

# 9 Geohazards

---

## 9.1 Geohazards Setting

### 9.1.1 Physiography

The proposed KSM Project (the Project) is located in the Coast Mountains of British Columbia (BC; Figure 9.1-1). This area is dominated by folded and faulted volcanic and sedimentary rock originating in the Mesozoic era (Valentine et al. 1978). After retreat of late-Wisconsin glaciation (11,000 years ago), most surficial materials deposited in valleys by glaciers were modified by geomorphic processes such as mass wasting, localized glacial advance and retreat, and fluvial processes.

Deep glacial deposits—such as ablation till, basal till, and glacial fluvial terraces—are generally restricted to the margins of major valley floors and adjacent lower slopes (Valentine et al. 1978). All of the main valleys have been subject to glacial advance and retreat, and associated processes such as erosion and deposition. Left behind are moderately steep upper slopes, steep valley walls, and gently sloping and wide valley floors, many of which are unstable. For example, lateral morainal till has been deposited on slopes exceeding the angle of repose, resulting in rubbly colluvium accumulating along moderately steep slopes and valley bottoms. Post-glacial processes contribute to terrain instability, as high rainfall results in high-energy rivers and streams, eroding the unconsolidated surficial material. Periglacial processes are also in evidence, as several glaciers at the Project site are receding, leaving behind glaciofluvial outwash, small ice-dammed lakes, and gravelly moraine. In addition, the unloading of the valley walls following glacial retreat has led to local instability on oversteepened slopes. This contributes to the incidence of geohazards, such as rockfall, debris avalanches, and slumping of surficial materials.

Elevations range from about 240 masl in the valley bottom of Coulter Creek to over 2,300 masl at the highest peaks. The total relief in the glaciated valleys is up to 1,100 m (north valley slope at Mitchell Pit). Mature forests dominated by *Abies lasiocarpa* (subalpine fir) and hybrid white spruce (*Picea engelmannii* x *glauca*) occupy mesic and wetter sites, while *Tsuga mertensiana* (mountain hemlock) is often dominant on submesic to xeric sites. Thick stands of green alder colonize avalanche tracks, often with an understory of herbaceous plants, such as *Athyrium filix-femina* (lady fern) and *Maianthemum racemosum* (False Solomon's Seal). Valley sidewalls are often forested, which transitions vertically and up glacier valleys to subalpine parkland; the treeline lies at about 1,200 masl. Above the parkland the landscape is dominated by alpine vegetation communities, characterized by the dominance of alpine heath, such as *Phyllodoce empetriformis* (pink mountain heather), *Juniperus communis* (common juniper), and *Empetrum nigrum* (crowberry).

### 9.1.2 Geology

The Project is hosted in a Late Triassic to Early Jurassic volcano-plutonic complex situated along the western margin of the Stikinia Terrane. The Stikinia Terrane consists of volcanic island arcs that were accreted onto another volcanic island arc, the Quesnellia Terrane, in the Triassic period. This composite terrane was later amalgamated to the North American Craton by the Middle Jurassic.

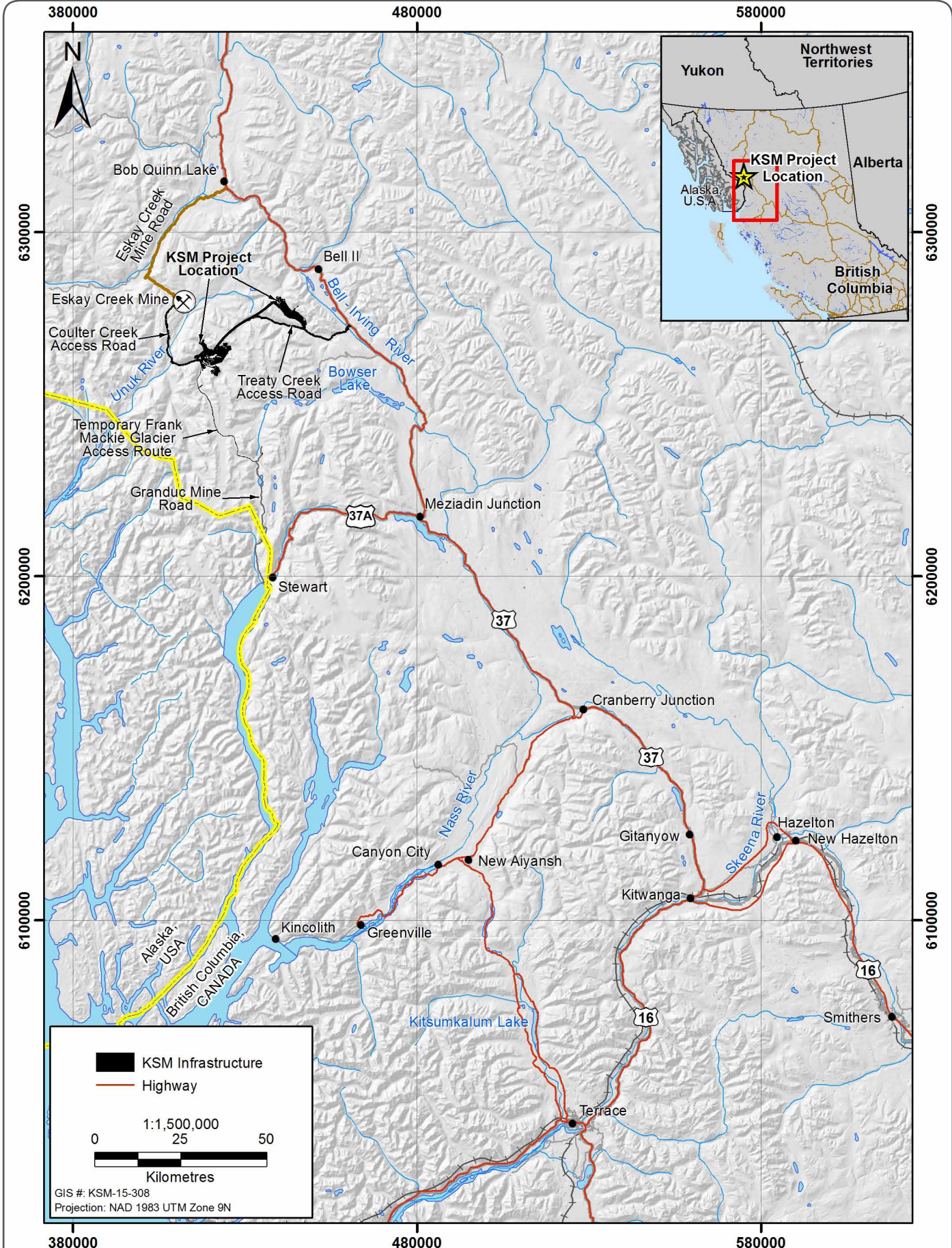


Figure 9.1-1

The stratigraphy of the Stikinia Terrane consists of Late Triassic Stuhini Group sedimentary rocks, composed primarily of coarse conglomerate, siltstone, mudstone, and minor greywacke. The Stikinia Terrane stratigraphy also consists of basic to intermediate subalkaline volcanic flows; pyroclastics and related arc sediments, including coarse augite porphyry and bladed-feldspar porphyry volcanic rocks separated by an erosional unconformity from the overlying Jurassic sediments; volcanics of the Jack Formation, composed of cobble to boulder conglomerate with limestone clasts overlain by fossiliferous lime sandstones and siltstones; and the Hazelton Group, dominated by andesitic flows and breccias deposited in a volcanic chain with high paleotopographic relief.

A variety of dikes, sills, and plugs of diorite, monzodiorite, syenite, and granite are found in the area. Radiometric dating indicates these are of Early Jurassic age, collectively referred to as the Mitchell Intrusions.

The Stikinia Terrane is the largest of several fault-bounded crustal allochthonous terranes within the Intermontane belt, which lies between the postaccretionary Tertiary intrusives of the Coast belt and the continental margin sedimentary prisms of the Foreland (Rocky Mountain) belt, which make up the BC Cordillera.

In the late Cretaceous period, compression from regional tectonics resulted in major folds and faults, including the McTagg Antiform, with a northwest-striking fold axis located west of the KSM Project area. Faults associated with this period of tectonic activity include the Brucejack Fault (a major normal or strike-slip fault with steep dip and north strike) and the Sulphurets Thrust Fault (a regional scale feature with gentle westerly dip that forms the contact between the Stuhini group above and the younger Hazelton group below).

### **9.1.3 Climate**

The climate in the regional area of the Project is typical of temperate rainforest, with an average monthly air temperature ranging between -12°C and 14.7°C. Within the last four years (2008 to 2011), the highest daily maximum ranged between 25.3°C and 30.2°C, and the lowest daily minimum ranged between -22.1°C and -31.1°C (Chapter 7, Air Quality). Within the same period, annual precipitation ranged from 689 mm at the Teigen Creek station to 1,914 mm at the Eskay Creek station. The highest precipitation occurs in September and October. Subarctic conditions are present at high elevations (i.e., above 1,500 masl), where strong winds blowing in a westerly direction predominate in winter.

### **9.1.4 Terrain Stability and Geohazard Baseline Studies**

Baseline studies conducted between 2009 to 2012 included terrain stability mapping, snow avalanche mapping, and geohazard assessments. The latter includes analyses of geohazards, geohazard scenarios, and geohazard risks. Geohazards are 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. 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. 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. However, consequences associated with the interaction—such as negative economic, social, or environmental impacts—are not part of the scenario description. 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.

In order to support the Project, 38,852 ha of terrain stability mapping was carried out in areas where Project infrastructure could potentially interact with terrain. This mapping is presented in Figure 9.1-2, the extent of which comprises the local study area (LSA) for the geohazards assessment. Baseline studies commenced in 2009, with a preliminary assessment of landslide and snow avalanche hazards in the vicinity of the Processing and Tailing Management Area (PTMA). Terrain stability and geohazard baseline studies were completed by BGC Engineering Inc. (BGC), while snow avalanche assessment studies were carried out by Alpine Solutions Avalanche Services (Alpine Solutions). These studies are presented in [Appendices 9-A to 9-E](#).

A geohazard and risk assessment of landslides and snow avalanches was carried out for the Mine Site and Coulter Creek Access Road (CCAR) in the summer of 2010. This work identified many landslide and snow avalanche hazards in the Project area. The work was updated based on a revised facility layout in March 2011.

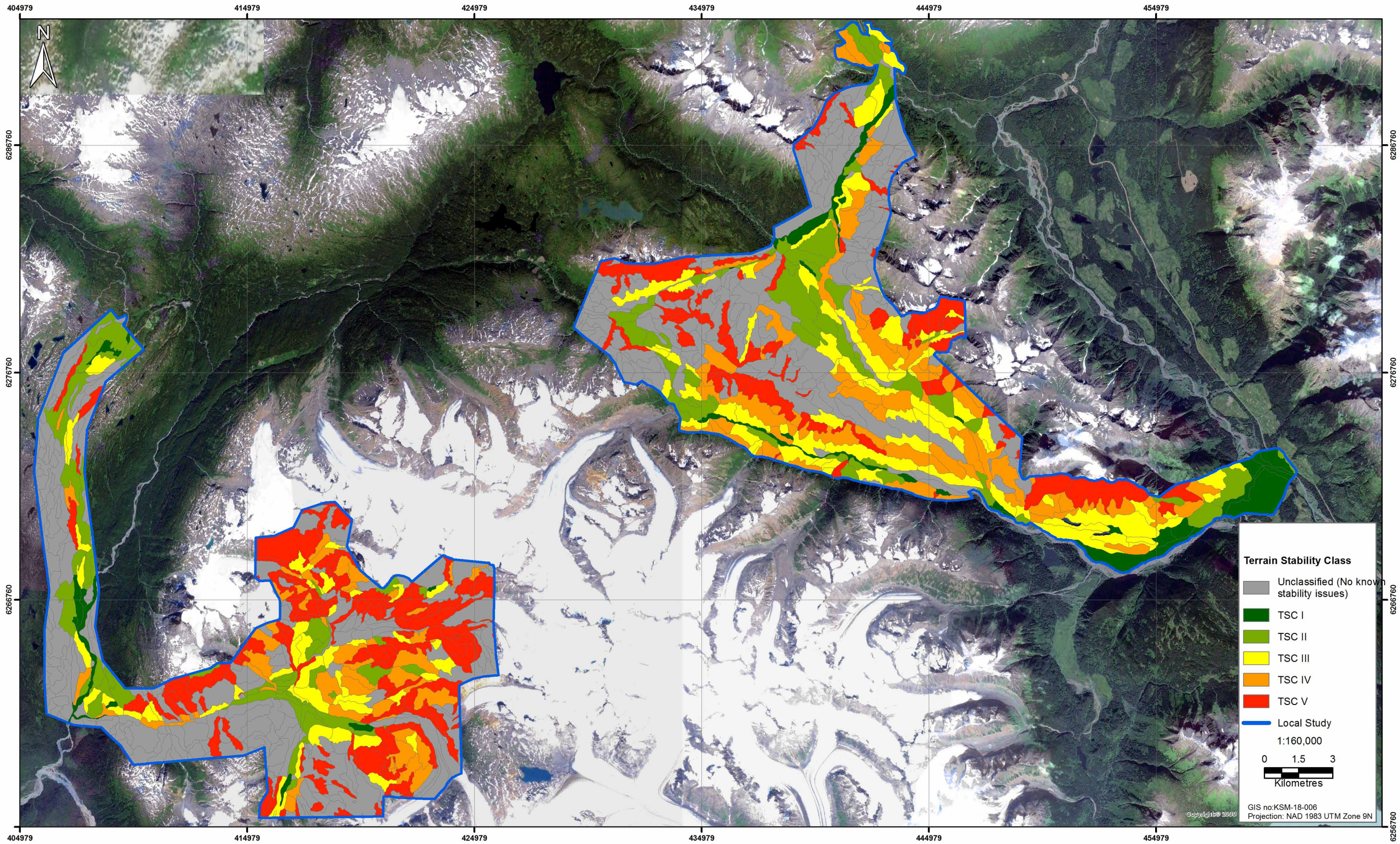
BGC completed a terrain stability field assessment of the proposed mine access roads in 2010. The results of the study provided information on surficial materials and texture, surface expression, geomorphological processes, slope gradient, slope drainage, terrain classification, and surface erosion potential. Snow avalanche hazards were assessed by Alpine Solutions.

A geotechnical assessment of the larger rock cuts expected on the proposed mine access roads was undertaken. The assessment was based on a review of previously collected map data; terrain interpretation and geohazard information; and road design geometry, geology, and geologic structure, followed by helicopter fly-over and foot traverse field review. Recommendations for rock cut slope angles were provided.

Based on the geohazard and risk assessment previously undertaken, further work was completed to determine the design of landslide and snow avalanche geohazard risk reduction measures for the Mitchell Ore Preparation Complex (OPC) in the Mitchell Valley. Additional work was undertaken to provide conceptual landslide and snow avalanche risk mitigation options for the Project facilities. In 2011, a separate study was undertaken to provide a geohazard and risk assessment of landslides and snow avalanches in the vicinity of the proposed Project construction camps, as well as mitigation options.

BGC also completed a stability study of the Mitchell Glacier to assess the potential effects on open pit development.

In September 2011, the Treaty Creek access road (TCAR) was identified as the preferred route to access the PTMA. Additional mapping was carried out by BGC to assess the route.



In April 4, 2012, Seabridge Gold Inc. provided BGC with an updated drawing of the Project layout. Using this drawing and the results of terrain mapping and geohazard identification, two baseline geohazard and risk assessment reports were created. The report assessing geohazards in the Mine Site and the CCAR is presented in [Appendix 9-A](#), and the report for the PTMA, TCAR, and Teigen Creek access road is presented in [Appendix 9-E](#). The Teigen Creek access corridor is no longer the preferred route for accessing the PTMA, and will not be considered during this assessment.

### **9.1.4.1 Geohazards Information, Analysis, and Reports in the Application**

The geohazards chapter addresses the effects of the Project on the environment, specifically the effects that construction, operation, closure, and post-closure activities could potentially have on terrain stability, and the related geohazards. Presented within the appendices are the current geohazards and terrain stability assessments for the Project site, along with proposed mitigation measures. As such, the appendix information will not be repeated within this document; rather, it will be used to support the analysis of terrain stability. The following section briefly summarizes the information available within each appendix, in order to provide guidance for those requiring detailed field data, analysis, and geohazard mitigation plans.

#### **9.1.4.1.1 [Appendix 9-A. KSM Project Geohazard and Risk Assessment, Mine Site and Coulter Creek Access: Revision C](#)**

This document summarizes the snow avalanche and landslide hazards within the Mine Site and along the CCAR. The document identifies 179 unmitigated geohazard scenarios within the proposed Mine Site, including the Mitchell, McTagg, Sulphurets, and Ted Morris valleys; 69 of these scenarios are considered high to very high risk. Nine geohazards were identified along the CCAR, three of which are considered high to very high risk. Most of the geohazards are associated with glacial advance and recent retreat, which has resulted in over-steepened slopes in combination with adverse geologic structures that promote toppling and transitional sliding of overburden materials. Snow avalanches were considered to present the highest overall geohazard risk to the Project, as their frequency of occurrence is of several orders of magnitude higher than that of landslides.

The document presents a Risk Assessment ([Appendix 9-A](#), Section 4) that investigates the probability and severity of an adverse effect to Project infrastructure. Snow avalanche and landslide assessments were carried out independently of each other.

#### **9.1.4.1.2 [Appendix 9-B. KSM Project Geohazard Risk Reduction Summary: Rev B](#)**

This document summarizes landslides and snow avalanche geohazards within all the Project areas (Mine Site, PTMA, and access roads). It assesses geohazard risks to the Project areas as low, moderate, high, or very high. High and very high risks to Project infrastructure are not considered acceptable, and require risk reduction. Mitigation strategies are presented in tabular format for geohazards rated high and very high.

### **9.1.4.1.3      *Appendix 9-C. KSM Geohazards: Ore Preparation Complex Pre-feasibility Geohazards Risk Reduction: Rev C***

This document summarizes landslides and snow avalanche geohazards for the Mitchell OPC. It assesses geohazard risks to the Mitchell OPC as low, moderate, high, or very high. High and very high risks to Project infrastructure are not considered acceptable, and require risk reduction. Mitigation strategies are presented in tabular format for geohazards rated high and very high.

The Mitchell OPC is located within a high-frequency snow avalanche zone. Mitigation of risk to the Mitchell OPC would preferably involve relocation; however, this is not considered to be a feasible option. As such, geohazard risk mitigation strategies are proposed.

### **9.1.4.1.4      *Appendix 9-D. KSM Project: Geohazard Risk Assessment of Updated Facility Locations***

This document provides a geohazard and risk assessment of landslides and snow avalanches for several facilities whose locations were revised since the preparation of BGC Revision C reports. This includes the revised locations of the North Cell seepage collection pond, the southeast seepage collection pond, the Tailing Management Facility (TMF) discharge line, the CCAR, and the Mitchell operating camp. It was determined that the geohazard risk is high for the Mitchell operating camp and the TMF discharge line, and moderate for the southeast seepage collection dam.

### **9.1.4.1.5      *Appendix 9-E. KSM Project Geohazard and Risk Assessment, Tailing Management Facility, Transmission Line, Treaty Creek and Teigen Creek Access: Revision C***

This document provides an assessment of geohazards and associated risks for the PTMA, the proposed facilities for tunnel construction in North Treaty Creek, the Teigen and Treaty Creek access roads, and the transmission line. The Teigen Creek access road is no longer the preferred option for accessing the PTMA; as such it is not discussed further in this chapter.

Eighty-nine geohazards, including landslides and snow avalanches, were identified that could potentially interact with Project infrastructure. Of these, 2 were rated as very high (interacting with the proposed transmission line route), while 42 were rated as high. The PTMA could potentially interact with 12 geohazards rated as high, the transmission line with 18, and the TCAR with 12. Proposed mitigation for high- and very high-risk geohazards is not included in this report; rather, it is included in [Appendix 9-B, KSM Project Geohazard Risk Reduction Summary: Rev B](#).

### **9.1.4.1.6      *Appendix 9-F. KSM Project Terrain Stability Field Assessment of the Proposed Coulter Creek, Teigen Creek and Tunnel Spur Access Roads***

This document assesses terrain stability within the vicinity of the proposed Coulter Creek and Teigen Creek (no longer an option) access roads. The access roads traverse several areas classified as Terrain Stability Class (TSC) IV and V terrain (see Table 9.1-2); several areas along Coulter Creek will require detailed design, mitigation, and construction planning. Mitigation recommendations are given for specific sections of the proposed roads.

### **9.1.4.1.7      *Appendix 9-G. KSM Project Terrain Stability Field Assessment of the Proposed Treaty Creek, North Treaty and Tunnel Adit Access Roads***

This report assesses terrain stability within the vicinity of the proposed Treaty Creek, North Treaty Creek, and Treaty adit access roads. While the proposed access roads traverse several areas classified as TSC IV and V, no areas that require detailed design, mitigation, and construction planning at this stage were identified in the assessment. However, further technical review was recommended for several locations along Treaty Creek and North Treaty Creek.

### **9.1.4.1.8      *Chapter 4. Project Description***

In Section 4.5, Project Development Components, a description of each Project component is presented. A summary of the geohazards associated with each of these components is provided, an outline of risks is presented, and some general mitigation measures are discussed.

### **9.1.4.1.9      *Chapter 34. Effects of the Environment on the Proposed Project***

In Section 34.3, an assessment of the potential effects of geohazards on Project infrastructure is presented. Each geohazard type (landslide, snow avalanche, glacier, seismic activity, and volcano) is discussed in a general manner as it relates to highlighted Project components. Possible interactions are summarized, and general mitigation strategies are presented. This assessment is largely based upon the work by BGC, which was previously summarized and presented in its entirety in [Appendices 9-A to 9-G](#).

