Appendix 4.2-A Terrain and Soil Baseline Report

TELKWA COAL
LIMITED

Tenas Project

Terrain and Soil Baseline Report

December 2021

VERSION 3.6.1

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EXECUTIVE SUMMARY

Terrain mapping and soil mapping for the Tenas Project (the Project) covers the Terrain and Soil Local Study Areas (T-LSA and S-LSA) which includes the project components and a 250 m to 500 m buffer zone around project components. Project components are the Minesite area between Goathorn and Tenas Creeks, the Rail Infrastructure area near the Bulkley River, and the Bypass Road connecting the Minesite area to the Rail Infrastructure area. The Goathorn Creek area connects the Minesite to the Telkwa River. The mapping was carried out at a scale of 1:5,000 within the Minesite, Goathorn Creek and Rail Infrastructure areas, and at 1:20,000 scale along the Bypass Road area. The terrain and soil data that informed the mapping were collected in 2017 through to 2019.

The physiography in the LSAs is typically subdued or rolling marking the transition of the Hazelton Mountains to the Nechako Plateau in the northern interior of BC. This subdued terrain is dissected by the 80 m deep incised, narrows valleys of Goathorn Creek and Tenas Creek, and by the Telkwa River. Short sections of the Bulkley River and Telkwa River floodplains are included in the LSAs.

Terrain, Terrain Stability and Natural Hazards

Terrain mapping delineates terrain units which are relatively homogeneous regarding landform, surficial material and geomorphological processes. Terrain mapping was carried out as bioterrain mapping to provide a terrain base layer for soil mapping and ecosystem mapping; and as terrain stability mapping delineating terrain units according to the likelihood of landslide initiation. Bioterrain mapping considers terrain characteristics such as the origin and the texture of the surficial material, surface expression of landforms, geomorphologic processes, drainage characteristics, aspect, and slope position. Terrain stability mapping considers terrain characteristics that influence slope stability such as surficial material texture and origin, stratigraphy, slope steepness, and geomorphological processes, particularly any evidence of active or past mass wasting. Each terrain stability unit is assigned a terrain stability hazard rating and a rating of the in-situ surface erosion potential of the surficial material. Existing and potential natural hazards were identified: Active and past landslide tracks are identified on the terrain stability map, while snow avalanche hazards and fluvial hazards that could affect a project component are discussed in the report.

During the last glaciation (28,000 to 10,000 years ago), the study area was completely covered by the Cordilleran Ice Sheet. The surficial materials in the LSAs are predominantly glacial deposits: basal till and ablation till; localized subglacial and supraglacial ice contact gravel and sand deposits; proglacial gravel and sand deposits transported by glacial meltwater streams; and clay and silt deposited in late-glacial lakes. During the final decay of the Cordilleran Ice Sheet, downcutting by glacial meltwater streams shaped the 80 to 120 m deep valleys of the lower Telkwa River, Goathorn Creek, Tenas Creek and Four Creek. The rapid erosion over-steepened and destabilized the valley walls and exposed underlying stratigraphic units: fine-textured and coal-bearing Cretaceous sedimentary rock; and advance-phase glacial sediments such as clayey silt and gravelly sand that were deposited in pre-glacial valleys. Since the end of the last glaciation, fluvial and colluvial processes have shaped the modern floodplains and fans of the rivers and major creeks in the LSA and have formed small toe slope deposits at the base of steep slopes.

At the Minesite, the dominant surficial material is glacial till. Based on differences in texture and degree of compaction, a basal till unit and an ablation till unit were distinguished. The basal till typically has a thickness of 2 m to 15 m but varies from <1 m to >50 m. At depths greater than 0.5 m below ground surface (bgs), the basal till is typically barely weathered and consists a of silt-clay matrix with 15% to 35% coarse fragment content; is stiff to very stiff, dark grey to maroon coloured with very low permeability. Geotechnical drilling has identified localized deposits of gravelly sand underlying the basal till. Ablation till has a sandy-silty matrix and 20% to 70% coarse fragment content with a typical thickness of 0.5 m to 1 m. The well to moderately well drained deposits commonly form a thin mantle over basal till, but can also form irregular, 1m high, narrow ridges which impede lateral dispersion of subsurface drainage and can create localized

imperfectly drained sites. Well-drained, glaciofluvial gravel and cobble deposits occur mainly along the shoulders of Tenas Creek and Four Creek valleys and reach a typical thickness of 2 m to 7 m over basal till. Sandy kame deposits in the northwest part of the Minesite overlie basal till and form a patchwork of imperfectly to poorly drained hollows between well drained ridges and hummocks. Well to rapidly drained bedrock outcrop is limited to the southern edge of the Minesite. While most of the Minesite is located on flat (0% to 5% / 0-3°) to gently sloping (<25% / <12°) terrain, steep, potentially unstable slopes exist immediately adjacent and downslope of the Minesite on the valley walls of Tenas Creek and Four Creek. The proposed water collection system at the Minesite will capture run-off and seepage currently draining from the Minesite location onto the potentially unstable terrain, and is expected to reduce the likelihood of gentle-over-steep landslide initiation on the Tenas Creek and Four Creek valley walls.

Access to the Minesite area from the Rail Infrastructure area is along the Bypass Road, and the existing Caribou FSR and Coalmine Road. The Caribou FSR on the western valley wall of Goathorn Creek is located on multi-benched terrain which is underlain by a 2 m to 20 m thick mantle of clay-rich waste material from past coal mining, while the steep, 20 m high, upper slope of the valley wall consists of a complex of glacial till and bedrock cliffs. Natural hazards along the Caribou FSR are indicated by rock fall and ravelling from the bedrock cliff; small debris slides in glacial till above the road; and by tension cracks where the road is located on waste rock material. The Coalmine Road is located on the 80 m high eastern valley wall which consists of glacial till, locally underlain by advance-phase glaciolacustrine silt and clay. A 5 m to 7 m thick glaciofluvial gravel and sand deposit overlies the glacial till and forms the crest of the valley wall. The valley wall slope above the Coalmine Road shows evidence of soil creep, slow vertical movement along tension cracks and small shallow debris slides that have reached the road. Downslope of the Coalmine Road, a 200 m wide section of the valley wall is failing following an initial fill slope failure triggered by piping during a wet spring in 2012. While the current landslide activity impacts the road, road widening will accelerate the slope movement unless preventative engineering measures are taken. The proposed crossing of Goathorn Creek is exposed to hydrogeomorphic hazards such as high-volume sediment transport along the main channel, lateral channel shifting, and channel avulsions. These processes have led to the wash-out of the old Goathorn Creek bridge in 2013. Immediately to the west of the proposed crossing, the Caribou FSR crosses the distal edge of an alluvial fan. Storm flow in distributary channels has scoured the existing roadside ditches. The Bypass Road will be located on stable, subdued terrain underlain by basal till and, at the east end, by a mantle of easily erodible glaciolacustrine silt. A hydrogeomorphic hazard was identified at the crossing of Helps Creek, where a debris flood in October 2017 filled the creek bed with gravel. Distributary channels will likely develop to re-establish a stream bed. Auxiliary drainage structures will likely be required at the crossing.

The Rail Infrastructure area will be located on the Bulkley River floodplain, within the 200-Year Floodplain Zone as determined by the BC Ministry of Environment. While geomorphic and ecologic evidence of active flooding is absent in the Rail Infrastructure area, a low hydrogeomorphic hazard remains during 200-year flood events. Immediately west of the Rail Loop, the floodplain is considered active with seasonal flooding due to high groundwater tables. .

A water discharge pipeline originally proposed within the Goathorn Creek area was to be located on the eastern shoulder of Goathorn Creek valley on stable, subdued terrain which is underlain by basal till and scattered deposits of glaciofluvial sand and small gravel. On the Telkwa River floodplain, the originally proposed water pipeline would have been exposed to potential hydrogeomorphic hazards such as overbank flooding, high groundwater tables and possibly overbank scour. Channel avulsion is not likely, but possible.

Soils Information

Soil mapping provides an inventory of the soil resources within the LSA. Soil map units (SMUs) reflect groupings of soil with related properties in order to provide soil information efficiently for environmental assessment, and reclamation purposes. The SMUs essentially provide a model of the most common soils within the study area, taking into consideration how soils have developed based on local parent materials, climate, topography and drainage, slope position, vegetation, and disturbance history. The bioterrain mapping is used as a basis for polygon organization and interpretation. Up to two SMUs are assigned to each bioterrain polygon. Each SMU describes soils with related properties such as parent material, soil texture, coarse fragment content, and degree of organic enrichment. These soil properties are assessed to determine soil salvage potential and soil erosion hazard for the purposes of mine reclamation planning. Soil trace metal analysis was conducted on representative soil samples.

Fine- to medium-textured, well to moderately-drained soil, derived from basal till (SMU 1.1) is the most common soil type within the study area. Fine- to medium-textured, imperfectly- to poorly-drained soil (SMU 1.2), occurs to a much more limited extent in lower, moisture-receiving slope positions, and is characterised by organic enriched humus and Ah layers and gleying. More coarsely textured, well-drained soil derived from ablation till (SMU 1.3). occur on parts of the Tenas plateau and is characterized by nutrient poor, freely-drained sandy loams.

Coarse-textured, well- to rapidly-drained soil derived from glaciofluvial parent material (SMU 2) occurs on the plateau in the vicinity of Four Creek and to lesser extent at the west end of the Bypass Road and the north end of the Goathorn Creek area. Soil textures include sand and loamy sand, and nutrient level is relatively low.

Fine-textured, moderately-drained soil with zero coarse fragments (SMU 3.1) is associated with a localized glaciolacustrine deposit at the east end of the Bypass Road. Fine-textured, imperfectly- to poorly-drained soil (SMU 3.2) characterized by rich humus and Ah layer development and gleying, occurs to a limited extent throughout the study area on depressional sites.

Coarse-textured, well- to rapidly-drained soil derived from active fluvial deposits (SMU 4.1) are similar to SMU 2, but seasonal flood events provide a source of nutrients and moisture. This soil map unit occurs on active floodplain benches of Goathorn Creek, Tenas Creek, the Telkwa River and the Bulkley River. Soil textures are generally sandy; and the soil is classed as Regosolic. Fine silty-textured, imperfectly- to poorly-drained soil (SMU 4.2) occurs to a limited extent in back-channel depressions. This SMU typically has a deep Ah layer and is classed as Humic Regosol. Coarse-textured, well to rapidly drained soil derived from inactive, high-bench floodplain deposits (SMU 4.3) is classed as Brunisolic and is nutrient poor.

Shallow soil over bedrock (SMU 5) and bedrock outcrops (SMU 6), occur to a limited extent at the south end of the Minesite, along parts of Tenas Creek, Goathorn Creek, and the Bypass Road. Organic soil (SMU 7) occurs in depressions left by meltwater channels and small kettle hole lakes. Organic soil is limited in extent in the study area.

Soils on the steep and potentially unstable valley wall slopes of Goathorn and Tenas Creeks are placed in their own category. SMU 8.1 describes fine- to medium-textured soil with moderate drainage that occur along the valley sides; and, SMU 8.2 captures the soils with rich humus and Ah layers and imperfect drainage that have developed on localized colluvial and fluvial deposits at the base of these slopes.

Most soil samples collected at the Minesite were found to be within the CCME industrial guideline limits for trace metals. One soil sample collected from a Spruce - Horsetail forest was found to be above the industrial guideline for Arsenic (As). Within ALR lands along the Bypass Road and Rail Infrastructure area, two sampling sites were found to be above the agricultural guideline for Arsenic, and numerous plots were above the guideline for Boron.

Lands along the Bypass Road, Goathorn Creek and Rail Infrastructure areas are designated as Agricultural Land Reserve (ALR). No ALR lands are found within the Minesite. Agricultural capability ratings were assigned to all polygons that intersect with the Bypass Road, Goathorn Creek, and Rail Infrastructure areas. Within the Rail Infrastructure area, agricultural capability is predominantly class 5AP, limited by aridity, stoniness and lack of fertility. Low-lying depressions are rated 5DI, limited by dense soil structure and a seasonal high water-table. Land at the east end of the Bypass Road is Class 4D, limited by dense soil structure. Cultivated fields and pasture above 600 meters, towards the west end of the Bypass Road are generally Class 5, limited by the short growing season at this elevation, and stoniness. Sloping terrain and wet draws are Class 6WP. Occasional steep slopes are Class 7T. Organic soil occurs to a very limited extent in small kettle hole depressions. Lands within the Goathorn Creek area are mostly Class 5 and Class 6. Above 600 m, crop potential is limited by a short growing season. The north end of Coalmine Road has sandy-gravelly soils that are limited due to stoniness, aridity, and lack of fertility. Seasonal inundation occurs along the Goathorn and Telkwa floodplains, most of which is Class 6.

ACKNOWLEDGEMENTS

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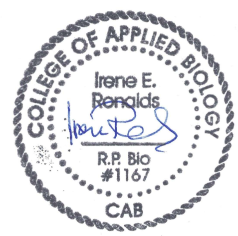

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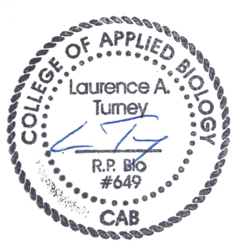

Laurence Turney, R. P. Bio.

Tenas Project

Terrain and Soil Baseline Report

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

Glossary and Abbreviations

ALC	Agricultural Land Commission
ALR	Agricultural Land Reserve
BP	Before Present
CLI	Canada Land Inventory
FRBC	Forest Renewal BC
RISC	Resources Information Standards Committee
SBSdk	Sub-Boreal Spruce dry cool biogeoclimatic subzone
SBSmc2	Sub-Boreal Spruce moist cool Babine variant biogeoclimatic subzone
SIL	Survey Intensity Level
SMU	Soil Map Unit
TEM	Terrestrial Ecosystem Mapping
TSIL	Terrain Survey Intensity Level
TSM	Terrain Stability Mapping
FSR	Forest Service Road
bgs	below ground surface

1. INTRODUCTION

Telkwa Coal Limited (TCL) is proposing to develop the Tenas Project (the Project), a surface coal mine designed to produce metallurgical coal at a planned annual production rate of between 775,000 and 825,000 metric tonnes, with a maximum daily production rate of 2,500 metric tonnes of processed coal. The Project requires a Certificate under the *BC Environmental Assessment Act* and major mines permitting under the *Mines Act* and *Environmental Management Act*, and subsequent permitting. These requirements trigger the need for baseline studies followed by assessment of potential effects of the Project on various Valued Components.

The proposed Project is located in northwestern BC, approximately 25 kilometres (km) south of Smithers and 7 km southwest of the village of Telkwa. The Project is on provincial Crown Land, on three freehold land parcels owned by TCL and nine coal licences held by TCL. The Project falls within Wet'suwet'en traditional territories: the mine site is located in Cas'Yex House territory; the rail loop and loadout are located in Kwen Bea Yex House territory (Budhwa et al. 2020).

The Project will be a conventional shovel and truck operation like other rock quarry and surface mine operations in the region. Coal will be extracted using heavy machinery and sent to an on-site coal processing plant. Following processing, the coal will be trucked to a rail loadout facility and associated rail loop connecting to the existing main Canadian National Railway line. In addition to the mine pit, coal processing plant and rail infrastructure, the Project will include the following major components: a materials handling system, various rock and soil storage piles, water management features, mine access and haul roads, a powerline, propane storage, explosives storage, administrative and warehouse buildings, and various other supporting infrastructure. An originally proposed water discharge pipeline to the Telkwa River is no longer part of the Project. The Project life will be approximately 25 years including the construction, operation, and reclamation phases.

Baseline Report Scope

This consolidated Terrain and Soil Baseline report provides information on the field programs undertaken between 2017 and 2019 and their respective data summaries. Work was completed by Irene Weiland, P. Geo, Eng. L. of Weiland Terrain Sciences, Smithers, BC and Irene Ronalds, R. P. Bio, of I. Ronalds Ecological Consulting and coordinated by Laurence Turney, R. P. Bio. of Ardea Biological Consultants Ltd., Smithers, BC.. Baseline programs covered by this report include: Terrain mapping, including bioterrain mapping, terrain stability mapping; and a description of natural hazards.; and Soil mapping, including soil map units and their ratings for soil salvage potential and soil erosion potential, and Agricultural Capability mapping.

The baseline information will inform the Environmental Assessment application, as well as the Joint Application for the Mines Act permit to the Ministry of Energy, Mines and Low Carbon Innovation (EMLCI), and Environmental Management Act permit to the Ministry of Environment and Climate Change Strategy (MOECCS).

The surficial geology and the geomorphological processes in the study area are described as part of the terrain description and are shown on the terrain stability map as polygons and symbols. A terrain stability class and a surface erosion potential rating is assigned to each polygon. Other natural hazards are assessed in the report. The terrain information is also compiled as a bioterrain map layer which serves as the base for soil interpretations and terrestrial ecosystem mapping (TEM).

For the soil mapping, soil map units are described, with up to two soil map units assigned to each bioterrain map polygon using a decile system. Soil depth and volumes are summarized for each map unit. Soil map units are characterized in terms of soil texture, drainage, and nutrient content, reclamation suitability, and erosion potential. Representative soil samples have been tested for baseline soil metal concentrations, and soil nutrients. Lands that are located within the Agricultural Land Reserve are assessed for agricultural capability.

1.1 Project Components and Study Areas

The study area is located in northwest BC, near of the village of Telkwa, just southwest of the confluence of the Telkwa and Bulkley rivers in the Skeena River watershed. Detailed mapping was completed in a Local Study Area (LSA), defined by a 250 m or 500 m buffer around the project components. Due to differences in mapping requirements, 3D mapping software, and objectives for the terrain stability, bioterrain and soil components, two slightly different **Local Study Areas** (LSAs) were mapped. The **Soil LSA** (S-LSA) was used for the bioterrain and soil mapping (S-LSA) as well as for the terrestrial ecosystem mapping (Ardea 2021). The **Terrain LSA** (T-LSA) was used for the terrain stability mapping, and was contracted in some areas and expanded slightly in others to take into account important terrain features. Both LSAs encompass four distinct sub-areas: the Minesite area, located between Goathorn Creek and Tenas Creek; the Rail Infrastructure area located near the Bulkley River; a Bypass Road area that connects the Rail Infrastructure area to the existing Coalmine Road; and the Goathorn Creek area, which contains Goathorn Creek downstream to the Telkwa River. Within the Goathorn Creek area are Coalmine Road and the Caribou Forest Service Road (FSR). The Bypass Road, along with portions of Coalmine Road and the Caribou FSR, form the Tenas Access Corridor connecting the Minesite to the Rail Infrastructure area. The LSAs and the sub-areas are shown in Figure 1-1.

The Regional Study Area (RSA) is the same for both the terrain and soil components and is approximately 35,726 ha, encompassing a minimum 5 km buffer around the Project Area. The RSA includes the Village of Telkwa and part of Tyhee Lake to the north; Round Lake to the east; the lower slopes of Hunter Basin to the south, and the lowest reaches of Pine Creek to the west. It overlaps portions of both the Telkwa and Bulkley rivers, as well as Tenas and Goathorn creeks. The RSA has a notable anthropogenic footprint including the Village of Telkwa and overlaps with the Highway 16 corridor. Agricultural development and rural residences are common in the lower elevations of the RSA, while higher elevation areas show a history of forest harvest activities.

1.1.1 Physiography

The Project is located on subdued terrain in the lower Telkwa River watershed. The Telkwa River drains parts of the Hazelton Mountains (Holland 1964) at the western edge of the Interior System of the Canadian Cordillera, with elevations between 500 m and up to 2,500 m. The Telkwa River watershed includes forested, mid-elevation plateau and mountain terrain, high elevation rugged and alpine terrain in the Hudson Bay Range and the Telkwa Range, and several glaciers in the Howson Range. Near the confluence of the Telkwa and Bulkley rivers the physiography is characterized by plateaus and rolling terrain of the Nechako Plateau, a part of the Interior Plateau. The physiography of the study area is characteristic of the transition of the Hazelton Mountains and the Nechako Plateau (Figure 1-2).

More specifically, the Project is located in the lower watersheds of Tenas Creek and Goathorn Creek (6,385 ha and 12,204 ha, respectively). Both streams originate in alpine cirques on the northern slopes of the Telkwa Range with elevations up to 2,000 m and 2,330 m, respectively (Figure 1-2). A small glacier remains at the head of Cabinet Creek, a main tributary to Goathorn Creek, on the north side of Mt Foster. Below 1,250 m to 1,400 m, Tenas and Goathorn creeks drain the forested, gently sloping foot hills and lower slope of the Telkwa Range. Below 900 to 1,000 m elevation, the two watersheds open up onto plateau terrain and gently sloping benches which are characteristic for the transition of the Hazelton Mountains to the Bulkley Valley and the Nechako Plateau. Tenas Creek and Goathorn Creek dissect this gently sloping,

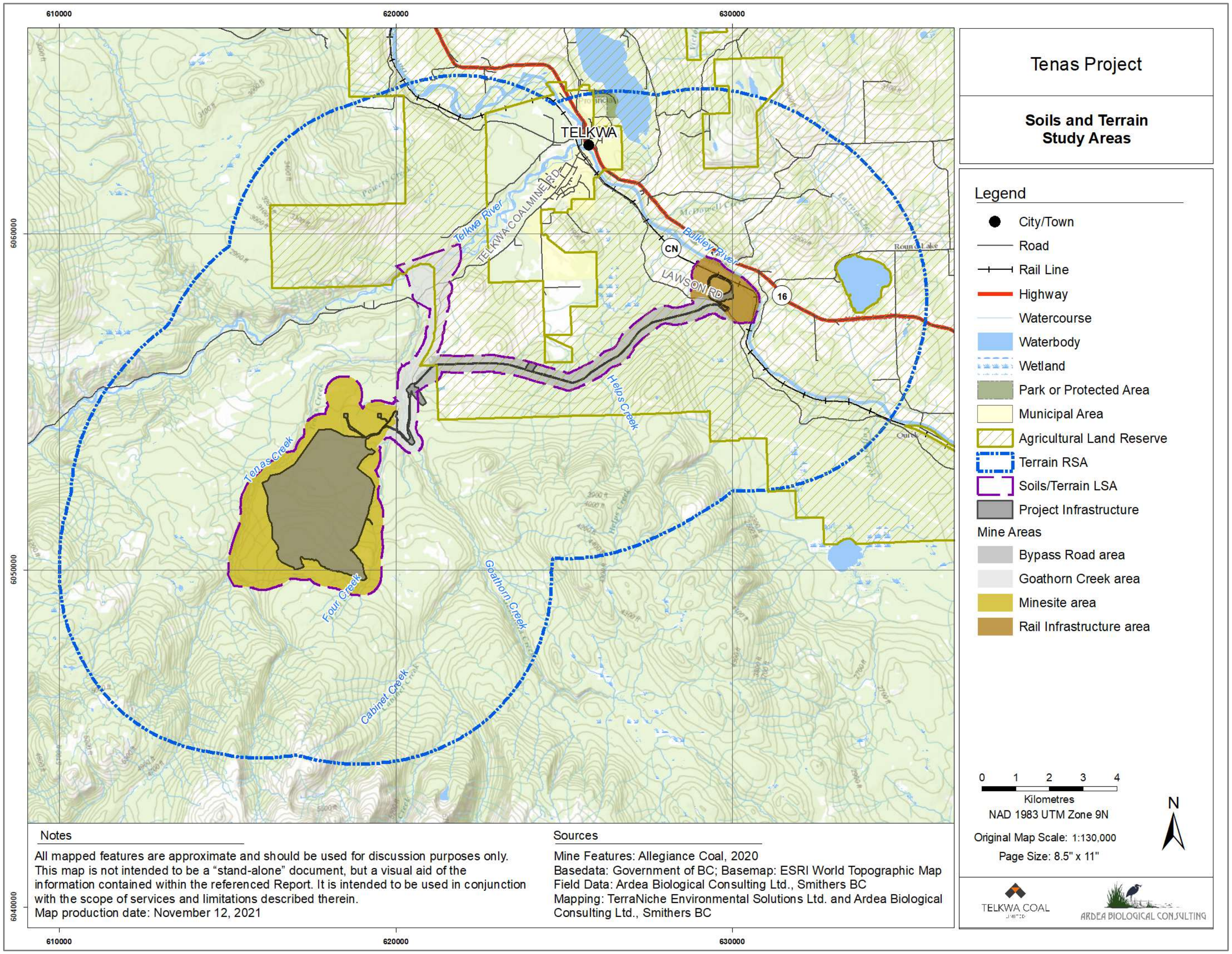

Figure 1-1: Local and regional study areas (LSA and RSA) and sub-areas of the Soil and Terrain LSAs.

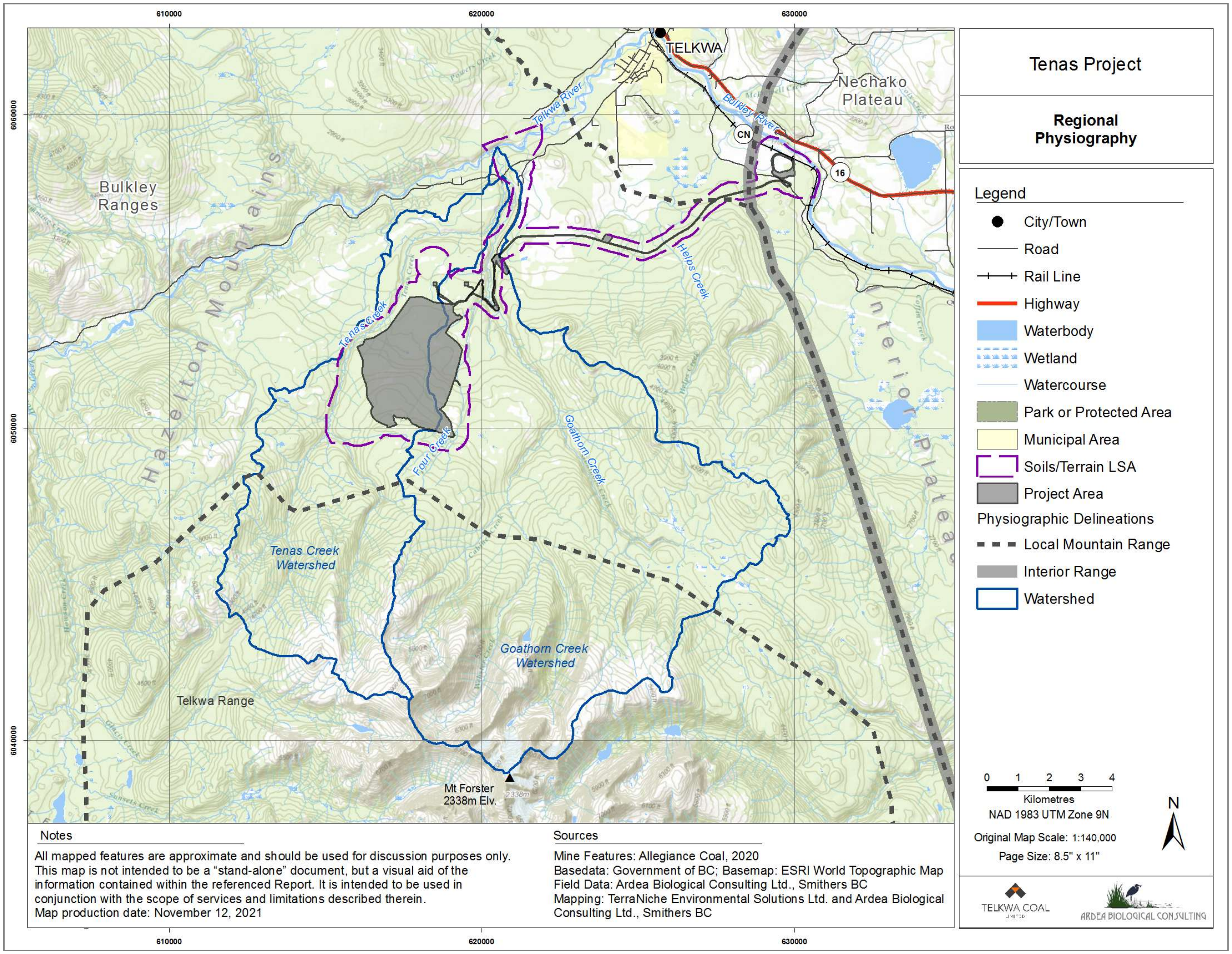

Figure 1-2: Physiographic areas (Holland 1964) near the Project.

lower part of their watersheds: the streams are incised into 60 to 100 m deep, box-shaped valleys with steep, potentially unstable valley walls and 110 to 150 m wide valley bottoms with active floodplains formed by gravel-bed rivers (Kellerhals et al. 1989).

The Minesite is located on a flat to gently sloping upland between Goathorn Creek, its tributary Four Creek, and Tenas Creek at 700 to 1,000 m elevation, while the Rail Infrastructure is located on the Bulkley River floodplain at 515 m elevation. The 14 km long Tenas Access Corridor connects the Minesite to the Rail Infrastructure and includes existing roads (Caribou FSR and Coalmine Roads) and the proposed Bypass Road. The Caribou FSR and the Coalmine Road are located on the western and eastern valley walls of Goathorn Creek, while the proposed Bypass Road would be located at 550 m to 750 m elevation on gently undulating terrain between Goathorn Creek and the Bulkley River.

1.2 Regulatory and Policy Framework

1.2.1 Legislation, Regulations and Guidelines

Under Part 3 of the Reviewable Projects Regulation for the BC *Environmental Assessment Act* (2002), the Project is required to prepare an Application for an EA Certificate under Section 10(1)(c) the Act. The federal government has determined that the Project does not require an assessment under the *Canadian Environmental Assessment Act* (2012), although they are participating with the Province in the Assessment).

The Project may require additional federal, provincial, or municipal licenses, permits, and authorizations, including (but not limited to) those issued under Canada's *Explosives Act*, *Fisheries Act*, *Species at Risk Act*, and *Navigation Protection Act*; BC's *Mines Act*, Health, Safety and Reclamation Code for Mines in British Columbia, *Coal Act*, *Environmental Management Act*, *Water Sustainability Act*, *Heritage Conservation Act*, *Forest and Range Practices Act*, and *Land Act.*

TCL may apply for concurrent review of permits under the BC *Mines Act* and *Environmental Management Act*) pursuant to the BC *Environmental Assessment Act* Concurrent Approvals Regulation (BC Reg. 371/2002). Under this Regulation, permits will be reviewed at the same time as TCL's Application for an EA Certificate. No decisions on permits can be made until an EA Certificate is issued by the Minister of Energy, Mines and Petroleum Resources and the Minister of Environment and Climate Change Strategy.

2. Terrain Information

Terrain mapping delineates landforms, surficial materials and geomorphologic processes. Additional terrain characteristics are considered to make interpretations for bioterrain mapping or for terrain stability mapping. Bioterrain mapping presents the terrain information as a base layer for further interpretation of soil units and ecosystem units. Terrain stability mapping (TSM) is a RISC standard approach used to delineate areas of stable and/or unstable terrain including the assessment of the landslide hazard (BCMOE 2020). The surface erosion potential was rated as part of terrain stability mapping. In addition, other natural hazards including snow avalanche hazards and hydrogeomorphic (fluvial) hazards are described in the report.

