

TERRAIN STABILITY ASSESSMENT

Rossiter 6500 FSR

Selkirk Forest District

**Prepared for:
British Columbia Timber Sales
Kootenay Lake Field Team**

Prepared by:



Project No. 23-1816

June 13, 2023

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June 13, 2023

Sitkum File No: 23-1816

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1.0 INTRODUCTION

At the request of Mr. Brody Jordan, T.F.T. of British Columbia Timber Sales – Kootenay Lake Field Team (BCTS-KLFT), Sitkum Consulting Ltd. (SCL) has carried out a Terrain Stability Assessment (TSA) for the proposed Rossiter 6500 FSR. Also included in the assessment is a proposed road upgrade of a 1.6 km section of Rossiter FSR. The proposed road development is situated within the Kaslo River and Rossiter Creek drainages in southeastern B.C., approximately 20 km northwest of the village of Kaslo (refer to Figure 1).

A TSA has been requested based on application of BCTS Terrain Stability Assessment Decision and Documentation Tool, part of the BCTS Terrain Stability Management Model. Taken into consideration was the proposed development being situated on or upslope of moderately steep to steep terrain. Also considered in the request for a TSA was the presence of Highway 31A and fish habitat downslope.

The scope of the assessment, as agreed upon by BCTS-KL and SCL is:

- to identify potential terrain stability concerns associated with the proposed development;
- to evaluate the potential impact relating to slope stability of the proposed development on downslope elements at risk;
- to provide recommendations where warranted to reduce the likelihood of landslides attributable to the proposed development; and
- to present a partial risk analysis relating to select downslope elements at risk.

The considered downslope elements at risk, determined by SCL and confirmed by BCTS-KLFT are Highway 31A (including human safety) and fish habitat in the Kaslo River and Rossiter Creek. The village of Kaslo also maintains a domestic water intake approximately 19 km to 20 km downstream of the proposed forest development. This intake is intended as a backup supply for the primary Keen Creek source. While this important element has not been itemized in the risk analysis presented in this report it can be assumed less at risk than the fish habitat in Kaslo River proximal to the proposed development. Other potential downslope elements which have been considered but have not been assigned a specific risk rating include a point of diversion (POD) for industrial use in Rossiter Creek (PD192693), wildlife habitat, visual resources, downslope resource roads, timber value and soil productivity.

2.0 METHODOLOGY

This TSA has been carried out in a method consistent with the *Guidelines for Professional Services in the Forest Sector - Terrain Stability Assessments* (ABCFP/EGBC 2010) and *Guidelines for Professional Services in the Forest Sector – Forest Roads* (ABCFP/EGBC 2012). This TSA is also in conformance with the *Guide to the Standard for Documented Independent Review of High-Risk Professional Activities or Work* (EGBC 2021). A partial risk analysis has been completed with specific definitions and an overview presented in Appendix A, along with a list of descriptive terms relating to soil drainage, soil texture and consistency, surface expression, and bedrock characteristics. Land Management Handbook 56, *Landslide Risk Case Studies in Forest Development Planning and Operations* (Wise et al. 2004) can be referenced for additional background information on partial risk analysis.

The likelihood of landslide initiation has been estimated in a qualitative manner based on generally accepted geotechnical interpretations and assumptions, the experience of SCL, comparative observations of both natural and forest development related landslides in the southern interior of B.C., and results from landslide attribute studies in the southern interior of B.C. (Jordan 2003). The landslide likelihood ratings are considered incremental to the existing state (natural or otherwise) as a result of the proposed development. **Where the assessed likelihood of a hazardous landslide attributable to the proposed development has been estimated at Very Low, no further risk analysis has been carried out.** Unless otherwise stated, **landslide likelihood and risk ratings are based on the assumption that generally accepted good development and maintenance practices have been implemented.** Residual likelihood and risk ratings are based on the assumption that all recommendations presented in this report are implemented along with generally accepted good development and maintenance practices.

It is the responsibility of the land manager to understand and accept the rating definitions used in this analysis as they are not set by any regional or provincial standards. It is also the responsibility of the land manager to determine the acceptable, tolerable, or unacceptable levels of risk for the development in order to complete the risk assessment, and decide whether or not to proceed with the development based on that decision.

Worker and road user safety during and after operations relating to layout and design is addressed by the forest development coordinating professional, along with work site safety standards and procedures. Worker and road user safety related to terrain stability is addressed in this assessment by means of identification of upslope hazards where they exist, and recommendations for construction of a stable road or trail prism where conventional practices may not be appropriate.

No visible channel (NVC) is the term used in this report and tables to confirm that there is no evidence of any type of channel resulting from surface runoff, either continuous or discontinuous. If a discontinuous channel exists, the drainage feature is then considered a non-classified drainage (NCD). If a continuous channel is present, either ephemeral or perennial, then the appropriate stream channel classification has been identified (e.g. S6).

Construction Summary Tables presented in Appendix B refer to hubs as flagged in the field by SNT Engineering Ltd. (SNT). A geometric road design produced by SNT was reviewed as part of this assessment to confirm the intent of recommendations presented in the construction summary tables were met in the final design.

Figures 1 through 3 in Appendix C indicate water features based on Terrain Resource Information Management (TRIM) mapping, supplemented with additional field information gathered by SCL.

2.1 Office Assessment

As part of the office assessment, the following information was reviewed by SCL:

- BCTS Terrain Specialist Assignment Form (BCTS – Kootenay Business Area), August 9, 2022;
- 1:50,000 scale overview map with the proposed roads provided by BCTS-KLFT, September 6, 2022;
- 1:20,000 scale overview map with the proposed roads provided by BCTS-KLFT, September 6, 2022;
- 1:1,500 scale LiDAR based slope map with proposed and existing roads provided by BCTS-KLFT, August 23, 2022;
- SNT road survey notes for Rossiter 6500 FSR;
- 1:5,000 scale LiDAR based slope themed, 5 m contour, slope, and bare earth model mapping prepared by SCL with TSM and planned road locations;
- *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory of Slocan Forest Products Ltd. Chart Area, Selected Streams*, prepared for Slocan Forest Products Ltd. by Timberland Consultants Ltd., March 29, 1999;
- Google Earth (GE) orthomosaic imagery;
- BC Water Licence Query, Habitat Wizard, and iMapBC web applications; and
- ClimateBC_Map (UBC Centre for Forest Conservation Genetics).

2.2 Field Assessment

Mr. Jeremy Major, P.Geo. and Ms. Caitlin Tatham, P.Geo., both of SCL carried out the field assessment of the proposed development on October 19, 2022. The weather at the time was sunny with temperatures near 20°C. There was no significant precipitation in the previous two weeks.

The total field traverse time by SCL took approximately 13 combined person hours to complete. Field positions were established based on field flagging, handheld GPS (Bad Elf GPS Pro+ and iPad mini) and recognizable land features (creeks, slope breaks, existing roads, etc.). Refer to Figure 2 for approximate traverse routes.

2.3 Limitations

Field assessments are a result of surface and near surface investigations of the surficial geology, soil drainage, and geomorphologic processes. Shallow soil pits, existing road cuts, and overturned root wads were examined; no deeper subsurface investigation was completed. Subsurface conditions are inferred from observations and interpretations of surface characteristics, and conditions encountered during excavation may vary.

Stereo air photo pairs were not reviewed as part of this assessment. This is not considered a significant limitation due to the quality of LIDAR products and orthomosaic imagery reviewed, in addition to the extent of fieldwork and the author and reviewers familiarity with the terrain in the area.

Interpretations of surface flow patterns were made by careful observations of the forest floor, vegetative indicators, and surface configuration, as is typical for geotechnical assessments. These interpretations take into account the experience of the authors observing conditions in similar terrain during periods of high runoff.

3.0 BACKGROUND INFORMATION

The following sections include background information and general details about the project area and present relevant information on terrain stability that provides the basis for the partial risk ratings presented within this TSA report.

3.1 Regional Terrain Stability Considerations

Landslides within B.C. occur both naturally and as a result of forest development. Landslide attribute studies completed in the region report an increase in landslide occurrence where forest development exists (Jordan 2003). Jordan reports slope steepness, terrain type, the presence of gullies, and the presence of natural landslides as significant terrain variables when looking at development related landslides. In general, landslide frequency was found to be much lower than average in areas with slopes less than 20° (35% gradient), and increase with slope steepness to a maximum in the 35° to 40° category (70% to 84% gradient), with a decrease in the > 40° category (likely due to the presence of steep yet stable bedrock slopes in this category). Landslide frequency was found to be greater in gullied terrain in comparison with non-gullied. Glaciofluvial and kame deposits were found to have the greatest landslide frequency of all the surficial material types, with thick morainal materials being second. Development-related landslides were also more frequent in areas with existing natural slope failures. Climate and bedrock geology are also variables which proved significant in some areas, with wetter climates and weak bedrock such as phyllite and mica schist generally having higher landslide frequencies.

In the southern interior of B.C., roads have been shown to be a much more significant factor than harvesting for landslides attributable to forest development. Landslide attribute studies in the Nelson Forest Region indicate approximately 80% of forest development-related landslides are caused by roads (Jordan et al. 2010). These studies also indicate that landslides caused by trails are mostly drainage-related, as opposed to cut or fill slope instabilities. With good development practices, harvesting-related landslides are very rare on slopes less than 50%, rare on slopes between 50% and 70%, and are still uncommon but occur most frequently on slopes between 70% and 84%. In many cases, harvesting can contribute to development-related landslides by increasing local runoff that can be intercepted by roads and trails.

With generally accepted good construction practices and favourable surficial material properties (e.g. free-draining, non-cohesive), road prism landslides following conventional sidecast fill construction in the region are virtually non-existent on side slope gradients less than 45%, and uncommon on side slope gradients between 45% and 60%. Road prism landslides are more likely to occur on slopes exceeding 60% to 65%. It is important to understand that these estimates are approximate and critical slope angles vary depending on site specific conditions, including drainage and surficial material properties. In most cases, the likelihood of road prism landslides can be reduced through modified construction methods and drainage management appropriate to specific site conditions.

Downslope drainage related landslides, as well as Gentle-over-Steep (GoS) landslides, are an important consideration in the region, with many drainage-related landslides initiating at some

distance (several to several hundred metres) downslope of a road or trail (Jordan 2001, 2002; Grainger 2002). These drainage related landslides most commonly occur at a slope break to steeper terrain with slopes at the headscarp typically greater than 60%, but occasionally as low as 45% (Jordan 2001). They also more commonly occur on gullied terrain, and where weathered surficial materials are relatively thin overlying an impermeable layer such as bedrock or dense basal till, as opposed to where downslope materials are thicker and permeable (Grainger 2002). Drainage related landslides occur more frequently where there is greater potential for concentrated and redirected drainage along a road or trail, and are most often preventable with a high level of effective drainage control including seasonal deactivation measures. Harvesting alone is very rarely a cause of downslope drainage related landslides, although harvested areas often contribute to these types of events by increasing the rate of runoff that can be redirected by roads or trails.