### **9.1.4.2      *Summary of Geohazard Incidence and Risk***

Geohazards were identified primarily through terrain stability mapping and snow avalanche mapping, which include the analysis of imagery, slope and hydrology shapefiles, soils mapping, and field data. The methodology is described in Section 2.0 of [Appendix 9-A](#), and is summarized in the following section. Geohazard scenarios were determined based upon the presence of infrastructure within the active path of geohazards. These scenarios are outlined in various sections of the appendices, and are summarized in Section 9.1.4.3 of this chapter. Geohazard risk was determined by assessing the scenarios in terms of likelihood of occurrence and cost. The methodology used is summarized in Section 3.0 of [Appendix 9-A](#).

In total, 268 geohazard scenarios were identified during baseline studies, presented in [Appendices 9-A to 9-G](#). A summary of general locations and the risk associated with the geohazards is presented in Table 9.1-1.

#### **9.1.4.2.1      *Terrain Stability Mapping***

Terrain stability refers to the potential for landslide initiation within the polygon, either by natural processes, or following disturbance by road and infrastructure construction or by removal of forest cover (BC MOF 1999). In general, the potential for terrain stability issues increases with slope gradient, increased moisture content, the presence of erodible soils, and the presence of existing instability features.

**Table 9.1-1. Summary of Identified Geohazard Scenarios and Associated Risks of the Project**

Risk	PTMA	Transmission Line	TCAR	CCAR	Mitchell Valley	McTagg Valley	Sulphurets Valley	Ted Morris Valley	Totals
Very High	0	2	0	1	10	1	0	0	14
High	12	18	12	2	42	8	7	1	102
Mod	5	6	12	2	22	5	13	4	69
Low	8	1	9	4	17	12	19	3	73
Very Low	4	0	0	0	5	1	0	0	10
Total	29	27	33	9	96	27	39	8	268

BGC carried out terrain stability mapping for the Project area from 2010 to 2012 ([Appendices 9-F](#) and [9-G](#)). Terrain stability class ratings range from TSC I (stable) to TSC V (unstable), as shown in Table 9.1-2, and were added to all terrain polygons intersecting proposed facilities, using infrastructure as proposed in April 2012. These ratings were specifically developed for forestry applications, and form part of the criteria used to identify terrain requiring further evaluation during a terrain stability field assessment. The class ratings are based on slope steepness, surficial material type, and geomorphological processes occurring within the polygon (e.g., gully erosion or existing landslides). Terrain stability criteria adapted by BGC for baseline studies are shown in Table 2-4 of [Appendix 9-A](#). The criteria are applied using judgment, and may vary depending on local terrain conditions. For example, a slope morphology that includes irregular, near-surface bedrock would typically be rated as more stable than a similar slope with a smooth profile, because bedrock irregularities tend to stabilize surficial material against failure. Polygons with existing landslides in bedrock or surficial material are automatically assigned TSC V ratings.

**Table 9.1-2. Terrain Stability Class Ratings (Adapted from [Appendix 9-G](#))**

Terrain Stability Class (TSC)	Interpretation
I	No significant stability problems exist.
II	There is a very low likelihood of landslides following road construction. Minor slumping is expected along road cuts, especially for one or two years following construction.
III	There is a low likelihood of landslide initiation following road construction. Minor slumping is expected along road cuts, especially for one or two years following construction.
IV	Expected to contain areas with a moderate likelihood of landslide initiation following road construction.
V	Expected to contain areas with a high likelihood of landslide initiation following road construction.

Terrain, terrain stability, and erosion potential mapping was carried out for the proposed access road corridors at a detailed terrain survey intensity level (TSIL C) using the BC Provincial Terrain Stability Mapping standards (Resources Inventory Committee 1996; Howes and Kenk 1997) and 1:15,000 scale aerial photographs. Terrain stability maps were prepared presenting terrain stability classes for each of the mapped polygons. Terrain stability maps were also prepared for the areas of the Project that intersect the footprint of all above-ground facilities (e.g., roads, buildings, diversion channels, conveyors, pits, and rock storage facilities [RSFs]).

**9.1.4.2.2 Landslide Mapping**

Landslide mapping involves identifying active or historical areas that have undergone mass movement, such as rock avalanches, debris flows, debris avalanches, rockfall, and earth slumps. These are often associated with steep slopes with recently deposited surficial material, areas recently cleared of vegetation, or areas where hydrological changes have resulted in increased pore water pressure, subterranean piping, or erosion. They often include initiation, transport, and depositional zones; any of these can constitute a geohazard scenario.

Risk associated with landslide geohazard scenarios is determined by likelihood of occurrence and hazard magnitude. Landslide likelihood of occurrence is estimated in terms of annual frequency. For example, debris flows occurring in areas with steep gradients having well-scoured channels free of vegetation, and easily discernable levees of previous flows would have a high likelihood of occurrence (0.1 to 0.9 annual frequency of occurrence). Debris flows in areas with poorly defined source areas and vegetated channels would only occur during extreme storm events, and would have a low likelihood of occurrence.

Landslide hazard magnitude is described using volume and discharge range (Table 9.1-3). Generally, the larger the volume and the greater the discharge range, the higher the magnitude of the landslide hazard.

**Table 9.1-3. Definitions of Hazard Magnitude for Landslides**

Size Class	Volume Range (m <sup>3</sup> )	Discharge Range (m <sup>3</sup> /s) (for coarse-grained debris flows)
0	< 10 <sup>1</sup>	n/a
1	< 10 <sup>2</sup>	< 5
2	10 <sup>2</sup> - 10 <sup>3</sup>	5 - 30
3	10 <sup>3</sup> - 10 <sup>4</sup>	30 - 200
4	10 <sup>4</sup> - 10 <sup>5</sup>	200 - 1,500
5	10 <sup>5</sup> - 10 <sup>6</sup>	1,500 - 12,000
6	10 <sup>6</sup> - 10 <sup>7</sup>	n/a

n/a = not applicable

**9.1.4.2.3 Snow Avalanche Mapping**

Snow avalanches are frequently occurring events in the Project area, and pose a hazard for both personnel and Project infrastructure. Guidelines indicating thresholds of avalanche risk for fixed facilities, worksites, and industrial roads have been developed, and are outlined in the *Guidelines*

for *Snow Avalanche Risk Determination and Mapping in Canada* (Canadian Avalanche Association 2002). Risk thresholds are not only based on magnitude and frequency of avalanches, but also consider differences in vulnerability and exposure time to the elements at risk.

Extent of avalanche hazard is primarily defined by a combination of specific terrain and climatic conditions. Under normal circumstances, there must be terrain that is open and steep, as well as sufficient snow supply to create avalanche hazard. Without the combination of these, there is no avalanche risk.

Avalanche risk planning for the Mine Site, with a combination of fixed facilities, worksites, and access roads, involves the consideration of maximum size avalanches; these generally have avalanche return periods of 100 years or more. The avalanche size classification was defined based on work by McClung and Schaerer (2006), and it is shown in Table 9.1-4.

**Table 9.1-4. Avalanche Size Classification**

Size	Destructive Potential	Typical Mass	Typical Path Length	Typical Impact Pressures
1	Relatively harmless to people	< 10 tonnes	10 m	1 kPa
2	Could bury, injure, or kill a person	10 <sup>2</sup> tonnes	100 m	10 kPa
3	Could bury a car, destroy a small building, or break a few trees	10 <sup>3</sup> tonnes	1,000 m	100 kPa
4	Could destroy a large truck, several buildings, or a forest with an area up to 4 ha	10 <sup>4</sup> tonnes	2,000 m	500 kPa
5	Largest snow avalanches known—could destroy a village or a 40-ha forest	10 <sup>5</sup> tonnes	3,000 m	1,000 kPa

Source: McClung and Schaerer (2006).

A snow avalanche hazard assessment developed by Alpine Solutions for the CCAR and the Mine Site was based on air photo interpretation of the hazards previously identified by BGC, in conjunction with two fieldwork days in October 2009 and April 2010; this is presented in [Appendix 9-A](#). An assessment of avalanche hazards in the TCAR and PTMA was carried out during the latter part of 2011, also by Alpine Solutions, and is presented in [Appendix 9-E](#).

### 9.1.4.3 Summary of Results of Geohazards Baseline Studies

#### 9.1.4.3.1 Summary of Landslide Geohazards Identified in Geohazard Baseline Studies

Potential mass movement events for the Mitchell and McTagg valleys include shallow debris avalanches, rockfall, debris flows, and deep-seated bedrock slumping. A small moraine-dammed lake is located in the up-valley of the Mitchell Pit footprint, and along the first 5 km of the proposed Mitchell Pit haul road. An existing landslide (Snowfield Landslide) and a large area of sackungen (gravitational slope sagging) situated above the Snowfield Landslide are located on the south side of the proposed Mitchell Pit. The volume of material in the Snowfield Landslide is estimated to be 57,000,000 m<sup>3</sup> and the deformation rates are approximately 10 cm to 50 cm per year. Movement of the Snowfield Landslide could potentially debutress unstable slopes above.

McTagg Creek is a major tributary to Mitchell Creek. Its valley is subject to shallow debris avalanches, rockfall, debris flows, rock avalanches, and deep-seated bedrock slumping.

A large rock slide is located north of the proposed McTagg Twinned Diversion Tunnel (MTDT) north portal. This slide has likely been activated through glacial debuttressing, but the rock mass has not yet been fully detached. A large scale rock deformation is inferred in the N-tributary of the Upper McTagg Valley.

The Sulphurets Valley is a steep-sided, glaciated valley. The upper basin splits into two major glaciated valleys and a glaciated tributary. This valley would have had repeated episodes of glacial scour during the Quaternary Period, leaving behind over-steepened side slopes along the valley axis.

Some features are interpreted as former paths of debris and snow avalanches in the northern side of the valley. A landslide feature is located east of the current KSM Project exploration camp, on the north side of the Kerr Pit. Dubbed the Kerr Landslide by BGC ([Appendix 9-A](#)), it is considered active. It is bounded by two normal faults, and it is located within a zone described as phyllitic-argillic alteration.

The east side of the Kerr Landslide is subject to debris flow hazards with sediments recruited from moraine deposits upslope of the proposed road.

West from the existing KSM Project exploration camp there is a landslide feature named the Sulphurets Landslide ([Appendix 9-A](#)). The scarp and the surficial geology suggest that slope deformation on this valley side has previously resulted in rapid failures; future failures will need to be considered.

Evidence of glacial outburst exists in the form of a series of small glacial lakes separated by stationary ice. These lakes are connected by potentially unstable subglacial drainage channels; collapse of part or all of this drainage network could impede flows, causing it to fill and re-establish on the ice surface. Sulphurets Lake would attenuate the flood wave, but there may still be some potential for discharge, requiring consideration when the Sulphurets access road is designed.

Within the Ted Morris Valley, the Ted Morris Landslide ([Appendix 9-A](#)) occurs above glacially over-steepened terrain and is considered active due to the presence of unvegetated slumping areas.

Potential landslide hazards for the TCAR include debris floods, debris flows, channel avulsions, and rockfall ([Appendix 9-E](#)). Large alluvial fans are present at several locations, most notably at km 4.5, km 14.3, km 16.2, km 26.8, and km 28.8. All of these fans will be subject to further channel avulsions and debris flows. Several other large debris flows are evident along the proposed route; however, these do not currently intersect with the proposed road alignment. However, since they are uphill of the proposed route, future effects are possible.

### 9.1.4.3.2 *Summary of Snow Avalanche Geohazards Identified in Geohazard Baseline Studies*

Snow avalanche hazards are abundant due to high elevation, snow supply, and slope gradient. Since the Project is located in a transition zone between maritime and continental climate zones, significant temperature and moisture fluctuations are expected throughout an average winter. The avalanche season typically begins in early October at the higher elevations and often extends until late June or early July. At the valley bottom, avalanches can be expected, in extreme years, from late October to late May ([Appendix 9-A](#)).

Evidence of avalanches, such as broken trees and bare chutes, is widespread in the Mitchell Valley and to a lesser extent in the McTagg Valley. In the Mitchell Valley there are large avalanche paths and steep slopes on both sides that could become a risk to infrastructure and personnel. Due to the abundance of steep terrain combined with sparse tree cover, there is limited availability of low hazard areas ([Appendix 9-A](#)). The footprint of the planned Mitchell Pit is composed of and surrounded by avalanche terrain. Size 3 avalanches are expected to release in most of these paths at least once per season. Size 4 avalanches would be expected in exceptional winters, which are estimated to occur every few years ([Appendix 9-A](#)).

The lower part of the Mitchell and McTagg valleys has terrain conducive to snow avalanches. They will affect the area in which the Mitchell OPC footprint will be located.

On the west side of the McTagg Valley, a gully with little or no sediment is found. The absence of sediments could be interpreted as a consequence of frequent snow avalanches, particularly wet avalanches during spring and early summer. The total volume along that gully could be several hundred to several thousand cubic metres. Large snow avalanches can also be expected from a long (1.8-km) gully to the immediate north of the Phase 3 West McTagg Inlet.

Snow avalanches occur frequently along the TCAR; currently 29 avalanche paths intersect the route. In total, only 10 km of the route is considered at low risk for avalanche, with the section from km 21 to km 30 having the highest risk. The majority of avalanches would be expected during winter and early spring months. However, avalanches may reach road elevations as early as October and as late as May.

The proposed Treaty Saddle road is subject to snow avalanches, with the sections of the route along upper Teigen Creek particularly susceptible.

## 9.2 Historical Activities

Within the regional area, past projects include the Eskay Creek Mine, Granduc Mine, Johnny Mountain Mine, Snip Mine, Kitsault Mine, and the Swamp Point Aggregate Mine. There is also a small-scale historical advanced exploration project at the Sulphurets property, which is a few kilometres to the east of the Project.

There are several mining projects in the region at various stages of permitting, including Brucejack, Galore Creek, Red Chris, Schaft Creek, and Forrest Kerr.

Activity at the KSM Project Mine Site has been restricted to periods of mineral exploration, which began during the early 20th century. Gold prospecting continued in the area until the early 1960s and accelerated with the introduction of modern exploration methods, such as airborne geophysical surveys, geological and geochemical surveys, and diamond drilling. Since 1961, several programs of drilling have been undertaken at the Sulphurets-Mitchell property. In 1982, exploration started at the Kerr property. Exploration activities have continued over the years at both properties using remote exploration methods and helicopter assisted drilling operations. Disturbance at the Mine Site due to exploration activity is minimal and is limited to active and non-active drilling works, construction, and seasonal exploration camps.

### 9.3 Land Use Planning Objectives

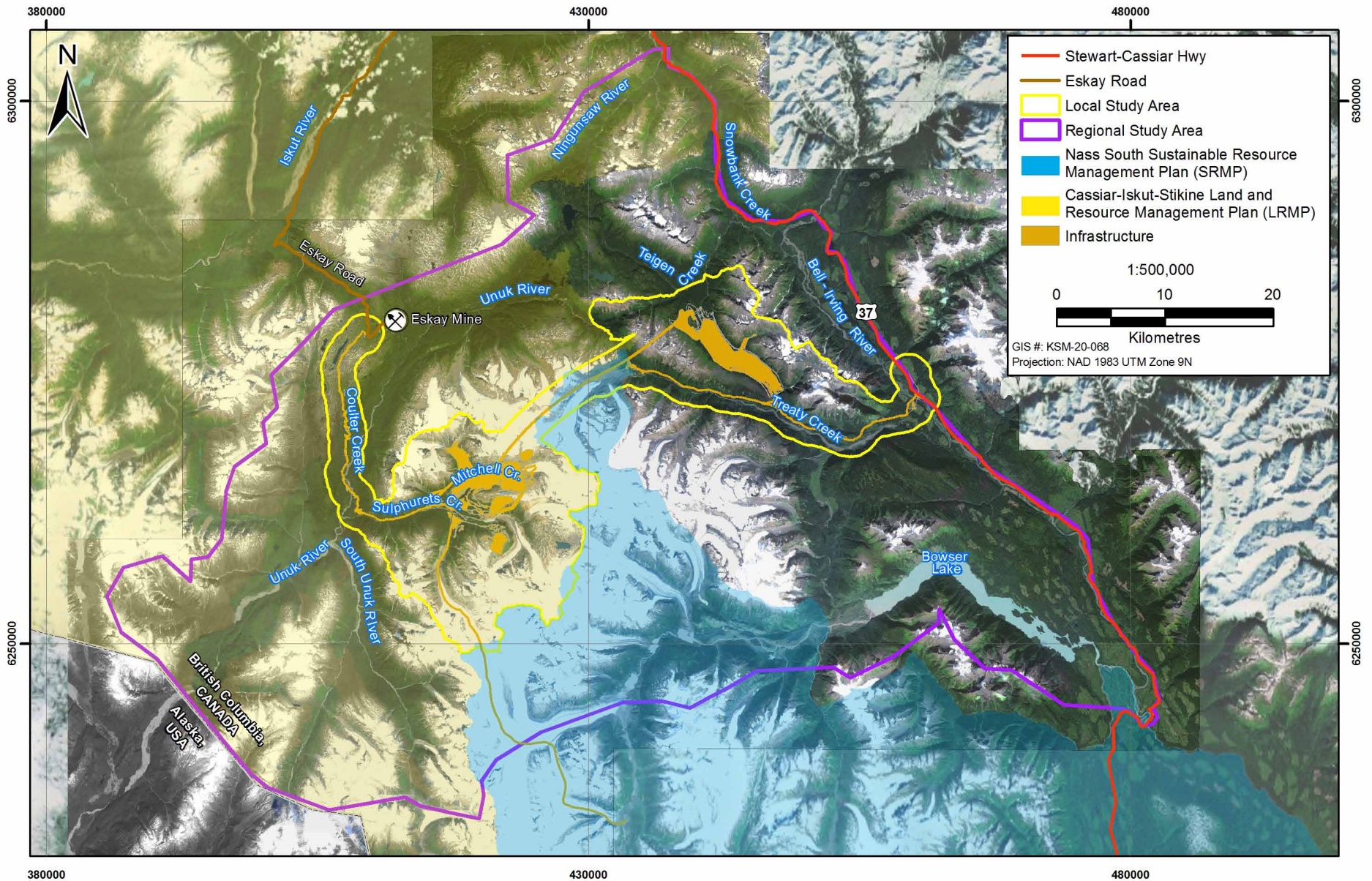
The Project overlaps portions of the Cassiar-Iskut-Stikine Land and Resource Management Plan (LRMP; BC ILMB 2000) area and the Nass South Sustainable Resource Management Plan (SRMP; BC MFLNRO 2012) area (Figure 9.3-1). LRMPs are sub-regional resource plans that establish the framework for land use and resource management objectives and strategies. SRMPs are landscape-level plans developed to address the sustainable management of land, water, and resources. They focus on similar issues and values as regional plans or LRMPs (e.g., timber, biodiversity, and tourism) but at a more detailed level. For example, SRMPs are used to identify old-growth management areas, for addressing specific economic development issues such as agriculture or tourism development, and are also useful for managing values such as spiritual and cultural resources as identified by Aboriginal peoples (BC MFLNRO 2012). The Nass South SRMP involves collaboration between the Gitanyow First Nation, Nisga'a Nation, key local stakeholders, and government.

Smaller watershed sustainability plans, as developed by the Gitanyow First Nation, are incorporated within larger land management plans, including the Nass South SRMP. Within wilp Wii'litsxw claimed traditional territory (downstream of the Project), the completed SRMP is expected to also provide protection of ecologically sensitive areas, high-value habitats, traditional use sites, and old-growth management areas.

Within their claimed traditional territories, current Gitxsan Nation watershed planning aims to develop sustainable development plans for each of the nine watersheds that incorporate considerations regarding Aboriginal title, contribute to capacity building, and enhance economic conditions (Gwaans 2007; Gitxsan Hereditary Chiefs' Office 2010; Rescan 2012a). Development planning tools may include full-cost accounting of social and environmental values, environmental assessment to avoid or minimize negative impacts, and ecosystem management (Gwaans 2007). Issues of concern are identified at a watershed level and include information regarding plant resources, fish and wildlife habitat, culturally modified trees, historical sites, and information about the respective wilp (Gitxsan Hereditary Chiefs' Office 2010).

#### 9.3.1 Protected Areas

BC's provincial parks protect nationally and internationally significant ecological and cultural values. Ecological reserves are areas selected to preserve representative and special natural ecosystems, plant and animal species, features, and phenomena. Three provincial parks and one ecological reserve are located in the regional area:



- Stewart-Cassiar Hwy
- Eskay Road
- Local Study Area
- Regional Study Area
- Nass South Sustainable Resource Management Plan (SRMP)
- Cassiar-Iskut-Stikine Land and Resource Management Plan (LRMP)
- Infrastructure

1:500,000

0 10 20

Kilometres

GIS #: KSM-20-068  
Projection: NAD 1983 UTM Zone 9N

Figure - " 1%

- Ningunsaw Provincial Park (15,000 ha);
- Ningunsaw River Ecological Reserve (2,372 ha);
- Lava Forks Provincial Park (7000 ha); and
- Border Lake Provincial Park (800 ha)

The Ningunsaw River Ecological Reserve was established to preserve an elevational sequence of three biogeoclimatic zones in a transition between coastal and interior climates. Resource extraction (e.g., commercial logging, mining, and hydro-electric development) within these protected areas is prohibited.

Lava Forks and Border Lake provincial parks are very remote. Access to the Lava Forks Provincial Park is by helicopter only. Border Lake is too small in which to land float planes. Visitors access the upper reaches of the Unuk River by air, then raft down to Border Lake Provincial Park. Ningunsaw Provincial Park is accessible by car from Highway 37.

### 9.3.2 Legislation and Best Management Practices

Legislation and best management practices regarding terrain stability and geohazards come from forest practices. Forest harvesting in BC is subject to the *Forest and Range Practices Act* (2002). This Act applies constraints to when, where, and how harvesting is undertaken. Stability of riparian ecosystems are protected by a variety of acts including the *Forest and Range Practices Act* (2002) and the *Fisheries Act* (1985). 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).

