PREPARED FOR:

British Columbia Timber Sales – Vernon Office
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CUTBLOCKS K0WG, K5M7, AND K5M8
BASTION CREEK AREA
TERRAIN STABILITY ASSESSMENT

Attn. Jennifer Wright, RPF

PREPARED BY

AZIMUTH FORESTRY & MAPPING SOLUTIONS LTD.

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1.0 Introduction

At the request of Mr. Brian Sye, RPF on behalf of British Columbia Timber Sales – Vernon Office (BCTS), Azimuth Forestry and Mapping Solutions Ltd. (Azimuth) has completed a terrain stability assessment (TSA) for the proposed cutblocks K0WG, K5M7, and K5M8 and associated access roads. The proposed development is located at the apex of the north sidewall of the Bastion Creek valley, approximately 8km west of Sicamous, BC.

Figure 1 - Location Key Map

Additional information concerning the soil, bedrock, and terrain classification and terminology used in this report is contained in Appendix B. Risk assessment process/terminology information and the TSA methodology is contained in Appendix A.

2.0 Rational for the TSA

This TSA was undertaken at the request of BCTS along with input from Azimuth personnel. In addition, a hydrological assessment was completed for the area by M.J. Milne & Associates Ltd. (MJMA) and the findings of the hydrological assessment are referenced in this report.

The proposed development is situated at the apex of the north sidewall slope of the Bastion Creek valley, a drainage path which has substantial residential and recreational development on the fan at the confluence with Shuswap Lake. In addition, previous landslide tracks are present on the sidewall downslope of the proposed development and much of the sidewall is mapped as Terrain Stability Class (TSC) P or U on Terrain Stability Mapping (TSM) of the area. Note that a P classification consists of potentially unstable terrain and a U classification consists of unstable terrain. The presence of previous instability on the Bastion Creek valley sidewall coupled with the private development downstream and the TSC P and U polygons provided the rational for undertaking the TSA.

The TSC P and U polygons in the vicinity of the proposed development are indicated on Figure 2 below.

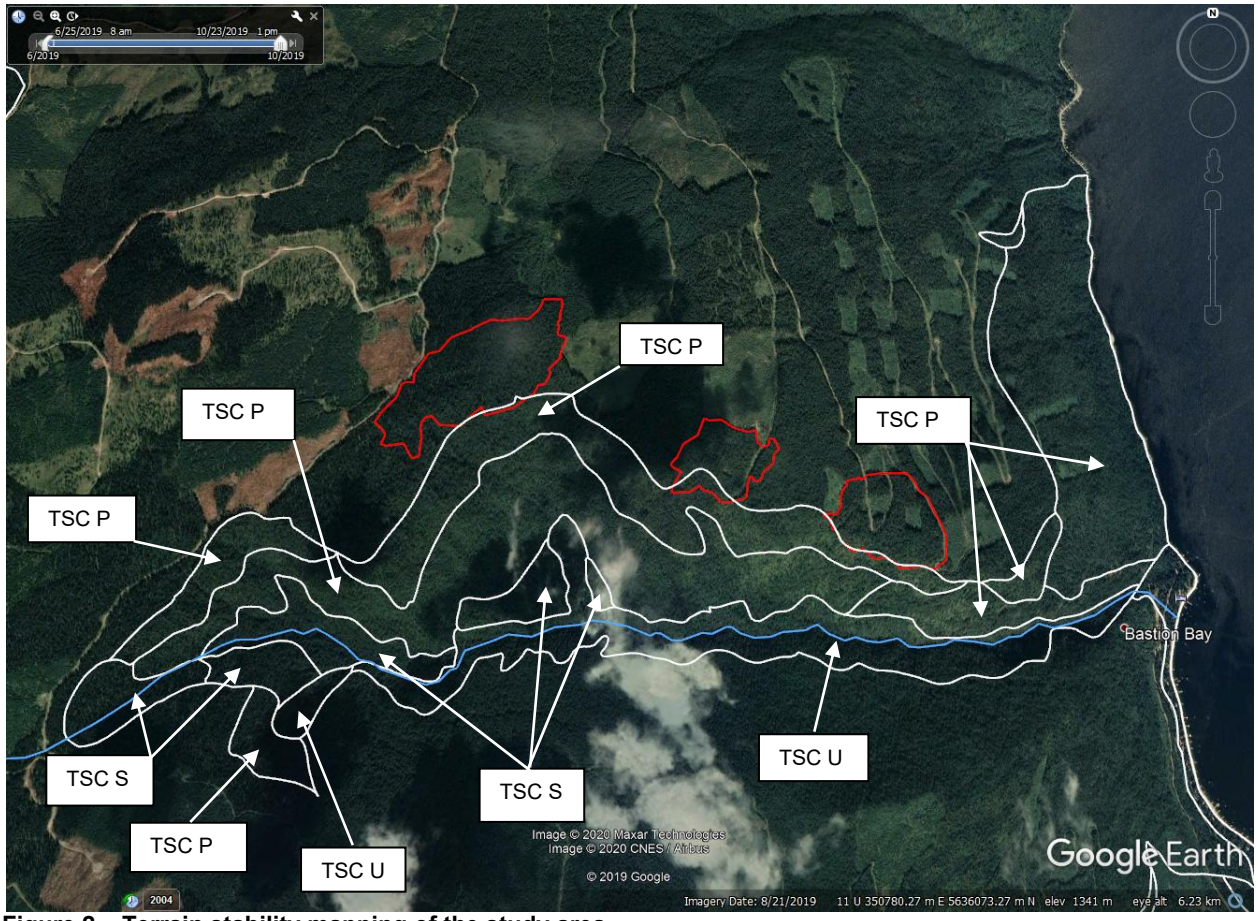


Figure 2 – Terrain stability mapping of the study area.

3.0 Office and Field Assessment

The following airphotos were reviewed as part of this assessment:

- 15BCC07016 #171-175 (2007)
- 15BCC01024 #095-098 (2001)
- 30BCC94044 #081-083, 111-115 (1994)
- 30BCC1048 #030-034, 179-182 (1989)
- 30BC84064 #145-147, 157-160 (1984)
- 30BC78061 #044-046 (1978)
- BC7648 #080-085, 100-102 (1974)
- BC5246 #177-178, 187-189 (1967)
- BC2626 #003-005, 044-049 (1959)
- BC1292 #066-067, 082-083 (1951)

The following additional information was also reviewed:

- Bastion K0WG, K5M7, and K5M8 Harvest Plan maps at a scale of 1:5,000 created by Azimuth.
- Bastion Creek Hydrologic Assessment authored by M.J. Milne & Associates Ltd. and dated August 17, 2018.
- Letter containing comments concerning the proposed development by Mr. Bill Grainger and dated July 12, 2019.
- Technical Memorandum titled “Hydrology Overview, Bastion Mountain – Geomorphic Assessment” and authored by Kerr Wood Leidal consulting engineers. The report is dated April 2, 2019.
- Report titled “Bastion Mountain Area – Overview Landslide Assessment” and authored by Westrek Geotechnical Services Ltd. The report is dated April 2, 2019.
- Lidar dataset for the area supplied by BCTS.
- Terrain stability mapping of the area – Mapping available online at IMapBC (http://maps.gov.ca/ess/sv/imapbc/).
- Bedrock geology mapping – Mapping available online at IMapBC (http://maps.gov.ca/ess/sv/imapbc/).
- Google Earth orthoimagery and digital terrain model. The date of the imagery is listed as 2019.

Fieldwork was completed by Ryan Williams, P. Geo. of Azimuth accompanied by Brian Sye, RPF of BCTS and Joe Talbot of Azimuth who laid out the development. Fieldwork occurred on August 28, 2019 and September 12, 2019 and consisted of a foot traverse of potential areas of concern with respect to terrain stability within and immediately downslope of the proposed development. The areas of concern were determined by Azimuth and consisted of the following:

- The southern boundary of K0WG and downslope area.
- The southern boundary of K5M7 and downslope area.
- The southern boundary of K5M8 and downslope area.

The traverse route is indicated on Figures 4, 7, and 8. Conditions at the time of the first assessment were warm and sunny and cool and rainy during the second field visit. Waypoints were collected at points of interest using a GPS enabled IPad. The accuracy of these points is estimated to be on the order of ±5m.

3.1 Elements at Risk

Elements at potential risk from a landslide initiating within or downslope of the proposed development were identified by Azimuth during the assessment. These elements are as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development.
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development.
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development.
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development.
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development for 34 residences at Totem Pole Resort.
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development for 3 individual residences and the Totem Pole Resort.

Note that timber and soil resources are not listed as an element at risk as it is assumed that this element will always be impacted if a landslide occurs.

4.0 General Setting

4.1 Physiographic Description

The proposed development is located at the apex of the north sidewall slope of the Bastion Creek valley. The majority of the development area is situated on the face unit slopes to the north of the Bastion Creek valley. The area is located in the Shuswap Highlands Physiographic Region of BC. The topography of the Bastion valley sidewall on which the southern portion of the development is situated on is that of moderately steep to steep gradient, somewhat irregular and gullied terrain rising directly out of Bastion Creek. This terrain breaks over in the vicinity of the proposed development into gentle to moderate gradient, benched terrain. The northern portion of the development is situated on the face unit slope of the Shuswap Lake valley. Terrain making up the face unit slope is that of irregular, moderately steep gradient terrain extending out of Shuswap Lake for approximately 1km. This is followed by moderate gradient, irregular and somewhat benched terrain extending for approximately 2.5km. An upper, rolling plateau is present after this point. The base of the Shuswap Lake valley is located at an elevation of 347m while the height of land to the west is 1630m. The proposed development spans an elevation range of 940m to 1555m.