Most forest development related landslides in the region are debris slides or debris avalanches, although many become channelized debris flows if gullies are present. Channelized debris flows generally initiate either by a destabilizing impact to a gully channel from a smaller initial landslide, or from a critical high flow reached in a stream channel which causes localized destabilization of the bedload and/or stream banks (Geertsema et al. 2010). Either mode of initiation can result in progressive channel destabilization and entrainment of debris. The former is by far the most common cause of debris flow initiation within the region. The latter is generally associated with significantly increased stream flows due to widespread watershed disturbances such as wildfires. Other contributing factors to in-channel debris flow initiation can be significant runoff concentration or redirection from resource roads or trails which greatly increase effective drainage areas, redirected stream flows, extreme runoff events, or stream flow blockage failures (e.g. short lived landslide dam).

Most road prism landslides are less than approximately 1000 m³ in volume, and commonly remain small in size (50 m³ to 500 m³) unless they enter a gully and cause a channelized debris flow as described above. They are generally limited in magnitude by source area volume and potential for entrainment of downslope materials. Drainage-related landslides are commonly larger, dependent on the length and steepness of slope, type and amount of material available for entrainment, and water discharge at the site. The concept of yield rate can be used to estimate potential event magnitude, taking into account the likely area and depth of scour (Hung et al. 2005).

Factors that can increase the length of runout and/or decrease the angle of deposition include, but are not limited to; increased event volume^{1,2,3}, increased vertical relief^{1,2}, slope geometry², increased water supply⁴, finer textured materials^{3,4}, confinement^{1,2,4}, and lack of obstructions or topographical constraints^{1,2,3,4}. Hung et al. (2005) reports variable published deposition angles for relatively coarse grained debris flows in B.C. ranging from 12% to 25%, with lower angles for finer textured materials. Jordan et al. (2011) reports on three specific long runout events that recently occurred in the southern interior of BC, and identifies fine textured materials, specifically those with substantial clay content, as an important contributing factor to the long runout. No detailed empirical-statistical analysis of runout distance specific to the region is available; however, consideration of the above factors combined with field observations of past landslide

1 Corominas 1996

2 Hunter and Fell 2003

3 Jordan et al. 2011

4 VanDine 1996

events in the area can provide context for the qualitative estimate of potential landslide runout distances.

The above findings are generally consistent with observations of SCL over the last 20+ years of assessing terrain stability in the region, and provide supporting rationale for the landslide likelihood and partial risk ratings presented in this report.

3.2 General Physiography

The proposed development is situated within the Kaslo River valley along the southern boundary of the Goat Range of the Selkirk Mountains, part of the Columbia Mountain System. The general physiography of the region consists of serrated ridges and peaks above approximately 2000 m elevation and rounded ridge crests and steep valley sides below 2000 m. Local summit levels lie between 2250 m and 3100 m, and local relief of approximately 1100 m to 1500 m is typical.

3.3 Site Location – General

The proposed development is situated on a mid-slope position on the southwest aspect slopes of the Kaslo River and Rossiter Creek drainages; refer to Figure 1 and Image 1. Proposed Rossiter 6500 FSR is situated between approximately 1550 m and 1600 m elevation, while the section of Rossiter FSR proposed for upgrade is located between approximately 1400 m and 1600 m elevation. There are multiple cutblocks and forest roads within the vicinity of the proposed development, including from the POC to Δ22 of Rossiter 6500 FSR.

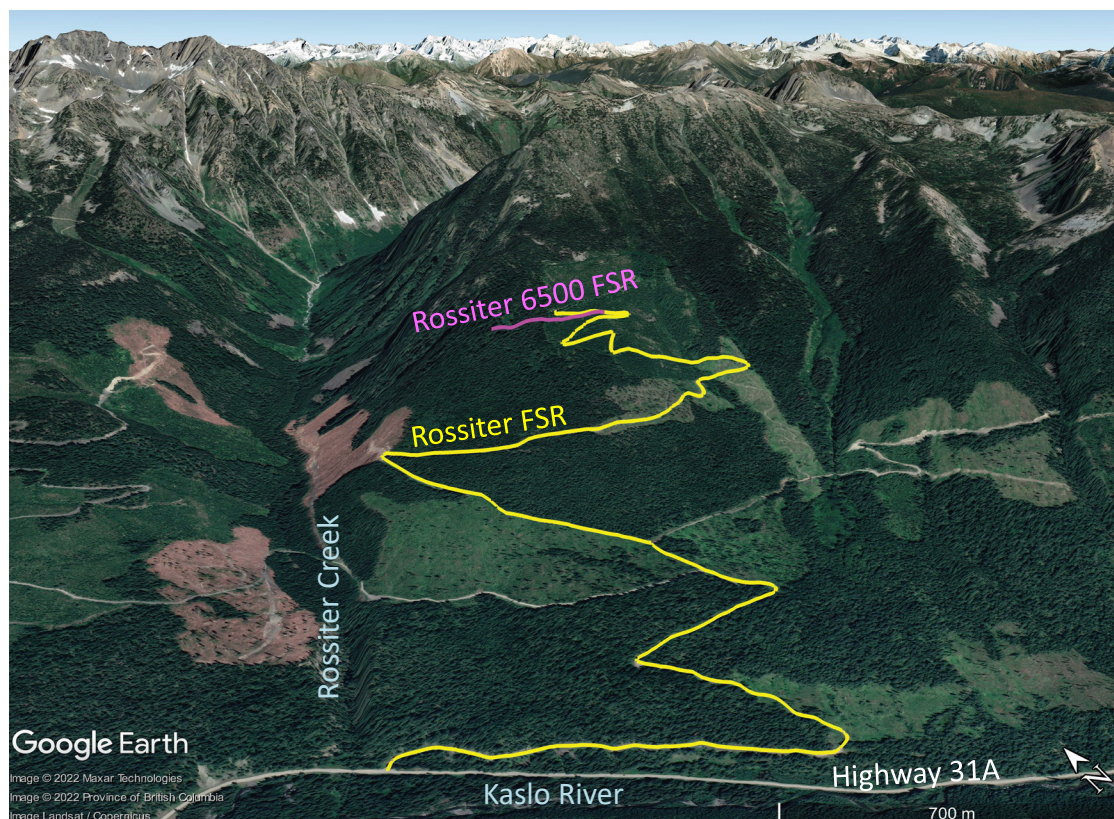


Image 1: Oblique aerial view looking northeast at proposed Rossiter 6500 FSR in pink, existing Rossiter FSR in yellow. Orthomosaic imagery was captured August 7, 2022.

The Kaslo River (S2) is located approximately 1800 m to 2000 m downslope of the proposed road and is confirmed fish bearing. A licensed POD (PD24530) for auxiliary use for the village of Kaslo is located approximately 19 km to 20 km downstream.

From $\Delta 35$ to the POT the road drains southwest to Rossiter Creek (S4), a tributary to the Kaslo River. Rossiter Creek is located approximately 1400 m downslope of the proposed road and its lower reach is confirmed fish bearing. There are no licensed domestic water intakes in Rossiter Creek. There is one POD in Rossiter Creek at Highway 31A (PD192693) held by the Ministry of Transportation and Infrastructure for industrial purposes.

Highway 31A is located near valley bottom, approximately 1700 m to 1900 m downslope of proposed Rossiter 6500 FSR.

Based on the available biogeoclimatic mapping, the proposed development is located in the Slocan variant of the Wet Hot subzone of the Engelmann Spruce – Subalpine Fir zone (ESSFwh1). The referenced climate model indicates that the mean annual precipitation ranges from 1130 mm to 1210 mm across the proposed development area, generally increasing with elevation.

The available regional geology mapping indicates that the proposed development is underlain by Carboniferous to Permian aged mafic basaltic volcanic rocks of the Kaslo Group, part of the Slide Mountain Assemblage. This is consistent with field observations.

4.0 OBSERVATIONS & INTERPRETATIONS

The following sections present observations and interpretations, as well as the partial risk analysis relating to the proposed forest development.

4.1 Rossiter 6500 FSR

Rossiter 6500 FSR is proposed for permanent construction and is approximately 464 m in length. The alignment takes off from existing Rossiter FSR at approximately 6.5 km and extends northwest. The road grade is rolling with a few sustained adverse sections, including near the POT. The available TSM has mapped the terrain along the alignment as stable.

The surface configuration along the alignment is uniform with no significant drainage features (Photo 1). Slope gradients along the alignment are generally gentle to moderate (30% to 50%), with moderately steep (50% to 60%) gradient slopes from $\Delta 8$ to $\Delta 14$ and moderately steep to steep (50% to 75%) gradient slopes from $\Delta 26$ to the POT. From the POC to $\Delta 25$ the alignment is underlain by a moderately well to well drained till blanket (2.5 m to 4 m thick) comprised of a sandy silt with some gravel, trace boulders and cobbles, and a coarse fragment content (CFC) of 25%. From $\Delta 25$



Photo 1: Typical uniform terrain along proposed Rossiter 6500 FSR.

to the POT the alignment is underlain by a moderately well to well drained colluvial blanket (1.5 m to 3 m thick) comprised of a sandy silt with some gravel and cobbles, trace boulders and a CFC of 35%. There are no watercourses along Rossiter 6500 FSR.

4.1.1 Rossiter 6500 FSR - Downslope Description

The surface configuration downslope of proposed Rossiter 6500 FSR is generally uniform, with no significant drainage features. Slope gradients immediately downslope of the POC to $\Delta 25$ are generally moderate with frequent short (<40 m) moderately steep (50% to 70%) gradient slopes. This includes a moderately steep gradient slope located immediately downslope of $\Delta 8$ to $\Delta 14$. Surficial material along these slopes is comprised of the moderately well to well drained till blanket described in Section 4.1. There are two mapped old trails downslope of the POC to $\Delta 25$. Both trails are narrow (~3 m wide) with irregular outsloped surfaces and no sign of instability. As a result, these trails are unlikely to redirect or concentrate runoff. The moderate gradient slopes with short sections of moderately steep gradient slopes continue downslope of the alignment for approximately 400 m.

Slope gradients downslope of $\Delta 25$ to the POT are generally moderately steep to steep (60% to 80%), with a short band of >80% bedrock bluffs (Photo 2). The band of bedrock bluffs are located approximately 10 m to 40 m downslope of the alignment, with the intervening distance increasing to the east. Surficial material in this area is comprised of the moderately well to well drained colluvial blanket observed along the alignment (refer to Section 4.1). The moderately steep to steep slopes continue downslope of the alignment for approximately 350 m.