## 9.4 Spatial and Temporal Boundaries

### 9.4.1 Spatial Boundaries

Spatial boundaries for the purpose of the geohazard effects assessment include all locations where Project infrastructure interacts with existing geohazards, where Project infrastructure could increase or decrease the hazard associated with existing geohazards, and where Project infrastructure could increase or decrease terrain stability. This corresponds with the area mapped for terrain stability by BGC, which covers 38,852 ha. This area comprises the LSA for the geohazards assessment, and is shown in Figure 9.1-2.

The proposed Mine Site includes three open pits, two underground mines, RSFs and laydown areas, the Mitchell OPC, and the Water Treatment Plant; all are located within the valleys of Mitchell Creek, McTagg Creek, and Sulphurets Creek, the latter being a main tributary to the Unuk River. The infrastructure associated with the Mine Site is presented in Figure 9.4-1 for the construction phase and in Figure 9.4-2 for the operation phase.

The PTMA, including the Treaty OPC and TMF, will be situated within the headwaters of tributaries of South Teigen Creek and North Treaty Creek. Both of these creeks are tributaries of the Bell-Irving River, which flows to the Nass River. The infrastructure associated with this area is presented in Figure 9.4-3 for the construction phase and in Figure 9.4-4 for the operation phase. The 23 km Mitchell-Treaty Twinned Tunnels will connect the Mine Site and the PTMA.



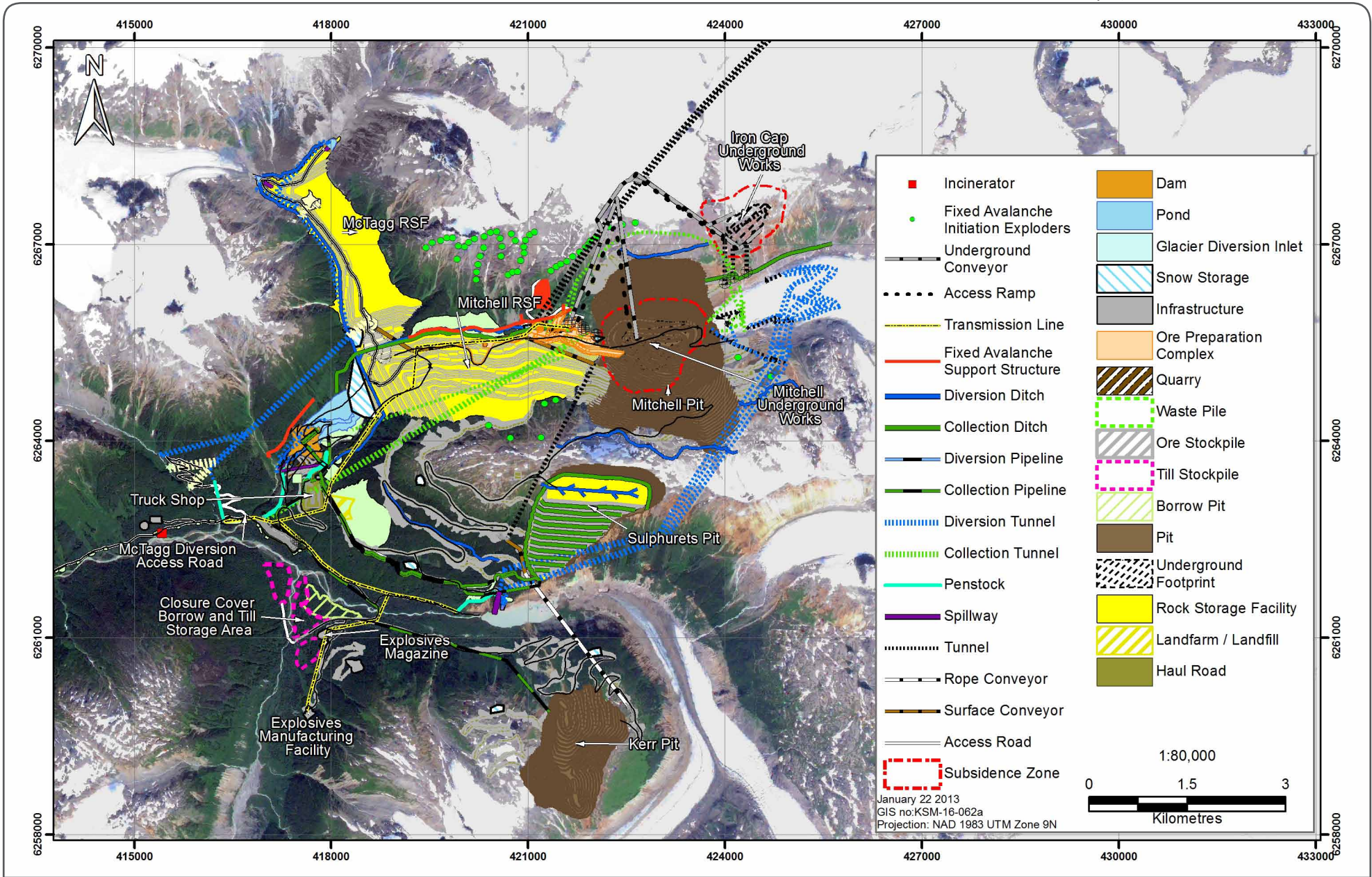


Figure 9.4-2

Figure 9.4-2

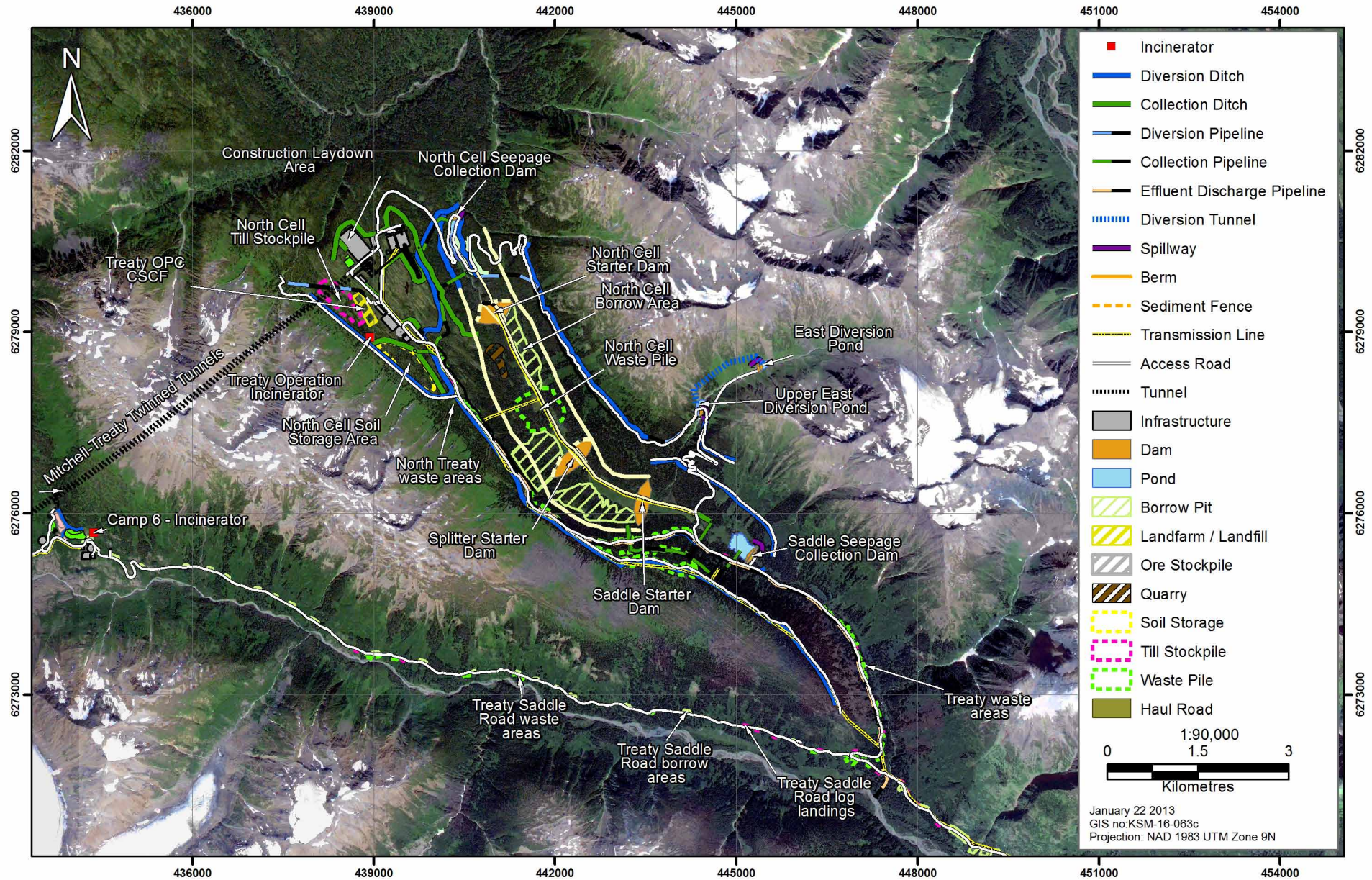
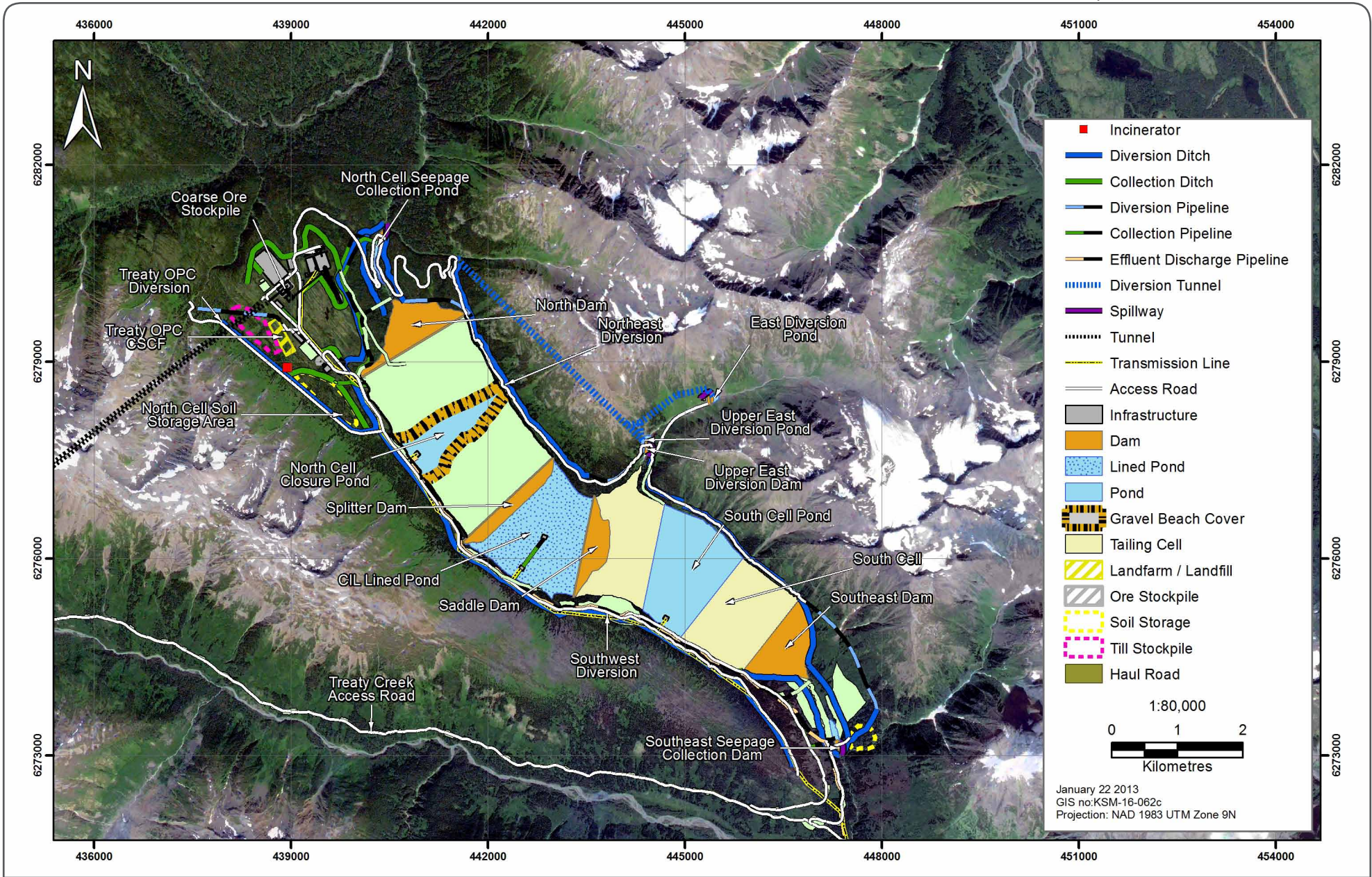


Figure 9.4-3



January 22 2013  
 GIS no:KSM-16-062c  
 Projection: NAD 1983 UTM Zone 9N

Figure 9.4-4

### Processing and Tailing Management Area Infrastructure and Treaty Creek Access Road - Operation

Figure 9.4-4

Access to the Mine Site will be via the CCAR (Figure 9.4-5 for construction, and Figure 9.4-6 for operation), while access to the Treaty Process Plant and TMF will be through the Treaty Creek and North Treaty Creek valleys (Figure 9.4-3 and 9.4-4).

### 9.4.2 Temporal Boundaries

The temporal boundaries include the following four phases:

- **Construction:** 5 years;
- **Operation:** 51.5-year life of mine;
- **Closure:** 3 years; and
- **Post-closure:** 250 years.

The construction phase will include the construction of access roads along the valleys, surface clearing for pipeline right of ways, site preparation and contouring, the establishment of preliminary berms during dam construction, as well as the development of several quarries and borrow pits required for the development of mine facilities, access roads, and associated infrastructure.

Throughout operation, successively increasing areas of land will be required to accommodate open pit mining activities, overburden, rock and ore storage, mineral crushing and transportation, ore processing, tailing disposal, and water management efforts.

The closure and post-closure phases involve mine decommissioning and reclamation, and adaptive management guided by monitoring to ensure reclamation objectives are met. Details of management activities to be undertaken during this time are provided in Chapter 27.

## 9.5 Valued Components

The determination of the geohazard valued components (VCs) involved the following steps:

- a review of the Application Information Requirements and the Comprehensive Study Scope of Assessment; and
- a review of the issues that were raised during consultation with provincial, federal, and local government agencies, Aboriginal groups, the public, and other stakeholders.

An assessment of geohazards can involve the effects of geohazards on Project infrastructure and personnel (i.e., an assessment of “effects of the environment on the Project,” which is also provided in Chapter 34), as well as the potential of the Project to change the landscape and therefore increase or decrease the incidence and magnitude of geohazards. Geohazards that could be affected by the Project are those related to mass movements (landslides, debris flows, rockfall, etc.) and snow avalanches. Alteration of natural terrain conditions during Project development could exacerbate baseline terrain stability, resulting in higher risks of adverse effects to terrain and Project infrastructure if design and mitigation are not adequate or feasible.

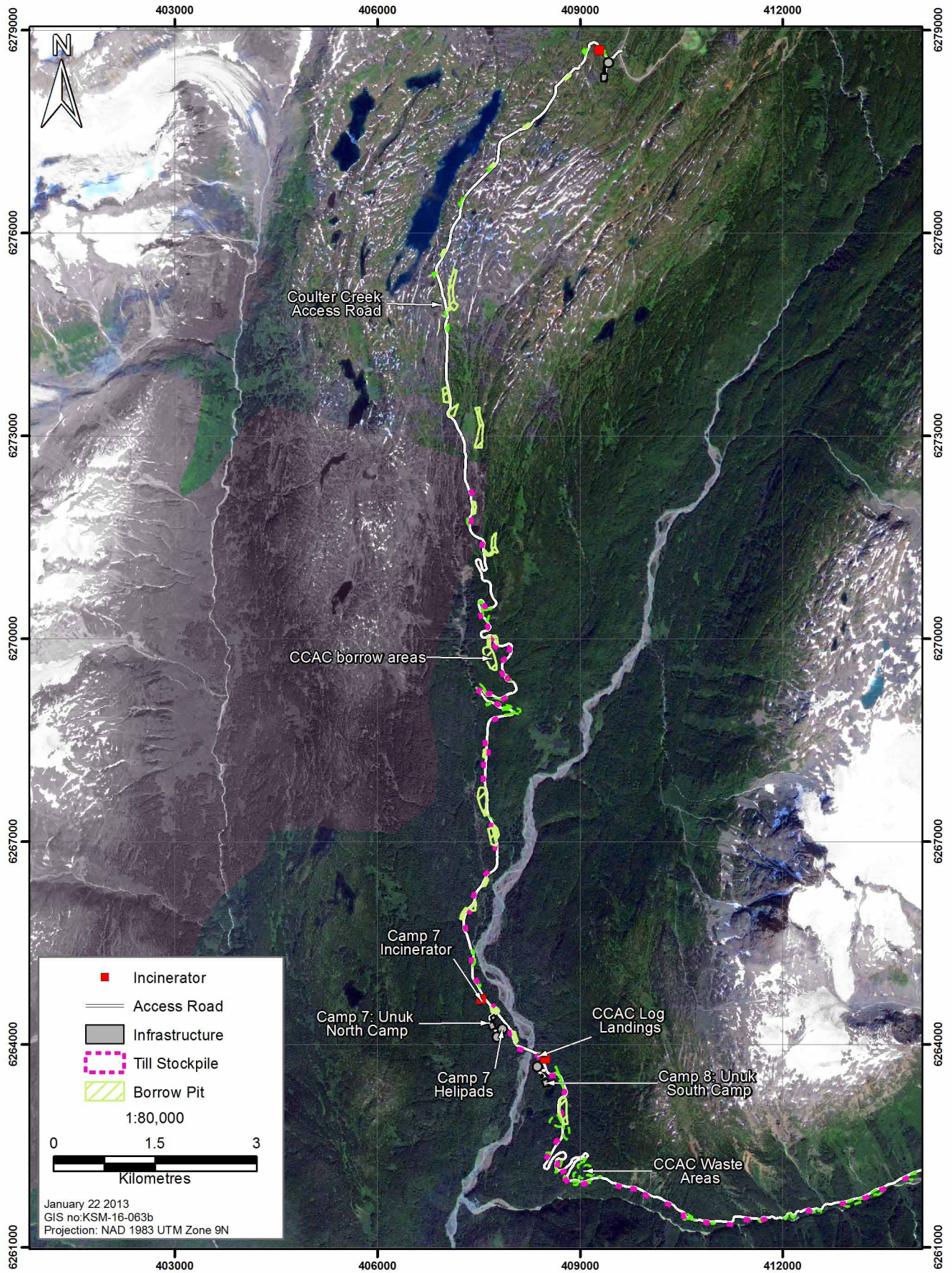
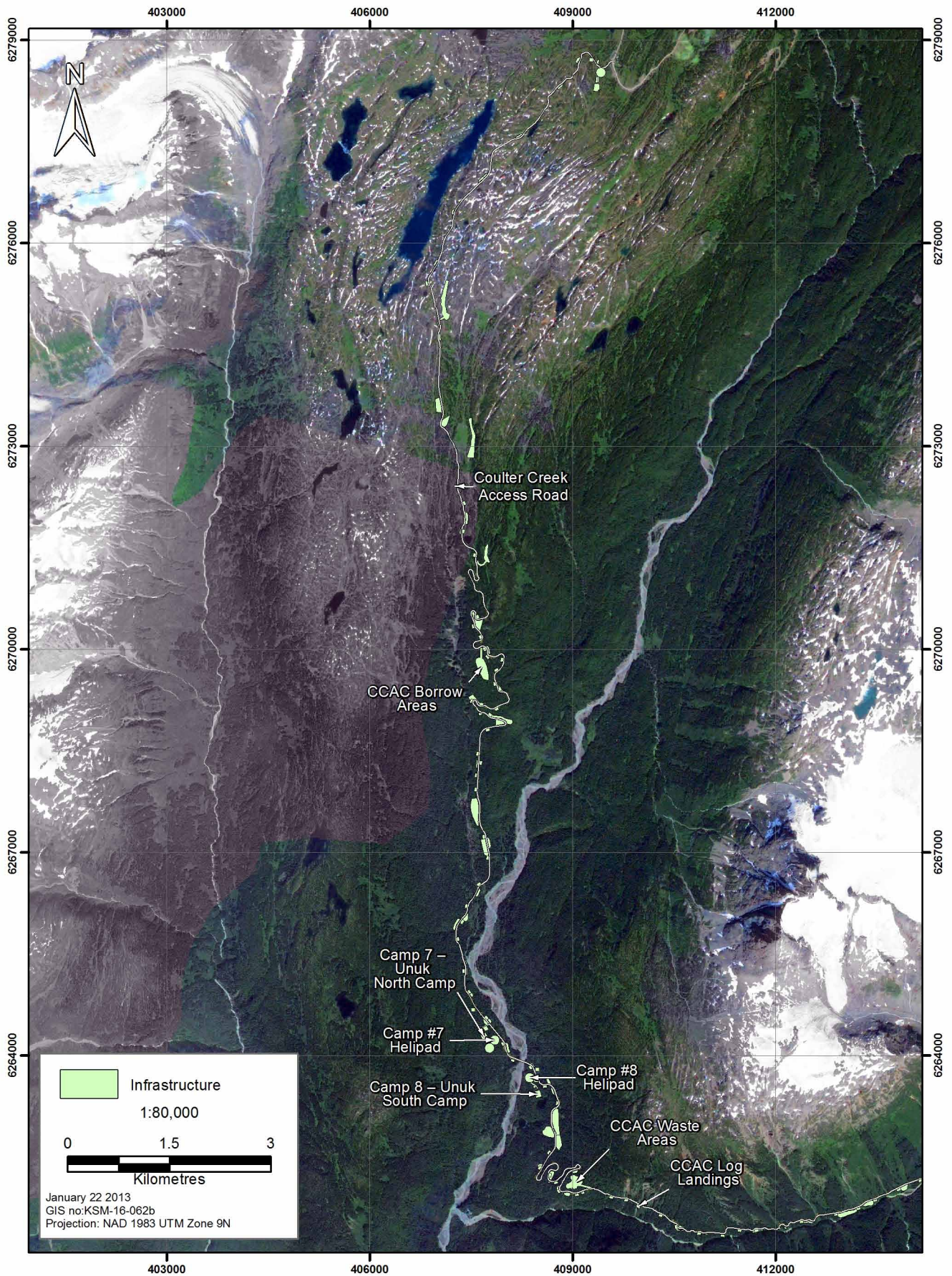


Figure 9.4-5



Infrastructure  
 1:80,000  
 0      1.5      3  
 Kilometres  
 January 22 2013  
 GIS no:KSM-16-062b  
 Projection: NAD 1983 UTM Zone 9N

Figure 9.4-6

Landslides and avalanches occur throughout the Project area, and are endemic to the landscape due to high precipitation, preponderance of surficial material veneers, steep slopes, and lack of vegetation in recently de-glaciated areas. Landslides and avalanches pose risks to Project infrastructure; these risks are identified in [Appendices 9-A to 9-G](#). Construction activity associated with Project development—including access road construction, dams, and berms—could potentially affect the natural processes present in the valleys (such as dormant landslides) or modify the natural path of the snow avalanches, thus increasing the risk to Project personnel or facilities.

