	Silt Loam								TRUE	22	0	7	C	40	99	5		TM
Hope Bay Belt	D93	26-Aug-10	DP, RM, DJ	347, 348	13	7519798	438438	2	999	100	level	aeolian	slope	solifluct	Sandy Loam		25						FALSE		<20%	1	B	60	0.3	40		BL
Hope Bay Belt	D94	26-Aug-10	DP, RM, DJ	351, 352	13	7519705	438390		999	94		lacustrine	plain	frost boils	Silt Loam	Mesic					1		TRUE	28	0	6	B	45	98	5		WM
Hope Bay Belt	D95	26-Aug-10	DP, RM, DJ	354, 355	13	7519182	438451			105	level	aeolian	ridge crest	br. outcrop	Sandy Loam								FALSE		35-70%	0	B	4.5	2	10		RO
Hope Bay Belt	D96	26-Aug-10	DP, RM, DJ	357, 358	13	7518693	438453	2		99	level	glacial fluvial	slope	solifluct	Sandy Loam								TRUE	90	<20%	4	C	77	22	60		DH
Hope Bay Belt	D97	26-Aug-10	DP, RM, DJ	360, 361, 362	13	7518237	438410	20	200	101	lower	moraine	beach	frost boils	Sandy								FALSE		<20%	2	B	60	5	0	DH and ES	DH
Hope Bay Belt	D98	26-Aug-10	DP, RM, DJ	367, 368	13	7518000	438382	5	variable	102		moraine	ridge crest	br. outcrop	Sandy Loam								FALSE		20-35%	2	B	50	2	13	DH and RO	DH
Hope Bay Belt	D99	26-Aug-10	DP, RM, DJ	370, 371	13	7517814	438580	0	999	102	level	lacustrine	plain	hummocky	Silty Loam						1		TRUE	47	0	6	B	60	70	40		TM