Approximately 350 m to 400 m downslope of the alignment, the terrain transitions to generally gentle to moderate (15% to 50%)

gradient slopes that become gentler towards valley bottom. There are isolated areas of moderately steep (50% to 70%) gradient slopes that are generally <40 m in length intermittently located within the generally gentle to moderate gradient slopes. In addition, there is a ~90 m long section of moderately steep gradient slopes downslope of the alignment at approximately 1320 m elevation.

The majority of the proposed Rossiter 6500 FSR drains down the southwest aspect face to the Kaslo River, which is located approximately 1800 m to 2000 m downslope of the alignment. The Kaslo river lies within the wide valley bottom with gentle (<5%) channel gradients. There is no watercourse connectivity between the proposed road and the Kaslo River.

From $\Delta 35$ to the POT, the alignment drains southwest to Rossiter Creek, which is located approximately 1400 m downslope of the alignment. The available TSM has mapped the portion of Rossiter Creek downslope of the alignment as unstable where it is confined in a 20 m to 30 m deep gully with steep to very steep (>80%) sidewalls. The average channel gradient in this section is

Photo 2: Moderately steep to steep gradient slopes with bedrock bluffs downslope of $\Delta 25$ to the POT.

35%, but it eases downstream where bull trout have been documented in the lowest reach prior to the confluence with the Kaslo River. Based on LiDAR imagery, it appears that there is evidence of past debris slides occurring along the Rossiter Creek gully sidewall. There is no watercourse connectivity between the proposed road and Rossiter Creek.

4.1.2 Rossiter 6500 FSR - Landslide Hazard and Partial Risk Analysis

The following sections outline the likelihood of a hazardous landslide for each considered event, and related partial risk associated with each considered element.

Likelihood of a hazardous road prism landslide

- $P(H)_{\text{road prism}}$: Very Low to Moderate, residual Very Low to Low

Taking into account the observations presented above, along with the regional terrain stability considerations present in Section 3.1, the likelihood of a hazardous road prism landslide along Rossiter 6500 FSR is estimated to be Very Low to Moderate following conventional sidecast fill construction. Considering the surficial material properties, drainage conditions, and other terrain attributes as discussed in Section 3.1 a Very Low rating is associated with sections where slope gradients are generally less than 45%, and a Low rating is associated with slope gradients ranging from 45% to 60%. A Moderate rating is associated with slope gradients ranging from 60% to 75% where conventional sidecast fill construction may not result in a stable road prism. With implementation of the recommendations outlined within this report and the Construction Summary Tables in Appendix B, as well as applying generally accepted good development practices, the residual likelihood of a hazardous road prism landslide is estimated to be Very Low to Low.

Likelihood of a hazardous downslope drainage related landslide

- $P(H)_{\text{downslope drainage related}}$: Low

While there is some potential for significant redirected runoff if drainage is not properly managed along Rossiter 6500 FSR given the sections of continuous adverse road grades, implementing the drainage recommendations outlined in Appendix B along with generally accepted good road construction and maintenance practices can reduce this potential. In addition, the generally linear drainage patterns and the lack of watercourses along the alignment further reduces this potential. The moderately steep to steep gradient slopes located immediately downslope of the alignment could be sensitive to significantly redirected or concentrated runoff, however, they are unlikely to be affected if all drainage recommendations are followed. While the steep to very steep gradient Rossiter Creek gully sidewall with evidence of past instabilities would be sensitive to significantly redirected or concentrated runoff, it is unlikely to be affected due to the >1000 m of intervening gentle to moderate gradient slopes and lack of watercourse connectivity. As a result, assuming the recommended drainage control is implemented along with maintenance inspections, seasonal deactivation measures, and generally accepted good development practices, the likelihood of a hazardous downslope drainage related landslide attributable to Rossiter 6500 FSR is estimated to be Low.

Partial Risk

Based on comparison with past forest development related landslides in the region and taking into account the site specific factors such as slope length, likely scour depth, and size of past events,

the considered hazardous landslide initiating as a result of the proposed development is a small to medium sized road prism failure (200 m^3 to 1000 m^3) or downslope drainage related debris slide (200 m^3 to 2000 m^3). In the event of a hazardous road prism failure or downslope drainage related debris slide, it would most likely terminate on gentle to moderate gradient terrain prior to valley bottom or the Rossiter Creek gully.

Highway 31A

- $P(\text{HA}_{\text{Highway 31A}})$ road prism: Very Low
- $P(\text{HA}_{\text{Highway 31A}})$ downslope drainage related: Very Low

Highway 31A is located near valley bottom approximately 1700 m to 1900 m downslope of the alignment. As discussed above, a hazardous road prism or downslope drainage related debris slide attributable to Rossiter 6500 FSR would likely terminate upslope of the highway due to the extent of gentle gradient and benched terrain. Taking the above factors into consideration, the likelihood of a spatial impact Highway 31A is estimated to be significantly less than the likelihood of a hazardous road prism or downslope drainage related landslide initiating along the proposed road. Therefore, the associated partial risk is estimated to be Very Low with respect to the considered hazardous road prism landslide and Very Low with respect to the considered downslope drainage related landslide.

In the unlikely event of a spatial impact with Highway 31A, debris could be deposited on the road surface causing a temporary blockage of the road, but permanent damage is unlikely given the generally limited volume of material and depositional state. With respect to road user safety, considering the combination of temporal and spatial probabilities required for an impact to safety, the risks associated with landslides attributable to Rossiter 6500 are estimated to be not significantly increased from those road users would be already exposed to on Highway 31A and similar highways in the region.

Fish Habitat in Rossiter Creek and Kaslo River

- $P(\text{HA}_{\text{Downslope Fish Habitat}})$ road prism: Very Low to Low, residual Very Low
- $P(\text{HA}_{\text{Downslope Fish Habitat}})$ downslope drainage related: Very Low

The Kaslo River is located approximately 1800 m to 2000 m downslope of the proposed road and is confirmed fish bearing. There is also confirmed fish habitat in Rossiter Creek, approximately 1400 m downslope of the westernmost portion of the alignment. Due to the intervening distance from the alignment with areas of gentle to moderate gradient terrain and the lack of connecting gullies or watercourses, it is unlikely for a hazardous road prism or downslope drainage related debris slide attributable to Rossiter 6500 FSR to adversely affect fish habitat in the Kaslo River or Rossiter Creek. As a result, the likelihood of significant sediment reaching fish habitat estimated to be less than the likelihood of a hazardous road prism or downslope drainage related landslide initiating along the proposed road. Therefore, the associated partial risk is estimated to be Very Low to Low with respect to the considered hazardous road prism landslide, with a residual partial risk of Very Low following the recommended construction methods presented in the Construction Summary Tables in Appendix B. The associated partial risk is estimated to be Very Low with respect to the considered downslope drainage related landslide.

In the unlikely event of elevated turbidity being introduced to fish habitat in the Kaslo River or Rossiter Creek it may last on the order of a few days to a few weeks immediately following the event but could reoccur to a lesser degree during periods of high runoff for a few years following the event, as a result of erosion of the landslide surface prior to self-armouring and revegetation.

4.2 Rossiter FSR Road Upgrade

As part of the Rossiter 6500 FSR TSA, BCTS-KLFT has requested SCL to review and provide road upgrade recommendations for a 1568 m section of existing Rossiter FSR. The assessed section of the road switchbacks west along a southwest aspect slope that drains to the Kaslo River. The POC of the road upgrade is located at 4.92 km on Rossiter FSR, and the POT of the road upgrade is located at Hub 1 of proposed Rossiter 6500 FSR. The available TSM has mapped the terrain along the road upgrade as stable.

The section of Rossiter FSR that was assessed is partially overgrown and was only accessible on foot. Based on a review of available air photos, the road was constructed between 1986 and 1988 (pre-Forest Practices Code). There is generally no ditch, and where there is a ditch, it is in poor condition. There are frequent existing cross-ditches and waterbars for drainage control. The existing road width is generally >4.5 m, with a few areas where the road width is <4.5 m wide. This includes a 30 m length where the road is approximately 3 m to 4 m wide near 5.47 km on Rossiter FSR. Minor settlement was observed on the outer 1 m of existing fill in this area (Photo 3). In addition, there is evidence of some minor fill slope settlement within the existing rock fill at 5.97 km. The fill slope settlement at both locations appears to have occurred following road construction and there are no signs of active instability. There are frequent areas of volcanic bedrock located along the existing road surface and cut slope, generally located upslope of 1450 m elevation.

The road upgrade crosses Blaylock Creek (S6) twice, at approximately 4.92 km and 5.34 km. The creek is contained in a 2 m deep gully at the upper crossing and a shallow swale at the lower crossing (Photo 4). Channel gradients along Blaylock Creek range from 20% to 55%. No other



Photo 3: Minor fill settlement at 5.47 km on Rossiter FSR.

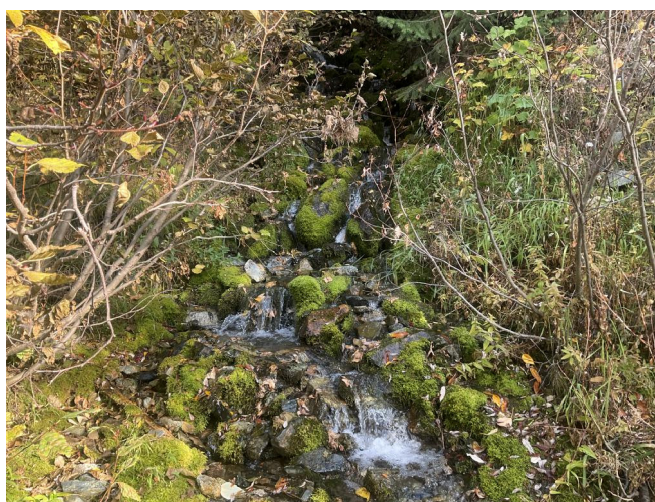


Photo 4: Blaylock creek at the cut slope along the upper Rossiter FSR crossing

watercourses or areas of seepage were observed during the field assessment along the assessed section of the road.

SCL has recommended culverts for drainage control along the assessed section of Rossiter FSR, including 1200 mm culverts at the Blaylock Creek crossings. It is recommended to construct a ditch where feasible, or in-slope the road 5% in areas where a ditch cannot be constructed. The road should be widened as necessary to gain the appropriate road width. Refer to the Prescription Summary table in Appendix C for more details on recommendations for the road upgrade.

5.0 RECOMMENDATIONS

Road construction recommendations, as well as maintenance and deactivation measures are provided in the construction summary tables in Appendix B. Refer to the attached prescription summary tables in Appendix C for both general and site-specific recommendations relating to the road upgrade of Rossiter FSR. These recommendations are intended to reduce the likelihood of landslide initiation and adverse effects to downslope water quality resulting from the proposed road development. The focus of the recommendations is on construction of a stable road prism and drainage control intended to reduce the likelihood of accelerated, concentrated, or redirected runoff which could cause downslope instability. The recommendations are intended to reinforce or supplement good construction practices in order to maintain the risk ratings as presented above.