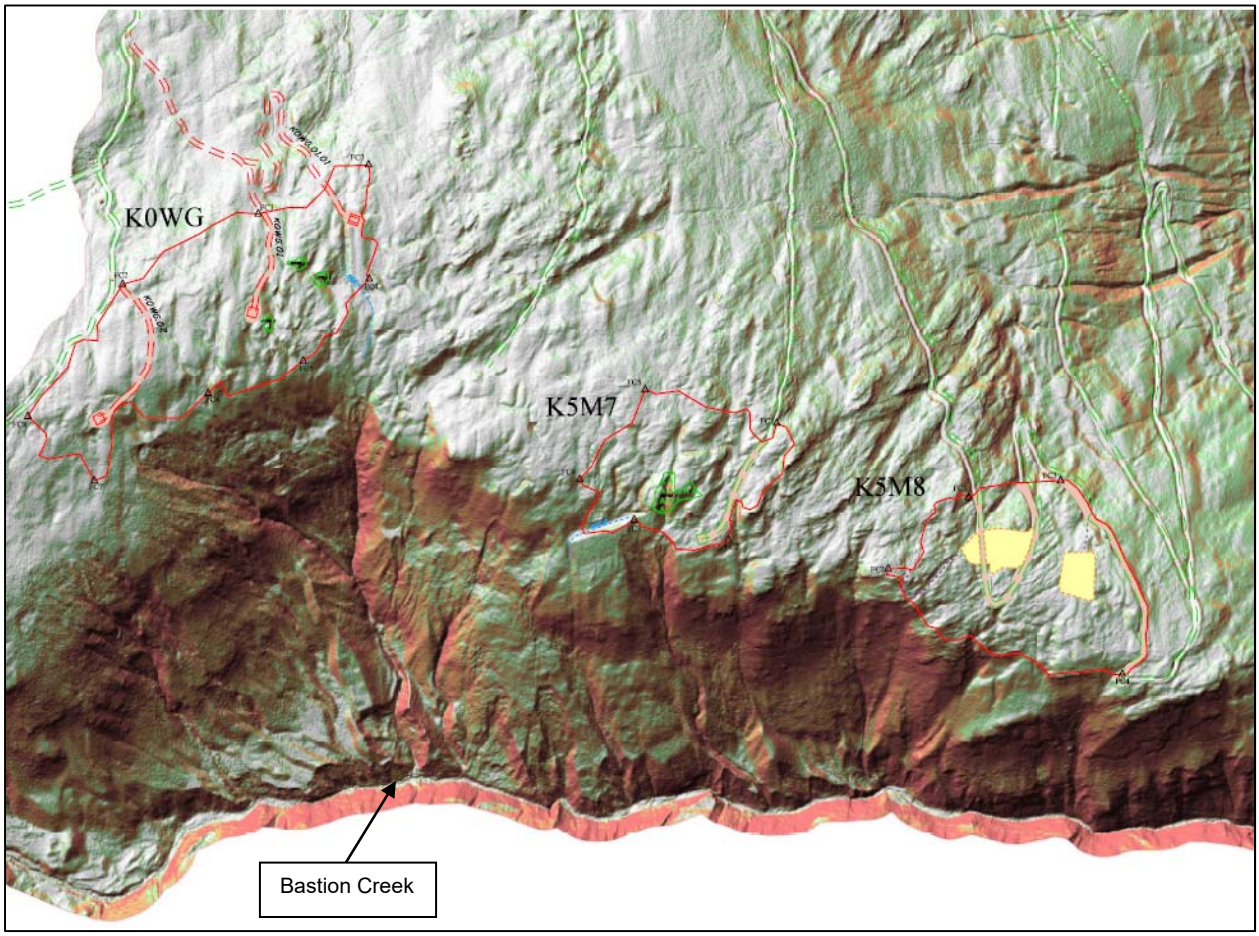


Figure 3 – Overview map of the proposed development. The colour gradient of the terrain correlates with the steepness of the slope.

Bedrock underlying the proposed development is mapped as Upper Proterozoic to Paleozoic greenschist metamorphic rocks of the Eagle Bay Assemblage. Bedrock observed in the field

consisted of compositionally variable weak to medium strong schist. The observed and mapped lithologies are in broad agreement.

4.2 Climate

The proposed development is mostly located in the ICH mw5 biogeoclimatic zone aside from the upper portion of block K0WG which is located in the ESSF mh biogeoclimatic zone. The closest weather station with sufficient data to calculate long term climatic normals is located in Salmon Arm, BC approximately 20km to the southwest. The station records a mean annual precipitation level of 653mm with 469mm falling as rain and is located at an elevation of 527m. As the study area is located at a higher elevation, precipitation in the form of snow will be greater than the weather station.

4.3 Logging and Landslide History

The airphoto record for the area dates from 1951 to 2007 and orthoimagery is available circa 2019. The availability of these photos and imagery provides a relatively comprehensive history of the land use and landslide events in the area. **Select airphotos with the landslides described in the paragraphs below are contained in Appendix C of this report**.

Starting in 1951, no roads, trails, or harvested areas are apparent within the Bastion Creek watershed or in adjacent areas. Development has yet to occur on the Bastion Creek fan. Timber in the area appears to be second growth. Historic wildfire records for the area available on iMapBC do not show a fire polygon overlapping with the proposed development area. However, a circa 1939 fire polygon is present on the south side of the Bastion Creek valley. Judging by the difference in timber size between the 1939 fire polygon and the north side of Bastion Creek, it appears that the development area likely burnt in the late 1800’s or early 1900’s.

Landslides visible on the 1951 airphotos within or downslope of the development consist of a single slump or slide (Landslide 1) on the lower portion of the Bastion Creek valley sidewall adjacent to a tributary stream which forms immediately downslope of proposed block K0WG.

In the 1959 airphotos a road network is visible traversing the midslopes of the south sidewall of the Bastion Creek valley and patchy selective harvesting begins to be visible. No development is visible at the headwaters of the valley or on the north sidewall of the valley. The precursor to Sunnybrae-Canoe Point road is also visible on the Bastion Creek fan. The landslide noted downslope of block K0WG on the 1951 airphotos is also present on the 1959 airphotos and shows no changes in shape, size, or vegetation coverage. In addition, a large rotational slump begins to develop on the south sidewall of the Bastion Creek valley approximately 1km upstream of the confluence with Shuswap Lake.

The 1967 airphotos reveal a new road network (the precursor to the 450.000 road) beginning to extend across the headwaters of the Bastion Creek valley. A large landslide (Landslide 2) is visible initiating on the road at the point where the road crosses a tributary stream to Bastion Creek. The landslide became entrained in the tributary stream draw and ran out to the base of the Bastion Creek valley. Evidence of a subsequent debris flow or debris flood event continuing down Bastion Creek is not visible on the airphotos. Landslide 1 is still visible on the airphotos and has not changed in shape, size, or vegetation cover.

The 1974 airphotos reveal a third landslide (Landslide 3) originating in a tributary stream draw immediately to the north of Landslide 2. No fill slope failure is apparent originating on the

450.000 road; however, a linear track is visible on the tributary stream draw extending downslope to Bastion Creek. This indicates that the 450.000 road intercepted water and increased the flow volume on the tributary stream, likely leading to initiation of a debris flow event. The debris flow event appears to have terminated upon reaching the mainstem of Bastion Creek and did not continue downstream. Landslide 1 is still visible on the airphotos and has not changed in shape, size, or vegetation cover.

The 1978 airphoto set is incomplete and does not include the headwaters of Bastion Creek. No new landslides are visible and Landslide 1 has not changed in shape, size, or vegetation cover.

The 1984 airphoto set shows a series of large cutblocks distributed throughout the headwaters of Bastion Creek. No new landslides are apparent in the area. Landslide 1 remains static in shape, size, and vegetation cover. Landslides 2 and 3 are slowly revegetating.

No changes are apparent in the 1989 airphotos.

No changes apparent in the 1994 airphotos.

The 2001 airphotos reveal the recent construction of the adverse road network down the face unit slope immediately to the north of the Bastion Creek valley. No landslides are apparent linked to the adverse road network.

The 2007 airphotos reveal a series of blocks and patch cuts harvested off the adverse road network to the north. Several of the blocks are situated as the crest of the slope break into the Bastion Creek valley. No signs of instability associated with these blocks are apparent.

4.4 Bastion Creek Watershed Morphometrics

The disposition of Bastion Creek to flood, debris flood, or debris flow events can be evaluated using the methodology outlined in *Wilford et al (2004)*[1] which is based on the Melton Ratio of the watershed and the watershed length. The hydrogeomorphic process disposition is contained in the table below:

Table 1 – Watershed Morphometrics		
Floods	Debris Floods	Debris Flows
Melton Ratio <0.3	Melton Ratio of 0.3 to 0.6 or Melton Ratio >0.6 and length >2.7km	Melton Ratio >0.6 and length <2.7km
*Note that the Melton ratio is defined as the watershed relief divided by the square root of the watershed area		

Based on this, the Melton Ratio for Bastion Creek is as follows:

$$Melton\ Ratio = \frac{Watershed\ Relief}{\sqrt{Watershed\ Area}} = \frac{(1724m - 347m)}{\sqrt{11630161m^2}} = 0.40$$

Given that the Melton Ratio is 0.40 and the length of the mainstem of the creek is 7.17km, this indicates that debris flood hydrogeomorphic events will dominate on Bastion Creek.

4.5 Bastion Creek Hydrologic Assessment

A joint hydrologic assessment was completed by Mr. Michael Milne, MES of M.J. Milne & Associates Ltd. (MJMA) on behalf of BCTS and Canoe Forest Products Ltd. (CFP) concerning the proposed BCTS and CFP timber development in the Bastion Creek watershed. The final report is dated August 17, 2018 and it is our understanding that CFP has since harvested the CFP blocks proposed in the Bastion Creek watershed.

The findings of the hydrologic assessment indicated that the proposed development “would increase ECA levels to 14% for the watershed and 24% in the ESSF”. The increase in the ECA is expected to result in “a minor shift in runoff timing and some effect on peak flow magnitude but the duration would be short with ECA recovering to 11% for the watershed by 2030”. MJMA anticipates that “the net effect of planned development on flooding on the fan is therefore expected to be negligible”.

Based on the findings of the hydrologic assessment, it appears that the increased ECA in the Bastion Creek watershed is not sufficient to significantly increase the likelihood of hydrogeomorphic events on Bastion Creek. Therefore, the primary concern with respect to the proposed BCTS development is with the potential for a landslide occurring on the sidewall slope of the Bastion Creek valley within or downslope of the proposed development. The remainder of this TSA report focus on the landslide likelihood associated with the proposed development rather than the potential for hydrogeomorphic activity on Bastion Creek associated with the ECA increase.

[1] Wilford D.J., Sakals M.E., Innes J.L., Sidle R.C., Bergerud W.A. (2004): *Recognition of debris flow, debris flood and hazard through watershed morphometrics.* In Landslides (2004) 1:61-66.

5.0 Proposed Cutblocks - Observations, Results, and Recommendations

The proposed development consists of 3 cutblocks (K0WG, K5M7, and K5M8) and associated access roads. The cutblocks are discussed in Sections 5.1 to 5.3 below and the proposed roads are discussed in Section 6.

5.1 Cutblock K0WG

Cutblock K0WG is a 27.0ha (gross) block slated for clearcut harvesting using ground based methods. The falling boundary of the block is broadly defined by a small ridge to the north, a previously harvested area to the east, the extent of ground based terrain to the south, and imperfectly drained terrain to the west. Terrain, surficial material, and hydrological conditions vary substantially across the block and as a result, northern, southwest, and southeast portions of the block are discussed separately in the sections below. These areas are delineated on Figure 3 (Note that the proposed road network is in red).

