11. Terrain and Soils Predictive Study

11.1 INTRODUCTION

This section provides an overview of the terrain and soils, including relevant legislation and guidelines, and assesses the potential effects of the Brucejack Gold Mine Project (the Project) on the terrain, soils and terrain stability. Baseline terrain stability and associated geohazards are discussed along with the potential effects of Project infrastructure on these baseline conditions. Section 11.3 provides an abbreviated discussion of surficial geology, terrain, and soils, suitable as background for the assessment of Project environmental effects. A more detailed description of terrain and soil conditions is presented in Appendix 16-A, Brucejack Terrestrial Ecosystem Baseline Studies. Local mineralogy and geochemistry of local surficial materials are discussed in Chapter 5, Project Description, Section 5.6, Geochemical Characterization.

Changes related to terrain and soils provided in this chapter are used to support the effects assessment on water quality, fish and fish, terrestrial ecology, wetlands, wildlife, and human health.

11.2 REGULATORY AND POLICY FRAMEWORK

A number of legislated requirements exist to guide mining proponents on the development of a mine site and on the management of terrain and surface soil disturbance. These requirements include the *Mines Act* (1996), the *Forest and Range Practices Act* (2002b), the federal *Fisheries Act* (1985a), and British Columbia's *Environmental Management Act* (2003). General guidance for various soils parameters is also provided via the *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* (CCME 2007). Each of these requirements and the guidance is discussed in the following subsections in relation to terrain, surficial geology, and soil management and monitoring. Some provisions of the *Nisg̱a'a Final Agreement* (NFA; NLG, Province of BC, and Government of Canada 1998) are also applicable.

Legislation and Standards

British Columbia's *Mines Act* (1996) governs mining activities in BC from exploration through to development, production, closure, and reclamation. The Project proponent must obtain a permit approving the work system and reclamation program prior to conducting any mining activities. To obtain this permit, a detailed Mine Development Plan and Reclamation Program must be submitted to the British Columbia Ministry of Energy and Mines (BC MEM) for approval.

Under the *Mines Act* (1996), the *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008) requires proponents to provide:

- information on surficial geology, terrain mapping, soil characterization, vegetation, wildlife, and present land use (Appendix 5-F and Appendix 16-A, Chapter 18, and Chapters 19 to 22);
- plans for salvaging and stockpiling of soils and overburden (Section 29.13, Soil Management Plan);
- an erosion control plan (Section 29.13, Soil Management Plan); and
- a reclamation plan (Chapter 30, Closure and Reclamation).

Relevant information requirements set under the Fish Habitat Protection and Pollution Prevention provisions of the *Fisheries Act* (1985a) include descriptions of measures that will be taken to avoid or minimize any effects on the aquatic environment, shoreline, or riparian areas during Project development or its subsequent operation (Section 37). The *Fisheries Act* (1985a) also regulates the discharge of harmful substances, including sediment (Section 34), into the fish habitat. Consideration of the above legislation is particularly important in cases when Project development takes place near shorelines, or riparian areas where migration of chemical contaminants and sediment into the aquatic environment could occur. The management of soils potentially contaminated by hazardous materials (hydrocarbons and reagents) is provided in the sections on waste management and spills/malfunctions, Sections 29.17 and 29.14, respectively in Chapter 29, Environmental Management and Monitoring Plans.

The Ministry of Environment's Environmental Protection Division (EPD) administers the *Environmental Management Act* (EMA) by setting criteria to define when "sediment yield" becomes a "pollutant" (Clark et al. 2012). Provincial water quality guideline documents provide targets of acceptable levels of sediment in water that are typically used when determining the performance of control measures when undertaking in-stream works ((Ambient Water Quality Guidelines (Criteria) for Turbidity, Suspended and Benthic Sediments; BC MOE 2001).

Erosion prevention and watercourse sedimentation resulting from accelerated soil erosion are the focus of various best management practices. Unpaved roads have potential to contribute significantly to soil erosion. The Brucejack Access Road is approved under the *Mines Act*; however, Pretium Resources Inc. (Pretivm) also works to the spirit of the forestry Codes for road construction. The aspect of forest-related legislation that applies to Pretivm is for vegetation removal (cutting authorizations). The Ministry of Forests, Lands and Natural Resource Operations has indicated a new cutting authorization will be required for part of the transmission line (south of the Bowser River), certain access road improvement sections the Bowser Aerodrome, and Knipple Transfer Area. Road construction and maintenance within Provincial forests is governed in BC by the *Forest and Range Practices Act* (2002b). The Act requires that road construction and maintenance conducted under *Forest Act* authority adhere to codes provided in the Forest Service Road Use Regulation (BC Reg. 70/2004), which focuses extensively on erosion prevention.

Matters related to contamination of the soil and its impact on various potential land uses are regulated by the *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* (CCME 2007). These guidelines provide Canada-wide standards that suggest maximum limits of various toxic substances (e.g., metals, hydrocarbons, pesticides, etc.) in the soil. The Contaminated Sites Regulation (BC Reg. 375/96) included in British Columbia's *Environmental Management Act* (2003) lists soil criteria for toxicity to soil invertebrates and plants. These provide numerical standards to define whether an applicable site is contaminated, to determine liability for site remediation, and to assess reclamation success.

Legislation and best management practices (BMPs) regarding terrain stability are derived from those within the forest industry. Forest harvesting in BC is subject to the *Forest and Range Practices Act* (2002b). Stability of riparian ecosystems are protected by the *Forest and Range Practices Act* (2002b) and the *Fisheries Act* (1985b). Development of roads is guided by the *Forest Road Engineering Guidebook* (BC MOF 2002). Guidelines for terrain stability assessments have been developed by the Association of British Columbia Forest Professionals (2009).

11.3 BASELINE CHARACTERIZATION

11.3.1 Regional Overview

The Project is situated within the Skeena Mountains Ecoregion, the Boundary Ranges Ecoregion, and the Nass Ranges Ecoregion, according to the BC Ecoregion Classification system (Demarchi 2011). Towards the Pacific coast, the Boundary Ranges consist of extensive ice fields capping granitic intrusions remnant of the Coast Range Arc, and are dissected by several major river valleys, including the Nass Valley. Inland and east of the Boundary Ranges lies the Skeena Mountains Ecoregion, which consists of high, rugged mountains and a moist, coast/interior transition climate, supporting many glaciers. The Nass Ranges Ecoregion, with a climate somewhat transitional between coastal and interior regimes (Demarchi 1996), is a mountainous area west of the Kitimat Ranges (south of the Project).

The Project is predominantly within the Meziadin Mountains Ecosection. This area is rugged and mountainous, lying on the leeward side of the main Boundary Ranges and west of the low Nass Basin. The mountains are predominantly underlain by volcanic and sedimentary rock. Some small granitic batholiths are also present. Ice that formed in the Boundary Ranges during the last years of the Pleistocene Epoch moved east into the Nass Basin, coalescing with ice moving south from the adjacent Skeena Mountains which then moved down and out the Nass Valley, through the adjoining Nass Basin Ecosection. The mountain summits still have small icefields and glaciers. The area of the proposed Project within this ecosection is drained by the upper Bowser River and many small streams that empty into the Nass River.

There is a strong rainshadow effect in the Meziadin Mountains Ecosection, as the western summits protect this area from moist Pacific air that arrives from over the Boundary Ranges to the west. Some Pacific air can enter into this area via the wide Nass River valley, bringing heavy rain and dense cloud cover. In the winter and early spring, cold Arctic air can override the Skeena Mountains to the west and build up along the east side of this ecosection, bringing short periods of intense cold, which, when encountering warm Pacific air, can lead to heavy snowfalls. According to the Biogeoclimatic Ecosystem Classification system (Demarchi 2011), the southern east-facing valleys have wet Coastal Western Hemlock forests, with wet Mountain Hemlock subalpine forests on the upper slopes. The northern portion of this ecosection has cold Interior Cedar – Hemlock forests in the low elevation east-facing valleys, with cold Engelmann Spruce – Subalpine Fir forests on the middle and upper slopes. Vegetation cover in alpine areas varies according to microsite conditions, ranging from thick mats of mountain-heather and crowberry to sparsely vegetated lichen-encrusted rock.

Close to Highway 37, the existing Brucejack Access Road, crosses through the Nass Basin Ecosection. Locally, this ecosection is expressed as a basin of low relief that is encircled by sharply rising mountains, the Boundary Ranges (and Meziadin Mountains Ecosection) to the west, and the Skeena Mountains on the east. Bedrock underlying this basin is predominantly volcanic, with localized sedimentary deposits. The topographic relief is typically flat to gently rolling. Glaciers that formed in the Boundary Ranges and Skeena Mountains during the most recent glaciation flowed over these flat lands, and south, down the Nass River. There are many meandering streams, wetlands and small lakes. This ecosection is drained primarily by the Bell-Irving River that flows to the lower Nass River.

The climate is intermediate between the cool, wet conditions of the outer coast and the drier conditions of the interior. The cold, Arctic air that invades this basin allows a more interior forest type, including the Interior Cedar – Hemlock Subzone forests that occupy the valley floor, and the subalpine forests of Engelmann Spruce - Subalpine Fir Subzone, which occupy higher elevations.

The western portion of the Brucejack Access Road and the southern half of the Brucejack Transmission Line cross into the Southern Boundary Ranges Ecosection from the Meziadin Mountains Ecosection. This is an area of wet rugged mountains capped with glaciers, small icefields, and exposed granitic and metamorphic bedrock. This area was heavily impacted by large sheets of ice that originated along the crest of the mountains during the most recent glaciation and into the early years of the Holocene Epoch. Many large remnant icefields and glaciers remain on the summits. The Unuk River dissects these mountains as do several smaller rivers, such as the upper Bowser River, Salmon River and Bear River.

Moist Pacific air moves over the Southern Boundary Ranges Ecosection, bringing intense precipitation to the windward slopes and adjacent mountains in the northern interior of BC. At the same time, the ranges also allow cold Arctic air to pass onto the north coast of BC. Forests are either very wet, such as those in the Coastal Western Hemlock Zone, or cold and wet, such as the mid- to high-elevation subalpine forests of the Mountain Hemlock Zone. Alpine areas are extensive, and are dominated by heath tundra, herbaceous meadows, exposed bedrock, and permanent snow/ice.

Surrounding the Project area, glaciers and recently deglaciated areas are common. Parkland ecosystems occupy a narrow elevation band above the dense coniferous forests and below the treeless alpine ecosystems. These ecosystems are characterized by discontinuous tree islands growing on elevated sites, which experience early snowmelt and drainage of excessive moisture that prohibits forest establishment at higher elevations. Avalanches are very common due to the steep topography and abundant snowfall. Avalanche track ecosystems develop in areas with frequent avalanches; the herbaceous vegetation that grows within many of these tracks provides valuable forage for several wildlife species, including grizzly and black bears. Mass wasting events such as landslides and debris flows occur regularly, many occurring in the over-steepened lateral moraines deposited during recent, and ongoing, deglaciation.

Below approximately 1,100 metres above sea level (masl), forested ecosystems dominate the landscape. In the general area of the Project they are fairly continuous, interrupted by natural disturbances including those already described (avalanches, mass wasting), as well as fluvial disturbances such as flooding, channel aggradation and degradation, and debris flows. Subalpine fir and hybrid white spruce are the dominant tree species on mesic and wetter sites, while single species stands of mountain hemlock occupy rocky and dry sites. Western hemlock stands are common at low elevations in the south and west of the Project, especially along the Brucejack Transmission Line, and become less common to the east and north. Many of the forests in the lower slopes and valley bottoms are at least 500 years old. This is due to the rarity of stand replacement disturbance events, such as wildfire (BC MOF 1995). In addition, there has been little forest harvesting activity, and that which has occurred is confined to the immediate area surrounding Highway 37. The diverse horizontal structures of these old growth forests provide a mosaic of habitats within close proximity to each other and retain an abundant biodiversity not associated with younger, less complex ecosystems. Forest soils have weathered so that distinct horizons are present, each with their own collection of unique biological, chemical, and physical characteristics. High-value habitat includes that for marten, fisher, and a diversity of forest bird species. Higher elevation forests provide forage and cover to moose and mountain goats as well as berries and herbaceous plants for bears. Early seral vegetation provides winter habitat for moose and spring forage to grizzly and black bears.

Local Geology

The interaction of local geology with geomorphic processes over time greatly determines how ecosystems develop, which in turn support various ecological functions. The BC Geologic Survey regional bedrock mapping is summarized by Groups/Formations (stratigraphic unit abbreviations) and rock types.

The Bowser Lake Group is mapped along the eastern half of the exploration access road. It includes the Middle to Upper Jurassic Bowser Lake Group Ritchie-Alger Assemblage of sedimentary, sandstone, siltstone, and rare conglomerate.

The Hazelton Group is mapped in most other areas around the Project, except for the extreme western edge, which is mapped as the Stuhini group and includes the Brucejack Mine Site. The Hazelton Group has many formations, including the following:

- Unuk River (lJHU) — andesitic volcanic rocks;

- Betty Creek (lJHB) — volcaniclastic rocks;
- Mount Dilworth (muJHM) — calc-alkaline volcanic rocks;
- (muJHca) — calc-alkaline volcanic rocks;
- (muJHs) — undivided sedimentary rocks;
- (lJHsf) — mudstone, siltstone, shale, fine clastic sedimentary rocks; and
- Eskay Porphyry, Knipple Porphyry or Inel Stock (EJEK) — feldspar porphyritic intrusive rocks.

11.3.2 Historical Activities

Several historical and current human activities are within close proximity to the proposed Project. These include mining exploration and production, hydroelectric power generation, forestry, and road construction and use.

The Granduc Mine was a copper mine located approximately 25 kilometres (km) south of the Project, which operated from 1970 to 1978 and 1980 to 1984. The mine included underground workings and a mill site near Summit Lake, connected by a 17-km tunnel. In addition, a 52 km all-weather access road was built from the communities of Stewart, BC and Hyder, Alaska to the former mill site near Summit Lake. The area of the former mill site near Summit Lake is currently used as staging for several mineral exploration projects in the region. The terminus of the Granduc Access Road is 25 km south of the proposed Brucejack Mine Site and is currently used by mineral exploration traffic and tourists accessing the Salmon Glacier viewpoint.

The Sulphurets Project, located at the currently proposed Brucejack Mine Site, was an advanced underground exploration project of Newhawk Gold Mines Ltd. Underground workings were excavated between 1986 and 1990 as part of an advanced exploration and bulk sampling program. Reclamation efforts following the Newhawk Gold Mines Ltd. advanced exploration work included deposition of waste rock and ore within Brucejack Lake in 1999.

The exploration phase of the proposed Brucejack Gold Mine Project commenced in 2011 and has included a drilling program, bulk sample program, construction of an exploration access road from Highway 37 to the west end of Bowser Lake, and rehabilitation of an existing access road from the west end of Bowser Lake to the Brucejack Mine Site.

In 2010, construction began on the Long Lake Hydroelectric Project which is located approximately 42 km south of the Project. It includes redevelopment of a 20-m-high rockfill dam located at the head of Long Lake, and a new 10-km-long 138-kilovolt (kV) transmission line.

Historical forestry activities occurred within the immediate Project area between Highway 37 and Bowser Lake, south of the Wildfire Creek and Bell-Irving River confluence. Additional details regarding historical and current human activities nearby the Project are included in Section 11.10, Cumulative Effects Assessment for Terrain and Soils.

11.3.3 Baseline Studies

Terrain and soils baseline studies were conducted in 2012 to support the environmental assessment application for the Project. The goal of this program was to characterize the terrain and soils that could potentially be affected directly or indirectly by the Project within a Local Study Area (LSA) defined for the Project. The main objectives of the baseline studies program were to:

- map and characterize the terrain, surficial materials, and soils in the LSA;

- identify soil characteristics that may be sensitive to disturbances and features that could potentially affect the construction, operation, and decommissioning of the Project facilities;
- provide sufficient information to develop the effects assessment, management and mitigation plans, and the reclamation and closure plan; and
- determine soil and vegetation baseline metal concentrations.

The information collected during the baseline program was used to carry out the effects assessments, develop management and mitigation plans, and guide the reclamation and closure plan. Methods utilized in the Terrain and Soils baseline studies follow Application Information Requirements (AIR) and Environmental Impact Statement (EIS) Guidelines.

A full description of the terrain and soils baseline studies is provided in Appendix 16-A.

11.3.3.1 Data Sources

Existing information regarding terrain, surficial materials, and soils was collected in order to augment the site-specific baseline studies.

These sources included:

- Biogeoclimatic Ecosystem Classification (BEC) mapping;
- Ecoregion Classification mapping;
- Terrain Resources Information Management data for deriving digital elevation models;
- publically available data associated with relevant adjacent projects;
- data acquired via Data Sharing Agreements; and
- data made available from First Nations.

11.3.3.2 Methods

Baseline Study Area

For the baseline studies, terrain and soils were characterized for a terrain and soils LSA (Figure 11.3-1). The LSA is 31,847 hectares (ha), and is defined by a buffer extending at least to the height of land or 1.0 km around the outer limits of the proposed infrastructure and linear developments. Buffers, watershed height-of-land borders, and other physical features are used to account for the potential effects that could migrate beyond the Project footprint, such as those related to hydrologic changes. The LSA use for terrain and soils is consistent with the LSA for other terrestrial ecosystems and wildlife baseline studies. Figure 11.3-1 also shows the RSA for the terrestrial ecosystems and wildlife baseline studies, which provide the regional biophysical context of the area, but was not specifically considered in the terrain and soils assessment. There is no RSA for soils, as effects on quality, quantity, and changes to terrain stability are best assessed as a local effect.

For terrain and soils, the LSA was divided into three separate sub-areas due to the variety of landforms and vegetation types present and the relatively large geographical separation among some of the various infrastructure components. The division of the LSA allows differentiating between disparate effects resulting from the various infrastructure components. These three areas include the Brucejack Access Road Sub-area (13,835 ha), the Brucejack Mine Site Sub-area (5,040 ha), and the Brucejack Transmission Line Sub-area (12,972 ha), henceforth the Brucejack Access Road, Brucejack Mine Site (Plate 11.3-1), and Brucejack Transmission Line respectively.