5.1 Field Reviews

Sufficient field supervision should be carried out by an experienced and qualified road construction supervisor to ensure generally accepted good construction practices are implemented along with all recommendations presented in this report.

A field review by a qualified registered professional at completion of construction is recommended to confirm subsurface conditions encountered, final culvert placement, and that the intent of the TSA recommendations is met. If at any time site conditions encountered vary significantly from those described in this report (e.g. unexpected significant seepage, unexpected material textures encountered in excavations, etc.), or if any stability or erosion concerns become apparent during operations, then a qualified registered professional should be consulted to confirm if a construction field review is warranted. Timely mitigation of problem sites can significantly reduce potential adverse effects.

6.0 CLOSURE

The discussions and recommendations presented above are based on a visual field assessment and additional information, which was reviewed at the time of the assessment. This report has been prepared for the use by British Columbia Timber Sales – Kootenay Lake Field Team, which includes distribution as required for purposes for which the assessment was commissioned. The assessment has been carried out in accordance with generally accepted geotechnical practice. Geotechnical judgment has been applied in developing the recommendations in this report. No other warranty is made, either expressed or implied.

SCL trusts that the information presented above meets your current requirements. If you have any questions, or require further information, please do not hesitate to contact the undersigned.

Respectfully submitted,

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Appendix A

**Risk Analysis
&
Soil, Slope, and Rock Classification
Definitions and Overview**

The following sections provide important definitions for terminology used in this report, and are based on definitions presented in Land Management Handbook 56 - Landslide Risk Case Studies in Forest Development Planning and Operations (Wise et al. 2004) (LMH-56).

Hazard: a source of potential harm, or a situation with the potential for causing harm, to a specified *element at risk*. With respect to landslide risk analysis, the landslide itself is the hazard.

Likelihood of occurrence: the qualitative estimate of probability (P), or the chance for an event to occur.

Elements at risk (elements): a thing of value that is known to be at risk. Elements at risk may include human life, public and private property, transportation system/corridor, utility and utility corridor, domestic or community water quality and supply, fish habitat, wildlife habitat and migration, visual resource in a scenic area, timber value, and soil productivity (adapted from B.C. MoF, 2002).

Hazard analysis, $P(H)$: an estimation of the probability of a specific hazardous event. With respect to landslide hazard analysis, it refers to the probability or likelihood of occurrence for a specific hazardous landslide.

Spatial probability, $P(S:H)$: relates to the potential for an event to reach or have a spatial effect on the location of a considered element, and mathematically can range from a value of 0 (certain not to reach the element) to 1 (certain to reach the element).

Temporal probability, $P(T:S)$: relates to the potential for a mobile element to be at the affected location, if the considered event occurs. If the element is of a fixed location and is always present (such as permanent infrastructure) then the temporal probability is numerically equal to 1, with a value of less than 1 applicable for mobile elements depending on the proportion of time exposed.

Consequence, C : the effect on a specified *element at risk*. With respect to landslide risk analysis, the consequence is the change, loss, or damage to the considered element caused by the landslide. Consequence takes into account the vulnerability as well as spatial and temporal probabilities of an event affecting an element.

Vulnerability, V : a measure of the robustness of an *element at risk* and its relative exposure to a hazard.

Partial risk analysis, $P(HA)$: the product of the probability of occurrence and the probability of a spatial effect, taking into account both spatial and temporal probabilities. With respect to landslide risk analysis, it is the product of the probability for a specific hazardous landslide and the probability of that landslide reaching or otherwise affecting a considered element. It can also be referred to as the probability of a specific hazardous affecting landslide. Partial risk does not take into account the vulnerability of the element at risk, or the consequence of the event.

Specific risk analysis, $R(S)$: the risk of loss or damage to an element. With respect to landslide risk analysis, it is the risk of loss or damage to a specific element resulting from a specific hazardous affecting landslide. Specific risk takes into consideration the vulnerability of the element at risk and consequence of the event.

Specific Value of Risk, $R(SV)$: the worth of loss, or damage to a specific element, excluding human life, resulting from a specific hazardous affecting event.

In general terms, risk is defined as the product of probability of occurrence and consequence ($R=PXC$). In the consideration of consequence to a specific element at risk, the vulnerability or robustness of the specific element must be understood. The vulnerability of specific elements is

generally best assessed by specialists (e.g. biologists, foresters, utility engineers) with a greater knowledge of the element than the terrain stability professional may have.

As a result, it is generally appropriate for a terrain stability professional to carry out a *partial risk analysis*, in which the likelihood of a specific hazardous landslide is determined, and whether or not a specific element at risk could be spatially affected by the hazardous landslide; however, the vulnerability of the specific element, including an estimation of consequence, is not considered (Wise et al. 2004; LMH 56).

The following tables further outline the terms and ratings presented in this report. Table 1 provides the qualitative descriptions for the relative likelihood of occurrence ratings for a considered event, and the related approximate quantitative probability ranges. While there is an inherent degree of uncertainty in estimating the probability of a specific landslide, and it is a subjective interpretation that is dependent on numerous factors, these relationships can give some physical meaning to the qualitative terms applied.

Table 1: Qualitative description of the likelihood of occurrence, and related quantitative probability ranges¹

Likelihood of Occurrence	Qualitative Description	Annual probability of occurrence ⁴	Probability of occurrence over a 20 year term
Very High (VH)	An event is imminent or likely to occur frequently; well within the lifetime of a typical resource road ² or soon after logging ³ .	>0.05 (>1/20)	>0.65
High (H)	An event can happen or is probable within the lifetime of a typical resource road ² or soon after logging ³ .	0.01 - 0.05 (1/100 - 1/20)	0.18 - 0.64
Moderate (M)	An event is not likely, but possible within the lifetime of a typical resource road ² or soon after logging ³ .	0.002 - 0.01 (1/500 - 1/100)	0.04 - 0.18
Low (L)	An event is unlikely to occur (remote possibility) within the lifetime of a typical resource road ² or soon after logging ³ .	0.0004 - 0.002 (1/2500 – 1/500)	0.01 - 0.04
Very Low (VL)	The likelihood of an event occurring is extremely remote to nil within the lifetime of a typical resource road ² or soon after logging ³ .	<0.0004 (<1/2500)	<0.01

1) Modified from Wise et al (2004), Table 2, pg 14; and B.C. MoF (2002), Appendix 10.2., and refers to a 1 km segment of road or a specified area of development.

2) Assumes a 20 year+ design life.

3) Time period between logging and establishment of a new-growth forest (generally on the order of 20 to 30 years).

4) Annual probability of occurrence does not consider the design life of the road.

These rating definitions are used for a considered event, and can apply to the likelihood of a specific hazardous landslide occurring [P(H)] as well as to the likelihood of a specific hazardous affecting landslide [P(HA)], or partial risk. This rating system can also be used to describe the likelihood for other events such as stream channel avulsion, soil erosion, or redirected runoff.

Table 2: Example of magnitude ratings and ranges of landslide area and volume

Magnitude Rating	Quantitative Range	
	Area affected (ha)*	Minimum Volume involved (m ³)**
Very Large	>5	50,000
Large	0.5-5	5,000-50,000
Medium	0.05-0.5	500-5,000
Small	0.005-0.05	50-500
Very Small	<0.005	< 50

*1 ha = 10,000 m²

**Based on planimetric area and assumed depth/thickness of 1 m.

As partial risk, $P(HA)$, is defined as the probability of a specific hazardous affecting landslide, it is derived from the product of the probability of a specific hazardous landslide [$P(H)$], the probability of that landslide reaching an element [$P(S:H)$], and the probability of the element being present at the time of event [$P(T:S)$]. This can be expressed mathematically as:

$$\text{Partial Risk, } P(HA) = P(H) \times P(S:H) \times P(T:S)$$

In the case where there is assumed certainty that the landslide would reach the element, and that the element would always be present, then $P(S:H)$ and $P(T:S)$ would both be numerically equal to 1 and the partial risk would be equal to the probability of the specific hazardous landslide occurring [$P(HA) = P(H)$]. Alternatively, if an element is always present [$P(T:S) = 1$], but it is not certain that the landslide would reach or otherwise affect the site of the element, [$P(S:H) < 1$], then the partial risk rating may be reduced from the probability of the hazardous landslide occurring depending on the situation and level of certainty.

With this methodology the partial risk rating can be equal to or less than the likelihood of the hazardous landslide occurring in the first place, but will not be increased as can result from some qualitative matrix multiplication. Understanding how risk ratings are derived is important when management decisions may be based on the outcome, or when ratings may be compared between different developments or assessments.

In some cases, land managers may choose to complete a specific risk or specific value of risk analysis by incorporating additional vulnerability [$V(L:T)$], consequence [C], or worth [E] information with input from the appropriate specialists as required (refer to LMH 56 for additional information on specific risk).

Note: It is the responsibility of the land manager to understand and accept the rating definitions used in the analysis as they are arbitrary and not set by any regional or provincial standards. It is also the responsibility of the land manager to determine the acceptable, tolerable, or unacceptable levels of risk (partial, specific, or specific value of risk) for the development in question.

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Soil, Slope, and Rock Classification

Course Grained Soils ¹ (Cohesionless):

Density	Field Test
Very Loose	Easily excavated with a spade
Loose	Some resistance to spade
Compact	Considerable resistance to space
Dense	Requires pick for excavation
Very Dense	High resistance to pick

Fine Grained Soils ¹ (Cohesive):

Consistency	Field Test
Very Soft	Easily excavated with a spade
Soft	Easily penetrated by thumb
Firm	Readily penetrated by thumb
Stiff	Readily indented by thumb
Very Stiff	Penetrated by thumbnail
Hard	Difficult to indent with thumb

Rock Strength ¹:

Strength	Field Identification
Extremely Weak	Indented by thumbnail
Very Weak	Crumbles under firm blow of hammer; can be peeled with a pocket knife
Weak	Can be peeled by pocket knife (difficult); shallow indents from firm blow of hammer point
Medium Strong	Cannot be scraped or peeled with knife; fractures with single blow of hammer.
Strong	Requires more than one blow of hammer to fracture
Very Strong	Requires many blows of hammer to fracture
Extremely Strong	Can only be chipped by hammer

Spacing of Discontinuities in Rock ¹:

Spacing	Spacing Width (m)
Extremely Close	<0.02
Very Close	0.02 – 0.06
Close	0.06 – 0.20
Moderately Close	0.2 – 0.6
Wide	0.6 – 2.0
Very Wide	2.0 – 6.0
Extremely Wide	>6.0

Soil Description¹⁴:

Noun	Gravel, sand, silt, clay	> 35% and main fraction
"and"	and gravel, and silt, etc	> 35%
Adjective	gravelly, sandy, silty, etc.	20-35%
"Some"	some sand, some silt, etc.	10-20%
"Trace"	Trace sand, trace silt, etc	1-10%

Soil Thickness^{2,3}:

Thickness	
Blanket	>1.0 m
Veneer	<1.0 m

Soil Drainage⁵(adapted):

Rapidly drained	Water is removed from the soil rapidly in relation to supply.
Well drained	Water is removed from the soil readily but not rapidly.
Moderately Well drained	Water is removed from the soil somewhat slowly in relation to supply.
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. Some mottling is common.
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. Soils are generally mottled and/or gleyed.
Very Poorly drained	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Typically associated with wetlands.