Appendix 8b. 2010 Wetland Field Data

Project Name	Ground Plot #	Visual Plot #	Surveyor	Date	Photos	UTM Zone	Northing	Easting	Aspect	Elevation (m)	Slope (%)	Moisture Regime	Hydrodynamic Index	Soil Nutrient Regime	Meso Slope Position	Hydrogeomorphic Position	Mineral Soils	Mineral Soil Texture	Moisture Subclass Organic Soil	Organic Soil Texture	Horizon Thickness	Rooting Depth	Rooting Type	Von Post	Coarse Fragment Content	Water Colour	pH	Conductivity	Open Water %
Hope Bay Belt	W001	-	NB, BG	24/07/10	1175-1191	13	7558531	433107	134	28	3	W	St	C	Level	Basins & Hollows	Poorly	Clayey	Aqueous	-	-	1	SiCL	-	-	Blue-Green Clear	5	91	<5%
Hope Bay Belt	W002	-	NB, BG	24/07/10	1196-1223	13	7559766	432323	240	40	3	VW	St	C	Mid slope	Seepage Slopes	Very Poorly	Clayey	Aqueous	Mesic	10	10	Clay	4	-	Tea Coloured	7	406	5
Hope Bay Belt	W003	-	NB, BG	25/07/10	1236-1280	13	7546736	438080	210	39	2	VW	St	C	Toe	Ponds & Potholes	Very Poorly	Clayey	-	-	-	3	Clay	-	-	Blue-Green Clear	6.3	140	55
Hope Bay Belt	W004	-	NB, BG	25/07/10	1282-1315	13	7546930	437149	-	37	3	W	St	C	Level	Basins & Hollows	Very Poorly	Clayey	Peraquic	Mesic	-	25	Water	4	-	Tea Coloured	6.6	90	-
Hope Bay Belt	W005	-	NB, BG	25/07/10	1320-1342	13	7546420	436737	-	40	2	-	SL	C	Mid slope	-	Poorly	Clayey	Aqueous	Fibric	15	15	-	3	-	Tea Coloured	6.6	88	10
Hope Bay Belt	W006	-	NB, BG	25/07/10	1346-1363	13	7545980	436225	-	33	-	M	-	C	Level	Basins & Hollows	Imperfectly	Clayey	Peraquic	Mesic	25	25	SiCL	4	-	Tea Coloured	6.3	120	<5%
Hope Bay Belt	W007	-	NB, BG	25/07/10	1365-1390	13	7544865	437582	-	47	-	VW	St	C	Level	Basins & Hollows	Poorly	Clayey	Aqueous	Fibric	20	20	SiCL	3	-	Tea Coloured	-	-	-
Hope Bay Belt	W008	-	NB, BG	26/07/10	1405-1442	13	7545225	435688	-	32	-	VW	Sl	C	Depression	Ponds & Potholes	Very Poorly	Clayey	-	Mesic	18	33.5	-	4	<20%	Tea Coloured	-	90	90
Hope Bay Belt	W009	-	NB, BG	27/07/10	1538-1563	13	7545399	435745	-	28	-	VW	SL-ST	C	Depression	-	Very Poorly	-	-	Mesic	16	42	Permafrost	4	-	Tea Coloured	6.5	209	20
Hope Bay Belt	W010	-	NB, BG	27/07/10	1580-1609	13	7543768	436289	-	53	-	VW	ST-SL	C	Depression	-	Very Poorly	Clayey	Aqueous	Fibric	19	19	Clay	3	-	Green-Brown Clear	-	100	35
Hope Bay Belt	W011	-	NB, BG	27/07/10	1636-1675	13	7543750	437000	110	28	3	VW	-	B	Level	Basins & Hollows	Poorly	Loamy	Aquic	Fibric	15	15	Clay	3	-	-	-	0	0
Hope Bay Belt	W012	-	NB, BG	27/07/10	1676-1706	13	7544291	436526	500	46	3	VW	SL	D	Depression	Ponds & Potholes	Very Poorly	Loamy	Aqueous	Mesic	15	15	-	4	-	Tea Coloured	5.5	90	40
Hope Bay Belt	W013	-	NB, BM	28/07/10	1782-1820	13	7543055	434532	-	44	-	VW	St	C	Level	-	Very Poorly	Clayey	Aqueous	Mesic	20	20	Clay	4	<20%	Tea Coloured	5.6	100	5
Hope Bay Belt	W014	-	NB, BM	28/07/10	1835-1870	13	7541292	434765	-	53	-	VW	SL	C	Depression	-	Very Poorly	Loamy	Aqueous	Mesic	16	16	Soil Type	4	<20%	Tea Coloured	6.1	73	20
Hope Bay Belt	W015	-	NB, BM	28/07/10	1871-1921	13	7542304	431874	-	41	-	VW	St	Very Wet	Depression	Ponds & Potholes	-	-	Aqueous	Mesic	20	20	Perma	4	<20%	Tea Coloured	6.3	73	55
Hope Bay Belt	W016	-	NB, DA	29/07/10	1972-1993	13	7541882	434068	-	31	-	VW	SL	C	Level	Basins & Hollows	Very Poorly	Clayey	Aqueous	Fibric	8	8	Clay	3	-	Tea Coloured	6.5	153	40
Hope Bay Belt	W017	-	NB, DA	29/07/10	1994-2031	13	7538199	434917	10	-	3	VW	St	C	Level	Basins & Hollows	Very Poorly	Clayey	Aqueous	Fibric	28	28	Clayey	3	<20%	-	6.3	106	90
Hope Bay Belt	W018	-	NB, DA	29/07/10	2045-2084	13	7543081	434739	-	38	-	VW	SL	D	Depression	Ponds & Potholes	Very Rapidly	Silty	Aqueous	Fibric	24	24	SIL	3	-	Tea Coloured	6.3	94	45
Hope Bay Belt	W019	-	NB, DA	30/07/10	2091-2130	13	7532462	435215	-	75	-	VW	St	C	Depression	Basins & Hollows	Very Poorly	Clayey	Aqueous	Fibric	-	15	Clayey	3	-	Tea Coloured	6.1	111	30
Hope Bay Belt	W020	-	NB, DA	30/07/10	2131-2176	13	7530329	435601	-	91	-	VW	St	C	Depression	Basins & Hollows	Poorly	-	Peraquic	Mesic	35	35	0	5	-	Green-Brown Clear	5.5	109	-
Hope Bay Belt	W021	-	NB, DA	30/07/10	2178-2210	13	7527877	436898	-	99	-	VW	St	D	Depression	Ponds & Potholes	Very Rapidly	-	Aqueous	Mesic	45	30	-	5	-	Green-Brown Clear	7.4	154	70
Hope Bay Belt	W022	-	NB, DA	30/07/10	2212-2249	13	7526697	437442	-	83	-	VW	St	D	Depression	Ponds & Potholes	Very Poorly	-	Aqueous	Mesic	34	35	Water	4	-	Tea Coloured	7	242	70
Hope Bay Belt	W023	-	NB, DA	30/07/10	2250-2295	13	7523853	437918	-	89	4	VW	St	-	Depression	Seepage Slopes	Very Poorly	Loamy	Aqueous	Mesic	19	19	Soil Type	4	-	Tea Coloured	6.5	180	<5%
Hope Bay Belt	W024	-	NB, JA	01/08/10	2300-2323	13	7520008	438277	-	92	-	-	-	-	Level	Basins & Hollows	Poorly	-	-	-	L5	L5	-	-	-	-	-	-	-
Hope Bay Belt	W025	-	NB, JA	02/08/10	013-017	13	7515762	439350	-	96	-	W	-	C	Depression	Basins & Hollows	Very Poorly	Loamy	Peraquic	Mesic	10	10	SC	5	-	-	-	-	-
Hope Bay Belt	W026	-	NB, KI	02/08/10	2405-2439	13	7502555	441360	30	88	3	VW	St	C	Lower slope	-	Very Poorly	Clayey	Aqueous	Mesic	25	25	-	4	-	Green-Brown Clear	6	73	-
Hope Bay Belt	-	W026b	NB, KI	02/08/10	2440-2457	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	W026c	NB	02/08/10	2458-2476	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	W027	-	NB, KI	02/08/10	2477-2517	13	7503024	446245	310	125	5	W	St	C	Mid slope	Seepage Slopes	Poorly	Loamy	Peraquic	Mesic	15	15	-	4	-	Tea Coloured	6	127	-
Hope Bay Belt	W028	-	NB	03/08/10	2518-2545	13	7502880	447763	-	118	-	-	-	-	Level	Basins & Hollows	Very poorly	Clayey	-	-	-	-	-	-	<20%	Tea Coloured	4.5	46	<5%
Hope Bay Belt	W029	-	NB	03/08/10	2546-2573	13	7503251	447387	-	116	2	M	St	B	Level	-	-	-	-	-	-	-	-	-	-	-	6	35	0
Hope Bay Belt	W030	-	NB	03/08/10	2574-2598	13	7502953	447263	320	121	4	3	-	B	Lower slope	-	Mod. Well	Loamy	-	-	-	<1	-	-	<20%	-	-	-	-
Hope Bay Belt	W031	-	NB	03/08/10	2599-2623	13	7503428	442936	-	69	-	VW	St	C	Depression	Ponds & Potholes	Very poorly	Clayey	Aqueous	Fibric	10	10	SiCL	3	<20%	Tea Coloured	6.5	180	45
Hope Bay Belt	W032	-	NB	03/08/10	2624-2640	13	7503604	442900	-	71	-	VW	St	C	Level	Basins & Hollows	Very poorly	-	Aqueous	-	-	1	Clay	-	-	Tea Coloured	5.5	88	15
Hope Bay Belt	W033	-	NB	04/08/10	2647-2679	13	7509865	444994	-	86	-	VW	St	C	Mid slope	Basins & Hollows	Very poorly	Clayey	-	-	2	<2	Clay	-	<20%	Green-Brown Clear	4.5	47	4
Hope Bay Belt	W034	-	NB	04/08/10	2680-2715	13	7508472	445067	-	84	-	-	-	-	Level	-	Imperfectly	Clayey	-	-	2	2	Soil Type	-	-	-	5.5	82	-
Hope Bay Belt	W035	-	NB	04/08/10	2745-2763	13	7509353	445712	-	94	-	VW	St	C	Depression	Basins & Hollows	Very poorly	Clayey	Aqueous	-	20	20	Clay	4	-	Tea Coloured	4.5	54	5
Hope Bay Belt	W036	-	NB	04/08/10	657-677	13	7508268	445878	-	102	-	VW	St	C	Depression	Basins & Hollows	Very poorly	Clayey	Aqueous	Mesic	18	18	SiC	4	-	Tea Coloured	5	63	<5%
Hope Bay Belt	W037	-	NB	04/08/10	678-702	13	7507013	444618	360	84	4	VW	Sl	-	Lower slope	Basins & Hollows	Well	Loamy	-	-	18	1	O	-	<20%	Tea Coloured	5	78	-
Hope Bay Belt	W038	-	NB	04/08/10	706-732	13	7506497	445538	290	100	3	VW	St	C	Mid slope	Basins & Hollows	Very poorly	Clayey	Aqueous	Humic	21	21	-	7	<20%	Tea Coloured	5.5	65	<5%
Hope Bay Belt	W039	-	NB	05/08/10	2764-2784	13	7506019	444566	-	88	2	VW	St	C	Depression	Basins & Hollows	Very poorly	Clayey	Aqueous	-	14	14	Water	4	<20%	Green-Brown Clear	5	82	<5%
Hope Bay Belt	W040	-	NB	05/08/10	2818-2837	13	7504688	443219	310	72	4	VW	St	C	Mid slope	-	Very poorly	Clayey	Aqueous	-	15	15	Clay	4	<20%	-	5	74	0
Hope Bay Belt	W041	-	NB	05/08/10	2838-2867	13	7057359	446507	-	104	-	VW	St	C	Depression	Basins & Hollows	Very poorly	Loamy	Aqueous	Mesic	15	15	-	6	<20%	Tea Coloured	5	65	0
Hope Bay Belt	W042	-	NB	05/08/10	2903-2922, 755-783	13	7511001	441601	-	86	-	VW	St	C	Level	Basins & Hollows	Very poorly	-	Aqueous	-	-	26	R	3	-	Tea Coloured	5	94	0
Hope Bay Belt	W043	-	NB	05/08/10	2925-2944, 766-819	13	7513547	440329	-	83	4	-	-	-	Mid slope	Basins & Hollows	-	Loamy	Subaquic	Mesic	25	25	-	4	<20%	-	-	-	-
Hope Bay Belt	W044	-	NB	06/08/10	2969-2992	13	7503799	445868	-	121	-	VW	St	C	Depression	Basins & Hollows	Very poorly	Loamy	-	-	-	2	Water	-	<20%	Tea Coloured	6	78	<5%
Hope Bay Belt	W045	-	NB	06/08/10	2993-3016	13	7508208	444120	270	82	4	VW	St	C	Mid slope	Basins & Hollows	Very poorly	-	Aqueous	Mesic	19	19	Rock	4	-	Tea Coloured	6	149	0
Hope Bay Belt	W046	-	NB	06/08/10	2993-3016	13	7542320	434907	350	54	4	-	-	B	Level	Basins & Hollows	-	Clayey	-	Mesic	15	15	Clay	5	-	-	-	-	-
Hope Bay Belt	W047	-	NB	07/08/10	3052-3104	13	7549411	433545	-	54	-	VW	St	C	Depression	Seepage Slopes	Very poorly	Clayey	Aqueous	Mesic	19	19	Clay	4	-	Tea Coloured	6.5	110	-
Hope Bay Belt	-	W047b	NB	07/08/10	3086-3096	13	7549464	433581	-	60	-	VW	St	C	Depression	Ponds & Potholes	Very poorly	Clayey	Aqueous	-	-	-	-	-	-	Tea Coloured	6	-	30
Hope Bay Belt	W048	-	NB	07/08/10	3133-3156	13	7548781	434033	-	44	-	-	-	-	Level	Seepage Slopes	Poorly	Clayey	Aquic	Fibric	6	6	SC	2	-	-	4.5	-	-
Hope Bay Belt	-	W048b	NB	07/08/10	3108-3132	13	7548792	434083	-	48	-	-	-	-	Level	Basins & Hollows	Well	-	-	-	29	29	-	-	-	-	4.5	-	5
Hope Bay Belt	W049	-	NB	07/08/10	3164-3187	13	7549422	436207	-	24	-	VW	St	C	Level	Ponds & Potholes	Very poorly	-	Aqueous	Fibric	23	23	-	3	-	Tea Coloured	7	143	20
Hope Bay Belt	W050	-	NB	07/08/10	3198-3231	13	7541440	433585	-	32	-	VW	St	C	Level	Ponds & Potholes	Very poorly	Clayey	-	-	-	2	-	-	-	Tea Coloured	7	132	40
Hope Bay Belt	W051	-	NB	08/08/10	3242-3262	13	7561930	432026	-	11	-	VW	St	C	Level	Basins & Hollows	Very poorly	Clayey	Aqueous	Mesic	8	8	Clay	4	<20%	Tea Coloured	6	242	30
Hope Bay Belt	W052	-	NB	08/08/10	3263-3282	13	7559490	435310	-	41	-	-	-	B	Level	Basins & Hollows	-	Loamy	-	-	3	3	-	3	<20%	-	4	-	10