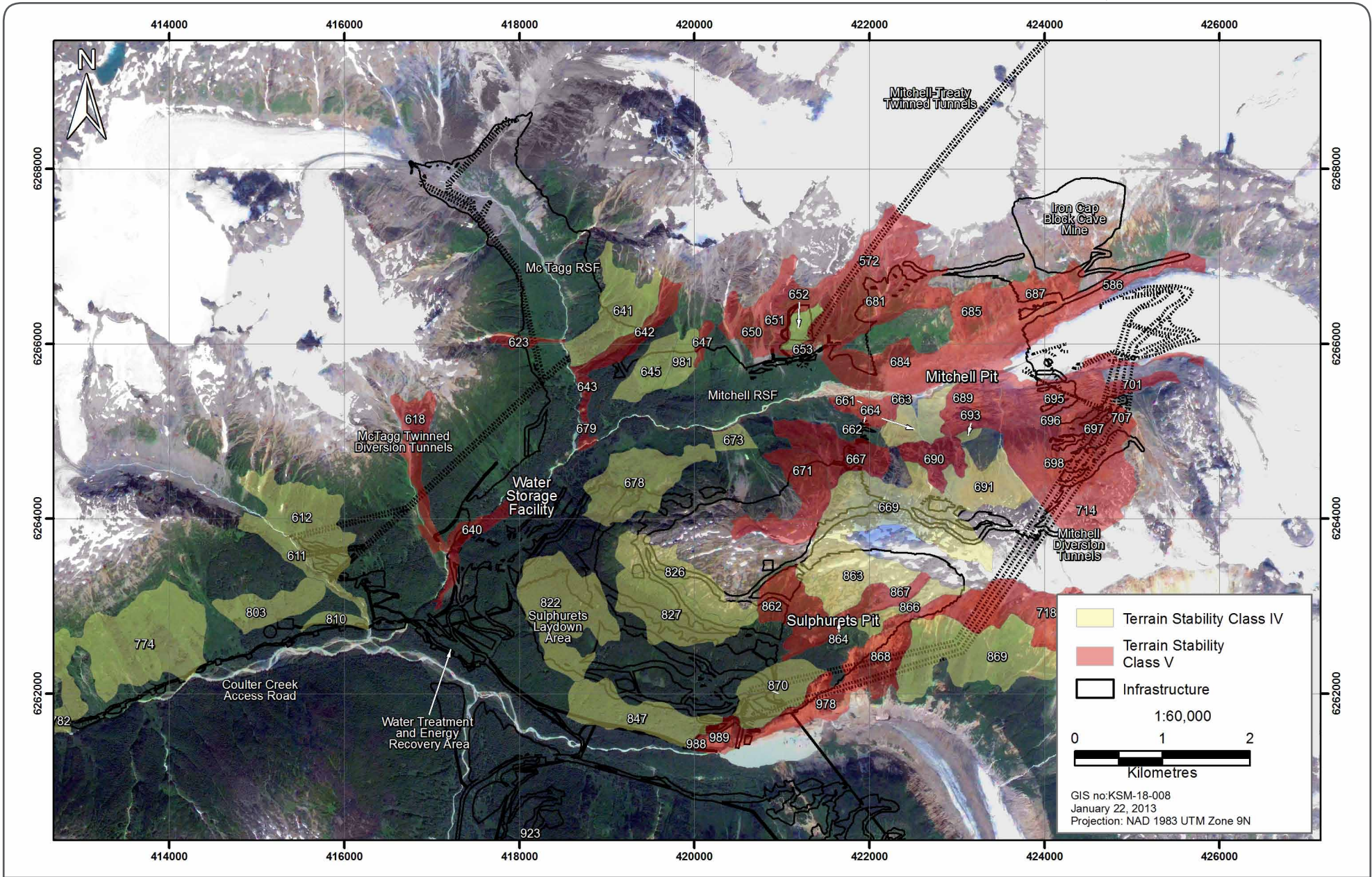
### **9.5.1 Valued Components included in the Assessment**

The geohazard VCs were selected based on information from several documents and databases, including the Application Information Requirements and associated public, government, and environmental assessment Working Group comments. Project infrastructure and personnel were identified as a VC by all groups. An analysis of existing geohazards and the risk they pose is covered in Chapter 34, Effects of the Environment on the Proposed Project. In addition, baseline geohazard assessments presented in [Appendices 9-A to 9-E](#) present mitigation for geohazard scenarios currently present. These documents do not address the potential effects the Project could have on terrain stability, which could result in the initiation of geohazards that could then affect Project infrastructure and personnel.

The Project has the potential to decrease terrain stability, which could increase the incidence and magnitude of geohazards. 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 occurrence. An increase in geohazards could result in increased risk to Project infrastructure and risk to the environment due to vegetation removal, soil loss, and sedimentation. An increase in terrain stability could result in less risk to infrastructure, personnel, and environmental values such as water quality and fish habitat. The assessment will examine the risk that Project infrastructure will increase the incidence of geohazards, above and beyond the baseline level. This will be determined by qualitatively assessing the likelihood that the construction of Project infrastructure within areas assessed as TSC IV will result in an increased incidence of geohazards compared to the natural background level. As well, Project infrastructure located in TSC V terrain will be assessed to determine if construction and operation activities could result in unstable terrain becoming more unstable, with the instability presented as increased incidence and magnitude of geohazards. Maps showing the TSC Class IV and V terrain that could potentially interact with Project infrastructure are presented in Figures 9.5-1, 9.5-2, and 9.5-3.

### **9.5.2 Valued Components excluded from the Assessment**

No other VCs related to geohazards have been suggested by the government, public, or Aboriginal peoples. Therefore, no other VCs were included in the assessment.



Terrain Stability Class IV and V Terrain Polygons Associated with Mine Site Infrastructure

Figure 9.5-1

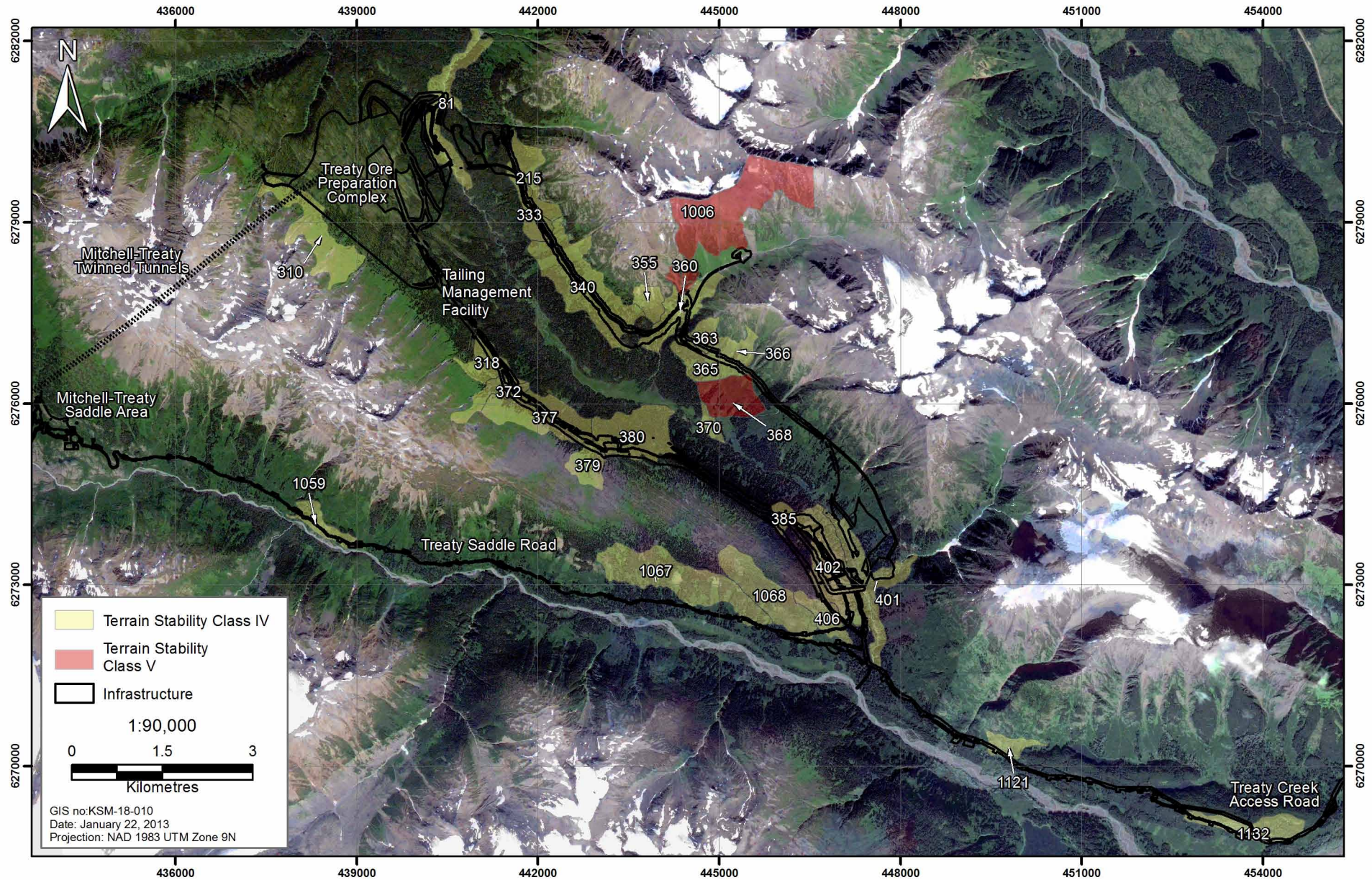
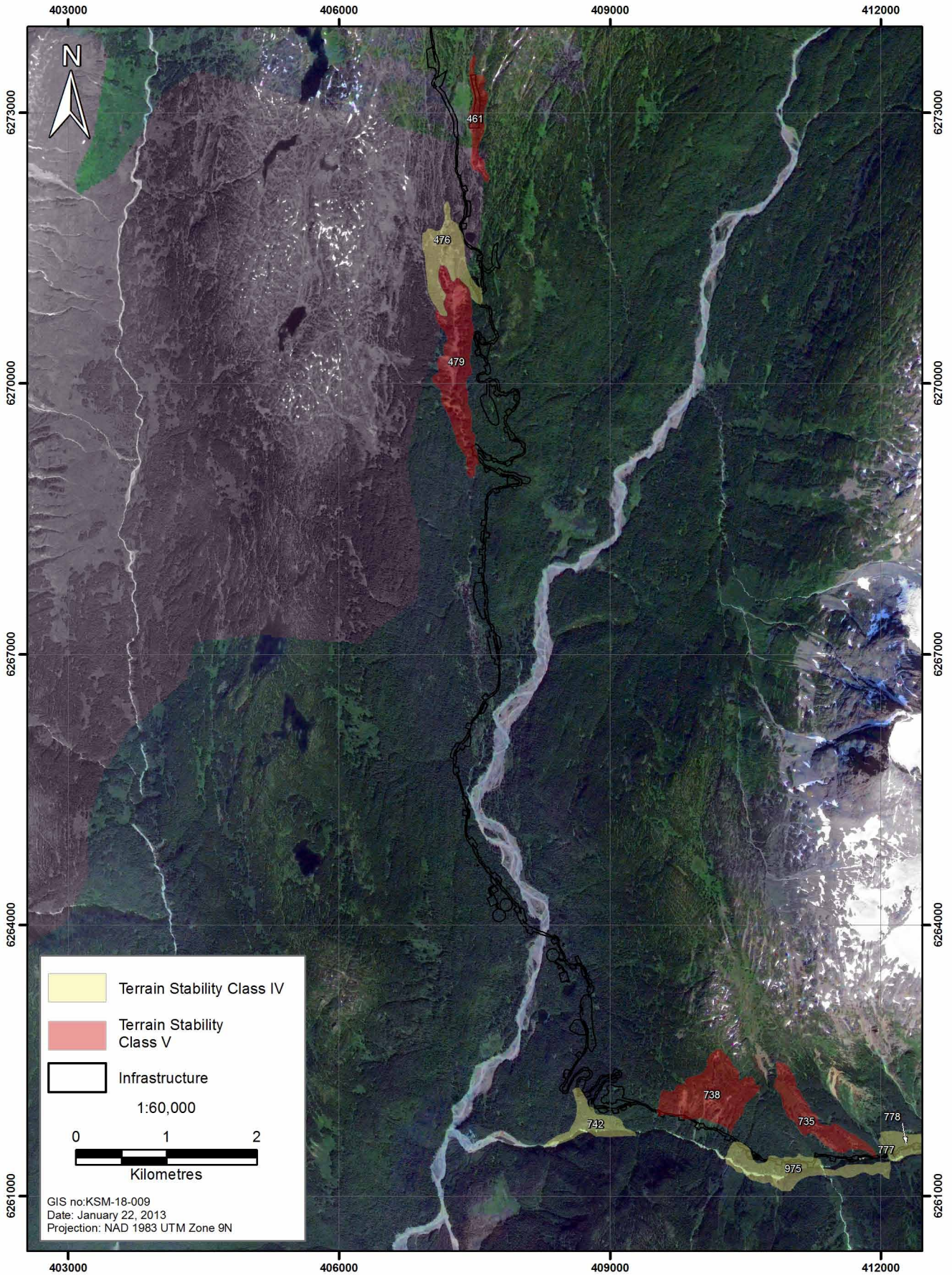


Figure 9.5-2

Terrain Stability Class IV and V Terrain Polygons Associated with the Processing and Tailing Management Area

Figure 9.5-2



GIS no:KSM-18-009  
Date: January 22, 2013  
Projection: NAD 1983 UTM Zone 9N

Figure 9.5-3

## 9.6 Scoping of Potential Effects for Geohazards

### 9.6.1 Terrain Stability

For construction scoping and assessment purposes, the Project components have been grouped into Project Areas. These are groups of components that occur in a confined spatial area, and thus can be expected to interact with terrain in a similar manner. The potential interactions of “unstable” and “potentially unstable” terrain with each Project Area are outlined in [Appendix 9-I](#) and are summarized in Table 9.6-1. The purpose of these scoping tables is to determine which Project components can potentially affect terrain stability.

**Table 9.6-1. Scoping Table for Potential Interactions between Project Areas and Unstable/ Potentially Unstable Terrain**

Project Region	Project Area	Class IV Terrain		Class V Terrain	Effect 1
Mine Site	Camp 3: Eskay Staging Camp				terrain instability
	Camp 7: Unuk North Camp				terrain instability
	Camp 8: Unuk South Camp				terrain instability
	Coulter Creek Access Road	x	x		terrain instability
	Mitchell Operating Camp	x			terrain instability
	McTagg RSF			x	terrain instability
	MTDT	x	x		terrain instability
	McTagg Power Plant				terrain instability
	Mitchell RSF	x	x		terrain instability
	Camp 4: Mitchell North Camp	x			terrain instability
	Mitchell OPC	x	x		terrain instability
	Mine Site Avalanche Control	x	x		terrain instability
	Iron Cap Block Cave Mine				terrain instability
	Mitchell Pit	x	x		terrain instability
	Mitchell Block Cave Mine				terrain instability
	Mitchell Diversion Tunnels (MDT)	x	x		terrain instability
	Upper Sulphurets Power Plant	x	x		terrain instability
	Mitchell Truck Shop				terrain instability
	Water Storage Facility (WSF)	x	x		terrain instability
	Camp 9: Mitchell Initial Camp				terrain instability
Camp 10: Mitchell Secondary Camp	x			terrain instability	
Water Treatment and Energy Recovery Area			x	terrain instability	
Sludge Management Facilities				terrain instability	
Sulphurets Laydown Area	x			terrain instability	

(continued)

**Table 9.6-1. Scoping Table for Potential Interactions between Project Areas and Unstable/ Potentially Unstable Terrain (completed)**

Project Region	Project Area	Class IV Terrain	Class V Terrain	Effect 1
Mine Site ( <i>cont'd</i> )	Sulphurets-Mitchell Conveyor Tunnel			terrain instability
	Sulphurets Pit	x	x	terrain instability
	Kerr Rope Conveyor			terrain instability
	Kerr Pit			terrain instability
	Camp 2: Ted Morris Camp			terrain instability
	Explosives Manufacturing Facility		x	terrain instability
	Temporary Frank Mackie Glacier Access Route			terrain instability
	Camp 1: Granduc Staging Camp			terrain instability
PTMA	Mitchell-Treaty Twinned Tunnels			terrain instability
	Construction Access Adit	x	x	terrain instability
	Mitchell-Treaty Saddle Area	x		terrain instability
	Camp 6: Treaty Saddle Camp			terrain instability
	Camp 5: Treaty Plant Camp			terrain instability
	Treaty Operating Camp	x		terrain instability
	Treaty OPC	x		terrain instability
	Concentrate Storage and Loadout			terrain instability
	North Cell TMF	x		terrain instability
	East Catchment Diversion	x	x	terrain instability
	Centre Cell TMF	x	x	terrain instability
	South Cell TMF	x	x	terrain instability
	Treaty Creek Access Road	x		terrain instability
	Camp 11: Treaty Marshalling Yard Camp			terrain instability
	Camp 12: Highway 37 Construction Camp			terrain instability
Off-site Transportation	Highway 37 and 37A			

**X = interaction between component and effect**

For the Mine Site, PTMA, and access roads, mapping indicates that there are 5,727 ha of TSC IV and 7,175 ha of TSC V terrain within the LSA. A total of 268 geohazard scenarios have been identified and characterized in the LSA. These scenarios are considered reasonable approximations of possible events or event chains; however, they cannot describe every possible scenario and potentially unforeseeable outcome. Other scenarios were found to be too insignificant to be included.

### 9.6.2 Snow Avalanches

Identification of snow avalanche hazards and the mitigation of associated risk(s) is presented in [Appendices 9-A, 9-B, 9-C, 9-D, and 9-E](#). Snow avalanches were not considered in the assessment, as they are not directly associated with terrain stability. However, the possibility exists that Project development could increase the amount of avalanche-prone terrain. The following is a general discussion of the effects of the Project on snow avalanches. In addition during the assessment, the impacts of snow avalanches will be discussed to provide geohazard context for each Project area, where and when appropriate.

It is possible that Project development (e.g., excavation of open pit slopes, excavation of high road cuts, construction of unbenched angle of repose fill slopes, and logging on slopes with gradients between 25° and 55°) 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. Potential effects can be mitigated by identification of snow avalanche hazards and by avalanche protection. Avalanche protection could include avoidance of areas by seasonal evacuation of work areas, closure of roads, installation of avalanche detection systems, or avalanche control using a variety of explosive delivery methods. In high-risk areas that cannot be avoided, avalanche prevention or deflection using permanent engineering structures or earthworks will be considered.

Considering that the terrain within the Mitchell Pit footprint area will be altered during the course of pit construction, there is potential for avalanche terrain to be created within the Mitchell Pit. As the pit expands in size and depth, the consequences of snow avalanches could increase. These risks will be managed through the life of the Project with the objectives of ensuring a safe work environment for employees and minimizing disturbance to the environment.

Avalanche terrain could also be created because of tree removal in initiation and run-out zones, and through recontouring of ground so that slopes increase. There appears to be little in the way of potential for the Project to create additional avalanche terrain, as the initiation zones of the existing avalanche tracks are in steep alpine areas where tree removal will not be a factor. In addition, recontouring primarily takes place in lower elevations, areas that might receive the effects of avalanches but not contribute to them.

Any additional avalanche terrain created will primarily have consequences for Project infrastructure, and not for the environment. Since mitigation of avalanches and their effects on Project infrastructure has already been covered extensively in the appendices, further analysis of avalanches will not take place in this assessment. The Proponent is committed to mitigating and managing all risk associated with snow avalanches.

### 9.6.3 Construction

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.

The Project Areas were assessed for whether they interacted with unstable terrain (TSC V) and potentially unstable terrain (TSC IV). If any portion of an individual construction Project Area was located in these polygons, it was accordingly indicated in the appropriate column in [Appendix 9-I](#). Maps of where TSC IV and TSC V terrain interact with Project infrastructure during construction are presented in Figures 9.6-1 to 9.6-6.