Slope Gradient:

Slope Gradient	Percent (%) Range	Degree Range
Flat	<5	<3
Gentle	5-26	3-15
Moderate	26-50	16-26
Moderately Steep	50-70	27-35
Steep	70-90	35-42
Very Steep	90	>42

Surface Configuration ² (modified):

Surface Configuration	Relief (metres)
Uniform	<1.0
Slightly Irregular	1.0 – 2.0
Irregular	2.0 – 4.0
Very Irregular	>4.0

Slope Shape ³ (modified) and Features

Based on the overall shape of the slope between distinct slope breaks; includes concave , convex and straight and benched shapes.
Gullies ⁶ (modified): sidewalls >3m high (measured along the fall line); sidewall gradients >50%; channel gradients typically >20% (may be less for some sections); may or may not contain an active stream channel.
Swailes : any linear depressions in the landscape that do not meet the gully criteria above; generally shallower with lower channel and sidewall gradients; may or may not contain an active stream channel.

Qualitative landslide magnitude ratings⁷

Magnitude Rating	Typical Area affected (ha)	Typical Volume Involved (m ³)
Very Large	>5	50,000
Large	0.5 - 5	5,000 – 50,000
Medium	0.05 – 0.5	500 – 5,000
Small	0.005 – 0.05	50 - 500
Very Small	<0.005	<50

REFERENCES:

1. Canadian Geotechnical Society, Canadian Foundation Engineering Manual, 4th Edition, *Identification and Classification of Soil and Rock*, 2006.
2. Ministry of Forests, A Guide for Management of Landslide Prone Terrain in the Pacific Northwest, 2nd Edition, *Land Management Handbook #18*, 1994.
3. Ministry of Environment, Terrain Classification for British Columbia, Revised Edition, *Manual # 10*, 1998
4. Ministry of Forests, Forest Road Engineering Guidebook, 2nd Ed., 2002.
5. Ministry of Environment Lands and Parks and Ministry of Forests, Field Manual for Describing Terrestrial Ecosystems, LMH#25, 1998.
6. Ministry of Forests, Gully Assessment Procedures Guidebook 1995
7. Ministry of Forests, Landslide Risk Case Studies in Forest Development Planning and Operations, LMH#56, 2004.

Appendix B

Construction Summary Tables & Typical Section Diagrams

Construction Summary Tables

Drainage: Kaslo River & Blaylock Creek
Current Access: Foot access
Proposed Access: Industrial access, Long term/Permanent

Road Section: Rossiter 6500 FSR, Δ1 to Δ39
Prescription Type: New construction
Prepared & Reviewed by: JM & CT

Rossiter 6500 FSR: Δ1 to Δ39

Refer to Terrain Stability Assessment (TSA; SCL #22-1816) for additional general recommendations and background information.

Hub numbers and P-station distances refer to the Geometric Road Design completed by SNT Engineering Ltd. (SNT) and are consistent with survey numbers in the field. Placemark (PM) numbers refer to SCL handheld GPS waypoints.

Road construction should be modified or suspended when there is abundant hill slope runoff occurring at the site, which is likely to occur during times such as spring break-up or periods of high runoff from prolonged heavy precipitation. This is intended to reduce the likelihood of concentrated or redirected drainage as well as erosion, sediment delivery, and unstable excavations and fill placements due to saturated soil conditions.

Cut slopes have been prescribed and designed for inferred subsurface conditions, which are based on observations from nearby rock outcrops and existing road cuts with similar materials to that expected. Where adjustments to cut slope angles are warranted based on actual conditions encountered during construction, then excavation, endhaul, and spoil volumes can be expected to change from those indicated in the design. In general, the following cut slope angles are recommended:

- 0.25H:1V for competent bedrock (SR)
- 0.5H:1V for highly fractured bedrock (FR), and as a cut off for the upper 0.5 m of soil where needed to reduce sliver cuts
- 1H:1V for compact to dense till and loose to compact colluvial materials (OM)

Fill Slopes have been prescribed at 1.5H:1V, with allowance for steeper fills where specific materials and methods are used. Refer to the Typical Sections appended to these tables for diagrams of these fill types.

- General Rock Fills (GRF): maximum 1.25H:1V
- Keyed Rock Fills (KRF): maximum 1.1H:1V
- Placed Rock Fills (PRF): maximum 1H:1V

Spoil sites have been identified in these tables and should be field confirmed by the BCTS Road Construction Supervisor prior to use. Additional spoil site options may exist on areas with slopes less than 45%, and if required can be field confirmed by the BCTS Road Construction Supervisor in consultation with a qualified registered professional at the time of construction. Spoil should be placed in suitably compacted lifts to avoid excessive settling or instability and should not interfere with natural or road drainage.

Surfacing requirements are to be confirmed by the BCTS Road Construction Supervisor at the time of construction based on conditions encountered. In general, significant haul distances of suitable surfacing materials are not anticipated due to primarily favourable construction materials.

Cross-drain culverts have been identified in these tables, on the TSA Map (Figure 3), and in the geometric road design prepared by SNT. Additional cross-drain culverts and changes to planned locations may be warranted based on conditions encountered during construction. Final cross-drain culvert requirements are to be confirmed by the BCTS Road Construction Supervisor in conjunction with a qualified registered professional at the time of construction based on conditions encountered.

Effective sediment and erosion control measures should be implemented with the intent of maintaining effective drainage control and road surface integrity.

Maintenance and Deactivation: Seasonal deactivation measures (cross-ditches and waterbars) should be implemented during periods of non-industrial use, including over-winter. Road inspections for additional required maintenance/work (possible ditch cleaning, culvert cleaning, additional cross-ditch placements, or cross-ditch improvement) should take place annually at minimum, and more frequently during the first two years following construction.

Field reviews: Sufficient field supervision should be carried out by an experienced and qualified BCTS Road Construction Supervisor to ensure generally accepted good construction practices are implemented along with all recommendations presented in this report. **A field review by a qualified registered professional at completion of construction is recommended to confirm subsurface conditions encountered, final culvert placement, and that the intent of the TSA recommendations is met.** If at any time site conditions encountered vary significantly from those described in this report (e.g. unexpected significant seepage, unexpected material textures encountered in excavations, etc.), or if any stability or erosion concerns become apparent during operations, then a qualified registered professional should be consulted to confirm if a construction field review is warranted. Timely mitigation of problem sites can significantly reduce potential adverse effects.

SNT Hub SNT Stn SCL PM	SLOPE		SOIL CHARACTERISTICS	*PARTIAL RISK ANALYSIS		RECOMMENDED CULVERT (mm)	DESIGN/CONSTRUCTION COMMENTS & RECOMMENDATIONS	Cut & Fill Angles
	Left %/m	Right %/m	Type Thickness (approx. in meters) & Drainage	P(H) / Residual P(H) [Hazard]	P(HA)/ Residual P(HA) [Partial Risk] (fish)			
Δ1 0+000 CT 19	0/3 -25/2 -80/..	0/2 93/7 50/..	Till; 4.0 m Sandy silt with some gravel, trace boulders, cobbles; CFC 25% Moderately well to well drained.	VL	VL	-	<p>POC of Rossiter 6500 road survey and geometric road design.</p> <p>Construction of Rossiter 6500 from the POC to approximately Hub 15 will need to avoid undermining the fill slope of the existing Rossiter FSR upslope. Import rock to construct keyed rock fill to limit fill slope length along the initial new road section while maintaining access to the existing road.</p> <p>There is also the option of moving the existing road inboard by increasing the cut and end hauling the material to a suitable soil site.</p> <p>Competent rock in the cut slope of Rossiter FSR at the switchback 90 m prior to the POC of Rossiter 6500 could be quarried and used in construction. Rock will also likely be encountered during construction of Rossiter 6500 between approximately Hub 31 and Hub 39.</p> <p>Excess material, if present, can be end hauled to the switchback on Rossiter FSR prior to the POC of Rossiter 6500. Material can be spoiled on the large existing landing, or there may be opportunity to spoil downslope of the landing on slopes <45% gradient.</p>	<p>Cut 1H:1V 0.25H:1V SR</p> <p>Fill 1.1H:1V KRF</p>

SNT Hub SNT Stn SCL PM	SLOPE		SOIL CHARACTERISTICS Type Thickness (approx. in meters) & Drainage	*PARTIAL RISK ANALYSIS		RECOMMENDED CULVERT (mm)	DESIGN/CONSTRUCTION COMMENTS & RECOMMENDATIONS	Cut & Fill Angles
	Left %/m	Right %/m		P(H) / Residual P(H) [Hazard]	P(HA)/ Residual P(HA) [Partial Risk] (fish)			
Δ6 0+049 CT 26	-40/10 -54/..	60/5 0/5 80/3 65/..	Till; 4.0 m Sandy silt with some gravel, trace boulders, cobbles; CFC 25% Moderately well to well drained.	VL	VL	450	Install 450 mm culvert at broad swale; low point in existing road upslope.	Cut 1H:1V 0.25H:1V SR Fill 1.1H:1V KRF
Δ8 0+072 CT 28	-41/5 -54/..	70/8 0/6 88/5 45/..	Till; 4.0 m Sandy silt with some gravel, trace boulders, cobbles; CFC 25% Moderately well to well drained.	L/VL	VL	-	Continue with keyed rock fill and shift the alignment outboard, if necessary, as the alignment crosses moderately steep side slopes in order to avoid undermining the fill slope of the existing road upslope.	Cut 1H:1V 0.25H:1V SR Fill 1.5H:1V 1.1H:1V KRF
Δ14 0+155 CT 28	-42/..	56/10 80/12 0/6 85/..	Till; 4.0 m Sandy silt with some gravel, trace boulders, cobbles; CFC 25% Moderately well to well drained.	VL	VL	450	Install 450 mm ditch relief culvert. Option to install culvert between Hub 14 and Hub 15 depending on location of low point in road. Transition to conventional sidecast fill construction as slope gradients ease and there is no further interference with the fill slope of the existing road upslope.	Cut 1H:1V 0.25H:1V SR Fill 1.5H:1V 1.1H:1V KRF
Δ19 0+224 CT 29	-35/5 -50/..	42/7 56/..	Till; 2.5 m Sandy silt with some gravel, trace boulders, cobbles; CFC 25% Moderately well to well drained.	L	VL	-	Spoil site option downslope between Hub 19 and Hub 25. Estimated spoil site capacity of 1000 m ³ . Ensure spoil does not impede drainage to and from culvert at Hub 25.	Cut 1H:1V 0.25H:1V SR Fill 1.5H:1V