Appendix 8b. 2010 Wetland Field Data

Project Name	Ground Plot #	Visual Plot #	Surveyor	Date	Photos	UTM Zone	Northing	Easting	Aspect	Elevation (m)	Slope (%)	Moisture Regime	Hydrodynamic Index	Soil Nutrient Regime	Meso Slope Position	Hydrogeomorphic Position	Mineral Soils	Mineral Soil Texture	Moisture Subclass Organic Soil	Organic Soil Texture	Horizon Thickness	Rooting Depth	Rooting Type	Von Post	Coarse Fragment Content	Water Colour	pH	Conductivity	Open Water %
Hope Bay Belt	-	REC1	NB	08/06/10	-	13	7502999.98	440900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	REC2	NB	08/06/10	-	13	7504749.98	443000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	REC3	NB	08/06/10	-	13	7503499.98	443000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V10	NB	07/27/10	1519-1533	13	7545914.67	435699.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V11	NB	07/27/10	1568-1571	13	7543284.38	436131	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V12	NB	07/27/10	1572-1579	13	7543559.03	436122.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V13	NB	07/27/10	1610-1616	13	7543775.03	436377.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V14	NB	27-JUL-10 1		13	7543764.05	436615.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V15	NB	07/27/10	-	13	7544743.5	436703.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V16	NB	07/27/10	1754 to 1762	13	7548731.61	435621.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V17	NB	07/27/10	1754 to 1762	13	7551173.04	435651.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V18	NB	07/27/10	1754 to 1762	13	7552574.67	434919.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V19	NB	07/28/10	-	13	7541367.02	434477.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V2-	NB	07/25/10	-	13	7546364.9	436702	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V20	NB	07/28/10	1914-1915	13	7541299.18	434603.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V21	NB	07/28/10	1916-1919	13	7542198.55	431868.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V23	NB	07/28/10	-	13	7542047.21	431955.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V24	NB	07/28/10	-	13	7541871.77	432061.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V25	NB	07/29/10	-	13	7538084.37	434924	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V27	NB	07/30/10	2269-2272	13	7523868.3	437862.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V28	NB	08/01/10	-	13	7520291.67	438236.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V29	NB	08/01/10	-	13	7520338.39	438262.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V32	NB	08/04/10	-	13	7508670.47	445206.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V33	NB	08/04/10	-	13	7508745.96	445265.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V34	NB	08/04/10	-	13	7508803.21	445303.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V35	NB	08/04/10	-	13	7509003.61	445423.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V36	NB	08/04/10	-	13	7509094.76	445502.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V37	NB	08/04/10	-	13	7509226.39	445606.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V38	NB	08/04/10	2763-2762	13	7508194.19	445784.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V39	NB	08/05/10	-	13	7506009.31	444616.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V4	NB	07/26/10	-	13	7545244.71	435714.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V40	NB	08/05/10	-	13	7505924.52	444808.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V41	NB	08/05/10	-	13	7507276.84	446518.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V42	NB	08/05/10	-	13	7502766.38	446717.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V43	NB	08/05/10	-	13	7503158.28	446420.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V44	NB	08/05/10	-	13	7503140.16	446222.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V5	NB	07/26/10	-	13	7545328.14	435728.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V6	NB	07/26/10	-	13	7545348.31	435724.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V7	NB	07/26/10	-	13	7545443.13	435717.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hope Bay Belt	-	V9	NB	07/26/10	-	13	7545617.21	435641.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 8b. 2010 Wetland Field Data

Project Name	Ground Plot #	Visual Plot #	Surveyor	Date	Depth to Water	Structural Stage	W1 (%)	WL1 Class	WL1 Association	WL1 Form	Map Unit1	WL2 (%)	WL2 Class	WL2 Association	WL2 Form	Map Unit2	WL3 (%)	WL3 Class	WL3 Association	WL3 Form	Map Unit3	Shrub (%)	Forb (%)	Bryophyte (%)
Hope Bay Belt	W001	-	NB, BG	24/07/10	0	2b	100	Fen	Willow - Cotton Grass	horizontal fen	TM (rich)	-	-	-			-	-	-			30	60	25
Hope Bay Belt	W002	-	NB, BG	24/07/10	0	2b	100	Fen	Cotton grass	horizontal fen	WM	-		-			-	-	-			4	45	5
Hope Bay Belt	W003	-	NB, BG	25/07/10	30	2	55	Shallow Open Water	Mares tail	-	-	45	marsh	Sedge	lacustrine marsh	EM	-	-	-			7	50	50
Hope Bay Belt	W004	-	NB, BG	25/07/10	0	2	100	Fen	Cotton grass	lowland polygon fen	WM	-	-	-			-	-	-			35	70	12
Hope Bay Belt	W005	-	NB, BG	25/07/10	-	2	100	Fen	Cotton grass	horizontal fen	TM	-	-	-			-	-	-			43	40	0
Hope Bay Belt	W006	-	NB, BG	25/07/10	0	2b/3a	40	Fen	Cotton grass - Willow - Sedge	horizontal fen	TM	30	fen	-	lowland polygon fen	WM	30	bog		lowland polygon bog	BM	70	30	5
Hope Bay Belt	W007	-	NB, BG	25/07/10	-	2b/3a	60	Fen	Cotton grass	horizontal fen	TM	40	fen	-	lowland polygon fen	WM	-	-	-			<5	15	5
Hope Bay Belt	W008	-	NB, BG	26/07/10	0	2b	90	Shallow Open Water	Mares tail	horizontal fen	-	10	marsh	Water sedge	lacustrine marsh	EM	-	-	-			2	55	30
Hope Bay Belt	W009	-	NB, BG	27/07/10	0	2	60	Fen	Water sedge - Cotton grass	lowland polygon fen	WM	20	fen	Willow	lowland polygon fen	TM	20	bog	-	lowland polygon bog	BM	T	55	10
Hope Bay Belt	W010	-	NB, BG	27/07/10	0	2	50	Marsh	Water sedge	lacustrine marsh	EM	50	fen	Cotton grass	horizontal fen	WM	-	-	-			25	80	8
Hope Bay Belt	W011	-	NB, BG	27/07/10	2	2/3a	70	Bog	Sedge - Dwarf labrador tea	lowland polygon bog	BR	30	fen	Cotton grass	lowland polygon fen	WM	-	-	-			25	35	35
Hope Bay Belt	W012	-	NB, BG	27/07/10	0	2c/3a	60	Marsh	Water sedge	lacustrine marsh	EM	30	Shallow Open Water	Mare's tail			10	bog	-	lowland polygon bog	BR	3	60	10
Hope Bay Belt	W013	-	NB, BM	28/07/10	0	2b	60	Fen	Water sedge - Cotton grass	lowland polygon fen	WM	20	Shallow Open Water	Open water			20	bog	-	peat mound bog	BR	20	60	20
Hope Bay Belt	W014	-	NB, BM	28/07/10	0	-	80	Fen	Sedge	lowland polygon fen	WM	20	bog	-	lowland polygon bog	BM	-	-	-			30	75	18
Hope Bay Belt	W015	-	NB, BM	28/07/10	0	2	50	Marsh	Sedge	lacustrine marsh	EM	30	Shallow Open Water	Open water			20	fen	-	lowland polygon fen	WM	5	45	50
Hope Bay Belt	W016	-	NB, DA	29/07/10	0	2	80	Fen	Sedge	lowland polygon fen	WM	10	marsh	Sedge	lacustrine marsh	EM	10	bog	-	lowland polygon bog	BM	8	45	55
Hope Bay Belt	W017	-	NB, DA	29/07/10	0	2c	70	Fen		lowland polygon fen	WM	30	bog		lowland polygon bog	BR	-	-	-			5	30	15
Hope Bay Belt	W018	-	NB, DA	29/07/10	0-2	2c	40	Marsh	Sedge - Rush	lowland polygon fen	WM	30	bog		lowland polygon bog	BM	30	marsh	-	lacustrine marsh	EM	0	30	5
Hope Bay Belt	W019	-	NB, DA	30/07/10	0	2	70	Fen	Cotton grass - Willow - Sedge	lowland polygon fen	WM	30	bog	-	lowland polygon bog	BM	-	-	-			20	45	10
Hope Bay Belt	W020	-	NB, DA	30/07/10	1	2	70	Fen	Sedge - Rush	lowland polygon fen	WM	30	bog	-	palsa bog	BR	-	-	-			6	25	55
Hope Bay Belt	W021	-	NB, DA	30/07/10	0	2 and 2b	40	fen	Water sedge	lowland polygon fen	WM	40	bog		peat mound bog	BR	20	marsh	-	lacustrine marsh	EM	T	35	30
Hope Bay Belt	W022	-	NB, DA	30/07/10	0	2b	70	fen	Water sedge	lowland polygon fen	WM	30	bog	-	peat mound bog	BR	-	-	-			2	25	35
Hope Bay Belt	W023	-	NB, DA	30/07/10	0	2 and 3a	80	Fen	Water sedge - Cotton grass	lowland polygon fen	WM	20	bog	-	peat mound bog	BR	-	-	-			60	30	3
Hope Bay Belt	W024	-	NB, JA	01/08/10	-	3a	60	Bog	Dwarf birch - Dwarf labrador tea	lowland polygon bog	BM	40	fen	Cotton grass	lowland polygon fen	WM	-	-	-			85	5	40
Hope Bay Belt	W025	-	NB, JA	02/08/10	-	2b	70	bog	Dwarf birch - Dwarf labrador tea	lowland polygon bog	BR	30	fen		lowland polygon fen	WM	-	-	-			25	35	8
Hope Bay Belt	W026	-	NB, KI	02/08/10	0	2b	70	Fen	Sedge - Dwarf labrador tea	lowland polygon fen	WM	30	bog	-	palsa bog	BM	-	-	-			15	25	3
Hope Bay Belt	-	W026b	NB, KI	02/08/10	-	3a		-	-			-	-	-			-	-	-			-		
Hope Bay Belt	-	W026c	NB	02/08/10	-	-	80	Marsh	Water sedge		EM	20	fen	Cotton grass	horizontal fen		-	-	-			4	30	5
Hope Bay Belt	W027	-	NB, KI	02/08/10	0	2b	100	Fen	Sedge	horizontal fen	WM	-	-	-			-	-	-			2	14	8
Hope Bay Belt	W028	-	NB	03/08/10	70	3a (2b)	100	Bog	Dwarf birch - Dwarf labrador tea	lowland polygon bog		-	-	-			-	-	-			19	10	9
Hope Bay Belt	W029	-	NB	03/08/10	-	3a(1)	100	tundra			BL	-	-	-			-	-	-			10	5	30
Hope Bay Belt	W030	-	NB	03/08/10	>55	3a(1)		-	-			-	-	-			-	-	-			50	0	25
Hope Bay Belt	W031	-	NB	03/08/10	0	2b	50	Fen	Water sedge	lowland polygon fen	WM	40	bog	-	palsa bog	BR	10	marsh	-	lacustrine marsh	EM	3	20	5
Hope Bay Belt	W032	-	NB	03/08/10	0	2b/3a	50	Fen	Water sedge	lowland polygon fen	WM	40	bog	-	peat mound bog	BR	10	marsh	-	lacustrine marsh	EM	8	15	2
Hope Bay Belt	W033	-	NB	04/08/10	5	3a (2b)	100	Bog	Cotton grass - Willow - Sedge	peat mound bog	BM	-	-	-			-	-	-			40	18	30
Hope Bay Belt	W034	-	NB	04/08/10	-	3a (2b)	60	Bog	Dwarf birch - Dwarf labrador tea	peat mound bog	BR	40	fen	Cotton grass - sedge	lowland polygon fen	WM	10	Shallow Open Water	Open water			30	18	6
Hope Bay Belt	W035	-	NB	04/08/10	0	2c	70	Bog	Cotton grass - Peat-moss	lowland polygon bog	BR	30	fen	Cotton grass - sedge	lowland polygon fen	WM	-	-	-			3	10	55
Hope Bay Belt	W036	-	NB	04/08/10	0	2b	100	Fen	Carex chor.	lowland polygon fen	WM	-	-	-			-	-	-			0	25	6
Hope Bay Belt	W037	-	NB	04/08/10	65	3a(1)		-	-			-	-	-			-	-	-			-		
Hope Bay Belt	W038	-	NB	04/08/10	12	2b	70	bog		lowland polygon bog	BR	30	fen	Sedge - Rush	lowland polygon fen	WM	-	-	-			5	10	5
Hope Bay Belt	W039	-	NB	05/08/10	1	2b	80	Fen	Cotton grass	lowland polygon fen	WM	20	bog	-	peat mound bog	BR	-	-	-			3	15	5
Hope Bay Belt	W040	-	NB	05/08/10	0	2b	100	Fen	Water sedge - Cotton grass	horizontal fen	WM	-	-	-			-	-	-			3	12	0
Hope Bay Belt	W041	-	NB	05/08/10	0	2b	90	Fen	Water sedge - Cotton grass	horizontal fen	WM	10	fen	-	tussock tundra	TM	-	-	-			5	25	10
Hope Bay Belt	W042	-	NB	05/08/10	0	2c	100	Marsh	Water sedge	lacustrine marsh	EM	-	-	-			-	-	-			0	25	15
Hope Bay Belt	W043	-	NB	05/08/10	-	3a	60	Bog	Dwarf birch - Dwarf labrador tea	lowland polygon bog	BM	40	fen	Cotton grass	lowland polygon fen	WM	-	-	-			55	3	35
Hope Bay Belt	W044	-	NB	06/08/10	0	2b	80	Fen	Cotton grass	horizontal fen	TM	20	marsh	-	slope marsh	EM	-	-	-			1	25	5
Hope Bay Belt	W045	-	NB	06/08/10	0	2b	80	Fen	Water sedge - Cotton grass	lowland polygon fen	WM	20	bog	-	peat mound bog	BR	-	-	-			5	10	5
Hope Bay Belt	W046	-	NB	06/08/10	-	3a	100	tundra	Willow - Cotton Grass	tussock tundra	TM	-	-	-			-	-	-			35	10	15
Hope Bay Belt	W047	-	NB	07/08/10	0	-	60	Fen	Cotton grass - Sedge	horizontal fen	WM	30	Marsh	Water sedge - rush	slope marsh	EM	10	bog	Dwarf birch	lowland polygon bog	BM	3	15	2
Hope Bay Belt	-	W047b	NB	07/08/10	0	2c	100	Marsh	Water sedge	slope marsh	EM	-	-	-			-	-	-			0	15	3
Hope Bay Belt	W048	-	NB	07/08/10	-	1(3a)	70	Bog	Dwarf birch - Dwarf labrador tea	peat mound bog	BR	30	fen	-	lowland polygon fen	WM	-	-	-			10	15	45
Hope Bay Belt	-	W048b	NB	07/08/10	> 40	3a(1)	100	Bog	Dwarf birch - Dwarf labrador tea	peat mound bog	BR	-	-	-			-	-	-			15	3	10
Hope Bay Belt	W049	-	NB	07/08/10	0	2c	60	Marsh	Carex chor.	slope marsh	EM	30	fen		horizontal fen	WM	10	bog	-	peat mound bog	BR	0	15	5
Hope Bay Belt	W050	-	NB	07/08/10	0	2c	70	Marsh	Carex chor.	basin marsh	EM	30	Shallow Open Water	Marsh cinquefoil			-	-	-			0	15	4
Hope Bay Belt	W051	-	NB	08/08/10	0	2b	70	Fen	Water sedge - Cotton grass	lowland polygon fen	WM	30	bog	-	peat mound bog	BR	-	-	-			3	15	0
Hope Bay Belt	W052	-	NB	08/08/10	30	1(3a)	60	Bog	Cotton grass - Peat-moss	lowland polygon bog	BR	40	fen	Cotton grass	horizontal fen	WM	-	-	-			8	5	30

