Appendix 13.9-H Telkwa Coal Snow Avalanche Assessment

TELKWA COAL
LIMITED

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Project No.: 2306001

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Dear Mr. Farmer,

Re: Telkwa Coal Snow Avalanche Assessment

1.0 INTRODUCTION

BGC Engineering Inc. (BGC) was retained by Telkwa Coal Limited (Telkwa Coal) to assess their proposed Telkwa Coal project, located southwest of Telkwa BC, for potential snow avalanche hazard. The objective of the snow avalanche assessment was to meet requirements outlined in Section 3.3.6 of the Health, Safety and Reclamation Code for Mines in British Columbia (British Columbia Ministry of Energy, Mines and Low Carbon Innovation, 2021), which indicates that an avalanche risk assessment is to be conducted in areas where a person may be exposed to an avalanche.

The scope of work, as described in BGC (October 19, 2021) included:

- Identify potential snow avalanche hazard areas in the project footprint (study area) given pre-mining topography and vegetation cover. Terrain was assessed using LiDAR imagery provided by Telkwa Coal. Vegetation cover was assessed from recent satellite imagery.
- Prepare a letter report outlining the findings of the study (this report). The report will provide details on the snow climate, terrain, vegetation cover, and identified avalanche hazard areas. If needed, recommendations for worker safety with respect to snow avalanche hazard will be included.

2.0 BACKGROUND

Telkwa Coal representatives Mr. Dan Farmer, P.Eng., Chief Operating Officer; Mr. James Henderson, P.Eng., Senior Mining Engineer & Logistics Management; and Ms. Kim Bittman, Senior Mine Permitting Specialist, provided project information and data to BGC. BGC understands that Telkwa Coal is currently in the BC Environmental Assessment stage for an EA Certificate , with no infrastructure currently developed. The study area includes the Tenas Access Corridor Line from Lawson Road south of Telkwa, BC, and continues along the existing Telkwa Coalmine Road and expands into the proposed mining area in the southwest portion of the study area (Drawing 1). The study area elevation ranges between approximately 500 metres (m) to the east and 1100 m to the west. Most of the study area is currently vegetated with forest cover except for along pre-existing logging roads. Portions of the study area were previously harvested but have since been reforested.

Telkwa Coal provided BGC with satellite imagery collected in 2018 and 2 to 5 m resolution LiDAR contours for the assessment. Previous reporting as part of the Terrain and Soils Baseline and Environmental Effects Assessment of the project indicated that avalanche paths were not identified in the study area but that sufficiently steep slopes to form snow avalanches exist (Telkwa Coal Limited, June 2021). Communication with Mr. Henderson indicated that slopes during mine development are mostly designed to be shallower than 26 degrees.

The Canadian Avalanche Association (CAA) provides guidelines for acceptable frequency and magnitudes of snow avalanches for exposed elements, outlined in the Technical Aspects of Snow Avalanche Risk Management (CAA, 2016) (Table 2-1). Appendix A includes a technical overview of snow avalanches.

Table 2-1. Relevant excerpts of Table 9.6 in CAA (2016), captioned "Typical elements at risk for worksites, exploration, survey, resource roads, energy corridors and utilities, managed forest land and other resources with avalanche size and return-period thresholds for avalanche planning".

Element at Risk	Typical avalanche size	Typical return period (years)		Typical Planning
Non-avalanche workers	> 1	≤ 30	Scale	Slope- to drainage-scale assessment for an exposure time scale of minutes to hours.
			Identification and analysis	Frequency-magnitude analysis.
			Assessment techniques and decision aids	Qualitative procedures; terrain exposure classification.
			Supporting map types	Terrain exposure map; locator map; avalanche path map.
			Mitigation options	Mitigation is primarily accomplished through short-term operational measures for workers engaged in backcountry travel. Location planning and specification of short-term operational measures for fixed worksites.
Resource roads	≥ 2	≤ 30	Scale	Mountain-scale followed by path-scale assessments for an exposure time scale of minutes to hours. Assessment of a group of paths (i.e., avalanche area) is often useful.
			Identification and analysis	Frequency-magnitude analysis.
			Assessment techniques and decision aids	Qualitative or quantitative procedures.
			Supporting map types	Locator map; linear hazard map.
			Mitigation options	Location planning; seasonal closures.