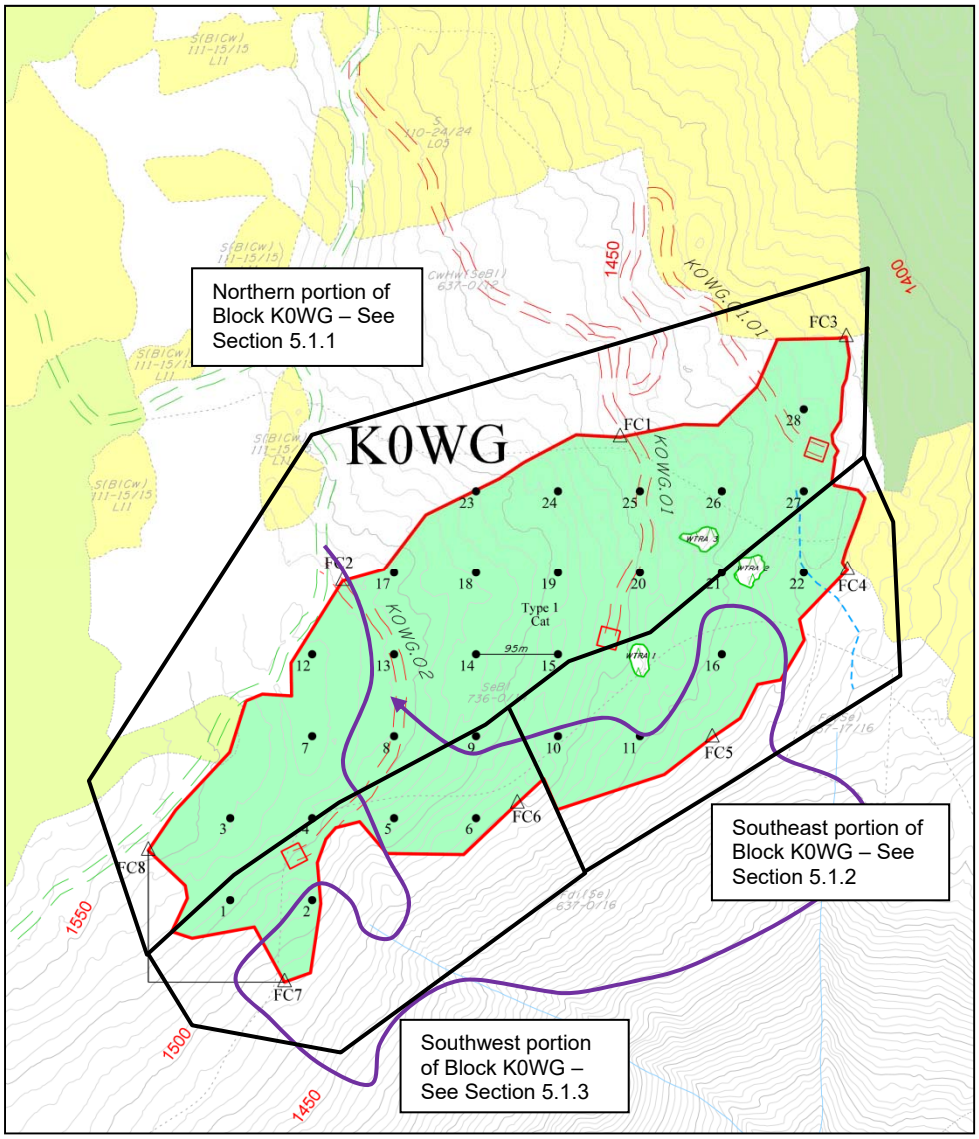


Figure 4 - Proposed Cutblock K0WG. The original map scale was 1:5,000. The traverse route is depicted by the dark purple line.

5.1.1 Northern Portion of Cutblock K0WG

Observations

The northern portion of block K0WG is situated on gentle gradient, rolling to irregular terrain. The surface irregularity appears to be a product of shallow bedrock throughout the area. The northern portion of the block is situated on the face unit slopes of the Shuswap Lake valley and drains to the northeast for the most part, away from the Bastion Creek valley to the south.

Surficial materials in this portion of the block consist of a thin blanket to veneer of moderately well to well drained silt and sand with some gravel till. Pockets of well drained gravel sized rubble in a silt and sand matrix is present adjacent to bedrock outcrops. The rubble material appears to be derived from insitu weathering of the local bedrock.

Bedrock was noted outcropping throughout this portion of the block and consisted of interbedded weak to medium strong schist and black shale.

Timber in the block consists of second growth SxBlFd with dbh ranging from 20-60cm. The stand appears to be a product of a large forest fire event which likely occurred in the late 1800's or early 1900's. Understory vegetation consists of a thick blanket of azalea and rhododendron as well as scattered ferns in low points.

No surface flows are present in this portion of the block and no signs of substantial shallow subsurface flow were noted.

Given the slope position of the northern portion of the block, it is unlikely that the proposed harvesting will have a significant impact on the sidewall of the Bastion Creek valley to the south. The northern portion of the block drains to the northeast for the most part and the rolling bedrock controlled terrain in this portion of the block limits the potential for drainage pattern disruption.

Results

The likelihood of a harvesting related landslide occurring within the northern portion of block K0WG is estimated as low (See Appendix A for a description of the risk assessment process)**.** This low likelihood is based on the following factors which reduce the probability of a landslide occurring as the result of harvesting operations:

(i) Slope gradients in the northern portion of the block are mostly gentle;
(ii) Surficial materials are moderately well drained for the most part;
(iii) No surface flows are present;
(iv) The majority of the northern portion of the block drains to the northeast onto face unit slopes rather than onto the Bastion Creek sidewall to the south.

In the unlikely event that a landslide did occur in the northern portion of the block, the slide would most likely consist of a small surficial landslide occurring due to excess ground disturbance during harvesting. The maximum magnitude and aerial extent of such an event is estimated as 500m^3 and 0.05ha respectively. Runout is not expected to extend a significant distance and terminate within the northern portion of the block. No impact to elements at risk is expected.

Note that the risk assessment concerning the likelihood of a landside in the downslope area is addressed in Sections 5.1.2 and 5.1.3 below.

Recommendations

The following recommendation is made from a best practices standpoint and to ensure that the likelihood of a harvesting related landslide is not increased from low:

1. **Any trails which are constructed to facilitate harvesting operations must be rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must consist of recontouring of the trail prism and restoration of natural drainage patterns.**

2. **Skidding activities should avoid areas where there is the potential to bring shallow subsurface water to surface via compaction or cutting. This will typically include toe of slope and base of draw locations.**

3. **If the proposed roads accessing this portion of the block are not intended for use following the completion of harvesting, then the road must be permanently deactivated. The deactivation prescription for the road must be formulated by a qualified registered professional (i.e. a P. Eng. or P. Geo.) and the deactivation works must be supervised by the author of the prescription.**

4. **The harvest area must be inspected by a Qualified Registered Professional (QRP) representing BCTS concurrent with the completion of harvesting activities to ensure that the above recommendations are correctly implemented and natural drainage patterns are maintained in the harvest area.**

5.1.2 Southeast Portion of Cutblock K0WG

Observations

The southeast portion of block K0WG is situated at the crest of the slope break to the Bastion Creek sidewall. Terrain within this portion of the block is irregular and somewhat benched with mainly gentle slope gradients and some isolated moderate gradient pitches. Downslope of this portion of the block, moderately steep to steep gradient slopes extend for approximately 150m down to a broad bench. Downslope of the bench an incised gully with moderately steep to steep slope gradients forms and extends down to Bastion Creek.

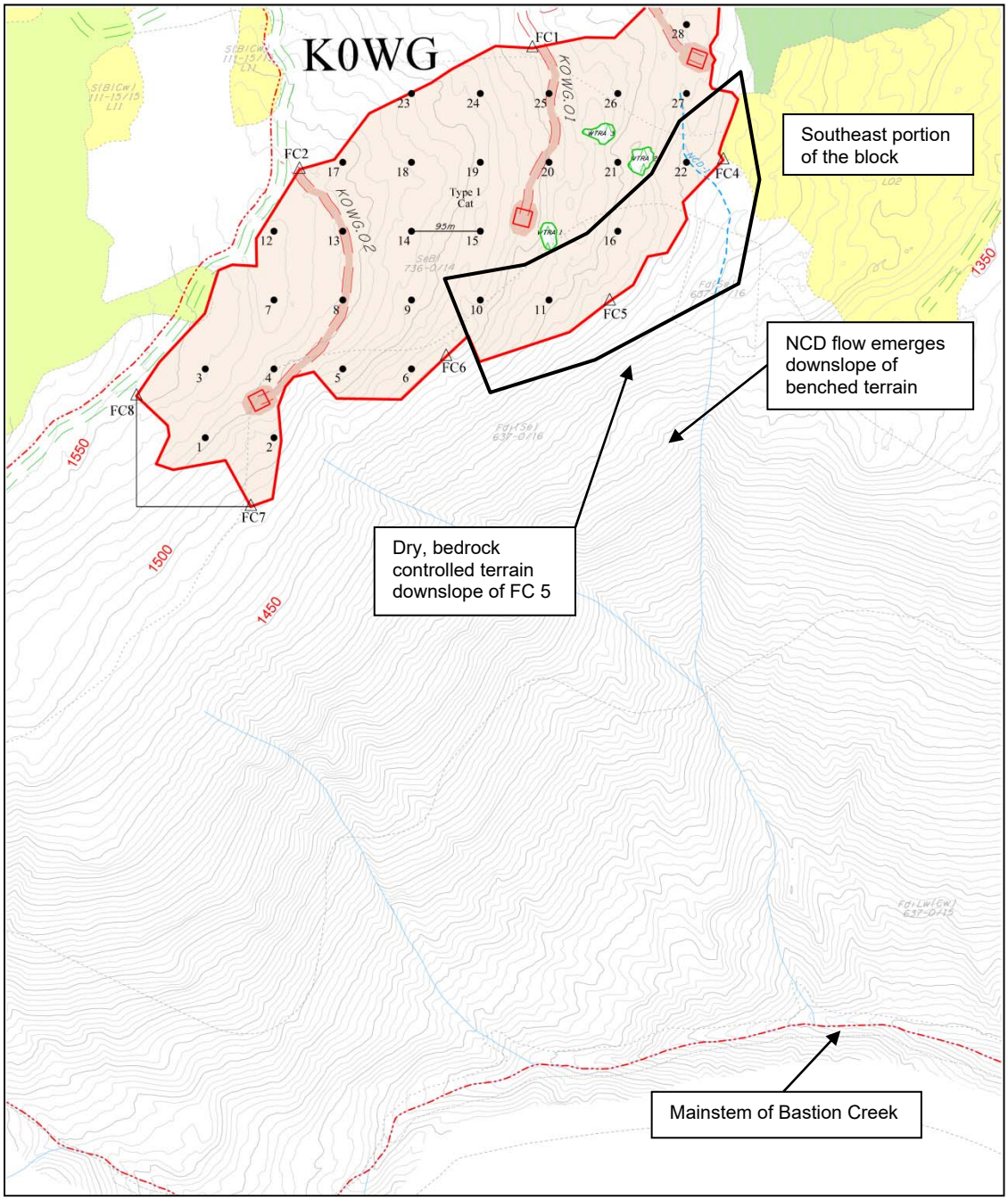


Figure 5 – Detailed view of block K0WG and the downslope area. The original map scale was 1:5,000.