Appendix 8b. 2010 Wetland Field Data

Project Name	Ground Plot #	Visual Plot #	Surveyor	Date	Depth to Water	Structural Stage	W1 (%)	WL1 Class	WL1 Association	WL1 Form	Map Unit1	WL2 (%)	WL2 Class	WL2 Association	WL2 Form	Map Unit2	WL3 (%)	WL3 Class	WL3 Association	WL3 Form	Map Unit3	Shrub (%)	Forb (%)	Bryophyte (%)
Hope Bay Belt	-	REC1	NB	08/06/10	-																			
Hope Bay Belt	-	REC2	NB	08/06/10	-																			
Hope Bay Belt	-	REC3	NB	08/06/10	-																			
Hope Bay Belt	-	V10	NB	07/27/10	-	2		DH																
Hope Bay Belt	-	V11	NB	07/27/10	-	2		BM																
Hope Bay Belt	-	V12	NB	07/27/10	-	2b		WM	Carex															
Hope Bay Belt	-	V13	NB	07/27/10	-	3a		Bl																
Hope Bay Belt	-	V14	NB	27-JUL-10 1	-	2		WM	Carex and Erio ang															
Hope Bay Belt	-	V15	NB	07/27/10	-	2	50	WM				30	WM	Erio Fen		Erio Fen	20	Dry shrub	Betula and Ledum					
Hope Bay Belt	-	V16	NB	07/27/10	-			see photos																
Hope Bay Belt	-	V17	NB	07/27/10	-			see photos																
Hope Bay Belt	-	V18	NB	07/27/10	-			see photos																
Hope Bay Belt	-	V19	NB	07/28/10	-	1	70	RO				20	Betula-Salix				10	DH						
Hope Bay Belt	-	V2-	NB	07/25/10	-			-																
Hope Bay Belt	-	V20	NB	07/28/10	-	2		WM																
Hope Bay Belt	-	V21	NB	07/28/10	-	2		WM	Carex															
Hope Bay Belt	-	V23	NB	07/28/10	-																			
Hope Bay Belt	-	V24	NB	07/28/10	-																			
Hope Bay Belt	-	V25	NB	07/29/10	-	2b		WM	Carex chor.															
Hope Bay Belt	-	V27	NB	07/30/10	-																			
Hope Bay Belt	-	V28	NB	08/01/10	-																			
Hope Bay Belt	-	V29	NB	08/01/10	-																			
Hope Bay Belt	-	V32	NB	08/04/10	-	2b		WM																
Hope Bay Belt	-	V33	NB	08/04/10	-	3a	70	BM and TM				30	Fen	Eriophorum		riophorur								
Hope Bay Belt	-	V34	NB	08/04/10	-	2b		TM																
Hope Bay Belt	-	V35	NB	08/04/10	-	a in moist depressions		RO																
Hope Bay Belt	-	V36	NB	08/04/10	-	2		WM																
Hope Bay Belt	-	V37	NB	08/04/10	-	1		RO																
Hope Bay Belt	-	V38	NB	08/04/10	-	1		RO																
Hope Bay Belt	-	V39	NB	08/05/10	-	a in moist depressions		RO																
Hope Bay Belt	-	V4	NB	07/26/10	-	2		EM																
Hope Bay Belt	-	V40	NB	08/05/10	-	2		TM																
Hope Bay Belt	-	V41	NB	08/05/10	-	1		RO																
Hope Bay Belt	-	V42	NB	08/05/10	-	a in moist depressions		RO																
Hope Bay Belt	-	V43	NB	08/05/10	-	1(3)		RO																
Hope Bay Belt	-	V44	NB	08/05/10	-																			
Hope Bay Belt	-	V5	NB	07/26/10	-	2		WM	Carex erio.															
Hope Bay Belt	-	V6	NB	07/26/10	-	2	50	EM				30	Fen-Erio				20	Shrubby						
Hope Bay Belt	-	V7	NB	07/26/10	-																			
Hope Bay Belt	-	V9	NB	07/26/10	-																			