SNT Hub SNT Stn SCL PM	SLOPE		SOIL CHARACTERISTICS Type Thickness (approx. in meters) & Drainage	*PARTIAL RISK ANALYSIS		RECOMMENDED CULVERT (mm)	DESIGN/CONSTRUCTION COMMENTS & RECOMMENDATIONS	Cut & Fill Angles
	Left %/m	Right %/m		P(H) / Residual P(H) [Hazard]	P(HA)/ Residual P(HA) [Partial Risk] (fish)			
Δ25 0+282 CT 30	-46/..	58/10 65/15 55/..	Colluvium; 3.0 m Sandy silt with some gravel and cobbles, trace boulders; CFC 35% Moderately well to well drained.	VL	VL	450	Install 450 mm culvert for ditch relief at low point, prior to ridge on wood side.	Cut 1H:1V 0.25H:1V SR Fill 1.5H:1V
Δ26 0+295 CT 32	-50/..	60/10 70/14 50/..	Colluvium; 3.0 m Sandy silt with some gravel and cobbles, trace boulders; CFC 35% Moderately well to well drained.	L/VL	VL	-	Transition from conventional sidecast fill construction to 3/4 bench construction at Hub 26 and continue to Hub 28 as alignment crosses moderately steep gradient slopes.	Cut 1H:1V 0.25H:1V SR Fill 1.5H:1V
Δ31 0+368 CT 34	-57/..	54/10 63/..	Colluvium; 1.5 m Sandy silt with some gravel and cobbles, trace boulders; CFC 35% Moderately well to well drained.	L/VL	VL	-	Transition from conventional sidecast fill construction to 3/4 bench with general rock fill or full bench construction at Hub 31 and continue to Hub 39 as alignment crosses moderately steep to steep slopes.	Cut 1H:1V 0.25H:1V SR Fill 1.25H:1V GRF
Δ37 0+438 CT 35	-57/17 -70/..	78/8 75/..	Colluvium; 2.0 m Sandy silt with some gravel and cobbles, trace boulders; CFC 35% Moderately well to well drained.	L/VL	VL	450	Install 450 mm culvert for ditch relief of adverse grade prior to proposed landing.	Cut 1H:1V 0.25H:1V SR Fill 1.25H:1V GRF

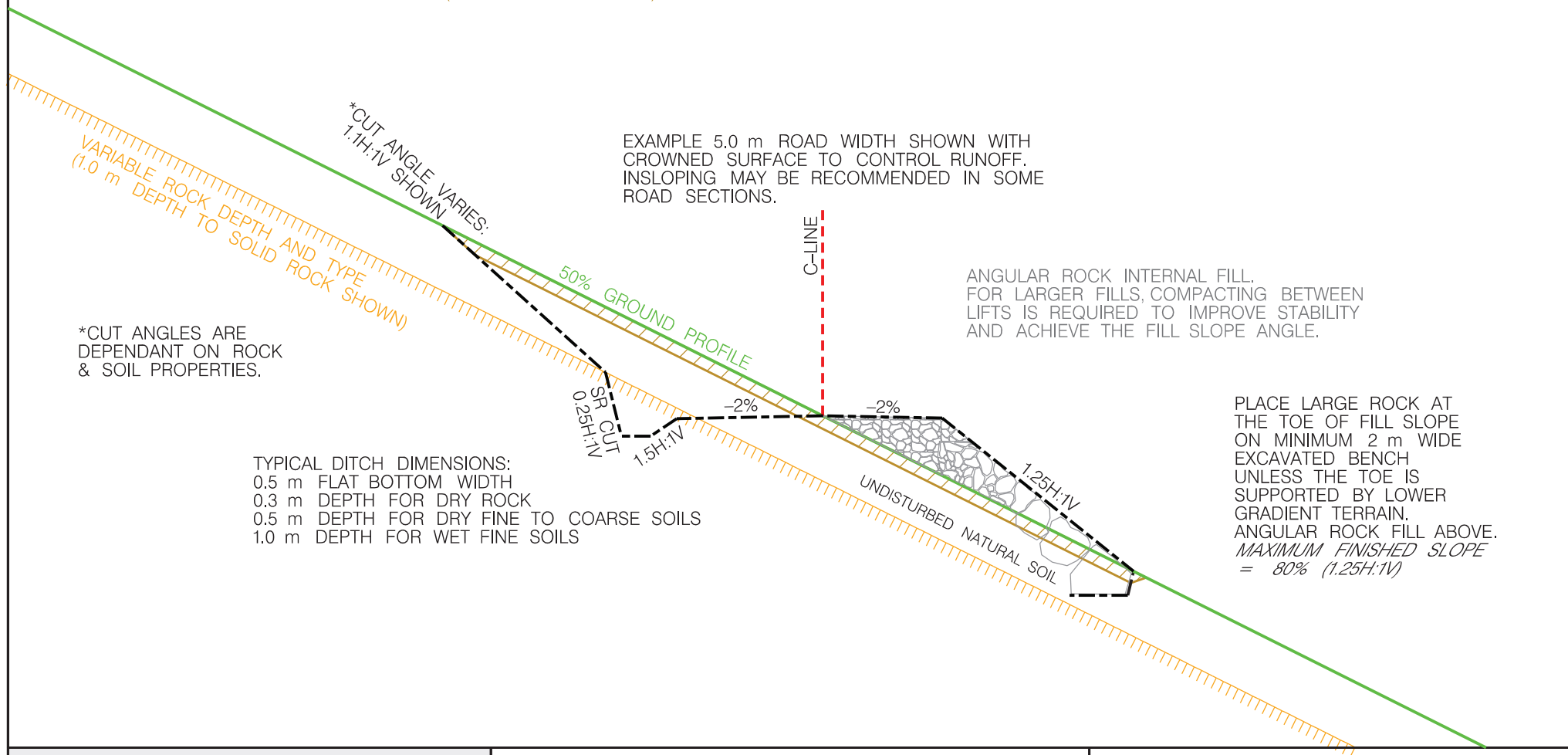
SNT Hub SNT Stn SCL PM	SLOPE		SOIL CHARACTERISTICS	*PARTIAL RISK ANALYSIS		RECOMMENDED CULVERT (mm)	DESIGN/CONSTRUCTION COMMENTS & RECOMMENDATIONS	Cut & Fill Angles
	Left %/m	Right %/m	Type Thickness (approx. in meters) & Drainage	P(H) / Residual P(H) [Hazard]	P(HA)/ Residual P(HA) [Partial Risk] (fish)			
Δ39 0+464 JM 20	-50/6 -63/15 -90/..	57/13 200/2 68/..	Colluvium; 1.5 m Sandy silt with some gravel and cobbles, trace boulders; CFC 35% Moderately well to well drained.	M/L	L/VL	-	POT of Rossiter 6500 on a narrow bench upslope of a steep, bedrock knoll. General rock fill can be used to construct landing to prevent sliver fill downslope of narrow bench.	Cut 1H:1V 0.25H:1V SR Fill 1.25H:1V GRF

* Risk analysis is based on definitions provided in Appendix A: Risk Analysis Definitions and Overview and is consistent with Land Management Handbook 56, *Landslide Risk Case Studies in Forest Development Planning and Operations* (BCMoF 2004). **P(H)** refers to the likelihood of a hazardous landslide at the road prism as a result of conventional ½ bench cut, side cast fill construction. **P(HA)** refers to the likelihood of a hazardous affecting landslide (partial risk) at the road prism as a result of conventional ½ bench cut, side cast fill construction, with the considered element shown in brackets. The residual likelihoods are based on following all recommendations as presented in these tables and the accompanying report. Refer to attached report for additional information concerning the likelihood of a downslope landslide as a result of redirected drainage. Refer to the attached report for discussion with respect to all considered elements.

GENERAL ROCK FILL:

FILL MATERIAL COMPRISED OF PRIMARILY ANGULAR ROCK FRAGMENTS WITH LOW FINES CONTENT. GENERALLY SOURCED FROM BLAST OR RIPPABLE ROCK SOURCES, BUT MAY INCLUDE SOME SUITABLE COLLUVIAL MATERIALS.

STRIP ORGANICS AND LOOSE LAYERS PRIOR TO FILL PLACEMENT UNLESS OTHERWISE NOTED; STRIP DEPTH IS SITE DEPENDENT (0.2 m DEPTH SHOWN).



TYPICAL CROSS-SECTION of
1/2 BENCH GENERAL ROCK
FILL CONSTRUCTION



TYPICAL SECTION: 1
REVIEWED BY: CT
PAGE SIZE Ansi A 8.5" x 11"
PLOT NAME: 22-1816_TS1_12 GRF.pdf
PLOT DATE: December 8, 2022

PRODUCED BY:



KEYED ROCK FILL:

USE LARGE ANGULAR ROCK (600 mm to 1000 mm DIAMETER) FOR KEYED TOE OF FILL AS SUPPORT FOR UPPER FILL AND TO LIMIT FILL SLOPE LENGTH.

STRIP ORGANICS AND LOOSE LAYERS PRIOR TO FILL PLACEMENT UNLESS OTHERWISE NOTED; STRIP DEPTH IS SITE DEPENDENT (0.2 m DEPTH SHOWN).

EXAMPLE 5.0 m ROAD WIDTH SHOWN WITH 5% INSLOPED SURFACE TO CONTROL RUNOFF. CROWNING MAY BE RECOMMENDED IN SOME ROAD SECTIONS.

THE FILL ABOVE THE KEYED IN ROCK SHOULD BE SUITABLE NON-COHESIVE MATERIAL WITH A LOW FINES (SILT /CLAY, <0.075 mm DIA.) CONTENT.

PLACE LARGE ROCK AT TOE OF FILL SLOPE ON EXCAVATED BENCH. KEY IN ROCK WITH LONG AXIS ANGLED SLIGHTLY DOWN AND INTO THE SLOPE.

MAXIMUM FINISHED SLOPE = 91% (1.1H:1V).

*CUT ANGLES ARE DEPENDANT ON ROCK & SOIL PROPERTIES.