3.0 SNOW AVALANCHE HAZARD ASSESSMENT

3.1. Snow Climate and Snow Supply

The project footprint generally experiences a transitional snow climate (Haegeli and McClung, 2003; McClung and Schaerer, 2006), which experiences influence from moist air over the Pacific Ocean as well as dry continental air (Table 3-1). The project area is relatively low elevation and on the northeastern and dryer portion of the Telkwa Range, providing less snowfall and generally warmer conditions than within the higher elevation mountains.

Snow depth was estimated for relevant elevations within the study area by computing linear regressions on freely available snowpack data obtained from nearby snow data sites. The sites included Hudson Bay snow course (BC River Forecast Centre, 1480 m, 18 km north of project), Hungry Hill weather stations (BC Ministry of Transportation and Infrastructure, 820 m, 25 km southeast of project), Quick weather station (Environment Canada, 533 m, 7 km southeast of project), and McKendrick Creek snow course (BC River Forecast Centre, 1050 m, 20 km northeast of project). Extreme value statistical methods were used to estimate snow depths for each station for given return periods beyond the length of the data record (Figure 3-1). The estimated 30-year snow depth for the study area for 500 m to 1100 m ranges from 0.8 m to 1.6 m, respectively.

Climate change is anticipated to affect snowpack and avalanche conditions as time progresses (IPCC, 2019). Since the study area is at relatively low elevation, future warming trends may result in a thinner and stronger snowpack. However, avalanche events are common during the accumulation of snowfall amounts over a period of days, which is dependent on short-term winter weather patterns. It is anticipated that such short-term weather fluctuations will continue even with a warming climate. That is, terrain within the study area capable of producing snow avalanches is expected to be able to do so for the foreseeable future.

Table 3-1. Characteristics of a transitional snow climate (after Haegeli and McClung, 2003).

Typical winter conditions	Typical snow avalanche character
Moderate to heavy snowfall, variable temperatures, moderate snow covers, some rain during winter, occasional persistent weak layer growth in open terrain (e.g., surface hoar in cut blocks and river banks).	Loose dry, Wind slab, Storm slab, Persistent slab, Deep persistent slab.

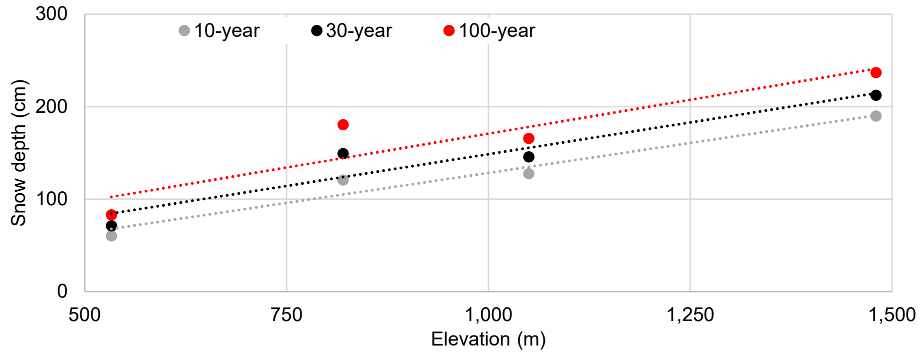

Figure 3-1. Estimated maximum snow depth with respect to elevation for the study area.

3.2. Terrain and Vegetation

Snow avalanches generally require slope angles of over 27 degrees to initiate (Appendix A) and typically a forest density of less than 200 to 300 stems per hectare (Schweizer et al., 2003; Jamieson, 2018) or 1000 stems per hectare for steep slopes (Weir, 2002; McClung and Schaerer, 2006). To assess for potential snow avalanche areas, LiDAR contours were used to define areas in the study area that were steeper than 27 degrees and 2018 satellite imagery was used to assess for forest cover. Most of the project area is within terrain shallower than 27 degrees and densely forested, which corresponds to Simple terrain as classified by the Avalanche Terrain Exposure Scale (ATES) (Statham et al., 2006). Portions of the study area that have localized steeper areas are summarized in Table 3-2, along with corresponding forest cover and expected magnitude and frequency of snow avalanches.