Appendix 9

Occurrence and Distribution of Wetland Forms in the Local Study Area

Engineers and Scientists

Appendix 9. Occurrence and Distribution of Wetland Forms in the Local Study Area

Location	Plot	Primary Wetland Form or Ecosystem Unit	Secondary Wetland Form or Ecosystem Unit	Tertiary Wetland Form or Ecosystem Unit
Doris Camp				
	W001	horizontal fen	-	-
	W002	horizontal fen	-	-
	W046	tussock tundra	-	-
	W047	horizontal fen	slope marsh	lowland polygon bog
	W048	peat mound bog	lowland polygon fen	-
	W049	slope marsh	horizontal fen	peat mound bog
	W051	lowland polygon fen	peat mound bog	-
	W052	lowland polygon bog	horizontal fen	-
Mid Belt				
	W003	shallow open water	lacustrine marsh	-
	W004	lowland polygon fen	-	-
	W005	horizontal fen	-	-
	W006	horizontal fen	lowland polygon fen	lowland polygon bog
	W007	horizontal fen	lowland polygon fen	-
	W008	horizontal fen	lacustrine marsh	-
	W009	lowland polygon fen	lacustrine marsh	lowland polygon bog
	W010	lacustrine marsh	horizontal fen	-
	W011	lowland polygon bog	lowland polygon fen	-

Appendix 9. Occurrence and Distribution of Wetland Forms in the Local Study Area

Location	Plot	Primary Wetland Form or Ecosystem Unit	Secondary Wetland Form or Ecosystem Unit	Tertiary Wetland Form or Ecosystem Unit
	W012	lacustrine marsh	shallow open water	lowland polygon bog
	W013	lowland polygon fen	shallow open water	peat mound bog
	W014	lowland polygon fen	lowland polygon bog	-
	W015	lacustrine marsh	-	lowland polygon fen
	W016	lowland polygon fen	lacustrine marsh	lowland polygon bog
	W017	lowland polygon fen	lowland polygon bog	-
	W018	lowland polygon fen	lowland polygon bog	lacustrine marsh
	W019	lowland polygon fen	lowland polygon bog	-
	W020	lowland polygon fen	palsa bog	-
	W021	lowland polygon fen	peat mound bog	lacustrine marsh
	W022	lowland polygon fen	peat mound bog	-
	W023	lowland polygon fen	peat mound bog	-
	W024	lowland polygon bog	lowland polygon fen	-
	W050	basin marsh	shallow open water	-
Boston Camp				
	W025	lowland polygon bog	lowland polygon fen	-
	W026	lowland polygon fen	palsa bog	-
	W027	horizontal fen	-	-

Appendix 9. Occurrence and Distribution of Wetland Forms in the Local Study Area

Location	Plot	Primary Wetland Form or Ecosystem Unit	Secondary Wetland Form or Ecosystem Unit	Tertiary Wetland Form or Ecosystem Unit
	W028	lowland polygon bog	-	-
	W029	tussock meadow	-	-
	W030	dwarf birch-Labrador tea-lichen	-	-
	W031	lowland polygon fen	palsa bog	lacustrine marsh
	W032	lowland polygon fen	peat mound bog	lacustrine marsh
	W033	peat mound bog	-	-
	W034	peat mound bog	lowland polygon fen	-
	W035	lowland polygon bog	lowland polygon fen	-
	W036	lowland polygon fen	-	-
	W037	tussock tundra	seepage marsh	-
	W038	lowland polygon bog	lowland polygon fen	-
	W039	lowland polygon fen	peat mound bog	-
	W040	horizontal fen	-	-
	W041	horizontal fen	tussock tundra	-
	W042	lacustrine marsh	-	-
	W043	lowland polygon bog	lowland polygon fen	-
	W044	horizontal fen	slope marsh	-
	W045	lowland polygon fen	peat mound bog	-

- No form observed

Appendix 10

2010 Plant Species Identified during Field Surveys

Rescan™
Engineers and Scientists

Appendix 10. 2010 Plant Species Identified during Field Surveys

Scientific Name	Common Name	Lifeform Type
Achillea sp.	yarrow	forb
Andromeda polifolia	bog rosemary	forb
Androsace septentrionalis	fairy candelabra	forb
Arctagrostis latifolia	ploar grass	gramminoid (grass)
Arctoparmelia centrifuga	rippled rockfrog	lichen
Arctoparmelia sp.	ring lichen	lichen
Arctostaphylos alpina	black bearberry	shrub
Arctostaphylos rubra	red bearberry	shrub
Armeria maritima	thrift	forb
Arnica sp.	arnica	forb
Astragalus alpinus	alpine milk-vetch	forb
Astragalus sp.	vetch species	forb
Aulacomnium palustre	glow moss	moss
Aulacomnium turgidum	mountain groove-moss	moss
Barbilophozia sp.	liverwort	moss
Betula glandulosa	dwarf birch	shrub
Betula nana	scrub birch	shrub
Bistorta vivipara	alpine bistort	forb
Calamagrostis sp.	reedgrass	gramminoid (grass)
Calliergon giganteum	giant water-moss	moss
Caltha palustris	yellow marsh-marigold	forb
Carex albonigra	two-toned sedge	gramminoid (sedge)
Carex aquatilis	water sedge	gramminoid (sedge)
Carex bigelowii	Bigelow's sedge	gramminoid (sedge)
Carex chordorrhiza	cordroot sedge	gramminoid (sedge)
Carex limosa	shore sedge	gramminoid (sedge)
Carex nardina var. hepburnii	Hepburn's sedge	gramminoid (sedge)
Carex saxatilis	russet sedge	gramminoid (sedge)
Carex vaginata	sheathed sedge	gramminoid (sedge)
Carex membranacea	fragile sedge	gramminoid (sedge)
Carex fuliginosa spp. misandra	short-leaved sedge	gramminoid (sedge)
Carex rotundata	round sedge	gramminoid (sedge)
Carex rariflora	looseflower alpine sedge	gramminoid (sedge)
Cassiope tetragona	four-angled mountain-heather	shrub
Cassiope tetragona	four-angled mountain-heather	forb
Cerastium sp.	chickweed	forb
Cetraria cucullata	furled paperdoll	lichen
Cetraria nivalis	ragged paperdoll	lichen
Cladina sp.	reindeer lichen	lichen
Cladonia ecmocyna	orange-foot cladonia	lichen
Cladonia pyxidata	pebbled pixie-cup	lichen
Cladonia sp.	clad lichen	lichen
Cystopteris fragilis	fragile fern	fern
Dactylina arctica	brown finger	lichen
Dicranum elongatum	dense heron`s-bill moss	moss