2.1 Standards for Terrain Information

The terrain mapping follows BC provincial standards; specifically, the *Guidelines and Standards for Terrain Mapping in British Columbia* (RIC 1996) and the *Terrain Classification System for British Columbia*, *Version 2* (Howes and Kenk 1997). Digital data management follows the *Standard for Digital Terrain Data Capture in British Columbia, Terrain Technical Standard and Database Manual, Errata 2002-1.1* (BC MOE 2007); bioterrain data management has been updated to follow the *Terrestrial Ecosystem Information Digital Data Submission Standard - Draft for Field Testing, Database and GIS Data Standards, Version 2.1.* (BC MOE 2012). The soil drainage classes follow those outlined in the *Field Manual for Describing Terrestrial Ecosystems, 2nd Edition* (BC MOFR & BC MOE 2010).

Terrain stability mapping, including assigning terrain stability classes and soil erosion potential ratings to each terrain polygon, follows the standards described in the *Mapping and Assessing Terrain Stability Guidebook* (BC MOF & BC MOE 1999).

2.2 Existing Information

Terrain information relevant to the Tenas Mine was available from a variety of sources (Table 2-1) including earlier mine development proposals by Manalta Coal and Crowsnest Resources which partially overlap with the current proposal. In addition, terrain stability mapping at 1:20,000 scale is available for crown land with operable forest in parts of the lower Telkwa River watershed (Madrone Consultants Ltd. 1999). Information about quaternary stratigraphy in parts of the Minesite area was compiled by Piteau Engineering Ltd. (1997) based on borehole and well logs. Several scientific publications describing the quaternary history and stratigraphy in the Bulkley-Telkwa river area and in the Babine Mountains-Bulkley Valley area are available (Levson et al. 1998, Stumpf et al. 2004).

Table 2-1: Existing terrain information.

Document	Used in Baseline Report
Soil Survey and Land Capability Evaluation of the Telkwa Coal Project. (Pedology Consultants 1983)	Used for reference. The report provides detailed descriptions of the surficial materials and surficial geology. The mapping was carried out at a 1:5,000 scale in a core area centred on Goathorn Creek and at 1:20,000 scale for a larger area north and east of Goathorn Creek. A polygon map was not available, however.
Borehole logs (Piteau Engineering Ltd. 1997)	Borehole logs provide information on surficial material quaternary stratigraphy and depth to bedrock in the Minesite area.
Manalta Baseline Report. Appendix 4.1.1: Terrestrial Ecosystem Mapping (1:20,000) (Oikos Ecological Services 1999)	Used for reference. Mapping of bioterrain polygons at 1:20,000 scale of the proposed Manalta Project encompasses all of the Tenas Mine project area. The polygon attributes include surficial material and surface expression.

Document	Used in Baseline Report
Terrain Stability Mapping funded by Forest Renewal BC (FRBC); 1:20,000. (Madrone Consultants Ltd. 1999)	Detailed terrain stability mapping (DTSM) completed at 1:20,000 scale available for operable forest on crown land in the lower Telkwa watershed (Minesite, parts of the Bypass Road and Goathorn Creek corridors). The DTSM does not cover private land such as land owned by Telkwa Coal Ltd.
Levson et al. (1998)	Description and discussion of quaternary ice-flow direction and till mineralogy in the Babine Mountains – Bulkley Valley area including the Telkwa watershed.
Stumpf (2001); Stumpf et al. (2004)	Descriptions of quaternary stratigraphy in the Babine Lake – Bulkley River Region, including stratigraphic description in the lower Telkwa watershed.

2.3 Methodology

The following sections describe the methodologies used for the bioterrain terrain and terrain stability mapping. Both mapping themes are based on terrain mapping according to the *BC Terrain Classification System* (Howes and Kenk 1997), a combination of surficial geology mapping, landform mapping and identification of geomorphologic processes. The mapping is carried out through the interpretation of remote sensing imagery and extrapolation from field observations while applying principles of quaternary geology and geomorphology. Bioterrain mapping delineates polygons with vegetation, ecology and wildlife interpretations in mind, while terrain stability mapping focuses on the identification of geohazards such as mass wasting and is applied to interpretations of landslide initiation potential and erosion potential of exposed surficial materials (i.e. surface erosion).

2.3.1 Data Acquisition and Preparation

The data acquisition and map preparation were done concurrently for both bioterrain mapping and terrain stability mapping. The base map layer was provided by TCL: Detailed contour information with 2 m contour intervals was available, generated from bare-earth LiDAR digital elevation data collected in 2017. Other topographic map information such as streams and roads were available from TRIM data (scale 1:20,000). TRIM contours and streams at a scale of 1:20,000 were used to look at the larger geographic context (T-RSA).

The initial terrain interpretation was carried out in early 2017 on 1:18,000 scale, colour air photographs taken as optical images in 2006 (Appendix A). The images were available as scanned digital images and were interpreted using ArcGIS 10.4 and DAT/EM's digital stereo plotter *Summit Lite*. However, the final polygon delineation was completed on digital orthophoto imagery collected in 2017 and provided by TCL; and hillshade imagery derived from the bare earth LiDAR data. The newer digital raster layers provided higher resolution and more current photographic imagery (orthophoto) and more detailed topographic representation of the landscape (LiDAR hillshades and contour map). The resolution of the 2017 digital orthophotos was equivalent to a hardcopy air photo scale of 1:2,000. The vertical resolution of the LiDAR hillshade was 0.5 m or less.

Spatial and attribute data from earlier terrain mapping was acquired from TCL's in-house data collection and from Data BC.

2.3.2 Field Assessment Methods and Standards

Reconnaissance-level field work was carried out in 2017. Following preliminary terrain polygon delineation in the winter of 2018, a more extensive field sampling program was carried out in the summer of 2018. Additional field sampling took place in the spring and summer of 2019. Figure 2-1 shows the location of terrain field sites on an overview map. For field sites that are described in this report, UTM coordinates are given in Appendix B. A shapefile with terrain field site information has been submitted to Telkwa Coal.

Bioterrain Mapping – Field Work and Survey Intensity

Terrain field information for bioterrain interpretations was collected by a multidisciplinary field team in conjunction with soil and ecosystem sampling with a terrain specialist and or soil specialist on the team. Observations were made during foot traverses with 15 to 35 plots completed per transect. Plot locations were recorded on a GPS-enabled iPad using the GIS Kit (Garafa LLC) or the Avenza Maps (Avenza Systems Inc.) applications. Traverses were also recorded on a Garmin GPS to an accuracy of +/- 10m.

Bioterrain information was recorded on field data collection forms (Site Description form FS882(1) and Soil Description form FS882(2)), as well as the Site Visit (SIVI) Form FS1333. Additional terrain information and incidental observations were recorded in free form notes.

Bioterrain observations were made at hand-dug soil pits, generally to a depth of 30 cm to 80 cm, in road cuts and at natural exposure sites such as overturned tree roots and eroding stream banks. Observations included the identification of surficial materials (parent materials or subsoil), their texture and stratigraphy, the terrain surface expression, and active or past geomorphic processes according to the *BC Terrain Classification System* (Howes and Kenk 1997); soil drainage according to the classification in the *Field Manual for Describing Terrestrial Ecosystems* (BC MOFR & BC MOE 2010); slope position and slope angle. The texture of the surficial material was typically sampled in the C-Horizon of the soil pit, below the rooting zone, using hand-texturing (BC MOFR & BC MOE 2010 - Section 9). On floodplain sites, indicators of fluvial processes were recorded, including vegetation indicators of seasonal surface water.

Together with ecological and soil data, the bioterrain field data was entered into VPro 15, an Access database used to store ecological data. The data was then exported to ESRI Systems ArcInfo Geographic Information System (GIS) (ArcGIS 10.4) and used to describe attributes for bioterrain polygons.

The proposed Minesite and Rail Infrastructure areas as well as the Goathorn Creek area were mapped at a scale of 1:5,000 and field-checked with a terrain survey intensity level (TSIL) B (BC MOF & BC MOE 1999). The average polygon size in these areas is 3.3 ha, a reflection of the complexity of terrain features, ecosystems and seral stages. 34% of the bioterrain polygons were checked with at least one field site. The Bypass Road area was mapped at 1:20,000 scale at TSIL C. The average polygon size was 5.4 ha, and 34% of polygons were field-checked (Table 2-2).

Table 2-2: Terrain survey intensity level for bioterrain mapping.

T-LSA Sub-Area	Mapping scale	Area (ha)	# of polygons	Avg. polygon size (ha)	Field checks		Polygons field checked		TSIL
					#	/100 ha	#	%	
Minesite, Goathorn Creek and Rail Infrastructure	1:5,000	2,845.5	861	3.3	634	22	295	34%	B
Bypass Road	1:20,000	567.7	105	5.4	67	11	36	34%	C
Total		***3,413.2***	***966***		***701***		***331***		

Terrain Stability Mapping – Field Work and Survey Intensity

Field sampling for terrain stability mapping was done concurrently with bioterrain sampling. Additional information was collected where possible such as information regarding soil consistency, compaction and plasticity, and indicators of slope instability and erosion of surficial materials. Additional field sites were visited by the terrain specialist, focussing on steep slopes and active landslide sites along Goathorn Creek and Tenas Creek, on tall road cuts such as along Coalmine Road and the Forest Service Road climbing the west side of Goathorn Creek. Additional field observations on actively eroding stream banks targeted bedrock outcrop sites that constrain fluvial processes; and stratigraphic relations of quaternary deposits that drive slope instability on the Goathorn Creek and Tenas Creek valley walls.

The terrain field information was compiled in a terrain field information table which includes spatial (plot location) and attribute data (site observations). The plot locations were imported into ESRI Systems ArcInfo Geographic Information System (GIS) (ArcGIS 10.4) and the site information was used to delineate and attribute terrain stability polygons.

The Minesite, the Rail Infrastructure and the Goathorn Creek T-LSA sub-areas were mapped at a scale of 1:5,000 at TSIL B). The average polygon size in these areas was 4.8 ha and 50% of polygons were field-checked. The Bypass Road sub-area was mapped at 1:10,000 scale at TSIL C. The average polygon size was 6.6 ha, and 41% of polygons were field-checked (Table 2-3).

Table 2-3: Terrain survey intensity level for terrain stability mapping.

T-LSA Sub-Area	Mapping scale	Area (ha)	# of polygons	Avg. polygon size (ha)	Field checks		Polygons field checked		TSIL
					#	/100 ha	#	%	
Minesite	1:5,000	2,080.2	330	6.3	336	16	141	42%	
Goathorn Creek	1:5,000	484.5	200	2.4	217	45	121	60%	
Rail Infrastructure	1:5,000	240.99	52	4.6	71	29	31	59%	
All 5k mapping	1:5,000	2,804.6	584	4.8	615	22	293	50%	B
Bypass Road	1:10,000	508.35	77	6.6	67	13	32	41%	C
Total		***3,314.1***	***659***		***682***		***325***		

2.3.3 Classification Process, Mapping and Attributing Methods/Standards

The terrain mapping combines surficial geology mapping, landform interpretation and delineation of geologic processes. It follows the *Terrain Classification System for British Columbia* (Howes and Kenk 1997), and the *Guidelines and Standards for Terrain Mapping* (RIC 1996). Terrain polygons were delineated using an ESRI Systems ArcInfo Geographic Information System (GIS) (ArcGIS 10.4). Bioterrain, terrain stability and geohazard information was determined through the interpretation of aerial photographic imagery, LiDAR hillshade imagery, extrapolation from field information, excavator test pits (Westrek Geotechnical Services 2019a and 2019b), existing information on earlier maps, reports and publications, and topographic information such as contours and streams. The terrain interpretation was compiled as polygon attributes using the terrain and drainage codes in Table 2-4 and Table 2-5 respectively. The terrain polygon labels are based on the terrain attributes and are shown on the TSM maps, and are available within the digital files.

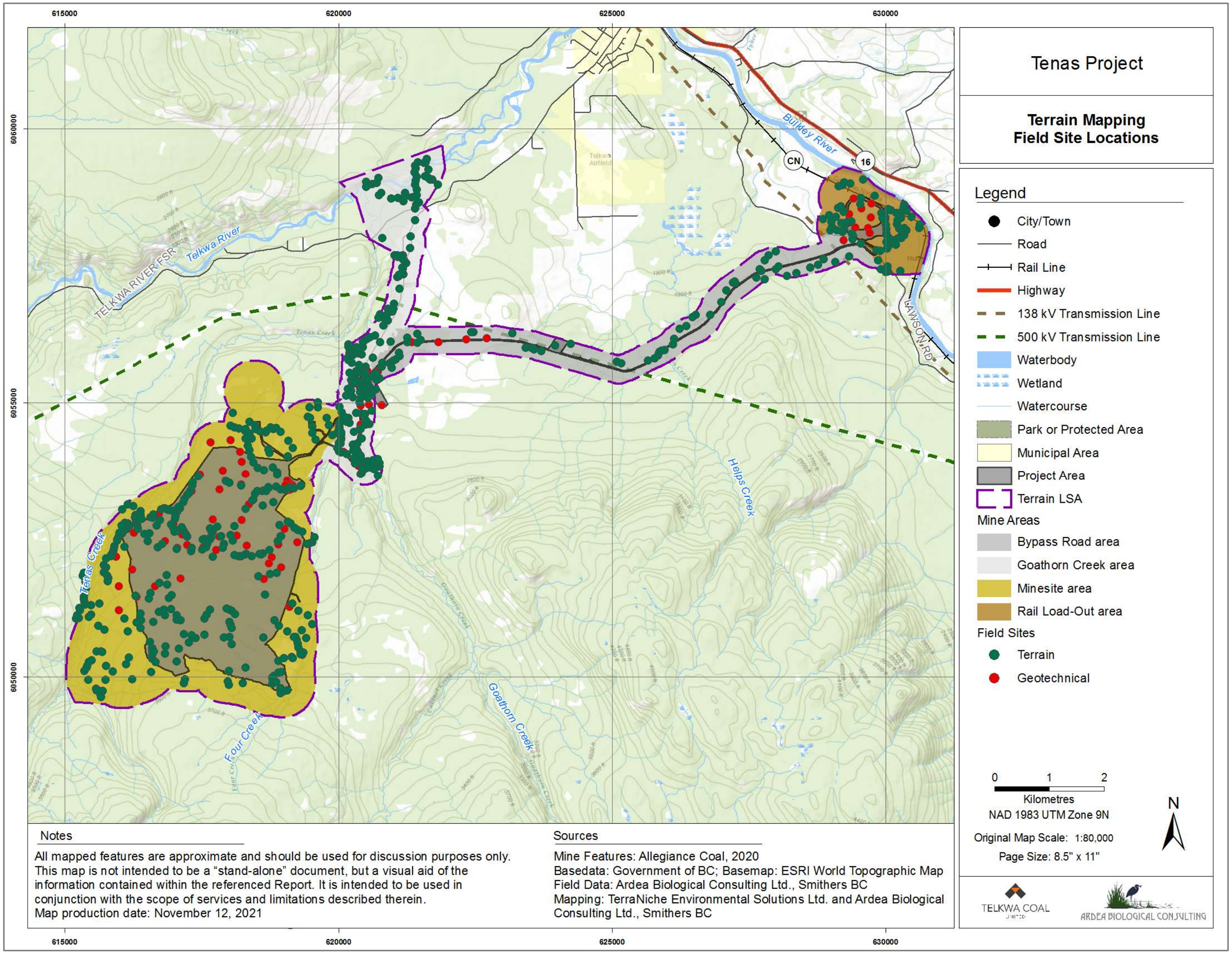

Figure 2-1: Field site locations with terrain information in the T-LSA.

Table 2-4: Terrain codes (Howes and Kenk 1997).

Symbol	Name	Description	
TEXTURE			
a	blocks	>256 mm	angular particles
b	boulders	>256 mm	rounded & subrounded particles
k	cobble	64-256 mm	rounded & subrounded particles
p	pebbles	2-64 mm	rounded & subrounded particles
s	sand	2-0.062 mm	
z	silt	0.062-0.002	
c	clay	<0.002 mm	
d	mixed fragments	>2 mm	mix of rounded and angular particles
g	gravel	>2 mm	mix of boulders, cobbles and pebbles
x	angular fragments	>2 mm	mix of rubble and blocks
r	rubble	2-256 mm	angular particles
m	mud	<0.062 mm	mix of clay and silt
e	fibric	organic	well-preserved fibre; (40%) identified after rubbing
u	mesic	organic	intermediate decomposition between fibric and mesic
h	humic	organic	decomposed organic material;
SURFICIAL MATERIAL			
A	anthropogenic	active	Man-made or man-modified material
C	colluvial	active	Products of mass wastage
D	weathered rock	active	In situ bedrock
F	fluvial	inactive	River deposits
FG	glaciofluvial	inactive	Fluvial materials deposited by meltwater streams
L	lacustrine	inactive	Lake sediments; includes littoral deposits
LG	glaciolacustrine	inactive	Sediments deposited in glacial lakes
M	morainal	inactive	Material deposited directly by glaciers
O	organic	active	Accumulation/decay of vegetative matter
R	bedrock		Outcrops/rocks covered by less than 10 cm
U	undifferentiated		Layered sequence; three materials or more
SURFACE EXPRESSION			
a	moderate slope		Unidirectional surface; 16 to 26°.
b	blanket		A mantle of unconsolidated materials; >1m thick.
c	cone		A cone or sector of a cone; >15°.
d	depression		A sharply demarked hollow.
f	fan		A sector of a cone ; up to 15°.
h	hummocky		Hillocks and hollows, irregular plan; 15 to 35°.

Symbol	Name		Description
j	gentle slope		Unidirectional surface; 4 to 15°.
k	moderately steep		Unidirectional surface; 27 to 35°.
m	rolling		Elongate hillocks; parallel in plan; 3 to 15°.
p	plain		Unidirectional surface; 0 to 3°.
r	ridged		Elongate hillocks; parallel in plan; 15 to 35°.
s	steep		Steep slopes; >35°.
t	terraced		Step-like topography.
u	undulating		Hillocks and hollows; irregular in plan; 0 to 15°.
v	veneer		Mantle of unconsolidated material; 10cm to 1m thick.
w	variably thick mantle		Surficial material of variable thickness; 0 to about 3 m.
x	thin veneer		Similar to veneer; 2-20 cm thick.
GEOMORPHOLOGICAL PROCESS			
A	avalanches	active	Terrain modified by snow avalanches
B	braiding	active	Diverging/converging channels; unvegetated bars
E	channeled	inactive	Channel formation by glacial meltwater
F	slow mass movement	active	Slow down-slope movement of masses of cohesive or non-cohesive material and/or bedrock
H	kettled	inactive	Depressions due to the melting of buried glacier ice
I	irregular channel	active	A single, clearly defined main channel displaying irregular turns and bends
J	anastomosing channel	active	A channel zone where channels diverge and converge around vegetated islands
L	surface seepage	active	Abundant surface seepage
M	meandering channels	active	Channels characterized by regular patterns of bends with uniformed amplitude and wave length
P	piping	active	Subterranean erosion by flowing water
R	rapid mass movement	active	Rapid downslope movement of dry, moist or saturated debris
U	inundation	active	Seasonally under water due to high water table
V	gully erosion	active	Parallel/subparallel ravines due to erosion by various processes

Table 2-5: Soil drainage classes (BC MOFR & BC MOE 2010).

Symbol	Name	Description
vr	Very rapidly drained	Water is removed from the soil very rapidly in relation to supply. There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient. Soil are usually coarse textured, or shallow, or both. Water source is precipitation.
r	Rapidly drained	Water is removed from the soil rapidly in relation to supply. Subsurface flow may occur on steep gradients during heavy rainfall. Soil are usually coarse textured, or shallow, or both. Water source is precipitation.

Symbol	Name	Description
w	Well drained	Water is removed from the soil readily but not rapidly. Soil are generally intermediate in texture and depth. Water source is precipitation. On slopes subsurface flow may occur for short durations.
m	Moderately well drained	Water is removed from the soil somewhat slowly in relation to supply due to shallow water table, lack of gradient, or some combination of these. Soil are usually medium to fine textured. Precipitation is the dominant water source in medium to fine textured soil; precipitation and significant additions by subsurface flow are necessary in coarse textured soil.
i	Imperfectly drained	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing-season.
p	Poorly drained	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Subsurface flow or groundwater flow, in addition to precipitation are the main water sources, with precipitation exceeding evapotranspiration.
vp	Very poorly drained	Water is removed from the soil so slowly that the water table is near or at the surface for the greater part of the time the soil is not frozen. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important.

Bioterrain Mapping

Classification process: Terrain polygons depict landscape units which are relatively homogenous regarding surficial material and texture, surface expression, geomorphic processes. In addition to these terrain features, bioterrain polygon delineation takes into account site characteristics relevant to site ecology, e.g. drainage, aspect, or slope position. To better reflect the ecological patchwork associated with the widespread logging and agricultural history in the study area, the bioterrain polygons were adjusted to conform to significant, often man-made vegetation changes at the cost of strict conformity to the underlying landform. The delineated and attributed bioterrain polygons were further interpreted, and possibly split, by a soil ecologist and a vegetation ecologist. The identification of soil management units (SMU) was based on bioterrain polygon delineation and attributing.

Attributing standards: Bioterrain polygon attributes were compiled in standard short form attribute fields that form part of the standard TEM attribute table (BC MOE 2012). Up to three terrain components were described per polygon with deciles indicating the distribution of each component. The label includes the surface and subsurface material, texture and surface expression for each component. Geomorphic processes and drainage classes were also recorded in the attribute table. The polygon attributes are available as bioterrain polygon labels (Figure 2-2) within the bioterrain digital file.

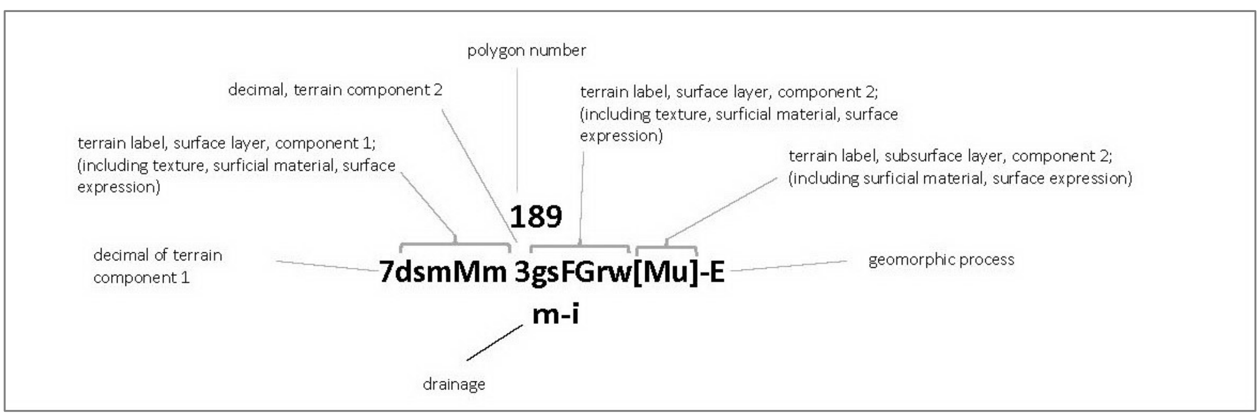

Figure 2-2: Example bioterrain polygon label.

Terrain Stability Mapping

Classification Process: Terrain stability polygons depict landscape units that are relatively homogeneous regarding terrain stability ratings and surface erosion potential. The delineation of terrain stability polygons takes into account the terrain criteria used to classify terrain stability and surface erosion potential such as surficial material origin and texture, material thickness, surface expression including slope angle and slope breaks, drainage and geomorphic processes including evidence of active or past terrain instability.

Table 2-6: Terrain stability classes (from BC MOF & BC MOE 1999).

Terrain Stability Class	Description
Class I	No significant problems of terrain stability are expected
Class II	No significant problems of instability are expected; low likelihood of minor inclusions of sensitive terrain
Class III	Minor problems of instability may occur; minor inclusions of sensitive terrain are possible but no slope failures occur
Class IV	Problems of instability are expected; marginally stable slopes and sensitive terrain exists. Natural landslides are rare but terrain conditions are similar to nearby unstable slopes; or evidence of small- scale instability or excessive steepness exists.
Class V	Significant problems of instability are expected; active or recurrent landslides initiate within mostly steep terrain. Sensitive terrain is common, such as steep-sided gullies; site with seasonally high soil pore water pressure; undercut tall stream banks.

Each polygon was assigned a terrain stability class that estimates the terrain stability (i.e. the likelihood of landslide initiation occurring within the polygon) following land clearing and / or road construction (Table 2-6). Each of the five standard terrain stability classes provides a relative ranking of mass movement potential but gives no indication of expected landslide frequency, magnitude or impact. Table 2-7 lists the terrain criteria used in this study to assign the terrain stability class. These criteria have been developed subjectively based on reviews of existing terrain stability mapping in the northwest Interior of BC, as well as on field observations of slope instability and surface erosion during the field work in the study area, combined with the mapper's previous experience in northwest BC.

Table 2-7: Terrain criteria for stability classification.

Stability Class	Slope Gradient[1]	Material Characteristics and Landforms	Slope Process	Slope Drainage[2]	Slope Morphology[3]
I	< 25% (< 14°)	Medium-coarse textures: ablation till, weathered rock, colluvium, (glacio) fluvial, bedrock	None	Well to moderate	flat, uniform or undulating, gently rolling
	< 15%	Fine-textured glacial (basal) till			
	< 10% (< 6°)	Fine textures: (glacio) lacustrine; Organics			
II	20-50% (11-27°)	Coarse-textures: ablation till, colluvium, (glacio) fluvial, rock-dominated, irregular ground with discontinuous coarse textured veneers	None		Uniform, gently sloping; strongly ridged or moderately dissected (-E)
	10-40% (6-22°)	Medium textured ablation till, colluvium			

Stability Class	Slope Gradient[1]	Material Characteristics and Landforms	Slope Process	Slope Drainage[2]	Slope Morphology[3]
II	10-30% (6-17°)	Fine-textured (glacio) lacustrine, basal till (clay matrix, low coarse fragment content)			
III	40-70% (22-35°)	Rock-controlled complexes of coarse to medium textured till, coarse angular colluvium and/or (glacio) fluvial	None	Well-drained	Slightly irregular
	30-70% (17-35°)	Erosional, constructional, or mantled slopes of medium-coarse textured till, colluvium, and/or (glacio) fluvial	Inactive or minor gullying	Well to moderately drained	Uniform
	25-65% (14-33°)	Medium to finer textured till and colluvium			
	20-50% (11-27°)	Fine-textured glaciolacustrine and basal till (clay matrix, low coarse fragment content)	None, or inactive slump blocks		Uniform or irregularly benched
IV	65-80% (33-38°)	Coarse-textured (glacio) fluvial	Minor dry ravelling	Well to rapid	Short slopes, e.g. terrace scarps
	20-50% (11-27°)	Fine-textured (glacio)lacustrine. Fine-medium sand deposits	Inactive or minor gullying.	Moderate to imperfect	
IV	> 70% (> 35°)	Coarse-textured colluvium & (glacio) fluvial; bedrock and coarse colluvial mantles	Inactive or minor gullying; ravelling or minor rockfall		Moderate to long, uniform slopes
	> 65% (> 33°)	Coarse-textured till			
	> 60% (> 30°)	Medium to fine textured till, colluviated till and clay-rich mine waste; (glacio) fluvial with finer interlayers	None or inactive small-scale sloughs or minor gullying	Well to moderate, locally imperfect	
	30-65% (17-33°)	Fine-textured (glacio) lacustrine; fine-textured or interlayered glacial till	Inactive slump blocks; small-scale slump-flows; minor creep inactive or minor gullying		Slightly to strongly irregular; stepped micro-topography due to slow creep
	15-50% (8-27°)	Fine-textured fill related to past mining activity	Active tension cracks		
V	Any	All	Active landslides; recurrent failures; active small-scale instability; accelerated creep with open tension cracks		

Stability Class	Slope Gradient[1]	Material Characteristics and Landforms	Slope Process	Slope Drainage[2]	Slope Morphology[3]
V	>60% (> 30°)	Fine-textured (glacio) lacustrine and clay-rich till; clay rich fill related to past	None		
	> 40% (> 22°)	Mining activity	Gullied or creeping		

Notes: 1) Polygons with gradients dominantly within 5-10% of an upper gradient range, may be assigned to the next highest stability class; units with gradients dominantly close to a lower gradient range may be assigned to the next lowest stability class

2) Wet slopes or those with prominent seepage sites may be assigned to the next highest stability class.

3) Bedrock-controlled slopes with irregular or benched topography have greater inherent stability and may be assigned to the next lower stability class; open slope units with prominent concave contours may be assigned to the next higher stability class.

Each polygon was also assigned a rating of the in-situ erosion potential of the surficial material (Table 2-8). This rating estimates the potential for generating sediment that could be delivered to a stream or lake, during and after road construction or land clearing (including stripping of organic material / top soil), and at fresh landslide sites where the surficial material is exposed to rain and, more importantly, to intermittent flow in road side ditches and across road cuts, and to seasonal overland flow during snow melt.

Table 2-8: Ratings of surface erosion potential (from BC MOF & BC MOE 1999).

Surface Erosion Ratings	Description
VL	Very Low; No or only minor surface erosion
L	Low; expect minor erosion of fines in ditch lines and where mineral soil is disturbed.
M	Moderate; expect moderate erosion when water is channeled down road surfaces or ditches
H	High; significant erosion problems can be created when water is channeled onto or over exposed surface material on these sites.
VH	Very High; severe surface erosion and gully erosion problems can be created when water is channeled onto or over these sites.

The interpretation of surface erosion potential considers terrain criteria such as surficial material texture, soil drainage, slope gradient and morphology, geomorphic process, landscape position and thickness of the deposit, with a qualitative rating assigned based on interpretation of those criteria:

- *Texture:* Fine textured sediments have a higher potential for entrainment than medium-textured materials. Non-cohesive sand and silt deposits are more easily entrained by surface flow than cohesive clay and over-consolidated, clay-bearing glacial till. Glaciolacustrine clayey silt deposits lack the coarse fragment content that allows the development of an erosion pavement and may experience rapid erosion along rills and channels in a single event. Deposits with low permeability, e.g. clayey silt, retain soil moisture for a longer period of time following soil saturation such as during spring snowmelt and remain sensitive to mechanical disturbance and entrainment by running water during this period of reduced cohesive strength. Once entrained by flowing water, clay and fine silt stay in suspension for considerable time even in natural or constructed sediment ponds and are more difficult to manage with erosion control measures than sand and coarse silt. Coarse-textured materials and mixed materials with a higher content of large coarse fragments (e.g. coarse gravel; > 20 mm diameter) will have a relatively low entrainment and transport potential.

- *Drainage:* Imperfectly to poorly drained sites, and lower slope receiving sites are more likely to experience seasonal overland flow (snow melt, intense rain fall) and higher flow volumes than dry upper slopes. Clay soil on seepage sites have a softer consistency than on dry, shedding sites and are more easily entrained. Overbank deposits on active floodplains can be eroded by overland flow during floods.
- *Gradient:* As slopes steepen, a higher energy erosional environment exists: (1) road or trail grades tend to steepen to gain elevation, accelerating road run-off; (2) a taller cut slope exposes more surface area than on gentler slopes.
- *Material thickness:* Thicker deposits have a higher potential for sediment yield because more surficial material may be exposed than on shallow-to-bedrock sites.
- *Geomorphic process:* Active landslide scars and sites prone to mass wasting and exposure of surficial material are likely exposed to post-landslide erosion. Deeply gullied slopes are the product of past 'surface erosion' and are apparently erodible.