Surficial material in this portion of the block consists of a veneer of gravel sized rubble in a silt and sand matrix. Deeper deposits of silt and sand with some gravel till are located in topographic lows. These materials are moderately well to well drained for the most part aside from a pocket of imperfectly drained surficial material adjacent to NCD-1 in the eastern corner of the block.

Bedrock was noted throughout this portion of the block and immediately downslope and consisted of interbedded weak to medium strong schist and black shale.

Timber in the block consists of second growth SxBlFd with dbh ranging from 20-60cm. The stand appears to be a product of a large forest fire event which likely occurred in the late 1800's or early 1900's. Understory vegetation consists of a thick blanket of azalea and rhododendron as well as scattered ferns in low points.

Surface flows in this portion of the block consist of a single small NCD (NCD-1) flowing through the eastern corner of the block. The NCD (Non classified drainage) is poorly confined and could be susceptible to diversion during harvesting.

Terrain stability mapping of the area indicates that the area immediately downslope of this portion of the block is mapped as TSC P. This suggests that harvesting related landslide activity in the downslope area is possible given the proposed development.

Extensive natural landslide activity was noted on the sidewall slope downslope of the southwest portion of the block. The landslide activity ceases downslope of the southeast portion of the block and the downslope area is bedrock controlled. The landslide activity is discussed in detail in Section 5.1.3 of this report.

The primary concern with respect to this portion of the proposed development is with the potential for drainage pattern disruption within the harvest area, leading to drainage concentration onto unconditioned terrain downslope of the block. Given that moderately steep to steep slope gradients are present downslope of the block, there is the potential for landslide activity to occur if sufficient water is intercepted within the block and focused onto the downslope terrain. While surface flows are confined to a single NCD, it is possible that trails constructed to facilitate harvesting operations could intercept snowmelt during the spring freshet period and focus that water onto the downslope terrain.

Results

The likelihood of a harvesting related landslide occurring within the southeast portion of block K0WG is estimated as low. This low likelihood is based on the following factors which reduce the probability of a landslide occurring as the result of harvesting operations:

(i) Slope gradients in the southeast portion of the block are mostly gentle;
(ii) Surficial materials are moderately well to well drained for the most part;
(iii) Surface flows consist of a single small NCD.

In the unlikely event that a landslide did occur in the southeast portion of the block, the slide would most likely consist of a small surficial landslide occurring due to excess ground disturbance during harvesting. The maximum magnitude and aerial extent of such an event is estimated as 500m^3 and 0.05ha respectively. Runout is not expected to extend a significant

distance and terminate within the northern portion of the block. No impact to elements at risk is expected.

The incremental increase in the likelihood of a harvesting related landslide occurring downslope of the southeast portion of the block K0WG is estimated as moderate. The terrain downslope of this portion of the block has moderately steep to steep slope gradients. While bedrock controlled, the thin veneer of surficial material present downslope of the block has the potential to saturate and slide given sufficient water concentration. Water concentration is possible if trails constructed to facilitate harvesting activities intercept snowmelt during the spring freshet period and focus the water onto downslope terrain.

In the event that a landslide did occur, the slide would most likely consist of a large translational landslide occurring due to drainage concentration onto unconditioned terrain. The maximum magnitude and aerial extent of such an event is estimated as 2000m^3 and 0.2ha respectively. Runout from the translational landslide is expected to terminate the draw complex downslope of the block where initiation of a secondary debris flow or entrained event is possible. The secondary event is expected to extend to the base of the valley sidewall and terminate in the mainstem of Bastion Creek. When including the secondary event, the maximum magnitude and aerial extent of the landslide is increased to 5000m^3 and 0.5ha respectively.

Upon terminating in Bastion Creek, initiation of a hydrogeomorphic event (most likely a debris flood event due to the Melton Ratio of 0.40) on the mainstem of Bastion Creek is not expected. No signs of a debris flood event on the mainstem of Bastion Creek over the airphoto record for the area (approximately 70 years) were apparent even though four development related landslides appear to have occurred during this time period impacting Bastion Creek. Furthermore, impact to the mainstem would need to occur under bank full flow conditions to have the possibility of a hydrogeomorphic event occurring. Under most prevalent flow conditions on the mainstem of Bastion Creek, an impinging landslide would be slowly eroded rather than entrained in a hydrogeomorphic event. Based on this information, debris floods do not appear to occur frequently on the Bastion Creek mainstem, even following impact on the mainstem by landslide events.

Therefore, the probability that the landslide event could impact elements at risk (i.e. the P(S:H)) listed in Section 3.1 of this report is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(S:H) = High.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**

And, the partial risk (i.e. the P(HA)) to elements which could be impacted by this event is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(HA) = High.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– P(HA) = Moderate.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– P(HA) = Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Low.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– P(HA) = Low.**

Recommendations

Implementation of the following recommendations is expected to reduce the incremental increase in the likelihood of a harvesting related landslide occurring downslope of the southeast portion of block K0WG as the result of the proposed harvesting activities to low.

1. **Any trails which are constructed to facilitate harvesting operations must be rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must consist of recontouring of the trail prism and restoration of natural drainage patterns.**

2. **Skidding activities should avoid areas where there is the potential to bring shallow subsurface water to surface via compaction or cutting. This will typically include toe of slope and base of draw locations.**

3. **Install a 5m Machine Free Zone (MFZ) around NCD-1 to ensure that the NCD is not diverted during harvesting operations.**

4. **Skid crossings over NCD-1 must be restricted to designated crossing which are identified prior to harvesting. A drainage structure (log bundle or 500mm culvert) must be installed at the designated crossing.**

5. **NCD-1 must be inspected concurrent with the completion of harvesting activities to ensure that the NCD is free of excess logging debris and continues to flow in its natural path.**

6. **If the proposed roads accessing this portion of the block are not intended for use following the completion of harvesting, then the road must be permanently deactivated. The deactivation prescription for the road must be formulated by a qualified registered professional (i.e. a P. Eng. or P. Geo.) and the deactivation works must be supervised by the author of the prescription.**

7. **The harvest area must be inspected by a Qualified Registered Professional (QRP) representing BCTS concurrent with the completion of harvesting activities to ensure that the above recommendations are correctly implemented and natural drainage patterns are maintained in the harvest area.**

Following the implementation of the above recommendations, the residual partial risk will also be reduced as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– Residual partial risk = Moderate.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– Residual partial risk = Low.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– Residual partial risk = Low.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**

5.1.3 Southwest Portion of Cutblock K0WG

Observations

The southwest portion of block K0WG contains irregular and somewhat benched terrain with mainly gentle to moderate slope gradients. Immediately downslope of the block, terrain breaks over into moderately steep gradient, planar to somewhat irregular terrain. A cutout is present between cruise plots 2 and 5 around a broad, moderately steep gradient bowl feature. This cutout was recommended by Azimuth at the time of fieldwork due to geotechnical concerns in the area. The various portions of this section of the block are discussed below.

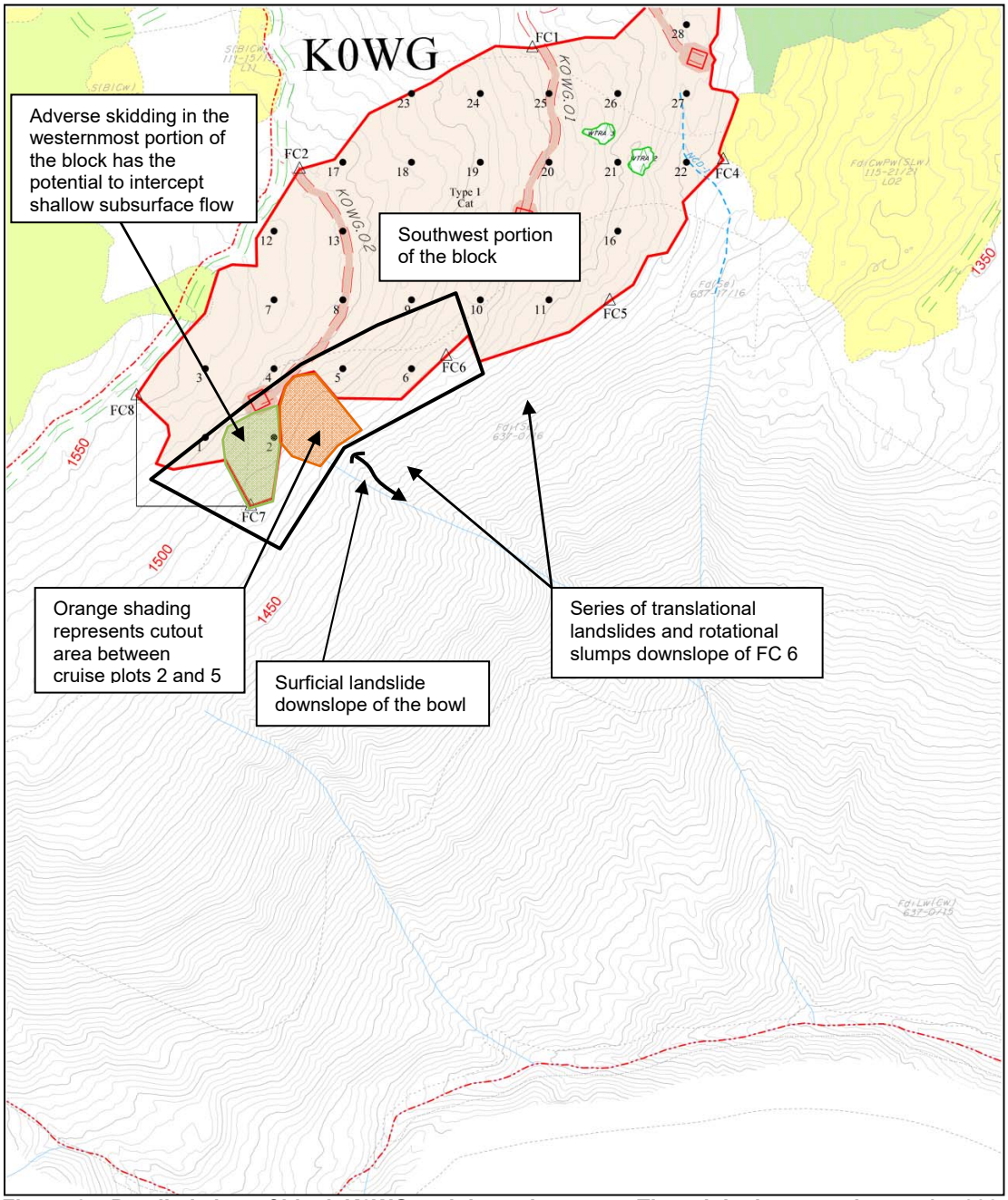


Figure 6 – Detailed view of block K0WG and downslope area. The original map scale was 1:5,000.