Appendix 10. 2010 Plant Species Identified during Field Surveys

Scientific Name	Common Name	Lifeform Type
Drepanocladus aduncus	common hook-moss	moss
Drepanocladus revolvens	limprichita moss	moss
Drepanocladus uncinatus	stickle moss	moss
Dryas integrifolia	arctic avens	shrub
Dryopteris fragrans	fragrant wood	Fern
Empetrum nigrum	crowberry	shrub
Epilobium angustifolium	fireweed	forb
Epilobium latifolium	broad-leaved willowherb	forb
Equisetum arvense	common horsetail	fern ally
Equisetum fluviatile	swamp horsetail	fern ally
Eriophorum angustifolium	narrow-leaved cotton-grass	gramminoid (sedge)
Eriophorum callitrix	arctic cotton-grass	gramminoid (sedge)
Eriophorum scheuchzeri	Scheuchzer's cotton-grass	gramminoid (sedge)
Eriophorum scheuchzeri	Scheuchzer's cotton-grass	gramminoid (sedge)
Eriophorum vaginatum	sheathed cotton-grass	gramminoid (sedge)
Festuca altaica	Altai fescue	gramminoid (grass)
Festuca sp.	fescue	gramminoid (grass)
Flavocetraria cucullata	curled snow	lichen
Hedysarum mackenzii	northern sweet-vetch	forb
Hedysarum sp.	sweet vetch	forb
Hierochloe alpina	alpine sweet	gramminoid (grass)
Hippuris vulgaris	common mare's-tail	forb
Kalmia microphylla	western bog-laurel	shrub
Ledum palustre ssp. decumbens	northern Labrador tea	shrub
Lycopodium sp.	clubmoss	Fern
Orthilia secunda	one-sided wintergreen	forb
Oxyria digyna	mountain sorrel	forb
Oxytropis arctica	arctic locoweed	forb
Oxytropis maydelliana	Maydell's locoweed	forb
Papaver radicatum	arctic poppy	forb
Pedicularis arctica	arctic lousewort	forb
Pedicularis capitata	capitate lousewort	forb
Pedicularis sudetica	Sudeten lousewort	forb
Peltigera aphthosa	freckle pelt	lichen
Peltigera sp.	pelt lichen	lichen
Petasites frigidus	sweet coltsfoot	forb
Petasites sagittatus	arrow-leaved coltsfoot	forb
Phleum pratense	common timothy	gramminoid (grass)
Pleurozium schreberi	red-stemmed feathermoss	moss
Poa sp.	bluegrass	gramminoid (grass)
Polytrichum strictum	bog haircap moss	moss
Potentilla nivea	snow cinquefoil	forb
Potentilla palustris	marsh cinquefoil	forb
Potentilla sp.	cinquefoil	forb
Ptillium sp.	feathermoss	moss

Appendix 10. 2010 Plant Species Identified during Field Surveys

Scientific Name	Common Name	Lifeform Type
Pyrola asarifolia	pink wintergreen	forb
Pyrola grandiflora	arctic wintergreen	forb
Racomitrium lanuginosum	hoary rock-moss	moss
Rhizocarpon sp.	map lichen	lichen
Rhododendron lapponicum	Lapland rosebay	shrub
Rhytidiopsis robusta	pipecleaner moss	moss
Rhytidium sp.		moss
Rubus arcticus	dwarf nagoonberry	forb
Rubus chamaemorus	cloudberry	forb
Salix arctica	arctic willow	shrub
Salix glauca	grey-leaved willow	shrub
Salix planifolia	plane-leaved willow	shrub
Salix pulchra	teal-leaved willow	
Salix reticulata	net-veined willow	shrub
Saxifraga cernua	nodding saxifrage	forb
Saxifraga nivalis	alpine saxifrage	forb
Saxifraga oppositifolia	purple mountain	forb
Saxifraga tricuspidata	three-toothed saxifrage	forb
Senecio atropurpureus	purple-haired groundsel	forb
Senecio congestus	marsh fleabane	forb
Senecio triangularis	arrow-leaved groundsel	forb
Shepherdia canadensis	soopolallie	shrub
Silene acaulis	moss campion	forb
Sphagnum sp.	peat-moss	moss
Stellaria sp.	starwort	forb
Stereocaulon foam	lichen	lichen
Taraxacum sp.	dandelion	forb
Thamnolia vermicularis	rockworm	lichen
Thamnolia vermicularis	the whiteworm	lichen
Tofieldia borealis	Scotch false asphodel	forb
Tofieldia coccinea	northern false asphodel	forb
Tomentypnum nitens	golden fuzzy	moss
Umbilicaria rock	tripe	lichen
Vaccinium uliginosum	bog blueberry	shrub
Vaccinium vitis-idaea	lingonberry	shrub
Zygadenus elegans	mountain death-camas	forb
	blk crustose	lichen
	crustose lichen	lichen
	fungi-unknown	fungi

Appendix 11

Analytical Results for Total Metals in Collected Vegetation Tissue

Rescan™
Engineers and Scientists

Appendix 11. Analytical Results for Total Metals in Collected Vegetation Tissue

Date	01-Nov-10	**Date Received**	19-Oct-10 17:55
ALS File No.	L944854	**Project**	1009-002-12,1009-002-17
Report To	NATASHA BUSH, RESCAN ENVIRONMENTAL SERVICES		