Table 3-2. Identified areas with slopes steeper than 27 degrees and greater than 10 m long within the study area. Refer to Drawing 1 for area polygons.

Location	Forest Cover	Slope Length (m)	Slope Description	Maximum Avalanche Size (1[1] to 5)	Estimated Return Period (years)	ATES[2] Rating
East slope of Goathorn Creek	Densely forested, clearing of 10 m wide by 20 m long on south end	50 to 100	Sections of benches and areas less than 27 degrees within larger slope, Telkwa Coalmine Road crosses slope on north end	1	10 to 30	Simple to Challenging
West slope of Goathorn Creek and Four Creek	Densely forested, local clearings 10 to 20 m long on road cutbanks and north of road	30 to 50	Locally steep approach slopes to creeks, Telkwa Coalmine Road crosses slope on south end	1	10 to 30	Simple to Challenging
Southwest side of project footprint	Densely forested	30 to 50	North aspect of a broad ridge, localized area of up to 40 degrees	1	10 to 30	Challenging

[1] Relatively harmless to people.
[2] ATES is a three-step scale that describes how terrain is affected by the potential for avalanches.

4.0 CONCLUSIONS AND FUTURE RECOMMENDATIONS

The snow supply, terrain, and vegetation cover analyses indicate that snow avalanches can form within localized sections of the study area, with a maximum magnitude of Size 1 (relatively harmless to people) and frequency of approximately once per 10 to 30 years. The expected snow avalanches are of smaller magnitude than the guidelines provided in CAA (2016) (Table 2-1), indicating that an avalanche safety program is not required for the study area, given the current terrain and vegetation cover.

Terrain capable of forming snow avalanches but not identified in this assessment may exist in the study area. Examples include terrain that was not properly represented by LiDAR and/or satellite imagery as well as slopes formed during project development. Slopes of potential concern are longer than approximately 10 m, steeper than 27 degrees, and clear of vegetation. Should such slopes be found or formed from project development, an updated snow avalanche hazard assessment should be completed by a qualified avalanche professional.

5.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of Telkwa Coal Limited. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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per:

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MC/DG/ksj/sjk

EGBC Permit to Practice 1000944

Attachment(s): Appendix A
Drawings

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APPENDIX A
TECHNICAL OVERVIEW OF SNOW AVALANCHES

Snow Avalanche Characteristics

A snow avalanche is a rapid flow of snow or ice down a slope. Snow avalanches may release spontaneously, with no obvious trigger, or may be triggered by rapid loading (e.g., human causes, explosives) or mechanical changes to the snowpack brought on by meteorological conditions (e.g., snow, rain, wind, warm air temperature, sun). Snow avalanches can also be triggered by seismic loading.

The two predominant types of snow avalanches include loose avalanches and slab avalanches (McClung and Schaerer, 2006). Loose avalanches occur within snow with low cohesion, where gravitational forces overpower frictional resistance, like sand sliding down a hill. This generally occurs during storms where cohesion of fallen snow is low or on days with substantial warming from air temperature or solar warming, where bonds between snow grains are weakened. Slab avalanches occur when a cohesive block of the snowpack is isolated on all sides and slides downslope due to gravitational forces. Slab avalanches are further categorized based on when they release with respect to storms.

Both loose and slab avalanches can be classified as dry or wet, depending on the water content of the snow involved. Dry avalanches are most common during winter months and wet avalanches are most common in spring months, although they can also occur in the winter during rain events and at low elevations. Fast-flowing dry avalanches may have a powder component, which is a suspended layer of snow, with a height that is often tens of metres above the dense flow. Slab avalanches are typically the most hazardous, as they can contain a large amount of snow that can reach the runout zone and be destructive.