Figure 11.3-1
Terrain and Soils Study Areas

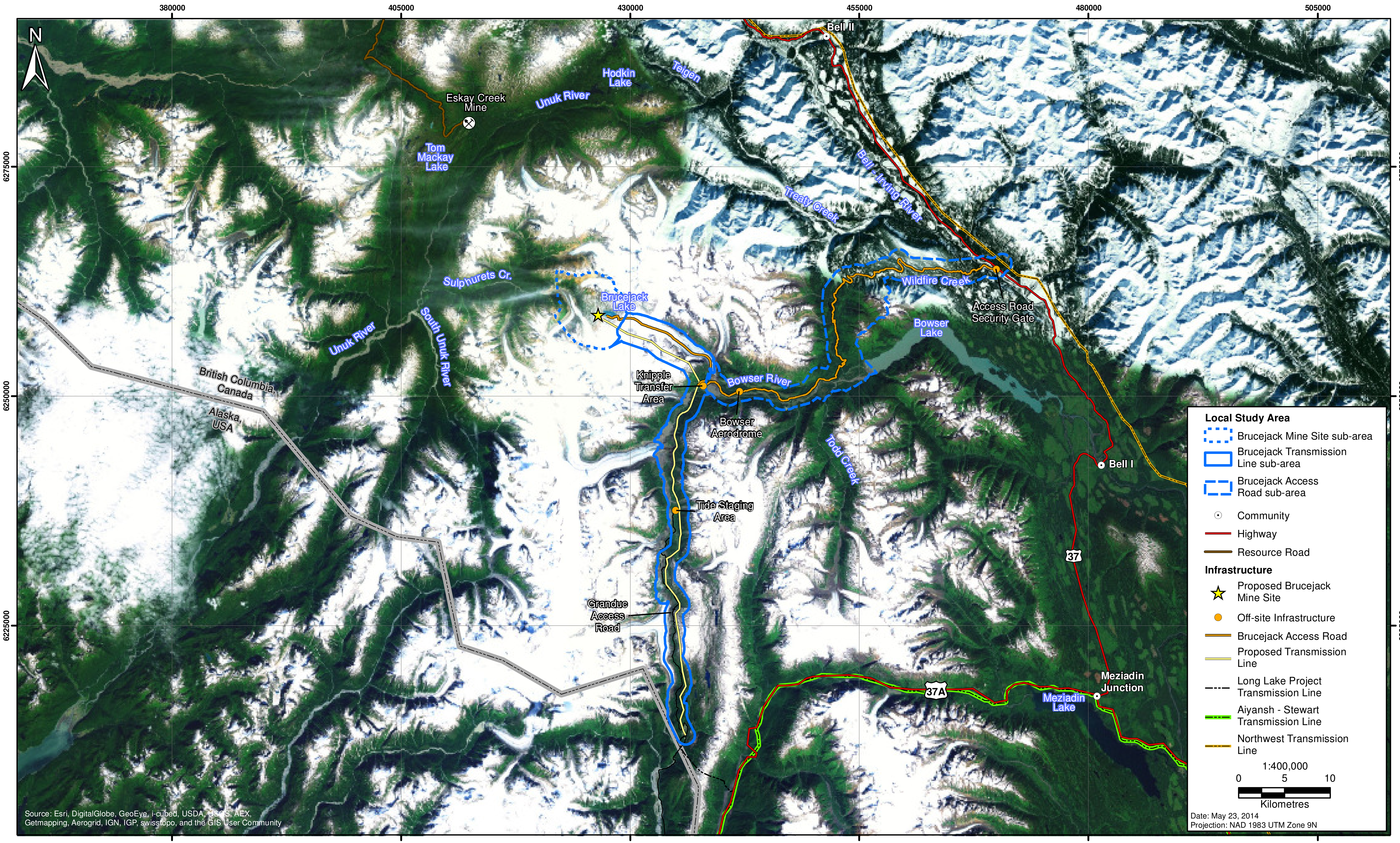

Plate 11.3-1. Brucejack Mine Site Sub-area.

Terrain Mapping

Terrain mapping is the identification of permanent terrain units based on surficial material, geomorphology, and landform. Initial mapping involves polygon delineation and the assigning of general attributes to the individual polygons. Terrain polygons are delineated based upon observable characteristics such as surficial material, texture, surface expression, and geomorphic processes. Detailed attributes are assigned using the field data collected from ground plots. Attributes were described using the Terrain System Classification for British Columbia (Howes and Kenk 1997).

Slope Analysis

Slope gradient maps were developed for the LSA as part of the terrain and soil assessment. Slope maps were produced at a scale of 1:20,000 using Terrain Resources Information Management data, though higher resolution maps were produced for areas with LIDAR data. Slope classes were based upon the standard terrain classification categories developed by Howes and Kenk (1997) with slight modifications to provide a better differentiation of local slope conditions which affect the soil resources in areas of relatively complex slopes. Slope classes are defined in Table 11.3-1.

Table 11.3-1. Slope Classes Used for Slope Gradient Maps within the Brucejack Local Study Area

Class	Slope Range	Descriptor
Class 0	0 to 2%	level
Class 1	> 2 to 5%	very gently sloping
Class 2	> 5 to 15%	gently sloping
Class 3	> 15 to 26%	moderately gently sloping
Class 4	> 26 to 50%	moderately sloping
Class 5	> 50 to 70%	moderately steeply sloping
Class 6	> 70%	steeply sloping

Soil Inspections

Soil inspections (including profile descriptions) were carried out in the field following the guidelines established in the *Field Manual for Describing Terrestrial Ecosystems* (Isbell et al. 2013). Soil classification, to the order level, is inferred primarily from soil morphologic observation interpretations, with very limited lab data. Soil orders are as described in the Canadian System of Soil Classification (CSSC; Soil Classification Working Group 1998). Soil inspection information is used to characterize the Soil Map Units, described below.

Soils Map Units

Soil mapping is largely an interpretive exercise based upon field data, terrain attributes, and local climate. Soil map units (SMUs) are the basic unit used to describe the soil within a mapping polygon and the range of soil resources in the LSA. SMU characteristics are interpreted for their relative suitability for management applications such as root zone materials in reclamation.

Project-specific soil maps were developed using information from the terrain, vegetation, wetland field data and mapping, as well as from the digital elevation models. The relationship between soil moisture regime and soil development (related to soil order classification) was derived from a combination of sources, including:

- Project soil (mineral soils) and wetland (primarily organic soils) inspection data;
- field guide landscape relationships for the LSA forest region (Banner et al. 1993); and
- *Biophysical Soil Landscapes Inventory of the Stikine-Iskut Area* (Fenger and Kowall 1992).

Individual SMUs were created using a combination of attributes, including soil climate, parent material (terrain surficial material), drainage (as derived from soil moisture regime, or SMR), and probable soil development to the CSSC order level of classification. Characterization of SMU soil properties including horizon type and depths, texture, coarse fragment content, and basic chemistry were derived from field data.

Soils Laboratory Analysis

To characterize the local soils beyond their field-observed characteristics, a range of parameters (pH, carbon content, texture, $CaCO_3$ equivalence, and cation exchange capacity) were analyzed to provide information on ecologically important characteristics relative to reclamation suitability and soil management.

Additionally, soil and plant samples were collected to establish baseline metal concentrations. These data comprise the basis to evaluate any changes in metal levels due to the Project. Results from the baseline metals analysis may be used for country foods assessments and/or future monitoring programs. All laboratory analyses were carried out by ALS Environmental in Burnaby, BC.

Samples were collected from within the three sub-areas of the LSA, as well as at reference sites (Reference) outside of the LSA. Baseline soil analyses included testing for concentrations of 31 metals. The interpretation of baseline data included comparing analytical results to the industrial guidelines provided for 19 of the metals, by the Canadian Council of Ministers of the Environment (CCME; 2007, Table 6.71).

11.3.4 Characterization of Terrain and Soils Baseline Condition

11.3.4.1 Terrain Mapping

Terrain maps for the Brucejack Mine Site, the Brucejack Access Road, and the Brucejack Transmission Line are presented at 1:15,000 scale in Appendix 16-A. A total of 1,035 terrain polygons were delineated for the entire LSA. The original mapping was refined by the field data, in order to have the attributes ascribed to best reflect the ground conditions. The surficial materials (based on the leading decile within the terrain database) within each of the sub-areas are summarized in Table 11.3-2.

Table 11.3-2. Surficial Material Summary by Sub-area within the Local Study Area

Surficial Material[1]	Map Code	Brucejack Mine Site (ha)	Brucejack Access Road (ha)	Brucejack Transmission Line (ha)	Total (ha)	% LSA
Moraine	M	559.1	4,688.9	2,975.3	8,223.2	26
Colluvium	C	854.0	3,661.5	3,172.7	7,688.2	24
Ice	I	1,835.0	38.2	2,768.7	4,641.9	15
Rock	R	1,540.3	675.4	1,788.8	4,004.5	13
Fluvial	F	10.8	1,988.6	108.7	2,108.1	7
Fluvial; active	FA	0.0	995.1	524.3	1,519.4	5
Glaciofluvial	FG	0.0	646.5	415.8	1,062.2	3
Water features	various	81.9	580.4	394.1	1,056.4	3
Weathered bedrock	D	141.8	131.8	431.5	705.1	2
Organic	O	4.3	398.5	10.0	412.8	1
Glaciolacustrine	LG	0.0	0.0	270.5	270.5	1
Anthropogenic	A	0.0	0.0	56.6	56.6	0
Unclassified	(blank)	0.0	0.0	55.0	55.0	0
Undifferentiated	U	0.0	23.0	0.0	23.0	0
Lacustrine	L	13.0	6.4	0.0	19.5	0
Total		**5,040.3**	**13,834.1**	**12,972.1**	**31,846.5**	**100%**

[1] *Based on leading surficial material decile.*

Terrain and Ecosystems of the Brucejack Mine Site Sub-Area

The high elevation Brucejack Mine Site is dominated by non-vegetated or sparsely vegetated regions which cover approximately 80% of the total sub-area. Of this, approximately 37% consists of non-vegetated areas including glaciers, permanent snow/ice, lakes, and ponds. Sparsely vegetated areas include rock outcrops, talus, and moraine. Much of the surficial material at the existing exploration camp infrastructure has been disturbed by site activities during the current and previous exploration programs.

Typical of alpine regions in northern coastal BC, surficial materials in the Brucejack Mine Site are dominated by morainal veneers over bedrock, colluvium, and weathered bedrock. Much of the moraine is recently exposed due to recent and ongoing deglaciation. It is poorly sorted and characterized by very high coarse fragment contents, often exceeding 70% within a matrix of sandy loam and silty loam mineral material. Surficial material spatial extent is summarized in Table 11.3-2.

Terrain and Ecosystems of the Brucejack Access Road Sub-Area

Terrain along the access road from the junction at Highway 37 to Bowser Lake is dominated by morainal deposits. At Bowser Lake, colluvium, glaciofluvial, and fluvial deposits predominate. As the road corridor continues west of Bowser Lake, glaciofluvial deposits become less common and colluvium and glacial till predominate and veneers of less than 1 m in thickness become more common. This reduction in till depth corresponds with increasing elevation where exposed bedrock becomes more common.

The road corridor then turns south along the Bowser River into an area with an abundance of braided stream systems in the Bowser River Delta. These fluvial deposits resulted from the bursting of the Tide Lake ice dam (damming of the Bowser River basin by the Frank Mackie Glacier) in 1931 and consequent drainage of the lake. The Bowser River now flows across what was once the lake bed and have incised channels up to 30 m deep in the sediments left by the proglacial lake. The parent materials are dominated by coarse textured fluvial sediments from the Tide Lake floods, overtopped with accumulations of modern alluvium.

The delta somewhat narrows to the west, towards Knipple Lake. The road corridor continues along the high bench floodplain, bounded by steep colluvial slopes on the north and the outflow on the south; the delta itself is confined by glacially scoured hummocky exposed bedrock until Knipple Lake, where the Bowser River turns sharply south. The landscape is recently deglaciated and thus soils are often either thin or absent. Surficial material spatial extent is summarized in Table 11.3-2.

<u>Terrain and Ecosystems of the Brucejack Transmission Line Sub-Area</u>

This sub-area starts near the Premier mine site and extends approximately 53 km northward to the top of the Knipple Glacier. The southern reaches consist of shallow colluvial veneers over bedrock. Slopes are very steep, often exceeding 60%. As the corridor proceeds north, soils become thin veneers over bedrock. In areas of recent disturbance, such as fresh moraine mounds, newly deposited glaciofluvial material and colluvium, there are hydrologically mesic soils with little to no soil development. Surficial material spatial extent is summarized in Table 11.3-2.

11.3.4.2 Soils Mapping and Classification

Soil formation in the LSA is limited by the cold climate and natural disturbance. Biological and chemical soil forming processes that are dependent on soil temperature thresholds can only be carried out during a brief seasonal window, while steep slopes limit pedogenesis due to constant downslope movement through soil creep, surface erosion, and mass movement. Soils that develop in colluvial and morainal surficial materials dominate the LSA; soils derived from fluvial, glaciofluvial, and organic deposits are common but of limited spatial extent. The dominant mineral soils in the LSA are weakly developed, and include Brunisols and Regosols. Other, less common mineral soils are Podzols and poorly drained Gleysols. The Organic soils, found in valley bottoms and depressions, are very poorly drained and very sensitive to disturbance. They include poorly decomposed Fibrisols and moderately decomposed Mesisols of varying thickness.

<u>Soil Mapping Units</u>

A total of eight soil mapsheets were developed for the LSA. The most general level of soil landscape differentiation is soil climate, which was derived from 2012 BEC mapping. The eight subzones identified in the LSA were grouped into two general soil climates: forested and alpine. These are presented in Table 11.3-3.

Table 11.3-3. Generalized Soil Climate Groups in the Brucejack Local Study Area

Soil Climate Group	BEC (2012) Subzone/Variant	Soil Climate Group	BEC (2012) Subzone/Variant
Forested	ICHvc	Alpine	ESSFunp
	ESSFun		MHmmp
	MHmm1		BAFAun
	MHmm2		CMAun

The soil maps were developed based on interpretation of the site information, the slope gradient, surficial materials, slope position, site drainage, and drainage inferred from site position and slope, coarse fragment content, soil texture, soil depth, and soil classification. The primary attribute in defining SMUs is the terrain surficial material followed by soil drainage characteristics. SMR, a proxy for soil drainage, was derived from the 77 TEM site series identified during baseline studies. The SMR is divided into eight classes from 0 to 7 with an SMR of 0 representing very dry sites, which are interpreted as rapidly drained, and an SMR of 7 representing very wet sites, which are interpreted as very poorly drained. An overview map is presented in Appendix 16-A.

Soil Potential for Use in Reclamation Assessment

The suitability of soils for salvage and reclamation was evaluated based upon the characteristics of the soils that comprise the SMUs. The evaluation of soil suitability was based on the analyses of several physical and chemical characteristics, as presented in Table 11.3-4.

Table 11.3-4. Criteria for Evaluating Suitability of Soil for Use in Reclamation

Limitation / Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	5.0 to 6.5	4.0 to < 5.0 or > 6.5 - 7.5	3.5 to < 4.0 or > 7.5 to 9.0	< 3.5 and > 9.0
Salinity (EC; dS/m)	< 2	2 to 4	4 to 8	> 8
Sodicity (SAR)	< 4	4 to 8	8 to 12	> 12
Available water storage capacity (mm/cm/50 cm)	> 45	25 to 44	10 to 24	< 10
Saturation %	30 to 60	20 to < 30, > 60 to 80	15 to < 20, > 80 to 100	< 15, and > 100
% coarse fragments (+2 mm size fraction)	< 50	50 to 70	> 70 to 90	> 90
Texture	SL, L, SiL	LS, CL, SCL, SiCL	S, SiC, Si, C, HC	Consolidated bedrock
Consistence (moist)	very friable, friable	loose, firm	very firm; sticky (wet)	extremely firm
% Organic carbon (topsoil use 3 categories only); subsoil (only considered limiting if > 17% C)	2 - 17 (topsoil)	1 to < 2 (topsoil), or, if > 17 (soil amendment only - topsoil and subsoil)	< 1 (topsoil)	Not limiting to this degree for either topsoil or subsoil
$CaCO_3$ equivalent (%)	< 2	2 to 20	> 20 to 70	> 70

The assumption is that these materials will be used in the reconstruction of a root zone soil profile for the development of representative upland habitat common to the LSA. Materials rated Good, Fair, or Poor are considered suitable for use. For comparative purposes, the soils from which samples were analyzed were classified at the horizon level (sometimes representing more than one discreet horizon) and grouped according to the order classification and soil type (parent material and soil drainage).

Generalized Soil Legend

SMUs represent unique combinations of soil parent materials, soil moisture regime, and soil development. A Generalized Soil Legend was developed to group nearly 100 combinations of SMUs into 22 groups based primarily on soil parent materials, soil development, and drainage (Table 11.3-5). The Soil Groups reflect SMU general soil management characteristics such as reclamation potential, salvage depth, and/or suitability.