RESULTS OF ANALYSIS

Sample ID		D73 FLAVOCETRARIA CUCULLATA	D82 FLAVOCETRARIA CUCULLATA	D114 FLAVOCETRARIA CUCULLATA	023 FLAVOCETRARIA CUCULLATA	021 FLAVOCETRARIA CUCULLATA	010 FLAVOCETRARIA CUCULLATA	011 FLAVOCETRARIA CUCULLATA	024 FLAVOCETRARIA CUCULLATA	D63 FLAVOCETRARIA NIVALIS
Date Sampled		24-AUG-10	25-AUG-10	28-AUG-10	16-JUL-10	16-JUL-10	14-JUL-10	14-JUL-10	16-JUL-10	23-AUG-10
ALS Sample ID		L944854-1	L944854-2	L944854-3	L944854-4	L944854-5	L944854-6	L944854-7	L944854-8	L944854-9
Matrix	**Units**	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Physical Tests										
% Moisture	%	8.06	11.7	35.9	61.2	50.2	22.2	14.1	31.3	18.8
Metals										
Aluminum (Al)-Total	mg/kg	70.3	115	56.4	81.9	842	83.1	75.0	63.2	47.6
Aluminum (Al)-Total	mg/kg wwt	64.7	102	36.1	31.8	419	64.7	64.4	43.4	38.7
Antimony (Sb)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	0.018	<0.010	<0.010	<0.010	<0.010
Antimony (Sb)-Total	mg/kg wwt	0.0037	0.0036	0.0031	0.0033	0.0089	0.0041	0.0041	0.0046	0.0028
Arsenic (As)-Total	mg/kg	0.042	0.042	0.038	0.043	0.140	0.046	0.048	0.056	0.028
Arsenic (As)-Total	mg/kg wwt	0.0385	0.0371	0.0242	0.0167	0.0699	0.0357	0.0412	0.0381	0.0231
Barium (Ba)-Total	mg/kg	9.05	7.20	5.70	4.02	4.83	8.39	8.04	2.86	13.7
Barium (Ba)-Total	mg/kg wwt	8.32	6.37	3.65	1.56	2.41	6.53	6.91	1.97	11.1
Beryllium (Be)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	mg/kg wwt	0.0021	0.0049	<0.0020	<0.0020	0.0064	0.0028	0.0034	<0.0020	0.0025
Bismuth (Bi)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bismuth (Bi)-Total	mg/kg wwt	<0.0020	<0.0020	<0.0020	<0.0020	0.0023	<0.0020	<0.0020	<0.0020	<0.0020
Boron (B)-Total	mg/kg	4.6	5.3	4.7	7.0	4.1	4.8	3.2	10.1	2.8
Boron (B)-Total	mg/kg wwt	4.20	4.71	3.01	2.71	2.04	3.71	2.75	6.91	2.25
Cadmium (Cd)-Total	mg/kg	0.071	0.041	0.066	0.039	0.053	0.040	0.047	0.125	0.076
Cadmium (Cd)-Total	mg/kg wwt	0.0657	0.0365	0.0420	0.0150	0.0264	0.0313	0.0399	0.0855	0.0614
Calcium (Ca)-Total	mg/kg	4790	1580	7260	2550	8970	1920	1500	40400	4520
Calcium (Ca)-Total	mg/kg wwt	4410	1400	4650	991	4470	1490	1290	27700	3670
Cesium (Cs)-Total	mg/kg	0.0460	0.0244	0.0480	0.0128	0.0328	0.0583	0.0765	0.0111	0.0353
Cesium (Cs)-Total	mg/kg wwt	0.0423	0.0215	0.0307	0.0050	0.0163	0.0453	0.0657	0.0076	0.0286
Chromium (Cr)-Total	mg/kg	0.51	1.62	1.10	0.93	7.33	0.68	0.42	0.85	0.56
Chromium (Cr)-Total	mg/kg wwt	0.473	1.43	0.704	0.360	3.65	0.531	0.361	0.585	0.454
Cobalt (Co)-Total	mg/kg	0.097	0.198	0.081	0.108	0.940	0.201	0.163	0.052	0.178
Cobalt (Co)-Total	mg/kg wwt	0.0893	0.175	0.0522	0.0420	0.468	0.157	0.140	0.0359	0.144
Copper (Cu)-Total	mg/kg	0.77	0.95	0.89	0.91	3.28	0.96	0.90	1.80	0.69
Copper (Cu)-Total	mg/kg wwt	0.707	0.835	0.571	0.353	1.63	0.748	0.775	1.24	0.561
Gallium (Ga)-Total	mg/kg	0.022	0.033	<0.020	0.028	0.284	0.023	0.022	0.021	<0.020
Gallium (Ga)-Total	mg/kg wwt	0.0203	0.0288	0.0114	0.0109	0.142	0.0180	0.0189	0.0144	0.0134
Iron (Fe)-Total	mg/kg	79.3	125	62.3	104	1580	84.2	72.1	88.1	52.5
Iron (Fe)-Total	mg/kg wwt	72.9	110	39.9	40.6	785	65.5	61.9	60.5	42.6
Lead (Pb)-Total	mg/kg	0.223	0.188	0.369	0.188	0.503	0.249	0.233	0.409	0.449
Lead (Pb)-Total	mg/kg wwt	0.205	0.166	0.237	0.0729	0.251	0.194	0.200	0.281	0.365
Lithium (Li)-Total	mg/kg	<0.10	<0.10	<0.10	<0.10	0.63	<0.10	<0.10	<0.10	<0.10
Lithium (Li)-Total	mg/kg wwt	0.064	0.080	0.026	0.029	0.314	0.042	0.043	0.023	<0.020
Magnesium (Mg)-Total	mg/kg	603	748	503	998	1900	605	814	419	1190
Magnesium (Mg)-Total	mg/kg wwt	554	661	322	388	945	471	699	288	968
Manganese (Mn)-Total	mg/kg	44.9	95.5	53.2	133	77.2	64.2	66.8	8.81	109
Manganese (Mn)-Total	mg/kg wwt	41.3	84.3	34.1	51.8	38.5	50.0	57.3	6.05	88.6
Mercury (Hg)-Total	mg/kg	0.0396	0.0386	0.0402	0.0268	0.0469	0.0519	0.0450	0.0311	0.0401
Mercury (Hg)-Total	mg/kg wwt	0.0364	0.0341	0.0257	0.0104	0.0234	0.0404	0.0387	0.0213	0.0326
Molybdenum (Mo)-Total	mg/kg	0.033	0.040	0.032	0.059	0.104	0.027	0.028	0.039	0.032
Molybdenum (Mo)-Total	mg/kg wwt	0.0303	0.0352	0.0206	0.0231	0.0518	0.0213	0.0243	0.0267	0.0260
Nickel (Ni)-Total	mg/kg	0.51	0.87	0.62	0.64	3.87	0.58	0.40	0.60	0.41
Nickel (Ni)-Total	mg/kg wwt	0.473	0.772	0.394	0.249	1.93	0.450	0.346	0.410	0.335
Phosphorus (P)-Total	mg/kg	650	1140	540	610	790	750	990	330	640
Phosphorus (P)-Total	mg/kg wwt	600	1010	350	240	400	590	850	230	520
Potassium (K)-Total	mg/kg	1600	2500	1900	1900	2000	2000	2200	1600	1900
Potassium (K)-Total	mg/kg wwt	1450	2200	1240	730	1020	1590	1880	1070	1560
Rhenium (Re)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Rhenium (Re)-Total	mg/kg wwt	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Rubidium (Rb)-Total	mg/kg	6.32	5.38	5.82	1.21	1.25	5.85	9.04	1.63	4.41
Rubidium (Rb)-Total	mg/kg wwt	5.81	4.75	3.73	0.468	0.623	4.56	7.76	1.12	3.58
Selenium (Se)-Total	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Selenium (Se)-Total	mg/kg wwt	0.049	0.040	0.040	<0.020	0.030	0.058	0.037	0.029	0.060
Silver (Ag)-Total	mg/kg	<0.0050	0.0074	0.0062	0.0083	0.0146	0.0065	0.0070	0.0075	0.0128
Silver (Ag)-Total	mg/kg wwt	0.0039	0.0065	0.0040	0.0032	0.0073	0.0050	0.0060	0.0052	0.0104
Sodium (Na)-Total	mg/kg	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Sodium (Na)-Total	mg/kg wwt	<900	730	<600	<400	<500	<700	810	<700	<700
Strontium (Sr)-Total	mg/kg	30.6	2.97	3.79	5.03	8.87	3.66	3.59	14.1	9.62
Strontium (Sr)-Total	mg/kg wwt	28.1	2.63	2.43	1.95	4.42	2.85	3.08	9.66	7.82
Tellurium (Te)-Total	mg/kg	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Tellurium (Te)-Total	mg/kg wwt	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Thallium (Tl)-Total	mg/kg	0.0076	0.0167	0.0098	0.0039	0.0051	0.0180	0.0233	<0.0020	0.0057
Thallium (Tl)-Total	mg/kg wwt	0.00696	0.0147	0.00629	0.00151	0.00256	0.0140	0.0200	0.00109	0.00464
Thorium (Th)-Total	mg/kg	0.018	0.049	0.019	0.036	0.150	0.030	0.021	0.026	0.014
Thorium (Th)-Total	mg/kg wwt	0.0169	0.0431	0.0122	0.0140	0.0745	0.0237	0.0179	0.0179	0.0112
Tin (Sn)-Total	mg/kg	0.048	0.023	0.140	0.038	0.041	0.024	0.041	0.033	<0.020
Tin (Sn)-Total	mg/kg wwt	0.0442	0.0205	0.0896	0.0147	0.0206	0.0183	0.0355	0.0225	0.0158
Titanium (Ti)-Total	mg/kg	3.64	7.32	3.03	5.18	56.7	5.13	3.29	3.91	4.05
Titanium (Ti)-Total	mg/kg wwt	3.35	6.47	1.94	2.01	28.3	3.99	2.83	2.68	3.29
Uranium (U)-Total	mg/kg	0.0053	0.0105	0.0043	0.0065	0.0226	0.0058	0.0052	0.0079	0.0029
Uranium (U)-Total	mg/kg wwt	0.00483	0.00930	0.00273	0.00253	0.0112	0.00449	0.00444	0.00543	0.00236
Vanadium (V)-Total	mg/kg	0.181	0.257	0.133	0.242	4.17	0.185	0.155	0.231	0.130
Vanadium (V)-Total	mg/kg wwt	0.166	0.227	0.0851	0.0939	2.08	0.144	0.133	0.159	0.105
Yttrium (Y)-Total	mg/kg	0.052	0.080	0.055	0.051	0.517	0.046	0.034	0.170	0.088
Yttrium (Y)-Total	mg/kg wwt	0.0482	0.0710	0.0351	0.0198	0.258	0.0359	0.0296	0.117	0.0713
Zinc (Zn)-Total	mg/kg	31.3	28.6	21.7	25.2	26.8	23.5	32.4	17.2	37.7
Zinc (Zn)-Total	mg/kg wwt	28.8	25.3	13.9	9.78	13.3	18.3	27.8	11.8	30.6
Zirconium (Zr)-Total	mg/kg	<0.20	<0.20	<0.20	<0.20	0.40	<0.20	<0.20	<0.20	<0.20
Zirconium (Zr)-Total	mg/kg wwt	0.054	0.135	<0.040	0.046	0.198	0.056	0.060	0.050	<0.040

Appendix 11. Analytical Results for Total Metals in Collected Vegetation Tissue

Date	01-Nov-10	**Date Received**	19-Oct-10 17:55
ALS File No.	L944854	**Project**	1009-002-12,1009-002-17
Report To	NATASHA BUSH, RESCAN ENVIRONMENTAL SERVICES		