Westernmost portion of the block

The westernmost portion of the block (end landing of the K0WG.02 road extending downslope to FC 7) consists of a broad gentle to moderate gradient bench. This portion of the block is imperfectly drained and while no water was noted at surface, extensive hydrophilic vegetation is present. This indicates that the local groundwater table is close to surface and could be intercepted by trails constructed to facilitate harvesting operations.

Surficial materials in this portion of the block consist of a veneer (0.5-1.0m) of gravel sized rubble in a silty matrix. This material was moist to the touch at the time of fieldwork and hand dug test pits revealed that black shale bedrock underlies the surficial material. The surficial material appears to have formed out of insitu weathering of the local bedrock. The imperfectly drained nature of the surficial material is likely a product of the shallow bedrock as the bedrock forms a restrictive layer and forces the local groundwater to surface.

Downslope of this portion of the block surficial materials appear to deepen and the composition shifts to sandy silt with some gravel and trace clay till. This material is also moist to the touch and is considered to be susceptible to changes to pre-existing drainage patterns in the upslope area. Slope gradients in this downslope area are moderate for approximately 150m before gradually breaking over into moderately steep to steep gradients via a broad convex roll.

This portion of the block is of concern from a terrain stability standpoint as an adverse skid network will need to be constructed in order to harvest the area. Given that local surficial material is imperfectly drained and groundwater is expected to be close to surface, the trail network is expected to intercept shallow subsurface flow. If this intercepted flow is concentrated onto unconditioned terrain in the downslope area then the likelihood of a landslide could be increased.

Cutout area between cruise plot 2 & 5

The area removed from the proposed block between cruise plots 2 and 5 consists of a broad bowl with a moderately steep gradient headwall and gentle gradient base. Downslope of the bench moderately steep to steep gradient irregular terrain is present with an incised draw swiftly forming.

Surficial material within the bowl feature consists of moist, imperfectly drained silt with some sand and trace gravel till deposits. Sweep is present on timber in the area and an ephemeral NCD channel is present at the base of the bowl.

Downslope of the bowl area a steep draw complex is present. A recent surficial landslide was noted on the sidewall slope of the draw. The surficial slide originated on 80% slopes in deep deposits of silt and sand with trace to some gravel till deposits. The slide track was approximately 10m across and extended 30m downslope into a small S6 stream at the base of the draw. A small subsequent debris pulse event occurred on the stream but terminate after approximately 50m on 60% slopes. There are no obvious signs of water input to the surficial slide from the upslope area and as a result the surficial slide appears to be a natural product of steep slopes, fine grained surficial materials, and imperfectly drained surficial materials. It is likely that instability in the area is an ongoing phenomena and any sort of major disturbance to the area such as a forest fire, wind throw event, or insect infestation is expected to result in further instability.

Area downslope of FC 6

Continuing to the east of the cutout area downslope of FC 6, a series of large rotational slumps and translational landslides are present. The landslide tracks and slumps are timbered with mature timber the same age as the trees in the proposed block. The airphoto record of the area shows no open scarps or landslide tracks in this area. This indicates that the landslides predate the current timber on the hillside and are expected to be >120years in age.

The landslides occurred on 60-70% terrain in deep silt with some sand and trace gravel till deposits. No signs of water inputs to the landslides from the upslope area are apparent. The landslides appear to be natural events and likely occurred as a product of one of the proceeding stand rotations on the hillside. The last stand rotation appears to be the result of a large forest fire event. It is possible that this forest fire event lead to the initiation of the observed landslides. Note that impact of a large forest fire on the hillside would have a much larger impact on hillside hydrology and ground disturbance than the proposed harvesting.

Results

The likelihood of a harvesting related landside occurring within the southwest portion of block K0WG is estimated as low. Terrain within this portion of the block has mainly gentle to moderate slope gradients. The slope gradients in this area are likely too shallow for landslide initiation and the main concern is with respect to the downslope area.

In the unlikely event that a landslide did occur in the southwest portion of the block, the slide would most likely consist of a small surficial landslide occurring due to excess ground disturbance during harvesting. The maximum magnitude and aerial extent of such an event is estimated as 500m^3 and 0.05ha respectively. Runout is not expected to extend a significant distance and terminate within the northern portion of the block. No impact to elements at risk is expected.

The incremental increase in the likelihood of a harvesting related landslide occurring downslope of the southwest portion of block K0WG is estimated as high. Extensive natural instability is present downslope of this portion of the block and moderately steep to steep slope gradients area present. Adverse trail construction is expected to be required in this portion of the block to facilitate harvesting operations. Imperfectly drained surficial materials are present in this portion of the block and it is expected that trail construction could intercept shallow subsurface flow. If this intercepted flow is concentrated onto the terrain downslope of the block a landslide is probable.

In the event that a landslide did occur downslope of the southwest portion of the block, the slide would most likely consist of a large translational landslide occurring due to drainage concentration onto unconditioned terrain. The maximum magnitude and aerial extent of such an event is estimated as 2000m^3 and 0.20ha respectively. Runout from such an event is expected to terminate in the draw complex downslope of the block where initiation of a secondary debris flow event is possible. The secondary event is expected to extend to the base of the valley sidewall and terminate in the mainstem of Bastion Creek. When including the secondary event, the maximum magnitude and aerial extent of the landslide is increased to 5000m^3 and 0.5ha respectively.

Upon terminating in Bastion Creek, initiation of a hydrogeomorphic event (most likely a debris flood event due to the Melton Ratio of 0.40) on the mainstem of Bastion Creek is not expected. No signs of a debris flood event on the mainstem of Bastion Creek over the airphoto record for

the area (approximately 70 years) were apparent even though four development related landslides appear to have occurred during this time period impacting Bastion Creek. Furthermore, impact to the mainstem would need to occur under bank full flow conditions to have the possibility of a hydrogeomorphic event occurring. Under most prevalent flow conditions on the mainstem of Bastion Creek, an impinging landslide would be slowly eroded rather than entrained in a hydrogeomorphic event. Based on this information, debris floods do not appear to occur frequently on the Bastion Creek mainstem, even following impact on the mainstem by landslide events.

Therefore, the probability that the landslide event could impact elements at risk (i.e. the P(S:H)) listed in Section 3.1 of this report is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(S:H) = High.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**

And, the partial risk (i.e. the P(HA)) to elements which could be impacted by this event is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(HA) = Very High.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– P(HA) = High.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– P(HA) = High.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Moderate.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Moderate.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– P(HA) = Moderate.**

Recommendations

Implementation of the following recommendations is expected to reduce the incremental increase in the likelihood of a harvesting related landslide occurring downslope of the southwest portion of block K0WG as the result of the proposed harvesting activities to low. Note that this applies to the incremental increase in the likelihood of a landslide only, a residual moderate natural likelihood of a landslide will persist downslope of this portion of the block. This natural likelihood will be present regardless of whether or not harvesting occurs in the upslope area.

1. **The area between cruise plots 2 and 5 must be excluded from the harvest area (note that this recommendation has already been implemented and the current cutblock mapping reflects the excluded area).**

2. **Any trails which are constructed to facilitate harvesting operations must be rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must consist of recontouring of the trail prism and restoration of natural drainage patterns.**

3. **Efforts must be made to minimize trail cuts and skid over the ground to as great a degree as is feasible when harvesting the portion of the block in the vicinity of FC 7 (green shaded area). If this is not considered feasible then the portion of the block downslope of the end landing of the K0WG.02 road extending down to FC 7 must be removed from the harvest area.**

4. **Skidding activities should avoid areas where there is the potential to bring shallow subsurface water to surface via compaction or cutting. This will typically include toe of slope and base of draw locations.**

5. **Log bundle cross drains must be installed along all trails at any locations where significant subsurface or surface flow is encountered. Intercepted flow must not be diverted down the trail or concentrated onto unconditioned terrain.**

6. **If harvesting is going to cease for a significant amount of time and no workers will be present on site, all trails must be temporarily deactivated via installation of cross ditches aligned with all natural drainage courses or features crossed by the trails. Additional cross ditches may be added in between the natural drainage locations as required.**

7. **If the proposed K0WG.02 road accessing this portion of the block is not intended for use following the completion of harvesting, then the road must be permanently deactivated. The deactivation prescription for the road must be formulated by a qualified registered professional (i.e. a P. Eng. or P. Geo.) and the deactivation works must be supervised by the author of the prescription.**

8. **The harvest area must be inspected by a Qualified Registered Professional (QRP) representing BCTS concurrent with the completion of harvesting activities to ensure that the above recommendations are correctly implemented and natural drainage patterns are maintained in the harvest area.**

Following the implementation of the above recommendations, the residual partial risk will also be reduced as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– Residual partial risk = Moderate.**
- Water quality at the domestic water source (POD 75398) on the lower portion of Bastion Creek downslope of the proposed development. **– Residual partial risk = Low.**
- Water quality at the domestic water source (POD 52827) on the lower portion of Bastion Creek downslope of the proposed development. **– Residual partial risk = Low.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**

- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- The crossing structure on the Sunnybrae-Canoe Point Road over Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**

5.2 Cutblock K5M7

Observations

Cutblock K5M7 is a 12.1ha (gross) block slated for clearcut harvesting using ground based methods. Access to the block is provided by an existing road which approaches from the north and no new road construction is proposed. The falling boundary of the block is broadly defined by a previously harvested area to the north, a small bedrock ridge to the east, the Bastion Creek valley sidewall to the south, and timber quality to the west. A map of the block is provided in Figure 6 below.