### 9.6.4 Operation

During operation, the environment will be affected by removal of overburden, quarrying for aggregate, and recontouring of the landscape. Those activities will result in permanent changes in the morphology and distribution of sediment. The mine pits and the TMF will continue to develop in size until the Project footprint specifications are met.

Road and pipeline construction is expected to be limited during the operation phase, although some road upgrades could be expected.

The Project Areas were analyzed to see whether they interacted with unstable terrain, which was assumed to be TSC IV and TSC V. If any portion of an individual operation's Project Areas was determined to fall within unstable terrain, it was indicated as such in the appropriate column in [Appendix 9-I](#).

Maps of where TSC IV and TSC V terrain interact with Project infrastructure during operation are presented in Figures 9.6-7 to 9.6-12.

### 9.6.5 Closure and Post-closure

During the closure and reclamation period, the re-distribution of the surficial material is limited. The removed materials will not be returned to their baseline distribution. Therefore, it is not anticipated that risks to terrain stability will increase during closure. However, it is possible that risks can decrease with reclamation. As well, it is anticipated that several areas that are currently unstable will be buried by RSFs and laydown areas, which would result in a decrease in instability. [Appendix 9-I](#) indicates which Project Areas will be assessed for the Project closure phase.

## 9.7 Potential for Residual Effects for 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.

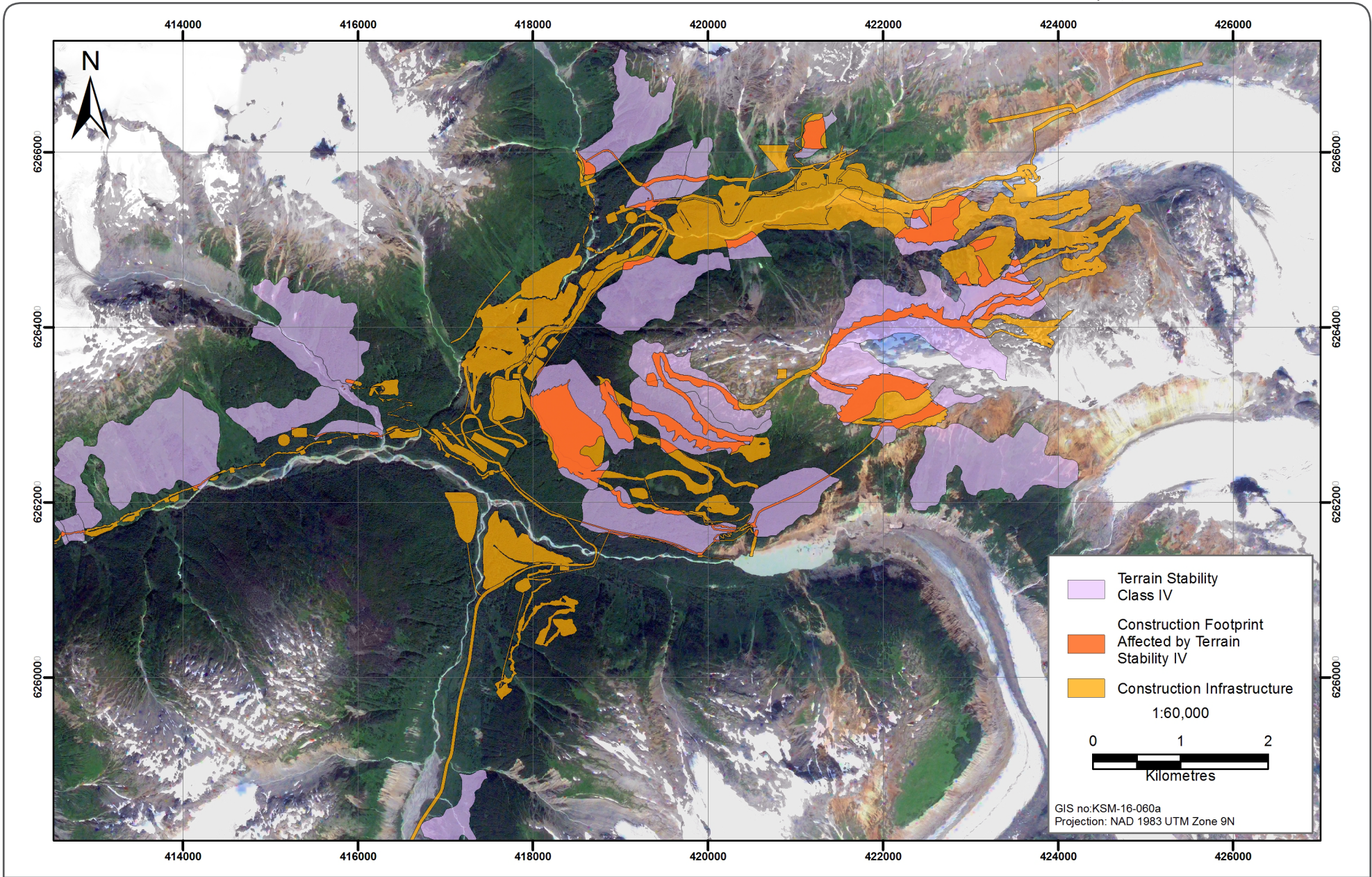
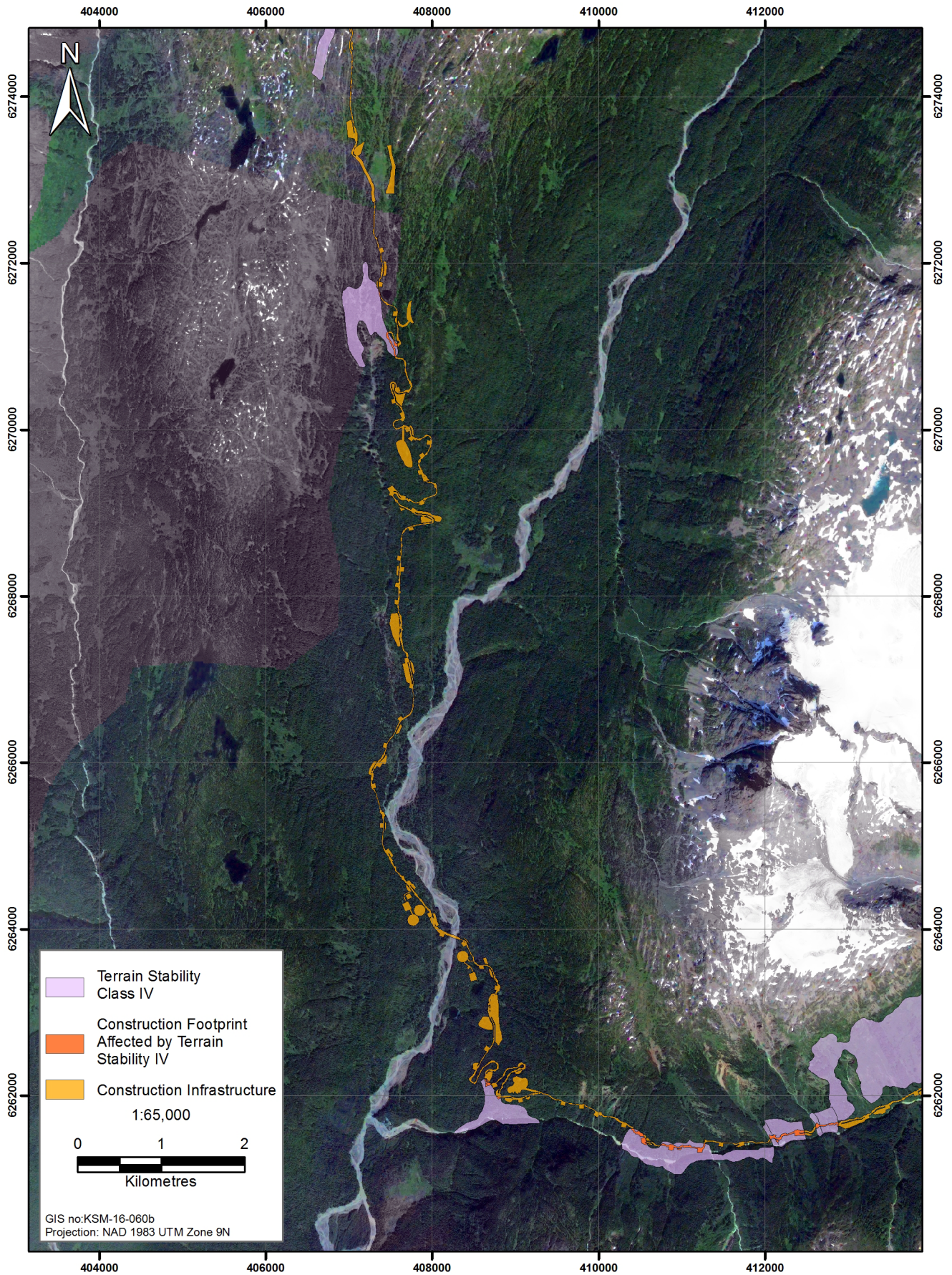


Figure 9.6-1

### Mine Site TSC IV Terrain Affected by Infrastructure - Construction

Figure 9.6-1



Coulter Creek Access Road TSC IV Terrain Affected by Infrastructure - Construction

Figure 9.6-2



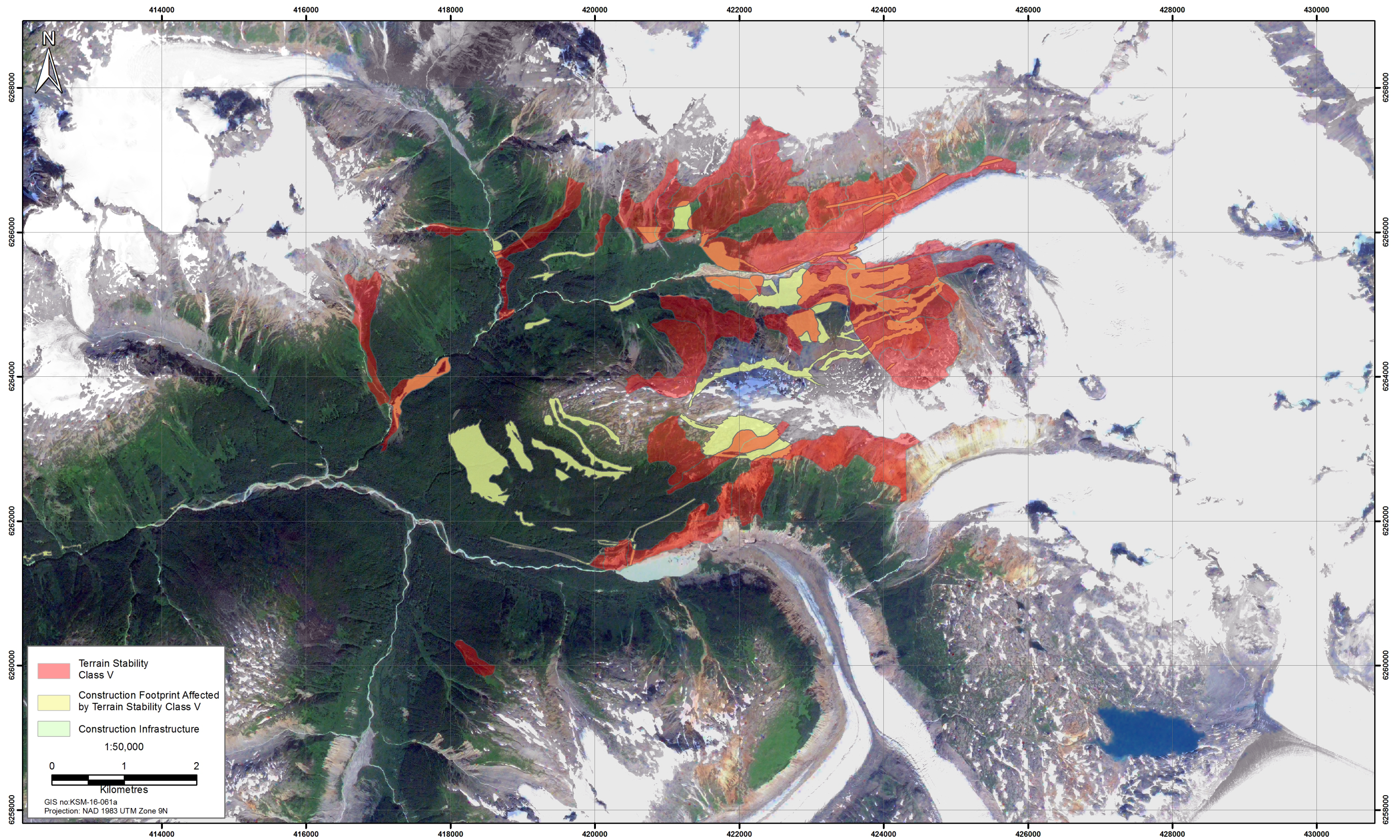
It is not feasible to quantitatively determine an increase in geohazard incidence and magnitude for each affected polygon. Therefore, a qualitative assessment was carried out. This involved assessing each Project Area interaction with TSC IV and TSC V terrain. The assessment involved an analysis of the type of construction method associated with the Project Areas (e.g., road, tunnel, and dam construction), where within the terrain stability polygon the infrastructure is located (i.e., certain areas of polygons are more stable or less stable than others), and the spatial extent of the polygon that the infrastructure occupies or affects.

The Project Areas eligible for assessment are presented in Tables 9.7-1 and 9.7-2. These tables present the areas of 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 9.7-1. Project Areas Associated with TSC IV Terrain**

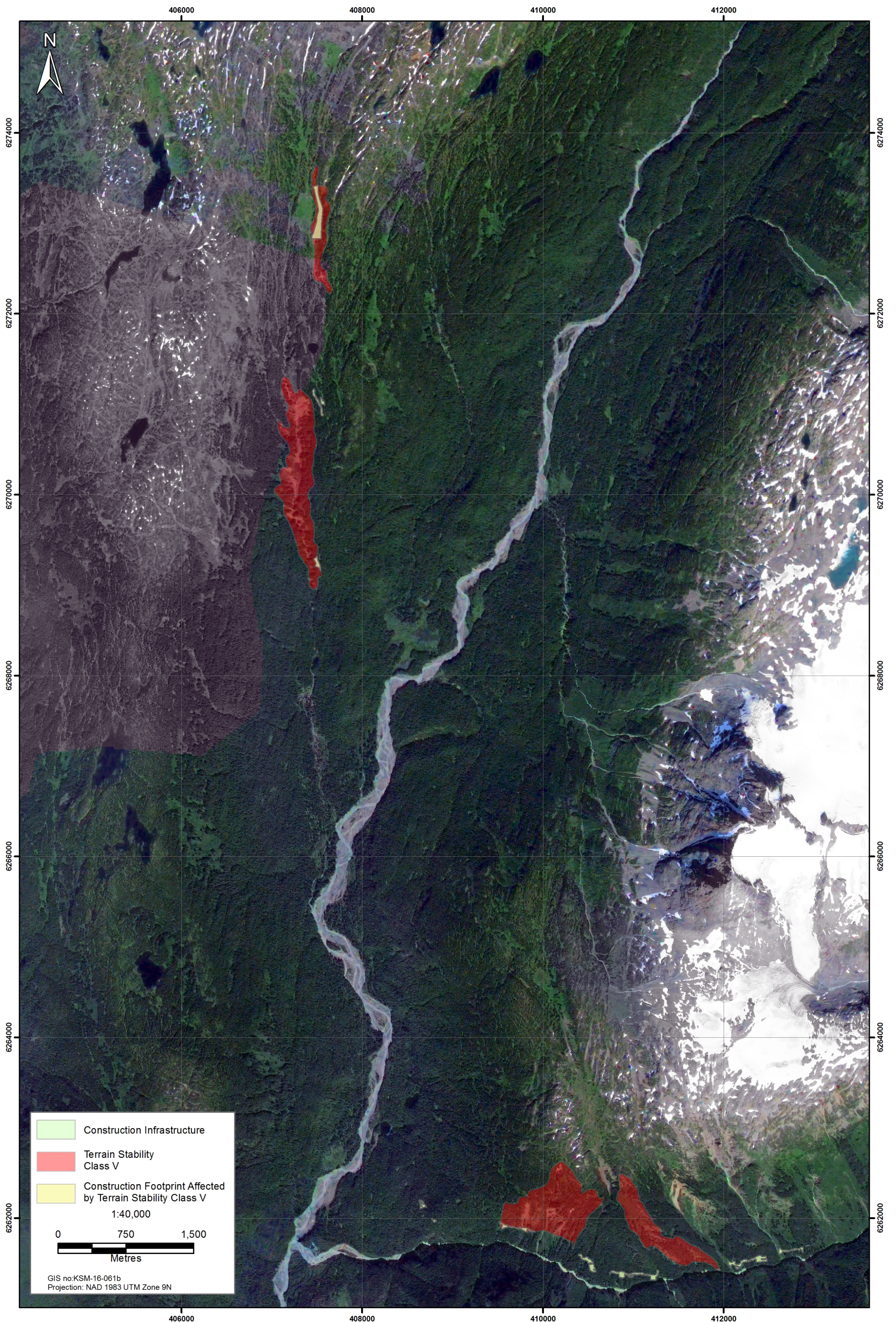
<b>Project Area</b>	<b>Area of TSC IV Terrain (ha)</b>
Camp 10: Mitchell Secondary Camp	5.4
Camp 4: Mitchell North Camp	5.2
Coulter Creek Access Road	139.6
Construction Access Adit	17.3
East Catchment Diversion	97.4
MDT	40.1
Mine Site Avalanche Control	10.7
Mitchell OPC	39.3
Mitchell Operating Camp	4.3
Mitchell Pit	320.5
Mitchell RSF	144.2
Mitchell-Treaty Saddle Area	53.5
MTDT	6.9
North Cell TMF	291.2
South Cell TMF	50.8
Sulphurets Pit	75.5
Sulphurets Laydown Area	63.2
Temporary Frank Mackie Glacier Access Route	153.3
TCAR	176.9
Treaty OPC	265.8
Treaty Operating Camp	8.9
Upper Sulphurets Power Plant	3.4
WSF	101.6
<b>Total ha</b>	<b>2,075</b>

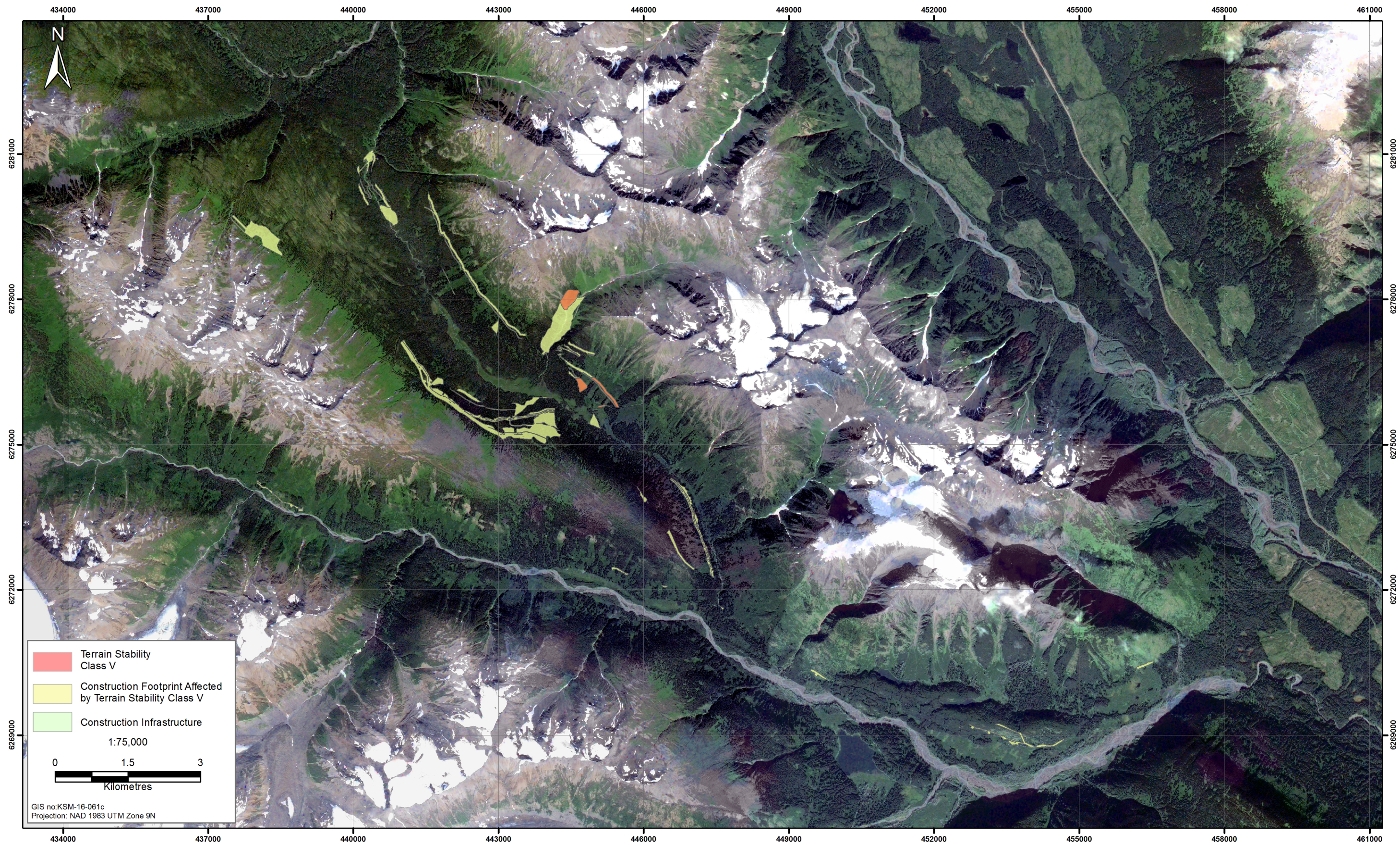
Tables 9.7-1 and 9.7-2 include the terrain and infrastructure interactions for all Project phases. As such, the total hectares calculated represents the total amount of currently potentially unstable and unstable terrain that could be affected by the Project. This is the total amount of terrain carried forward in the assessment.