Attributing Standards: The terrain stability polygon attributes were compiled in a standard attribute table following the format outlined within the TEI_LONG_Terrain_Fields database (BC MOE 2012). Up to three terrain components and their relative abundance were identified in each polygon, using the terrain classification codes listed in, including texture, genetic material type, and surface expression of the surface and subsurface material. Four subtypes of glacial till were identified (Table 2-4). Up to three geomorphologic process classes were identified per polygon, including process class, qualifier, initiation zone indicator, and process subclass. Two soil drainage classes (Table 2-5) and a drainage class separator, as well as the dominant and subdominant slope range were identified; terrain stability class and surface erosion potential ratings were assigned to each polygon. Other polygon attributes include a polygon number, field check indicator and field site number. The terrain polygon attributes are shown as terrain polygon labels (Figure 2-3) on the terrain stability map.

Additional Information: Site-specific information about geomorphic processes was collected during the mapping to assist in the interpretation of surficial geology patterns and mass wasting activity. Onsite line symbols were used to depict landslides, glacial features such as kettles, eskers and meltwater channels. These on-site symbols were recorded in a separate spatial file and attributed in a custom format.

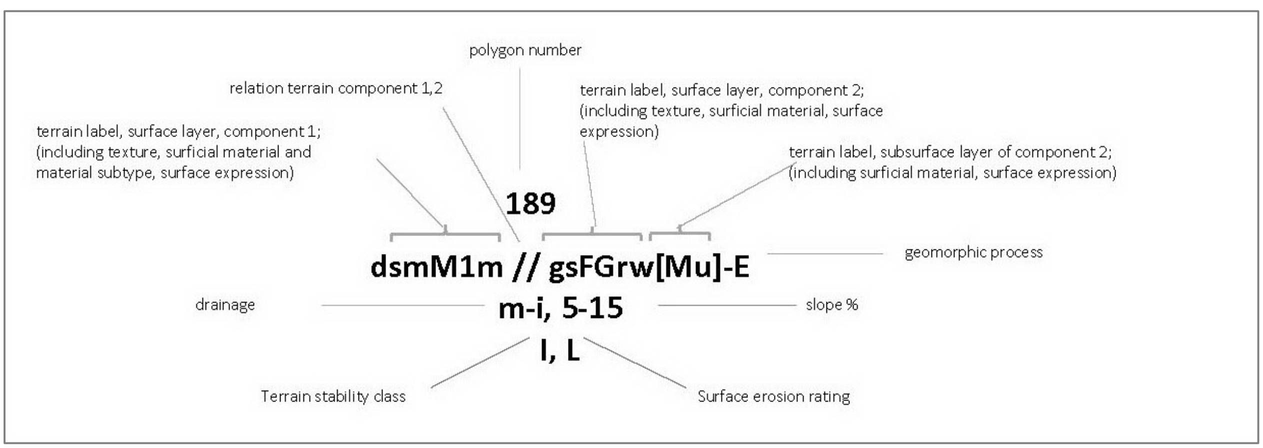

Figure 2-3: Example terrain stability polygon label.

2.3.4 Quality Assurance and Quality Control

Bioterrain Mapping

Quality Assurance (QA) and Quality Control (QC) assessments were carried out on the bioterrain mapping polygons delineation and attributing in 2018 by qualified independent professionals: Claudia Houwers, R.P.Bio., of Houwers Ecological Consulting and Dave Yole, P.Ag. of D. Yole Consulting. Field assessments for the QA/QC were conducted following the same methods as used in the mapping assessments, with the study design outlined in the *Protocol for Accuracy Assessment of Ecosystem Maps* (Meidinger 2003). Plot information was collected across a representative range of sites across the Project area.

Terrain Stability Mapping

The quality assurance (QA) procedure for the terrain stability mapping was modified from the *Quality Assurance Guidelines: Terrain Stability Mapping (TSM)* (MoE. 2010). A field sampling review was carried out in conjunction with the bioterrain field sampling QA review by Dave Yole, P.Ag, Claudia Houwers, R.P.Bio. The review included a review of field data consistency and incorporation into polygon attributing. Final terrain stability mapping was reviewed in-house by D. Maynard under the supervision of Irene Weiland, P.Geo and included the following: polygon delineation on Lidar hillshade imagery and orthophoto imagery; polygon attributing such as incorporation of field findings, incorporation of principles of quaternary geology and published quaternary history in the study area, and consistent application of interpretation criteria.

2.4 Data Summary

The geomorphic history described below was developed from published information and from field observations made during the mapping. It describes the depositional environments for the surficial materials found in the study area. It provides a context for the description of landforms, surficial material textures and distribution described in section 0 and for the geomorphic processes described in section 2.4.3. Findings regarding terrain stability and surface erosion concerns are presented in section 2.5.1. Natural hazards that impact the project are described in 2.5.2.

2.4.1 Geomorphic History

The bedrock underlying the study area dates back to the Jurassic and Cretaceous age. The coal-bearing Lower Skeena Group consists of interbedded marine and non-marine clastic sedimentary rocks that formed 97 to 145 million years ago during the Lower Cretaceous age. This sequence unconformably overlies volcanic rocks of the Lower Jurassic Telkwa Formation of the Hazelton Group, which formed during a period of intense volcanism between roughly 160 to 190 million years ago. The Telkwa Formation consists of pyroclastic rocks, maroon, green and purple subaerial lava flows and tuffs. The area was later intruded by Late Cretaceous intrusive rocks and was subject to widespread block faulting (MEMPR 2019, Matheson et al. 1990).

The mountain ranges and major valleys around the study area became established in early to middle Tertiary time following uplift of the Coast and Intermontane mountains. Wide-spread block faulting forming horst and grabens followed by erosion created a patchwork of older and younger geologic units. However, it was the recurrent glacial erosion and deposition during the Pleistocene Epoch which modified the area to its present-day form (Clague 1984). Very few deposits from the early Pleistocene glacial and interglacial periods have been identified in the Bulkley Valley area. Sediments deposited during the last major glaciation (Fraser Glaciation, 29,000 to 8,500 Before Present [BP]) form most of the surficial materials found in the study area. Erosion and deposition during the Holocene (post-glacial time) have further modified the landscape.

At the onset of the Fraser Glaciation, 25,000 to 30,000 BP, the climate cooled and alpine glaciers in the Hazelton and Skeena Mountains expanded (Clague 1984, Stumpf et al. 2004). Ice flowed down mountain valleys such as upper Goathorn Creek and upper Tenas Creek valleys and along the Telkwa River valley. During this glacial advance phase, proglacial meltwater streams deposited glaciofluvial sediments such as gravel and sand, typically raising the pre-existing fluvial base level. Advancing glaciers and aggrading proglacial streams disrupted and locally dammed the drainage system, forming proglacial lakes in the Telkwa River valley and its tributaries such as Goathorn Creek and Tenas Creek. Deltas containing gravel and sand formed at the mouth of glacial meltwater streams feeding into the lakes and thick glaciolacustrine deposits of silt and clay accumulated in the lakes. With further glacier advance, poorly sorted ice-contact sediments such as debris melt-out and ice-rafted diamicton were deposited in the proglacial lakes (Stumpf et al. 2004). Advance-phase silty-sandy glacial sediments were encountered in boreholes in the Minesite area: Gravel and sand underlying glacial till have been documented in boreholes (Piteau Engineering Ltd.1997) along the east side of Tenas Creek[1] and to a lesser degree in the vicinity of Four Creek[2]. Non-cohesive, silty sandy deposits underlying 6 to 20 m of glacial till were encountered in several boreholes[3] by SRK Consulting in 2018 and 2019 (pers. communication, Ed Saunders). A more than 11 m thick, silty clay deposit underlying glacial till was encountered in a borehole[4] on the eastern valley wall of Goathorn Creek and was interpreted as glaciolacustrine deposit (Westrek Geotechnical Services Ltd. 2019b). No advance-phase glacial sediments were encountered at natural exposure sites during the mapping.

As valley glaciers advanced farther out from the ice centres in the Skeena and the Hazelton Mountains, they coalesced in the Bulkley Valley, overriding the advance-phase sediments. Ice emerging from the Skeena and Hazelton Mountains initially moved southeasterly across the Nechako Plateau as well as north and west along the Skeena Valley. With continued ice accumulation, the coalescing glaciers formed part of the Cordilleran Ice Sheet which attained a thickness of over 2,000 m at the glacial maximum, 15,600 to 10,500 BP (Stumpf et al. 2004). In the Bulkley Valley area, ice flow of the Cordilleran Ice Sheet was unconstrained by valley topography and ice flowed in a westerly direction across the Hazelton Mountains towards the Pacific Ocean. The ice eroded older sediments and bedrock and deposited the entrained material down-ice as basal till, a dense diamicton with a silt-loam matrix and subangular clasts of small pebble to boulder-size. Both the matrix and the clasts typically reflect the lithology of the source area; for example, diamicton down-ice of maroon-coloured Jurassic andesite has a distinctive dark reddish-brown colour. In the study area, particularly in the Minesite area, basal till is the dominant surficial material and typically forms a subdued, irregularly undulating landscape. Subtle, 1 to 5 m high, strongly parallel, streamlined flutings with an ENE-WSW orientation form the micro-topography of the basal till, likely reflecting the westerly ice movement during the glacial maximum.

During the later part of the Fraser Glaciation, the Cordilleran ice sheet thinned rapidly through a complex of downwasting and localized frontal retreat. The melting ice left behind supraglacial and englacial debris including boulders, gravel, sand, silt and locally clay. This debris formed a discontinuous blanket of ablation till, about 1 to 2 m thick, that commonly overlies the basal till.

With the thinner ice, the direction of the ice flow again became controlled by local topography (Stumpf et al. 2004; Levson et al. 1998). Glaciers extended from ice centres in the Hazelton and Skeena Mountains along established mountain valleys while upland and mountain ridges emerged from the ice. A wide glacier extended from an ice-centre in the Telkwa Ranges at the headwaters of Goathorn and Tenas creeks towards the Telkwa River valley, covering the Minesite, the Bypass Road and adjacent low-elevation

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[1] Boreholes TOB96-04, T94R-11; T94R-09

[2] Boreholes TOB96-02, TOB96-11

[3] Boreholes T18-02S, T18-03S, T18-04S, T18-07S, T18-11S, T18-12S, T18-13S, , T19-19S, T19-22S T19-34S, T19-35S

[4] Borehole T18-15S (9U 620557E 6054967N)

subdued terrain. Recessional or lateral moraines are uncommon in this part of the study area and rapid downwasting and disintegration of stagnant ice appears to have been the dominant form of deglaciation.

During downwasting, complex subglacial and proglacial meltwater channel systems followed the approximate present-day locations of Tenas Creek, Four Creek and Goathorn Creek, which were not yet incised after earlier infilling with advance-phase sediments and glacial till. Glacial meltwater flowed along subglacial tunnels and along supraglacial or ice-marginal channels and deposited gravel and sand between blocks of disintegrating ice, leaving a landscape of disorganized gravel and sand ridges and several glacial ponds which infilled with silt and clay. Associated glaciofluvial landforms include eskers[5] and irregularly undulating and hummocky kame deposits[6] while glacial ponds are now occupied by wetlands. Glacial meltwater in the vicinity of present-day Goathorn Creek emerged from the gradually retreating ice front and continued as proglacial meltwater flow, locally forming several braided sander deposits and proglacial fans. Remnants of these glaciofluvial deposits occur along the eastern shoulders of Goathorn Creek[7].

With further down-wasting and retreat of the local glacier, the Minesite became ice free. Small deglacial landforms such as shallow proglacial lakes and ponds connected by sinuous shallow meltwater channels formed on the almost flat terrain in the northern part of the Minesite. In the gently to moderately sloping southern part of the Minesite, higher energy meltwater eroded 3 to 7 m deep channels into the basal till. Well- to poorly-sorted glaciofluvial kame deposits with clast sizes ranging from small pebbles to cobbles were found at the mouth or at the start of these meltwater features.

While uplands and mountain ridges emerged first during this phase of rapid down-wasting, glacier ice likely remained active in the Bulkley Valley (Clague 1984) and possibly blocked the drainage at the mouth of the Telkwa River. For some time, the base level of Tenas and Goathorn creeks was 80 to 100 m higher than the present-day level, controlled by a proglacial lake in the lower Telkwa River valley at about 700 m elevation, and later at 670 m elevation[8]. A braided meltwater channel[9] occupied the Telkwa River valley and formed a delta advancing into the proglacial lake. As this glacial lake drained, the base level of Tenas and Goathorn creeks dropped rapidly and the creeks became incised 40 to 60 m deep, respectively, into the undulating terrain. Meltwater still emerged from the Tenas and Goathorn valley tongues of the Telkwa Range glacier and contributed to the rapid downcutting of the present-day 'valleys' of lower Goathorn and Tenas Creeks. The erosion cut through the thick sequence of glacial sediments[10] and locally also eroded the underlying sedimentary bedrock[11]. The rapid downcutting over-steepened the valley sidewalls which responded with wide-spread slumping, particularly where advance-phase glaciolacustrine sediments or late-glacial, groundwater-bearing, interbedded gravels, silts and sand are present. Slump blocks on the eastern valley wall of Goathorn Creek form irregular, back-sloped benches (up to 100 m long, 15 to 30 m wide) with slope gradients of 5% to 35% (3° to 20°). Locally, the benches show intact sections of quaternary sediments with gravel overlying till on juxtaposed benches[12]. Where the toe of the valley wall is supported

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[5] E.g. west of Four Creek (fieldsite IW071, 9U 619255E 6050600N), and east of Tenas Creek (field site IW088, 9U 618030E 6054581N)

[6] E.g. east of Tenas Creek, general vicinity of field site IW084, 9U 616830E 6053065N and IR093 (9U 617019E 6052927N)

[7] The 2013 fill slope failure at station 4+650 along the Bypass Road occurred in sandy proglacial sediments that had been reworked during earlier mining operations and road construction.

[8] Interpreted from LiDAR hillshade imagery.

[9] This is the origin of the extensive gravel deposit on a bench above the Telkwa River, locally known as "Hydro Hill".

[10] Including the recent glacial meltwater deposits (1 to 10 m thick gravel and sand), the underlying basal till (3-10 m thick diamicton) and the advance-phase glaciofluvial and glaciolacustrine sediments (0 m to > 30 m thick sand, silt and clay)

[11] Along upper Tenas Creek and along numerous sections of Goathorn Creek.

[12] E.g. field sites IW231, IW232

by bedrock, slope gradients have locally become over-steepened (>60% to 80%; >30° to 40°) and shallow (translational) debris slides have occurred.

Once the glacial lake at 670 m elevation in the Telkwa River valley drained, a smaller, distal, proglacial lake remained at the confluence of the Telkwa River and Bulkley River valleys, with a lake elevation of 555 m. It is possible that the glaciofluvial fan and plain of lower Goathorn Creek that underlies the Coalmine Road subdivision was graded to this lake level. Nothing is known about a possible blockage of the outlet of this lake. However, there is evidence that this proglacial lake covered the Rail Infrastructure area and the east end of the Bypass Road where a continuous blanket of glaciolacustrine silt mantles the undulating terrain up to 555 m elevation. The bottom of the glacial lake was approximately at 500 m elevation[13] (Westrek Geotechnical Services 2019a) and possibly deeper under the Bulkley River floodplain. The late-glacial lake level eventually dropped to 525 m elevation, leaving an even smaller lake extending from the Skillhorn Road subdivision into the Bulkley Valley. Again, nothing is known about the feature that dammed this lake. With the late-glacial Telkwa River and Bulkley River both flowing into this lake, the lake filled with silt, fine sand and clay up to 525 m elevation, forming a mudflat or seasonal, very shallow lake. The late-glacial Telkwa River built a large fan (now occupied by the Skillhorn Road subdivision) onto this mudflat, then shifted its main channel away from the area towards the present-day confluence with the Bulkley River. The late-glacial Bulkley River flowed into the south end of the lake, eroding low-gradient shallow channels into the mudflat and depositing a mantle of pebbles and sand. This gravel-sand deposit was mapped as a glaciofluvial plain at 525 m elevation adjacent to the Rail Infrastructure area and Lawson Road.

The Bulkley Valley likely became ice free around at 9,500 BP (Clague 1984). Rapid erosion and fluvial deposition in the first 1,000 years after deglaciation shaped the present-day floodplain of the Bulkley River: The early postglacial Bulkley River eroded a channel into the glaciolacustrine and glaciofluvial plain at 525 m elevation, creating a long, 10 to 15 m high terrace scarp. The present-day floodplain of the Bulkley River is at 510 to 515 m elevation and consists of approximately 4 m of sand and gravel overlying glaciolacustrine silt (Westrek Geotechnical Services 2019a). Near the Rail Infrastructure area, the contemporary Bulkley River forms an almost straight, single gravel bed channel along the east side of its floodplain and experiences moderate rates of progressive lateral bank erosion. Remnant channel depressions on the floodplain experience seasonal, groundwater-fed flooding and a part of the floodplain is inside the 200-year floodplain zone (BC MOE 1984).

Currently active geologic processes include mass wasting and fluvial processes. Mass wasting processes affect the valley walls of Goathorn Creek and Tenas Creek; slope instability occurs where the slope is saturated by surface water or groundwater and where slopes are undercut by the present-day stream channel .Fluvial processes continue to shape the floodplains of the Telkwa River, of Goathorn Creek and Tenas Creek, and to a lesser degree, of the Bulkley River.

2.4.2 Characteristics of Surficial Materials

The following section describes the characteristics of the surficial materials in the study area (**Error! Reference source not found.**), organized by depositional age; including the typical and atypical textures that were encountered, the typical surface expression of landforms associated with these materials; and implications for soil development, ecology, terrain stability, surface erosion and subsurface water pathways.

Bedrock outcrop (R) and weathered rock (D)

Bedrock outcrop in the study area represents the volcanic rocks of the Lower Jurassic Telkwa Formation which consists of pyroclastic rocks and lava flows such as maroon, green and purple subaerial andesitic to dacitic feldspar phyric flows, pyroclastic and epiclastic rocks, basalt, breccia, welded tuff; and the marine

[13] Borehole T18-17S

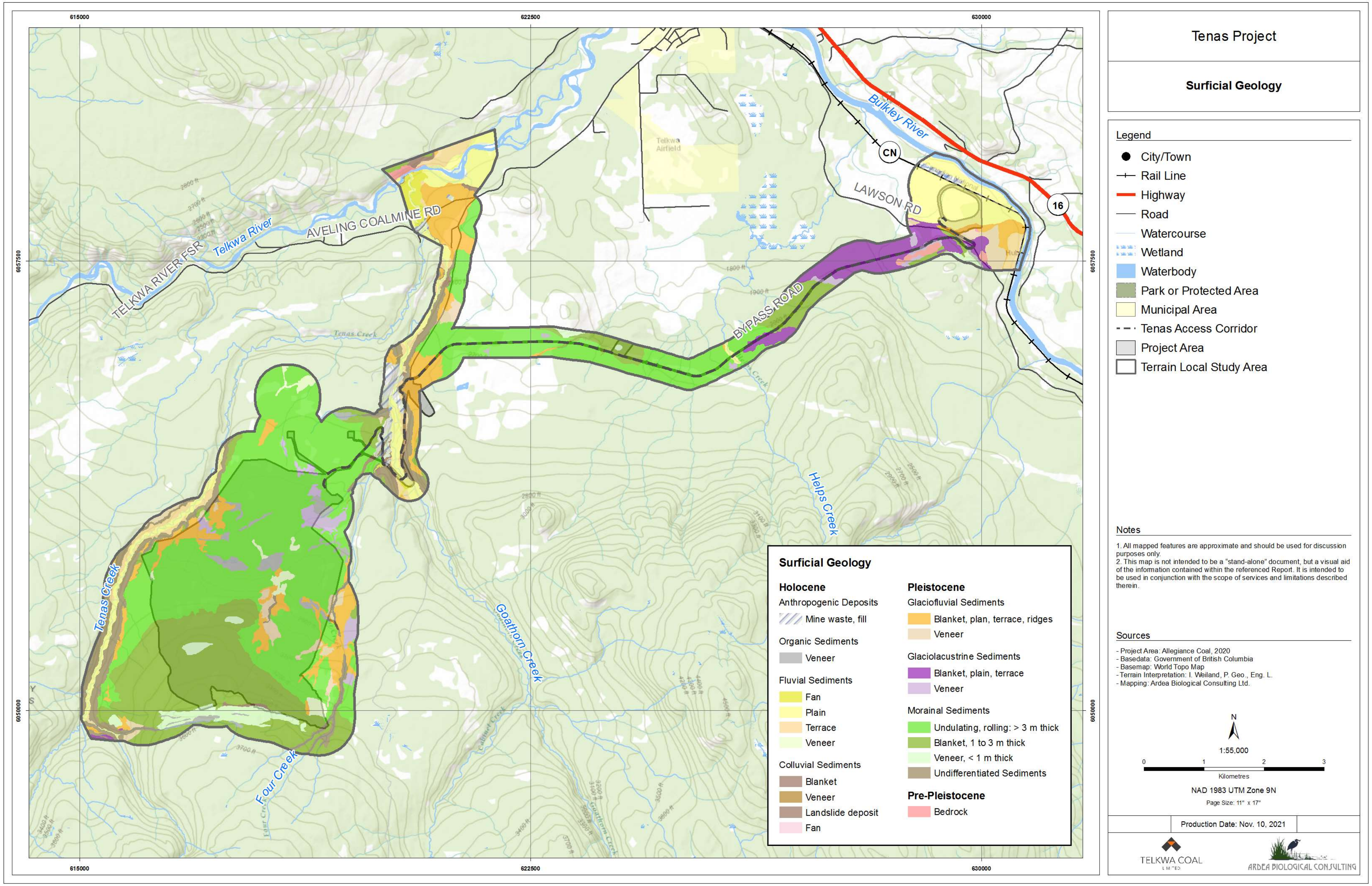

Figure 2-4: Overview of surficial materials in the T-LSA.

and non-marine, clastic sedimentary rocks of the Lower Cretaceous Skeena Group which consists of sandstone, siltstone, shale, conglomerate and coal. Locally, granitic intrusive rocks of the Late Cretaceous Bulkley Plutonic Suite occur just outside the study area (BC MEMPR 2019). The bedrock type and tectonic characteristics greatly influence today's landscape through their response to weathering and erosion. The fine-grained tuffs, mudstone and shales contribute to a fine matrix texture in glacial till and residual materials such as colluvium and weathered rock. Harder volcanics and sandstone-conglomerate rocks contribute to sandier, coarser textures.

Weathered rock and bedrock outcrops are relatively uncommon in the study area. They are marked on the TSM map (Appendix C) with an on-site point symbol. Bedrock outcrop was found along valley walls of incised streams and occasional small hummocks that emerge above the thick sequence of glacial sediments.

In the Minesite area, weathered rock overlying bedrock was found at 1,000 m elevation in the southern part of the area.

Bedrock outcrop occurs along the valley walls and the valley floor of Goathorn Creek. An outcrop of thinly-bedded siltstone above the Caribou FSR forms a 5 m high cliff band with a 15 m high colluvial slope below (Plate 2-1). Mudstone weathers readily in-situ to 0.5 m to 1 m depth and forms small, angular particles with 2 to 3 cm diameter in a silty matrix (Plate 2-2). Thinly-bedded, coal-bearing sandstone and conglomerate is exposed in stream banks and on the Goathorn Creek valley wall, reaching 2 to 30 m height above the valley bottom (Plate 2-3). The rock fractures easily forming small to foot-sized platy particles. Coal bearing sedimentary rock is also exposed along the recently eroded streambanks of Goathorn Creek (Plate 2-4).

Hard volcanic rock forms 10 m high cliffs on the west and east side of Goathorn Creek at the Water Survey of Canada hydrometric station.

Near the Rail Infrastructure and along the eastern Bypass Road, small hummocks protrude from the quaternary sediments with 1 to 2 m high outcrop of hard volcanic rock (e.g. field site IR246).

A 2 to 3 m high bedrock outcrop of crudely stratified conglomerate rock controls part of the Goathorn Creek fan at the confluence with the Telkwa River.

Outcrops of fine-textured sedimentary rock are prone to ravelling or rock fall, and locally to shallow debris slides in rubbly weathered rock. Outcrops of volcanic bedrock are typically stable. Weathered sedimentary

Plate 2-1: Bedrock cliff and ravelling colluvial slope along the Caribou FSR, fieldsite IW122.

Plate 2-2: Soil pit in rubbly weathered mudstone, Caribou FSR, fieldsite IR131.

Plate 2-3: Bedrock outcrop, valley wall of Goathorn Creek, field site IW280.

Plate 2-4: Bedrock outcrop, recent erosion, Goathorn Creek streambank, field site IW247.

rock typically has a silty-sandy matrix that can be easily entrained by surface flow; however, where it forms thin veneers over bedrock surface erosion potential is limited. Bedrock sites have a wide range of permeability for subsurface water flow depending on the degree of fracturing and jointing.

Morainal material (M)

Glacial till (moraine) is material transported by and deposited directly from glacier ice during the last glaciation. It is a poorly-sorted mixture of a fine-textured matrix and subrounded or subangular rock fragments of all sizes. Pedology Consultants (1983) distinguish between a dense, impervious basal till, commonly mantled by a thin, loose compacted, sandy-textured ablation till. Levson et al. (1998) describe the till in the Babine and Hazelton Mountains as “a massive, matrix-supported, dense silty diamicton”, which was deposited during the last glacial maximum, with westerly ice flow from the Babine Mountains across the Hazelton and Coast Mountains to the Pacific Ocean. Stumpf et al. (2004) describe the basal till in the Bulkley River area as a massive, matrix-supported silty diamicton that was deposited during the last glacial maximum of the Fraser Glaciation Its overall colour and clast content reflect the underlying sediments or bedrock, e.g. the maroon colour of the lower Jurassic Telkwa Volcanics. Stumpf also describes a sandier, less consolidated till deposit of englacial or supraglacial origin that forms a thin mantle overlying the basal till or bedrock.

Basal till was encountered throughout the Minesite area, along the Bypass Road and within the Goathorn Creek area. The deposit is typically a dark brown to maroon, highly consolidated matrix-supported diamicton consisting mostly of clay and silt, some sand, with 15 to 35% pebbles[14] and cobbles, and a few small boulders. At relatively fresh exposure sites (failing stream banks, road cuts and excavator test pits) the till was stiff to very stiff. Hand-textured samples had a low to high plasticity. Basal till is typically mapped as **dsmM.** The material is often associated with moist sites due to imperfect drainage, but can be dry on convex microsites. Basal till is exposed in numerous shallow debris slides along Goathorn Creek where the toe of slope was undercut and was also found in small slumps on the east side of Goathorn Creek along the Coalmine Road. Numerous geotechnical bore holes in the Minesite area intersected basal till, where it typically forms a massive deposit with a thickness ranging from 10 m up to 60[15] m overlying bedrock.

[14] Rounded particles 2-64 mm in diameter.

[15] SRK drilling program 2019; borehole T19-26S

Several boreholes[16] encountered an upper and lower glacial till separated by 2 to 25 m thick deposits of silty sand, sandy silt and locally clay. These fine-textured glaciofluvial or glaciolacustrine deposits were encountered at a depth of 6 m to 20 m below surface.

Basal till was typically stable on slopes less than 50% (26°) slope angle; well to rapidly drained sites can be stable up to 70% (35°) slope while imperfectly drained sites steeper than 50% (26°) typically show signs of creep, tension cracks or past small debris slides. While basal till is typically strongly cohesive, it becomes susceptible to surface erosion once the material has become weathered or saturated. The surface erosion potential is initially mitigated by the high degree of consolidation of the unweathered material and eventually by the coarse fragment content. Basal till is has a low permeability for subsurface water flow.

Ablation till was encountered in many shallow, hand-dug soil pits in the Minesite area and along the Bypass Road and water pipeline. The textures were silt-dominated with a very low clay content and a coarse fragment[17] content of up to 40 to 50%, including pebbles, cobbles and small boulders. Ablation till has a pale brown to tan colour; cohesion ranges from none to weak; compaction can be loose to dense. Ablation till is mapped as **dszM** or **zdsM**. It typically occurs as a thin mantle over basal till and does not affect terrain stability as much as the underlying basal till. Ablation till is prone to surface erosion due to its silty texture and low cohesion. While the silty-sandy matrix and the smallest pebbles are easily entrained by surface flow, the rate of erosion is greatly reduced once the remaining clasts form an erosion resistant surface. Ablation till has a higher permeability for subsurface water than basal till.

In the Minesite area, a correlation was established during the mapping between glacial till textures observed in the field and the surface expression of subtle landforms visible on the LiDAR-based hillshade image. Four sub-types of glacial till were distinguished.

Subtype M1: The typical surface expression is a pattern of strongly parallel, straight flutes of about 1 to 2 m height and 20 to 30 m length with an east-north-east to west-south-west orientation. Areas with this pattern were interpreted as **basal till** deposited during westerly ice flow during the last glacial maximum (Plate 2-5). The dark brown to maroon colour of the basal till is consistent with regional ice movement across the maroon-coloured, regionally wide spread, Lower Jurassic andesite ('Telkwa Volcanics'), rather than the locally underlying, pale brown sedimentary rocks of the Lower Skeena Group. This subtype of glacial till is common in the very gently sloping northern part of the Minesite. It is locally overlain by ablation till features (M3).

Subtype M2: Highly consolidated glacial till with a high content of coarse fragments such as cobbles and boulders. Erratics may be present. The matrix texture is highly variable with silty-sandy and clayey-silty layers. The micro-surface expression appears uniform with a noticeable absence of small features such as ridges or flutings. Small patches (several hectares in size) were found in the northern part of the Minesite. Sites underlain by this till subtype were typically poor growing sites.

Subtype M3: This till subtype forms thin mantles of silty-sandy diamicton that was deposited as **ablation till** (Plate 2-6)**.** Typical textures are silt-dominated and contain sand, a little clay and subangular, mostly pebble-size clasts. The matrix colour is highly variable, ranging from pale grey to maroon. The material is typically loose to compact and its thickness appears to be 1 to 3 m. It was commonly associated with a pattern of irregular, narrow, 1 to 2 m high micro-ridges, between 5 and 100 m long. Many of the micro-ridges were oriented towards a drainage feature such as a gully or glacial meltwater channel or glacial pond. The deposit was interpreted as supraglacial debris, with the debris that filled supraglacial rills and holes now forming the micro ridges. Also included in this till subtype were isolated, distinct, 1 to 3 m high, narrow-crested ridges that consist of a clay-rich matrix with a low clast content. While this texture resembles

[16] SRK drilling program 2018 and 2019; boreholes T18-02S, T18-03S, T18-04S, T18-07S, T18-11S, T18-12S, T18-13S, T19-19S, T19-22S, T19-34S, T19-35S.

[17] Coarse fragments are soil particles larger than 2 mm in diameter, e.g. pebbles, cobbles, boulders, rubble and blocks

basal till, the orientation of the ridges towards meltwater features suggests that the features are associated with the ablation phase of glaciation.

The ablation till mapped as subtype M3 typically overlies the basal till M1. The irregular ridges and channels impede the lateral movement of shallow subsurface water and create a patchwork of wetter and drier ecologic units.

Plate 2-5: Basal till (M1) exposed in a landslide upslope of the Goathorn Bridge location, fieldsite IW256.

Plate 2-6: Soil pit in ablation till ridge (M3), field site IR106.

Table 2-9: Glacial till subtype labels[18] and associated typical material textures and surface expression.