Table 11.3-5. Generalized Soil Legend for the Brucejack Gold Mine Project

Soil Climate[1]	Soil Group	Drainage	SMU Range per Soil Map[2]	Soil Order Range[2]
Alpine, Forest	**Colluvial Soils — commonly occur in steep to very steep topography. High in CFC, often poorly developed**			
	1	Very Rapid – Well	C1.B, C2.P, C3.B, C3.P	B, P
	2	Mod. Well – Imperfect	C4.B.so, C5.B, C5.B.g, C5.P, C5.P.g, U5.B.g	B, B.so, B.g, P, P.g
	3	Poor	C5.G, C6.G, C7.G	G
	4	Variable	C2.n, C2.R, C3.R, C6.R	n, R
Alpine	**Residual Soils — occur in variable, often hummocky to steep, topography**			
	5	Very Rapid –Well	D1.B, D3.B.so, D3.P	B, B.so, P
	6	Variable	D5.R.g, D6.B.g, D6.G, D1.n, D2.R	R, R.g, B.g, G, n
Forest	**Fluvial Soils — near level, commonly with terraces. Well sorted, often high in CFC but variable. Range from fine silts to gravel in texture**			
	7	Variable	F '2.R, F '4.R, F '5.R, F4.R, F5.n, F6.R, F 'n.n, F5.R, Fn.n, G5.R; L1.n, L2.R	R, n
	8	Mod. Well – Imperfect	F '5.R.g, F '6.G, F '7.G, F5.B.g, F5.G, F5.R.g	R.g, G, B.g
	9	Rapid –Well	F5.B, F5.P	B, P
Forest	**Glacio-fluvial Soils — near level terraces to undulating topography. Often very high in coarse fragment content, poorly developed**			
	10	Mod. Well – Imperfect	G5.B, G5.B.g, G5.P, G5.P.g	B, B.g, P, P.g
	11	Poor	F6.G, F6.R.g, F7.G, F7.G.p, G6.G, G7.G, G7.G.p, L6.G	G, R.g, G.p
Forest (Alpine)	**Morainal Soils — variable topography, commonly on complex, gentle to moderate slopes**			
	12	Rapid – Well	M1.P, M2.P, M3.B, M3.B.so, M3.P	P, B, B.so
	13	Mod. Well – Imperfect	M4.B.g, M4.B.so, M4.P, M4.P.so, M5.B, M5.B.g, M5.P, M5.P.g	B, B.g, B.so,P, P.so, P.g
	14	Poor	M5.G, M6.G, M6.P.g, M7.G, M7.G.p	G,P.g,G.p
	15	Rapid –Mod. Well	M2.n, M2.R, M4.n, M4.R	n, R
Forest (Alpine)	**Wetland / Organic Soils — simple, level to near level topography. Poorly to moderately decomposed**			
	16	Very Poor	O7.O	O (M, F)
	17	Very Poor	O5.G.p, O6.G.p, O7.G.p	G.p
Alpine (Forest)	**Bedrock/Residual Soils — variable topography though commonly moderately steep to steep**			
	18	Variable	R1.R, R2.B, R2.R, R3.R, R4.B.so, R4.R, R5.B, R5.G, R5.R	R, B, B.so, G
	19	Restricted	R1.n,R2.n	n
	Non-Soils — variable topography			
Alpine, Forest	20	Not applicable	Wn.n - Water covered	n
Alpine	21	Not applicable	In.n - Ice and permanent snow	n
Alpine	22	Variable	An.R - anthropogenic (mine waste soils)	R, n

[1] Soil climates are defined as follows: Alpine - includes alpine and parkland BEC subzones (BAFAun, CMAun, ESSFunp, MHunp); Forest - includes forested subzones and variants (ICHvc, ESSFun, MHmm1, MHmm2)
[2] Soil Order Abbreviations: B - Brunisol, B.g -gleyed, B.so -sombric/turfy A; G - Gleysol, G.p -peaty; n - non-soils; O - organic orders (Mesisols and Fibrisols); R - Regosol, R.g -gleyed; P - Podzol, P.g - gleyed.

<u>Soil Groups</u>

Soil Group 1 to 4: Colluvial Soils

Generally, soils derived from colluvium are high in coarse fragments, associated with steep slopes, and have discontinuous pedogenic processes due to continual downslope movement. Materials for these soils are commonly derived from rockfall along the exploration access road and from moraine-derived colluvium along the transmission line. Four Soil Groups were established in the LSA based on relative drainage and soil development. Soil Group 1 includes well to rapidly drained Dystric Brunisols and Ferro-Humic and Humo-Ferric Podzols in upper and mid slope positions. Soil Group 2 includes moderately well to imperfectly drained gleyed Brunisols and gleyed Podzols, typically in low slope positions. Soil Group 3 includes poorly drained Gleysolic soils typically occurring in lower toe and depression slope positions. The remaining non-soils or weakly developed regosolic soils in colluvial materials are included in Group 4.

Soil Group 5 to 6: Residual Soils

Residual soils typically occur at high elevation and have an alpine soil climate. The topography is often complex with an irregular occurrence of bedrock outcrops and soils that are characteristically shallow to very shallow. Soil Group 5 shows moderate subsoil development (Brunisols), while Soil Group 6 shows weak development (Regosols) or signs of wetness (Gleysols).

Soil Group 7 to 9: Fluvial Soils

Fluvial soils commonly occur in the valley bottoms on level to nearly level topography, usually in a series of terraces above the active channel. They often display a stratigraphically variable, though commonly very high, coarse fragment content and coarse soil textures. Soil moisture is dependent upon the fluctuating groundwater level. Soil Group 7 soils most commonly show no or very weak profile development (Orthic Regosols), often with evidence of past burial of the soil surface (Cumulic Regosols) by shifting channel deposits. The generally less well-drained, weakly developed Regosols and shallow, often gleyed, Brunisols comprise Soil Group 8, while better developed soils (Soil Group 9) usually occur on the higher fluvial benches.

Soil Group 10 to 11: Glaciofluvial Soils

Glaciofluvial deposits are materials deposited by ice-contact rivers. Due to the high energy, high volume natures of these rivers, the deposits tend to be poorly to moderately stratified and very coarsely textured. Soils derived from glaciofluvial materials will usually have very rapid drainage and low nutrient content. Soil pedogenesis is very slow due to lack of fine textured material. Soil Groups 10 and 11 commonly occur in valley bottoms and lower side slopes on elevated, often level to irregular terrain associated with the main creeks and river valleys. These soils display commonly high to very high coarse fragment content and coarse textures, in a range of soil moisture regimes. Rapidly to moderately well to imperfectly drained Regosols, Brunisols, and Podzols typify Soil Group 10.

Soil Group 12 to 15: Morainal Soils

Morainal soils commonly occur on complex terrain of variable steepness and exhibit medium to coarse soil textures. Soil development varies from very well developed, moderately deep, Podzols and Brunisols (Soil Group 12) to very weak or undeveloped Regosols and non-soils, in areas of active de-glaciation (Soil Group 15). Soil drainage differences account for the soil development differences noted in seep affected, imperfectly drained Soil Group 13 soils (gleyed subgroups of Brunisols and Podzols), and poorly to very poorly drained Gleysols of Soil Group 14, commonly located in depressions or at toe slope positions.

Soil Group 16 to 17: Wetland — Organic Soil

Organic soils occur on near level to depressional, poorly to very poorly drained terrain. These are located primarily in valley bottoms and the near level depressions in the hummocky terrain in the eastern segment of the exploration access road, near the Bell River (Highway 37). They also occur at the height of land near Todedada Wetland in wetlands fens. Soil Group 16 comprises deep, thick, mesic, and fibric organic deposits (Typic and Terric Mesisols and Fibrisol soil). Soil Group 17 includes shallower peat deposits, including soils classed as Terric Fibrisols and Terric Mesisols and peaty phase Gleysols.

Soil Group 18 to 19: Bedrock

Exposed bedrock occurs in variable topography, most commonly ranging from steep to very steep in the forested soil climate zone to hummocky to very steep in the alpine soil climate zone. These Soil Groups represents primarily bedrock outcrops, but with pockets of shallow soil of variable SMR. These are mostly very dry, with a turfy, mineral surface layer. Soil Group 18 is characterized by a comparatively deeper lithic contact including a range of soil classes, namely Regosols, Brunisols, and, less commonly, Gleysols. Soil Group 19 is defined by a very shallow, lithic contact and commonly includes soils too thin to be considered soil, as well as Orthic Regosols, which are commonly associated with exposed soil.

Residual soils units, Soil Groups 5 and 6, are differentiated by having less exposed, consolidated bedrock (less than 50% cover) than Soil Groups 18 to 19. Folisols (shallow upland, organic soils) may be associated with bedrock and with inactive talus slopes, and are present in the wet, upper elevations of the forested soil climate zone.

Soil Groups 20 to 22: Non-soils

The remaining Soil Groups 20 through 22 include surface covers not associated with soils. These include water-covered areas occurring across all soil climate zones (Group 20), ice and permanent snow cover areas (Group 21), and anthropogenic materials from past exploration activities, currently restricted to the alpine Brucejack Lake area (Group 22).

11.3.4.3 Soil Analytical Results

Fifty soil samples were collected from 34 inspection sites representing various soil parent materials from across the various soil climates in the LSA. At all 34 sites, samples were collected from the near surface, and at 12 sites samples were collected from the less weathered subsoil. Soil results for the analyses used to characterize soil development and rate suitability for reclamation are presented in the 2012 Terrestrial Ecosystem Baseline Studies (Appendix 16-A).

Soil Reaction (pH)

The range of pH found in soil in the LSA is relatively wide, from 3.8 (extremely acidic) to 8.1 (moderately alkaline). However, most topsoil samples have extremely to strongly acidic reaction. Subsoil samples commonly have extremely acid to medium acidic reaction (pH < 4.5 to 6.0), though range to pH 8.1 (moderately alkaline). The paired comparison of topsoil to subsoil generally shows slightly less acidic reaction. The subsoil soil reaction suggests that many of the soil parent materials may be base poor.

Free Carbonates

Testing for free carbonates was conducted on 11 subsoil and surface soil samples from a range of acidities. Free carbonates are typically absent from samples with a pH of 6.6 or less. The $CaCO_3$ Equivalence (inorganic carbon) was below detection on all but one of the acidic samples, while mildly to moderately alkaline samples from the same soil profile displayed moderately high $CaCO_3$ Equivalence.

Soil Carbon

Organic matter accumulation in the soil profile is assessed by the measurement of the organic carbon content of the soil. Based on the 35 samples tested, total carbon is a reasonable proxy for organic carbon in the local soils with the exception of soils displaying alkaline soil reaction. Results show organic matter accumulation decreases with depth. There is a 1.3% median difference in total carbon content between the surface soil and subsoil. This trend confirms the basis for selective surface soil topsoil handling separate from the un-weathered parent materials. The presence of organic matter strongly influences the cation exchange capacity (CEC) of local soils as increasing carbon content shows a positive relationship with increasing CEC.

Soil Texture

Most hand texturing in the field indicates that soils are coarse to moderately coarse and medium textured. The lab results confirm that soils in the Project area display a range of texture classes from medium to very coarse. Based on the lab data, the moderately fine rated (Sandy Clay Loam - SCL) field textures may overestimate the clay content and may actually include slightly coarser, loam textured materials.

Cation Exchange Capacity and Exchangeable Cations

The CEC reflects the soil's ability to retain cations in an exchangeable form, an important characteristic for root zone fertility. CEC reflects the presence of colloidal materials, typically humus and clay-size mineral material, within the soil profile. Representative samples from both near surface and at depth allow comparison of topsoil versus subsoil from a range of common textures and soil reaction classes.

The lab results display a relatively wide range of CEC, from 1.6 to 80.5 milliquivalents of cations per 100g of soil. The lowest CEC is associated with the coarsest texture with the lowest organic matter, while the highest CEC is associated with an organic surface with moderately high clay.

Exchangeable cation concentrations were only determined on a few samples representing a range of soil reaction classes. Most local soils exhibit a very low base saturation percentage. The highest percent base saturation is associated with soils displaying an alkaline reaction.

Soil Metals

Fifty samples from 34 soil sites across the three sub-areas were analyzed for a suite of 31 metals, of which 19 have CCME Industrial Use Guideline criteria values. Seven of the nineteen metals (Sb, As, Cr, Cu, Ni, Tl, and V) were noted to exceed industrial use criteria at least once. Of the metals of concern, arsenic is the most frequently occurring and exceeded the CCME criteria of 12 mg/kg in 31 of 50 samples. Nickel had the second highest number of soil samples exceeding the CCME guidelines, with eight samples along the exploration access road in exceedance. Copper and chromium exceedance was noted once at a site along the exploration access road. Thallium exceeded in four samples from the Brucejack Mine Site and vanadium exceedance was also noted at two sites.

11.3.5 Characterization of Baseline Terrain Stability

Geohazard and risk assessments conducted between 2012 and 2013 by BGC Engineering included terrain stability mapping, snow avalanche mapping, and geohazard assessments. The latter includes analyses of geohazards, geohazard scenarios, and geohazard risks. The term "geohazard" refers to the specific nature of the active process, including type (e.g., shallow seated landslide), frequency, and magnitude, but does not imply consequences or outcomes. Geohazards include landslide or snow avalanche processes that have the potential to result in some undesirable outcome, such as damage to infrastructure, endangering or injuring personnel, or damage to environmental values (e.g., soil quality and quantity, fish habitat, and water quality). Geohazards are identified through terrain stability mapping, landslide identification, and snow avalanche track mapping. Geohazard scenarios are used to describe the potential outcomes of a geohazard event. They assess the interaction between the geohazard and some predetermined component of value, such as specific infrastructure. Geohazard risk is concerned with estimating the likelihood of an event occurring, as well as the consequence in terms of economic, social, or environmental impacts. These geohazard and risk assessments provided relevant information for the baseline characterization of terrain and soils.

In order to support the Project, terrain stability mapping was conducted within 41,065 ha. The area mapped overlaps with the LSA used for Terrain and Soils baseline studies, except at the Brucejack Mine Site, where a smaller area was assessed for terrain stability. This mapping is presented in Appendix 5-F (Brucejack Gold Mine Project Geohazard and Risk Assessment). Baseline studies commenced in 2012; a preliminary assessment of landslide and snow avalanche hazards was conducted to support construction of the existing exploration access road and Brucejack Mine Site. Terrain mapping of the Brucejack Transmission Line was carried out in 2013. However, no geohazard assessment was completed as tower locations had not yet been determined. Snow avalanche assessment studies were carried out by Alpine Solutions Avalanche Services in 2013. These studies are presented in Appendices 5-F and 11-A.

Based upon the terrain stability mapping, Table 11.3-6 presents the distribution of terrain instability amongst the three sub-areas.

Table 11.3-6. Distribution of Slope Stability Classes within the Local Study Area by Sub-area

	Local Study Area			
Slope Stability Class	Brucejack Mine Site (ha)	Brucejack Transmission Line (ha)	Exploration Access Road (ha)	Entire Local Study Area (ha)
i	0	109.3	0	109.3
I	13.1	1,010.2	3,296.1	4,319.4
II	193.1	1,881.4	2,997.8	5,072.3
III	519.4	2,207.4	3,726.9	6,453.7
IV	428.6	1,246.6	1,630.1	3,305.3
V	453.3	3,613.8	1,198.3	5,265.4
Not Classified	3,432.8	2,903.4	986.3	7,322.5

The distribution of identified geohazards is presented in Appendices 5-F and 11-A. Table 11.3-7 presents the baseline level of risk that geohazards pose to the Project. This is detailed in Appendix 5-F.

Table 11.3-7. Summary of Geohazard Risk to the Brucejack Gold Mine Project at Baseline[1]

Facility	Hazard Type	Facility Risk	Safety Risk
Brucejack Camp	Landslide	Low	Low
	Avalanche	Moderate	High
Mine Site Roads	Avalanche	-	High
Brucejack Access Road	Landslide	Moderate	Low
	Flood	High	-
	Avalanche	Low	Moderate
Knipple Transfer Area	-	Very low	Low
Aerodrome	Flood	High	-

[1]The Brucejack Camp has been relocated from baseline to reduce geohazard risk. Safety risk is now low for the new camp location.

The Project area generally demonstrates a low landslide hazard at baseline condition, while certain areas, such as the exploration access road along the Bowser River, have high risk for flooding. Avalanche risk is high at the Brucejack Mine Site.

11.4 ESTABLISHING THE SCOPE OF THE ASSESSMENT FOR TERRAIN AND SOILS

This section of the Terrain and Soils Predictive Study includes a description of the scoping process used to identify potentially affected intermediate components that are a pathway to other receptor Valued Components (VCs), and to select assessment boundaries. Scoping is fundamental to focusing the Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS) on those issues where there is the highest potential to cause significant adverse effects. The scoping process for the assessment of terrain and soils consisted of the following three steps:

- Step 1: scoping process to select intermediate components, sub-components, and indicators based on a consideration of the Project's potential to interact with terrain and soils;
- Step 2: consideration of feedback on the results of the scoping process; and
- Step 3: defining assessment boundaries for terrain and soils.

These steps are described in detail below.

11.4.1 Selecting Intermediate Components

To be considered for assessment, a component must be of recognized importance to society, the local community, or the environment, and there must be a perceived likelihood that the component will be affected by the proposed Project. Intermediate components are specific attributes of the biophysical environment that, if affected (i.e., there is a positive or negative change in the baseline condition), act as a pathway to pass on those changes to other components of the environment, thereby having the potential to also affect or change the baseline condition of receptor VCs. Intermediate components are scoped during consultation with key stakeholders, including Aboriginal communities and the environmental assessment (EA) Working Group[1]. Consideration of certain components may also be a legislated requirement, or known to be a concern because of previous project experience. Terrain and soils were selected as an intermediate component because of their intrinsic link with vegetation, wildlife habitat, water quality, and a broad spectrum of ecosystem functions. Terrain and soils were further refined into the following sub-components and indicators which are used to determine potential effects. A summary of the sub-components and their corresponding indicators is provided in Table 11.4-1.

Table 11.4-1. Summary of Terrain and Soils Sub-components and Indicators

Sub-components	Indicators
Soil quality	Productivity, metal content, water infiltration capacity, organic matter content, pH, structure
Soil quantity	Volume, depth to lithic contact
Terrain stability	Mass movement, vegetation patterns, altered hydrology, sedimentation

[1] The EA Working Group is a forum for discussion and resolution of technical issues associated with the proposed Project, as well as providing technical advice to the British Columbia Environmental Assessment Office (BC EAO) and Canadian Environmental Assessment Agency (CEA Agency), who remain ultimately responsible for determining significance. It comprises representatives of provincial, federal, and local government, and Aboriginal groups.

11.4.2 Potential Interactions between the Project and Intermediate Components

A scoping exercise was conducted during the development of a draft AIR, to explore potential Project interactions with candidate intermediate components and receptor VCs, and to identify the key potential adverse effects associated with that interaction. The results of the scoping exercise were circulated for review and approval by the EA Working Group and feedback from that process and from additional comments received have been integrated into the Application/EIS. Table 11.4-2 provides an impact scoping matrix of Project components and the terrain and soils intermediate component that reflects Project components and activities that have a possible or likely interaction with terrain and soils. Interactions between the Project and terrain and soils were assigned a colour code as follows:

- not expected (white);
- possible (grey); and
- likely (black).