■ Terrain Stability Class V  
■ Construction Footprint Affected by Terrain Stability Class V  
■ Construction Infrastructure  
 1:50,000  
 0 1 2  
 Kilometres  
 GIS no:KSM-16-061a  
 Projection: NAD 1983 UTM Zone 9N

Figure 9.6-4





Terrain Stability Class V  
 Construction Footprint Affected by Terrain Stability Class V  
 Construction Infrastructure

1:75,000

0 1.5 3  
Kilometres

GIS no:KSM-16-061c  
Projection: NAD 1983 UTM Zone 9N

Figure 9.6-6

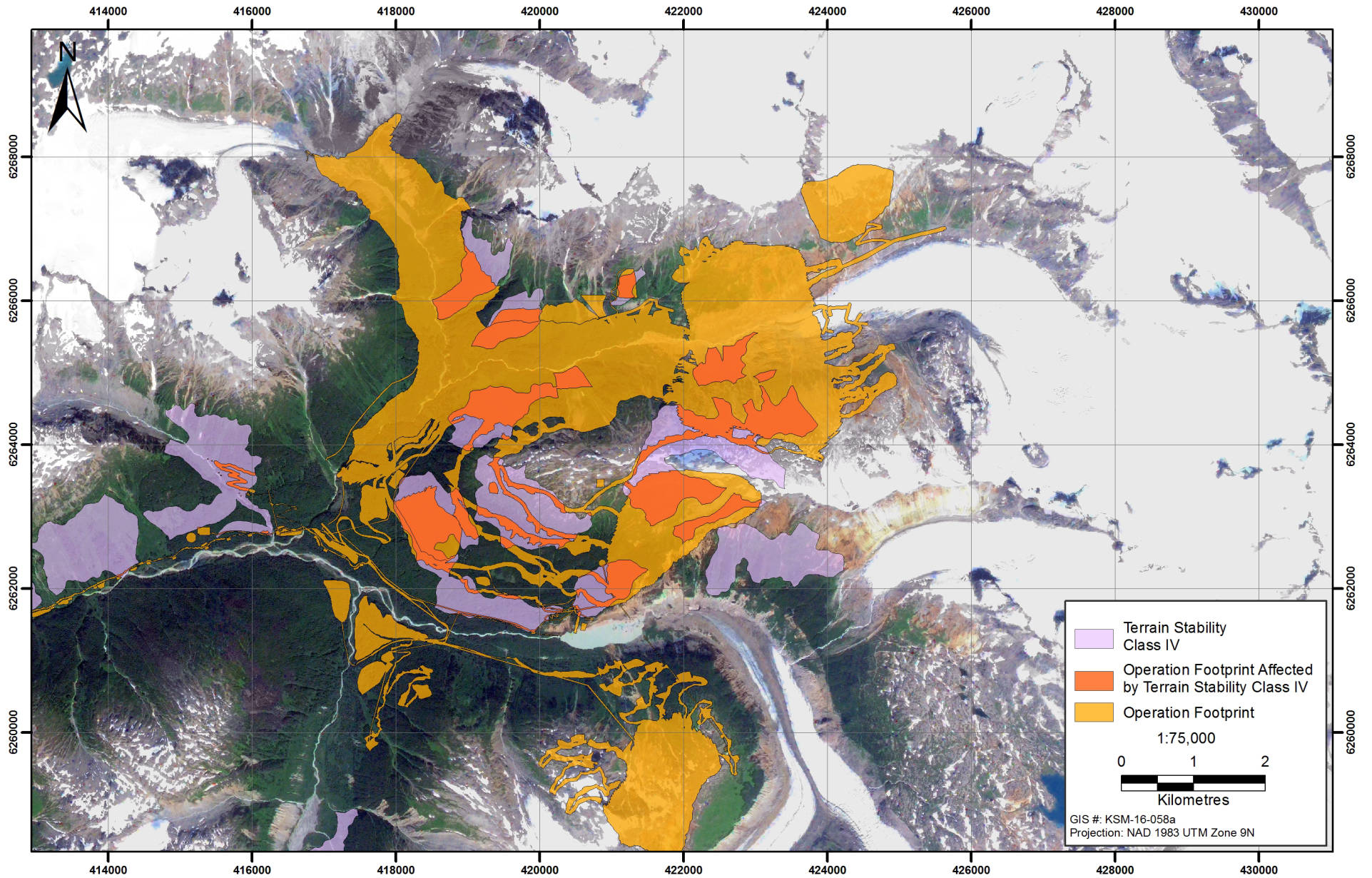
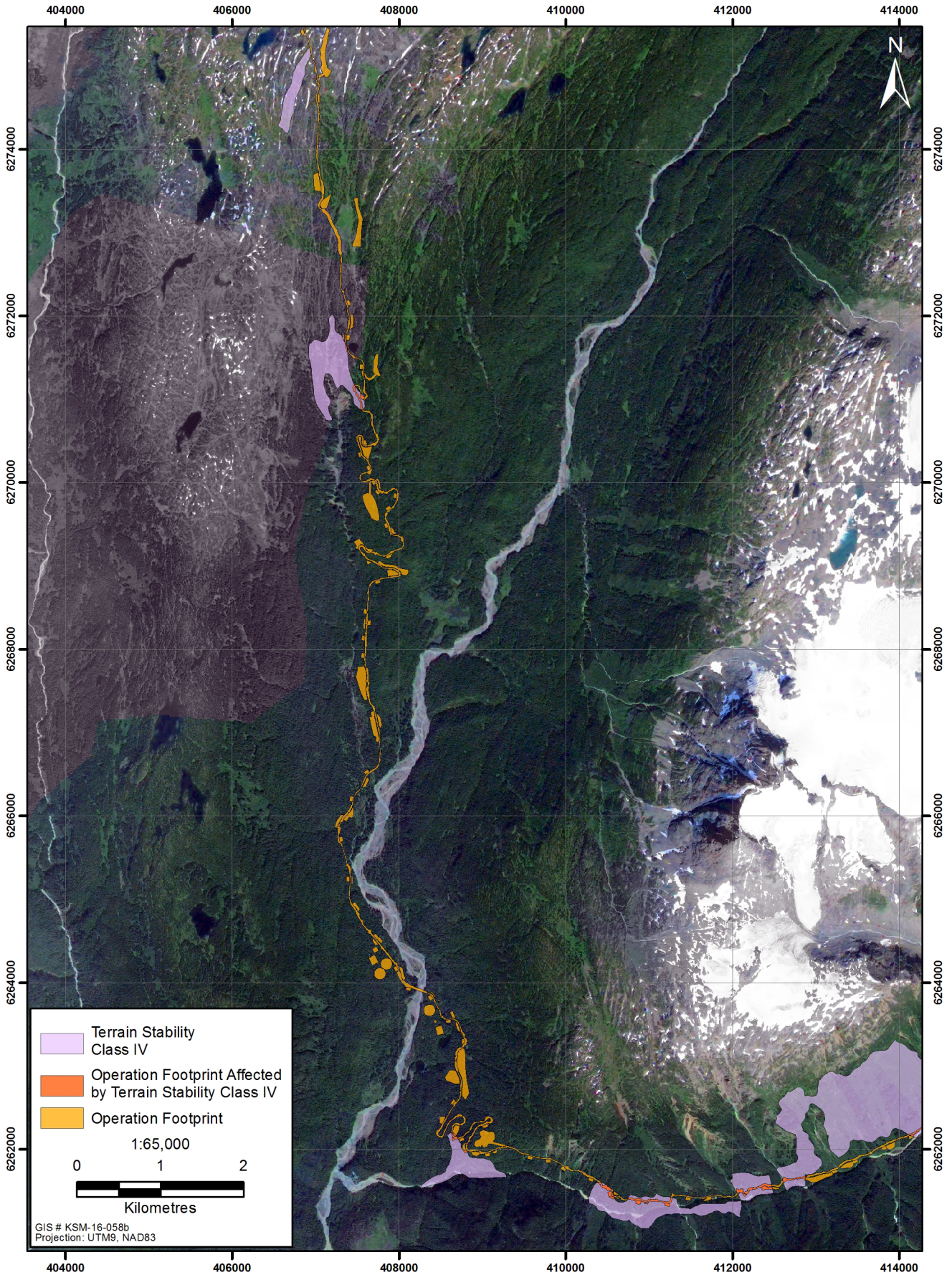


Figure 9.6-7

Figure 9.6-7



Coulter Creek Access Road TSC IV Terrain Affected by Infrastructure - Operation

Figure 9.6-8

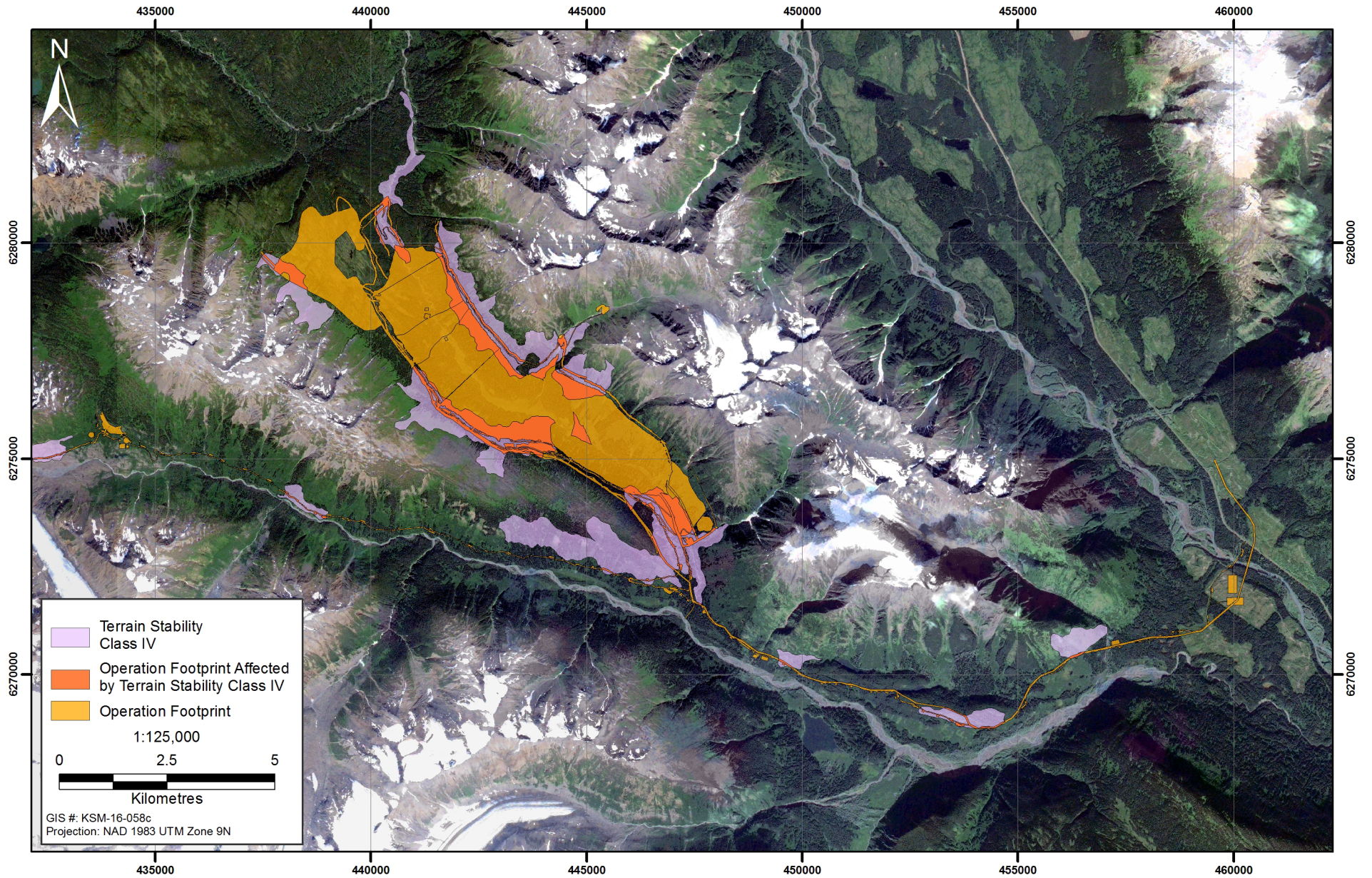


Figure 9.6-9

Figure 9.6-9

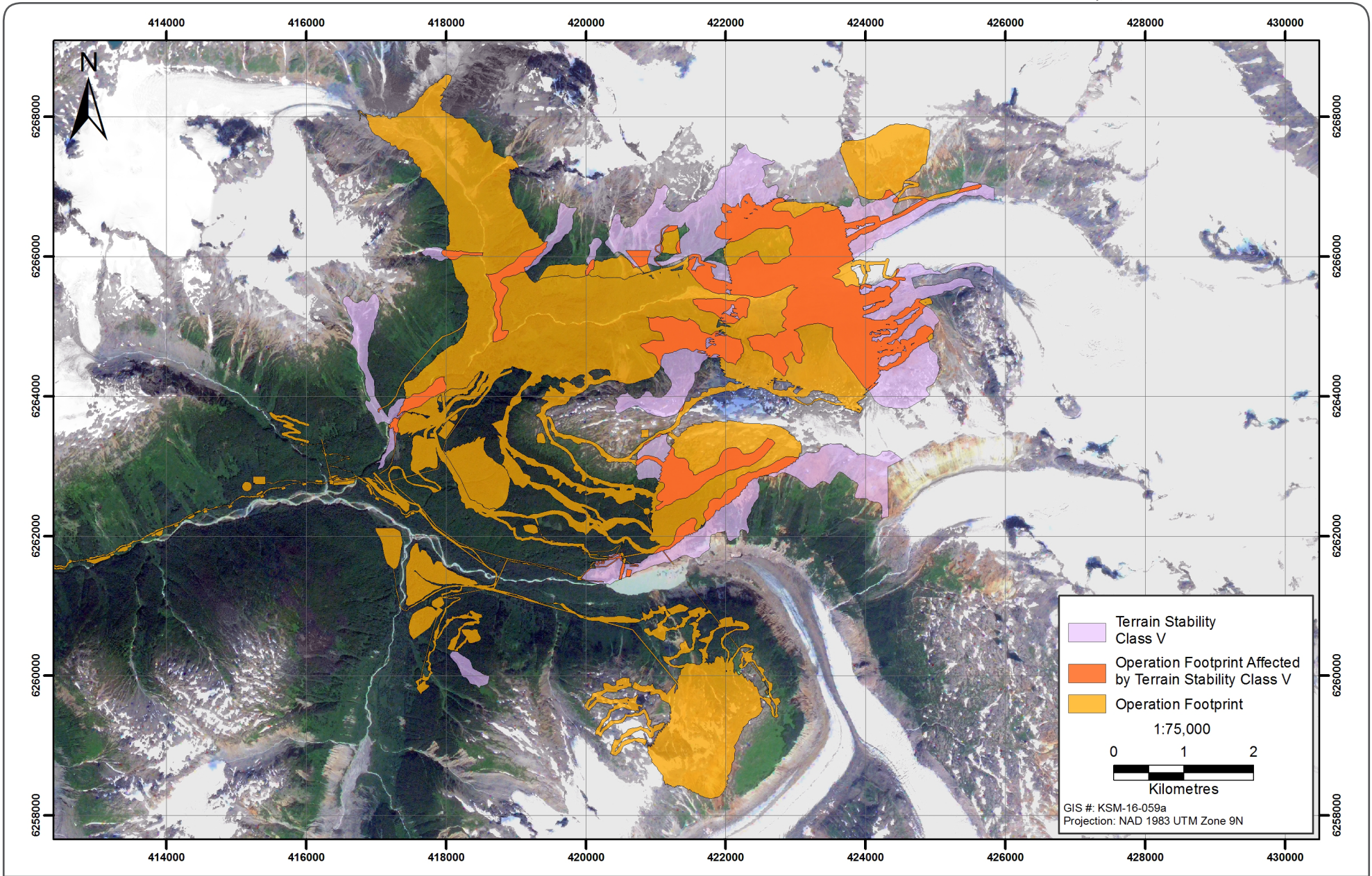
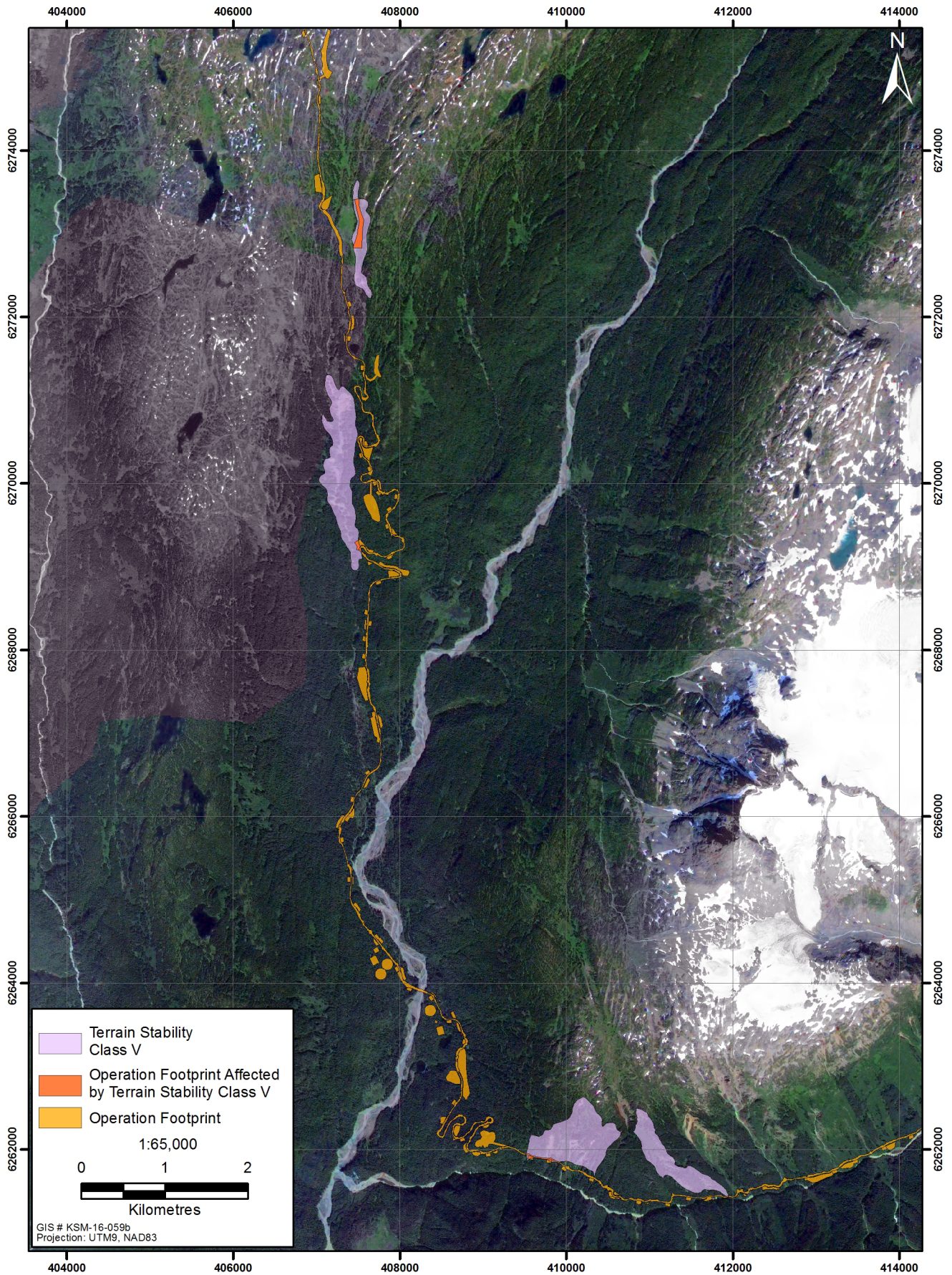