Glacial Till Subtype	M1	M2	M3	M4
Map Label	dsmMm	bsmMup	dszMvwr	dszMub
Surface Expression	rolling, gently ridged or fluted with straight, strongly parallel orientation	level or weakly undulating	unifom, gently sloping; can form distinct narrow 1 to 2 m high ridges.	irregularly undulating
Texture	fine-textured matrix; 15-35% coarse fragment content (pebbles and cobbles)	fine- to coarse-textured matrix; 30-60% coarse fragment content dominated by small boulders and cobbles. Erratics may be present.	fine- to coarse-textured; silt-dominated matrix; 30-50% coarse fragments content; sand and pebbles may dominate in ridges.	fine to coarse textured, silt-dominated matrix; typically matrix-supported; 15-55% coarse fragment content.
Other properties	strong cohesion, high consolidation	weak cohesion; high consolidation	weak cohesion; normal consolidation; loose to dense compactness	weak cohesion; normal consolidation; loose to dense compactness

[18] Applied in the Minesite area only

Glaciolacustrine material (LG)

Glaciolacustrine sediments were deposited in lakes that form part of a glacial meltwater system. Sediments typically consist of silt and clay with variable amounts of sand, and locally scattered pebbles. The deposits can be massive or rhythmically layered. Due to the high turbidity of glacial meltwater, sedimentation rates in glacial lakes are typically higher than in present-day lakes.

Advance-phase glaciolacustrine sediments underlying glacial till were encountered in a geotechnical borehole on the east side of Goathorn Creek (Westrek Geotechnical Services Ltd. 2019; T18-15S) at a depth of 19 m below surface. The sediments were described as maroon-coloured, laminated silty clay, silt, and sand, with a thickness >10 m.

Glaciolacustrine sediments occur as surficial deposits in the Minesite area in localized depressions left by late-glacial lake and ponds, typically as veneers **(mLGv)** or thin plains (**LGp**). These sites are typically poorly and very poorly drained and are occupied by thick organic soil or wetlands.

Along 2.3 km of the east end of the proposed Bypass Road a continuous blanket of glaciolacustrine clayey silt (**mLGb**) mantles the undulating terrain. Drainage at these sites is typically moderate and imperfect.

Plate 2-7: Glaciolacustrine silt exposed along the driveway on the McDonald's property near the proposed rail infrastructure at field site IW216.

In the Rail Infrastructure area, glaciolacustrine silty clay was found as surficial material **(zcLGp)** on level terrain near Lawson Road (e.g. field site IW001) at 525 m elevation. The same deposit is exposed along the driveway to the McDonald's property in the 12 m high escarpment between Lawson Road and the Bulkley River floodplain at field site IW216 (Plate 2-7) where it underlies 8 to 10 m of glaciofluvial sand and gravel. West of the driveway, the glaciolacustrine deposit extends to the top of the 12 m high escarpment (field sites IR237, IR239) and has a clayey-sandy-silty texture (**szLGak**). East of the driveway, the escarpment consists of 12+ m thick, medium to coarse sand and gravel. The glaciolacustrine material was also encountered as a clayey silt deposit underlying the 3 to 4 m thick gravel and sand deposits of the Bulkley River floodplain (Westrek Geotechnical Services Ltd. 2019a[19]).

Glaciolacustrine sediments are susceptible to soil creep and small slides on slopes steeper than 35% when imperfectly drained, e.g. on the 12 m high escarpment west of the Bypass Road, but can form steep cutbanks when dry year-round. The deposits are susceptible to surface erosion and typically have a low permeability, and may be acting as a water barrier.

[19] Borehole T18-17S, test pit TP18-23

Glaciofluvial material (FG)

Glaciofluvial materials are materials deposited by glacial meltwater: either in contact with glacier ice, or directly in front of the glacier, or by glacial meltwater streams at some distance from the glacier. Particle size and sorting ranges from non-sorted, non-bedded sand, gravel and cobble to well sorted deposits such as interbedded gravel and sand or deposits of fine sand in low energy glaciofluvial environments. Advance-phase glaciofluvial materials underlying glacial till are typically outwash materials consisting of interbedded sand and gravel. They were encountered in the study area during geotechnical drilling (Piteau Engineering Ltd. 1997; SRK, personal communication in 2019) but are not further described in this section.

This section describes glacial and late-glacial glaciofluvial landforms and sediments deposited by receding and downwasting glaciers. Eskers (**FGr**) are gravel ridges deposited by subglacial or supraglacial meltwater streams with variable-sized, often coarse-grained particles. Kettle holes (**FG-H**) and gravelly kame ridges indicate burial of glacier ice by ice-contact gravel followed by ice melt and collapse. Glaciofluvial plains (**FGp**) were deposited as sandurs by proglacial meltwater streams and can exhibit sorting patterns similar to fluvial deposits, reflecting the variable transport energy of the depositional environment, resulting in interbedded coarse gravel and fine sand layers. Late-glacial downcutting by meltwater into earlier glaciofluvial deposits leaves the earlier deposits as glaciofluvial terraces (**FGt**).

In the Minesite area, glaciofluvial material was deposited mainly as eskers and gravelly kame deposits. Gravel and cobble deposits are found along Four Creek[20] and just west of Four Creek[21]. Kame deposits and eskers[22] just east of Tenas Creek were commonly sandy, sandy-pebbly, and locally also gravelly with cobbles. The thickness[23] of these deposits was estimated as ranging from 2 to 10 m. The kame deposits are typically well-drained, however, the long extent and irregular orientation of kame and esker ridges tend to disrupt, divert and concentrate ephemeral surface flow parallel to the ridges and create a small-scale mosaic of wet and dry ecosystems. The kame and esker deposits typically have a low slope angle and slope stability is not a concern. Sandy deposits are sensitive to surface erosion. Due to the variable texture and limited extent, most of these deposits have limited aggregate potential.

Along the eastern shoulder of Goathorn Creek, several proglacial and ice-contact outwash fan deposits exist. They were probably deposited during successive stages of ice retreat, prior to downcutting of Goathorn Creek. The thickness[24] of these deposits varies from 4 m to about 12 m. The texture is typically a pebbly sand or a medium to fine sand; locally, the deposit has a 5 to 10% cobble content or may consist of silty sand. One proximal, proglacial outwash deposit of pebbles and sand covers approximately 14 ha in the vicinity of the BC Hydro transmission line at 650 m elevation (field sites IW230, IW234, QA42). Another large ice-contact outwash fan complex, covering 36 ha, occurs at the junction of the Coalmine Road and the Bypass Road[25] at 690 m elevation. Cross-bedded pebble and sand are exposed in an inactive gravel pit (field site IW202; Plate 2-8) and form a 20 m high, hummocky ice-contact deposit; from there towards the northwest, particle sizes decrease to pebbly sand (field site IR146) and then to sand and silty sand (field sites IR145, IR147). The sandy outwash deposit has been disturbed by the excavation of several borrow pits which are now mainly abandoned. South of the hummocky ice-contact deposit and the gravel pit, undulating kame deposits at 690 m to 705 m elevation form part of the same outwash complex and consist of well-graded sandy gravel (D_{max}=10 cm) with only a trace of silt (field sites IW264, IW265). Farther south

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[20] Field sites IR082a, IR082b; IW070 to IW073; covering approximately 60 ha.

[21] Field sites IR020; IW021a, IW022, IW023; covering approximately 31 ha

[22] Field sites AD127 to AD129; IR092 to IR094, IW081 to IW084, covering approximately 30 ha

[23] Extrapolated from select observations at the crest of valley walls of incised streams.

[24] Determined from Westrek Geotechnical Services, 2019b; bore holes and terrain field observations.

[25] Bypass Rd stations 10+800 and 11+600

along the Caribou FSR 01, another ice-marginal glaciofluvial complex covers approximately 9 ha along the eastern shoulder of the Goathorn Creek valley. It consists of a proglacial outwash plain of sandy gravel with 5 to 10% cobbles (field sites IW261, IW263)[26] which issues from a strongly undulating, cobbly-pebbly-sandy supraglacial deposit (field site IW258) at 730 to 745 m elevation. Slope stability concerns exist where these outwash deposits form the crest of the Goathorn Creek valley wall. Groundwater exits onto the valley wall at the base of the relatively permeable glaciofluvial deposit, at the contact with the underlying impervious glacial till, adding to the porewater pressure and water saturation of the valley wall sediments. This process partly contributed to the 2013 fillslope failure along the Coalmine Road. Surface erosion concerns exist where the sandy outwash deposits form part of the steep valley walls. On the gently-sloping upland away from the valley walls the glaciofluvial sand deposits have a low to moderate surface erosion potential depending on the slope gradient and site drainage conditions.

Near the mouth of Goathorn Creek, a glaciofluvial fan covers about 60 ha, at 570 m to 600 m elevation. The fan consists of cobbles, gravel and sand, with small boulders near the fan apex. Thickness of the deposit varies from 3 m to 25 m (field sites IW316, AD188, IW133, IR202). This well to rapidly drained, near-level deposit underlies the Cottonwood subdivision and a Pacific Natural Gas (PNG) substation. The present-day Goathorn Creek and Telkwa River have eroded a 10 to 25 m high escarpment along the western and northern edge of this deposit (Plate 2-9). Localized slope stability concerns exist along these steep escarpments where the gravel is underlain by fine-textured, possibly glaciolacustrine sediments (field site IR203), or where Goathorn Creek undercuts the steep escarpment (field site IW316). Surface erosion is typically not a concern due to the coarse textures and high permeability of the deposit.

Plate 2-8. Glaciofluvial ice-contact deposits of sand and gravel, field site IW202.

Plate 2-9. Road cut in sandy gravel above the Telkwa River, field site IW133.

In the Rail Infrastructure area, a late-glacial outwash deposit was mapped at 525 m elevation. The deposit covers about 21 ha and consists of medium to coarse sand and pebbles, covered by a veneer of fine sand or silty sand. The deposit is 2 to 15 m thick and overlies glaciolacustrine silt and clay (field site IW216). The glaciofluvial deposit thins-out along the western edge of the Bulkley River valley floor, where the underlying glaciolacustrine silt and clay comes to the surface (field sites IW001, IR237).

[26] See also Westrek Geotechnical Services 2019b; borehole T18 to 15S

Fluvial material (F)

Fluvial materials are materials deposited by streams and rivers under contemporary (Holocene) geologic conditions. Generally, they are moderately to well sorted and consist of gravel and sand (**sgFp**), and sand and silt deposited as overbank deposits (**zsFv[Fp]**) and locally of clayey silt deposited in backchannels. The formative process of fluvial materials is considered inactive unless an active fluvial process is identified.

The most common fluvial landform in the study area are valley bottom floodplains (**Fp**) of the Bulkley River, the Telkwa River, Goathorn Creek and Tenas Creek, with minor occurrences of fluvial terraces (**Ft**). Vegetated floodplain areas away from the main channel and higher than the level of overbank flooding were mapped as **Fp** or **Fpt** and, where sandy-silty materials were encountered as **szFv[Fpt]**. Fluvial terraces and high-bench floodplain areas with remnants of channel depressions that are no longer flooded but have a thicker infill of fine sediments were mapped as **szFbv[sgFpd]**. Floodplain deposits that are currently modified by active fluvial processes (section 0) such as bank erosion, channel avulsion and presence of backchannels, were identified as active fluvial deposits **(FA**), typically near the main channel. Vegetated floodplain areas subject to seasonal or occasional flooding resulting in ongoing deposition of overbank silt and fine sand (indicated by the absence or burial of H or Ah horizon or by the presence of silt veils at the base of tree trunks) were mapped as **FAv[Fp]**.

In the Minesite area and along the Bypass Road, fluvial sediments were deposited by upland streams on gentle or flat terrain and form pebbly, sandy and silty fluvial veneers (**Fv**) and blankets (**Fb**), and fluvial fans (**Ff**).

<u>Bulkley River</u>

Fluvial deposits of the 1 km wide Bulkley River floodplain underlie the proposed rail infrastructure area. The fluvial deposits are about 4 m thick (Westrek Geotechnical Services Ltd. 2019a) and unconformably overlie a +/-10 m thick glaciolacustrine deposit. Three fluvial facies can be distinguished: the active Bulkley River channel, an active floodplain with seasonal flooding of back channel remnants, and an inactive part of the floodplain.

The Rail Infrastructure will be located on the inactive floodplain (**Fp**) which consists of interbedded sand and gravel deposits with a variable content of cobbles. A 0.3 to 1.2 m thick overbank deposit of medium to fine, loose to compact sand and compact, fine sand and silt overlies much of the sand and gravels (**sFv[sgFp]**). These sites are well to moderately well drained (Plate 2-10). Locally, rapidly drained, sandy, fine to medium gravels form the floodplain surface (Plate 2-11). While this inactive floodplain surface does not experience seasonal flooding, it is partially inside the 200-year floodplain as shown by the floodplain mapping (BC MOE 1984).

The west side of the rail infrastructure T-LSA sub-area is considered active floodplain with seasonal flooding along former channels. A well to rapidly drained, sandy gravelly level surface (**sgFp**) 1.5 to 2 m above bankfull river level is dissected by a series of 0.5 to 1.5 m deep former back channels which are filled with 0.5 to 2 m thick fine sand, silt and clay (**smFAvb**) overlying gravel and sand (Plate 2-12). These channel remnants flood most years in the spring, fed by a high groundwater table corresponding to the river level. In addition to the seasonal flooding, this part of the rail area is part of the 200-year floodplain (BC MOE 1984). The active channel environment of the 125 m wide, main channel (**FAp-I**) consists of sand and gravel with subrounded cobbles up to 25 cm diameter (field sites IW010, IR160;). The active channel bank is formed by a narrow, discontinuous low-bench floodplain with a surface elevation corresponding to bankfull flow, showing a 1 m thick fine sand deposit overlying the cobbly channel deposits at 510 to 513 m elevation (Plate 2-13).

Plate 2-10: Bulkley River floodplain, field site IW013.

Plate 2-11: Bulkley River floodplain, field site IR154.

Plate 2-12: Medium to coarse sand over gravel; field site IR236.

Plate 2-13: Bulkley River, field site IR160; overbank deposit of fine sand.

<u>Telkwa River</u>

Fluvial deposits along the 0.5 to 1 km wide Telkwa River floodplain include the current channel environment, active and inactive floodplain deposits and fluvial terraces that rise 5 to 8 m above the active floodplain. The bed material of the current river channel includes boulders (riffles), cobbles, pebbles (gravel bars) and sand (eddies and side channels). The forested floodplain has a similar range of textures as the active channel, however, a 0.5 to 1 m thick overbank deposit of medium to fine sand and silt is common. There was considerable evidence of regular or episodic overbank flooding depositing fresh sand (**zsFAv[FAp]**). In a few areas the floodplain surface consists of well to rapidly drained gravel, cobbles and small boulders (**ksgFp;** field sites AD182, AD185) and rises 0.5 m above the level of overbank flooding. Back channel remnants exist and are filled with 0.5 to 1.5 m thick deposits of sand and silt and organic matter (field site AD181). A 7 m high fluvial terrace forms a 135 m long section of the north bank of the Telkwa River (Plate 2-14), approximately 250 m upstream of the existing crossing of the natural gas pipeline (Plate 2-15). The exposed bank consists of weakly horizontally-bedded gravel and sand (**sgFt**) and is gradually being undercut by the river.

Overbank flooding along the Telkwa River has deposited coarse woody debris and logjams in several areas, with some of the deposits affecting stream bank stability (Plate 2-16 and Plate 2-17).

Plate 2-14: Telkwa River, eroding fluvial terrace, field site IW308a, IW326.

Plate 2-15: Telkwa River, natural gas pipeline crossing; field site IW308b.

Plate 2-16: Telkwa River, coarse woody debris deposited by overbank flooding; field site IW322.

Plate 2-17: Telkwa River, logjam affecting stream bank stabilization; field site IW323.

Goathorn Creek

Fluvial deposits on the 250 m wide Goathorn Creek floodplain include the active channel zone, the forested floodplain and 3 to 8 m high fluvial terraces; as well as the fan at the confluence with the Telkwa River. Long floodplain sections with an unconfined main channel alternate with short narrow floodplain sections that are partially confined by bedrock.

Along unconfined floodplain sections, the active channel zone and the adjacent forested floodplain were typically mapped as a complex polygon to account for the rapid lateral shifting of the main channel in recent and future years (Plate 2-19, field site IW054). The active channel bed material ranges in size from gravel to boulders (50 cm diameter) and sand (**ksgFAp,** field site IW045, IW277, IW279). Clasts are rounded to subrounded and include maroon and green-grey volcanic rocks and light-coloured granitic rocks. The adjacent forested floodplain consists of similar material and is typically overlain by a 1 m thick deposit of sand, silt or, locally, silty clay(**zsFAv**). These overbank and backchannel deposits contain small chunks of coal. In many places the fluvial deposits are underlain by bedrock at 1 to 5 m depth (Westrek Geotechnical Services Ltd. 2019[27]), or bedrock is exposed in the stream banks (**FAp[Ru]**) (Plate 2-20).

The southern-most section of Coalmine Road is located on a 20 to 100 m wide, 3 to 8 m high fluvial terrace that extends between the floodplain and the eastern valley wall. The terrace consists of non- or poorly stratified cobbles, pebbles and sand and some small boulders(**ksgFt**). Locally, a 0.5 m thick, predominantly sandy veneer overlies the gravel. Where fluvial terraces border the main channel of Goathorn Creek, bedrock was commonly exposed at 3 to 5 m below the terrace surface (**Ft[Ru]**).

Plate 2-18: Goathorn Creek, field site IW050.

Plate 2-19: Goathorn Creek, field site IW054.

Plate 2-20: Goathorn Creek, field site IW241.

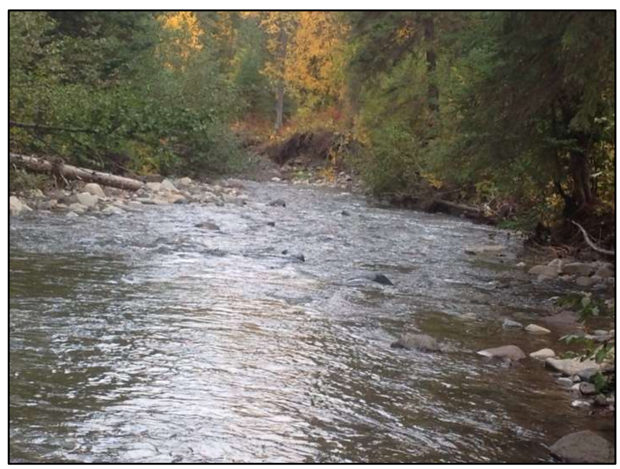

Plate 2-21: Goathorn Creek, field site IW226.

Tenas Creek

Fluvial deposits occur along the 90 m wide active floodplain and on a 2 to 5 m high fluvial terrace along both sides of the Tenas Creek floodplain. The deposits consist of pebbles, subrounded to subangular cobbles (D_{max}=15 cm) and sand, typically overlain by a 0.5 to 1 m thick veneer of loose fine sand, deposited by overbank flooding (**ksgFAp/zsFv**).

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27 Boreholes T18-16S, 19-33S

Upland fluvial deposits

Small streams on upland areas in the Minesite and along the Bypass Road transport sand, silt and small pebbles. The sediments are deposited as veneers where the confined streams deposit open up onto shallow fans (**sFfv**) or onto level site as in-filled glaciolacustrine lakes (**szFv**). These contemporary deposits are typically mixed with humic organic material and have a dark brown colour. Drainage is typically imperfect. While these deposits are less than 2 m thick, they affect the soil and ecosystem development and were delineated in particular on the bioterrain map.

A 50 to 75 m wide complex of fluvial deposits was mapped at 5.5 km along the Bypass Road at the crossing of Helps Creek. The active channel and floodplain are contained by several 0.5 m to 2 m high fluvial benches consisting of medium to fine sand with thin, buried organic horizons. The main channel and the immediately adjacent floodplain was buried by a 1 m thick, 5 m wide, recent deposit of sand, pebbles and subangular to subrounded cobbles (D_{max}=20 cm). It is likely that the sediment was deposited by a debris flood triggered by an intense rain event on October 25, 2017.

Colluvial material

Colluvium is material mobilized through weathering or mass wasting processes which has reached its position as a result of gravity-induced movement. The character of particular colluvial deposits depends on the nature of the material from which it was derived and the specific process whereby it was deposited.

In the study area, colluvial deposits were mapped where landslide deposits were encountered on the steep valley walls of Goathorn Creek and Tenas Creek at the base of recent or past debris slides. The pre-failure material was typically a glacial till often overlain by glaciofluvial gravel and sand deposits. These colluvial deposits also consist of clay, silt, sand and gravel and form a toe slope or lower slope deposit (**Cajb, csCbu)** with significantly lower slope angle than the initiation zone (field site IW053, IW239). The deposits are typically imperfectly drained and can be mixed with organic and humic material. Due to the fine texture, these deposits have relatively low permeability.

Fine-textured, cohesive colluvium was also mapped complexed with mine waste and fill on the western slopes of Goathorn Creek valley, just north of the mouth of Four Creek. The material has a high clay content and is prone to creep and small flow slides when it becomes saturated by seepage and undercut and oversteepened at the Goathorn Creek streambanks (Plate 2-23).

Well to rapidly drained, rubbly, sandy colluvial aprons derived by rock fall and shallow debris slides below bedrock cliffs or below steep-sided hummocky bedrock outcrop were also mapped on the valley walls of Goathorn Creek (Plate 2-1; field sites IR134a, IW268, IW280) and in the southern part of the Minesite (field site IR058). These deposits were typically of limited extent and form part of a larger polygon.

Anthropogenic (A)

Anthropogenic material (**A**) was mapped where the encountered geological materials were modified by past human (industrial) activity, including excavation from one site followed by sidecasting downslope or deposition elsewhere. It includes sites where topography was extensively changed by mine excavation or deposition of mine waste, as well as sites excavated or built-up for railway and bridge construction.

Evidence of past mining excavation and deposition was found at numerous sites along Goathorn Creek, particularly on the west side of the valley, extending for about 1.5 km north from the mouth of Four Creek. Thick deposits of mixed mining waste consisted of angular to subangular rubble of siltstone, sandstone, and coal in a light brown to very dark brown silty-clayey matrix (Plate 2-22; field sites IW270, IW292). The material was soft to stiff (depending on moisture content) with low to high plasticity and resembled a clay-rich till with coal. The deposits reached a thickness of 15 to 18 m, overlying bedrock or, locally, glacial till

(Westrek Geotechnical Services Ltd. 2019b[28]). Where the material is undercut by Goathorn Creek, it is prone to sliding, flowing and creep (Plate 2-23). Deposits containing mainly coal fragments and coal dust, interbedded with fluvial material were encountered on 3 to 4 m high terraces along Goathorn Creek at and near the BV Horsemans' Camp, a former coal loading site operated by Bulkley Valley Collieries in the 1960s, where the deposits are now being eroded by Goathorn Creek (Plate 2-24; field site IW060a).

Plate 2-22: Past mine waste material exposed in an eroding streambank along Goathorn Creek; field site IW270.

Plate 2-23: Goathorn Creek, undercut streambank exposing mine waste; field site IW240.

Plate 2-24: Mine waste material at the BV Horsemans' Camp, former BV Collieries operation; field site IW060a.

Plate 2-25: Fill material as an extension of a fluvial terrace; field site IW247.

2.4.3 Geomorphological Processes

Geomorphological ('geomorphic') processes are natural processes of erosion, sediment transport, and deposition that modify the surficial materials and associated landforms. In the study area, deglacial

[28] Bore hole T18-28S

processes, mass movement processes, erosional processes, fluvial and hydrologic processes were identified. Mass movement and fluvial process contribute to present-day geohazards in the study area.

Deglacial Processes

Deglacial processes such as erosion and channeling by glacial meltwater (-**E**) alongside, beneath or in front of the ice and formation of kettle holes (-**H**) formed by the melting of buried or partially buried glacier ice are common in the study area. These processes are now inactive; however, the associated landforms can influence terrain stability and surface hydrology. The Bypass Road crosses several 10 to 15 m deep, incised meltwater channels with moderately steep sidewalls with a potential for minor, localized slope instability. Major meltwater channels are commonly occupied by an undersized stream. Minor meltwater channels and kettle holes affect the routing of ephemeral surface run-off, site moisture conditions and vegetation patterns, e.g. small wetlands or ponds tend to form in kettle holes in glacial till; wet organic-rich soil and moist ecosystems occur in low-gradient shallow meltwater channels or at the mouth of larger meltwater channels. Eskers and glacial till ridges are also deglacial micro-landforms that tend to redirect or concentrate ephemeral surface run-off, typically alongside the ridge. Eskers, till ridges, glacial meltwater channels and kettle holes were identified with onsite symbols on the terrain stability map.

Mass Movement Processes

Mass movement processes involve the downslope movement, due to gravity, of surficial materials and bedrock fragments, often mixed with vegetation debris. Slow (-**F**) and rapid (-**R**) mass movement processes are distinguished by the BC Terrain Classification System (Howes et al, 1997), with specific mass movement processes indicated by subclass symbols.

Rapid and slow mass movement has significantly shaped the valley walls of Goathorn Creek and Tenas Creek during the rapid downcutting of the two valleys during the last deglaciation, and is now mostly inactive. Oversteepening and loss of toe support of the new valley walls triggered slumping (-**Flu**), rotational and downward movement of large blocks of surficial material, creating an irregularly benched and undulating landscape on the valley walls, with a mean slope angle between 35 and 55% (19 and 28°). In several locations, the original quaternary stratigraphy, e.g. a glaciofluvial mantle of sand and gravel overlying glacial till, was preserved within each slump block, resulting in a patchwork of surficial materials juxtaposed on the valley walls. Locally, bedrock with interlayered mudstone might also have been subject to slumping (**-Flm**). Other locations along the Goathorn Creek and Tenas Creek valley walls have been subject to repeated shallow debris slides (-**Rls**) during deglacial and post-glacial times and now form relatively uniform, slightly concave long slopes with slope gradients of 50 to 80% (27 to 38°).

Mass wasting processes continue on the Goathorn Creek and Tenas Creek valley walls at this time. Rock fall **(-Rb**) occurs at a few small bedrock cliffs exposed along Goathorn Creek (field sites IW122, IW268, IW280) and rubbly to blocky scree accumulates at the toe of these cliffs. Ravelling of weathered rock and thin colluvium occurs on the dry, south-facing slopes on the valley wall of Tenas East tributary at the south end of the study area.

Debris slides (**-Rs**) occur at numerous locations along the steep valley walls of Goathorn Creek and Tenas Creek. Locally, small (<0.03 ha) slides occur on gravelly-sandy, steep upper valley walls. Several small (0.03 to 0.07 ha), lower slope slides were identified that are triggered by bank undercutting at the creek level (field site IW231). They consisted of glacial till and are subject to surface erosion on the bare mineral soil, small sloughing, and slow retrogression at the landslide headscarp. Two larger valley wall slides in thick glacial till, triggered by toe slope undercutting, were identified along Tenas Creek in the southwest part of the T-LSA[29]. These slides have generated considerable amounts of suspended load and bedload to

[29] UTM coordinates 9U 615039E 6049908N; 9U 615090E 6050341N

Tenas Creek. Trees delivered by one of the slides has formed a large logjam, trapping much of the bedload that is transported along Tenas Creek.

A 115 m wide debris slide track (-**R"s**) exists at field site IW235 (Plate 2-26) adjacent to Coalmine Road near Bypass Road station 11+400. This slide started in the spring of 2012[30] when water appeared on the slope below Coalmine Road, saturating the weathered surface material on the slope and triggering a failure in the over-steepened, loose fill slope material of Coalmine Road. Ongoing seepage onto the slope subsequently increased the size of the failure (Fred Seychuck, MoTH Bulkley/Stikine Operations Manager; April 8, 2020, pers. communication). Numerous seepage sites were still active on the landslide track during the 2018 and 2019 field seasons, with water surfacing near the contact of the glaciofluvial sand and the underlying glacial till causing occasional small failures and oversteepening of the sandy sediments at the top of the landslide.

Slow mass movement continues at the present time as creep (-**Fc**) at several valley wall sites of Goathorn Creek and Tenas Creek, including upslope of Coalmine Road, locally creating wide open, 1 m deep tension cracks in glacial till (Plate 2-27, Plate 2-28; field sites IW251, IW064). Creep also occurs in clay-rich mining waste material which starts to flow (**-Fe**) on slope gradients as low as 40 to 50% (21 to 27°) when saturated and undercut by Goathorn Creek (field site IW275; Plate 2-29).

Plate 2-26: Start zone of the Coalmine Road landslide; field sites IW065, IW235.

Plate 2-27: Shallow slide and soil creep above Coalmine Road; field site IW251.

[30] Numerous embankment failures occurred in the Bulkley Valley area in the spring of 2012, following unusually wet antecedent conditions in the later summer and fall of 2011 and a high snowpack and late snowmelt in 2012 (e.g. small slide at km12 Telkwa FSR, slide east side of, Hwy 16 opposite from Donaldson Road Jct.).

Plate 2-28: Soil creep and tension cracks (purple mark-up) on the steep slope above Coalmine Road; field site IW064.

Plate 2-29: Debris slide in till, weathered rock and mine waste along Goathorn Creek; field site IW275.

Erosional Processes

Erosional processes such as gully erosion (**-V**) and piping (**-P**) occur in the study area. Gully erosion was mapped where current streams have cut 50 to 100 m wide and up to 60 m deep stream gullies into the valley walls of Tenas and Goathorn Creek. These V-shaped gullies have stream gradients of 8% to 15% (5° to 9°) and gully side wall slopes of 40 to 80% (22° to 38°). Gully side walls were typically stable or showed only minor evidence of creep. Downcutting along the gully base and retrogression at the gully head occurs at a very slow rate.

Piping is the process of subterranean erosion of surficial material resulting in small collapse depressions that are irregularly aligned along the slope. Typically, this process is driven by the movement of subsurface flow along preferential pathways or at the contact of a permeable over impermeable material. Piping was encountered on a slope on the west side of Goathorn Creek, where a thick deposit of fine sand forms a 27 to 35% (15° to 20°), imperfectly drained slope (field sites IW281 and IW282). The slope was forested with mature spruce, many with an uphill lean.

Fluvial Processes

Fluvial processes were identified based on channel patterns as they relate to floodplain sediments and floodplain ecosystems as well as fluvial hazards. In the study area, fluvial processes were identified along Goathorn Creek, Tenas Creek, the Telkwa River and the Bulkley River. On all four streams the channel pattern was identified as an irregularly sinuous channel (**-I**) common in wandering gravel bed rivers (Kellerhals et al, 1989). Characteristics of the irregular sinuous channel pattern are a clearly defined main channel with irregular turns and bends without repetition of similar features; gravel bars that occur as lateral or mid-channel bars; occasional islands formed between side channels and the main channel; back channels are typically present and may be common throughout the floodplain forest. Fluvial processes affecting these channels and floodplains were identified by subclass indicators (Howes et al, 1997) and include progressive bank erosion (**-Iu**); avulsions (**-Ia**), abrupt channel diversion from a main channel into a side channel or backchannel; and the presence of back channels (**-Ib**), small channels that may or may not be connected to the main channel. Channel remnants were identified where abandoned side- and backchannels have been infilled with sediment and continue to flood seasonally due to high floodplain groundwater (**-Is**). These channel remnants typically form shallow channel-like depressions (**Fpd, FApd**).