Table 11.4-2. Interaction of Project Components and Physical Activities with Terrain and Soils

Project Components and Physical Activities by Phase	Terrain and Soils
Construction Phase	
Activities at existing adit	
Air transport of personnel and goods	
Avalanche control	
Chemical and hazardous material storage, management and handling	
Construction of back-up diesel power plant	
Construction of Bowser Aerodrome	
Construction of detonator storage area	
Construction of electrical tie-in to BC Hydro grid	
Construction of electrical substation at Mine Site	
Construction of equipment laydown areas	
Construction of helicopter pad	
Construction of incinerators	
Construction of Knipple Transfer Area	
Construction of local site roads	
Construction of Mill Building (electrical induction furnace, backfill paste plant, warehouse, mill/concentrator)	
Construction of mine portal and ventilation shafts	
Construction of Brucejack Operations Camp	
Construction of ore conveyer	
Construction of tailings pipeline	
Construction and decommissioning of Tide Staging Area construction camp	
Construction of truck shop	
Construction and use of sewage treatment plant and discharge	
Construction and use of surface water diversions	
Construction of water treatment plant	
Development of underground portal and facilities	

(continued)

Table 11.4-2. Interaction of Project Components and Physical Activities with Terrain and Soils (continued)

Project Components and Physical Activities by Phase	Terrain and Soils
Construction Phase (cont'd)	
Employment and Labour	
Equipment maintenance/machinery and vehicle refueling/fuel storage and handling	
Explosives storage and handling	
Grading of the mine site area	
Helicopter use	
Installation and use of Project lighting	
Installation of surface and underground crushers	
Installation of transmission line and associated towers	
Machinery and vehicle emissions	
Potable water treatment and use	
Pre-production ore stockpile construction	
Procurement of goods and services	
Quarry construction	
Solid waste management	
Transportation of workers and materials	
Underground water management	
Upgrade and use of exploration access road	
Use of Granduc access road	
Operation Phase	
Air transport of personnel and goods and use of aerodrome	
Avalanche control	
Backfill paste plant	
Back-up diesel power plant	
Bowser Aerodrome	
Brucejack Access Road use and maintenance	
Brucejack Operations Camp	
Chemical and hazardous material storage, management, and handling	
Concentrate storage and handling	
Contact water management	
Detonator storage	
Discharge from Brucejack Lake	
Electrical induction furnace	
Electrical substation	
Employment and Labour	
Equipment laydown areas	
Equipment maintenance/machine and vehicle refueling/fuel storage and handling	
Explosives storage and handling	
Helicopter pad(s)	
Helicopter use	

(continued)

Table 11.4-2. Interaction of Project Components and Physical Activities with Terrain and Soils (continued)

Project Components and Physical Activities by Phase	Terrain and Soils
Operation Phase (cont'd)	
Knipple Transfer Area	
Machine and vehicle emissions	
Mill building/concentrators	
Non-contact water management	
Ore conveyer	
Potable water treatment and use	
Pre-production ore storage	
Procurement of goods and services	
Project lighting	
Quarry operation	
Sewage treatment and discharge	
Solid waste management/incinerators	
Subaqueous tailings disposal	
Subaqueous waste rock disposal	
Surface crushers	
Tailings pipeline	
Truck shop	
Transmission line operation and maintenance	
Underground backfill tailing storage	
Underground backfill waste rock storage	
Underground crushers	
Underground: drilling, blasting, excavation	
Underground explosives storage	
Underground mine ventilation	
Underground water management	
Use of mine site haul roads	
Use of portals	
Ventilation shafts	
Warehouse	
Waste rock transfer pad	
Water treatment plant	
Closure Phase	
Air transport of personnel and goods	
Avalanche control	
Chemical and hazardous material storage, management, and handling	
Closure of mine portals	
Closure of quarry	
Closure of subaqueous tailing and waste rock storage (Brucejack Lake)	
Decommissioning of Bowser Aerodrome	

(continued)

Table 11.4-2. Interaction of Project Components and Physical Activities with Terrain and Soils (completed)

Project Components and Physical Activities by Phase	Terrain and Soils
Closure Phase (cont'd)	
Decommissioning of back-up diesel power plant	
Decommissioning of Brucejack Access Road	
Decommissioning of camps	
Decommissioning of diversion channels	
Decommissioning of equipment laydown	
Decommissioning of fuel storage tanks	
Decommissioning of helicopter pad(s)	
Decommissioning of incinerators	
Decommissioning of local site roads	
Decommissioning of Mill Building	
Decommissioning of ore conveyer	
Decommissioning of Project lighting	
Decommissioning of sewage treatment plant and discharge	
Decommissioning of surface crushers	
Decommissioning of surface explosives storage	
Decommissioning of tailings pipeline	
Decommissioning of transmission line and ancillary structures	
Decommissioning of underground crushers	
Decommissioning of waste rock transfer pad	
Decommissioning of water treatment plant	
Employment and Labour	
Helicopter use	
Machine and vehicle emissions	
Procurement of goods and services	
Removal or treatment of contaminated soils	
Solid waste management	
Transportation of workers and materials (Mine Site and access roads)	
Post-closure Phase	
Discharge from Brucejack Lake	
Employment and Labour	
Environmental monitoring	
Procurement of goods and services	
Subaqueous tailing and waste rock storage	
Underground mine	

Notes:
White = interaction not expected between project components/physical activities and an intermediate component
Grey = possible interaction between project components/ physical activities and an intermediate component
Black = likely interaction between project components/ physical activities and an intermediate component

Interactions coded as not expected (white) are considered to have no potential for adverse effects on terrain and soils, and are not considered further.

11.4.2.1 Consultation Feedback on Intermediate Components

Potential effects on terrain and soils resulting from the Project, or similar industrial developments, were included in the Application for Information (AIR), due to regulatory requirements (as outlined in Section 11.2). These issues, summarized in Table 11.4-3, were raised in a variety of forums and reports including public/stakeholder comments, reviews of best management practices, scientific literature, and land use plans, as reflected in Chapter 3, Information Distribution and Consultation.

Table 11.4-3. Terrain and Soils Intermediate Components Included in the Application/EIS

Terrain and Soils Sub-components	Identified by*				Rationale for Inclusion
	AG	G	P/S	IM	
Soil Quality		x		x	Necessary to maintain ecological function of ecosystems; has direct influence on wildlife habitat availability; affects traditional hunting, fishing, trapping, and gathering needs; protection required by *Mines Act*(1996).
Soil Quantity		x		x	Affects ecological function and quality of fish and wildlife habitat, quality of groundwater resources and associated human and wildlife needs; affects traditional way of life of local Aboriginal peoples; protection required by *Environmental Management Act* (2003), *Mines Act*(1996).
Terrain Stability		x		x	Important to understand the dynamic physical environment in order to mitigate through design and management the risks that Project interactions with existing geohazards and potentially unstable terrain present to the environment and the Project.

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; IM = Impact Matrix*

11.4.2.2 Summary of Intermediate Components Included in the Application/EIS

Each sub-component of the terrain and soils intermediate component included in the Application/EIS meets the following three criteria:

1. There is a spatial and temporal overlap between the Project and the sub-component such that interactions may occur.
2. Baseline data are available for the sub-component, which can be used to characterize Project interactions and serve as the basis for assessing potential effects of the Project.
3. There is a perceived and reasonable likelihood (i.e., as assessed by government regulators, Aboriginal groups, or stakeholders) that the sub-component could be affected by the Project.

Soil quantity and quality have been chosen as sub-components that could be affected by the Project. Reduction of soil quantity through erosion, mass wasting, burial, excavation, and construction reduces the area available to support vegetation growth and provide nutrient, carbon, and water cycling. Reduction in soil quality can result from changes in site drainage patterns, compaction, or contamination. It can also occur from alteration of soil attributes such as structure, organic matter content, pH, chemical composition, and microbial populations and associated activity. Reductions in soil quantity and quality can affect the ecological function of ecosystems, habitat quality, and water quality. This, in turn, can affect traditional hunting, fishing, and plant gathering.

Terrain stability was selected as a sub-component based on information from several sources, including the AIR, and government regulators.

11.4.3 Assessment of Boundaries for Terrain and Soils

Assessment boundaries define the maximum limit within which the effects assessment is conducted. They encompass the spatial and temporal boundaries within which the Project is expected to interact with the intermediate components, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). Assessment boundaries encompass possible direct, indirect, and induced effects on terrain and soils, inclusive of Project effects on relevant end-point receptor VCs, as well as the trends in processes that may be relevant.

11.4.3.1 Spatial Boundaries

For the purpose of the Application/EIS, the definitions provided below are used to define the study areas.

<u>Project Footprint</u>

Project Footprint is defined as the area of land or water associated with the proposed sites for all physical structures and activities that comprise the Project (see Figure 6.4-1).

<u>Assessment Footprint</u>

Assessment Footprint is defined as an area that extends beyond the Project Footprint and provides a conservative area assumed to be functionally lost due to Project activities (see Figure 6.4-1). The Assessment Footprint allows for an area of disturbance beyond the anticipated Project Footprint to allow for minor adjustments in the realized footprint disturbances between completion of the EA and ground disturbance during physical activities related to Project development. At the Mine Site, the boundary extends to the height of land or to the nearest sub-watershed boundary (e.g. East Lake) around Project infrastructure. In certain areas other physical features were also used to define the Assessment Footprint when they were considered to be the limit of the potential effects of the Project such as natural terrain features, buffers from infrastructure (minimum of 100 m) and geology.

<u>Local Study Area</u>

The potential effects of the Project on terrain and soils sub-components were identified and evaluated within the LSA used during the baseline studies, which includes the assessment footprint. The details regarding the delineation of the LSA are discussed in Section 11.3.3.2.

<u>Regional Study Area</u>

No Regional Study Area was established for this predictive study, as effects to terrain and soils are primarily local in extent.

11.4.3.2 Temporal Boundaries

The temporal boundaries of the Project correspond to the following four phases:

- Construction: 2 years;
- Operation: 22 years;
- Closure: 2 years (includes Project decommissioning, abandonment and reclamation activities); and
- Post-closure: minimum of 3 years (includes ongoing reclamation activities and post-closure monitoring).

11.4.3.3 Administrative Boundaries

The Project is situated within the Regional District of Kitimat-Stikine, an administration providing local government services to member municipalities within northwestern BC. It is situated within the Kalum and Skeena-Stikine Forest Districts, and the Nass and Cassiar Timber Supply Areas, administrative boundaries within which forest resources are managed by the provincial Ministry of Forests, Lands and Natural Resource Operations.

The Project also overlaps portions of the Cassiar Iskut-Stikine Land and Resource Management Plan (CIS LRMP) area, completed in October 2000 (BC ILMB 2000), and the Nass South Sustainable Resource Management Plan (Nass South SRMP) area, completed in June 2012 (BC MFLNRO 2012). The CIS LRMP is a sub-regional resource plan that establish the framework for land use and resource management objectives and strategies (BC ILMB and Ministry of Agriculture and Lands 2006). The Nass South SRMP is a landscape-level plan developed to address sustainable management of land, water, and resources. It focuses on similar issues and values as regional plans or LRMPs (e.g., timber, biodiversity, tourism) but at a more detailed level.

11.4.4 Identifying Key Potential Effects on Terrain and Soils

This assessment identifies key potential effects of the Project on soil quantity and/or quality. The severity of effect is categorized according to location within:

1. Project or infrastructure development footprint. This area is characterized as the potential soil 'loss' area, where effects of both soil quantity and quality and probable.
2. Peripheral buffer areas. Soils quality in these areas surrounding the development footprint may be either degraded or altered (neutral or beneficial effect) due to activities or interactions other than direct footprint development. Soils within a 100 m zone immediately adjacent to the development footprint are considered to be most likely to be affected, though in reality this would vary (could be less) depending on the type of infrastructure development.

The most significant effects on soils typically occur within the infrastructure development footprint, as these areas experience the most severe ground disturbance. Site preparation activities generally result in some level of soil loss; this occurs during Construction and is not mitigated until the site is reclaimed. Direct loss occurs when soils are buried as a result of infrastructure development, or if large scale erosion occurs due to exposures that are created. The effects of infrastructure development activities on soils are however, at least partially mitigated for soils that are salvaged for use in future site reclamation. The extent of these effects on soils depends on such factors as salvage quantities, handling during salvage and replacement, and storage methods and length. All such handling results in some level of soil degradation, however where in situ soil quality is good, salvage and replacement is still generally beneficial to reclamation success.

Peripheral to development footprint areas, there may be alteration (may include improvement) or degradation effects on soil quality due to other effects of Project related activities. As described above, these effects are expected to be greatest in a 100 m zone surrounding the development footprint. Soils are not lost in these areas, but may be affected due to such factors as:

- Compaction due to motorized or foot traffic, or other activities;
- Erosion due to vegetation loss which may also results from motorized or foot traffic, which may also result in reduced soil fertility;
- Spills, including potentially of fuel;

- Hydrological effects; and
- Dust deposition.

Soil compaction may occur through traffic impacts on soils, equipment and soil material storage, foot traffic, and the conversion of a soil to an engineering medium. Typically, compaction affects vegetation establishment and growth due to decreased root penetration and soil aeration. Compaction reduces movement of water down the soil profile, resulting in increased runoff. This has the effect of increasing surface soil erosion rates, which may adversely affect water quality.

Soil contamination may result from spills of deleterious substances, which have the potential to occur throughout the Project life. These substances may accumulate in the soils, increasing the concentration of metals and other pollutants and may lead to loss of soil fertility and increased toxicity to vegetation and soil fauna, or, in extreme cases, render soil unsuitable to support ecological functions.

Wind and water erosion of soil, usually induced by soil surface disturbance or vegetation removal, can result in the loss of fertile soil horizons and may introduce sediments into watercourses. Soil fertility can also be compromised during soil salvaging operations. For example, there is a risk that soil fertility will be reduced if fertile surface soils are inadvertently mixed with infertile subsurface material (admixing).

Alteration of stream channels or hydrological regimes may change the moisture regime of nearby soils.

Soil alteration may occur as a result of dust deposition. Dust deposition along roads or surrounding other potential dust sources (e.g. open stockpiles or platform areas) has the potential to alter soil characteristics, such as productivity, in a neutral or beneficial way depending on characteristics and thickness of the deposited dust layer.

The Project also has the potential to affect terrain stability, which is assessed using slope stability classes. The Project has the potential to decrease terrain stability, which could increase the incidence and magnitude of geohazards. Project activities that could potentially affect terrain stability include those that destabilize slopes, affect hillslope hydrology, and create over-steepened terrain. Development that involves excavation at the base of identified landslides or excavation in areas classified as potentially unstable could have a destabilizing effect, resulting in failure and adverse downslope consequences.

It is possible that Project development (e.g., excavation of high road cuts, construction of unbenched angle of repose fill slopes, and logging on steep slopes) could create additional snow avalanche terrain. Logging of slopes directly below snow avalanche terrain could result in longer avalanche run-out paths. Unmitigated effects or consequences could include damage or destruction of access roads, transportation vehicles, mining equipment, and mine infrastructure, as well as injury to personnel.

The Project also has the potential to increase terrain stability in certain areas by modifying unstable areas in a manner that reduces the likelihood of geohazard occurrences. An increase in geohazards could result in increased risk to Project infrastructure and personnel, and risk to the environment due to vegetation removal, soil loss, and sedimentation. An increase in terrain stability could reduce risk to infrastructure, personnel, and environmental values such as water quality and fish habitat.

Mine subsidence can be defined as ground surface movements that occur due to the collapse of overlying or adjacent strata into mined out voids, which expresses itself in cracks, fissures, step fractures, pits or sinkholes, troughs, or sags.

It is possible that subsidence could result due to the establishment of the subsurface mine. Subsidence is associated with a variety of processes including compaction of natural sediments, groundwater dewatering, wetting, melting of permafrost, liquefaction and crustal deformation, and hardrock mining. While subsidence can occur naturally, most subsidence is either created or accelerated by human activity.

Subsidence is often an inevitable consequence of underground mining; however, it varies greatly from project to project, depending on local site conditions, construction methods, and the depth of mining from the surface. It can range from being virtually undetectable; of significant magnitude but localized; or gradual, continuous, and extensive over very large areas. Subsidence may take years to occur (as in the case of potash mining), or can occur over very short time periods (as in the case of hard rock mining in the Project in question).

A desktop-based study of subsidence potential at the Project is presented in Appendix 11-B. A rock mechanics assessment is presented in Appendix 11-C.

11.4.4.1 Construction

Construction of the mine will result in a loss of soil through excavation, burial, or potentially through erosion of surficial materials. Soil will be salvaged from areas that will be used for construction. During the process of soil salvage and stockpiling, soil may be compacted and mixed, which will likely lead to loss of its natural structure and sequence of horizons.

During the Construction phase, soil can be altered or degraded by erosion, compaction, contamination, or other physical, chemical, and biological changes leading to a loss of soil fertility. Alteration is primarily limited to deposition of dust from roadways. The majority of this effect is expected to occur within the 100-m buffer areas around the mine facilities, laydown areas, construction camps, quarries, borrow pits, soil stockpiles, in areas disturbed by construction of the stream diversions, and along roads. There is the potential for some soil contamination due to inadvertent small spills of cement, reagent, fuel, lubricant, or other materials during the Construction phase. Soil stripping and stockpiling may result in a reduction of soil fertility due to compaction and mixing of the fertile surface soils with overburden or other unsuitable material. A gradual loss of organic matter, native plant reproductive material, and microbial activity is expected to occur in the soil stockpiles, resulting in a loss of fertility (Defra 2009).

Construction activities that could potentially affect terrain stability include those that destabilize slopes, affect hillslope hydrology, and create over-steepened terrain. Development that involves excavation at the base of identified landslides or excavation in areas classified as potentially unstable could have a destabilizing effect, resulting in failure and adverse downslope consequences. Potential effects can be mitigated by identification of areas where there is a moderate to high likelihood of slope failure following Project development, field assessment of those areas by a qualified terrain specialist, and design adaptation to address stability issues.

11.4.4.2 Operation

No additional soil quantity loss is predicted during Operation, as there is no planned expansion of the footprint established during the Construction phase.

Soil quality may potentially be adversely affected within the 100-m buffers around mine facilities and storage areas at the Mine Site. Soil degradation could result from changes in local hydrology, erosion, and disturbance from vehicles and construction equipment. In addition, spills of cement, processing reagents, fuels, lubricants, and other materials, could lead to soil contamination in some of the buffer areas. Beneficial alteration of soil quality, such as increasing soil productivity, could occur in areas of dust deposition where the dust inputs do not contain high concentrations of metals. The Brucejack Mine Site is entirely located on a gossan and is surrounded by same (see Plate 11.6-1). Due to extensive bedrock exposures and natural acidity and high metals content of most soil size materials that are present, any dust originating at the mine site that contains elevated metals concentrations is unlikely to differ to any large degree from the in situ materials. Road construction is expected to be limited during the Operation phase, although road maintenance activities are expected.

As the mine continues operating, subsidence becomes a greater risk. Maintaining mine stope and ramp stability is a critical operational component; maintaining a safe working environment is a primary aspect of any ongoing mine operation. Subsidence related to underground collapse is not expected; however, regularly monitoring for potential subsidence will be undertaken.

11.4.4.3 Closure

During the Closure phase, reclamation will be undertaken at the Brucejack Mine Site. Reclamation of high elevation areas, such as the Brucejack Mine Site, is a difficult undertaking, and achieves varying degrees of success. Therefore, for the purposes of this assessment, there will be an assumption that reclamation efforts will not result re-establishment of natural alpine tundra ecosystems for the Brucejack Mine Site. This assumption makes this assessment a “worst-case scenario” assessment, as reclamation will restore some ecological function, compensating somewhat for soils that have been lost or degraded by Project activities.