Figure 9.6-10

Figure 9.6-10



Coulter Creek Access Road TSC V Terrain Affected by Infrastructure - Operation

Figure 9.6-11

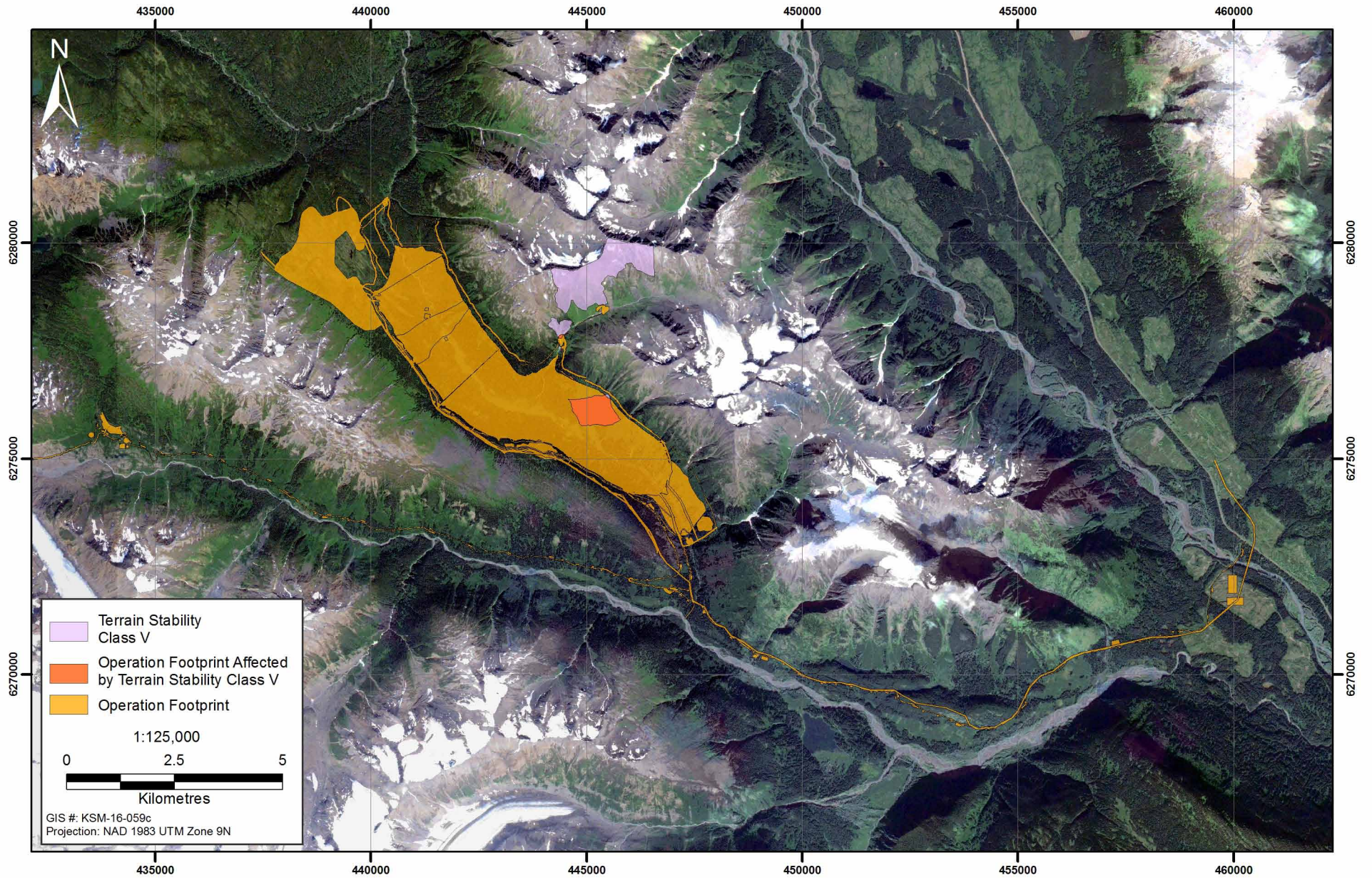


Figure 9.6-12

### Treaty Creek Access Road and Processing and Tailing Management Area Infrastructure Affected by TSC V Terrain - Operation

Figure 9.6-12

**Table 9.7-2. Project Areas Associated with TSC V Terrain**

<b>Project Area</b>	<b>Areas of TSC V Terrain (ha)</b>
Coulter Creek Access Road	139.6
Centre Cell TMF	277.0
Construction Access Adit	17.3
East Catchment Diversion	97.4
Explosives Manufacturing Facility	85.9
McTagg RSF	4.6
MDT	40.1
Mine Site Avalanche Control	10.7
Water Treatment and Energy Recovery Area	8.1
Mitchell OPC	39.3
Mitchell Pit	320.5
Mitchell RSF	144.2
MTDT	6.9
South Cell TMF	50.8
Sulphurets Pit	75.5
Upper Sulphurets Power Plant	3.4
WSF	101.6
<b>Total</b>	<b>1,422.9</b>

The Project Areas presented in Tables 9.7-1 and 9.7-2 were assessed using the data in [Appendices 9-A](#) through [9-H](#), high resolution imagery in a GIS environment (ArcMap 10.1), slope maps, soils maps, and surficial materials maps. The appendices contain data regarding specific geohazards and terrain stability. For example, Appendix A of [Appendix 9-G](#) contains the tabulated field data for terrain stability field assessments for Treaty Creek, while Appendix C of [Appendix 9-G](#) presents terrain stability maps for Treaty Creek. Each delineated polygon was assigned a TSC rating (I through IV), geomorphic process (if relevant), sediment source potential, and geotechnical prescriptions and risk mitigation plans. The imagery provided information regarding the specific location where the Project Area infrastructure occurred within the TSC IV or TSC V polygon. Slope was viewed as an overlay in ArcMap 10.1, using a combination of light detection and ranging (where available) and Terrain Resource Information Management data. Soils and surficial materials maps were developed by Rescan Environmental Services Ltd. during Project baseline studies. They are presented in Chapter 8, [Appendices 8-B](#) and [8-C](#). Detailed soils and terrain information developed by Rescan Environmental Services Ltd. is presented in Chapter 8, [Appendix 8-A](#).

Based upon this information, an assessment was made as to whether or not the presence of the infrastructure may result in increased or decreased terrain stability. This assessment is presented in Tables 9.7-3 (access roads), 9.7-4 (Mine Site), and 9.7-5 (PTMA).

### **9.7.1 Potential Instability of Road Sections**

Table 9.7-3 presents the potential effects, mitigation, and residual effects associated with the interactions of potentially unstable and unstable terrain with access roads. Each section of road that intersected terrain classified as TSC IV and TSC V was assessed with respect to its potential to increase or decrease terrain stability in that area. This is largely determined by where the road occurs in the polygon (e.g., roads traversing the upper portions of potentially unstable terrain generally have less of a destabilizing effect than those that traverse lower sections), how much of the road is located within the polygon, the type of parent material in the area, the slope, and the presence of existing geohazards at close proximity to the road. Based upon this assessment, a final determination of residual effects was made by indicating an expected increase (or decrease) in frequency of occurrence and magnitude of geohazards over and above current conditions.

#### **9.7.1.1 Treaty Creek Access Road**

The TCAR interacts with both unstable terrain and snow avalanches. According to baseline studies, there are currently 33 geohazards along the length of the TCAR (this includes the North Treaty road). Since the road will have little foreseeable effect on the frequency and magnitude of snow avalanches, only the road effects on unstable and potentially unstable terrain are discussed.

While the TCAR is presented as a single Project Area in Tables 9.6-1 and 9.7-1, the length of the entire road requires assessment. Eight polygons identified as TSC IV terrain were identified as interacting with the TCAR. These are presented in Table 9.7-3.

In total, 3.94 km of road was identified as being present within TSC IV polygons. All of these polygons contain colluvial veneers over steep bedrock. Some polygons show evidence of soil instability, such as evidence of slow mass movement and, in isolated instances, gullying. Colluvial veneers on steep terrain tend to be prone to sudden mass movement when weakened at the base. As a result, road construction along the base of slopes can result in higher incidence of landslides. Based upon this assessment, six polygons classified as TSC IV are raised to Class V due to potential effects of the TCAR, and carried forward in the assessment. For TSC V, no polygons were identified. Therefore, interactions between TSC V terrain and the TCAR are not carried forward in the assessment.

#### **9.7.1.2 North Treaty Upper and Lower Road**

The North Treaty access road leaves the TCAR at the junction of Treaty Creek and North Teigen Creek. In total, five polygons were identified as being TSC IV, encompassing 5.34 km of road. The first 3 km access TSC IV terrain, characterized by colluvial veneers over steep bedrock; some deep till deposits are also present. The area is geomorphically active with numerous gullies and slope failures. The presence of deep tills means that the area is probably a sediment source for Treaty Creek; sediment loading into Treaty Creek has the potential to be exacerbated by road construction and use. Drainage is moderate to imperfect, which could result in high pore water pressure and saturated soil conditions which can promote mass movement. Kilometres 6.83 to 8.00 traverse TSC IV terrain with steep slopes, variable depth tills, and some colluvial veneers. This areas shows evidence of slow soil creep, as indicated by pistol butted trees. Details of terrain stability and geohazards present along the CCAR are presented in [Appendix 9-F](#).

**Table 9.7-3. Potential Residual Effects of Road Construction on Terrain Stability**

VC	Timing	Project Area(s)	Details	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect
Terrain Stability	Construction/operation/ closure/post closure	Treaty Creek Access Road	Treaty Creek Access Road KM 5.29 to 5.62 (Polygon 1113)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. Medium risk of sediment delivery	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 7.99 to 10.02 (Polygon 1132)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. Medium risk of sediment delivery	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Geotechnical review of >10 m high cuts from Km 9+160 to 9+200 and Km 9+340 to 9+840. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 13.4 to 13.74 (Polygon 1121)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. Very low risk of sediment delivery due to thin veneers	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 16.06 to 16.1 (Polygon 401)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. High potential for sediment delivery	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Geotechnical review of >10m high cuts between Km 16+080 and Km 16+100 (full bench cuts proposed in design). Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 18.32 to 18.68 (Polygon 1067)	Road traverses TSC IV polygon. Construction could result in initiation of landslide	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Geotechnical review of >10m high cuts at Km 18+320, Km 18+500 to Km 18+660 and >10m fill at Km 18+320. Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 25.42 to 26.59 (Polygon 1059)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. Road is within 200m of Treaty Creek floodplain. Risk of sediment delivery is high	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. BGC (2012b) identified rockfall hazard below a bench from Km 25.8 to 26.3. Very steep at Km 26+190: GRS wall (see section Km 26+200). Geotechnical review of >10m high cut at Km 25+540 to 25+. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 33.0 to 34.5 (Polygon 1158)	Road traverses TSC IV polygon. Construction could result in initiation of landslide. High risk of erosion, however, background environment already has high rates of erosion	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		Treaty Creek Access Road	Treaty Creek Access Road KM 34.5 to 35.5 (Polygon 1151)	Road traverses TSC V polygon. Construction could result in initiation of landslide. High risk of erosion, however, background environment already has high rates of erosion	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		North Treaty Access Road	North Treaty Creek Access Road KM 0.86-3.09 (Polygons 401 and 402)	Road traverses TSC IV polygon. Construction could result in initiation of landslide	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		North Treaty Access Road	North Treaty Creek Access Road KM 5.92 to 8.92 (Polygons 380, 372, 377)	Road traverses TSC IV polygon. Construction could result in initiation of landslide	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
Coulter Creek Access Road	9.23 to 9.94 (Polygon 318, 476)	Road traverses TSC IV polygon. 80 m to landslide to the east of the road right of way.	Incursion into polygon 476. Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. note that many pistol-butt conifers and evidence of recent slope deformation. A 5-10 m wide tension crack, vertically offset 3-5 m, at least 50 m long, is interpreted as a backscarp to a larger rock slope failure. 19.15 20.03 0.88. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no		

(continued)

**Table 9.7-3. Potential Residual Effects of Road Construction on Terrain Stability (completed)**

VC	Timing	Project Area(s)	Details	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect
Terrain Stability (cont'd)	Construction/operation/ closure/post closure (cont'd)	Coulter Creek Access Road	25.64 to 26.61 (Polygon 975)	Road traverses TSC IV polygon. Crosses lower portions of colluvial veneer with some fan-like qualities. High potential for sediment delivery.	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	9.68 to 9.77 (Polygon 479)	Road traverses TSC V polygon. Crosses lower portions of colluvial veneer with some fan-like qualities. High potential for sediment delivery. Many pistol-butt conifers and evidence of recent slope deformation. A 5-10 m wide tension crack, vertically offset 3-5 m, at least 50 m long, is interpreted as a backscarp to a larger rock slope failure.	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Avoid construction and loading slope above unstable terrain.	no
		Coulter Creek Access Road	Polygon 742	Road traverses across upper portions of TSC IV polygon. Due to location of road, minimal effects on terrain stability are anticipated	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Avoid construction and loading slope above unstable terrain.	no
		Coulter Creek Access Road	Polygon 738	Road traverses TSC V polygon. Construction could result in initiation of landslide. Abundant existing landslides in polygon	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	27.41 to 27.48 (Polygon 777)	Road traverses TSC IV polygon. Evidence of past landslide in in unstable colluvial veneer. Construction could result in initiation of landslide	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	27.48 to 27.88 (Polygon 778)	Road traverses middle of TSC IV polygon. Evidence of past landslide in in unstable colluvial veneer. Construction could result in initiation of landslide	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	Polygon 781	Road traverses TSC IV polygon. Crosse gully with active movement of fluvial and colluvial surficial materials	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	Polygon 782	Road traverses TSC IV polygon. Crosses seepage slope with probably slow downslope movement of surficial colluvium	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V. Follow up monitoring required. Note that conceptual design as is could result in residual effects. Detailed geotechnical plans required	no
		Coulter Creek Access Road	Polygon 774	Road traverses TSC IV polygon. Crosses some avalanche tracks and seepage slope. Road traverses polygon for about 600m. Traverse is in treed area which indicates some stability	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no
		Coulter Creek Access Road	Polygon 810	Road traverses TSC IV polygon. No residual effects on terrain stability are expected, as road is located in stable area of polygon	Detailed geotechnical design, mitigation and construction planning prior to road construction.	Avoid excavation into unstable terrain. Construct with fill slopes. Control surface water drainage. Monitor slope for movement. Cut and fill design follows 1.5H:1V for soil, 1H:1V for talus. 0.25H:1V for bedrock. Angle of repose not to exceed 1.4:1V	no

**Table 9.7-4. Potential Residual Effects of Mine Site Infrastructure on Terrain Stability**

VC	Timing Start	Project Area(s)	Details	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect
Terrain Stability	construction/operation/closure/reclaimed during post closure	Mitchell Operating Camp	Portions of facility located at base of slope, within TSC IV terrain (polygon 803)	no impact to terrain stability expected, as infrastructure is located mostly in stable polygon	none required	not applicable	no
	construction (terrain stability no considered past construction as all terrain will be buried in rock during operations)	McTagg Laydown Area	Portions of facility located within TSC V terrain (polygons 642, 643, 679), where construction roads access the facility. Road intersects with TSC V terrain at several locations. Minor incursions into TSC IV terrain	Initial construction of roads could destabilize terrain, resulting in increase incidence of landslides. Potential for increases in frequency and magnitude of landslides along road route. Incidence and magnitude of geohazards in TSC V terrain polygons 642, 643, 679 could increase. Reduction of geohazard risk in all polygons buried during operations phase	detailed geotechnical design, mitigation and maintenance	Detailed geotechnical design will mitigate potential effects of road on terrain stability. Follow up monitoring and adaptive management required, especially in polygons 642, 643 and 679.	no
	construction/operation/closure/post closure	McTagg Twinned Diversion Tunnels (MTDT)	Infrastructure associated with tunnels and access roads is located in TSC Class IV (Polygons 847 and 870) and V (Polygons 978, 988, 989) terrain.	Construction of tunnels could destabilize terrain leading to increased incidence and magnitude of landslides. Outlet of diversion tunnel could lead to increased erosion at outlet. Potential increases in frequency and magnitude of landslides along Sulphurets Creek during construction. Highest risk is within polygons 978, 988, 989, with reduced risk in 847 and 870.	detailed geotechnical design, mitigation and maintenance	Geotechnical design of tunnel construction access roads and outlets to ensure outlet flow energy is dispersed. Detailed geotechnical design in polygons 847, 870, 978, 988 and 989. Follow up monitoring required.	no
	construction/operation/closure/post closure	Mitchell Laydown Area	Infrastructure associated with tunnels is located in TSC Class IV (Polygons 645, 673, 678, 981 and V (647, 650, 653, 661, 662, 667, 671, 679, 684) terrain.	During construction, road and facility construction could lead to further destabilization of terrain, resulting in increased incidence and magnitude of landslides. Risk decreases during operations due to burying of unstable terrain with rock. Potential increases in frequency and magnitude of landslides along road route. Reduction of geohazard risk in all polygons buried during operations phase	detailed geotechnical design, mitigation and maintenance	Geotechnical design will mitigate potential effects of road on terrain stability. Detailed geotechnical design required with special attention to construction in polygons 645, 678 and 981. Follow up monitoring and adaptive management required.	no
	construction/reclaimed during operation	Camp 4: Mitchell North Camp (for MTT construction)	Infrastructure partially located in TSC IV terrain	no impact to terrain stability expected, as infrastructure is located mostly in stable polygon	detailed geotechnical design, mitigation and maintenance	Geotechnical design will mitigate potential effects of infrastructure on terrain stability	no
	construction/operation/closure/reclaimed during post closure	Mitchell Ore Preparation Complex (Mitchell OPC)	Infrastructure partially located in TSC IV terrain	no impact to terrain stability expected, as infrastructure is located mostly in stable polygon	none required	not applicable	no
	construction/operation/closure/post closure	Mine Site Avalanche Control	Infrastructure partially located in TSC IV and V terrain	no impact to terrain stability expected, due to nature of infrastructure	none required	not applicable	no
	construction/operation/decommisioned during closure	Mitchell Pit	numerous interactions of TSC IV and V terrain. Snowfields landslide present at south end of pit (deforming 10 to 50 cm per year).	oversteepened slope due to excavation	detailed geotechnical design, mitigation and maintenance	Mitchel Pit will be subject to detailed design. Destabilizing of terrain will occur as pit is developed, but this will be addressed during detaile design phase. Follow up monitoring required	no
	construction/operation/closure/post closure	Mitchell Diversion Tunnels (MDT)	Infrastructure located in TSC IV (polygon 645) and TSC V (polygons 586, 684, 689, 695)	numerous potential impacts to terrain stability due to blasting and other construction techniques	detailed geotechnical design, mitigation and maintenance	carry out blasting and construction in a manner to minimize disturbance of unstable terrain.	no
	construction/operation/closure/post closure	Upper Sulphurets Power Plant	Infrastructure located in TSC IV (polygon 847) and TSC V (polygon 989)	power plant infrastructure located at head scarp of landslide (polygon 989). Loading of site could promote additional instability. Potential increases in frequency and magnitude of landslides in polyon 989.	detailed geotechnical engineering design	ensure slope loading does not occur. Follow up monitoring required for polygons 847 and 989	no
	construction/operation/closure/post closure	Water Storage Facility (WSF)	Infrastructure located in TSC IV (polygon 678) and TSC V (polygon 640)	no impact to terrain stability expected, due to nature of infrastructure	detailed geotechnical design, mitigation and maintenance	design of dam and facility infrastucture must mitigate geohazards. Follow up monitoring required for polygons 640 and 678	no
	construction/operation/reclamed during closure	Sulphurets Laydown Area (SLA)	Portions of facility located within TSC IV (polygons 645, 673, 678, 981) and TSC V terrain (polygons 643, 661, 662, 667, 671, 679, 681, 684). Road intersects with TSC V terrain at polygon 681 and 684.	initial construction of roads could destabilize terrain, resulting in increase incidence of landslides. Most of unstable terrain will be covered by waste rock. Potential increases in frequency and magnitude of landslides along road route. Increased incidence of geohazards for 681 and 684. Reduction of geohazard risk in all polygons buried during operations phase	detailed geotechnical design, mitigation and maintenance	geotechnical design will mitigate potential effects of road on terrain stability. Follow up monitoring required for polygons 681 and 684.	no
	construction/operation/reclamed during closure	Sulphurets Pit		no impact to terrain stability expected, as infrastructure is located mostly in stable polygon	none required	not applicable	no
	construction/operation/reclamed during closure	Explosives Manufacturing Facility	minor interaction with TSC V polygon 923	no impact to terrain stability expected, as infrastructure is located mostly in stable polygon	detailed geotechnical design, mitigation and maintenance	not applicable	no

**Table 9.7-5. Potential Residual Effects of Processing and Tailing Management Area Infrastructure on Terrain Stability**

VC	Timing	Project Area	Details	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect
Terrain Stability	construction/operation/reclaimed during closure	Construction Access Adit	Construction access adit goes beneath TSC IV terrain (polygon 1158). Landslides and gullying are present in this polygon. Adit will be through consolidated bedrock, not overburden	No effect on surficial terrain stability anticipated as tunnel does not go through overburden	none	not applicable	no
	construction/reclaimed during operations	Mitchell-Treaty Saddle Area	Saddle Road is assessed as part of the Treaty Creek Road. No other infrastructure occurs in TSC IV and V terrain	no effect			no
	construction/reclaimed during operations	Treaty Operating Camp	Portions of camp located at base of slope, within TSC IV terrain (polygon 310)	Landslides and avalanches are risk to the camp. Infrastructure is on gentle slope	None required as location of camp infrastructure will not destabilize terrain	not applicable	no
	construction/operation/reclaimed during closure	Treaty Ore Preparation Complex	Portions of OPC located at base of slope, within TSC IV terrain (polygon 310)	Landslides and avalanches are risk to the camp. Infrastructure is on gentle slope	None required as location of OPC infrastructure will not destabilize terrain	not applicable	no
	construction/reclaimed during operations	North Cell Tailing Management Facility	Portions of facility located at base of slope, within TSC IV terrain (polygons 81, 310, 333, 340)	Infrastructure occurs in TSC IV terrain polygon	characteristics of infrastructure will not affect terrain stability. Facility will be at risk of landslides and snow avalanches	not applicable	no
	construction/operation/closure	East Catchment Diversion	Portions of facility located at base of slope, within TSC IV terrain (polygons 81, 215, 333, 340, 360)	Landslides and avalanches are risk to the infrastructure. Terrain stability may be affected by diversion due to alteration of drainage, road construction and operation, and tunnels construction. Debris flows are evident in polygon 360.	ensure ditch is stable and lined, and does not weaken upslope stability due to slope undercutting at the slope toe. Ensure roads are constructed to mitigate against destabilizing terrain	endure detailed geotechnical plans area followed. In particular infrastructure in polygon 360 must be carefully designed in order to avoid both affecting and being affected by geohazards and unstable terrain	no
	operation/reclaimed during closure	South Cell Tailing Management Facility	Portions of facility located at base of slope, within TSC IV terrain (polygons 360, 363, 370, 380, 385, 401, 402, 406)	Landslides and avalanches are risk to the infrastructure. Terrain stability may be affected by diversion due to alteration of drainage. Debris flows are evident in polygon 360.	many interactions of infrastructure with unstable terrain. Diversion ditches and access road impacts will require mitigation in order to not destabilize terrain.	endure detailed geotechnical plans area followed, in order to avoid both affecting and being affected by geohazards and unstable terrain	no

As a result of potential road impacts on terrain stability, five of the TSC IV polygons (along the North Treaty Upper and Lower roads) will require follow-up monitoring after construction of the access road. Adaptive management will be used to address any stability issues that arise due to construction and use.