All fluvial processes are considered to have an ‘active’ status and the fluvial landform associated with the process was marked with an ‘active’ qualifier (e.g. **FAp-I**)

Fluvial processes along the Bulkley River include slow, progressive bank erosion (**FAp-Iu**) along the main channel causing some bank loss every year; and seasonal flooding of low-lying floodplain areas, typically remnants of former channels that have been infilled with 1 to 2 m thick clay and silt (**smFAvb[sgFpd]-U**). In addition, floodplain mapping along the Bulkley River by the BCMOE (1984) determined that the 200-year floodplain overlaps with parts of the Rail Infrastructure T-LSA sub-area, below 515 m elevation.

Fluvial processes along the Telkwa River main channel include bank erosion and channel avulsion (**bsgFAp-Iua**). Lateral gravel bars and point bars are common along the main channel. Slow bank erosion of a 10 m high, sandy-pebbly fluvial terrace occurs along a 100 m long channel section about 100 m upstream of the proposed water pipeline outlet. An overlay of the 1990 and the 2017 scanned air photos showed less than 2 m of bank retreat on the face of fluvial terrace in 27 years, while field photos taken in June and November 2019 indicate that high flows (e.g. early November 2019) entrained sediment and woody debris from the face of the bank. The vegetated floodplain has numerous backchannels (**-Ib**), some of which are well connected to the main channel while some are spring-fed channels (**szFApd-Is**). Logjams occur on mid-channel bars and point bars and at the entrance to back channels. Overbank flooding (**FAv**) of forested areas is common and leads to deposition of sand, silt and organic debris along the main channel (field site IW322), while silt deposition occurs regularly at many sites away from the main channel (field site AD183).

Fluvial processes along Goathorn Creek include channel avulsion, lateral bank erosion, formation of mid-channel gravel bars along the main channel; and overbank flooding on forested floodplain sites. The activity of main channel processes (**-Iau)** appears to have accelerated following a late spring flood event[31] on June 20th, 2013 that washed out the bridge crossing at the end of Coalmine Road (pers. communication[32], K. Coish). Subsequent flood events, including a major event on October 25th, 2017, reworked the mid-channel gravel bars and the channel bed material, further widening the active channel. The new gravel bars are dissected by numerous, narrow and shallow channels, however, a single irregularly sinuous main channel (**-I**) continues to be the defining characteristic of the Goathorn Creek floodplain. The rapid bank erosion during the recent flood events has exposed the stratigraphy in many fluvial terraces bordering the main channel, including 1 to 3 m of sandy gravel overlying sedimentary bedrock (field site IW059); and 3 to 5 m thick mine waste material (field site IW060, IW060a). High volume sediment transport and deposition events have occurred along Goathorn Creek prior to the 2013 flood: A 2 m high levee of pebbles, cobble and small boulders, overgrown with 30- to 40-year-old conifers, was found just downstream of the proposed bridge site at field site IW050. The levee possibly formed during a flood in 1968, the largest flood[33] along Goathorn Creek recorded in 60 years (Water Survey of Canada, 2020). The forested floodplain has numerous back channels (**-Ib**) and areas of seasonal overbank flooding (**-U**).

Fluvial processes along Tenas Creek include progressive bank erosion, a few localized channel avulsions, and deposition of overbank sand in the vicinity of the main channel and in backchannels. In the northwestern part of the Minesite area, Tenas Creek is unconfined or confined by fluvial terraces and small colluvial fans at the mouth of tributary gullies. Lateral channel bars, occasional point bars, individual logs and logjams

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[31] Daily discharge estimated as 30 m3/s at WSC station 08EE008.

[32] A localized rain event, most likely a rain-on-snow event, reportedly caused the “Father’s Day flood”. The peak flow impacted Cabinet Creek, a main tributary to Goathorn Creek, where the bridge approach was lost during the flood; and Howson Creek which drains the west Telkwa Range. No damage or significant channel changes were noted along Tenas Creek during this event (K.Coish, P.Eng. Pacific Inland Resources; pers. communication April 2020). The watersheds of Goathorn Creek and Howson Creek include considerable high elevation area between 1,800 and 2,200 m elevation that were almost certainly still snow-covered on June 20th, while Tenas Creek watershed does not include much area above 1,800 m elevation.

[33] WSC Station 08EE008; May 20, 1968; Daily discharge 40.8 m3/s.

are common features along the main channel while mid-channel gravel bars are uncommon. Side channels are rare, while backchannels exist in the forested floodplain. In the southwestern part of the mapped area, Tenas Creek is confined by steep valley walls where lateral bank erosion mobilizes suspended sediment and bed load from undercut, failing slopes. Channel-spanning logs and logjams trap some of the entrained sediment, controlling sediment transport along Tenas Creek.

Tenas Creek and Goathorn Creek form a common fluvial fan at the confluence with the Telkwa River. Channel avulsion and bank erosion are common features along the main channel, while backchannels, distributary channels and fine sand deposits from overbank flooding are common on the forested part of the fan. The fan extends across the full width of the Telkwa River floodplain forcing the river into a single channel against a 75 m high bedrock slope on the north side of the floodplain (field site IW312). This suggests that sediment deposition and aggradation on the Goathorn Creek fan is greater than on the Telkwa River floodplain.

Hydrologic Processes

Hydrologic processes in the study area include inundation and seepage. Areas affected by inundation (**-U**) are covered seasonally by standing water which results from a high-water table. This affects parts of the Bulkley River floodplain in the Rail Infrastructure area and a few sites on the Telkwa River floodplain.

Seepage (**-L**) indicated by vegetation or seeping surface water was observed on some lower slopes in the Minesite area, at low-gradient meltwater channels with a thin sandy, silty organic infilling and in thin deposits of upland fluvial sediments.

2.5 Hazard Assessments

This section describes the results of the terrain stability classification and surface erosion potential rating and the assessment of other geomorphic hazards such as fluvial hazards and snow avalanche hazards.

2.5.1 Terrain Stability Classification and Surface Erosion Potential

Each terrain polygon on the TSM map (Appendix C) was assigned a terrain stability class (TSC) and a surface erosion potential rating. Terrain stability classes indicate the likelihood of any landslide of any type, size of character initiating in the polygon. The terrain stability classes delineate the relative slope stability of the polygon following mine development. Surface erosion potential is a highly qualitative rating of the potential for generating sediment during mine development and operations. Both analyses consider general land development activities associated with mine development such as land clearing, excavation along roads, trails, drainage ditches and test pits, and deposition of excavated material for storage, fill or as side cast. Hazards related to activities in the mine pit are outside of the scope of this report.

Terrain Stability Classification

The five terrain stability classes ranging from TSC I (stable terrain) to TSC V (unstable terrain) are defined in Table 2-6. The terrain characteristics used to assign terrain stability classes are listed in Table 2-7. Table 2-10 and Figure 2-5 provides an overview of the distribution of terrain stability classes in the T-LSA. Stable terrain mapped as TSC I and II dominates the T-LSA and makes up 90.9% of the T-LSA. The remainder of the mapped area is dominated by unstable terrain mapped as TSC III to TSC V, and comprises 9.1% of the T-LSA.

TSC I and II terrain have a low likelihood of landslide initiation resulting from mine development activity. This terrain dominates throughout the T-LSA (Figure 2-6). In the Minesite area of the T-LSA, the stable terrain includes flat, undulating and gently sloping upland terrain consisting of glacial till; well-drained, flat to ridged gravel deposits; upland alluvial fans and thin veneers along small streams; and thin organic deposits in depressions. While the likelihood of landslide initiation on this terrain is low, concentration and

Table 2-10: Distribution of terrain stability classes I to V in the T-LSA.

T-LSA Sub-Area	ha		TSC I	TSC II	TSC III	TSC IV	TSC V
Minesite	2,080.25	ha	1,272.48	648.23	30.49	10.2	118.85
		%	61.2	31.2	1.5	0.5	5.7
Goathorn Creek	484.53	ha	260.75	110.51	23.85	30.31	59.11
		%	53.8	22.8	4.9	6.3	12.2
Bypass Road	508.35	ha	261.87	222.96	16.82	5.59	1.11
		%	51.5	43.9	3.3	1.1	0.2
Rail Infrastructure	240.99	ha	224.49	11.19	0	5.31	0
		%	93.2	4.6	0.0	2.2	0.0
Total T-LSA	3,314.12	ha	2,019.59	992.89	71.16	51.41	179.07
		%	60.9	30.0	2.1	1.6	5.4

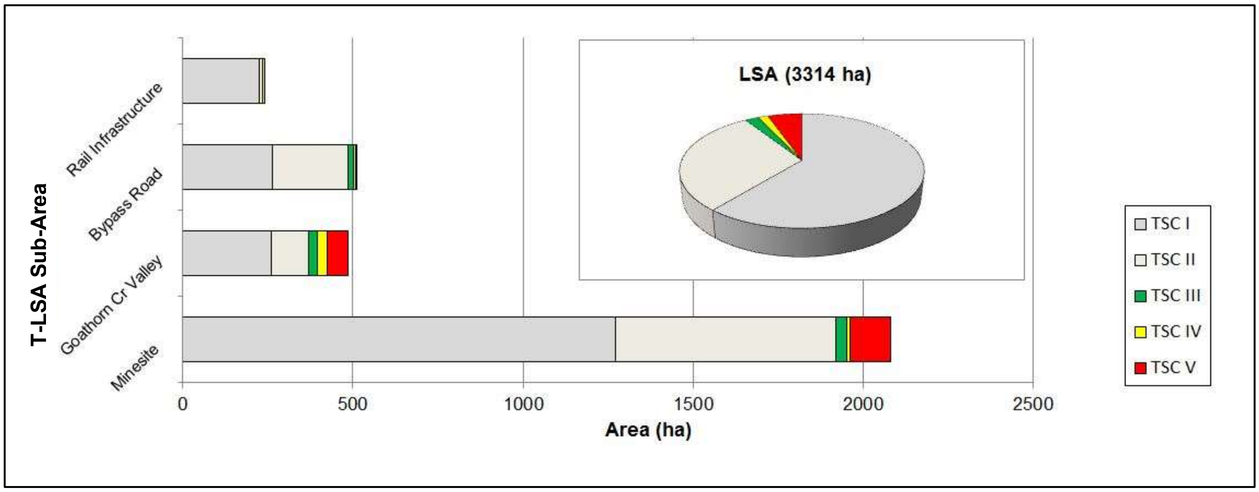
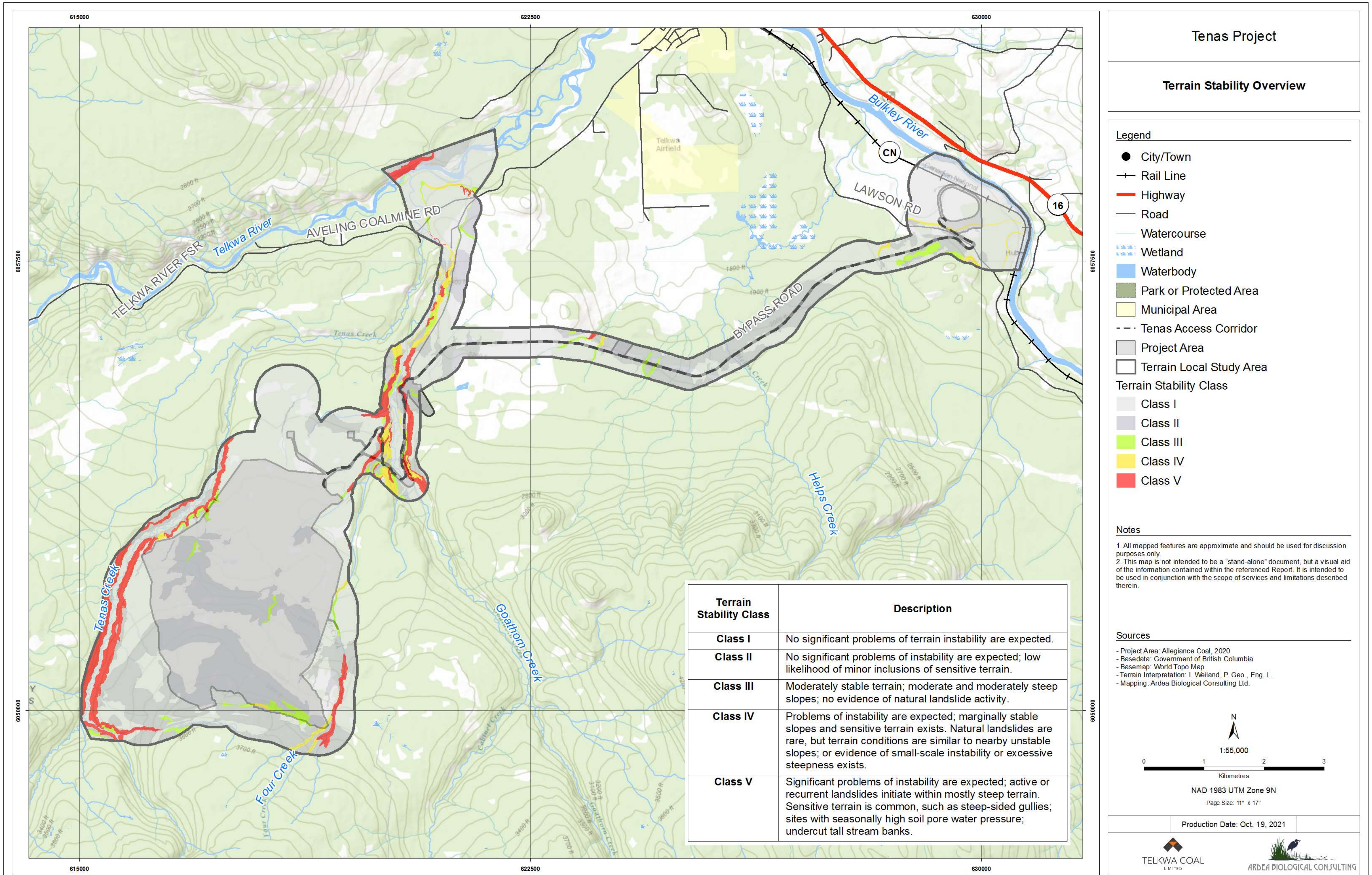


Figure 2-5: Distribution of TSC I to V in the T-LSA.

diversion of run-off from the stable upland terrain onto unstable terrain downslope can trigger landslides on the downslope terrain. Along the Goathorn Creek valley, subdued stable terrain is located in upland positions upslope of unstable terrain, with characteristics similar to those in the Minesite area. In addition, stable terrain is found in valley bottom settings along Goathorn Creek and Telkwa River where it consists of sandy-gravelly floodplain deposits, fluvial terraces and gravelly glaciofluvial terraces. The landslide hazard along the valley bottom terrain is low; however, other hazards are present such as hydrogeomorphic hazards on the floodplain and fluvial fans; and locally, landslide run-out hazards near the toe of unstable terrain. Terrain along the Bypass Road was mapped almost entirely as TSC I and II and consists of subdued, undulating, flat or gently sloping glacial till or glaciolacustrine silt. The landslide hazard is low, however, fluvial activity along Helps Creek poses a localized hydrogeomorphic hazard. The terrain in the vicinity of the Rail Infrastructure was mapped largely as TSC I and consists of flat, sandy-gravelly floodplain deposits of the Bulkley River, with interbedded gravel, sand and silt layers. The 4 to 5 m thick floodplain sediments are underlain by a silty-clay glaciolacustrine deposit. While the landslide hazard is very low, hydrogeomorphic hazards were identified in the vicinity of the Rail Infrastructure. In addition, the fine-textured subsurface material has the potential for consolidation and deep-seated failure as a result of mining activities.



Terrain Stability Class	Description
Class I	No significant problems of terrain instability are expected.
Class II	No significant problems of instability are expected; low likelihood of minor inclusions of sensitive terrain.
Class III	Moderately stable terrain; moderate and moderately steep slopes; no evidence of natural landslide activity.
Class IV	Problems of instability are expected; marginally stable slopes and sensitive terrain exists. Natural landslides are rare, but terrain conditions are similar to nearby unstable slopes; or evidence of small-scale instability or excessive steepness exists.
Class V	Significant problems of instability are expected; active or recurrent landslides initiate within mostly steep terrain. Sensitive terrain is common, such as steep-sided gullies; sites with seasonally high soil pore water pressure; undercut tall stream banks.

Figure 2-6: Overview map, showing the distribution of terrain stability classes in the T-LSA.

TSC III terrain represents only 2.1% of the T-LSA area. Polygons mapped as TSC III include moderately steep terrain where excavation and side-casting may cause minor problems with slope stability. Problems may be related to the presence of steep (>70% (35°) slope gradient) microsites in a moderately steep polygon with thin mantles of surficial material over bedrock. In thick deposits of glacial till, TSC III was assigned to escarpments and steep side slopes of ravines and incised glacial meltwater stream, where slope height is less than 15 m. TSC III was also assigned to slopes above Tenas Creek and Goathorn Creek that form part of the landslide-prone valley wall complex but now have stable slope angles of 30 to 55% (17° to 29°) (Figure 2-6).

TSC V and IV was assigned to unstable and potentially unstable terrain. This terrain makes up 7.0% of the T-LSA and occurs predominantly along the steep valley walls of Tenas Creek, Goathorn Creek and some sections of Four Creek (Figure 2-6). TSC V terrain units typically have moderately steep to steep slope gradients and show evidence of active or recent slope movement[34]. TSC IV terrain typically has similar slope angles or is located adjacent to TSC V terrain, and commonly shows signs of historic mass movement. Landslides or soil creep are expected to occur during excavation or following cut-and-fill road construction. TSC IV and V terrain units may include small sites of stable terrain. A geotechnical investigation is required to determine the site-level landslide hazard associated with proposed development and to design mitigative measures that reduce or eliminate the landslide hazard.

In the Goathorn Creek valley, much of the valley wall terrain was assigned a TSC IV or V (Figure 2-7). Slopes above and below Coalmine Road are subject to active debris slides or accelerated creep in glacial till leading to deep, open tension cracks. These geologic processes are described in Section 2.4.3. The stratigraphy of the thick sequence of quaternary sediments that are exposed in the valley wall drives some of these processes: Pre-glacial glaciolacustrine clay and silt deposits locally underlie the highly consolidated, fine-textured glacial till and contribute to very slow, deep-seated slope deformation that can be accelerated when the slope is undercut, e.g., during road excavation. Thick sand deposits overlying impervious glacial till promote seepage horizons on the valley wall, contributing to soil saturation, creep and occasional, natural shallow debris slides. This process can accelerate when additional fill, such as road fill, is placed on the slope. Along the Caribou FSR, the identified slope instability includes rockfall and ravelling in steep colluvium above the road (Plate 2-1); shallow debris slides and slumping in thick glacial till above the road; and tension cracks due to settling and creep in 2 to 5 m thick, clay-bearing mine waste rock. These old mine-waste deposits are locally undercut by Goathorn Creek, resulting in debris slides along the undercut toe of the valley side wall and settling and tension cracks 20 to 50 m above the toe of slope.

The valley walls of Tenas Creek were mapped as TSC IV and V following criteria similar to those used along the Goathorn Creek valley walls (Figure 2-6). Steep slope angles, active toe slope undercutting by Tenas Creek, the fine texture of the thick quaternary sediments and seepage surfacing on the valley wall at stratigraphic contacts all contribute to active and potential slope instability.

TSC IV and V terrain was identified on the 15 to 20 m high, steep sidewalls of Four Creek (Figure 2-6). No active landslides were identified, however, some of the slopes along the incised stream were classified as TSC V due to the very steep slope angle (locally up to 90% (42°).

Most of the TSC IV and V terrain in the T-LSA is located along incised stream valley walls, immediately downslope of gentle, stable terrain. This terrain configuration has been described as ‘gentle-over-steep terrain’. Experience in the forest industry has shown that the steep, potentially unstable slopes may be exposed to additional run-off when surface water on the gentle terrain above is concentrated during development and diverted onto the steep terrain below. This can result in debris slides or gully erosion,

[34] TSC IV and V are assigned to the initiation zones of slope movement. Landslide run-out areas on gentle terrain were typically assigned to TSC I, II or III.

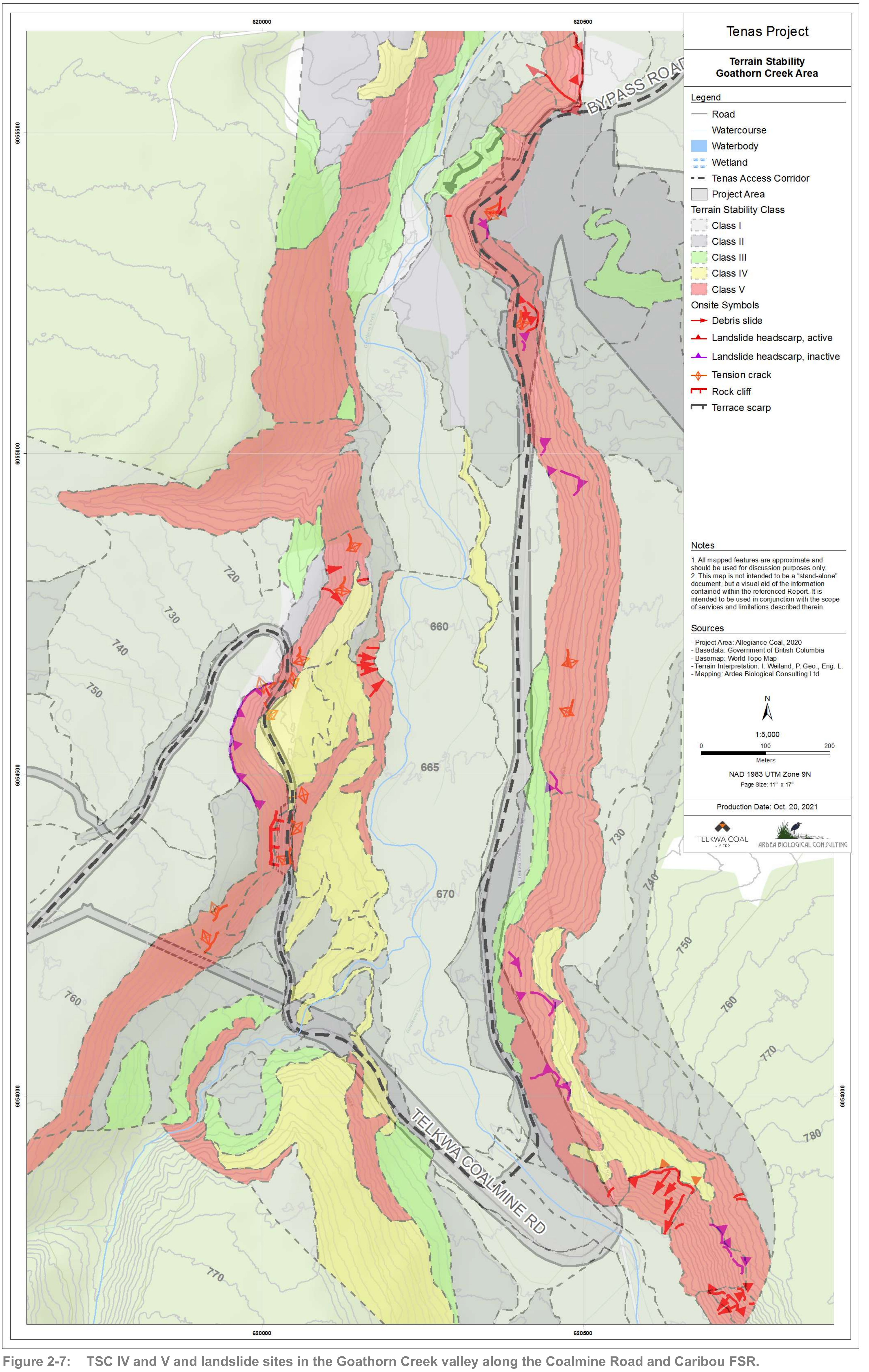


Figure 2-7: TSC IV and V and landslide sites in the Goathorn Creek valley along the Coalmine Road and Caribou FSR.

involving 50 to 15,000 m^3 of debris. Gentle-over-steep landslides are more likely to occur during periods of unusually high precipitation or rapid snow melt, during extended temporary shut-down periods and at sites downslope of abandoned development.

Small polygons of TSC IV and V were mapped along 8 to 25 m high terrace escarpments along the Telkwa and the Bulkley River floodplains (Figure 2-6). Typically, this escarpment instability was related to fine-textured sediments underlying coarse-textured sediments with groundwater exiting onto the terrace escarpment, creating a seepage horizon at the contact. Localized slope instability must be expected following excavation or placement of fill.

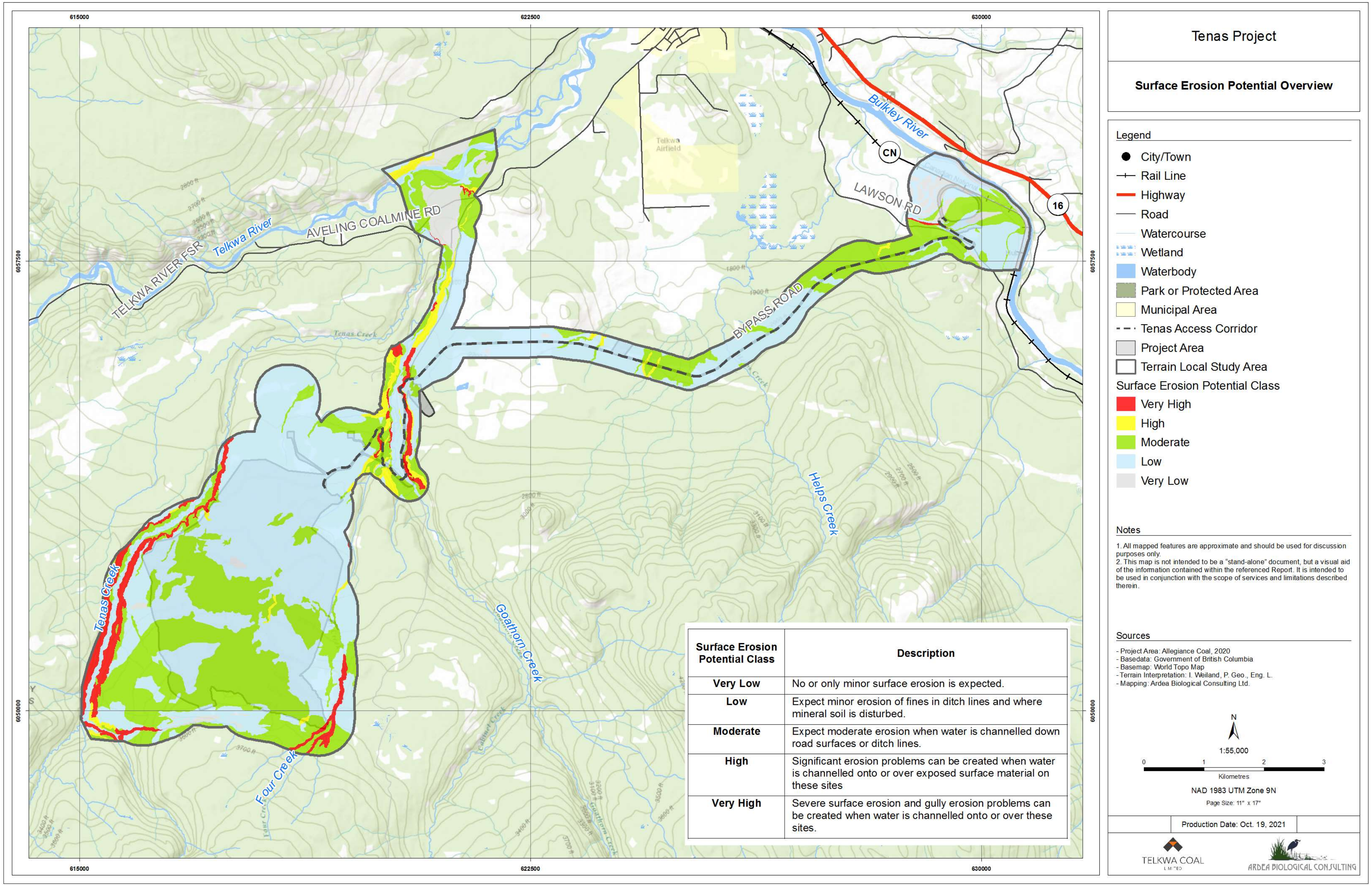
Surface Erosion Potential

A surface erosion potential rating was assigned to each terrain polygon. This rating describes the erosion of surficial geologic materials that are exposed to overland flow or heavy rain as a result of construction, excavation or land-clearing using heavy equipment or natural landslides.

Areas of high or very high surface erosion potential were identified on the steep and moderately steep, fine-textured valley side walls of Goathorn Creek and Tenas Creek (Figure 2-8). Glacial till with a clay-silt matrix is the dominant surficial material in these units and the high erosion potential is related to the steeper slope gradient, material thickness and taller exposed cut slopes. In addition, the units include unstable and potentially unstable sites and have a greater potential for exposure of disturbed mineral soil in landslides. Sandy glaciofluvial materials on the steep valley side walls also have a high surface erosion potential as they become exposed in road cuts or landslides tracks. Fluvial fans consisting of sand and gravels are highly susceptible to surface erosion along existing and potentially new distributary channels. Floodplain units with silty overbank deposits were also assigned a high erosion potential rating; while slope gradients are typically <5% (3°), the sandy soil lack cohesion and overland flow during peak run-off events or along spring-fed back channels may easily entrain any mineral soil exposed by construction or land clearing. Any development on areas of high and very high surface erosion potential requires erosion control planning and installation.

Areas of moderate surface erosion potential include: subdued landforms with glaciolacustrine sediments at the east end of the Bypass Road; landforms underlain by glacial till with slopes as steep as 30% (17°) in the Minesite area, along Coalmine Road and along the Caribou FSR; and units of mine waste with a silty-clay matrix. These units are particularly sensitive to surface erosion when the soil is seasonally wet and soft, or following mechanical disturbance. In the Minesite area, a few glacial till units with slope gradients as low as 10% (6°) were assigned a moderate erosion potential rating due to imperfect drainage and a greater chance of encountering wet, soft soil or to intercept subsurface flow during excavation. Many pebbly-sandy to fine-sandy glaciofluvial deposits on gentle slope gradients on the eastern shoulder above Goathorn Creek were also assigned a moderate erosion potential rating due to the lack of cohesion in the sediments. These units are particularly sensitive to erosion during overland flow during spring snowmelt. Floodplain units with thin, sandy overbank deposits were assigned a moderate erosion potential rating. Areas of moderate surface erosion potential require careful planning of erosion control measures, including a detailed assessment of the relevant site and soil characteristics.

Surficial materials in and surrounding the Minesite area, along the Bypass Road and along the shoulder above the valley wall of Goathorn Creek have a low surface erosion potential, reflecting the low slope gradients and the cohesive soil textures as well as presence of coarse fragments in glacial till. At the southern edge of the Minesite T-LSA sub-area, thin veneers of glacial till or weathered rock over hummocky bedrock also have a low erosion potential. A low surface erosion potential was assigned to the coarse-textured, active channel areas on the floodplain along Goathorn and Tenas creeks and the Telkwa and Bulkley rivers. These active floodplain units are subject to fluvial erosion which is distinct from surface erosion. Standard mitigative measures of erosion control must be considered when operating in units with low surface erosion potential.



Surface Erosion Potential Class	Description
Very Low	No or only minor surface erosion is expected.
Low	Expect minor erosion of fines in ditch lines and where mineral soil is disturbed.
Moderate	Expect moderate erosion when water is channelled down road surfaces or ditch lines.
High	Significant erosion problems can be created when water is channelled onto or over exposed surface material on these sites
Very High	Severe surface erosion and gully erosion problems can be created when water is channelled onto or over these sites.