Each tower base along the Brucejack Transmission Line is expected to cover an area of less than 4 m^2, and construction by use of helicopters is planned so reclamation should be a straightforward removal of the lines and towers with little required beyond that. No assessment of reclamation, and its ability to compensate for soil loss and degradation (due to tower placement or removal, etc.), is undertaken in this assessment with respect to the Brucejack Transmission Line.

It is not anticipated that any Closure and reclamation activities will decrease terrain stability or increase the incidence of avalanches. The Mine Site will be monitored for subsidence.

11.4.4.4 Post-closure

After the Closure phase, there is a possibility of continued soil alteration or degradation in buffer areas around the remaining facilities (e.g., water diversion, roads, and the Brucejack Transmission Line) that are required for maintenance. Management of soil during the life of the Project will affect the long-term recovery of soil productivity. For example, moving soil to and from the stockpiles will negatively affect soil structure. Long-term storage will lead to anaerobic conditions, which reduce soil fertility (Defra 2009). Consequently, it may take many years for soils to recover to baseline biological conditions and to resume providing ecological functions.

11.5 PREDICTIVE STUDY METHODS FOR TERRAIN AND SOILS

The objectives of the predictive study for terrain and soils are to determine the potential effects of the Project on soil quantity, soil quality, and terrain stability, and to determine the potential effectiveness of mitigation of these effects. Effects to soil quantity were assessed using the spatial extent of the Project footprint, including the potential for surface erosion on cut and fill areas within the footprint. Effects on soil quality were assessed in the context of potential for soil contamination, soil compaction, loss of soil fertility, and changes to hydrological regime, and for potential alteration (neutral or negative) due to dust deposition.

Baseline terrain stability mapping and geohazard assessments (Appendices 5-F and 11-A) include a risk assessment for geohazard scenarios, but do not address the potential effects the Project could have on terrain stability. The potential effects of the Project on terrain stability were examined by assessing the potential impacts of Project infrastructure on terrain that is already unstable or potentially unstable. This assessment involved analyzing how Project infrastructure could potentially interact with terrain and soils. Resources included imagery viewed in a digital stereoscopic environment, terrain and ecosystem maps produced during baseline studies, field data including soil chemistry data to determine metal content and soil characteristics for potential use in reclamation, and topographical maps. These resources were used to define soil ecological function.

11.6 PREDICTIVE STUDY RESULTS FOR TERRAIN AND SOILS

11.6.1 Loss of Soil Quantity

This section discusses the loss of soil under the footprint of the Project, which includes the cut and fill slopes most likely to experience soil loss due to erosion during the life of the Project.

Potential soils losses are presented in Table 11.6-1. They are displayed according to the loss of in-situ ecologically functional soil. In-situ soil is that which has some level of ecological value as soil in that it supports ecosystem development. As such, it has undergone a certain amount of weathering, so that nutrient cycles are active and contributing to soil nutrient regimes. The ecological value of these soils is rated from good to poor, based upon the relative productivity of the soil mapping units used to construct the rating classes. The rating system reflects the sustainable biomass-generating potential within the respective BEC subzone, based primarily on parent material and soil taxonomic class of the soils. Soils rated as good include those which have high productive potential or special environmental value. This value may or may not be reflected in the ecological community currently supported by the soil medium. For example, many organic soils have high value as reclamation materials, but, as they develop, support little biomass production due to other limiting factors (such as saturation). Section 11.3.4.2 describes the criteria used to classify the soils in the Project area. Appendix 11-D details the ecological ratings for each SMU identified in the Project area.

Table 11.6-1. Potential Loss of Soil Quantity due to Project Infrastructure

Soil Function Rating for In-situ Ecologically Functional Soil	Brucejack Mine Site Sub-area	Brucejack Access Road Sub-area				Brucejack Transmission Line Sub-area
	Mine Site Project Footprint[1] (ha)	Bowser Aerodrome (ha)	High Ground (ha)	Knipple Transfer Area (ha)	Access Road Upgrades	Tide Staging Area (ha)
Good	0	5.8	1.6	0.4	0.7	2.9
Medium	0	2.5	0	6.1	0.4	0
Poor	24.0	16.8	0	0	0.9	1.8
Total	**24.0**	**35.2**				**4.7**

[1]Includes footprint of infrastructure to be developed within the Brucejack Mine Site Assessment Footprint which is 393.1 ha in size.

Loss of soils is summarized for the infrastructure within the Mine Site, Access Road, and Transmission Line Sub-areas. Soil losses for the Mine Site Sub-area were calculated for the areas which fall within the Project Footprint (Table 11.6-1). Soil loss calculated for the Brucejack Access Road does not include that associated with the construction of the existing exploration access road but does include 2.0 ha of soil loss associated with road upgrades. As such, calculated loss represents that associated with infrastructure including the Bowser Aerodrome, high ground to be removed, Knipple Transfer

Area, and upgrades to the access road (primarily road widening sections). Calculated loss for the Brucejack Transmission Line represents loss associated with the Tide Staging Area infrastructure only. No soil loss is calculated for the Brucejack Transmission Line, as tower locations have not yet been determined, and are expected to have a minimal footprint. Additionally, no new access roads associated with the Brucejack Transmission Line are anticipated.

During the Construction phase, 63.9 ha of in-situ soil will potentially be lost in total. Although as previously noted, the mine site is located on a recently deglaciated gossan where fine materials are not well differentiated from parent materials (Plate 11.6-1). Of the 63.9 ha, 24 ha of ecologically poorly functional soil will be lost due to construction of facilities within the Brucejack Mine Site (Table 11.6-1). At the Mine Site, there is an additional 8.3 ha of non-soil that falls within the infrastructure footprints, consisting of snow, water, or material which has not yet undergone sufficient weathering to meet soil classification criteria.

During the Construction phase, 35.2 ha of in-situ ecologically functional soil will potentially be lost due to construction of facilities within the Brucejack Access Road and 4.7 ha within the Brucejack Transmission Line (Table 11.6-1) from the Sub-Area associated with the Tide Staging Area. Soil potentially lost includes 7.8 ha of in-situ ecologically functional soil rated as good within the Access Road Sub-Area and 2.9 ha within the Transmission Line Sub-Area. In addition, 10.2 ha of non-soil will potentially be lost in the Access Road and 1.5 ha in the Transmission Line but this material has not yet undergone sufficient weathering to meet soil classification criteria. As per the Soils Management Plan, presented in Section 29.13, some of the material considered to be lost will be salvaged during Construction, to be used in reclamation during closure.

The Soils Management Plan outlines BMPs designed to maximize reclamation success. However, as success is difficult to predict, the success of reclamation has not been considered in the assessment of Project effects, and the assessment presents the “worst-case scenario”.

Plate 11.6-1. Poor, thin soils are common at Brucejack Quarry (shown in the foreground) and Mine Site (in the background).

11.6.1.1 Loss of Soil due to Erosion

Much of the Project development area is characterized by moderate to steep slopes. The areas of particularly high erosion risk include buffers along the roads and water crossings. Potential for soil loss exists on most slopes where vegetation has been removed or the integrity of the soil surface has been disturbed. The highest probability of soil loss due to erosion will be during mine Construction and Closure. Removal of vegetation during construction activities as well as gradual removal of soil from the stockpile berms and spreading it over reclaimed areas during Closure may expose the soils to increased erosion. However, additional losses associated with these activities are not quantified because they depend upon a number of factors associated with operation and reclamation.

11.6.2 Potential Alteration and Degradation of Soil Quality

Soil alteration is defined as changes to soil quality that have neutral or beneficial effects on soil characteristics. Examples of this include increases in productivity (such as mixing of organic material with surface horizons or addition of nutrients through dust deposition) or reductions in soil density (due to tilling or soil remediation works).

Soil degradation is defined as the loss of soil quality due to adverse effects. Soil degradation is caused by contamination, erosion, or loss of soil structure due to disturbances such as excavation, transport, or surface compaction. Transportation and long-term storage of soil can also adversely affect soil fertility. Changes to hydrological regime may also adversely affect soil quality, at least in its value as a growth medium.

It is expected that soil quality will be affected during the Project life within the Project footprint. Soils within the Project footprint – i.e. potential soil loss areas – are therefore expected to be affected both in terms of quantity and quality.

In order to capture potential effects outside the footprint, a 100-m buffer was applied around the facilities and infrastructure excluding the Mine Site. For the Mine Site, the Assessment Footprint around the entire mine site area (which encompasses the project footprint but does not include this area in the calculation as this area is considered lost) was considered in the assessment of soil alteration and degradation. The spatial extent of the loss of soil quality is presented in Table 11.6-2. This table summarizes all of the Project components in a single footprint. The access road and related infrastructure were considered in the assessment of soil alteration and degradation. The Brucejack Transmission Line was excluded from the assessment, as it is not anticipated that the operation of the transmission line will result in changes to soil quality.

Table 11.6-2. Area of Potential Soil Quality Alteration and Degradation Outside of the Development Footprint

Soil Function Rating for In-Situ Ecologically Functional Soil	Brucejack Mine Site Sub-Area[1] (ha)	Brucejack Access Road Sub-Area (ha)	Brucejack Transmission Line Sub-Area (ha)
Change in Quality	**Degradation**	**Alteration**	**Alteration**
Good	0	524.1	1.8
Medium	0	76.2	7.8
Poor	187.3	115.2	9.4
Total	**187.3**	**715.5**	**11.2**

[1] Total area of 393.1 ha is comprised of 187.3 ha of low value ecologically functional soil. The remaining 205.8 ha is comprised of unclassified material primarily water, snow-covered ground, or bedrock.

Of the 393.1 ha Brucejack Mine Site Assessment Footprint, 187.3 ha of ecologically functional soils rated as poor could be degraded as a result of project activities. The majority of the potential alteration, 726.7 ha, is situated along the Brucejack Access Road, due to dust created by traffic. Of the potentially altered soils along the Access Road, 524.1 ha are rated as good for ecological function. Within the Transmission Line Sub-Area, 11.2 ha of ecologically functional soils could be altered, 1.8 ha of which are rated as good for ecological function.

Soil contamination can also result from potential spills of reagents, lime, cement, fuels, lubricants, or other chemicals during the mine life and during the Post-closure phase. Most potential spills of cargo transported within the LSA resulting from container leaks, lost cargo, and vehicle accidents will be minimized by monitoring and timely remediation.

Soils can also be altered through soil eutrophication and soil acidification. These issues are discussed in Section 16.5.

11.6.2.1 Alteration or Degradation due to Soil Erosion and Compaction

Soil compaction, typically caused by construction activities and associated heavy equipment traffic, can affect vegetation establishment and growth. It can also result in increased surface runoff and soil erosion. The extent of land affected by surface compaction, and the severity of this adverse effect, are generally expected to be primarily impacted during the Construction and Closure phases.

Roads constructed on slopes can interfere with subsurface water flow and runoff, making the slopes vulnerable to erosion and slope failures (Noss 1995; Gunn 2009). Furthermore, some level of land subsidence is expected in the mining areas (see Appendices 11-B and 11-C). The exact effect of land subsidence on soil compaction is difficult to establish; however, due to potential changes in slope stability, soil mass movement and soil compaction can be anticipated near the underground mine works.

11.6.2.2 Alteration or Degradation due to Loss of Soil Fertility

While stripping and stockpiling operations are necessary to conserve soil for future reclamation, the process itself can result in soil degradation through the loss of soil structure, compaction, and erosion. With time, such activity can result in the loss of native plant reproductive material, organic matter, and faunal and microbial activity. Mixing of fertile topsoils with subsoils during soil salvage can result in a reduction of soil quality.

Soil fertility can also be affected by alteration of soil drainage patterns due to Project development. Exposed soil surfaces are known to reduce infiltration, capture and channelize surface runoff, and modify subsurface flow paths (MacKenzie and Shaw 2000; Sayers, Hall, and Meadowcroft 2002), which all affect the soil moisture regime and thus a number of related soil characteristics, such as soil fertility. Soil erosion associated with roads also decreases soil productivity in surrounding areas (Ohlson et al. 2003).

Roads can also affect soil fertility by increasing solar radiation and air movement in previously shaded environments, which leads to changes in soil temperature and moisture (Harris 1988; Sheldon 2005; Hanson et al. 2008), alters composition and activity of soil micro-organisms (Brown, Smith, and Batzer 1997), and increases the risk of fire occurrence (Mitsch and Gosselink 2000; Arienti et al. 2009). Fires, in turn, affect a variety of physical and chemical properties of soil, including the loss of organic matter and reduced infiltration, which, interacting with removal of slope stabilizing vegetation, results in increased runoff and soil erosion (Azous and Horner 2010).

11.6.2.3 Alteration or Degradation due to Soil Contamination

Soil contamination can result from fugitive dust, potential spills of reagents, lime, cement, fuels, lubricants, or other chemicals during the mine life and during the Post-closure phase. Most potential spills of cargo transported within the LSA resulting from container leaks, lost cargo, and vehicle accidents will be minimized by monitoring and timely remediation.

Soils can also be altered through soil eutrophication and soil acidification. These issues are discussed in Section 16.5.

Pathways of potential soil contamination for the mine site area and Brucejack Access Road are listed below.

<u>Mine Site Area</u>

In the absence of mitigation, soils contamination could potentially occur due to direct contact with ore under the pre-production ore stockpile or due to possible ML/ARD from temporary waste rock stockpiles. These potential effects pathways will be addressed through pre-development soil salvage and installation of HDPE liners at the locations where ore and waste rock are to be stored.

During soil salvage of whatever suitable root zone materials are present on the mineralized surface of the gossan, there is the potential for unintended incorporation or mixing of ML/ARD overburden into stockpiles intended for reclamation use. Carefully following ML/ARD protocols and development of a detailed soil salvage plan will reduce the potential for this pathway.

Exposure of PAG material (primarily at construction or near areas of long-term storage and handling of these materials) can also indirectly result in soil contamination due to ARD draining onto soils areas. This pathway will be mitigated through water management planning.

<u>Access Road</u>

Improper handling/disposal of PAG bedrock materials during cut/fill operations exposures could potentially result in soil contamination. PAG roadcuts could potentially result in ARD in surface runoff, which could impact soils. Following ML/ARD protocols will reduce the likelihood this occurring.

11.6.3 Effects of the Project on Terrain Stability

The potential effect of decreased stability is elevated incidence and magnitude of geohazards, the effects of which include soil loss, sedimentation of streams and associated degradation of fish habitat, damage to Project infrastructure, and health and safety risks to Project personnel. It is not necessary or feasible to assess each of these effects in isolation. Such an assessment would require data inputs regarding sediment load, volume of soil loss, and timing. Rather, the effects assessed will be limited to the potential increase in the incidence and magnitude of geohazards, as related to the potential increase in unstable terrain.

Terrain stability mapping for the Project area is presented in Appendix 5-F. It is not feasible to quantitatively determine an increase in geohazard incidence and magnitude for each affected polygon. Therefore, a qualitative assessment was carried out. This involved assessing each Project area interaction with terrain stability classes (TSCs), especially the interaction of infrastructure with TSC IV (potentially unstable) and TSC V (unstable) terrain. In order to determine whether unstable and potentially unstable terrain would interact with proposed Project infrastructure, the datasets for each were compiled in ArcGIS.

The areas assessed are presented in Table 11.6-3. This table shows the areas of stable, potentially unstable, and unstable terrain, as determined by summing of polygon areas that intersect with each specific Project area. It is the intersection of infrastructure with potentially unstable and unstable terrain that results in a potential future geohazard scenario.

Table 11.6-3. Spatial Extent of Slope Stability Classes that Intersect with Project Infrastructure

Terrain Stability Class	Brucejack Mine Site (ha)	Brucejack Transmission Line (ha)	Brucejack Access Road (ha)	Brucejack Aerodrome (ha)	High Ground to be Removed (ha)	Knipple Transfer Area (ha)	Tide Staging Area (ha)
I (stable)	13.1	154.5	1,759.8	224.2	0	19.3	28.7
II (low likelihood of landslides following disturbance)	164.1	915	1,343.3	0	11.4	0	11.1
III (minor baseline stability issues)	431.3	776.7	1,983.4	0	13.3	11.7	0
IV (moderate likelihood of landslides following disturbance	379.8	585.2	505.2	0	0	0	0
V - unstable	86.8	1,572.7	152.7	0	0	0	0

TSC IV and V terrain is associated with the Brucejack Mine Site, the Brucejack Transmission Line, and the Brucejack Access Road. The Brucejack Transmission Line is associated with 1,572.7 ha of TLC V terrain. This is terrain that is unstable, and identified as such by existing geohazards, steep slopes with unconsolidated deposits, and dynamic hydrology. Also intersecting with the Brucejack Transmission Line is 585.2 ha of TSC IV terrain. The Brucejack Mine Site has 86.8 ha of TSC V terrain and 379.8 ha of TSC IV terrain. The Brucejack Access Road intersects with 152.7 ha of TSC V terrain and 505.2 ha of TSC IV terrain.

11.7 MITIGATION MEASURES FOR TERRAIN AND SOILS

11.7.1 Mitigation for Loss of Soil due to Footprint Development

The main objective of the Soils Management Plan presented in Section 29.13 is to minimize the area of land where the ecological function of soil is lost or severely compromised. To facilitate this objective, land will be cleared only in areas necessary for mine activities during each phase. One of the principles followed in developing the overall Project plan has been to minimize the area covered by the Project footprint. In addition, to the extent practicable, environmentally sensitive or technically difficult areas will be avoided through facility layout planning.

Where practical, disturbed areas will be reclaimed and re-vegetated as soon as it is feasible to do so. During Construction (mainly during the development of mine facilities), soil will be stripped and stockpiled for future reclamation. However, the amount of suitable material available for salvage is quite limited.

11.7.2 Mitigation for Bulk Soil Erosion

As detailed in Section 29.13, Soils Management Plan, erosion control measures will focus on preventing soil loss associated with wind, water, and gravity. Prompt re-vegetation of soil stockpiles, ditches, road cuts, and embankments will reduce the potential of soil erosion. Erosion control measures include seeding exposed soils with an erosion control seed mix or hydro-seeding with a mix of seed, mulch, and a tackifier as soon as possible following disturbance.

On steeper slopes, more intensive soil erosion control measures may be required, such as construction of channel bank protection or the installation of erosion control blankets or bonded fibre matrices onto the soil surface. Slope stabilization techniques, including terracing or installing bioengineering structures, such as wattle fences and modified brush layers, will also be considered on highly erodible soils and on long or steep slopes. Silt fences may also be used to contain sediments eroding off-site or entering waterways. Rock material, willow bundles, or gabions will also be used, as appropriate, to protect erodible channel banks.