RESULTS OF ANALYSIS

Sample ID		D65 FLAVOCETRARIA NIVALIS	D62 FLAVOCETRARIA NIVALIS	D89 FLAVOCETRARIA NIVALIS	D97 FLAVOCETRARIA NIVALIS	D93 FLAVOCETRARIA NIVALIS	D116 FLAVOCETRARIA NIVALIS	D86 FLAVOCETRARIA NIVALIS	D114 FLAVOCETRARIA NIVALIS	D125 FLAVOCETRARIA NIVALIS
Date Sampled		23-AUG-10	23-AUG-10	26-AUG-10	26-AUG-10	26-AUG-10	28-AUG-10	25-AUG-10	28-AUG-10	29-AUG-10
ALS Sample ID		L944854-10	L944854-11	L944854-12	L944854-13	L944854-14	L944854-15	L944854-16	L944854-17	L944854-18
Matrix	**Units**	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue	Tissue
Physical Tests										
% Moisture	%	9.51	35.8	18.1	11.4	17.1	15.8	9.85	36.4	16.2
Metals										
Aluminum (Al)-Total	mg/kg	44.1	94.6	26.9	40.5	45.9	36.0	29.2	33.5	47.2
Aluminum (Al)-Total	mg/kg wwt	39.9	60.7	22.1	35.9	38.0	30.3	26.3	21.3	39.6
Antimony (Sb)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Antimony (Sb)-Total	mg/kg wwt	0.0025	0.0054	0.0020	0.0027	0.0022	0.0037	0.0028	0.0031	0.0031
Arsenic (As)-Total	mg/kg	0.037	0.160	0.034	0.041	0.028	0.037	0.044	0.033	0.035
Arsenic (As)-Total	mg/kg wwt	0.0333	0.103	0.0277	0.0368	0.0230	0.0308	0.0395	0.0208	0.0297
Barium (Ba)-Total	mg/kg	23.1	21.6	7.67	16.4	6.96	24.2	14.7	13.6	12.8
Barium (Ba)-Total	mg/kg wwt	20.9	13.9	6.28	14.5	5.77	20.4	13.3	8.65	10.7
Beryllium (Be)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	mg/kg wwt	0.0030	0.0043	<0.0020	0.0026	<0.0020	0.0034	<0.0020	<0.0020	0.0031
Bismuth (Bi)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bismuth (Bi)-Total	mg/kg wwt	<0.0020	0.0022	<0.0020	0.0021	<0.0020	<0.0020	<0.0020	<0.0020	0.0031
Boron (B)-Total	mg/kg	6.4	7.1	6.0	7.2	6.5	4.2	7.6	5.2	4.1
Boron (B)-Total	mg/kg wwt	5.76	4.55	4.91	6.38	5.37	3.56	6.86	3.30	3.41
Cadmium (Cd)-Total	mg/kg	0.072	0.078	0.141	0.071	0.114	0.080	0.053	0.108	0.083
Cadmium (Cd)-Total	mg/kg wwt	0.0649	0.0500	0.115	0.0629	0.0942	0.0675	0.0478	0.0687	0.0696
Calcium (Ca)-Total	mg/kg	5540	7130	15400	6200	5920	3860	4170	7270	5580
Calcium (Ca)-Total	mg/kg wwt	5010	4570	12600	5500	4910	3250	3760	4630	4680
Cesium (Cs)-Total	mg/kg	0.0382	0.0297	0.0399	0.0144	0.102	0.0407	0.0307	0.0303	0.0410
Cesium (Cs)-Total	mg/kg wwt	0.0346	0.0191	0.0327	0.0128	0.0847	0.0343	0.0276	0.0193	0.0344
Chromium (Cr)-Total	mg/kg	0.65	1.06	0.35	0.48	0.30	0.34	0.61	1.73	0.59
Chromium (Cr)-Total	mg/kg wwt	0.587	0.683	0.290	0.421	0.252	0.287	0.553	1.10	0.496
Cobalt (Co)-Total	mg/kg	0.227	0.373	0.035	0.161	0.155	0.166	0.080	0.115	0.124
Cobalt (Co)-Total	mg/kg wwt	0.205	0.240	0.0283	0.142	0.129	0.140	0.0721	0.0730	0.104
Copper (Cu)-Total	mg/kg	0.70	1.09	0.79	0.67	0.62	0.68	0.77	0.84	0.74
Copper (Cu)-Total	mg/kg wwt	0.631	0.701	0.649	0.592	0.512	0.569	0.697	0.533	0.616
Gallium (Ga)-Total	mg/kg	<0.020	0.026	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Gallium (Ga)-Total	mg/kg wwt	0.0140	0.0168	0.0066	0.0076	0.0082	0.0089	0.0079	0.0067	0.0107
Iron (Fe)-Total	mg/kg	53.9	137	33.0	47.4	37.2	39.1	31.4	45.2	54.9
Iron (Fe)-Total	mg/kg wwt	48.8	87.9	27.0	42.0	30.8	32.9	28.3	28.8	46.0
Lead (Pb)-Total	mg/kg	0.354	0.612	0.241	0.342	0.419	0.352	0.205	0.377	0.465
Lead (Pb)-Total	mg/kg wwt	0.320	0.393	0.197	0.303	0.348	0.297	0.185	0.240	0.389
Lithium (Li)-Total	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Lithium (Li)-Total	mg/kg wwt	<0.020	0.037	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Magnesium (Mg)-Total	mg/kg	904	1060	714	941	1030	888	852	882	692
Magnesium (Mg)-Total	mg/kg wwt	818	683	585	834	851	748	768	561	579
Manganese (Mn)-Total	mg/kg	124	144	66.2	127	62.1	102	161	137	49.8
Manganese (Mn)-Total	mg/kg wwt	112	92.7	54.2	113	51.5	86.4	145	87.0	41.7
Mercury (Hg)-Total	mg/kg	0.0411	0.0370	0.0309	0.0361	0.0316	0.0333	0.0399	0.0419	0.0386
Mercury (Hg)-Total	mg/kg wwt	0.0372	0.0238	0.0253	0.0320	0.0262	0.0280	0.0360	0.0267	0.0323
Molybdenum (Mo)-Total	mg/kg	0.028	0.039	0.032	0.029	0.027	0.032	0.026	0.055	0.056
Molybdenum (Mo)-Total	mg/kg wwt	0.0251	0.0251	0.0261	0.0257	0.0225	0.0271	0.0238	0.0352	0.0468
Nickel (Ni)-Total	mg/kg	0.67	0.90	0.27	0.42	0.42	0.32	0.36	0.95	0.43
Nickel (Ni)-Total	mg/kg wwt	0.607	0.578	0.224	0.369	0.351	0.273	0.329	0.606	0.358
Phosphorus (P)-Total	mg/kg	420	420	380	390	390	580	600	440	430
Phosphorus (P)-Total	mg/kg wwt	380	270	310	340	330	490	540	280	360
Potassium (K)-Total	mg/kg	1900	1600	1500	1600	1400	1900	2100	1800	1400
Potassium (K)-Total	mg/kg wwt	1710	1030	1210	1390	1170	1590	1900	1120	1200
Rhenium (Re)-Total	mg/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Rhenium (Re)-Total	mg/kg wwt	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Rubidium (Rb)-Total	mg/kg	4.97	4.14	3.56	2.62	6.46	4.74	3.64	4.49	4.43
Rubidium (Rb)-Total	mg/kg wwt	4.50	2.66	2.92	2.33	5.35	3.99	3.28	2.85	3.71
Selenium (Se)-Total	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Selenium (Se)-Total	mg/kg wwt	0.075	<0.020	0.040	0.034	<0.020	0.038	0.053	0.029	0.047
Silver (Ag)-Total	mg/kg	0.0089	0.0139	0.0061	0.0079	0.0068	0.0082	0.0052	<0.0050	0.0124
Silver (Ag)-Total	mg/kg wwt	0.0081	0.0089	0.0050	0.0070	0.0056	0.0069	0.0047	0.0031	0.0104
Sodium (Na)-Total	mg/kg	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Sodium (Na)-Total	mg/kg wwt	<900	<600	<700	<900	<800	<800	<800	<700	<800
Strontium (Sr)-Total	mg/kg	11.5	16.8	12.1	11.2	7.87	9.41	4.77	8.42	9.30
Strontium (Sr)-Total	mg/kg wwt	10.4	10.8	9.93	9.92	6.52	7.93	4.30	5.35	7.79
Tellurium (Te)-Total	mg/kg	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Tellurium (Te)-Total	mg/kg wwt	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Thallium (Tl)-Total	mg/kg	0.0153	0.0069	<0.0020	0.0043	0.0024	0.0100	0.0076	0.0051	0.0069
Thallium (Tl)-Total	mg/kg wwt	0.0138	0.00441	0.00141	0.00378	0.00201	0.00839	0.00686	0.00323	0.00582
Thorium (Th)-Total	mg/kg	0.016	0.040	0.013	0.042	<0.010	0.014	<0.010	0.019	0.015
Thorium (Th)-Total	mg/kg wwt	0.0146	0.0257	0.0103	0.0372	0.0081	0.0116	0.0068	0.0123	0.0127
Tin (Sn)-Total	mg/kg	0.021	0.037	0.024	0.050	0.036	<0.020	0.033	0.041	0.032
Tin (Sn)-Total	mg/kg wwt	0.0186	0.0238	0.0194	0.0445	0.0302	0.0144	0.0297	0.0260	0.0271
Titanium (Ti)-Total	mg/kg	2.92	9.10	1.84	3.95	1.90	2.36	1.58	2.27	2.93
Titanium (Ti)-Total	mg/kg wwt	2.64	5.84	1.51	3.50	1.57	1.99	1.42	1.44	2.45
Uranium (U)-Total	mg/kg	0.0094	0.0148	0.0023	0.0050	0.0023	0.0032	0.0025	0.0032	0.0059
Uranium (U)-Total	mg/kg wwt	0.00851	0.00949	0.00191	0.00442	0.00190	0.00272	0.00223	0.00203	0.00497
Vanadium (V)-Total	mg/kg	0.143	0.278	0.073	0.116	0.075	0.083	0.072	0.089	0.148
Vanadium (V)-Total	mg/kg wwt	0.130	0.179	0.0596	0.103	0.0624	0.0700	0.0650	0.0568	0.124
Yttrium (Y)-Total	mg/kg	0.191	0.489	0.034	0.175	0.057	0.036	0.022	0.065	0.085
Yttrium (Y)-Total	mg/kg wwt	0.173	0.314	0.0277	0.155	0.0475	0.0300	0.0197	0.0413	0.0708
Zinc (Zn)-Total	mg/kg	25.9	25.1	17.6	22.4	17.9	27.6	28.9	27.2	18.5
Zinc (Zn)-Total	mg/kg wwt	23.4	16.1	14.4	19.9	14.8	23.3	26.0	17.3	15.5
Zirconium (Zr)-Total	mg/kg	<0.20	0.26	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Zirconium (Zr)-Total	mg/kg wwt	<0.040	0.166	<0.040	0.051	<0.040	<0.040	<0.040	<0.040	<0.040