For TSC V, no polygons were identified. Therefore, interactions between TSC V terrain and the North Treaty road are not carried forward in the assessment.

### 9.7.1.3 Coulter Creek Access Road

Baseline studies indicate that there are currently nine geohazards along the CCAR. From km 9 to km 32, the CCAR traverses 10 polygons labelled TSC IV terrain. All of these polygons are unstable, due to the presence of colluvial veneers over steep rock. Gullying is present at several locations, and drainage is moderate to well drained. The materials present indicate that future potential geohazards will consist of landslides composed of coarse materials, with little potential for sediment delivery. Details of terrain stability and geohazards present along the CCAR are presented in [Appendix 9-F](#).

The CCAR encounters one TSC V polygon, at Polygon 738, between km 24.69 and km 25.02. Although the road crosses into the polygon at a discreet location and exits it quickly, the interaction could lead to an increase in geohazard incidence and magnitude, and thus was carried forward in the assessment.

### 9.7.2 Mine Site Infrastructure

Currently, there are 170 geohazards associated with the proposed Mine Site (including the Mitchell, McTagg, Sulphurets, and Ted Morris valleys). Mine Site infrastructure will evolve during the life of the Project; as the infrastructure develops, the effects on terrain stability will change. For example, the McTagg and Mitchell RSFs will take decades to reach their full extent. Initially, construction of the RSFs will be in areas associated with unstable terrain, and operation could have the potential to increase terrain instability. Over time, however, the unstable terrain associated with the RSFs will be buried, at which point they will no longer be considered unstable.

The effects of Mine Site infrastructure must be assessed for all phases of the Project: construction, operation, closure, and post-closure. Table 9.7-4 presents the potential effects, mitigation, and residual effects associated with the interactions of potentially unstable and unstable terrain with Mine Site infrastructure. Each Project Area that intersects with terrain classified as TSC IV or TSC V during any Project phase was assessed with respect to the infrastructure's potential to destabilize terrain. This is largely determined by where the infrastructure occurs in the polygon (e.g., infrastructure elements occurring in the upper portions of potentially unstable terrain generally have less of a destabilizing effect than those that occur in lower sections), how much of the infrastructure is located within the polygon, the type of parent material in the area, the slope, and the presence of existing geohazards at close proximity to the infrastructure. Based upon this assessment, a final determination of residual effects was made.

The assessment identified 14 components in the Mine Site area that intersect with TSC IV and TSC V terrain. In certain instances, mine development could result in an increase in terrain stability in these areas.

For example, within the Mitchell and McTagg valleys, once excavation advances on the Iron Cap Block Cave Mine (the source area for snow avalanches), rockfall and debris flows will be reduced, decreasing the frequency and magnitude of geohazards. However, in most cases, infrastructure development is more likely to be a destabilizing influence rather than a stabilizing one. For example, in the McTagg RSF, a large-scale rock deformation is inferred in the N-tributary of Upper McTagg Valley. All roads that are planned to be built there require detailed geotechnical design, as rock slides and rock avalanches could create a landslide dam and impounded lake, which, if breached, could have major downstream impacts to infrastructure and the environment.

Of the 14 identified Project components, 6 were found to have interactions with terrain that warranted increase follow-up monitoring to ensure no residual effects. The Mitchell RSF is located in extensive unstable terrain. The nature of the RSF infrastructure will result in the burying of unstable terrain; therefore, while an increase in geohazards could be anticipated during construction and the early stages of operation, the risk should decline over time as more of the unstable terrain is buried. However, roads and other types of infrastructure will still be operating in both TSC IV and TSC V terrain during all Project phases, and could cause increases in terrain instability throughout the life of the Project.

Some features are interpreted as former debris paths and snow avalanches in the northern side of the Sulphurets Valley. In the absence of development, surficial materials in this area will continue creeping slowly. However, the movement rate could increase if affected by the construction of the MDT. A sudden failure of this landslide into Sulphurets Lake could cause a flood wave, affecting other proposed facilities downstream.

The Mitchell Pit will contribute to an increase in terrain instability. However, this infrastructure is subject to intense engineering and geotechnical planning, design, and mitigation. Therefore, while the terrain associated with the Mitchell Pit is carried forward in the assessment, mitigation of the impacts will be covered by detailed engineering plans.

Portions of the infrastructure associated with the Upper Sulphurets Power Plant are located on TSC IV and TSC V terrain. It is possible that construction and operation of the Upper Sulphurets Power Plant could increase geohazards incidence and magnitude.

The southern and western sections of the Kerr Pit footprint straddle a broad, downsloping ridge, and become very steep on either side of the ridge. The steep sections are large avalanche initiation zones, and avalanches could be triggered on a regular basis by work activities.

### **9.7.3 Processing and Tailing Management Area Infrastructure**

PTMA infrastructure will evolve during the life of the Project. As it does, the effects on terrain stability will change. For example, the TMF will take decades to reach full extent. Initially, it will be operating in areas associated with unstable terrain, and operation could have the potential to increase terrain instability. Over time, however, these polygons will become part of the TMF, at which point they will no longer be considered unstable.

The effects of PTMA infrastructure on terrain instability was assessed for construction, operation, closure, and post-closure. Table 9.7-5 presents the potential effects, mitigation, and the potential for residual effects associated with the interactions of potentially unstable and unstable terrain with PTMA infrastructure. Each Project component that intersects with terrain classified as TSC IV or TSC V during any Project phase was assessed with respect to the infrastructure's potential to destabilize terrain in the specific area. This is largely determined by where the infrastructure occurs in the polygon (e.g., infrastructure elements occurring in the upper portions of potentially unstable terrain generally have less of a destabilizing effect than those that occur in lower sections), how much of the infrastructure is located within the polygon, the type of parent material in the area, the slope, and the presence of existing geohazards at close proximity to the infrastructure. Based upon this assessment, a final determination of potential residual effects was made.

Avalanche terrain affecting the PTMA is located primarily to the northeast of the PTMA. The South and North cells of the TMF and the southeast and northeast diversion ditches are all exposed to avalanches. Magnitude and frequency of avalanche impact varies significantly depending on the location affected. Avalanches reaching the TMF would have limited effect on solid material; however, they could create displacement waves in the decant pond, which could potentially overtop the Saddle seepage collection dam and affect areas downstream.

It was determined that eight PTMA Project Areas intersect with TSC IV and TSC V terrain. Two of these, the East Catchment Diversion tunnel and the South Cell TMF, were assessed as requiring follow-up monitoring in order to ensure that no residual effects arise after construction and during the life of the mine.

## 9.8 Summary of Required Mitigation and Monitoring

The following section presents a summary of the polygons assessed that will require follow-up monitoring. While the entire Project requires detailed design in order to mitigate potential effects on terrain stability, these polygons have been identified as having the greatest potential to destabilize following construction of infrastructure (see Figure 9.8-1).

Mitigation strategies can reduce risk in different ways. They can reduce the:

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

The proposed risk reduction options for particular sites will vary according to operational requirements. For example, measures described for the OPC consider the need for uninterrupted operation, whereas strategies for access roads may tolerate temporary closures for active avalanche control. In other cases, strategies include adjustments to mine planning, such as consideration of the Snowfield Landslide in the excavation staging of the Mitchell Pit.

The principal general mitigation measure for the terrain stability related potential effects is standard best management practices for erosion and sediment control. Practices for grading, site contouring, and the maintenance of slope lengths and gradient parameters based on universal soil loss equation (USLE) guidelines (BC MOF 2001) reduce wind and water erosion of stockpiled soil materials. These best management practices are presented in Chapter 26, in the following sections:

- Section 26.13.1, Soil Salvage and Handling Plan
- Section 26.13.2, Erosion Control Plan
- Section 26.20.1, Vegetation Clearing Management Plan
- *Coulter Creek and Treaty Creek Access Road Construction Erosion and Sediment Control Plan* (Rescan 2012b).

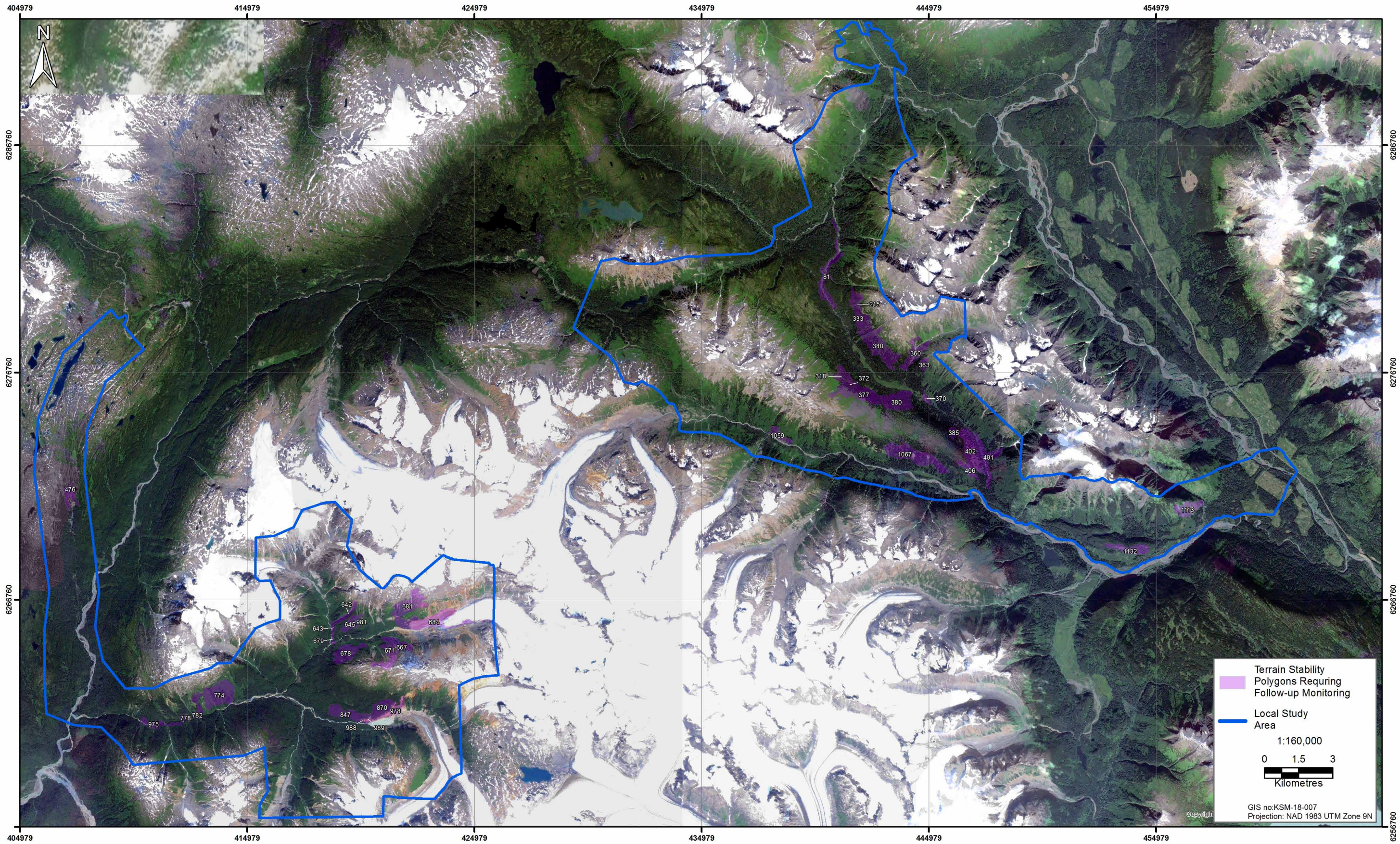
In addition to the plans presented in these sections, specific mitigation of effects of the Project on geohazards and terrain stability has been prepared. Much of this has been carried out during feasibility design. The Explosives Manufacturing Facility, once proposed to be located within the vicinity of the Ted Morris Landslide, was moved upstream of Mitchell Creek in order to avoid interactions with the Ted Morris Landslide. The Water Storage dam was relocated in order to avoid the effects of avalanches. Foundations of the Mitchell RSF will be strengthened via the buttressing of slopes in the Mitchell Valley. In that same area, the Snowfields Landslide will be removed during years one through seven to ensure the safety of Project personnel and to eliminate the potential impact to operation. The efficiencies of the diversion ditches around the WSF were lowered, and the storage capacity of the WSF itself was increased in order to mitigate terrain instability on the west side of the McTagg Valley. The portal entrances for the MTDT and the Mitchell-Treaty Twinned Tunnels were designed to avoid the effects of avalanches.

Mitigation strategies for geohazard and terrain stability risks are presented in [Appendices 9-A to 9-E](#), and [9-H](#).

### **9.8.1 Mitigation and Monitoring — Mine Site**

It was determined that 5 TSC IV polygons, comprising 231.2 ha, and 10 TSC V polygons, comprising 457.2 ha, were most susceptible to destabilization due to the Project infrastructure (Tables 9.8-1 and 9.8-2). These polygons were associated with the MTDT, the McTagg RSF, the Mitchell RSF, and the Sulphurets laydown area. Several polygons (including 847, 678, and 989) could be affected by more than one Project Area.

The above polygons comprise those in the Mine Site that are at highest risk for terrain destabilization. In all cases, 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.



**Table 9.8-1. TSC IV Summary of Polygons Requiring Follow-up Monitoring — Mine Site**

General Area	Associated Project Area	TSC IV Polygon	Area (ha)
Mine Site	MTDT/Sulphurets Power Plant	847	64.5
	MTDT	870	48.4
	Mitchell RSF	645	28.4
	Mitchell RSF	981	15.4
	Mitchell RSF/WSF	678	74.5
<b>Total</b>			<b>231.2</b>

**Table 9.8-2. TSC V Summary of Polygons Requiring Follow-up Monitoring — Mine Site**

General Area	Associated Project Area	TSC V Polygon	Area (ha)
Mine Site	MTDT	978	47.0
	MTDT	988	3.0
	MTDT/Sulphurets Power Plant/Mitchell RSF	989	11.9
	Mitchell RSF	667	48.9
	Mitchell RSF	671	58.0
	Sulphurets Laydown Area	681	104.2
	Sulphurets Laydown Area	684	143.5
	McTagg RSF	642	29.9
	McTagg RSF	643	4.3
	McTagg RSF	679	6.4
	<b>Total</b>		

### 9.8.2 Mitigation and Monitoring — Processing and Tailing Management Area

Twelve TSC IV polygons comprising 776.8 ha were assessed as most susceptible to destabilization due to the Project infrastructure (Table 9.8-3). These polygons are associated with the East Catchment diversion dam and the South Cell TMF. Polygon 360 interacts with both of these Project components. 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.

### 9.8.3 Mitigation and Monitoring — Treaty Creek Access Road, North Treaty Access Road, and Coulter Creek Access Road

It was determined that five, seven, and seven TSC IV polygons are most susceptible to destabilization due to the TCAR, North Treaty road, and CCAR, respectively (Table 9.8-4). These polygons comprise those along the access roads that are at highest risk for terrain destabilization. In some cases, polygons interact with more than one type of infrastructure area. For example, polygon 401 contains portions of the TCAR and North Treaty road. In all cases, 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.

**Table 9.8-3. TSC IV Summary of Polygons Requiring Follow-up Monitoring — Processing and Tailing Management Area**

General Area	Associated Project Area	TSC IV Polygon	Area (ha)
PTMA	East Catchment Diversion Dam	215	43.3
	East Catchment Diversion	81	107.8
	East Catchment Diversion Dam	333	36.5
	East Catchment Diversion Dam	340	154.7
	East Catchment Diversion/South Cell TMF	360	60.2
	South Cell TMF	363	19.1
	South Cell TMF	370	13.2
	South Cell TMF	380	97.2
	South Cell TMF	385	14.8
	South Cell TMF	401	95.1
	South Cell TMF	402	101.9
	South Cell TMF	406	33.0
	<b>Total</b>		

**Table 9.8-4. Summary of Polygons Requiring Follow-up Monitoring — Access Roads**

Access Road	Polygon	Area (ha)
TCAR	1132	60.8
TCAR	401	95.1
TCAR	1067	151.7
TCAR	1059	32.3
North Treaty Road	401	95.1
North Treaty Road	402	101.9
North Treaty Road	372	32.4
North Treaty Road	380	97.2
North Treaty Road	377	94.7
North Treaty Road	318	40.9
North Treaty Road	476	35.5
CCAR	975	38.6
CCAR	777	1.7
CCAR	738	54.0
CCAR	778	10.7
CCAR	781	1.8
CCAR	782	6.2
CCAR	774	154.4
<b>Total</b>		<b>1,105</b>

## **9.9 Geohazards Conclusions**

The Project is located in an area that, due to the interactions of terrain, climate, and glacial history, has naturally high occurrences of geohazards. During the life of the Project, there is the potential that geohazards could affect Project infrastructure and personnel, and that the Project infrastructure could affect terrain stability. Studies completed by BGC identified 268 geohazard scenarios between Project infrastructure and existing geohazards. Mitigation will be used to reduce the risk associated with these scenarios 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 and peak discharge);
- reduce the geohazard intensity (e.g., run-out distance, velocity, and 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).

Extensive mitigation has been carried out during the feasibility design phase of the Project. This includes locating infrastructure to avoid geohazards, construction techniques, and timing of activity.

During baseline studies, terrain stability mapping was carried out on 38,852 ha of terrain that could potentially be affected by the Project. Of this, 5,727 ha were classified as TSC IV (potentially unstable) and 7,175 ha as TSC V (unstable). Interactions between the Project components and terrain have the potential to both decrease and increase terrain stability. In order to determine the potential effects of the Project on terrain, an assessment was carried out. An assessment was then carried out to determine the potential of Project infrastructure to influence terrain stability. This assessment involved analyzing the type of infrastructure, the proposed construction method, and where the infrastructure was located within the mapped terrain stability polygon. For the Mine Site, it was determined that 231.2 ha of TSC IV terrain and 457.2 ha of TSC V terrain were at particular risk of destabilizing due to interactions with Mine Site infrastructure. For the PTMA, it was determined that 776.8 ha of TSC IV terrain were at particular risk of destabilizing due to interactions with PTMA infrastructure. For the TCAR and the CCAR, it was determined that 1,111.9 ha of TSC IV terrain were at particular risk of destabilizing due to interactions with road infrastructure. These polygons will require follow-up monitoring and adaptive management strategies to ensure mitigation strategies are successful.

## References

1985. *Fisheries Act*, RS. C. F-14. s. 1.
2002. *Forest and Range Practices Act*, SBC. C. 69. s. 149.1.
- Association of British Columbia Forest Professionals. 2009. *Guidelines for Terrain Stability Assessments in the Forest Sector*. [http://www.abcfp.ca/publications\\_forms/publications/documents/Terrain\\_Stability.pdf](http://www.abcfp.ca/publications_forms/publications/documents/Terrain_Stability.pdf) (accessed January 2013).
- BC ILMB. 2000. *Cassiar Iskut - Stikine Land and Resource Management Plan*. <http://www.ilmb.gov.bc.ca/slrp/lrmp/smithers/cassiar/index.html> (accessed November 2012).
- BC MFLNRO. 2012. *Nass South Sustainable Resource Management Plan*. <http://www.ilmb.gov.bc.ca/slrp/srmp/south/nass/index.html> (accessed November 2012).
- BC MOF. 1999. *Forest Practices Code of British Columbia, Second Edition: Mapping and Assessing Terrain Stability Guidebook*. Prepared by the British Columbia Ministry of Forests: Victoria, BC.
- BC MOF. 2001. *Best Management Practices Handbook: Hillslope Restoration in British Columbia*. British Columbia Ministry of Forests: Victoria, BC.
- BC MOF. 2002. *Forest Practices Code of British Columbia, Second Edition: Forest Road Engineering Guidebook*. Prepared by the British Columbia Ministry of Forests: Victoria, BC.
- Canadian Avalanche Association. 2002. *Guidelines for Snow Avalanche Risk Determination and Mapping in Canada*. Prepared by the Canadian Avalanche Association: Revelstoke, BC.
- Gitxsan Hereditary Chiefs' Office. 2010. *Gitxsan Hereditary Chiefs' Office Home Page*. [www.gitxsan.com](http://www.gitxsan.com) (accessed April 2010).
- Gwaans. 2007. *Gitxsan Houses of Nii Kyap & Miluulak: Submission to Joint Panel Review May 14-17, 2007*. Prepared by the Office of Gitxsan Hereditary Chiefs: Wet'sutwet'en Territories.
- Howes, D. E. and E. Kenk. 1997. *Terrain Classification System for British Columbia, Version 2. A System for the Classification of Surficial Materials, Landforms and Geological Processes of British Columbia*. Prepared by the Resource Inventory Branch, British Columbia Ministry of Environment, Lands and Parks: Victoria, BC.
- McClung, D. M. and P. Schaerer. 2006. *The Avalanche Handbook, 3rd Edition*. Seattle, WA: The Mountaineers Books.
- Rescan. 2012a. *KSM Project: Gitxsan Traditional Knowledge and Use Desk-based Research Report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.
- Rescan. 2012b. *Sediment and Erosion Control Management Plans for Mine Site*. Prepared by Rescan Environmental Services Ltd.: Vancouver, BC.
- Resources Inventory Committee. 1996. *Guidelines and Standards to Terrain Mapping in British Columbia*. Prepared by Resources Inventory Committee, Surficial Geology Task Group, Earth Sciences Task Force: n.p.
- Valentine, K. W. G., P. N. Sprout, T. E. Baker, and L. M. Lawkulich. 1978. *The Soil Landscapes of British Columbia*. Prepared by the Resource Analysis Branch, British Columbia Ministry of Environment: Victoria, BC.