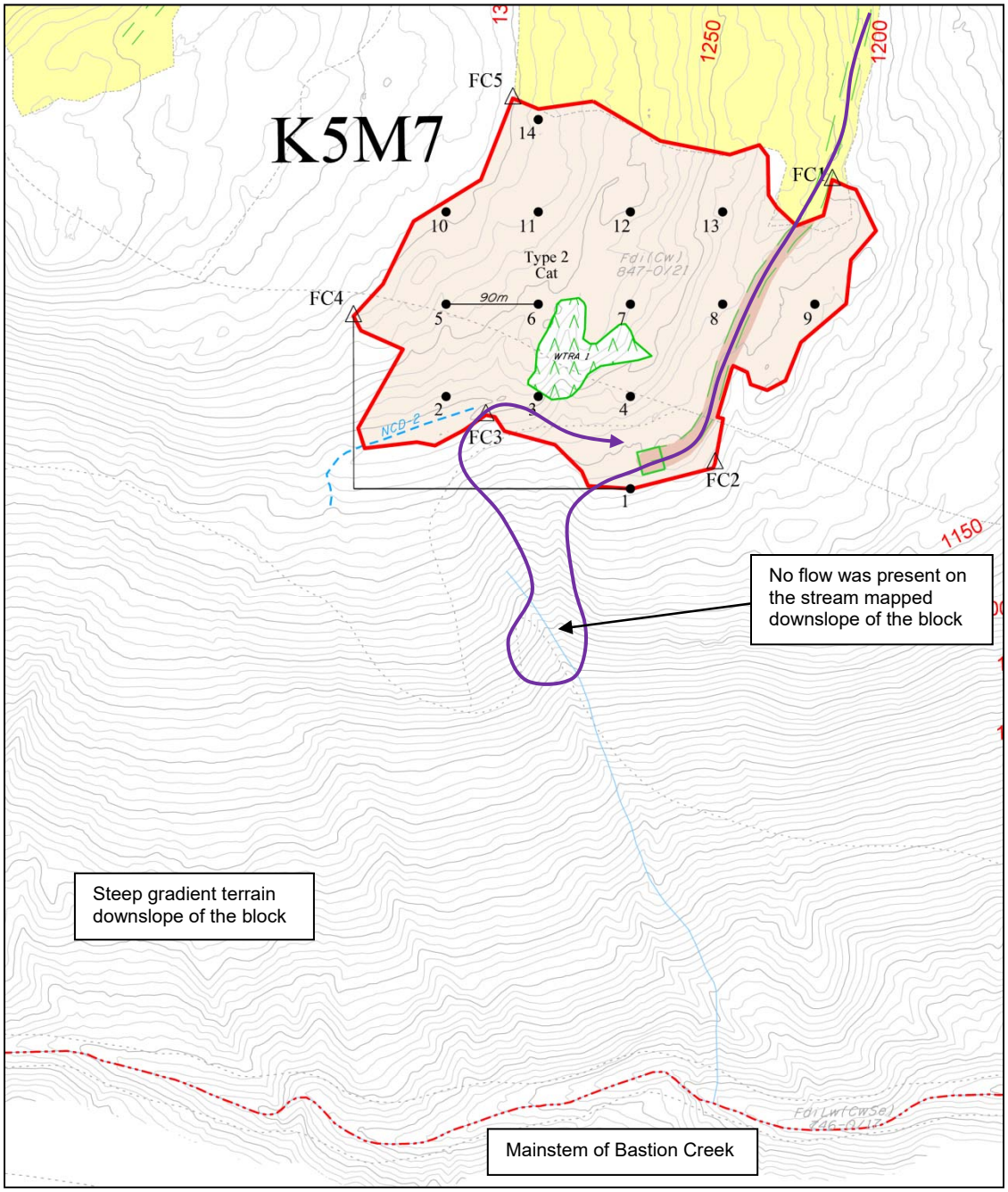


Figure 7 – Proposed Cutblock K5M7. The original map scale was 1:5,000. The traverse route is depicted by the dark purple line.

Terrain in the block is irregular with a series of bedrock knobs, outcrops, and ridges. Slope gradients in the block are gentle for the most part with some short moderate gradient pitches (10-40%). Terrain downslope of the eastern boundary of the block is irregular and bedrock controlled with gentle to moderate slope gradients.

Terrain downslope of the southern boundary of the block comprises the sidewall of the Bastion Creek valley. The terrain in this area consists of a broad bowl with moderately steep (50-60%) slope gradients. The bowl funnels down into an incised, bedrock controlled draw with moderately steep to steep gradient slopes.

The slope break to moderately steep gradient terrain to the south of the block creates a gentle over steep (GOS) landform. GOS landforms are a terrain type that can be susceptible to drainage concentration related landslides. Harvesting typically occurs on the gentle portion of the landform which appears relatively innocuous. However, the harvesting operations can disrupt natural drainage patterns, leading to drainage concentration onto the steep portion of the landform, potentially leading to landslide activity on the steep portion of the landform.

Surficial materials within the block consist of well drained gravel sized rubble in a silt and sand matrix. This material is well drained, <1m in depth, and appears to have formed out of insitu weathering of local bedrock. Similar material was noted downslope of the block on the Bastion Creek valley sidewall.

Bedrock outcrops were noted throughout the harvest area and consist of weak to medium strong black shale.

Timber in the block consists of second growth Fd(CwHw) with dbh ranging from 20-60cm. The stand appears to be the product of a forest fire event in the late 1800's to early 1900's. Understory vegetation is sparse and mainly consists of mosses and scattered ferns. The understory vegetation is consistent with well drained surficial material.

Surface flows in the block are confined to a single small NCD that was dry at the time of fieldwork in the western corner of the block. This NCD is poorly confined and is susceptible to diversion; however, the flow volume in the stream is minimal. Base mapping of the area indicates that a stream also originates in the bowl downslope of the southern boundary of the block. The stream location was reviewed in the field and no evidence of surface or shallow subsurface flow was noted.

Results

The likelihood of a harvesting related landslide occurring within block K5M7 or immediately downslope of the eastern side of block K5M7 is estimated as low. This low likelihood is based on the following factors which reduce the probability of a landslide occurring as the result of harvesting operations:

(i) Slope gradients within and downslope of the eastern boundary of the block are gentle to moderate;
(ii) Surficial materials are well drained;
(iii) Surface flows consist of a single NCD.

In the unlikely event that a landslide did occur within or downslope of the eastern boundary of the block, the slide would most likely consist of a small surficial landslide occurring due to

excess ground disturbance during harvesting. The maximum magnitude and aerial extent of such an event is estimated as 500m^3 and 0.05ha respectively. Runout is expected to terminate within or immediately downslope of the eastern boundary of the block. No impact to elements at risk is expected.

The likelihood of a harvesting related landslide occurring downslope of the southern boundary of block K5M7 is estimated as low to moderate. The slope break to moderately steep to steep gradient terrain downslope of the southern boundary of the block creates a GOS landform. Changes to natural drainage patterns within the block have the potential to intercept flow during the spring freshet period and focused this water onto the terrain downslope of the southern boundary of the block. This could increase the probability of a landslide downslope of the southern boundary of the block.

In the unlikely event that a landslide did occur, the slide would most likely consist of a large translational landslide occurring due to drainage concentration onto unconditioned terrain. The maximum magnitude and aerial extent of such an event is estimated as 5000m^3 and 0.5ha respectively. Runout from such an event is expected to extend to the lower portion of the valley sidewall and possibly deposit directly into Bastion Creek.

Upon terminating in Bastion Creek, initiation of a hydrogeomorphic event (most likely a debris flood event due to the Melton Ratio of 0.40) on the mainstem of Bastion Creek is not expected. No signs of a debris flood event on the mainstem of Bastion Creek over the airphoto record for the area (approximately 70 years) were apparent even though four development related landslides appear to have occurred during this time period impacting Bastion Creek. Furthermore, impact to the mainstem would need to occur under bank full flow conditions to have the possibility of a hydrogeomorphic event occurring. Under most prevalent flow conditions on the mainstem of Bastion Creek, an impinging landslide would be slowly eroded rather than entrained in a hydrogeomorphic event. Based on this information, debris floods do not appear to occur frequently on the Bastion Creek mainstem, even following impact on the mainstem by landslide events.

Therefore, the probability that the landslide event could impact elements at risk (i.e. the P(S:H)) listed in Section 3.1 of this report is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– P(S:H) = Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**

And, the partial risk (i.e. the P(HA)) to elements which could be impacted by this event is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(HA) = Low to Moderate.**

- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Very Low to Low.**
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– P(HA) = Very Low to Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Very Low to Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– P(HA) = Very Low to Low.**
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– P(HA) = Very Low to Low.**

Recommendations

Implementation of the following recommendations is expected to reduce the likelihood of a harvesting related landslide occurring downslope of the southern boundary of block K5M7 to low:

1. **Any trails which are constructed to facilitate harvesting operations must be rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must consist of recontouring of the trail prism and restoration of natural drainage patterns.**

2. **Skidding activities should avoid areas where there is the potential to bring shallow subsurface water to surface via compaction or cutting. This will typically include toe of slope and base of draw locations.**

3. **Install a 5m Machine Free Zone (MFZ) around NCD-2 to ensure that the NCD is not diverted during harvesting operations.**

4. **The NCD flowing in the western portion of the block must be inspected concurrent with the completion of harvesting activities to ensure that the NCD is free of excess logging debris and continue to flow in its natural path.**

5. **Ensure that ditchlines and drainage structures along the existing road passing through the block remain intact and free of debris concurrent with the completion of harvesting operations.**

6. **The harvest area must be inspected by a Qualified Registered Professional (QRP) representing BCTS concurrent with the completion of harvesting activities to ensure that the above recommendations are correctly implemented and natural drainage patterns are maintained in the harvest area.**

Following the implementation of the above recommendations, the residual partial risk will also be reduced as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**

- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– Residual partial risk = Very Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**

5.3 Cutblock K5M8

Observations

Cutblock K5M8 is a 19.7ha (gross) block slated for clearcut harvesting using ground based methods. Access to the block is provided by an existing road which switchbacks down through the northern portion of the block. The falling boundary of the block is broadly defined by a previously harvested area to the north, an existing road to the east, the Bastion Creek valley sidewall to the south, and a previously harvested area to the west. A map of the block is provided in Figure 7 below.