11.7.3 Mitigation for Soil Degradation

Mitigation and monitoring for soil is outlined in the Soil Management Plan (Section 29.13). This plan includes BMPs for soil salvage and storage, and erosion prevention. Contaminated dustfall that may influence soil quality is believed to be unlikely. However, dustfall will be monitored by the Air Quality Management Plan (Section 29.2), allowing for adaptive management if prescribed mitigation is found to be ineffective.

Refuelling stations and heavy equipment maintenance facilities will be designed to minimize and control spillage. Spill response equipment and procedures will be provided and transportation, storage and use of all petroleum products and chemicals will comply with regulatory requirements. Mitigation will include immediate remediation of any spills that occur, to minimize the inflow of contaminants to soils. Contaminated soils will be disposed of appropriately off site, or treated on site by bioremediation. The amount of human-generated waste will be minimized through reduction, reuse, recycling, and proper disposal of remaining material.

Reclamation methods that reduce equipment traffic during soil removal and redistribution will be employed to lessen soil compaction (see details in Section 29.13, Soils Management Plan).

Mitigation of soil degradation associated with salvage operations often focuses on minimizing the number of times the soil is moved, reducing the vehicle traffic over the soil surface, and avoiding handling soils when they are too dry or too wet. Reducing the erosion of soil stockpiles will be accomplished by timely re-vegetation of the stockpile berms. Erosion monitoring and prevention programs will be established to provide timely detection and mitigation. Adaptive management measures directed toward identification and implementation of new or modified mitigation approaches will be initiated if monitoring data indicate that mitigation is not able to eliminate or adequately reduce environmental effects (e.g., soil degradation; (CEA Agency 2009).

11.7.4 Mitigation for Terrain Stability

Potential effects on terrain stability can be mitigated by identifying areas where there is a moderate to high likelihood of slope failure following Project development, conducting terrain stability field assessments of those areas by a qualified terrain specialist, and adapting designs to address stability issues. Detailed geotechnical plans will be required in order to avoid adverse effects on terrain. Follow-up monitoring is required in these areas in order to determine the effectiveness of mitigation. Mitigation will be used to reduce the risk of associated Project development in areas of potentially unstable and unstable terrain to an acceptable level. These strategies will reduce the risk in the following ways:

- reduce the probability of the geohazard occurring;
- reduce the geohazard magnitude (e.g., volume, peak discharge);

- reduce the geohazard intensity (e.g., run-out distance, velocity, impact forces);
- reduce the spatial probability of impact (likelihood that the geohazard will reach or impact the element at risk);
- reduce the temporal probability of impact (likelihood of workers being present in the zone subject to the hazard); and
- reduce the vulnerability (the degree of loss to a given element at risk within the area affected by the snow avalanche or landslide hazard).

11.8 PREDICTED CHANGES ON TERRAIN AND SOILS

The residual effects on terrain and soils sub-components were characterized in terms of likelihood, magnitude, geographic extent, duration, frequency, reversibility, and resiliency, according to the definitions provided in Section 6.7.1.

11.8.1 Predicted Changes to Soil Quantity

Development of the Project will be associated with a residual loss of approximately 63.9 ha of soil. The loss of soils under the footprints of retained mine components will extend into the foreseeable future. An additional 19.8 ha of non-soils fall within the area lost within infrastructure footprints for all of the Sub-Areas however these are not considered to be ecologically functional soils because they consist of glaciers, water, or material which has not yet undergone sufficient weathering to meet soil classification criteria. Total losses of soils are 24.0 ha within the Brucejack Mine Site, 33.2 ha within the Brucejack Access Road, and 4.7 ha within the Brucejack Transmission Line as reflected in Table 11.6-1 above.

Considering the above listed soil characteristics, the magnitude of the soil loss is predicted to be low within the 31,847 ha LSA. The duration will be far future for ecologically functional soil and medium term for non-soil suitable for reclamation. The loss will occur with one-time or sporadic frequencies.

The geographic extent of effects related to terrain and soils is expected to remain local (limited to the immediate area of the Project surface facilities). Although the effect is considered irreversible, since soil recovery through pedogenesis involves timespans of hundreds of years, reclamation through the use of salvaged soil in suitable circumstances may see reversible effects in some areas. Considering the natural predominance of low quality, young soils in the Project area, the resilience of the receiving environment to land loss is considered neutral. The ecological context for the terrain and soils is neutral, as the soils identified are in their natural state, but are subject to natural disturbance. The likelihood of effects is high, as the results of similar project interactions with soils are well understood.

11.8.2 Predicted Changes to Soil Quality

Despite dedication of resources and effort to monitoring and application of mitigation measures, some aspects of soil alteration or degradation within the 100m buffers are expected. Examples of such effects include alteration of the soil moisture regime, changes in productivity, changes in flora and fauna communities, erosion of the most fertile fractions of soil, and loss of soil structure.

It is predicted that alteration of up to 715.5 ha along the Brucejack Access Road Sub-Area, and up to 11.2 ha within the Transmission Line Sub-Area may occur primarily due to dust deposition. While changes in soil may be seen as positive in terms of productivity, effects on vegetation may occur that alter community composition, such as increase in coniferous growth and effects on species favouring low nutrient sites. As noted previously however, there are significant limitations to model-based predictions of dust dispersion along the access road, therefore the stated area of potential effect is considered extremely conservative.

It is predicted that degradation of up to 187.3 ha, due primarily to dust, could occur within the Brucejack Mine Site Sub-Area (within the Assessment Footprint). While it is expected that a considerable portion of reclaimed areas will recover over time, the harsh local climate and demanding site topography will likely limit the success of the planned reclamation efforts at the Mine Site.

Residual effects on the physical, chemical, and biological soil conditions in disturbed areas are expected to display a wide range of variability, both in terms of severity and duration. While it is possible that the severity, duration, and type of environmental effects associated with the Project will differ from those induced by natural causes, it is important to recognize that the incidence of soil disturbance, due to natural processes, is high. In view of this, because it is expected that monitoring and mitigation programs will effectively mitigate the more severe instances of soil degradation, and because the overall development footprint of the Project is very small, the overall magnitude of the incremental Project-related disturbance to soil quality is expected to be medium with predicted degradation of up to 187.3 ha of low value ecologically functioning soil within the LSA and alteration of 726.7 ha. The duration of soil degradation will extend into the far future. Alteration is expected to be of shorter duration as nutrient additions will be taken up in plants and microbial communities. The frequency of events leading to soil alteration and degradation will be sporadic throughout and beyond the Project's life. The predicted spatial extent of this effect will be apparent at the landscape level (concentrated within the 100-m-wide zones around the Project development footprint). At the Mine Site, notwithstanding the generally poor quality of the soils, the effect is considered irreversible due to its slow recovery rate, although reclamation through the use of salvaged soil in suitable circumstances may see reversible effects in some areas. In the altered areas, the effect is considered reversible as changes in productivity due to nutrient addition are generally medium-term. Considering the generally low productivity and natural high acidity of the potentially affected soils (which results in low buffering capacity to acidification), the resilience of the receiving environment in response to Project-related potential soil degradation effects is expected to be low. Resilience to dust additions and alteration of soils is neutral and as long as additions are not chemically disparate from local soils, which should not be the case as road material was locally sourced. The ecological context for the terrain and soils is neutral, as the soils identified are in their natural state, but are subject to natural disturbance. The likelihood of effects is high, as the results of similar project interactions with soils are well understood.

Due to high variability of baseline conditions in the Project area and the large number of potentially interacting adverse factors (e.g., short vegetative season, low temperatures, high metal concentration in mine site soil, potential disruption of groundwater flow patterns) the likelihood of soil alteration and degradation due to Project activity is generally medium and the confidence in the predicted outcome is medium.

11.8.3 Predicted Changes to Terrain Stability

Due to geotechnical engineering design, mitigation, and follow-up monitoring, it is not expected that the Project will result in residual effects for terrain stability.

11.9 TERRAIN AND SOILS AS A PATHWAY TO RECEPTOR VALUED COMPONENTS

Project related changes to terrain and soils is expected to be a pathway to effects for six receptor VCs, including surface water quality, human health, fish and fish habitat, terrestrial ecosystems, wetlands, and wildlife. These linkages are shown in Figure 11.9-1. The key pathways and resultant effects between terrain and soils and relevant receptor VCs are summarized in Table 11.9-1 and discussed in more detail below.

Figure 11.9-1

Linkages between Intermediate and Receptor Valued Components

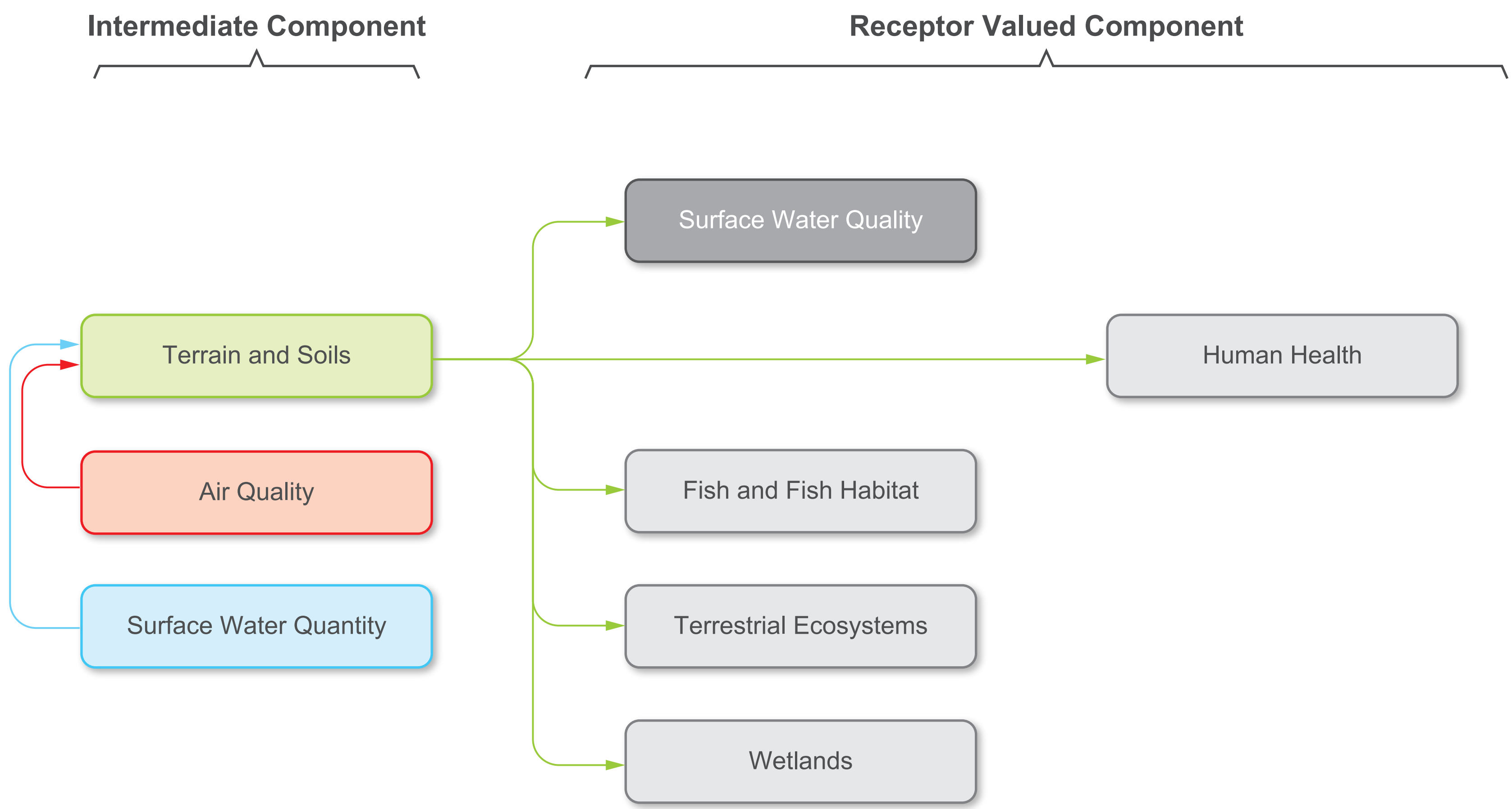

Table 11.9-1. Key Pathways and Resultant Effects between Terrain and Soils and Relevant Receptor Valued Components

Receptor Valued Component	Pathway	Effect
Terrestrial Ecology	• removal or alteration of soil through clearing activities • erosion and sedimentation • compaction • alteration of chemical composition • temporary or permanent redirection of surface flow	• alteration of terrestrial ecosystem extent or function
Wildlife	• removal or alteration of soil through clearing activities • erosion and sedimentation • wildlife may uptake chemicals of potential concern from camp or industrial sites, or receiving environments, from ingestion of dust, or via bioaccumulation from vegetation	• direct mortality • habitat loss and/or alteration • health effects due to chemical hazards
Human Health	• metals in soils can enter the food chain when uptaken or consumed by organisms that are collected or harvested as country foods	• alteration of quality of country foods
Wetlands	• erosion and sedimentation • alteration of chemical composition	• loss or alteration of wetland ecosystem extent or function
Fish and fish habitat	• erosion and sedimentation • fish may ingest fuel or lubricant that migrates from the road surface used by vehicle(s) into aquatic habitat	• loss or alteration of riparian or floodplain ecosystems • health effects due to chemical hazards
Surface water quality	• erosion and sedimentation	• potential transference of deleterious substances into the receiving environment

11.9.1 Terrestrial Ecology

The loss of soil quantity and/or changes in quality is expected to act as a pathway for potential effects on four terrestrial ecology valued sub-components: alpine, forested, and floodplain ecosystems; and culturally or economically important plants. The removal or alteration of productive, ecologically valuable soil is expected to alter ecosystem development and potentially function.

The development of ecosystems is determined by the complex interactions of abiotic (e.g., soil parent material, climate, recent glacial history, and natural disturbance) and biotic (i.e., nitrogen-fixing bacteria, mycorrhizae, pollination, humans, and wildlife) components. Thus, any changes to these abiotic and biotic interactions, including alteration or removal of soil, have the potential to alter ecosystem development.

For example, compaction can result in soil temperature changes, degradation of the organic horizon, and reduction of pore space between soil particles, which in turn limits water, nutrient, and air movement in the soil, leading to a decline in soil fertility and reduction in plant establishment and growth. Furthermore, changes to soil quality or quantity may affect key ecological functions, such as site stability, productivity, nutrient cycling, carbon storage, water regulation, and wildlife habitat.

11.9.2 Wildlife and Wildlife Habitat

Due to the intrinsic link between soil and landscape, any considerable changes to soil quality and/ or quantity could affect wildlife habitat. Degradation to soil quality and/or quantity will impact the terrestrial landscape and thus have potential to alter or change the quality of wildlife habitat. Riparian, wetland, and alpine habitats are examples of important habitat types for key wildlife species and are also susceptible to soil erosion, sedimentation, or alteration. The quality and persistence of wildlife habitat depends on the maintenance and conservation of soil quality and quantity.

11.9.3 Human Health

The quality of country foods is directly related to the quality of the surrounding environmental media (e.g., soil, water, and vegetation). Human health may be affected by consumption of country foods that contain contaminants that occur naturally or as a result of anthropogenic activities. Fugitive dust or atmospheric emissions containing metals from a variety of sources such as the mill building, access roads, quarries, underground mines, incinerators, waste rock and ore handling areas, and a variety of equipment and transportation methods can result in metal deposition to soils. The metals in soil can be taken up by vegetation and, in addition to metals deposited directly on the surface of vegetation, the metals in soils can enter the food chain when consumed by organisms that are collected or harvested as country foods.

11.9.4 Wetlands

Changes to the physical and chemical characteristics of soil may affect wetland functions, including biochemical and hydrological functions, as well as altering habitat functions. Inputs such as sedimentation, dust, or contaminants could affect wetland habitat, biochemical processes, and hydrological functions by changing physical properties related to water storage and treatment depending on the chemical composition of the contaminants. Loss of wetland soils can result in the long-term degradation or permanent loss of these ecosystems, especially in wetland types such as fens or bogs that are dependent on complex soils that have developed in response to interactions between soil parent materials, hydrology, topography, and vegetation communities.

11.9.5 Fish and Fish Habitat

The loss of soil quantity and/or quality may act as a pathway for potential effects on fish habitat, specifically riparian vegetation. Loss of fish habitat refers to the removal or physical alteration of the environment that is used either directly or indirectly by fish. Riparian vegetation is included as fish habitat because it provides numerous functions including shading, stabilizing stream banks and controlling erosion, and contributing large woody debris and organic litter. Physical or chemical changes in soil quantity and/or quality, including erosion, sedimentation, and change in water quality (metals, nutrients, process chemicals, and petroleum products) may impact fish habitat.

Potential effects associated with erosion and sedimentation, as well as petroleum product spills, could result from maintenance activities such as road grading. The transportation of chemicals and petroleum products could result in a spill into streams and waterbodies along the Brucejack Access Road. Most activities during the Closure phase involve decommissioning Project infrastructure and returning the site to a baseline condition. These activities will involve the use of heavy equipment in or around water for the decommissioning of Project infrastructure (e.g., road and bridges). As a result of working in and around water, erosion and sedimentation of waterbodies (e.g., sedimentation to streams from road decommissioning) and soil quality degradation (e.g., petroleum product spills) could occur when conducting Closure phase activities.

11.9.6 Surface Water Quality

Terrain and soils influence surface water quality in a number of ways. Terrain provides and dictates surface shape expression, which defines the broad hydrology of an area. The geomorphology of a region will determine the potential erosivity of an area, which will influence the quantity and quality of the sediments in surface water.

11.10 CUMULATIVE EFFECT ASSESSMENT FOR TERRAIN AND SOILS

Cumulative effects are defined in this Application/EIS as "effects which are likely to result from the designated project in combination with other projects and activities that have been or will be carried out". This definition follows that in Section 19(1) of the *Canadian Environmental Assessment Act, 2012* (2012) and is consistent with the International Finance Corporation's *Good Practice Note on Cumulative Impact Assessment* (ESSA Technologies Ltd. and IFC 2012) which refers to consideration of other existing, planned and/or reasonably foreseeable future projects and developments. Cumulative effects assessment (CEA) is a requirement of the AIR and the EIS Guidelines and is necessary for the proponent to comply with the *Canadian Environmental Assessment Act, 2012* (2012) and the BC *Environmental Assessment Act* (2002a).