Figure 2-8: Overview map, showing the surface erosion potential in the T-LSA.

Few, isolated areas of very low surface erosion potential were identified in the study area, typically in organic wetlands and shallow depressions that are not drained by streams. Low gradient units with very coarse textures and rapid drainage, such as fluvial or glaciofluvial terrace, plain or inactive fan units consisting of gravel, cobble and boulders have a very low erosion potential. Such units exist in the Coalmine Road residential subdivision and on fluvial terrace and plain units on the Bulkley and Telkwa River floodplains.

2.5.2 Natural Hazard Assessment

This section assesses natural geohazards other than those resulting from mass wasting processes which were discussed in section 2.5.1. Specifically, fluvial hazards long Bulkley River, Telkwa River, Goathorn Creek, and Helps Creek are described. Snow avalanche hazards are discussed as hazards that might develop following mine development.

The assessment of these hazards was carried out based on field information and interpretation of current and historic air photos. Hydrologic information for Goathorn Creek watershed was obtained online from the Water Survey of Canada website and through the BC Water Tool, an interactive website. Snow avalanche hazards were reviewed and discussed with Christoph Dietzfelbinger, avalanche forecaster, of Bear Enterprises Ltd., Smithers, BC.

Snow avalanche hazards

No snow avalanche tracks were identified in the study area. The low slope angle, dense forest cover and low elevation in much of the study area explains the absence of snow avalanches.

Slopes steep enough to allow an unstable snow pack to slide exist on the valley walls of Goathorn Creek above the Coalmine Road and the Caribou FSR. These slopes are up to 80 m high, forested and show no sign of snow avalanche activity at this time. The existing forest cover generally reduces the snow avalanche potential by reducing snow depth[35], as well as reducing wind transport and radiative processes. In addition, snow falling off tree branches disrupts snow pack layering. However, land clearing changes the snow conditions, such as potentially increasing snow depth, increasing surface hoar formation and wind transport, which can create a snow avalanche potential. These slopes could produce a snow avalanche up to size 2[36] if the thick forest cover was removed by land clearing or a landslide.

Excavations in the pit area have the potential to create snow avalanche prone slopes on the pit walls. This hazard needs to be considered as part of the design of the pit.

Fluvial hazards

Fluvial hazards were identified along the Bulkley River, the Telkwa River, Goathorn Creek and Helps Creek. The hazards are closely related to the fluvial processes described in section 2.4.3. and include flooding, lateral bank erosion, channel bed aggradation and widening, and channel avulsion.

Floodplain hazard mapping was carried out to characterize the fluvial hazards on the wide floodplain sections of the Bulkley River and the Telkwa River that are inside the T-LSA (Figure 2-9 and Figure 2-10). Fluvial hazard ratings were assigned to the terrain polygons shown on the terrain stability map, using the available terrain attributes describing texture, parent material, surface expression and geomorphic process, including subclasses of fluvial processes. The fluvial hazard classes are described in Table 2-11. The qualitative hazard ratings range from very low (VL) to very high (VH) and rank the likelihood and the relative

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[35] By about 30%

[36] A size 2 avalanche could kill, bury or injure a person on foot but does no or little harm to a vehicle. This level of snow avalanche hazard is often managed with simple warning signs at exposed sites.

Table 2-11: Fluvial hazard ratings at Goathorn Creek, on the Telkwa River and near the Rail Infrastructure area at the Bulkley River.

Rating	Terrain Label	Terrain Characteristics and Process Description	Expected Fluvial Hazard
VL Very Low	Ft	The terrain is outside the 200-year floodplain (Bulkley River) or 5 m elevated above the active channel zone and does not border the main channel (Telkwa River). The terrain is part of the inactive floodplain.	None
L Low	Fp	The terrain is 3 to 5 m elevated above the active channel zone. There is no field evidence of recent overbank flooding, or inundation due to a seasonally high-water table, or lateral bank erosion. The groundwater level fluctuates corresponding to the river level.	Excavations may encounter groundwater at shallow depths and a fluctuating groundwater table. The area will likely be inundated during a 200-year flood (Bulkley River). Locally, overbank flow is possible during a 200-year flood.
M Moderate	FAp-U; FAp-Is; szFAv[Fp]	The terrain forms part of the active floodplain. Field evidence of flooding exists such as deposition of silt, fine sand and small woody debris. Remnant channels are vegetated (forested, agricultural fields). Fluvial terraces with slowly eroding terrace escarpments (Telkwa River).	Seasonally high groundwater table, locally coming to the surface. Flooding due to overbank flow is expected during extreme peak flows (20-year < 200-year flood). Very slow progressive bank erosion of fluvial terraces (Telkwa River).
H High	FAp-U,Ib; FAp-Iu	The terrain forms part of the vegetated (forest or field), active floodplain. Field evidence of overbank flooding is common on low-bench riparian forest sites along the Bulkley River. Remnant channel depressions or seasonally flooded back channels exists. High-bench floodplain areas adjacent to the main channel are exposed to bank erosion.	Surface water may be present in remnant channels (seasonal or year-round; ponding or slow flow). Overbank flooding occurs during moderate to high peak flows. Progressive bank erosion. Channel avulsion is not likely but possible during a very high peak flow event.
VH Very High	FAp-Iu;	Typically includes the active channel zone including gravel bars and side channels. Progressive bank erosion has been ongoing for 30+years. Mid-channel gravel bars exist. Thalweg has shifted between main and side channels.	Annual or bi-annual overbank flooding. Progressive bank erosion at variable rates (up to several meters of bank loss in a single event), depending on flow volume during flood events. Lateral shifting of the channel thalweg and shifting of the main flow into side channels (Telkwa River: up to 75 m in 20 years) Channel avulsion and reactivation of back channels is possible during extreme peak flow events.

severity[37] of several fluvial processes affecting the floodplain over the next 30 years. The ranking is based on the characteristics of geomorphic features.and past and active processes that were identified in the

[37] The potential to damage infrastructure located in the polygon or to interfere with operation.

field[38] or by air photo comparison of a 30-year period from1986 to 2019 (e.g. the elevation of the polygon above the mean river level, the proximity and connectivity of the floodplain polygon to the main channel and the main channel configuration adjacent to the floodplain polygon). The ranking assumes that the fluvial regime on the Bulkley and Telkwa rivers in the next 30 years can be extrapolated from the past 30 years. The ratings take into account

Bulkley River Floodplain

Inside the T-LSA, the Bulkley River floodplain is 1 km wide. The Bulkley River forms a 80 to 100 m wide, single-thread main channel that follows the eastern edge of the floodplain. Floodplain mapping by BCMOE in 1984 delineated the extent of the 200-year floodplain[39] which approximately follows the 515 m contour line (Figure 2-9). Parts of the proposed rail loop are located inside the 200-year floodplain. The CN Rail track (originally completed in 1914) roughly parallels the Bulkley River separates the proposed rail loop from the Bulkley River. The CN track is raised 0.5 to 1 m above the floodplain which brings the rail grade at least to the same elevation as the 200-year flood level.

Much of the assessed floodplain area is located southwest of the CN track and was mapped as inactive floodplain. The fluvial hazard on these sites was rated as very low (VL) outside the 200-year floodplain or as low (L) for sites located inside the 200-year floodplain. A moderate fluvial hazard (M) was assigned to low-lying floodplain sites with vegetated remnant channels near the northwest edge of the mapped area These sites are considered residual features of an abandoned meander bend of the Bulkley River. Due to the low elevation, these 0.5 to 1 m deep residual depressions can be inundated during seasonally high groundwater levels. Areas along the Bulkley River main channel were assigned a high (H) or very high (VH) fluvial hazard. This includes forested, low-bench riparian areas with evidence of regular overbank flow; and areas immediately behind eroding banks with a steady rate of bank erosion. The eroding stream banks along the main river channel were assigned a very high (VH) hazard rating.

Telkwa River Floodplain

The T-LSA includes a short section of the Telkwa River floodplain. Immediately downstream of the fan of Goathorn Creek, the floodplain is 200 to 400 m wide and confined by fluvial terraces on the north side of the river. Just upstream of the existing PNG pipeline crossing, the floodplain widens to greater than 1 km. The Telkwa River forms a wandering gravel bed channel with an irregularly sinuous planform, including a single main channel, a few side channels, point- and mid-channel gravel bars, and small forested islands. The bankfull channel width (wetted width plus gravel bars) varies from 35 m to 100 m. Channel bed material includes gravel, sand and small boulders up to 35 cm diameter. Several older, partially decayed logjams are located at the tip of gravel bars or islands but don’t obstruct the active main channel.

Over the last 30 years (1987-2019), the thalweg has wandered considerably in response to gravel bar erosion and sediment deposition, switching main- and side channels and cutting off a large meander bend. These changes occurred mostly within the existing bank full channel width. Lateral bank erosion of riparian forest has been slow. The exception is the outside of the now cut-off meander bend, where the bank retreated as much as 40 m between 1987 and 2019. Most of this bank retreat occurred when the site was occupied by the main channel between 1987 and 2006. While the site is now occupied by a low-gradient side channel with extensive sand deposition, the bank erosion continues during high flow levels at a very slow rate.

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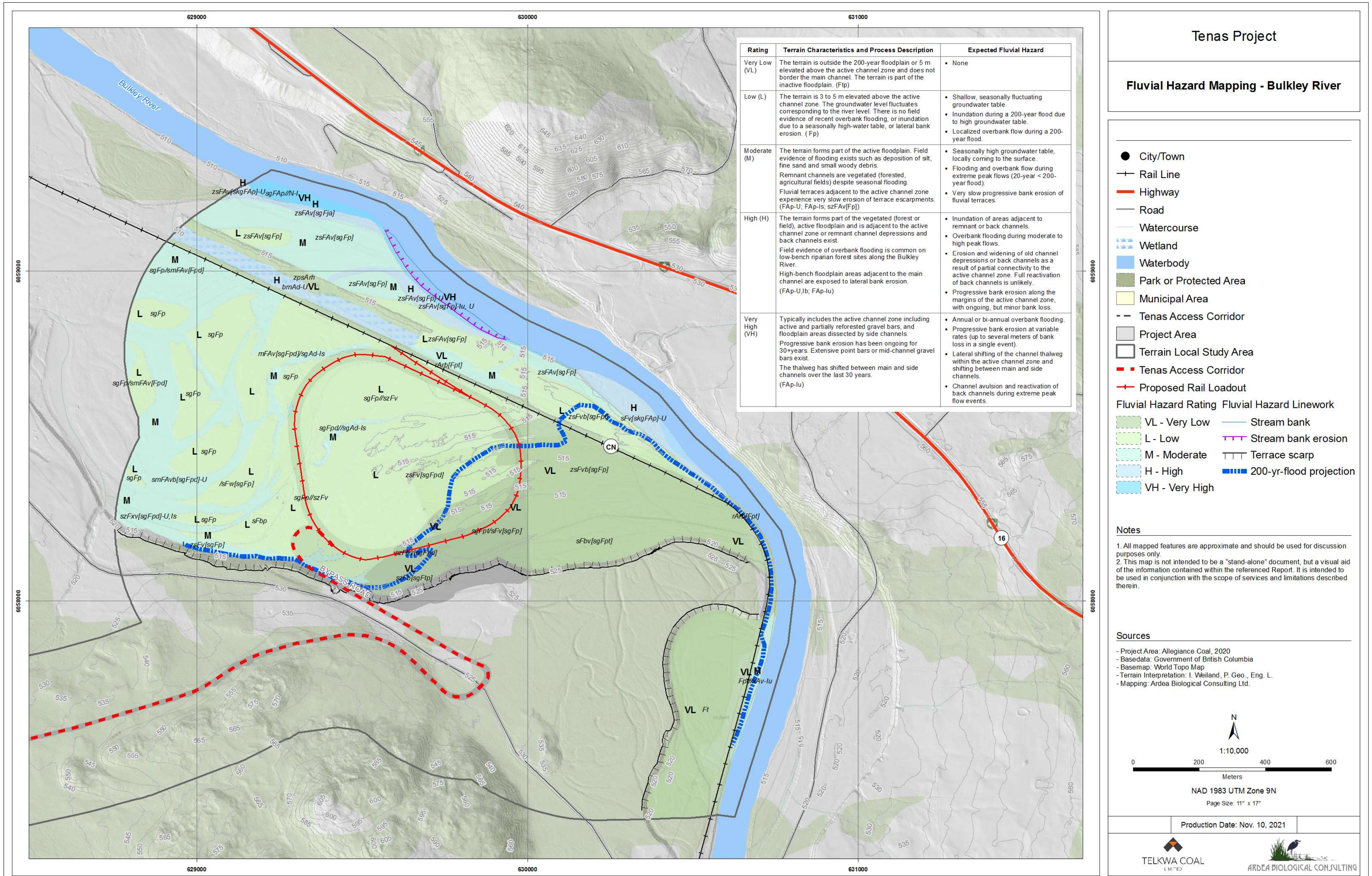
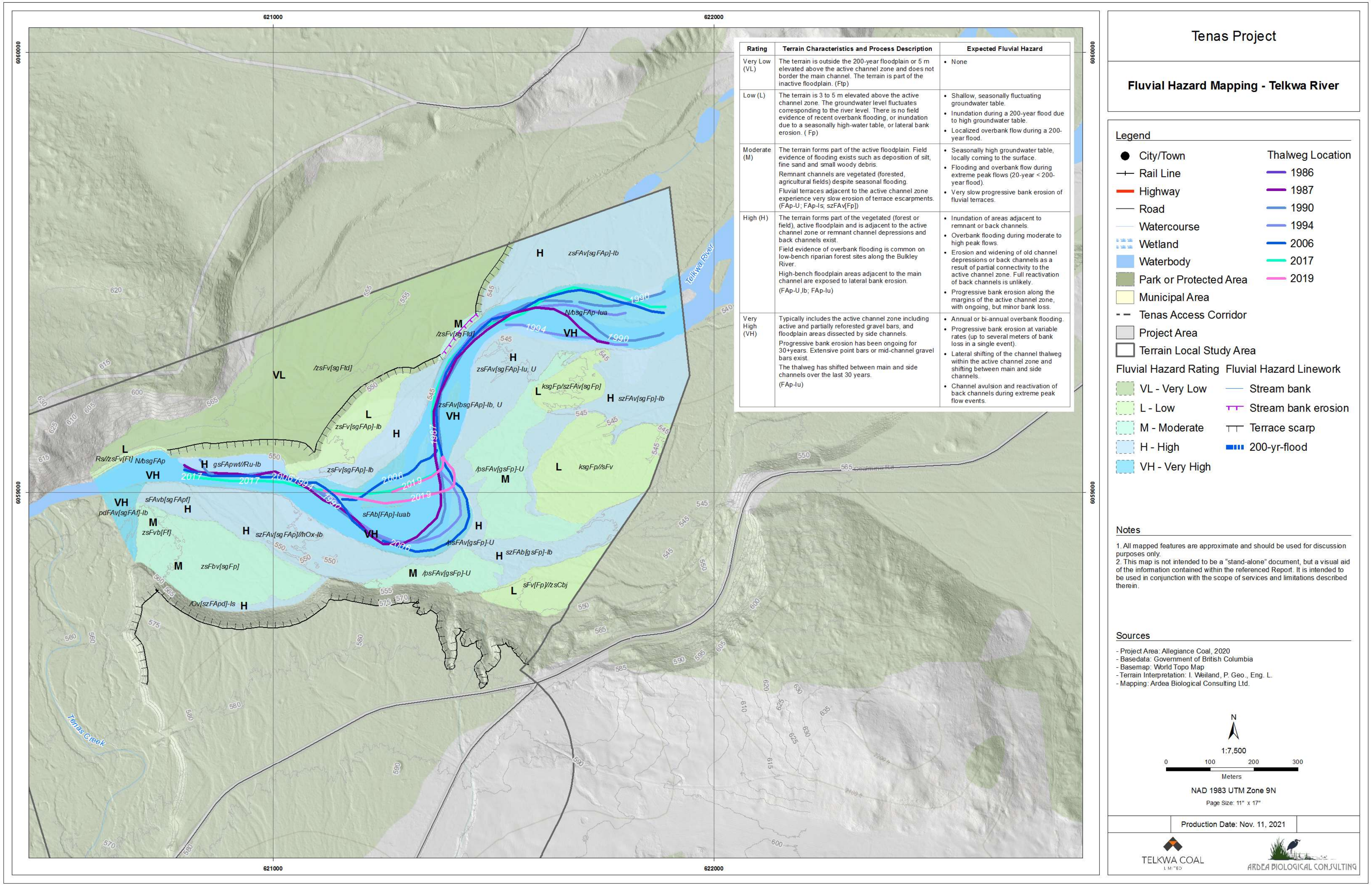
[38] The current agricultural use of the Bulkley River floodplain limits the evaluation of the flooding history from the geomorphic field information

[39] The area that can be expected to flood, on average, once in every 200 years. A 200-year flood can occur at any time in any given year and can exceed the indicated flood level.



Rating	Terrain Characteristics and Process Description	Expected Fluvial Hazard
Very Low (VL)	The terrain is outside the 200-year floodplain or 5 m elevated above the active channel zone and does not border the main channel. The terrain is part of the inactive floodplain. (Ftp)	• None
Low (L)	The terrain is 3 to 5 m elevated above the active channel zone. The groundwater level fluctuates corresponding to the river level. There is no field evidence of recent overbank flooding, or inundation due to a seasonally high-water table, or lateral bank erosion. (Fp)	• Shallow, seasonally fluctuating groundwater table. • Inundation during a 200-year flood due to high groundwater table. • Localized overbank flow during a 200-year flood.
Moderate (M)	The terrain forms part of the active floodplain. Field evidence of flooding exists such as deposition of silt, fine sand and small woody debris. Remnant channels are vegetated (forested, agricultural fields) despite seasonal flooding. Fluvial terraces adjacent to the active channel zone experience very slow erosion of terrace escarpments. (FAp-U; FAp-ls; szFAv[Fp])	• Seasonally high groundwater table, locally coming to the surface. • Flooding and overbank flow during extreme peak flows (20-year < 200-year flood). • Very slow progressive bank erosion of fluvial terraces.
High (H)	The terrain forms part of the vegetated (forest or field), active floodplain and is adjacent to the active channel zone or remnant channel depressions and back channels exist. Field evidence of overbank flooding is common on low-bench riparian forest sites along the Bulkley River. High-bench floodplain areas adjacent to the main channel are exposed to lateral bank erosion. (FAp-U,Ib; FAp-Iu)	• Inundation of areas adjacent to remnant or back channels. • Overbank flooding during moderate to high peak flows. • Erosion and widening of old channel depressions or back channels as a result of partial connectivity to the active channel zone. Full reactivation of back channels is unlikely. • Progressive bank erosion along the margins of the active channel zone, with ongoing, but minor bank loss.
Very High (VH)	Typically includes the active channel zone including active and partially reforested gravel bars, and floodplain areas dissected by side channels. Progressive bank erosion has been ongoing for 30+years. Extensive point bars or mid-channel gravel bars exist. The thalweg has shifted between main and side channels over the last 30 years. (FAp-Iu)	• Annual or bi-annual overbank flooding. • Progressive bank erosion at variable rates (up to several meters of bank loss in a single event). • Lateral shifting of the channel thalweg within the active channel zone and shifting between main and side channels. • Channel avulsion and reactivation of back channels during extreme peak flow events.

Figure 2-9: Fluvial hazard zones on the Bulkley River floodplain.



Rating	Terrain Characteristics and Process Description	Expected Fluvial Hazard
Very Low (VL)	The terrain is outside the 200-year floodplain or 5 m elevated above the active channel zone and does not border the main channel. The terrain is part of the inactive floodplain. (Ftp)	• None
Low (L)	The terrain is 3 to 5 m elevated above the active channel zone. The groundwater level fluctuates corresponding to the river level. There is no field evidence of recent overbank flooding, or inundation due to a seasonally high-water table, or lateral bank erosion. (Fp)	• Shallow, seasonally fluctuating groundwater table. • Inundation during a 200-year flood due to high groundwater table. • Localized overbank flow during a 200-year flood.
Moderate (M)	The terrain forms part of the active floodplain. Field evidence of flooding exists such as deposition of silt, fine sand and small woody debris. Remnant channels are vegetated (forested, agricultural fields) despite seasonal flooding. Fluvial terraces adjacent to the active channel zone experience very slow erosion of terrace escarpments. (FAp-U; FAp-Is; szFAv[Fp])	• Seasonally high groundwater table, locally coming to the surface. • Flooding and overbank flow during extreme peak flows (20-year < 200-year flood). • Very slow progressive bank erosion of fluvial terraces.
High (H)	The terrain forms part of the vegetated (forest or field), active floodplain and is adjacent to the active channel zone or remnant channel depressions and back channels exist. Field evidence of overbank flooding is common on low-bench riparian forest sites along the Bulkley River. High-bench floodplain areas adjacent to the main channel are exposed to lateral bank erosion. (FAp-U,Ib; FAp-Iu)	• Inundation of areas adjacent to remnant or back channels. • Overbank flooding during moderate to high peak flows. • Erosion and widening of old channel depressions or back channels as a result of partial connectivity to the active channel zone. Full reactivation of back channels is unlikely. • Progressive bank erosion along the margins of the active channel zone, with ongoing, but minor bank loss.
Very High (VH)	Typically includes the active channel zone including active and partially reforested gravel bars, and floodplain areas dissected by side channels. Progressive bank erosion has been ongoing for 30+years. Extensive point bars or mid-channel gravel bars exist. The thalweg has shifted between main and side channels over the last 30 years. (FAp-Iu)	• Annual or bi-annual overbank flooding. • Progressive bank erosion at variable rates (up to several meters of bank loss in a single event). • Lateral shifting of the channel thalweg within the active channel zone and shifting between main and side channels. • Channel avulsion and reactivation of back channels during extreme peak flow events.

Figure 2-10: Fluvial hazard zones on the Telkwa River floodplain.

Field observations on the forested floodplain identified several sites of recent[40] overbank flow due to flooding on low-lying floodplain sites 100 to 150 m distant from the main channel, side channel or a back channel. Other hazards affecting parts the forested floodplain are inundation of remnant channels due to a seasonally high groundwater table; and possibly reactivation of back channels or remnant channels during high stream flow events leading to avulsion.

Goathorn Creek

Goathorn Creek drains a 122 km^2 watershed area. Elevations range from 693 m to 2,241 m, with a mean elevation of 1,200 m. Approximately 80% of the watershed area is forested and 20% are alpine, with a small glacier and snow fields covering about 1.4 km^2. Mean annual discharge is 1.76 m^3/s. The mean monthly discharge peaks in May, June and July with 3.85, 5.62 and 3.97 m^3/s, respectively (BC Water Tool).

The 6 km long lower section of Goathorn Creek is located in the T-LSA, extending from the old bridge location near the southern map boundary to the mouth of Goathorn Creek at the confluence with the Telkwa River at the northern map boundary. Most of this section has the characteristics of a wandering gravel bed channel (Kellerhals et al. 1989) which is partially confined in a 70 to 130 m wide floodplain. Interspersed are several short sections where the channel is confined between bedrock outcrop, fluvial terraces and glacial till slopes.

A 3 to 4 km long section of mostly unconfined channel exists in the vicinity of the proposed bridge crossing, extending 2.4 km upstream and about 1 km downstream of the proposed bridge site. In this reach the channel width, including the main channel, side channels and gravel bars, varies from 20 to 50 m in a 130 m wide floodplain. The channel bed material includes small boulders, cobbles and pebbles, while sand is mostly deposited as overbank deposits outside of the active channel. At the proposed bridge site, this mostly unconfined, geomorphologically active reach is split into an upper and a lower part by a fluvial fan that receives relatively high sediment delivery from a small tributary basin west of Goathorn Creek. This fan on the left stream bank narrows the active part of the Goathorn Creek floodplain and forces Goathorn Creek into a 15 to 20 m wide, 100 m long single channel between forested streambanks.

A comparison of historic air photos[41] taken in 1986, 2006 and 2017 indicates that this section of Goathorn Creek has recently been subject to considerable bank erosion resulting in loss of riparian forest and channel widening with the formation of extensive lateral and point bars. Locally, sediment aggradation has led to the formation of mid-channel gravel bars that have buried standing trees. Information obtained from Pacific Inland Resources dates the wash-out of the old Goathorn Creek bridge to June 20, 2013. Field observations in 2018 and 2019 suggest that the recent lateral channel migration and localized channel avulsion has occurred in combination with sediment aggradation in the main channel and formation of small debris jams (Plate 2-19). Field evidence at site IW050 of a 2 m high boulder levee covered with 30- to 50-year-old trees indicates that flood events transporting very high sediment volumes have occurred episodically in the past.

Numerous sediment sources exist in the Goathorn Creek watershed: recently ice-free, alpine areas in the headwaters of Webster Creek and Cabinet Creek drainages; unstable bedrock slopes along the upper main stem of Goathorn Creek, and a 40 m wide and 50 m tall stream bank failure located 1.5 km upstream of the proposed Goathorn Creek crossing.

Hydrometric data (Water Survey of Canada, 2020) for Goathorn Creek shows that four large peak flow events have occurred since recording started in 1960: 1968, 1988, 2013 and 2017. Maximum Daily and instantaneous discharge data are plotted in Figure 2-11. For the flood on June 20th, 2013, only daily

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[40] Occurrence within the last +/-15 years

[41] BC Government air photo 30bcc440 #192 – 194, taken in 1986, 30bcc06043 #119, taken in July 2006; Project air photo provided by Telkwa Coal, taken in July 2017.

discharge data was available. However, the flood was large enough to wash out the Goathorn Creek forestry bridge as well as the bridge across Cabinet Creek[42], a tributary to Goathorn Creek.

While significant peak flow events have occurred at intervals of 5 to 20 years over the past 60 years, the geomorphic channel disturbance caused by the 2013 peak flow (Figure 2-12) was significantly larger than that of the peak flows in 1968 and 1988: the width of the active channel doubled and the rate of lateral channel migration as well as the number of avulsion channels increased significantly. The volume of bed material that is stored in mid-channel gravel bars rather than in the forested floodplain is significantly greater following the 2013 and the 2017 flood events compared to prior to 2013.

High rates of sediment transport from upstream channel sections to the proposed bridge site are likely to continue for several years or decades, causing channel migration and avulsions on the Goathorn Creek floodplain.

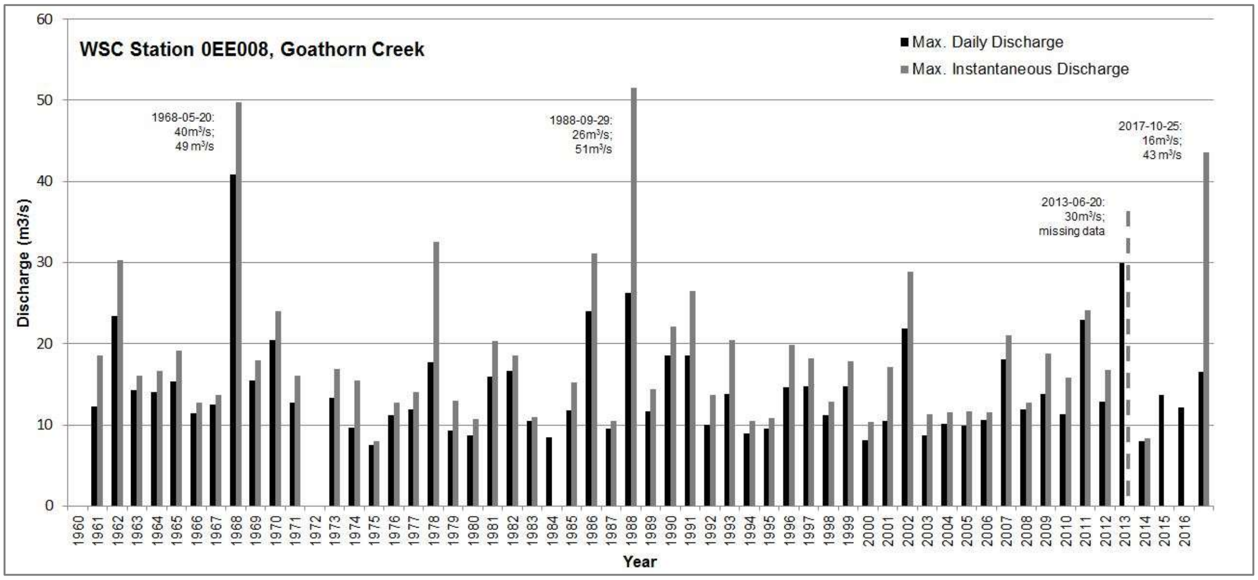


Figure 2-11: Hydrometric Data for Goathorn Creek, 1960 to 2017.

[42] Personal Communication, Kent Coish, West Fraser Mills, Smithers

Figure 2-12: Goathorn Creek near the proposed bridge site in 2006 (left image) and 2017 (right image). Note the channel widening following the flood in June 2013.

Helps Creek

A hydrogeomorphic hazard was identified at the proposed crossing of Helps Creek, near station 5+500 along the Bypass Road. Sediment aggradation during the Oct 25, 2017 flood filled and dewatered the existing channel (Section 0). The upstream source for the deposited sediment was not determined as part of this assessment. It is possible that the event entrained upstream channel bed material rather than sediment input from a landslide into the upstream reaches of Helps Creek.

As the channel of Helps Creek becomes re-established in future high flow events, the aggraded gravel and cobble will likely be reworked (entrained and re-deposited). A new channel may become established anywhere within 10 to 20 m on either side of the filled-in channel. Large sediment pulses transporting residual bed material the disturbed upstream reaches of Helps Creek towards the Bypass Road crossing are unlikely, but possible.

Plate 2-30: De-watered channel of Helps Creek due to sediment aggradation near the proposed crossing of the Bypass Road.

3. Soil Information

Soil mapping provides an inventory of the soil resources within the S-LSA. Soil map units (SMUs) reflect groupings of soil with related properties in order to provide soil information efficiently for environmental assessment, and reclamation purposes. The SMUs essentially provide a model of the most common soils within the study area, taking into consideration how soils have developed based on local parent materials, climate, topography and drainage, slope position, vegetation, and disturbance history. The bioterrain mapping is used as a basis for polygon organization and interpretation. Up to two SMUs are assigned to each bioterrain polygon. Each SMU describing soils with related properties such as parent material, soil texture, coarse fragment content, and degree of organic enrichment. These soil properties are assessed to determine soil salvage potential and soil erosion hazard for the purposes of mine reclamation planning. Soil trace metal analysis was conducted on representative soil samples.

3.1 Standards for Soil Information

The BC provincial standards for soil mapping include Soil Inventory Methods for British Columbia (RIC 1995), and the Field Manual for Describing Terrestrial Ecosystems, 2nd Edition (BC MOFR & BC MOE 2010). The Canadian System of Soil Classification, 3rd Edition (SCWG 1998) is used for soil classification. Assessing and classifying soil salvage potential is based on criteria found in Soil Quality Criteria Relative to Disturbance and Reclamation (Revised) (SQCWG 1987), while soil erosion potential is based on standards found in Proceedings of the BC Soil Survey Workshop on Soil Interpretations for Forestry (Vold 1982) and Mapping and Assessing Terrain Stability Guidebook (BC MOF 1999). Agricultural capability mapping follows Land Cability Classification for Agriculture in British Columbia (Kenk and Coltic 1983, and BC ALC 2017), which is consistent with the Canada Land Inventory (CLI) Soil Capability Classification for Agriculture (1972).