TYPICAL DITCH DIMENSIONS:
0.5 m FLAT BOTTOM WIDTH
0.3 m DEPTH FOR DRY ROCK (AS SHOWN)
0.5 m DEPTH FOR DRY FINE TO COARSE SOILS
1.0 m DEPTH FOR WET FINE SOILS



TYPICAL CROSS-SECTION of
3 / 4 BENCH with KEYED
ROCK FILL CONSTRUCTION

TYPICAL SECTION: 2
REVIEWED BY: CT
PAGE SIZE Ansi A 8.5" x 11"
PLOT NAME: 22-1816_TS2_34 KRF.pdf
PLOT DATE: December 8, 2022

PRODUCED BY:



Appendix C

Prescription Summary Tables

Prescription Summary Table

Drainage: Kaslo River & Blaylock Creek

Current Access: Foot/ATV

Proposed Access: Industrial access, Long term/Permanent

Road Section: Rossiter FSR; 4+920 to 6+488

Prescription Type: Road upgrade

Prepared & Reviewed by: JM & CT

General upgrade requirements include ditch cleaning or ditch construction, localized widening, culvert installation, grading, and brushing.

Where additional cut is required to widen the road surface or construct a ditchline, the following cut slope angles are generally appropriate based on the existing cut slopes observed:

- 0.25H:1V for competent bedrock
- 0.5H:1V for highly fractured bedrock, and as a cut off for the upper 0.5 m of soil where needed to reduce sliver cuts
- 1H:1V for compact to dense thick till and loose to compact colluvial materials

If additional fill is required to increase road widths, fill slopes should not exceed 1.5H:1V in OM sections or 1.25H:1V in sections where the fills are comprised of primarily angular rock fragments with a low fines content (general rock fill). Any new fill placement must be free of underlying organics and be structurally sound with a keyed in toe.

Distances are based on GIS measurements from the start of Rossiter FSR and are not referenced in the field (relevant GPS placemark references are flagged).

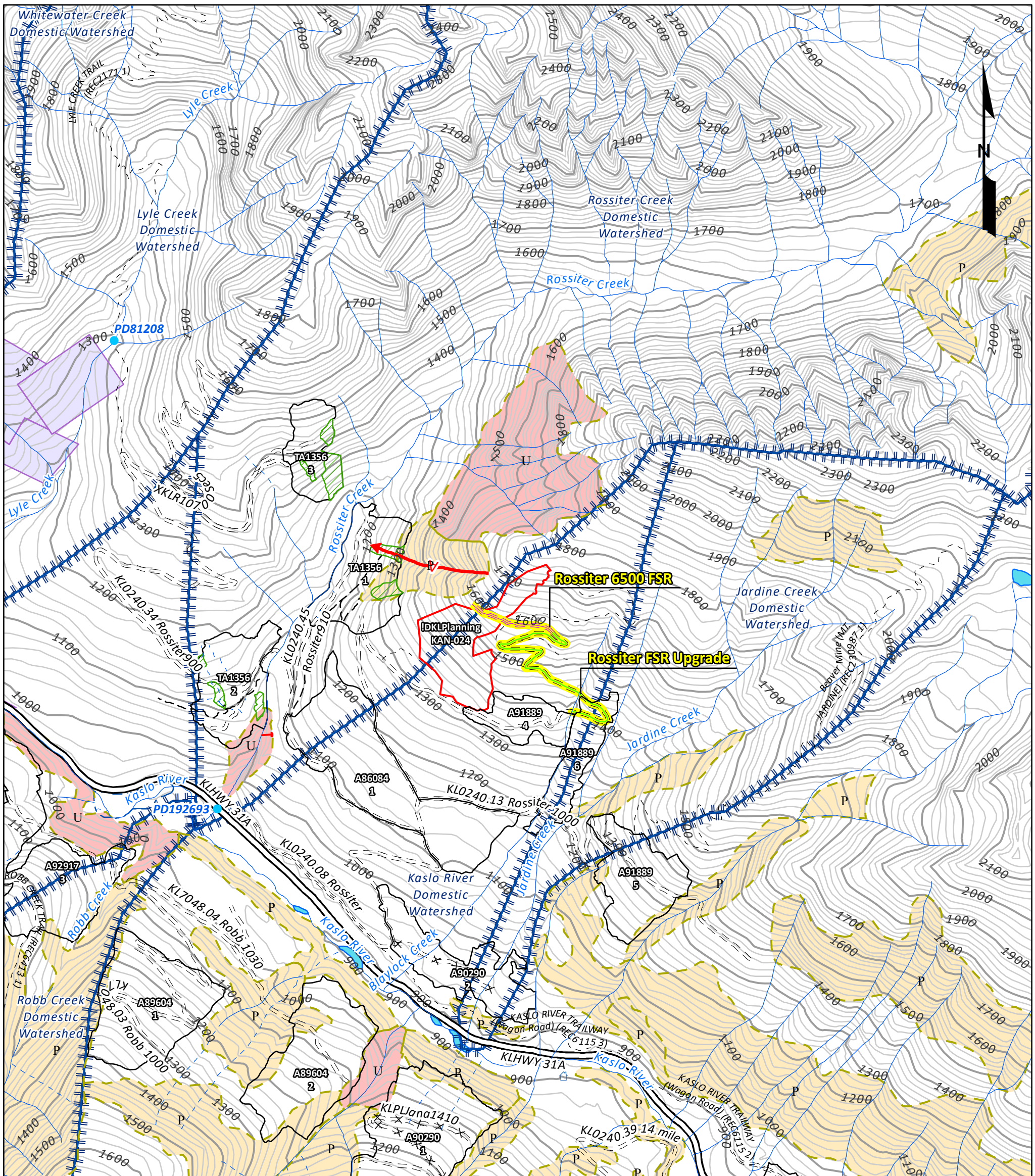
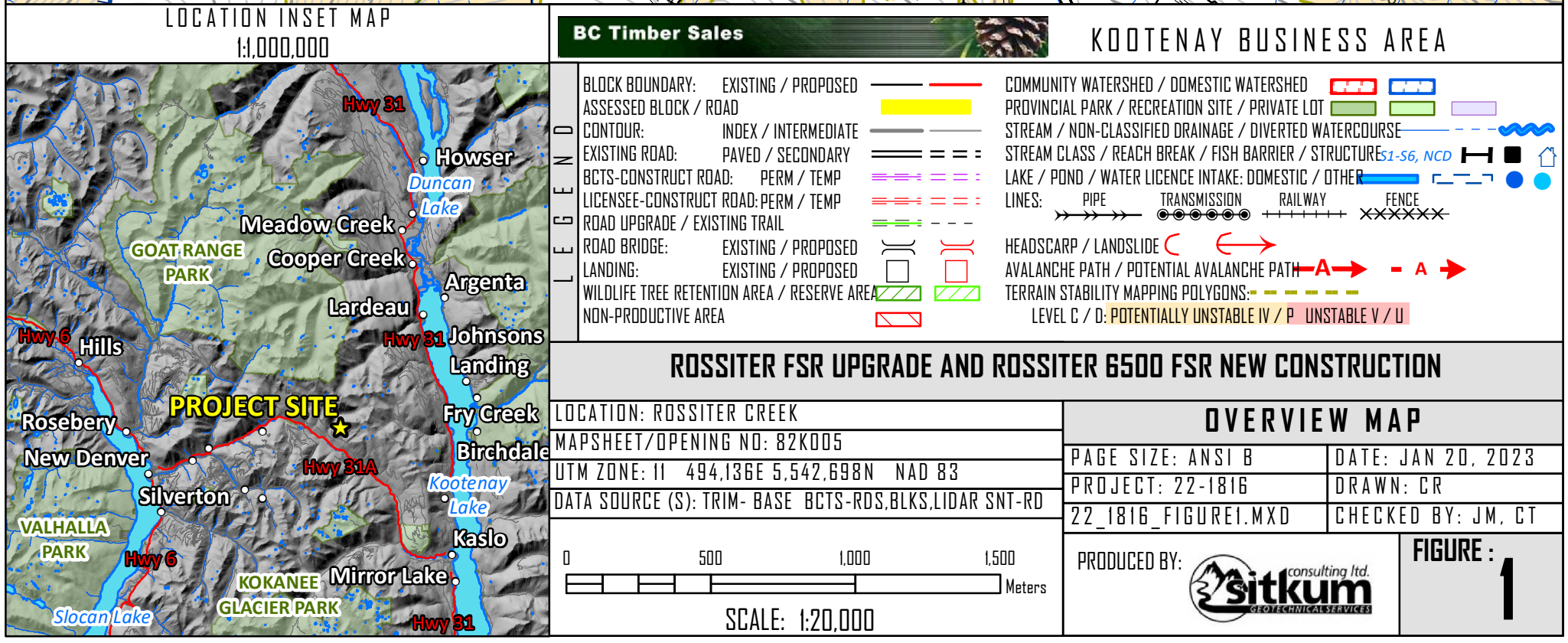
Distance (m)	GPS placemark	Recommended culvert (mm x m)	Work Required \ Comments
4+920	CT 38	1200 x 12	POC of SCL road upgrade assessment of Rossiter FSR. Refer to TSA map for recommended culvert locations. Install 1200 mm culvert at Blaylock Creek (S6). The stream lies within a shallow swale on moderate gradient terrain. There is generally no ditch along the assessed section of Rossiter FSR. Construct a ditch where feasible. In areas where a ditch cannot be constructed, in-slope the road 5%.
4+973	CT 39	450 x 9	Install 450 mm culvert for ditch relief between Blaylock Creek and the switchback at CT 2, within the broad southwest trending swale that contains a proposed culvert on the upper road segment at CT 3. The location is not flagged in the field; final culvert location can be determined by the BCTS Road Construction Supervisor.
5+089	CT 2	-	Existing cross ditch at start of switchback. Culvert not required due to proximity to switchback.
5+205	CT 3	450 x 9	Install 450 mm culvert at existing cross ditch.