The CEA Agency issued an Operational Policy Statement in May 2013 entitled *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012,* which provides a method for undertaking CEA (CEA Agency 2013). Recently the BC EAO also released the updated *Guideline for the Selection of Valued Components and the Assessment of Potential Effects* (BC EAO 2013), which includes advice for determining the need for a cumulative impact assessment. The CEA methodology adopted in this Application/EIS therefore follows the guidance of the CEA Agency as outlined above, as well as the selection criteria in BC EAO (2013).

The method involves the following key steps which are further discussed in the proceeding sub-sections:

- scoping;
- analysis;
- identification of mitigation measures;
- identification of residual cumulative changes; and
- characterization of residual cumulative changes.

11.10.1 Establishing the Scope of the Cumulative Change Assessment

The scoping process involves identification of the intermediate components for which residual changes are predicted, definition of the spatio-temporal boundaries of the assessment, and an examination of the relationship between the residual effects of the Project and those of other projects and activities.

11.10.1.1 Identifying Intermediate Components for the Cumulative Effects Assessment

Intermediate components included in the terrain and soils CEA were selected using four criteria following BC EAO (2013):

- there must be a residual change as a result of the Project being proposed;
- that predicted change in the condition of the intermediate component must be demonstrated to interact cumulatively with residual environmental effects from other projects or activities;

- it must be known that the other projects or activities have been or will be carried out and are not hypothetical; and
- the cumulative environmental effect must be likely to occur.

The sub-components for terrain and soils that are included in this CEA are:

- soil quantity; and
- soil quality.

The terrain stability sub-component is not carried forward into the cumulative effects assessment for terrain and soils as there are no residual effects for terrain stability. The Project will not result in an increase in residual terrain instability or geohazards, as all potential geohazard scenarios will be mitigated through engineering and Project design.

11.10.1.2 Potential Interaction of Projects and Activities with the Brucejack Gold Mine Project for Terrain and Soils

A review of the interaction between predicted changes on intermediate components from the Project and effects of other projects and activities on terrain and soils was undertaken. The review assessed the projects and activities identified in Section 6.9.2 of the Assessment Methodology, including:

- regional projects and activities that are likely to affect the intermediate component, even if they are located outside the direct zone of influence of the project;
- effects of past and present projects and activities that are expected to continue into the future (i.e., beyond the effects reflected in the existing conditions of the intermediate component); and
- activities not limited to other reviewable projects, if those activities are likely to affect the intermediate component cumulatively (e.g., forestry, mineral exploration, and commercial recreational activities).

A matrix identifying the potential cumulative effect interactions for terrain and soils is provided in Table 11.10-1 below, using watershed boundaries to determine which projects and activities should be considered.

Table 11.10-1. Potential Cumulative Effect Interactions for Terrain and Soils Valued Components

Projects and Activities	Terrain and Soils
Past Projects	
Eskay Creek Mine	
Galore Creek Project – Access Road Only	
Goldwedge Mine	
Granduc Mine (Past Producer)	
Johnny Mountain Mine	
Kitsault Mine (Past Producer)	
Silbak Premier Mine	
Snip Mine	
Sulphurets Advanced Exploration Project	
Snowfield Exploration Project	
Swamp Point Aggregate Mine	

(continued)

Table 11.10-1. Potential Cumulative Effect Interactions for Terrain and Soils Valued Components (completed)

Projects and Activities	Terrain and Soils
Present Projects	
Brucejack Exploration Program	Black
Forrest Kerr Hydroelectric Power Facility	
Long Lake Hydroelectric Power Facility	Grey
McLymont Creek Hydroelectric Project	
Northwest Transmission Line	Grey
Red Chris Project	
Reasonably Foreseeable Future Projects	
Arctos Anthracite Coal Project	
Bear River Gravel Project	
Bronson Slope Project	
Coastal GasLink Pipeline Project	
Galore Creek Project	
Granduc Copper Mine	Grey
KSM Project	Black
Kinskuch Hydroelectric Project	
Kitsault Mine	
Kutcho Project	
LNG Canada Export Terminal Project	
Northern Gateway Pipeline Project	
Prince Rupert Gas Transmission Project	
Prince Rupert LNG Project	
Schaft Creek Project	
Spectra Energy Gas Pipeline	
Storie Moly Project	
Treaty Creek Hydroelectric Project	Grey
Turnagain Project	
Storie Moly Project	
Volcano Hydroelectric Project	
Land Use Activities - All Stages (past, present, future)	
Parks and Protected Areas	
Guide Outfitting	
Aboriginal Harvest (fishing, hunting/trapping, plant gathering)	
Hunting	
Trapping	
Commercial Recreation (including fishing)	
Forestry	Black
Transportation	

Notes:
Black = likely interaction between Brucejack Gold Mine Project and other project or activity
Grey = possible interaction between Brucejack Gold Mine Project and other project or activity
White = interaction not expected between Brucejack Gold Mine Project and other project or activity

11.10.1.3 Spatio-temporal Boundaries of the Cumulative Effects Assessment

The CEA boundary for terrain and soils VCs represents the maximum limit within which the effects assessment is conducted. It encompasses the areas within, and times during, which the Project is expected to interact with the intermediate component and receptor VCs and with other projects and activities, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the terrain and soils CEA, and encompasses possible direct, indirect, and induced effects of the Project on terrain and soils.

<u>Spatial Boundaries</u>

As the area of the industrial footprint and the density of road networks within the matrix of predominantly natural ecosystems gradually increase, the level of interactions between the environmental effects of individual projects is expected to rise. Because the spatial and temporal scales of observation can have a considerable impact on conclusions regarding the ecological significance of those interactions (McGarigal et al. 2001), it can be difficult to precisely delineate the extent of the area in which such interactions could be meaningfully assessed. Consequently, a considerable effort was focused on choosing appropriate spatial scales within which the effects of the Project were expected to contribute to the overall cumulative impact under consideration.

Due to the important role of water in soil erosion and pollutant transfer, watersheds are a natural unit within which distribution of most erosion and contamination takes place. Scientific evidence suggests that the most important long-term environmental impacts associated with soil disturbance are related to soil erosion and subsequent sedimentation of streams (Forman et al. 1997; Seiler 2001). Soil erosion and resulting sedimentation of watercourses are also usually discussed at the watershed scale.

Due to the confinement of most effects on a watershed basis, this natural boundary was used to define the CEA spatial boundary. The Project footprint extends into two watersheds; the Lower Bell-Irving River watershed, occupying 353,718 ha, and the Unuk River watershed, covering an additional 196,912 ha. Together, these comprise the terrain and soils CEA area, which occupies approximately 550,630 ha. This is presented in Figure 11.10-1. Table 11.10-2 shows which historical, present, and future projects are located (at least partially) within the terrain and soils CEA area. Table 11.10-3 identifies the type of cumulative effect that may be expected.

A small part of the Project extends into the Salmon River Watershed. This is confined to 3.15 km of the Brucejack Transmission Line. As the cumulative effects assessment study area is based upon watershed boundaries, the inclusion of this portion of the Transmission Line in the CEA would have added the 24,380 ha of the Salmon River watershed to the CEA study area. Given the nature of the disturbance associated with the Transmission Line disturbance will be mostly confined to tower pad installation, (i.e. potential for effects is very small), the cumulative effects assessment was not extended into the Salmon River watershed.

<u>Historical Projects within the Terrain and Soils Cumulative Effects Assessment Area</u>

The Eskay Creek Mine, located approximately 25 km from the Project site, was an underground gold/silver mine. Operation of the mine began in 1995 and required the construction of the Eskay Creek Mine Road. The mine was closed in the first quarter of 2008. During decommissioning, reclamation activities included removing buildings and infrastructure and re-vegetating some of the project area. Reclamation is continuing. The mine site will continue to be monitored (Rescan 2010).

Figure 11.10-1

Spatial Distribution of Human Activities within the Brucejack Cumulative Effects Assessment Area

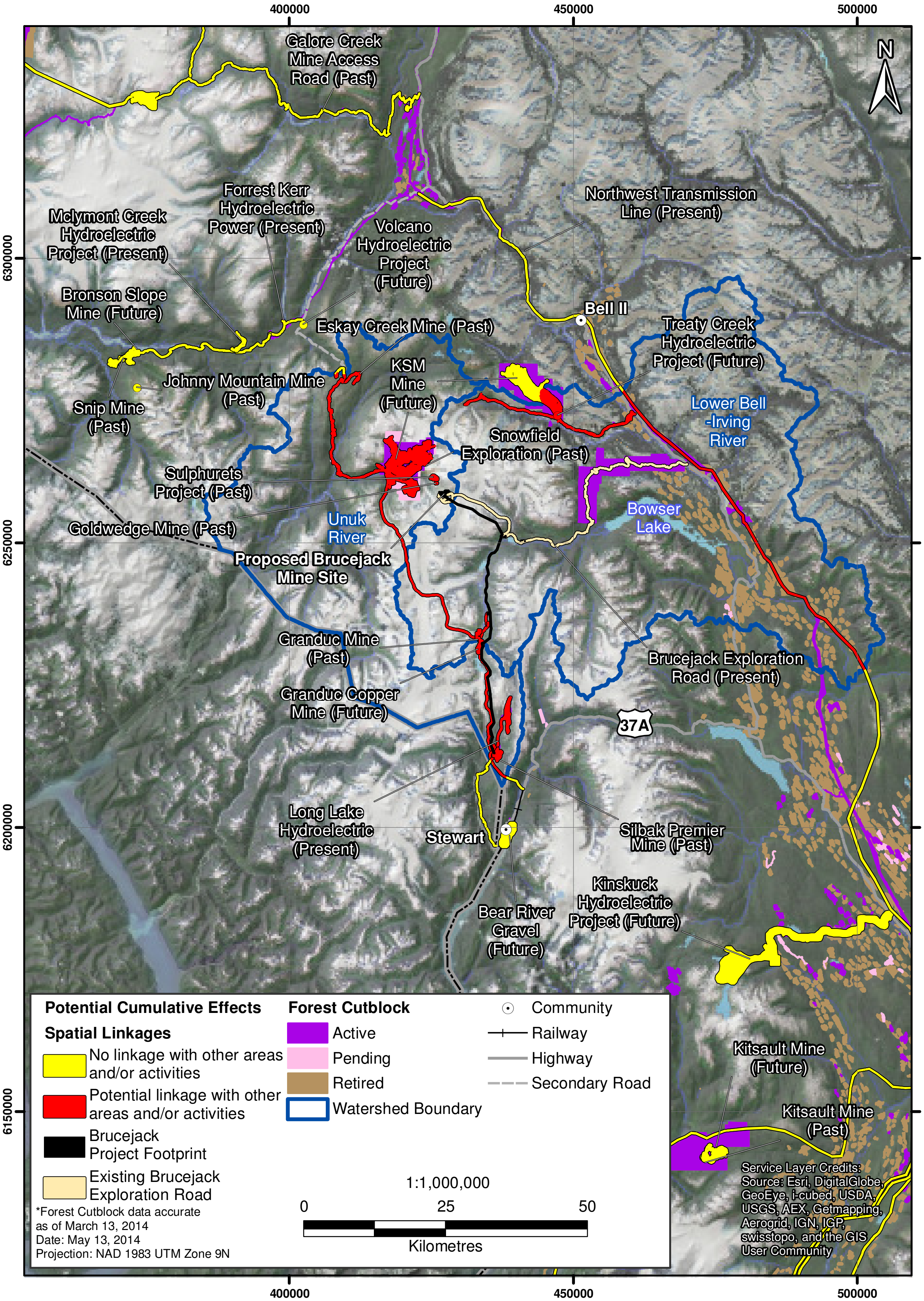

Table 11.10-2. Projects Located within the Terrain and Soils Cumulative Effects Assessment Area

Project	Time Frame	Watershed Boundary
Eskay Creek Mine	Historical	In
Galore Creek Project – Access Road Only	Historical	Out
Goldwedge Mine	Historical	In
Granduc Mine (Past Producer)	Historical	In
Johnny Mountain Mine	Historical	Out
Kitsault Mine (Past Producer)	Historical	Out
Silbak Premier Mine	Historical	In
Snip Mine	Historical	Out
Snowfield Exploration Project	Historical	In
Swamp Point Aggregate Mine	Historical	Out
Sulphurets Advanced Exploration Project	Historical	In
Brucejack Exploration and Bulk Sample Program	Present	In
Forrest Kerr Hydroelectric Power Facility	Present	Out
Long Lake Hydroelectric Power Facility	Present	In
McLymont Creek Hydroelectric Project	Present	Out
Northwest Transmission Line	Present	In
Red Chris Project	Present	Out
Arctos Anthracite Coal Project	Future	Out
Bear River Gravel Project	Future	Out
Bronson Slope Project	Future	Out
Coastal GasLink Pipeline Project	Future	Out
Galore Creek Project	Future	Out
Granduc Copper Mine	Future	In
KSM Project	Future	In
Kinskuch Hydroelectric Project	Future	Out
Kitsault Mine	Future	Out
Kutcho Project	Future	Out
LNG Canada Export Terminal Project	Future	Out
Northern Gateway Pipeline Project	Future	Out
Prince Rupert Gas Transmission Project	Future	Out
Prince Rupert LNG Project	Future	Out
Schaft Creek Project	Future	Out
Treaty Creek Hydroelectric Project	Future	In
Turnagain Project	Future	Out
Storie Moly Project	Future	Out
Volcano Hydroelectric Project	Future	Out

The Goldwedge Mine was owned by Catear Resources Ltd., and is located approximately 70 km northwest of Stewart, BC and 2 km northwest of Brucejack Lake on Catear Creek, a tributary of Brucejack Lake (E.R. Kruchkowski Consulting Ltd. 1989).

Table 11.10-3. Potential Cumulative Effects between the Brucejack Gold Mine Project Terrain and Soils and Other Projects and Activities

CEA Temporal Project Status	Projects within the Terrain and Soils CEA Area	Loss of Soil Quantity	Loss of Soil Quality	Type of Potential Cumulative Effect
Past Project or Activity	Eskay Creek Mine	✓	✓	Nibbling loss; physical-chemical transport
	Goldwedge Mine	✓	✓	Nibbling loss; physical-chemical transport
	Granduc Mine	✓	✓	Nibbling loss; physical-chemical transport
	Silbak Premier Mine	✓	✓	Nibbling loss; physical-chemical transport
	Snowfields Exploration Project	✓	✓	Nibbling loss; physical-chemical transport
	Sulphurets Advanced Exploration Project	✓	✓	Nibbling loss; physical-chemical transport
Present Projects	Long Lake Hydroelectric Power Facility	✓	✓	Nibbling loss; physical-chemical transport
	Brucejack Exploration and Bulk Sample Program	✓	✓	Nibbling loss; physical-chemical transport
	Northwest Transmission Line	✓	✓	Nibbling loss; physical-chemical transport
Reasonably Foreseeable Future Project or Activity	KSM Project	✓	✓	Nibbling loss; physical-chemical transport
	Treaty Creek Hydroelectric Project	✓	✓	Nibbling loss; physical-chemical transport
	Granduc Copper Mine	✓	✓	Nibbling loss; physical-chemical transport

Granduc Mine was a copper mine located approximately 32 km south of the Project. Construction of the Granduc Mine began with tunnel driving in 1964 and was completed in 1970. The mine operated until 1978, was re-opened in 1980, and operated again until its closure in 1984. Since construction of the Granduc Mine began in the 1960s, there have been several other mining projects in the area, many of which use the Granduc Access Road and staging area to support their activities.

Silbak Premier Mine is located approximately 35 km south of the proposed Brucejack Gold Mine Project. The mine operated continuously under various owners from 1918 to 1953. During that time, about 4.7 million tonnes of ore were produced. From 1953 to 1996 the mine operated intermittently, producing another 26,000 tonnes of ore (StewartBC.com 2011). Westmin Resources Ltd. operated the mine from 1989 to 1996 and production was 550 tonnes per day in 1995 (BC MEMPR 2013). The project was placed in long term care and maintenance in April 1996 due to poor grades in the developed zones and dwindling reserves. Ascot Resources Ltd. released a technical report and resource estimate for the property in March 2013 which indicates that future redevelopment of this project is possible (P&E Mining Consultants Inc. 2011).

The Snowfield Exploration Project involved drilling and exploration activities on the Snowfield property, which is located approximately 7 km north of the Brucejack Gold Mine Project (Pretium Resources Inc. 2013). Exploration was undertaken by Silver Standard Resources between the mid-1980s and 2010 and the property was sold to Pretivm in 2010. Pretivm and Seabridge Gold Inc. have signed a Mutual Confidentiality and Cooperation Agreement which provides for, amongst other things, the completion of an engineering study examining the economics of combining Pretivm's Snowfield project and Seabridge's KSM Project into one operation (Pretium Resources Inc. 2013). At this stage, no formal indications have been made by either party that the resource will be developed.

The historical Sulphurets Project was an advanced underground exploration project located near Brucejack Lake. Newhawk Gold Mines Ltd. excavated underground workings between 1986 and 1990 as part of an advanced exploration and bulk sampling program. Construction of the underground workings generated approximately 124,000 tonnes of waste rock. The waste rock was placed as a shallow pad along the southern boundary of Brucejack Creek and used as the foundation for the camp and other facilities (Price 2005). The operation never went into production, and in 1996 the Sulphurets property was placed in care and maintenance. Development plans for the project were indefinitely suspended and Newhawk Gold Mines Ltd. decided to fully reclaim the property in 1999 (Price 2005). The West Zone adit from the Sulphurets Project is currently used by Pretivm for exploration.

<u>Present Projects within the Terrain and Soils Cumulative Effects Assessment Area</u>

The exploration phase of the Brucejack Gold Mine Project commenced in 2011 and included a drilling program, reactivation of an access road constructed by Newhawk Gold Mines Ltd., construction of an exploration access road from Highway 37 to the reactivated access road, and a bulk sample program. The bulk sample program has included development and dewatering of underground workings initially established by Newhawk Gold Mines Ltd., and subaqueous deposition of waste rock in Brucejack Lake. In addition, historical mineral exploration activities associated with the Sulphurets Project took place within the Project area.

The Long Lake Hydroelectric Power Facility is located on Cascade Creek, approximately 17 km north of Stewart, BC (CEA Agency 2012) and approximately 42 km south of the Brucejack Gold Mine Project. Features of the facility included the re-development of a 20 m high rockfill dam located at the head of Long Lake, and a new 10 km long 138 kV transmission line. In 2010, the project was awarded a contract with BC Hydro, construction began in July 2010, and the project is currently undergoing start up and commissioning.