3.2 Existing Information

Soil information relevant to the Tenas Project was available from previous resource development proposals made by Manalta Coal (1999) and Crowsnest Resources (1984) (Table 3-1). While the study area boundaries are different for each proposal, much of the information was useful in developing this baseline report. Canada Land Inventory mapping (1974) informs agricultural land capability mapping.

Table 3-1: Existing soil information.

Document	Used in Baseline Report
Soils of the Telkwa Coal Project Area for Crowsnest Resources Ltd. 1:5,000 and 1:20,000 (Pedology Consultants, 1983).	1:5,000 scale mapping of a proposed development area centred on Goathorn Creek, and 1:20,000 scale mapping of larger area north and west of Goathorn Creek. The mapping does not cover Minesite or Rail Infrastructure area. 52 soil units were described, based on soil class, morphology, landform and materials. Field plot locations are unavailable. The detailed soil descriptions help to confirm SMUs, but the map polygons were large and generalized, and did not cover the same study area (paper copy only, not in a GIS).
Manalta Baseline Report. Appendix 4.1.1: Terrestrial Ecosystem Mapping (1:20,000) (Oikos Ecological Services Ltd. 1999)	Mapping completed at 1:20,000 scale encompassed most of the Tenas Project area. Nine soil management units (SMU) were described, along with suitability ratings. Active and inactive floodplain units were not differentiated. Rich lower (seepage slope) fluvial fans and colluvial cones were not differentiated. Digital ecological plot file includes detailed soil descriptions but plot locations are only referenceable to the map polygon, not a specific UTM location. Soil map layer not found. The range of land capability for agriculture was described for each SMU.

Document	Used in Baseline Report
Canada Land Inventory, Soil Capability for Agriculture, Map sheet 93L NW Telkwa (1974)	1:125,000 scale agriculture capability mapping was available for reference, but is at a very large scale. The mapping is 50 years old, carried out at a time when Agriculture Canada had a research station based in Smithers.

3.3 Methodology

The following section describes the methodologies used for soil mapping, including assessments for soil salvage and soil erosion potential, and for agricultural capability. Field methods and standards, and protocols for soil sample collection and analyses are also described.

3.3.1 Data Acquisition and Preparation

Soil and Agricultural Land Capability mapping uses the same digital imagery data as for Bioterrain and Ecosystem mapping. Initial polygons are delineated based on bioterrain. Polygons may be further delineated based on distinct changes in ecosystem structural stage or drainage. TCL provided digital orthophoto imagery and bare-earth Light Detection and Ranging (LIDAR) imagery, collected in 2017. Additional imagery was accessed via open-source Bing and Google satellite imagery (3 meters resolution). TCL provided shape files describing mine infrastructure. Other topographic map information such as streams and roads were available from TRIM data (scale 1:20,000). GIS linework and analysis was carried out using open-source QGIS 3.8 and ESRI Systems ArcInfo Geographic Information System (GIS) (ArcView ver. 9.3.1 and ver. 10.1).

3.3.2 Field Assessments and Survey Intensity

Soil survey methods for site and soil classification follow the *Field Manual for Describing Terrestrial Ecosystems* (BC MOFR & BC MOE 2010). *Soil Inventory Methods for British Columbia* (RIC 1995) provides direction regarding field sampling design and survey intensity, and organization of SMUs. Soil field data was collected by a multidisciplinary team so that terrain, ecosystem, soil, and wildlife data could be collected concurrently at the same plot locations. Plot locations were marked on a GPS-enabled iPad using the GIS Kit (Garafa, LLC) or Avenza Maps app (Avenza Systems Inc).

The Pit and Rail Infrastructure areas were mapped at a scale of 1:5,000. At this scale a Soil Survey Intensity (SIL) of 1 to 2 is recommended, in which a minimum of one field inspection is collected per 1-20 hectares (RIC 1995). The Bypass Road was mapped at 1:20,000 scale. At this scale a SIL of 3 or Reconnaissance level is recommended, in which one field inspection is collected per 20 to 200 hectares.

Soil pits were dug by hand, generally to a depth of 40 to 80 cm or to bedrock. Site and soil characteristics described include:

- Slope position
- Slope gradient
- Aspect
- Surface shape
- Exposure type
- Site disturbance
- Rooting zone drainage
- Humus / organic form and thickness
- Ah or Ae layer (organic enrichment or eluviation)
- Estimated soil depth and rooting depth
- Rooting zone soil texture, structure and coarse fragment content
- Gleying or mottling
- Seepage
- Restricting layer

Site Visit (SIVI) Form FS1333, and the Site and Soil Description forms FS882(1 and 2) were used for recording data in the field. Detailed soil profile descriptions, describing each soil layer, were collected for a representative sample of plots in the study area. All site, soil, vegetation, terrain and ecosystem data collected by the field teams were entered into VPro 15, an Access database, and imported into the GIS to facilitate polygon interpretation.

3.3.3 Soil Map Units

Soil map units (SMUs) reflect groupings of soil with related properties in order to provide soil information efficiently for environmental assessment, and reclamation purposes. The units represent systematic and predictable changes of soil properties across the landscape and have a minimum number of inclusions and unidentified features (RIC 1985, MSWG 1981). Ordering of SMUs follow concepts outlined in Table 4.1 of the *Soil Inventory Methods for British Columbia* (RIC 1995). For example, SMU 1 is the modal or most commonly occurring soil in the mapping area; SMU 2 is drier than modal soil due to coarser textures; SMU 3 soil have finer soil textures than the modal soil.

Up to two SMUs are assigned to each polygon representing the dominant soil map units in each polygon. A decile system is applied to describe the relative abundance of each SMU within a polygon. Polygons may contain minor inclusions of other soil types (e.g., less than 10% of polygon area).

The SMUs are organized by soil parent material from which they have developed, and differentiated based on soil texture, drainage, coarse fragment content, and degree of organic enrichment. For each map unit, the range in slope position, soil texture, coarse fragment content, common taxonomic soil orders, and average rooting depth are described. SMUs with similar properties but different parent materials may be amalgamated together as necessary for reclamation planning.

Soil Order and Great Group (Table 3-2), as described by the Canadian System of Soil Classification, help to understand the soil forming processes that influence each soil map unit (SCWG 1998).

Table 3-2: Soil orders and great groups in the Project Area.

Soil Order	Soil Great Group	Characteristic Features
Brunisolic Sufficient development to exclude them from the Regosolic order, but they lack the degree or kind of horizon development specified for other orders	Melanic Brunisol Eutric Brunisol Sombric Brunisol Dystric Brunisol	Ah > 10cm, pH > 5.5 Ah < 10cm, pH > 5.5 Ah > 10cm, pH < 5.5 Ah < 10cm, pH < 5.5
Gleysolic Properties that indicate prolonged periods of intermittent or continuous water saturation and reducing conditions with mottling and gleying. Bg horizon within 50 cm of soil surface	Gleysol Humic Gleysol Luvic Gleysol	Ah < 10cm Ah > 10cm Btg horizon
Luvisolic Light colored, eluvial horizon overlying alluvial B horizons in which silicate clay has accumulated	Grey Luvisol	Eluvial and Bt horizons May have an Ah May show signs of gleying
Podzolic Podzolic Bf, Bhf horizons	Ferro-Humic Podzol Humo-Ferric Podzol	Bhf > 10 cm BF > 10 cm
Regosolic Very weak soil development, B horizon < 5 cm	Humic Regosol Regosol	Ah > 10 cm

Soil Order	Soil Great Group	Characteristic Features
Organic Composed largely of organic materials; water saturated for prolonged periods	Mesisol Humisol	Mesic middle tier Humic middle tier

3.3.4 Soil Sample Collection and Analyses

Soil samples were collected for physical and chemical analysis following procedures outlined in *Soil Quality Criteria Relative to Disturbance and Reclamation* (SQCWG 1987). Soil samples were collected from a representative cross-section of sites across the Project area. Most samples were collected from the first 15 cm the soil profile. Stainless steel trowels, nitrile gloves and sterile plastic bags were used to prevent contamination of the soil samples. Samples were sent to CARO Analytical Services for analysis of total carbon, moisture, pH, potassium, ammonia, phosphorus, particle size distribution, and strong acid leachable metals. Physical and chemical analyses help confirm soil textural and nutrient properties, and identify any naturally occurring chemical (pH) or trace metal exceedances that may be present within the study area.

The Canadian Council of Ministers of the Environment (CCME) sets *Environmental and Human Health Soil Quality Guidelines* for residential/parkland (SQG_{RP}), agricultural (SQG_{AG}) and industrial (SQG_{IN}) uses. Soil samples were analysed for metal or element concentrations (mg/kg) of Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silver, Sodium, Strontium, Sulfur, Tellurium, Thallium, Thorium, Tin, Titanium, Tungsten, Uranium, Vanadium, Zin, and Zirconium. Analysis results from the soil samples were compared to the CCME guidelines and exceedances noted.

3.3.5 Soil Salvage Potential Assessment

Soil texture, coarse fragment content and organic content are the major factors driving soil salvage potential in the study area (J. Straker pers com, June 2018). By grouping soil with similar properties, it is possible to use the resultant soil map as a planning tool for soil salvage and reclamation. Criteria for evaluating the suitability of surface material for revegetation are presented in Table 3-3. These criteria are adapted from *Soil Quality Criteria Relative to Disturbance and Reclamation* (SQCWG 1987). Effective rooting zone and depth of Ah mineral soil horizons are additional criteria for rating soil salvage potential. These criteria were used for assigning a soil salvage potential rating to each of SMU.

Table 3-3: Criteria for rating soil salvage potential.

Property	Soil Salvage Potential Rating			
	Good	Fair	Poor	Unsuitable
Reaction (pH)	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	< 3.5 or > 9.0
Stoniness (% coarse fragments)	< 30[43] < 15[44]	30 to 50 15 to 30	50 to 80 30 to 50	> 70 > 50

[43] Matrix texture finer than sandy loam.

[44] Matrix texture sandy loam and coarser.

Property	Soil Salvage Potential Rating			
	Good	Fair	Poor	Unsuitable
Texture	L, SiCL, SCL, SL, FSL	CL, SiL, VFSL, SC, SiC	LS, S, Si, C, HC	Consolidated bedrock
Effective Rooting Zone (cm)	> 50	30 to 50	< 20	< 10
Depth of black Ah horizon (cm)	> 5	1 to 3	0	0

3.3.6 Soil Erosion Potential Assessment

Soil erosion potential in the context of baseline soil mapping refers to the potential for soil erosion, based on inherent soil properties. Generally, coarse-textured materials have lower potential for erosion than fine-textured materials. Cohesive (clay-rich) soil has low erodibility when in a consolidated state. Ratings for soil erosion potential, provided in Table 3-4, were assigned to each SMU using the standards set out in *Proceedings of the BC Soil Survey Workshop on Soil Interpretations for Forestry* (Vold 1982). Note that soil erosion potential is different than surface erosion potential, which is an aspect of terrain stability mapping described in Section 2.5.1.

Table 3-4: Criteria for rating soil erosion potential.

Property	Soil Erosion Potential Rating			
	Low	Medium	High	Very High
Soil texture	Clay Loam and Loam ---Loamy Sand ------------ Fine sand ------------ Clay -------- Silt			
Cohesiveness	Clay rich < -- > No clay			
Coarse Fragments	Abundant ------------------ Angular boulder ---------- Rounded gravelly --------- Absent			
Permeability	Rapid ------------------ Moderate ---------------------Slow --------------------- Very Slow			

3.3.7 Agricultural Capability Assessment

Methods for mapping agricultural capability ratings and limitations are based on the *Land Capability Classification for Agriculture in British Columbia* (Kenk and Coltic 1983) and the Canada Land Inventory (CLI) *Soil Capability Classification for Agriculture* (CLI 1972). Field procedures followed the criteria for agriculture capability assessments set out under Policy P-10 of the *Agricultural Land Commission Act* (BCALC 2017). The Policy states that the soil survey must be completed at a Survey Intensity Level 1, consistent with the *Soil Inventory Methods for British Columbia* (RIC 1995), at a density of one detailed soil test pit per 5 hectares, and that the soil surveyor must use their discretion in the field to determine how many test pits are required to accurately assess the site.

Classification of agricultural land using Kenk and Coltic (1983) groups mineral and organic soil into seven broad classes (Table 3-5) based on climate and soil parameters for potential crops as well as limitations for agriculture. In general, the range and types of crops suitable for growing generally decreases from class 1 to class 7, with soil and/ or site factors that limit agricultural productivity captured by land capability subclasses (Table 3-5).

Most of the lands along the Bypass Road, Goathorn Creek, and Rail Infrastructure areas are designated as Agricultural Land Reserve (ALR). CLI agriculture capability mapping provides a framework for setting reclamation and/or mitigation targets for lands currently used for agriculture.

Table 3-5: Agricultural capability classes and sub-classes.

Class	Description
1	No or only slight limitations that restrict its use for the production of common agricultural crops. (Does not occur in north central British Columbia).
2	Minor limitations that require good ongoing management practices or slightly restrict the range of crops, or both. (Does not occur in north central British Columbia).
3	Limitations that require moderately intensive management practices or moderately restrict the range of crops, or both. (Rare in northern central British Columbia).
4	Limitations that require special management or severely restrict the range of crops, or both. Land in this classification is often only suitable for a few crops. The yield may be low or the risk of crop failure may be high for a wider range of crops.
5	Capability is limited to producing perennial forage crops or other specially adapted crops.
6	Non-arable but capable of producing native and/ or uncultivated perennial forage.
7	No capability for arable culture or sustained natural grazing. Local climate results in unsuitable natural vegetation. Also included are rockland, other non-soil areas, small water-bodies.
O	Organic soil
Subclass	**Description**
Soil Moisture Deficiency (A)	Crops adversely affected by low water-holding capacity of soil. Common on glaciofluvial deposits.
Climate (C)	Cool climate and short growing season generally limit agricultural productivity within the study area at large.
Undesirable Soil Structure (D)	This subclass applies to soil that would be difficult to till and that would easily become compacted by passage of farm machinery. Compact soil structure and/ or low soil perviousness is common on the glaciolacustrine deposits in the Helps and Hubert Creek area.
Fertility (F)	On forest sites over morainal or glaciofluvial materials available nitrogen is likely deficient.
Inundation (I)	Soil on sites subject to seasonal flooding where crop damage or limits to agricultural use may occur.
Stoniness (P)	Soil with sufficient coarse fragments to significantly hinder tillage, planting, or harvesting operations. Stoniness is a factor on gravelly fluvial plain and glaciofluvial plain sites within the Rail Infrastructure area at the west end of the Bypass Road. This subclass would also apply to morainal or colluvial deposits with high coarse fragment.
Depth to Bedrock and Rockiness (R)	Soil in which the presence of bedrock near the surface restricts rooting and tillage and/or the presence of rock outcrops restricts agricultural use.
Topography (T)	Soil on sites for which topography limits agricultural use by affecting the use of farm machinery, results in uneven growth and maturity of crops, or increases the potential for erosion. This subclass applies to the steep slopes associate with rock outcrops at the east end of the Bypass Road.
Excess Water (W)	Excess water due to imperfect to very poor drainage due to high water tables, seepage, or runoff from surrounding areas.

3.3.8 Quality Assurance and Quality Control of Soil Mapping

Quality Assurance (QA) and Quality Control (QC) assessments were carried out for the soil mapping during 2018 by a qualified independent professional: David W. Yole, M. Sc, P.Ag. of D. Yole Consulting. Field assessments for the accuracy assessment were conducted following a stratified sampling methodology as outlined in the *Protocol for Accuracy Assessment of Ecosystem Maps* (Meidinger 2003). The soil mapping QA was coordinated with the TEM QA, carried out by Claudia Houwers R.P. Bio. Full and SIVI plots were completed in a representative range of sites across the Project area. The study area was stratified so that plots would be collected across the Minesite area at low, mid and upper elevations in a variety of soil and ecosystem types. Plots were also collected along the Bypass Road and within the Rail Infrastructure zone.

Following the field assessments, the plot data was compared to the polygon mapping to determine how similar the ecosystem and soil data were. Scoring of data to determine similarity was completed by comparing QA results to our data or ortho-photo interpretations. Areas of congruence, errors of omission and commission were summarised in a confusion matrix following methods outlined in Meidinger (2003).

3.4 Data Summary

3.4.1 Field Assessments

Field sampling locations for 2017 to 2019 are identified in Figure 3-1. A total of 774 site inspections were completed during the 2017 to 2019 field seasons (Table 3-6). Approximately 26% of these plots include detailed descriptions of soil attributes (i.e., FS882 and SIVI plots). Visual plots make up an additional 74% of the field data, which may contain terrain, soil or ecosystem information that helped to confirm SMUs. Only the FS882 and SIVI plots were used to calculate survey intensity.

For the Minesite, Goathorn Creek and Rail Infrastructure areas, the site inspection rate per 100 ha was 6.5 which met the SIL 1 requirement as described in Section 3.3.2. for the Bypass Road, the site inspection rate per 100 ha area was 12, which met the SIL 3 requirement. Survey intensity along the Bypass Road was higher than SIL 3 to capture necessary soil inspections for ALC mapping, as well as to meet Terrestrial Ecosystem Mapping objectives.

Table 3-6: Number of polygons and survey intensity in the S-LSA.

S-LSA Sub-Area	Area (ha)	Number of Polygons	Survey Type				Soil Field Inspections per 100 ha	Survey Intensity
			FS882	SIVI	Visual	Total		
Minesite, Goathorn Creek and Rail Infrastructure Areas (1:5,000)	2,805	861	30	151	450	631	6.5	1
Bypass Road Area (1:20,000)	508	105	7	54	120	143	12	3
Totals	***3,314***	***966***	***40***	***167***	***570***	***774***		

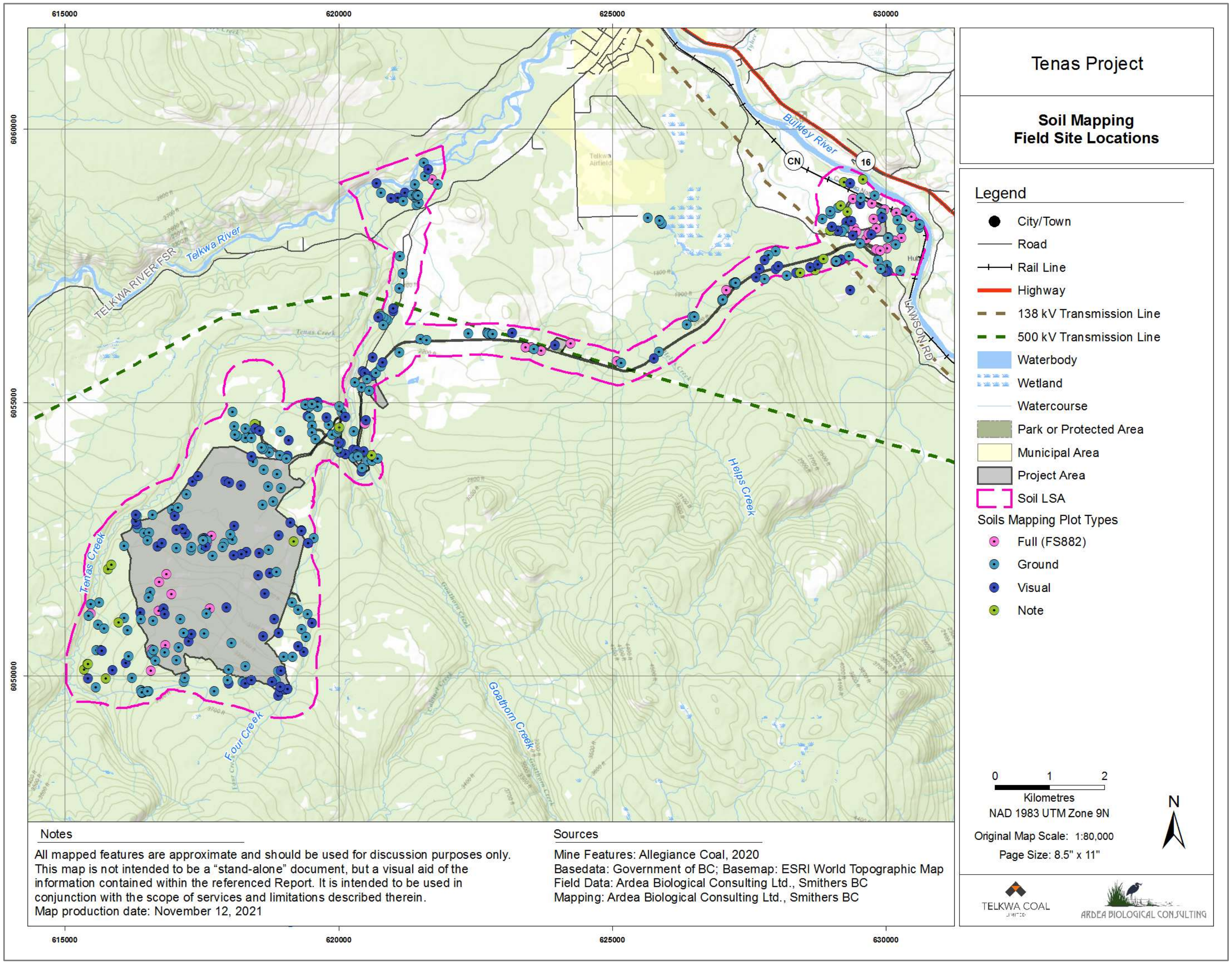


Figure 3-1: Location of soil field assessments within the S-LSA.

3.4.2 Soil Map Unit (SMU) Descriptions

Important soil properties for each soil map unit are summarized in Table 3-7. Detailed write-ups for each SMU, describing soil properties, soil erosion concerns, soil salvage potential and comments regarding CLI agricultural capability as it applies to polygons within the Agricultural Land Reserve, are found in Appendix D.

Table 3-7: Descriptions for soil map units.

SMU	Parent Material	General Description	Topography	Soil Texture	Average Rooting Depth (cm)	Coarse Fragment Content (%) R.Z.
1.1	M	Medium textured, well- to moderately-drained Orthic and Brunisolic Grey Luvisols, Eutric and Dystric Brunisols derived from tills, coarse fragment content from 10 to 40%. May have compacted Bt horizon. Limited organic enrichment.	Level to moderately steep	SiL, L, SiCL, (SL)	30	10-35
1.2	M (Fv)	Medium textured, Imperfectly- to poorly-drained Humic Gleysols, Gleyed Grey Luvisols, Gleyed Melanic Brunisols, derived from tills on receiving slope positions. Organic enriched A layer is typical.	Lower receiving slope positions	SiL, SiCL, SiC, (SL, LS)	30	10-40
1.3	M	Coarse textured, silty-sandy, well to rapidly-drained nutrient- poor Dystric Brunisols, derived from ablation tills. Cold-air ponding.	Undulating, convex	SL, LS	25	30-50
2	FG	Coarse textured, sandy, coarse-loamy to gravelly, well- to rapidly-drained Dystric Brunisols, derived from glaciofluvial parent materials.	Level to gently sloping	S, LS, (SL)	30	20-60
3.1	LG, (FG)	Fine-textured, moderately-drained Orthic and Brunisolic Gray Luvisols, derived from glaciolacustrine parent materials. Zero coarse fragments, and relatively high clay content.	Level to gently sloping	SiCL, SiL, Si	25	0
3.2	Fv [LG], LGp, Mp	Fine-textured, imperfectly- to poorly-drained Gleyed Dark Grey Luvisols, Gleyed Brunisolic Grey Luvisols, Humic Luvic Gleysols. Organic enriched A layer > 10 cm. Often signs of prolonged water saturation.	Level to gently sloping and depressions	Si, SiCL, SiL	25	0-10
4.1	F^{A}p, Fp	Coarse textured, sandy-silty, well- to moderately-drained Orthic and Cumulic Regosols on active floodplain deposits. Subsurface flooding or over-bank flooding. Organic enrichment variable.	Level to gently sloping	LS, S, SL, SiL	30	0-60

SMU	Parent Material	General Description	Topography	Soil Texture	Average Rooting Depth (cm)	Coarse Fragment Content (%) R.Z.
4.2	FAp, Fp	Fine-textured, silty, imperfectly- to poorly-drained Humic Regosols associated with floodplain deposits, often with organic enrichment. (Similar to SMU 3.2)	Level	SiL, SiCL, Si	25	0
4.3	Ft	Coarse-textured, sandy-silty, well- to rapidly-drained Brunisols derived from inactive fluvial deposits. (Similar to SMU 2)	Level to gently sloping	SL, LS	25	0-40
5	Mv [R or D]	Shallow, well- to rapidly-drained Dystric Brunisols over bedrock. Medium textured with high coarse fragments.	Gentle upper slopes and crests	SiL, FSL, SL	20	30-75
6	R, D	Skeletal. Rapidly drained bedrock outcrops.	Upper slopes, crests	Skeletal	< 5	Skeletal
7	O	Organic soil, poor to very poorly drained. Veneers and blankets.	Level to depression	Fibric, mesic organics	30	n/a
8.1	Cbv, FGks	Well to moderately well drained Regosols, Brunisols, Luvisols on steep to moderately steep escarpment slopes, some active failures and slumps.	Moderately steep, steep slopes	SiL, L, SiCL	30	25-80
8.2	Cfb	Humic Regosols with organic Ah horizons > 10 cm, situated in toe-slope receiving positions at base of escarpment slopes.	Gentle to moderate receiving slopes	SiL, L, SiCL	40	0-50

3.4.3 Soil Map Units Mapping

A 1:10,000 scale map outlining the SMUs mapped within the S-LSA is provided in Appendix E and summarized below.

Minesite

The most common soil map unit within the Minesite area is SMU 1.1, characterized by medium- to fine-textured, well- to moderately-drained Brunisolic and Luvisolic soils derived from basal morainal tills. These soils have a relatively high clay content and may have a compact Bt horizon. Average soil rooting depth is 30 cm. Similar soils in moisture-receiving slope positions has organic enrichment (SMU 1.3). More coarsely-textured Brunisolic soils derived from ablation-tills (SMU 1.3) occur to a limited extent on the across the plateau. Coarse-textured soil derived from glaciofluvial materials (SMU 2) occur associated with esker formations on the plateau in the vicinity of Four Creek and Tenas Creek. Silty-clayey soils with poor drainage and organic enrichment (SMU 3.2) occur in depressions in the plateau surface. Shallow soil (SMU 5) and skeletal soil (SMU 6) occur at the south end of Minesite, where occasional bedrock outcrops occur. Organic soil (SMU 7) is limited in extent, associated with poor to imperfectly drained depressions.

Goathorn Creek

The escarpments leading down to Tenas and Goathorn Creeks are mapped as SMU 8.1, where fine-textured Regosols, Luvisols and Brunisols have developed on colluvium. Rich and imperfectly-drained

Humic Regosols (SMU 8.2) occur along the base of these slopes where seepage is concentrated and or slumps have occurred. Coarse textured, sandy to gravelly Regosols (SMU 4.1) occur along the active floodplains of Goathorn Creek, Tenas Creek and the Bulkley River. Rapidly- to well-drained, sandy-silty Brunisols with high coarse fragments (SMU 4.3) are associated with inactive high-bench floodplain sites and fluvial terraces. Pockets of fine silty materials, often with organic enrichment (SMU 4.2) occur in old backchannel areas where drainage is poor to imperfect.

Bypass Road

The soils that intersect with the Bypass Road are predominantly SMU 1.1, characterized by medium- to fine-textured, well- to moderately-drained Brunisols and Luvisols derived from morainal tills. At the west end just before dropping into the Goathorn Creek valley, SMU 2 occurs, characterized by coarse-textured, well- to rapidly-drained Brunisols associated with a large glaciofluvial deposit. At the east end in the vicinity of Lawson Road and up to about 500 m elevation, SMU 3.1 is extensive, characterized by fine-textured, moderately drained Luvisols derived from glaciolacustrine parent materials. A few small rock outcrops (SMU 5 and 6) occur along the route, but do not intersect with the road itself.

Rail Infrastructure

Within the Rail Infrastructure area, SMU 4.3 is widespread, characterized by coarse sandy-silty, well-drained, nutrient poor Brunisols, associated with the high-bench floodplain of the Bulkley River. Fine silty, imperfectly to poorly-drained soil with organic enrichment (SMU 4.2) occupies the low-lying swales within the floodplain which can experience seasonal flooding.

3.4.4 Soil Sample Collection and Analyses

A total of 78 soil samples were collected from a representative cross-section of locations and soil types during the 2017 through to 2019 field seasons, as illustrated in Figure 3-2. The results of the trace metals analysis are presented in Appendix F. A summary of the plots in which CCME soil guidelines were exceeded is presented in Table 3-8.

Within the Minesite area, concentrations of Arsenic in the soil samples were the only samples found to exceed the CCME (2019) industrial guidelines of 12 mg/kg dry weight. Three sites (four soil samples), at plots IR025, IR034 and LTVeg20 ranged from 12.8 to 16.8 mg/kg. Five other soil samples from four plots also exceeded the CCME (2019) residential / parkland and agricultural guidelines of 12 mg/kg dry weight guidelines for Arsenic at sites LR04 in the Bypass Road area, and QA31, QA32, and QA35 in the Goathorn Creek area.

Boron concentrations were above the CCME (2019) residential / parkland and agricultural guidelines of 2.0 mg/kg dry weight for several plots within the Rail Infrastructure area (AD001, IR006, IR243, IR248, IR254, IR256, IR258, QA50, QA51and QA52). Samples were also above the guideline for Boron obtained from sites along the Bypass Road (IR213, IR218, LR02, LR03 and QA53) and in the Goathorn Creek area (LTVeg04, LTVeg13, LTVeg14, QA31, QA32 and QA44).

One soil sample from site LR06 in the Bypass Road area was found to just slightly exceed the CCME (2019) agricultural guideline of 1.4 mg/kg dry weight for Cadmium.

Four soil samples sites were identified with Sulphur concentrations above the CCME (2019) agricultural guideline of 500 mg/kg dry weight. One was in the Rail Infrastructure area (AD001), while three were within the Goathorn Creek area (QA31, QA35 and QA44). It is possible that other soil samples outside of the Minesite area could also exceed the CCME (2019) agricultural guideline as the method reporting limit for Sulphur (1000 mg/kg dry weight) was greater than the guideline and so those exceedances would not have been identified.