A third and much less common type of snow avalanche is a glide avalanche. In this circumstance, the entire snowpack slowly glides downslope because of water flow at the base of the snowpack, possibly opening cracks within the snowpack. The cracks may expand and release a portion of the snowpack downslope, termed a glide avalanche. Such avalanches generally occur in wet snow climates or during the spring in dry snow climates.

Snow avalanche hazard may exist anywhere with enough snow accumulation and steep slopes (generally greater than 27°) (Jamieson, 2018). The terrain feature where a snow avalanche forms, slides, and deposits is referred to as a snow avalanche path. The path includes a starting zone, track, and runout zone. Starting zones are where the snow avalanche initiates and begins to slide, generally on terrain steeper than 30°, but sometimes as low as 25°. Snow avalanches entrain more snow within the track and speed up, usually in terrain with slope angles between 15° and 30°. Snow avalanches then decelerate and stop in the runout zone with slope angles typically less than 15°, leaving a deposit of snow. Larger paths are generally capable of producing avalanches of higher destructive potential, but hazardous snow avalanches may also release and deposit debris on relatively short slopes at any elevation.

Uncertainty and Limitations

Snow avalanche prediction is complex and subject to uncertainty. There is uncertainty in snow avalanche runout extent and frequency estimates due to limited historical avalanche observations in the study area, alterations to forest cover from anthropogenic activities, and limitations of statistical and dynamic models. Future alteration of the landscape and vegetation, such as from anthropogenic activities, forest fire, infestation, or other geohazards may alter the frequency and magnitude of snow avalanches and their runout extent and characteristics.

Frequency and Magnitude

Jamieson (2018) describes frequency as the average number of avalanches that reach or exceed a given location within a specified time period, often a year. The reciprocal of the average annual frequency is the return period. Jamieson (2018) indicates that return period is described as the average time, usually in years, between avalanches that reach or exceed a specified location. For land-use planning, return periods of 3, 10, 30, 100 and 300 years are often used because uncertainty in the data makes it difficult to estimate return periods more accurately. It is possible for two 100-year avalanches to occur within the same year or within consecutive years, although this would be considered a low probability (unlikely) event.

In Canada, snow avalanche magnitudes are classified by destructive size (Table A-3). The maximum size of an avalanche depends on snow supply and terrain configuration and therefore will vary for any given path.