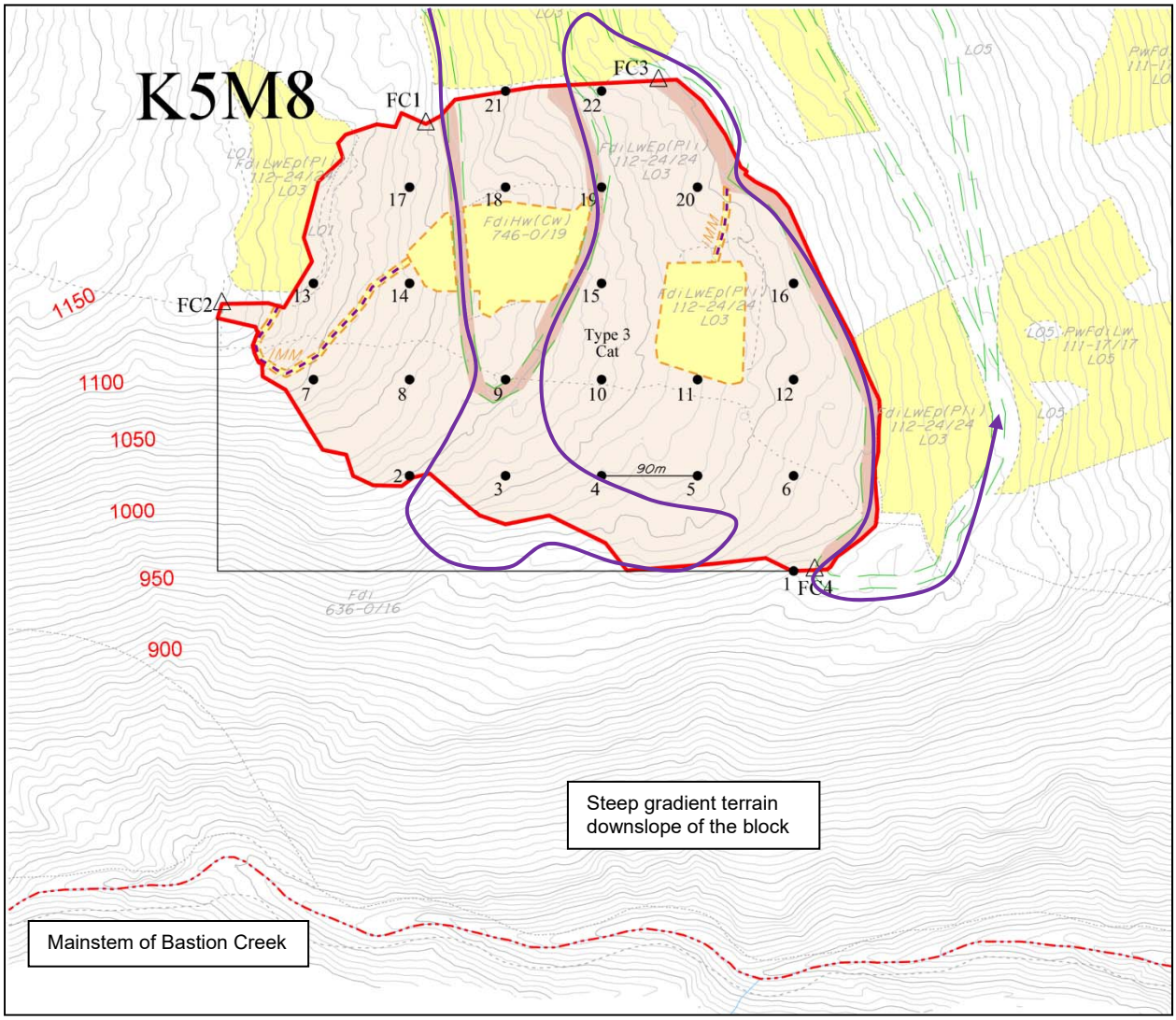


Figure 8 – Proposed Cutblock K5M8. The original map scale was 1:5,000. The traverse route is depicted by the dark purple line.

Terrain in the block is irregular with gentle to moderate slope gradients. The irregularity of the terrain appears to be an expression of the underlying bedrock morphology and surficial materials appear to be relatively shallow. Terrain downslope of the eastern portion of the block is planar to irregular with gentle to moderate slope gradients. Terrain downslope of the southern boundary of the block comprises the sidewall of the Bastion Creek valley. The terrain in this

area is planar to somewhat irregular with moderately steep slope gradients. This extends for approximately 400m down to Bastion Creek.

The slope break to moderately steep gradient terrain to the south of the block creates a gentle over steep (GOS) landform. GOS landforms are a terrain type that can be susceptible to drainage concentration related landslides. Harvesting typically occurs on the gentle portion of the landform which appears relatively innocuous. However, the harvesting operations can disrupt natural drainage patterns, leading to drainage concentration onto the steep portion of the landform, potentially leading to landslide activity on the steep portion of the landform.

Surficial materials within the block consist of well drained gravel sized rubble in a silt and sand matrix. This material is well drained, <1m in depth, and appears to have formed out of insitu weathering of local bedrock. Similar material was noted downslope of the block on the Bastion Creek valley sidewall.

Bedrock was noted outcropping throughout the harvest area and consists of weak to medium strong black shale.

Timber in the block consists of second growth Fd(CwHw) with dbh ranging from 20-60cm. The stand appears to be the product of a forest fire event in the late 1800's to early 1900's. Understory vegetation is sparse and mainly consists of mosses and scattered ferns. The understory vegetation is consistent with well drained surficial material.

No surface flows are present within the harvest area. In addition, no streams are present on the base mapping of the Bastion Creek sidewall directly downslope of the block.

Results

The likelihood of a harvesting related landslide occurring within block K5M8 or immediately downslope of the eastern side of block K5M8 is estimated as low. This low likelihood is based on the following factors which reduce the probability of a landslide occurring as the result of harvesting operations:

(i) Slope gradients within and downslope of the eastern boundary of the block are gentle to moderate;
(ii) Surficial materials are well drained;
(iii) No surface flows are present within the block.

In the unlikely event that a landslide did occur within or downslope of the eastern boundary of the block, the slide would most likely consist of a small surficial landslide occurring due to excess ground disturbance during harvesting. The maximum magnitude and aerial extent of such an event is estimated as 500m^3 and 0.05ha respectively. Runout is expected to terminate within or immediately downslope of the eastern boundary of the block. No impact to elements at risk is expected.

The likelihood of a harvesting related landslide occurring downslope of the southern boundary of block K5M8 is estimated as low to moderate. The slope break to moderately steep to steep gradient terrain downslope of the southern boundary of the block creates a GOS landform. Changes to natural drainage patterns within the block have the potential to intercept flow during the spring freshet period and focused this water onto the terrain downslope of the

southern boundary of the block. This could increase the probability of a landslide downslope of the southern boundary of the block.

In the unlikely event that a landslide did occur, the slide would most likely consist of a large translational landslide occurring due to drainage concentration onto unconditioned terrain. The maximum magnitude and aerial extent of such an event is estimated as 4000m^3 and 0.4ha respectively. Runout from such an event is expected to extend to the lower portion of the valley sidewall and possibly deposit directly into Bastion Creek.

Upon terminating in Bastion Creek, initiation of a hydrogeomorphic event (most likely a debris flood event due to the Melton Ratio of 0.40) on the mainstem of Bastion Creek is not expected. No signs of a debris flood event on the mainstem of Bastion Creek over the airphoto record for the area (approximately 70 years) were apparent even though four development related landslides appear to have occurred during this time period impacting Bastion Creek. Furthermore, impact to the mainstem would need to occur under bank full flow conditions to have the possibility of a hydrogeomorphic event occurring. Under most prevalent flow conditions on the mainstem of Bastion Creek, an impinging landslide would be slowly eroded rather than entrained in a hydrogeomorphic event. Based on this information, debris floods do not appear to occur frequently on the Bastion Creek mainstem, even following impact on the mainstem by landslide events.

Therefore, the probability that the landslide event could impact elements at risk (i.e. the P(S:H)) listed in Section 3.1 of this report is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(S:H) = Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– P(S:H) = Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(S:H) = Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– P(S:H) = Low.**

And, the partial risk (i.e. the P(HA)) to elements which could be impacted by this event is as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– P(HA) = Low to Moderate.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Very Low to Low.**
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– P(HA) = Very Low to Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– P(HA) = Very Low to Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– P(HA) = Very Low to Low.**

- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– P(HA) = Very Low to Low.**

Recommendations

Implementation of the following recommendations is expected to reduce the likelihood of a harvesting related landslide occurring downslope of the southern boundary of block K5M8 to low:

1. **Any trails which are constructed to facilitate harvesting operations must be rehabilitated concurrent with the completion of harvesting activities. Rehabilitation must consist of recontouring of the trail prism and restoration of natural drainage patterns.**

2. **Skidding activities should avoid areas where there is the potential to bring shallow subsurface water to surface via compaction or cutting. This will typically include toe of slope and base of draw locations.**

3. **Ensure that ditchlines and drainage structures along the existing road passing through the block remain intact and free of debris concurrent with the completion of harvesting operations.**

4. **The harvest area must be inspected by a Qualified Registered Professional (QRP) representing BCTS concurrent with the completion of harvesting activities to ensure that the above recommendations are correctly implemented and natural drainage patterns are maintained in the harvest area.**

Following the implementation of the above recommendations, the residual partial risk will also be reduced as follows:

- Water quality and fisheries resources in Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**
- Private land and residential structures situated on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- The crossing structure on Sunnybrae-Canoe Point Road over Bastion Creek downslope of the development. **– Residual partial risk = Very Low.**
- Public safety on the Sunnybrae-Canoe Point Road and in residential structures on the Bastion Creek fan downslope of the proposed development. **– Residual partial risk = Very Low.**
- Domestic water source (POD 75398) on Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**
- Domestic water source (POD 52827) on Bastion Creek downslope of the proposed development. **– Residual partial risk = Very Low.**

6.0 Proposed Roads – Observations, Results, Recommendations

The proposed development is accessed by three proposed roads; the K0WG.01, K0WG.01.01, and K0WG.02 roads. The proposed roads locations were not finalized at the time of fieldwork but LiDAR data for the area indicates that of the roads are situated on mainly gentle gradient terrain and can be constructed using standard cut and fill method. The following general construction recommendations are included below for the proposed roads. In addition, the reader is referred to the Ministry of Forests, Lands and Natural Resource Operations Engineering Manual for additional information on forest road construction methods and best practices.

Cut and fill construction methods are considered suitable for the proposed road alignments.

Cross drain culverts must be installed at all streams, NCDs, and seepage sites crossed by the proposed road.

The following cut and fill angles are suggested for road construction in the local surficial material:

- Cut – 100% (1H:1V) in moderately well to well drained till.
- Cut – 70% (1.5H:1V) in imperfectly drained till.
- Cut – 200% (1H:2V) in black shale bedrock.
- Fill – 70% (1.5H:1V) for sidecast fill of local material.

In addition, the road construction map for the proposed roads and the proposed culvert locations must be reviewed by the author of this report prior to construction and modified as needed.

Any of the proposed roads which are not intended for use following the completion of harvesting must be permanently deactivated. The deactivation prescription for the roads must be formulated by a qualified registered professional (i.e. a P. Eng. or P. Geo.) and the deactivation works must be supervised by the author of the prescription.

7.0 Closure

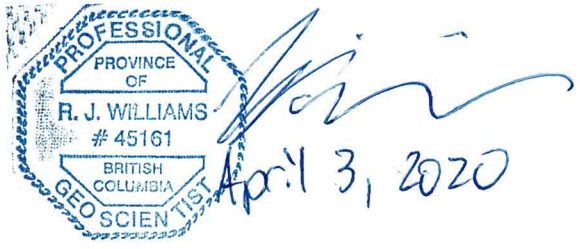
The discussions and recommendations presented in this report are based on a field assessment of the proposed development and additional background information. The report has been prepared for use by British Columbia Timber Sales – Vernon Office, however, this also includes distribution as required for the purposes for which the assessment was commissioned. The assessment has been carried out in accordance with generally accepted geotechnical practice and professional geotechnical judgement has been applied in developing the recommendations contained in this report. No other warranty is made, either expressed or implied.

Azimuth trusts that the information contained in this report meets your present requirements. Please contact the undersigned at your convenience if you have any questions or if further information is required.

Sincerely,

Azimuth Forestry & Mapping Solutions Ltd.

Prepared by:



Ryan Williams, P.Geo.
Geoscientist

Appendix A
Risk Analysis Process/Terminology & TSA Methodology

Risk Analysis Process/Terminology:

Landslide hazard and risk ratings in this assessment are based on the definitions and terminology in the Land Management Handbook 56 (LMH 56) – Landslide Risk Case Studies in Forest Development Planning and Operations[1].

Risk analysis is the process by which the potential for an injury or loss is quantified through the likelihood or probability of a harmful event occurring and the estimation of its effect to a given element or group of elements at risk.