The NTL will be an approximately 344 km electricity transmission line (BC Hydro 2012). The 287 kV capacity line generally follows the Highway 37 corridor, running from the Skeena Substation at Terrace and connecting with a new substation near Bob Quinn Lake; the line will pass within approximately 36 km of the Brucejack Gold Mine Project (BC Hydro 2012).

BC Hydro received an EA Certificate in February, 2011 and construction began January 2012. The project is expected to be operational in Spring 2014 (BC Hydro 2012).

<u>Future Projects within the Terrain and Soils Cumulative Effects Assessment Area</u>

The proposed reopened Granduc Copper Mine is located 40 km northwest of Stewart in northwestern BC, and previously produced between 1971 and 1984. Castle Resources Inc. acquired the Granduc property from Bell Copper in July 2010, and began exploration drilling with the aim of redeveloping the mine (Marketwire 2010; Scales 2012).

In 2011, Castle Resources Inc. had the 17 km tunnel rehabilitated, and plans to rehabilitate specific levels of the old underground mine to establish underground drill stations for exploration. In February 2013, Castle Resources Inc. completed a Preliminary Economic Assessment that evaluates mining methods, tailings impoundment, and a suitable milling process (Dickson 2012). The mine will use sub-level caving techniques and the borehole open stoping method (Dickson 2012; Scales 2012). Infrastructure will include a new mill, tailings management facility, upgrades to the existing haul road, a transmission line to the planned Long Lake Hydroelectric Project, and several ancillary facilities (Tetra Tech 2013).

The proposed KSM Project is a copper, gold, and silver deposit located approximately 65 km north-northwest of Stewart, BC and 4 km northwest of the Brucejack Gold Mine Project, with infrastructure also 22 km to the northeast. The project will use open pit mining and block cave underground mining methods and as of May 14, 2012 has reported reserves of 38.2 million ounces of gold, 9.9 billion pounds of copper, 191 million ounces of silver, and 213 million pounds of molybdenum (Rescan 2012; Tetra Tech-Wardrop 2012). The mine will operate at 130,000 tonnes per day over the first 25 years of the 52.5 year mine life and 90,000 tonnes per day for the remainder (Rescan 2012). The project officially entered the environmental assessment process in April 2008 with the submission of a project description to the BC EAO. In February 2013, Seabridge Gold Inc. announced completion of the filing process of its Application/EIS (Rescan 2012).

The Treaty Creek Hydroelectric Project is still in the early planning stages. As currently proposed, it is located approximately 25 km northeast of the Brucejack Gold Mine Project. Northern Hydro Limited has proposed three inter-connected run-of-river hydroelectric projects on Treaty Creek, Todedada Creek, and an un-named creek with a combined installed capacity of 24.3 megawatts (BC MFLNRO 2012).

Northern Hydro Limited was granted an investigative use permit for Treaty Creek for determining the distribution limits of fish, measuring water quality and water quantity parameters, and deriving its expected output capacity. The project would consist of an intake, weir, penstock, powerhouse and tail race, transmission line, access road and laydown area(s). Northern Hydro Limited plans to commission the project in 2015 (BC MFLNRO 2012).

11.10.1.4 Temporal Boundaries

The Project's temporal boundaries cover four phases: Construction, Operation, Closure, and Post-closure. The CEA temporal boundary commences in 1964 and extends to 20 years beyond the Post-closure phase of the Project. This time frame encompasses past, present, and reasonably foreseeable cumulative transient and residual permanent effects from the Project in combination with other relevant projects. It is expected that the majority of predictable cumulative effects have occurred or will have occurred within this time frame.

- Past – 1964 to 2011: Coinciding with the development of the Granduc copper-gold mine, which influenced the growth of the community of Stewart and other human activities in the area.
- Present – 2011 to 2014: From the start of Brucejack Gold Mine Project baseline studies to the completion of the environmental effects assessment.
- Future – Variable according to the time estimated for VCs to recover to baseline conditions.

11.10.1.5 Potential for Cumulative Changes

Cumulative changes occur when there are interactions between projects, between projects and the environment, and between components of the environment. For cumulative effects to occur there must be a pathway between action and effect, with these pathways also existing amongst other projects within the established boundary for cumulative effects assessment. For terrain and soils, these can occur in various ways:

- physical-chemical transport: a physical or chemical constituent is transported away from the action under review where it then interacts with another action. An example of this would be the spread of invasive plants;

- nibbling loss: the gradual disturbance and loss of land and habitat. This occurs with removal of soil quantity from the landscape; and
- spatial and temporal crowding: cumulative effects can occur when too much is happening within too small an area and in too brief a period of time. A threshold may be exceeded and the environment may not be able to recover to pre-disturbance conditions. This occurs with the fragmentation of ecosystems.

Potential Project-related residual effects in combination with residual effects from other past, present, or future project or development activities in the CEA study area on the terrain and soils intermediate component were identified through reviews of relevant literature (e.g. project description, data made available from First Nations and local stakeholders or through ethnographic reports, scientific literature, data acquired via Data Sharing Agreements, government documents, and publically available data associated with relevant adjacent projects) and professional judgement and experience. Based on this review, it is expected that past, existing, and future activities will also result in loss of soil quantity and soil quality as a result of nibbling loss, and/ or physical-chemical transport cumulative effects.

11.10.2 Analysis of Cumulative Changes

Cumulative loss of soil quality and quantity was determined for each footprint of past, present, and future projects within the terrain and soils CEA area. This information is summarized per project footprint in Table 11.10-4.

Table 11.10-4. Footprints of Projects Included in the Cumulative Effects Assessment

CEA Temporal Project Status	Projects within the Terrain and Soils CEA Area	Project Footprint (ha)
Past Project or Activity	Eskay Creek Mine	93
	Goldwedge Mine	6
	Granduc Mine	84
	Silbak Premier Mine	123
	Snowfield Exploration Project	6
	Sulphurets Advanced Exploration Project[1]	85
Present Projects	Long Lake Hydroelectric Power Facility	430
	Northwest Transmission Line	2,766
	Brucejack Exploration and Bulk Sample Program	184
Reasonably Foreseeable Future Project or Activity	KSM Project	5,224
	Treaty Creek Hydroelectric Project	Not available
	Granduc Copper Mine	1,956
Total		**10,872**

[1]The Sulphurets Project is situated at the same location as the Project and thus is not included in the final total.

Loss of soil quantity and quality is expected to result from the removal of soil due to clearing for infrastructure footprints; erosion due to exposure of mineral soil and alteration of local hydrology from ground clearing activities associated with the mine and road; and power transportation development. Development of these Project components results in disturbances that may or may not be reclaimed. Permanent access roads and non-reclaimed, disturbed areas such as landings and laydown areas contribute to a direct loss of soil quantity otherwise available to perform a number of ecological functions, and constitute a fundamental change in land use (Bulmer et al. 2008).

11.10.2.1 Cumulative Changes on Soil Quantity

It is preferable to calculate soil loss and degradation as a percentage of the soils present within the terrain and soils CEA area; however, terrain, soils, or ecosystem mapping for the entire area is not available. As a result, the ratio of soils lost and degraded to soils available was calculated using cumulative project footprints and total area (ha) within the terrain and soils CEA area. The assumption within this calculation is that the relative amounts of soils, rock, ice, and water within a project footprint is relatively similar to that represented within the CEA area; if this is so, the percentage loss yielded using footprints may approach the actual percentage loss. For mining projects, this is more probably the case than for linear corridors.

The footprints of the past, present, and future projects and activities are presented in Table 11.10-4. The footprints represent the worst-case scenario for loss of soil quantity, as the project effects applied to these areas do not necessarily result in soil loss. For example, the NTL footprint includes the entire linear corridor, within which very little soil loss will occur, being confined to access road, laydown areas, and other areas of infrastructure development. As well, a certain percentage of the disturbed land base will undergo reclamation, which will be carried out with varying degrees of success.

The footprints of all historic, current and reasonably foreseeable future projects and activities cumulatively add up to 10,688 ha, representing about 1.94% of the terrain and soils CEA area.

11.10.2.2 Cumulative Changes on Soil Quality

There is potential for changes to soil quality to occur within the footprints of the project-related infrastructure, as well as in areas that are spatially linked to project activities. Soil compaction will occur due to the establishment of laydown areas and vehicular traffic. Foot traffic around project sites may also result in soil compaction. Linkages such as hydrological connectivity and air movement provide means for alterations of soil quality to occur away from the project footprint. Hydrological linkage can result in the transfer of contaminants and sediments off site, while aerial deposition of metals away from the project footprint can occur through air movement. Within each project footprint some level of soil contamination can occur due to metal leaching from waste rock storage areas, from road cuts through acid generating rock, and from fluid leaks. Soil degradation will also occur during salvage, long-term storage, and redistribution. Landslides and other forms of soil erosion associated with roads have been shown to decrease the productivity of surrounding areas (Smith, Commandeur, and Ryan 1986; Bulmer et al. 2008).

Consequently, as the proportion of developed land increases, the cumulative spatial extent of soil degradation is expected to rise. Soil degradation associated with the projects considered in this CEA is expected to spatially and temporarily interact with soil degradation associated with the Project.

11.10.3 Mitigation Measures to Address Cumulative Predicted Changes

Soils environmental management and monitoring plans are designed to avoid and minimize adverse effects to soil quality and soil quantity resulting from project activities within the feasible limits of project design and activities. Each past, present, and future project would have had or will have different mitigation measures and management practices for soil quality and soil quantity; however, it is generally assumed that any present and future projects will take into consideration the goals and requirements/objectives outlined in the relevant management plans.

11.10.3.1 Project-specific Cumulative Effects Mitigation for Loss of Soil Quantity

Project-specific cumulative effects mitigation for loss of soil quantity involves following the objectives and targets as outlined in the Soils Management Plan (Section 29.13). No additional mitigation measures are proposed.

11.10.3.2 Other Project/Activity Mitigation to Address Loss of Soil Quantity

In order to mitigate impacts to the soil resource, current and future projects must follow project-specific management plans designed to minimize both loss and degradation of soil. These plans should have similar objectives and targets as presented in Section 29.13, Soils Management Plan. However, the cumulative effects of soil loss are best addressed by early review of alternative design options and introduction of changes leading to reduction of the area on which ecological function of soil will be lost to soil excavation, burial, or erosion.

While the above strategies require participation of each of the involved projects, proactive and comprehensive regional planning will also provide effective mitigation of the cumulative effects of soil loss. Whenever feasible, resource sharing (e.g., highways, power lines, water, and fuel stations) and data sharing (e.g., assessment of the effectiveness of the monitoring methodologies and actions taken to improve the program if relevant, as well as the identification of any emerging negative trends) could be considered.

11.10.3.3 Project-specific Cumulative Effects Mitigation for Loss of Soil Quality

Project-specific cumulative effects mitigation for loss of soil quality involves following the objectives and targets as outlined in Section 29.13, Soils Management Plan. No additional mitigation measures are proposed.

11.10.4 Predicted Cumulative Changes for Terrain and Soils

Predicted cumulative changes are those effects remaining after the implementation of all mitigation measures and are summarized in Table 11.10-5.

Table 11.10-5. Summary of Predicted Cumulative Changes on Terrain and Soils

Soils and Terrain	Timing of Predicted Cumulative Change[1]	Description of Cause-Effect[2]	Description of Additional Mitigation (if any)	Description of Predicted Cumulative Change
Soil quantity	Construction – beyond Post-closure	Removal of soil due to clearing for infrastructure footprints, mass wasting and alteration of local hydrology.	No additional measures beyond Project specific BMPs as outlined in Soil Management Plant	Loss of soil quantity
Soils quality	Construction – beyond Post-closure	Alteration of soil due to dust or physical mixing Degradation of soil due to metal loading via dust, contamination due to spills, alteration of physical characteristics due to compaction, surface erosion.	No measures required No additional measures beyond Project specific BMPs as outlined in Soil Management Plan	Alteration of soil quality including increases in soil productivity Loss of soil quality, including reductions in productivity and increases in contamination

[1] Refers to the Project phase or other timeframe during which the effect will be experienced by the intermediate component.
[2] "Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of the intermediate component, and the actual change or effect that results.

11.10.5 Characterizing Predicted Cumulative Changes for Terrain and Soils

The predicted cumulative changes for each intermediate component were characterized by considering the Project's incremental contribution to the predicted cumulative change under two scenarios:

- Future case without the Project: a consideration of residual effects from all other past, existing, and future projects and activities on a sub-component without the Brucejack Gold Mine Project.
- Future case with the Project: a consideration of all residual effects from past, existing, and future projects and activities on a sub-component with the Brucejack Gold Mine Project.

This approach helps predict the relative influence of the Project on the residual cumulative change for each intermediate component, while also considering the role of other projects and activities in causing that effect. The introductory paragraph to the characterization of cumulative residual change in Section 11.10.6 below provides a spatial dimension to the with and without scenarios.

The likelihood or probability that a Project activity (e.g. mine construction, road use, and tower installation) will result in an effect on soil quantity or quality was determined through reviews of relevant literature, proposed Project activities, baseline information, and/or professional judgement.

The confidence regarding how well residual effects are understood, which includes a consideration of the acceptability of the data inputs and analytical methods used to predict and assess project effects, was taken into consideration when characterizing residual effects.

It is very difficult to accurately determine the magnitude of loss, alteration and degradation of soils within a cumulative context due to data limitations, disparate methodologies between projects, and an overall absence of measurable criteria and indicators. Nevertheless, there is some empirical information on the amount of habitat loss (i.e., ecosystems) beyond which effects to wildlife species is predicted to be unacceptably high. Since soils support these ecosystems, magnitude determinations will be left to those chapters that have linkages to soils, such as Terrestrial Ecosystems (Chapter 16).

11.10.6 Cumulative Residual Change Characterization

The other projects included in the CEA combine for a total project footprint of 10,688 ha. This represents about 1.94% of the terrain and soils CEA study area (550,630 ha). The Project will potentially result in loss of 63.9 ha of ecologically functional soil, alteration of 927.6 ha, and degradation of 187.3 ha of ecologically functioning soil. Therefore, in total, all past, present, and future projects as well as the Project have a combined footprint of 10,749.9 ha. This represents 1.95% of the terrain and soils CEA area. Therefore, the inclusion of the Project with the list of future projects results in an increase of approximately 0.01% of the area within the terrain and soils CEA area occupied by industrial footprint. This is the worst-case scenario for soil loss, as no reclamation activity is taken into consideration with this calculation.

11.10.6.1 Cumulative Residual Change Characterization for Soil Quantity

The probability of soil loss due to cumulative project development is high, while the confidence in the predicted outcome is medium due to potential interactions with natural slope instability, seismic activity, and other projects. While the spatial extent of this effect is expected to remain local on a project-by-project basis, the duration of the land loss will extend into the far future. The losses will occur with sporadic frequency throughout and beyond the life of the projects. The effect is irreversible, as the soils in some areas of the projects (e.g., quarry and/or some roads) will be permanently lost, while other areas will take decades to recover. Due to the scarcity of quality soils and the high degrees of acidity in those present, the resilience of the receiving environment is considered low. The overall ecological context is neutral.

11.10.6.2 Cumulative Residual Change Characterization for Soil Quality

The probability of loss of soil quality due to cumulative project development is medium, while the confidence in the predicted outcome is also medium due to potential interactions with natural slope instability, seismic activity, other projects, variability of contamination sources and pathways, and success of mitigation measures. While the spatial extent of this effect is expected to remain local on a project-by-project basis, the duration of the land loss will extend into the far future. The losses of soil quality will occur with sporadic frequency throughout and beyond the life of the projects. Soil degradation is considered irreversible because many of the causal agents will not be removed, and recovery takes decades. Soil alteration is medium-term as recover will occur relatively rapidly. There is a high incidence of natural slope erosion and sporadically high soil metal concentrations; however, the high degree of acidity present in the soils means that they have limited capacity to buffer further chemical inputs. Therefore, the resilience of the receiving environment is considered low. The overall ecological context is neutral.

11.10.7 Terrain and Soils as a Pathway for Interaction with Receptor Valued Components

Due to the intrinsic link between soil and landscape, any considerable changes to soil quality and/ or quantity will directly affect terrestrial ecosystems and wildlife habitat. The implications of these effects are summarized in Section 11.9, Terrain and Soils as a Pathway to Receptor Valued Components, and described in Chapter 16, Assessment of Potential Terrestrial Ecology Effects, and Chapter 18, Assessment of Potential Wildlife Effects. As well, changes to soil quality and quantity can have indirect effects on human health, fish and fish habitat, and surface water quality. These are also discussed in Section 11.9.

11.11 SUMMARY AND CONCLUSIONS FOR TERRAIN AND SOILS EFFECTS ASSESSMENT

The Project will result in potential loss of 63.9 ha of ecologically functional soil. However, the concept of loss must be seen in the context of the mine site being located on a gossan that is void of actual soil and the generally low ecological function of soil in the area.

The Project will result in the alteration of 927.6 ha, and the degradation of 187.3 ha of low value ecologically functional soil.

Key mitigation measures will be to minimize clearing activities, stockpile soils and non-soil materials for eventual use in reclamation, and follow best management practise for soil handling. Project related effects to terrain stability will be mitigated by appropriate geotechnical and engineering design measures.

Considered cumulatively with other past, present, and future projects in the Unuk and Lower Bell-Irving watersheds, Project activities would account for less than 1% increase in the area of soils lost or degraded.

The summary of predicted overall changes on soils is presented in Table 11.11-1.

Table 11.11-1. Predicted Changes to Soils

Predicted Effects	Project Phase(s)	Mitigation Measures	Residual Change	Receptor VCs Affected
Soil Quantity				
Loss of soil	Construction to Post-closure	Minimize clearing, stockpile and store soil adequately	Loss[1] of 63.9 ha ecologically functional soils	Terrestrial ecosystems, human health, fish and fish habitat, surface water quality
Soil Quality				
Soil compaction	Construction to Closure	Minimize footprints, confine vehicles to designated access corridors	Alteration of 927.6 ha Degradation[2] of 187.3 ha of ecologically functional soil	Terrestrial ecosystems
Soil contamination	Construction to Closure	Minimize accidents and spills, monitor for dust accumulation		Terrestrial ecosystems, human health, fish and fish habitat, surface water quality
Erosion of ecologically productive soils	Construction to Closure	Erosion control measures as specified in Soil Management Plan		Terrestrial ecosystems, human health, fish and fish habitat, surface water quality

[1] Seen in the context of the mine site being located on a gossan that is void of actual soil and the generally low ecological function of soils in the area.
[2] Seen in the context of degradation thought to be derived largely from project activities at the mine site and dust.

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