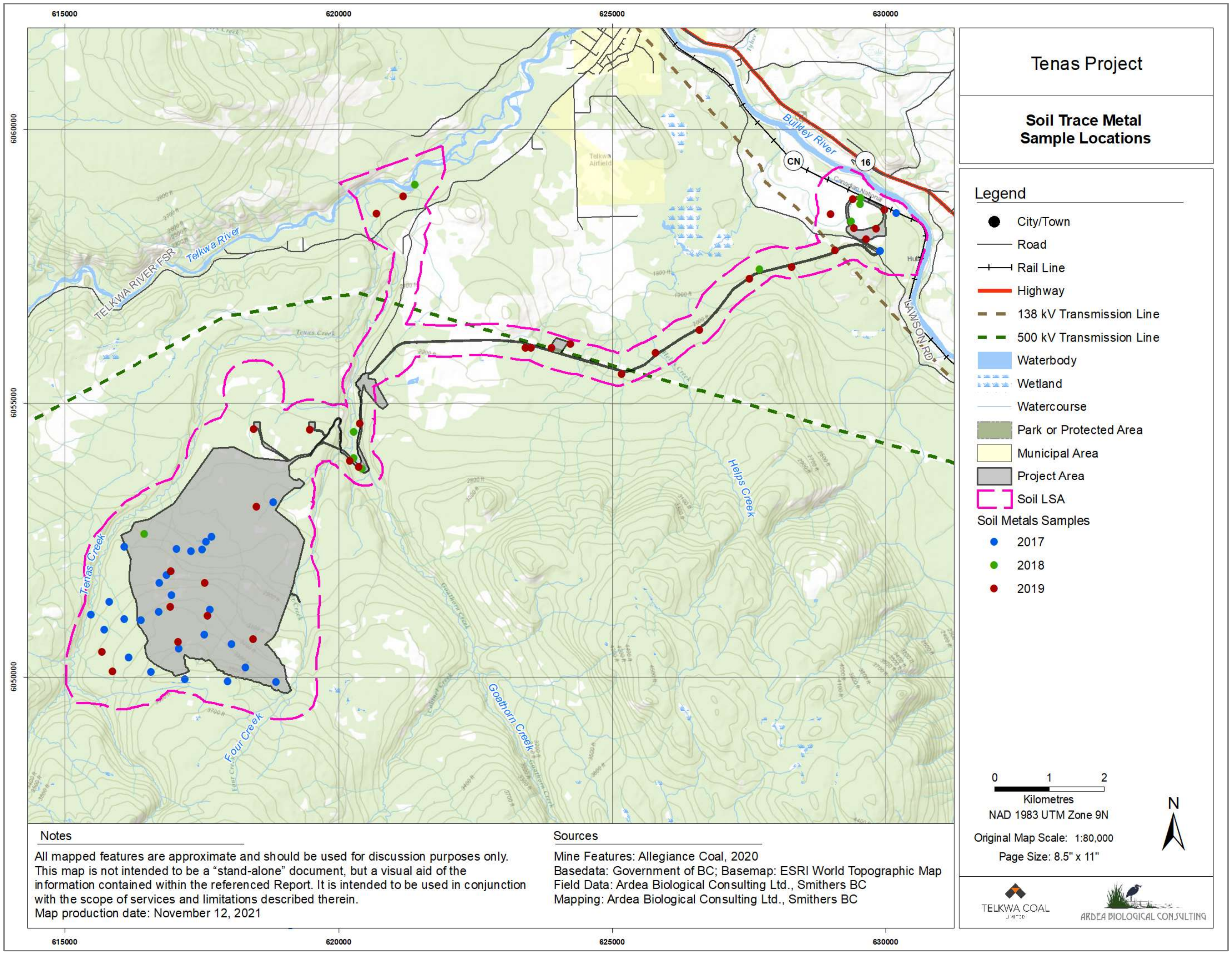


Figure 3-2: Locations of soil trace metals sample collection sites in the S-LSA.

Table 3-8: Soil samples that exceed CCME (2019) trace metals/ elements guidelines (mg/kg dry weight) for industrial in minesite area, and for agricultural and residential/parkland soils in all other areas.

				Plot number	AD001	AD001	IR006	IR025	IR034	IR034	IR213	IR218	IR243	IR248	IR254	IR256	IR258	LR02	LR03
				Depth (cm)	0-15	15-30	0-15	0-15	0-15	15-40	0-15	0-15	0-15	0-15	0-15	0-15	0-15	5-30	5-30
				Area	Rail	Rail	Rail	Mine	Mine	Mine	Bypass	Bypass	Rail	Rail	Rail	Rail	Rail	Bypass	Bypass
	SQG_{IN}[1]	SQG_{AG}[2]	SQG_{RP}[3]	MRL[4]															
Arsenic	12	12	12	0.3				15.8	16.8	14.0									
Boron	22	2	2	2	6.4	2.8	2.4				2.8	2.3	2.4	2.1	2.1	2.4	2.9	3.0	2.3
Cadmium	87	1.4	10	0.04															
Sulphur		500		1000	1100														

				Plot number	LR04	LR06	LTVeg04	LTVeg13	LTVeg14	LTVeg20	QA31	QA32	QA32	QA35	QA44	QA50	QA51	QA52	QA53
				Depth (cm)	5-30	5-30	5-30	5-30	5-30	5-30	0-20	0-15	15-30	0-15	0-15	0-15	0-15	0-15	0-15
				Area	Bypass	Bypass	Goathorn	Goathorn	Goathorn	Mine	Goathorn	Goathorn	Goathorn	Goathorn	Goathorn	Rail	Rail	Rail	Bypass
	SQG_{IN}[1]	SQG_{AG}[2]	SQG_{RP}[3]	MRL[4]															
Arsenic	12	12	12	0.3	13.2					12.8	13.6	13.2	16.5	13.2					
Boron	22	2	2	2			2.7	3.5	2.8		2.2	4.7	2.9		2.8	2.7	3.6	2.3	2.6
Cadmium	87	1.4	10	0.04		1.44													
Sulphur		500		1000							1910			1710	1020				

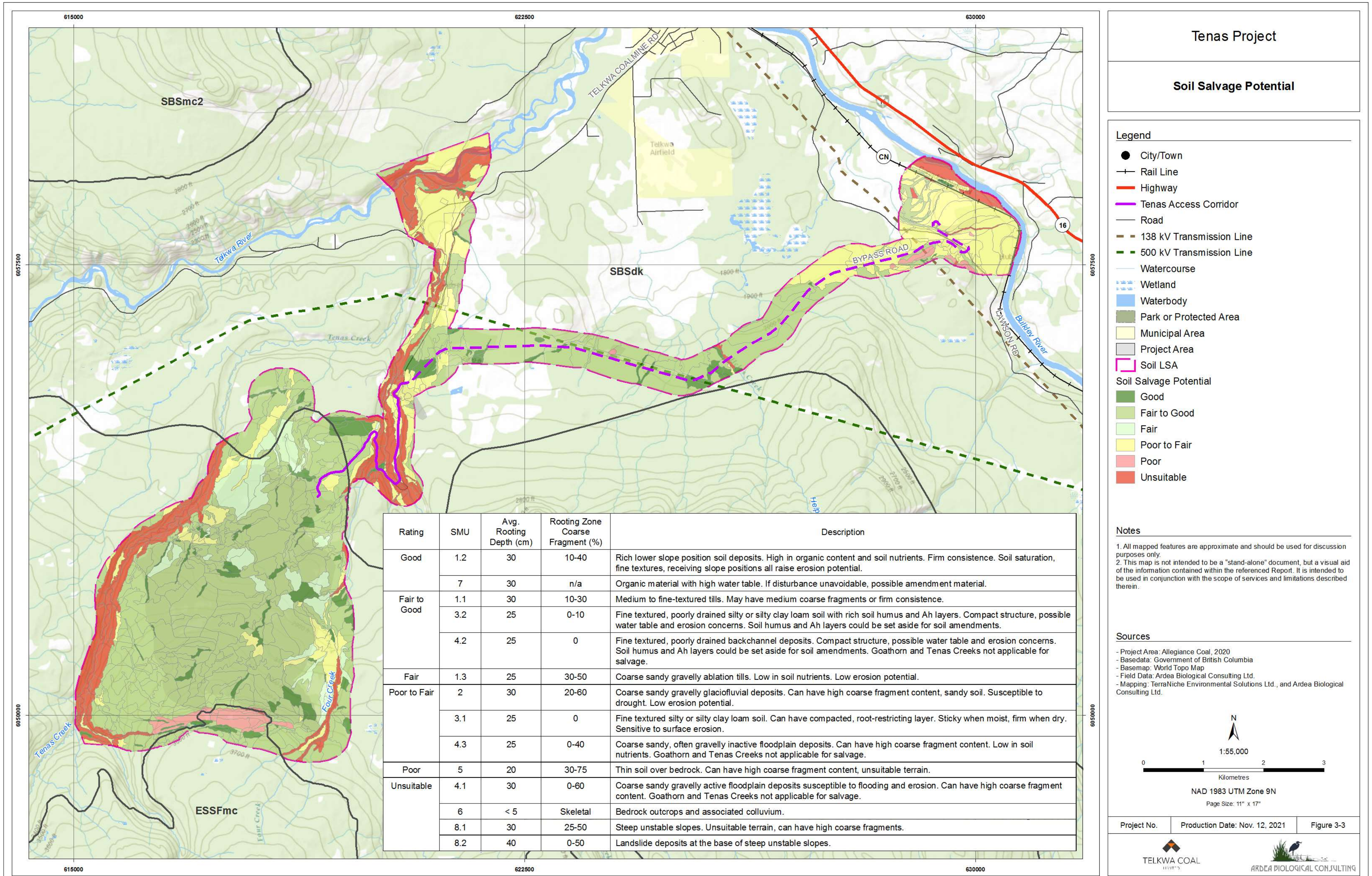
Notes: 1) CCME Soil Quality Guideline for Industry
2) CCME Soil Quality Guideline for Agriculture;
3) CCME Soil Quality Guideline for Residential / Parkland
4) Method Reporting Limit

3.4.5 Soil Salvage Potential Assessment

A summary of the soil salvage potential ratings and effective rooting zone depths by SMU is provided in Table 3-9 along with general comments related to soil salvage and management. An overview map of the soil salvage potential based on the dominant SMU within the polygon is outlined in Figure 3-3.

Table 3-9: Summary of soil salvage potential for soil map units.

SMU	Average Rooting Depth (cm)	Coarse Fragment Content (%) R.Z.	Rating	Soil Salvage / Management Comments
1.1	30	10-30	Fair to Good	Medium to fine-textured tills. May have medium coarse fragments or firm consistence.
1.2	30	10-40	Good	Rich lower slope position soil deposits. High in organic content and soil nutrients. Firm consistence. Soil saturation, fine textures, receiving slope positions all raise erosion potential.
1.3	25	30-50	Fair	Coarse sandy gravelly ablation tills. Low in soil nutrients. Low erosion potential.
2	30	20-60	Poor to Fair	Coarse sandy gravelly glaciofluvial deposits. Can have high coarse fragment content, sandy soil. Susceptible to drought. Low erosion potential.
3.1	25	0	Poor to Fair	Fine textured silty or silty clay loam soil. Can have compacted, root-restricting layer. Sticky when moist, firm when dry. Sensitive to surface erosion.
3.2	25	0-10	Fair to Good	Fine textured, poorly drained silty or silty clay loam soil with rich soil humus and Ah layers. Compact structure, possible water table and erosion concerns. Soil humus and Ah layers could be set aside for soil amendments.
4.1	30	0-60	Unsuitable	Coarse sandy gravelly active floodplain deposits susceptible to flooding and erosion. Can have high coarse fragment content. Goathorn and Tenas Creeks not applicable for salvage.
4.2	25	0	Fair to Good	Fine textured, poorly drained backchannel deposits. Compact structure, possible water table and erosion concerns. Soil humus and Ah layers could be set aside for soil amendments. Goathorn and Tenas Creeks not applicable for salvage.
4.3	25	0-40	Poor to Fair	Coarse sandy, often gravelly inactive floodplain deposits. Can have high coarse fragment content. Low in soil nutrients. Goathorn and Tenas Creeks not applicable for salvage.
5	20	30-75	Poor	Thin soil over bedrock. Can have high coarse fragment content, unsuitable terrain.
6	< 5	Skeletal	Unsuitable	Bedrock outcrops and associated colluvium.
7	30	n/a	Good	Organic material with high water table. If disturbance unavoidable, possible amendment material.
8.1	30	25-50	Unsuitable	Steep unstable slopes. Unsuitable terrain, can have high coarse fragments.
8.2	40	0-50	Unsuitable	Landslide deposits at the base of steep unstable slopes.



Rating	SMU	Avg. Rooting Depth (cm)	Rooting Zone Coarse Fragment (%)	Description
Good	1.2	30	10-40	Rich lower slope position soil deposits. High in organic content and soil nutrients. Firm consistence. Soil saturation, fine textures, receiving slope positions all raise erosion potential.
	7	30	n/a	Organic material with high water table. If disturbance unavoidable, possible amendment material.
Fair to Good	1.1	30	10-30	Medium to fine-textured tills. May have medium coarse fragments or firm consistence.
	3.2	25	0-10	Fine textured, poorly drained silty or silty clay loam soil with rich soil humus and Ah layers. Compact structure, possible water table and erosion concerns. Soil humus and Ah layers could be set aside for soil amendments.
	4.2	25	0	Fine textured, poorly drained backchannel deposits. Compact structure, possible water table and erosion concerns. Soil humus and Ah layers could be set aside for soil amendments. Goathorn and Tenas Creeks not applicable for salvage.
Fair	1.3	25	30-50	Coarse sandy gravelly ablation tills. Low in soil nutrients. Low erosion potential.
Poor to Fair	2	30	20-60	Coarse sandy gravelly glaciofluvial deposits. Can have high coarse fragment content, sandy soil. Susceptible to drought. Low erosion potential.
	3.1	25	0	Fine textured silty or silty clay loam soil. Can have compacted, root-restricting layer. Sticky when moist, firm when dry. Sensitive to surface erosion.
	4.3	25	0-40	Coarse sandy, often gravelly inactive floodplain deposits. Can have high coarse fragment content. Low in soil nutrients. Goathorn and Tenas Creeks not applicable for salvage.
Poor	5	20	30-75	Thin soil over bedrock. Can have high coarse fragment content, unsuitable terrain.
Unsuitable	4.1	30	0-60	Coarse sandy gravelly active floodplain deposits susceptible to flooding and erosion. Can have high coarse fragment content. Goathorn and Tenas Creeks not applicable for salvage.
	6	< 5	Skeletal	Bedrock outcrops and associated colluvium.
	8.1	30	25-50	Steep unstable slopes. Unsuitable terrain, can have high coarse fragments.
	8.2	40	0-50	Landslide deposits at the base of steep unstable slopes.

Figure 3-3: Overview map of soil salvage potential based on the dominant SMU in the polygon.

Using the average soil rooting depth as a guide, a potential soil salvage depth was assigned to each SMU. Table 3-10 provides estimates of potential soil salvage volumes for each SMU. The estimates are based on the proportions of the two SMUs and the associated potential soil salvage depths in each polygon.

Table 3-10: Potential soil salvage volumes by soil management units by project area.

SMU	Rating	Depth (m)	Soil Salvage Volumes by Project Area (m^3)			
			Minesite	Goathorn Creek	Bypass Road	Rail Infrastructure
1.1	Good to Fair	0.30	3,694,503	163,079	1,021,001	15,971
1.2	Good	0.30	518,547	40,816	202,412	
1.3	Fair	0.25	452,814	1,228		
2	Fair to Poor	0.30	424,100	354,206	44,922	77,115
3.1	Fair to Poor	0.25	10,642	5,714	278,909	75,875
3.2	Fair to Good	0.25	234,033	293,644	32,478	13,791
4.1	Unsuitable	0.30	137,595	64,833	7,198	90,329
4.2	Fair to Good	0.25	21,703	150,047		74,032
4.3	Fair to Poor	0.25	14,349	1,128		256,994
5	Poor	0.20	112,429	1,260	26,676	1,401
6	Unsuitable	0.05	2,363	3,761	565	
7	Good	0.30	127,366	194,818	7,354	7,001
8.1	Unsuitable	0.30	377,890	94,582	3,009	5,977
8.2	Unsuitable	0.40	82,867	163,079		

3.4.6 Soil Erosion Potential Assessment

Soil erosion potential ratings and a listing of soil textures for each SMU are provided in Table 3-11.

Table 3-11: Soil erosion potential ratings for soil management units.

SMU	Rating	Soil Textures	Comments
1.1	Low to Moderate	SiL, L, SiCL, (SL)	Cohesive tills
1.2	Moderate to High	SiL, SiCL, SiC, (SL, LS)	Silty, clayey, low permeability
1.3	Low to Moderate	SL, LS	Ablation tills, sandy
2	Moderate to High	S, LS, (SL)	Sandy glaciofluvial
3.1	Moderate to High	SiCL, SiL, Si	Silty, clayey, zero coarse fragments
3.2	Moderate to High	Si, SiCL, SiL	Silty, clayey, zero coarse fragments, low permeability
4.1	Moderate to High	LS, S, SL, SiL	Sandy gravelly fluvial
4.2	High	SiL, SiCL, Si	Silty, clayey, zero coarse fragments, low permeability
4.3	Moderate to High	SL, LS	Sandy gravelly fluvial
5	Low to Moderate	SiL, FSL, SL	Can have high coarse fragments
6	Low	Skeletal	Bedrock outcrops
7	Low	Fibric, mesic organics	Organic

SMU	Rating	Soil Textures	Comments
8.1	Very High	SiL, L, SiCL	Steep slopes
8.2	Very High	SiL, L, SiCL	Landslide deposits

3.4.7 Agricultural Capability Assessment

Agricultural Capability ratings were assigned to all polygons within the Agricultural Land Reserve (ALR) and are shown in Figure 3-4 in a general way and in greater detail in Appendix G. These lands occur along the Bypass Road and Rail Infrastructure areas, and within the Goathorn Creek area along Coal Mine Road.

Within lands designated as ALR, the Rail Infrastructure zone covers an area of 50 hectares. Approximately 10.5 km of Bypass Road bisects ALR lands, and 5 ha of the Goathorn Creek area is within ALR lands. Assuming a 15-metre-wide right of way, the Bypass Road covers an area of 16 hectares. Soil survey data is summarized in Table 3-12 for project infrastructure areas that fall within the ALR. ALC survey intensity standards recommend 1 detailed soil survey per 5 hectares.

Table 3-12: Number of detailed soil inspections for agricultural capability assessment.

Areas	Area (Ha)	Soil Inspection Type			Inspections per 5 Ha	SIL
		Detailed	Visual	Total		
Rail Infrastructure	50	11	6	17	1.1	1
Bypass Road	16	7	21	28	2.1	1
Goathorn Creek	5	4	4	8	4	1

The Rail Infrastructure extends over roughly 50 hectares of inactive floodplain adjacent to the Bulkley River, characterized by sandy, often gravelly soil interspersed with narrow swales of poorly-drained silty-clays in old backchannel areas. Agriculture land capability is predominantly class 5 with limitations due to low soil fertility, stoniness and aridity. Coarse-textured, sandy, and often gravelly soil described by SMU 4.3 are typical. Most of the area has been cleared. A few fields are cultivated for hay production, but most fields are pasture. Forage is limited as the pasture is dominated by hawkweed and dandelion, as illustrated at plot IR255 in Plate 3-1.

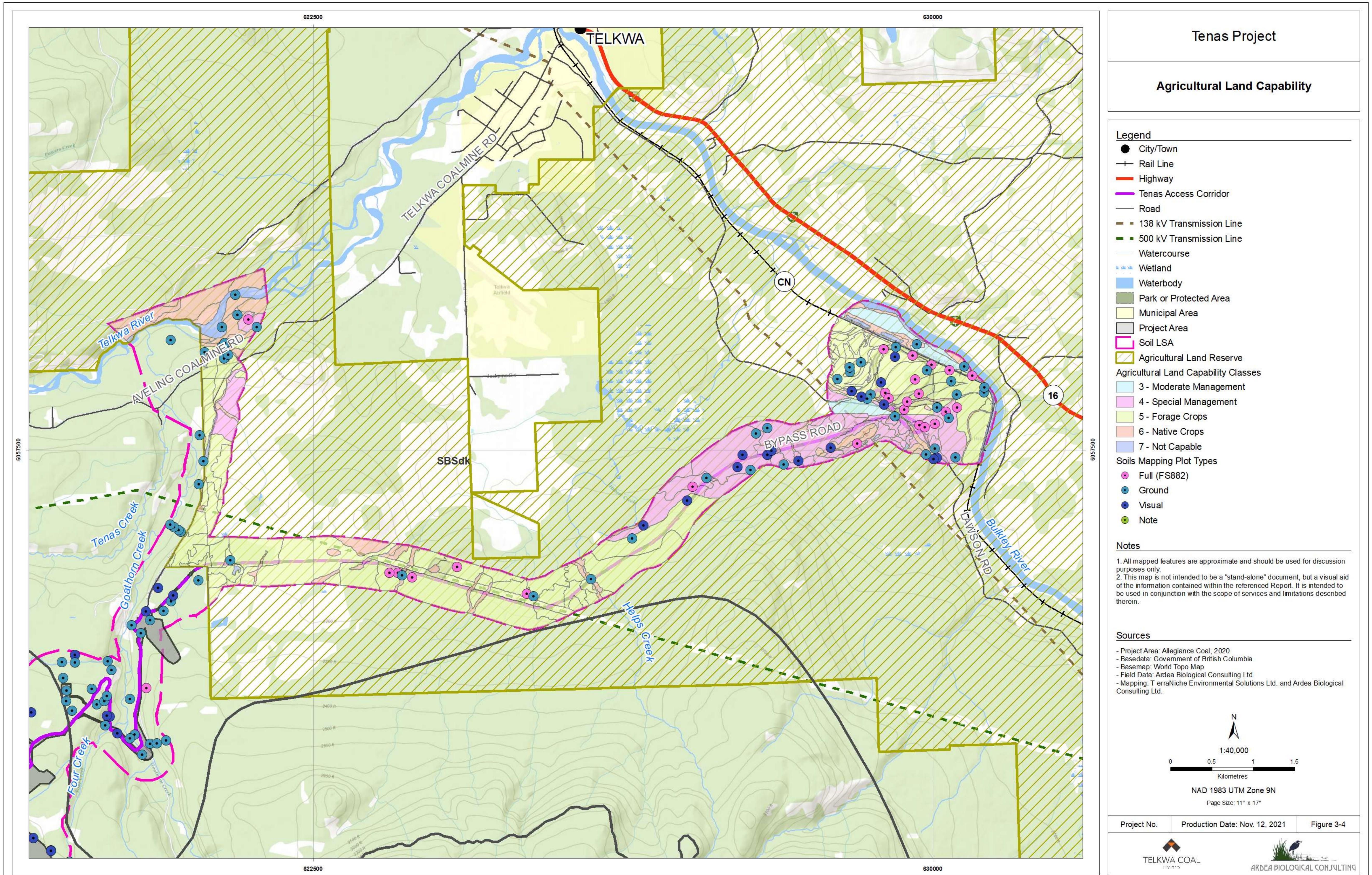


Figure 3-4: Agricultural Capability ratings mapped within the S-LSA.

Plate 3-1: View of pasture looking east across Rail Infrastructure area and soil profile.

A summary of area in hectares by agricultural capability class for the Rail Infrastructure, Bypass Road, and Goathorn Creek are provided in Table 3-13.

Table 3-13: Agricultural capability classes within the mapped areas of the ALR.

Areas	Agricultural Land Capability Class					Total Area (Ha)
	3	4	5	6	7	
Rail Infrastructure	21.2	41.9	135.0	22.2	14.2	234.4
Bypass Road	9.5	140.5	310.9	68.7	4.5	534.1
Goathorn Creek		22.7	69.6	70.3	17.2	179.8
Total Area (ha)l	30.6	205.1	515.5	161.3	35.9	948.3

Agricultural capability within the Bypass Road is dominantly undeveloped Class 4 and Class 5, with limitations due to stoniness and climate. Receiving sites at the base of slopes and along creek channels are Class 6, with limitations for excess water. Pasture and cultivated hayfields and at the west end of the Bypass Road are Class 5 with limitations due to climate and stoniness. At elevations above 600 metres, crop potential is limited by a short growing season. At the east end of the Bypass Road an area of fine-textured soils derived from glaciolacustrine parent materials causes dense soil structure, rated as Class 4D. Class 7 lands occur to a limited extent along slope breaks and the few bedrock outcrops in the mid-section and east end of the Bypass Road, with limitations due to topography and shallow soil. The Organic soil class is applied to a limited number of polygons, in the vicinity of Helps Creek, adjacent to Lawson Road, and to a few small kettle hole depressions along the Bypass Road.

Agriculture capability within the Goathorn Creek area is predominantly Class 5 and Class 6. At elevations above 600 metres, crop potential is limited by a short growing season. At the north end of Coalmine Road, a large glaciofluvial terrace results in sandy gravelly soil that are Class 5 with limitations due to soil aridity, stoniness, and lack of fertility. Seasonal inundation occurs along the Goathorn and Telkwa floodplains, most of which are Class 6.

3.4.8 Quality Assurance and Quality Control of Soil Mapping

Quality assurance (QA) results are summarized in the confusion matrix shown in Table 3-14 as per Meidinger (2003) for the 52 plots completed during the QA review. Overall, our results displayed an accuracy rate of 83%. These errors reflect differences in interpretation between the closely related SMUs 1.2 and 3.2 which are both fine textured, and SMUs 1.3 and 2 which are both coarse textured.

As a result of the QA review, D. Yole recommended a few additions to the list of SMUs: 1) the floodplain unit, SMU 4, be divided into SMU 4.1 for soil on active floodplain sites that experiences seasonal over-bank flooding, and SMU 4.3 for soil on inactive floodplain sites; and, 2) SMU 8 for unstable slopes be divided into SMU 8.1, for soil on steep escarpment slopes, and SMU 8.2, for rich imperfectly drained soil often found on landslide deposits at the base of such slopes. Both of these recommendations are reflected in the final classification.

Table 3-14: Soil management unit accuracy assessment.

		Field Assessment SMU															
	SMU Units	1.1	1.2	1.3	2	3.1	3.2	4.1	4.2	4.3	5	6	7	8.1	8.2	Total	Omission Error
Interpreted SMU	1.1	3	1				1									5	40%
	1.2		4													4	0%
	1.3	1		4	1											6	33%
	2		1	1	5											7	28%
	3.1					4										4	0%
	3.2		1				6									7	14%
	4.1							5								5	0%
	4.2								0							0	0%
	4.3									3						3	0%
	5										1					1	0%
	6											0				0	0%
	7												4			4	0%
	8.1					1								4		4	0%
	8.2					1									0	0	0%
Total		4	7	5	6	6	7	5	0	3	1	0	4	4	0	52	8%
Commission Error		25%	42%	20%	16%	32%	14%	0%	0%	0%	0%	0%	0%	0%	0%	11%	

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Appendix A List of Air Photos

Table A-1: Air Photos Used for Terrain and Soils Mapping and for Natural Hazard Analysis

Exposure Date		Flight Line[1] and Air Photo Number		Scale	Comment
2017		Digital orthophoto provided by Telkwa Coal			Terrain LSA
2013	Sep 2	bcd13305	135 - 136	1:15,000	Goathorn bridge
		bcd13307	115, 116		Cabinet Creek
2006	Jul 1	bcc06043	015 – 021; 078 – 081; 118 – 122	1:20,000	Terrain LSA
		bcc06044	004 – 008		
		bcc06054	051 - 057		
2003	Jul 28	bcc03008	053	1:35,000	Goathorn Creek
1994	May 18	bcb94014	177 – 179; 284 - 286	1:5000	Telkwa River
	Jul 11	bcb94027	025, 026	1:15,000	Goathorn Bridge
1993	Jul 17	bcc93014	065 – 066	1:15,000	Telkwa River
	Aug 19	bcc93064	101, 134 – 135	1:15,000	Goathorn Bridge
1990	Jul 19	bcc90043	088, 089	1:15,000	Telkwa River
1988	Aug 11	bcc810	007, 008	1:10,000	Bulkley River
1987	Aug 24	bcc704	190	1:10,000	Telkwa River
1986	Jun 3	bcc438	008	1:10,000	Goathorn Creek
	Jun 5	bcc440	192, 193	1:10,000	Goathorn bridge
			206		Bulkley River
			214		Telkwa River
1982	Jun 29	bc82008	136	1:20,000	Bulkley River
1980	Jun 7	bc80041	047	1:15,000	Bulkley River

[1] BC Government air photos except the 2017 orthophoto

Appendix B Terrain Field Site Locations

Table B-1: UTM coordinates of terrain field sites referenced in the Baseline report.

Field ID	UTM Zone	UTM Easting	UTM Northing
AD001 (12-8537)	9U	629904	6057772
IR006 (12-8642)	9U	630203.5249	6058465.363
AD127	9U	616606.7355	6052899.33
AD129	9U	616804.5663	6053066.25
AD181	9U	621818	6058987
AD182	9U	621718	6059080
AD183	9U	621585	6059133
AD185	9U	621648	6059259
AD188	9U	620960	6058727
IR020	9U	617959	6051242
IR034	9U	617511	6052314
IR058	9U	617975	6049913
IR082a	9U	619270.2941	6050528.568
IR082b	9U	619216.777	6050718.818
IR092	9U	617007.7947	6052878.028
IR094	9U	617051.7122	6053010.286
IR106	9U	618001.0599	6053533.242
IW131	9U	620035.0725	6054260.97
IR134	9U	620047.5388	6054416.781
IR145	9U	620689.8666	6055536.81
IR146	9U	620786.3272	6055661.671
IR147	9U	620802.7641	6055730.623
IR160	9U	629587.5117	6059074.506
IR202	9U	621469.7863	6058656.936
IR203	9U	621376.5017	6058764.004
IR236	9U	629245.984	6058165.731
IR237	9U	629216.3506	6058115.989
IR239	9U	628985.6335	6058155.148
IR246	9U	630039.5028	6057493.868
IW001	9U	630054.399	6057863.053
IW010	9U	630342.6147	6058620.639
IW013	9U	629997.0517	6058384.158
IW045	9U	620507.8103	6053813.961
IW050	9U	620377.6873	6053931.44
IW053	9U	620420.7072	6054355.717
IW054	9U	620265.4222	6054241.636
IW059	9U	620219.3809	6055164.09
IW060	9U	620195.9098	6055241.551
IW060a	9U	620171.4259	6055258.003
IW064	9U	620393.3313	6055189.603
IW065	9U	620468.6738	6055533.499
IW122	9U	620050.2297	6054358.442
IW133	9U	621337.1881	6058748.532
IW202	9U	620563.7645	6055299.893
IW215	9U	629400.653	6057986.486
IW216	9U	629386.6222	6058085.551
IW226	9U	621076.6585	6057301.808
IW230	9U	621017.2712	6056807.828
IW231	9U	620905.9767	6056720.832
IW234	9U	620986.2391	6056664.641
IW235	9U	620478.1721	6055547.047
IW239	9U	620414.4028	6055606.871
IW240	9U	620324.4801	6055580.125
IW241	9U	620299.3424	6055509.941
IW247	9U	620250.3604	6055348.186
IW251	9U	620365.8822	6055377.662
IW256	9U	620651.554	6053848.623
IW258	9U	620623.5556	6053949.382
IW261	9U	620569.6955	6054617.657
IW263	9U	620607.3602	6054856.174
IW264	9U	620478.7378	6055146.833
IW265	9U	620537.1673	6055093.696
IW268	9U	620721.9728	6053673.243
IW270	9U	620183.9706	6054727.473
IW275	9U	620147.2295	6054699.39
IW277	9U	620204.5411	6054634.292
IW279	9U	620440.0315	6056115.387
IW280	9U	620343.4499	6055908.984
IW281	9U	620334.0036	6056012.943
IW282	9U	620265.68	6056011.054
IW292	9U	620183.9941	6056065.889
IW308a	9U	621454.9947	6059387.262
IW308b	9U	621608.03	6059454.572

Field ID	UTM Zone	UTM Easting	UTM Northing
IW312	9U	620501.8523	6059034.684
IW316	9U	620803.8538	6058006.557
IW322	9U	621409.2267	6059054.385
IW323	9U	621425.199	6059124.715
IW326	9U	621398.499	6059327.762
QA32	9U	620432	6053798
QA35	9U	620284	6054476

Field ID	UTM Zone	UTM Easting	UTM Northing
QA42	9U	621004	6056722
QA44	9U	621397	6058987
QA50	9U	629374	6058318
QA51	9U	629542	6058624
QA52	9U	629553	6058743
QA53	9U	627698	6057437