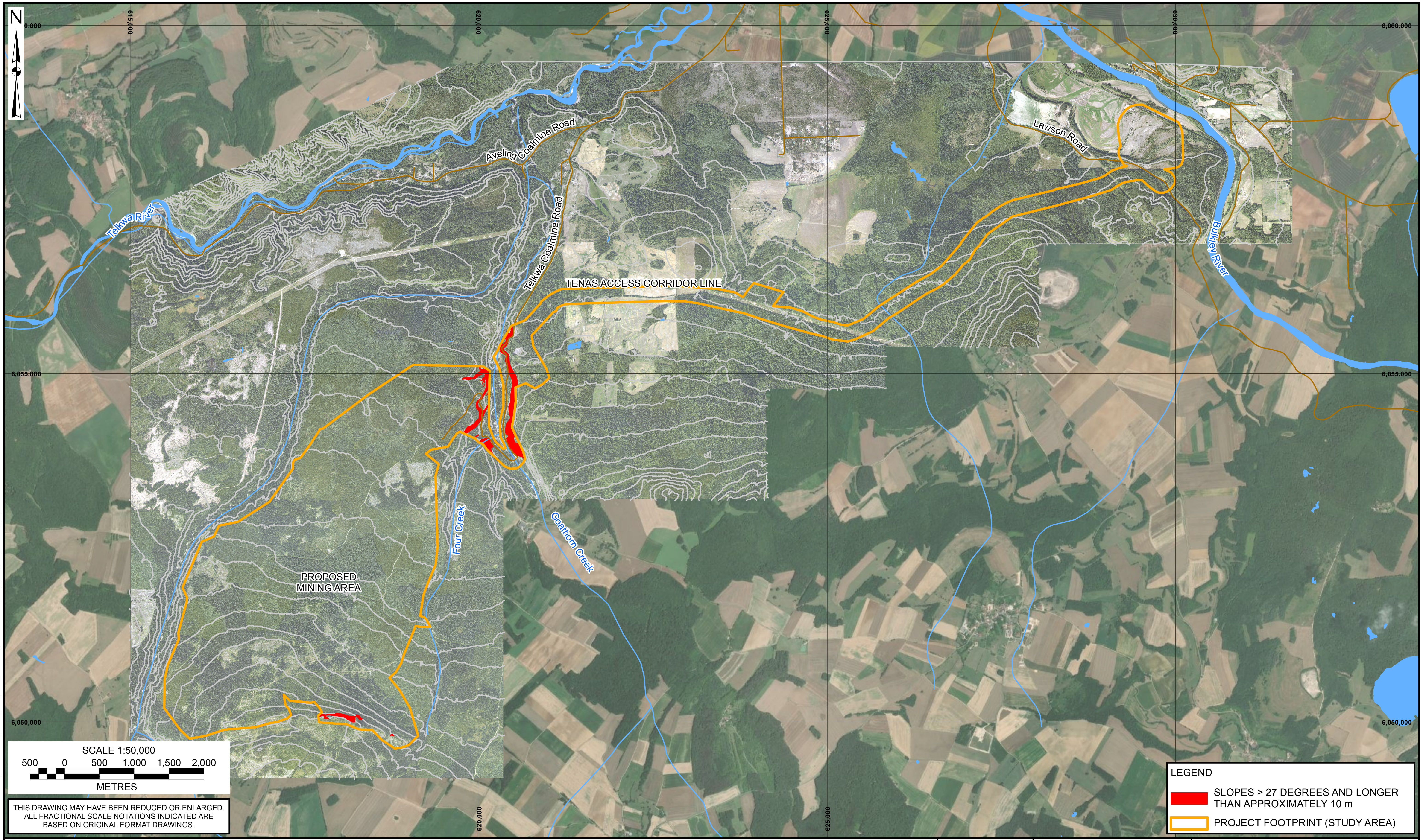
Magnitude is often related to frequency; in general, large destructive avalanches occur less frequently, while small ones occur more frequently. The magnitude and frequency are also related to location in the overall path.

Table A-3. Canadian classification system for snow avalanche destructive size (CAA, 2016).

Size	Destructive Potential	Typical Mass	Typical Path Length	Typical Impact Pressure
1	Relatively harmless to people	<10 t	10 m	1 kPa
2	Could bury, injure, or kill a person	10^2 t	100 m	10 kPa
3	Could bury and destroy a car, damage a truck, destroy a wood framed house, or break a few trees	10^3 t	1,000 m	100 kPa
4	Could destroy a railway car, large truck, several buildings, or a forest area of approximately 4 hectares	10^4 t	2,000 m	500 kPa
5	Largest snow avalanche known. Could destroy a village or a forest area of approximately 40 hectares	10^5 t	3,000 m	1,000 kPa

Note: Size 1 is the minimum size rating. In general, half sizes are not defined, but may be used by experienced practitioners for avalanches which are midway between defined avalanche size classes (i.e., size 2.5).

DRAWING



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "TELKWA COAL SNOW AVALANCHE ASSESSMENT", AND DATED NOVEMBER 2021.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY TELKWA COAL LIMITED. CONTOUR INTERVAL IS 25 m.
4. SATELLITE IMAGERY PROVIDED BY TELKWA COAL LIMITED, DATED 2018.
5. IDENTIFIED SLOPES ARE FOR PRE-MINING TERRAIN. CHANGES IN LAND USE (E.G., DEVELOPMENT) MAY WARRANT RE-DRAWING OF CERTAIN AREAS.
6. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 9N. VERTICAL DATUM IS UNKNOWN.
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PROJECT: TELKWA COAL SNOW AVALANCHE ASSESSMENT

TITLE: STUDY AREA AND IDENTIFIED SLOPES

PROJECT No.:	DWG No:
2306-001	01

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