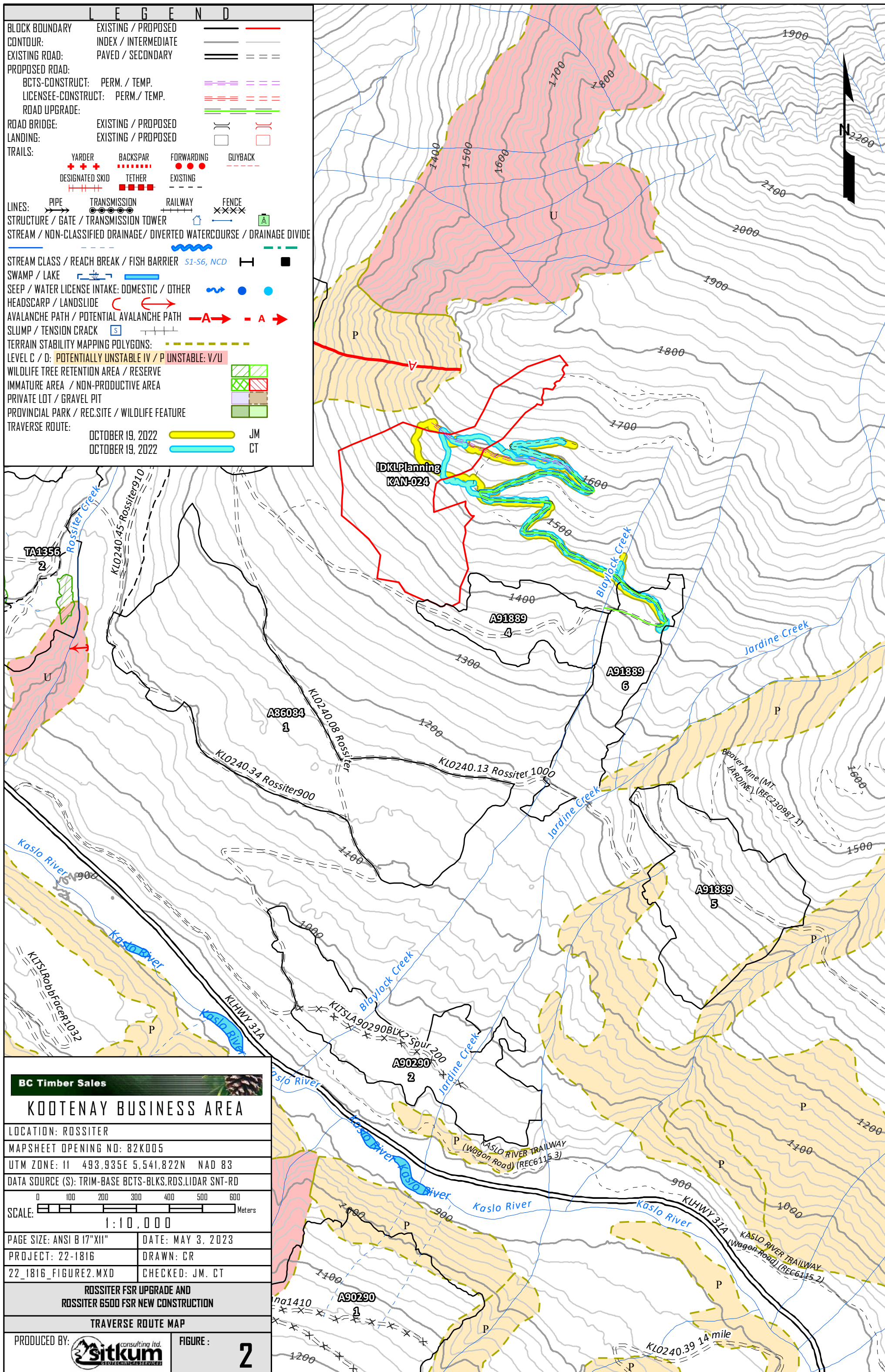
Distance (m)	GPS placemark	Recommended culvert (mm x m)	Work Required \ Comments
5+335	CT5	1200 x 12	Install 1200 mm culvert at 2 m deep gully containing Blaylock Creek (S6). Import suitable rock to key into the slope in order to reconstruct the crossing due to downstream channel gradient of 55%.
5+398	CT 6	450 x 9	Install 450 mm culvert at existing cross ditch.
5+475	CT 7	-	Existing road width is approximately 3-4 m along a 30 m length, with minor settlement of outer 1 m of existing fill. Repair existing fill. Additional cutting is recommended to gain the required width as downslope gradients along this section of road are too steep for placement of additional fill (70-80%). Surficial materials transition from bedrock in cut slope on town side to thick till with large boulders on woods side. Excess material from the cut slope can be pushed ahead, around the curve on the woods side and used as structural fill to widen the road where downslope gradients ease to 45-55%.
5+571	CT 9	450 x 9	Install 450 mm culvert at existing cross ditch.
5+624	CT 10	450 x 9	Install 450 mm culvert at existing cross ditch.
5+712	CT 11	450 x 9	Install 450 mm culvert at existing cross ditch.
5+762	CT 12	-	Existing water bar at start of switchback. Culvert installation not necessary due to proximity to switchback.
5+797	CT 13	-	Switchback is located in broad swale. Construct ditch to direct runoff off end of the switchback.
5+841	CT 14	450 x 9	Install 450 mm culvert at existing cross ditch.
5+936	JM 15	450 x 9	Install 450 mm culvert for ditch relief on town side of switchback.
5+970	CT 15	-	Minor fill slope settlement within existing rock fill. No signs of active instability and fill is supported by 45% gradient slope. Grade the road and/or apply surfacing material as needed.
6+069	JM 14	450 x 9	Install 450 mm culvert for ditch relief on woods side of bedrock in cut slope at top of switchback.
6+193	CT 17	450 x 9	Install 450 mm culvert at existing cross ditch.

Distance (m)	GPS placemark	Recommended culvert (mm x m)	Work Required \ Comments
6+406	JM 7	-	Potential rock source for use in new construction and potential small spoil site (500 m ³) on large existing landing or downslope of the landing where slope gradients are < 45%.
6+429	CT 18	-	Existing cross ditch. Culvert not necessary due to location on a rocky ridge with no signs of significant runoff.
6+488	CT 19	-	POT of road upgrade of Rossiter FSR at POC (Hub 1) of Rossiter 6500 FSR.

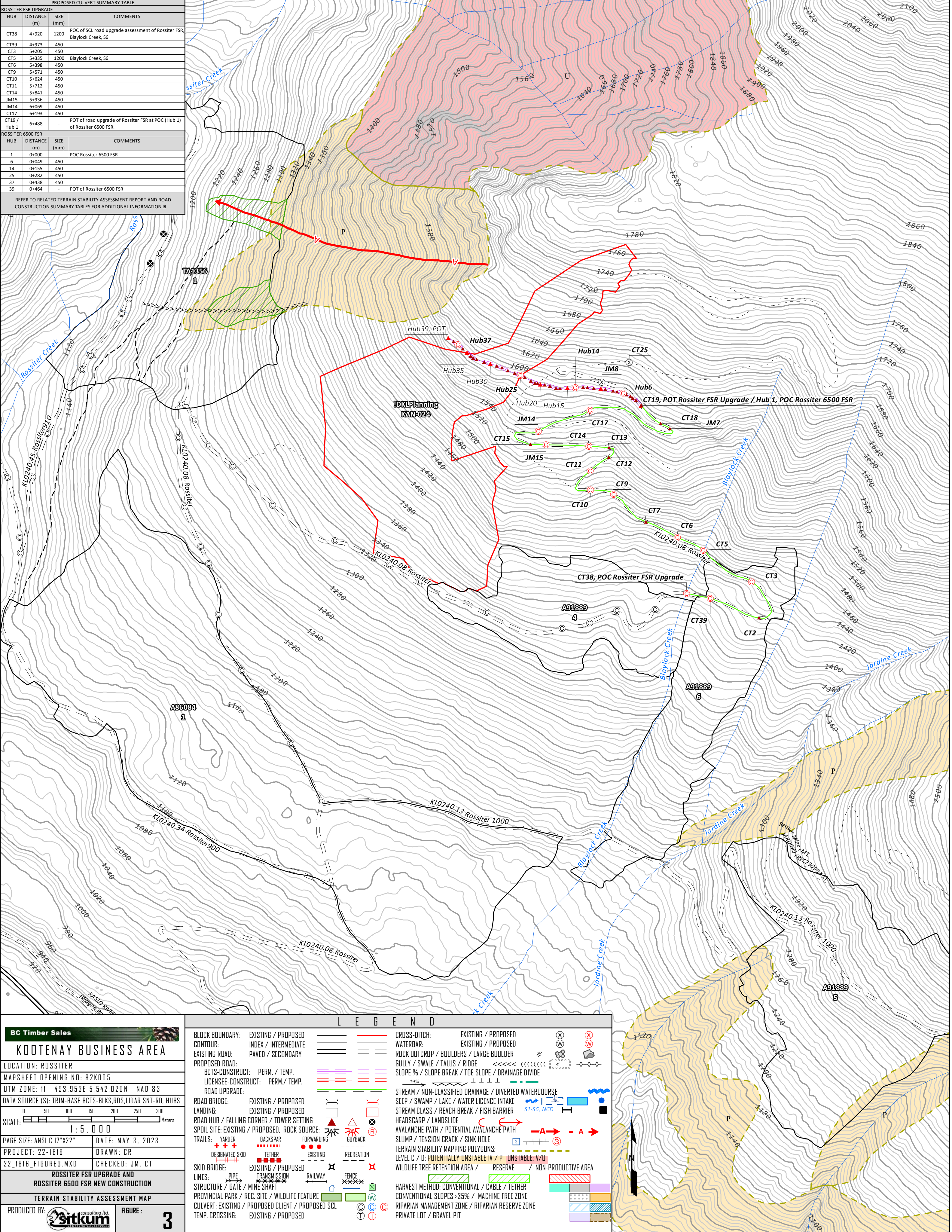
Appendix D

Figures





PROPOSED CULVERT SUMMARY TABLE			
HUB	DISTANCE (m)	SIZE (mm)	COMMENTS
CT38	4+920	1200	POC of SCL road upgrade assessment of Rossiter FSR, Blaylock Creek, S6
CT39	4+973	450	
CT3	5+205	450	
CT5	5+335	1200	Blaylock Creek, S6
CT6	5+398	450	
CT9	5+571	450	
CT10	5+624	450	
CT11	5+712	450	
CT14	5+841	450	
JM15	5+936	450	
JM14	6+069	450	
CT17	6+193	450	
CT19 / Hub 1	6+488	-	POT of road upgrade of Rossiter FSR at POC (Hub 1) of Rossiter 6500 FSR.
ROSSITER 6500 FSR			
HUB	DISTANCE (m)	SIZE (mm)	COMMENTS
1	0+000	-	POC Rossiter 6500 FSR
6	0+049	450	
14	0+155	450	
25	0+282	450	
37	0+438	450	
39	0+464	-	POT of Rossiter 6500 FSR
REFER TO RELATED TERRAIN STABILITY ASSESSMENT REPORT AND ROAD CONSTRUCTION SUMMARY TABLES FOR ADDITIONAL INFORMATION.			



BC Timber Sales

KOOTENAY BUSINESS AREA

LOCATION: ROSSITER

MAPSHEET OPENING NO: 82K005

UTM ZONE: 11 493.953E 5.542.020N NAD 83

DATA SOURCE (S): TRIM-BASE BCTS-BLKS.ROSLIDAR SNT-RD, HUBS

SCALE: 1:5,000

PAGE SIZE: ANSI C 17"x22"

DATE: MAY 3, 2023

PROJECT: 22-1816

DRAWN: CR

22_1816_FIGURE3.MXD

CHECKED: J.M. CT

ROSSITER FSR UPGRADE AND ROSSITER 6500 FSR NEW CONSTRUCTION

TERRAIN STABILITY ASSESSMENT MAP

PRODUCED BY: sitkum consulting ltd.

FIGURE: 3