In practice in the forest sector in BC, a "partial risk analysis" process is used to assess risk in Terrain Stability Assessments (TSA). This method includes an estimation of the probability of a landslide occurring (P(H)), an estimation of the probability of the landslide reaching an element at risk (P(S:H)), and an estimation of the probability of the element at risk being present at the site at the time that the landslide occurs (P(T:S)). Note that for most elements at risk in the forest sector the P(T:S) = 1 as the element at risk is typically stationary. The "partial risk" (P(HA)) can be expressed mathematically as:

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

The determination of a quantitative probability for any of the risk components in the equation above is complex, particularly in the forest sector where much of the necessary data is not available or is not of sufficient detail. As a result, qualitative relationships are commonly used, which are based on probability ranges or descriptive ratings. The tables below define the qualitative ratings used in the partial risk analysis process.

Table 1 – Landslide Likelihood (P(H)) Qualitative Descriptors and Probability Ranges

Landslide Likelihood P(H)	Description	Probability Range	
		Annual Probability $P(H)_a$	20 Year Probability $P(H)_{20}$
Very Low	The likelihood of the event occurring during the lifespan of the development is extremely remote to nonexistent.	<1/2500	<0.01
Low	The event is unlikely to occur during the lifespan of the development.	1/2500 to 1/500	0.01 to 0.04
Moderate	The event is possible during the lifespan of the development.	1/500 to 1/100	0.04 to 0.18
High	The event is probable during the lifespan of the development.	1/100 to 1/20	0.18 to 0.64
Very High	The event is imminent or is expected to occur during the lifespan of the development.	>1/20	>0.64

[1] Wise, M.P., Moore, G.D., and VanDine, D.F. (editors), 2004. Landslide Risk Case Studies in Forest Development Planning and Operations. B.C. Ministry of Forests, Resource Branch, Victoria, B.C. Land Management Handbook 56. https://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh56_HiRes.pdf

Appendix A
Risk Analysis Process/Terminology & TSA Methodology

Table 2 – Spatial Probability (P(S:H)) Quantitative Descriptors and Probability Ranges		
Likelihood of a Spatial Impact P(S:H)	**Description**	**Probability Range**
Low	It is unlikely a given landslide will impact an element at risk	<0.1
Moderate	It is possible that a given landslide will impact an element at risk	0.1 to 0.5
High	It is likely that a given landslide will impact an element at risk	>0.5

Table 3 – Partial Risk Analysis (P(HA)) Qualitative Risk Matrix				
Partial Risk P(HA): The probability of occurrence of a specific hazardous landslide and the probability of it impacting a site occupied by a specific element at risk.		P(S:H): The probability that the hazardous landslide will reach or otherwise impact the site occupied by a specific element at risk, assuming that the landslide occurs.		
		High	**Moderate**	**Low**
P(H): The annual probability of occurrence of a specific hazardous landslide.	**Very High**	*Very High*	*Very High*	*High*
	High	*Very High*	*High*	*Moderate*
	Moderate	*High*	*Moderate*	*Low*
	Low	*Moderate*	*Low*	*Very Low*
	Very Low	*Low*	*Very Low*	*Very Low*

Table 4 – Quantitative Landslide Magnitude Ratings		
Magnitude Rating	**Typical Affected Area (ha)**	**Typical Volume Involved (m^3)**
Very Small	<0.01	<100
Small	0.01 – 0.05	100 – 500
Medium	0.05 – 0.1	500 – 1,000
Large	0.1 – 0.5	1000 – 5,000
Very Large	>0.5	>5,000

Appendix A
Risk Analysis Process/Terminology & TSA Methodology

TSA Methodology:

This TSA has been carried out in a method consistent with the *Guidelines for Professional Services in the Forest Sector - Terrain Stability Assessments*[2]. Observations have been made on the existing slope gradients, slope morphology, surficial material composition, site drainage, groundwater conditions, and bedrock characteristics. This information was gathered via field observations of root wads and road cuts as well as shallow hand dug test pits. No deeper subsurface information was collected via machine test pitting or drilling. Note that site conditions may vary from those described in this report and that this is an inherent characteristic of natural systems. The author of the report should be contacted if conditions differ substantially to review the recommendations made in this report and amend the recommendations if warranted.

The likelihood of landslide initiation has been estimated using the partial risk analysis method outlined in Land Management Handbook 56, *Landslide Risk Case Studies in Forest Development Planning and Operations*[3]. Further information concerning the partial risk assessment process, including examples, is contained in Appendix A. The landslide likelihood estimation has been performed in a mainly qualitative manner using a comparative-observational approach which relies on generally accepted geotechnical interpretations and assumptions, the experience of the report author, the terrain response of forest development on similar terrain in the surrounding area, and results from landslide attribute studies in the southern interior of BC[4].

The landslide likelihood ratings presented in this report are incremental to the natural state with respect to the proposed development. The landslide likelihood and risk ratings are based on the assumption of standard construction, logging, and maintenance practices in the forest sector unless otherwise stated. Residual landslide likelihood and risk ratings are also based on the assumption that the recommendations in this report are implemented.

It is the responsibility of the land manager that this report is directed to review, understand, and accept the landslide rating definitions used in this report. The ratings are consistent with values usually used in assessing landslide risks with respect to forest development is BC (see Appendix A), however; they are not set by any regional or provincial standard. It is also the responsibility of the land manager to determine whether the levels of risk associated with the proposed development are acceptable, tolerable, or unacceptable and whether to proceed with the development on this basis.

[2] AFPBC/APEGBC 2010. Guidelines for professional services in the forest sector - terrain stability assessments. Association of Professional Engineers & Geoscientists of British Columbia (APEGBC), Burnaby, BC.
[3] Ministry of Forests, Landslide Risk Case Studies in Forest Development Planning and Operations, *Land Management Handbook #56*, 2004.
[4] Jordan, P. 2003. Landslide and Terrain Attribute Study in the Nelson Forest Region. Final Report to the Ministry of Forest Research Branch. FRBC Project Number: KB97202-0RE1. Unpublished Report.

Appendix B
Soil, Slope, and Rock Classification

Soil Classification[1]:

Coarse Grained Soils (Cohesionless)[1]	
Density	**Field Test**
Very Loose	Easily excavated with a spade
Loose	Some resistance to a spade
Compact	Considerable resistance to a spade
Dense	Requires a pick for excavation
Very Dense	High resistance to a pick

Fine Grained Soils (Cohesive)[1]	
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

Soil Description[2]		
Noun	Gravel, sand, silt, clay	>50%
"and"	Silt and gravel, etc.	>35%
Adjective	Gravely, sandy, silty, etc.	20-35%
"Some"	Some sand, some silt, etc.	10-20%
"Trace"	Trace sand, trace silt, etc.	1-10%

Soil Thickness[3,4]	
Thickness	
Blanket	>1.0m
Veneer	<1.0m

Soil Drainage (adapted)[5]	
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 typically 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.

[1] Canadian Geotechnical Society, Canadian Foundation Engineering Manual, 3rd Edition, *Identification and Classification of Soil and Rock,* 1992.
[2] Ministry of Forests, Forest Road Engineering Guidebook, 2nd Ed., 2002.
[3] Ministry of Forests, A Guide for Management of Landslide Prone Terrain in the Pacific Northwest, 2nd Edition, *Land Management Handbook #18*, 1994.
[4] Ministry of Environment, Terrain Classification for British Columbia, Revised Edition, *Manual #10*, 1998.
[5] Ministry of Environment Lands and Parks and Ministry of Forests, Field Manual for Describing Terrestrial Ecosystems, *Land Management Handbook #25*, 1998.

Appendix B
Soil, Slope, and Rock Classification

Rock Classification[1]:

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

Spacing of Discontinuities in Rock	
Spacing	**Spacing Width (m)**
Extremely Close	<0.02
Very Close	0.02 – 0.06
Close	0.06 – 0.20
Moderately Close	0.20 – 0.60
Wide	0.60 – 2.0
Very Wide	2.0 – 6.0
Extremely Wide	>6.0

Slope Classification[3,4]:

Slope Gradient		
Slope Gradient Descriptor	**Percent (%) Range**	**Degree (º) Range**
Flat	<10	<4
Gentle	10-26	4-15
Moderate	26-50	16-26
Moderately Steep	50-70	27-35
Steep	70-90	35-42
Very Steep	>90	>42

Slope Shape (modified) and Features
Based on the overall shape of the slope between distinct slope breaks; includes **concave, convex, uniform, 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.
Swales: Any linear depressions in the landscape that do not meet the gully criteria described above; generally shallower with lower channel and sidewall gradients; may or may not contain an active stream channel

[6] Ministry of Forests, Gully Assessment Procedures Guidebook, 1995.

Appendix C

Airphotos

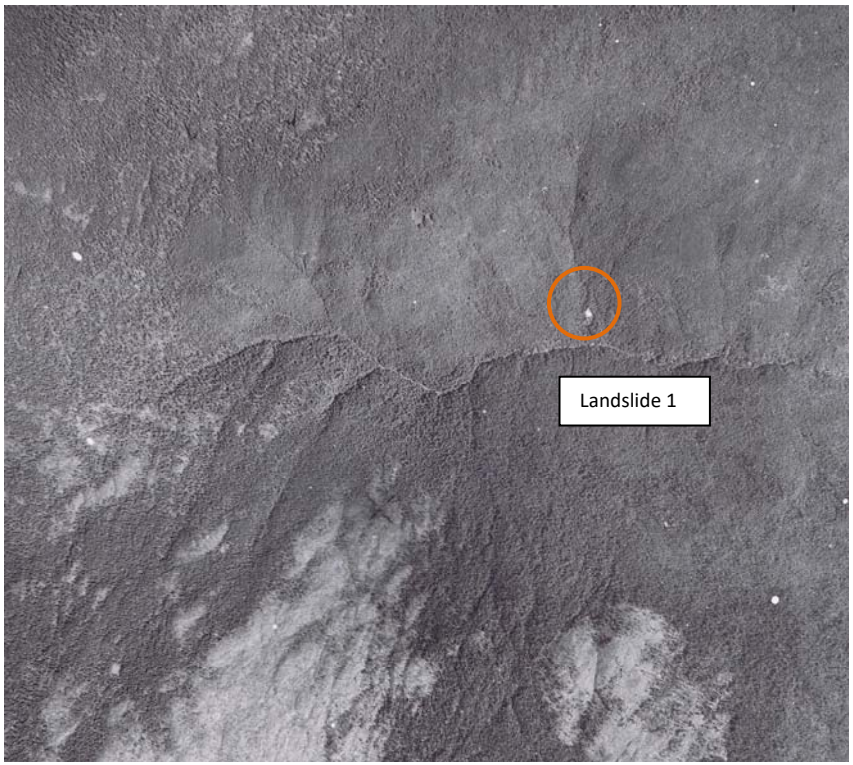


Photo 1 – 1951 airphoto of the study area. Note the 1939 forest fire to the south of Bastion Creek valley and the relatively young timber on the north side of the valley.

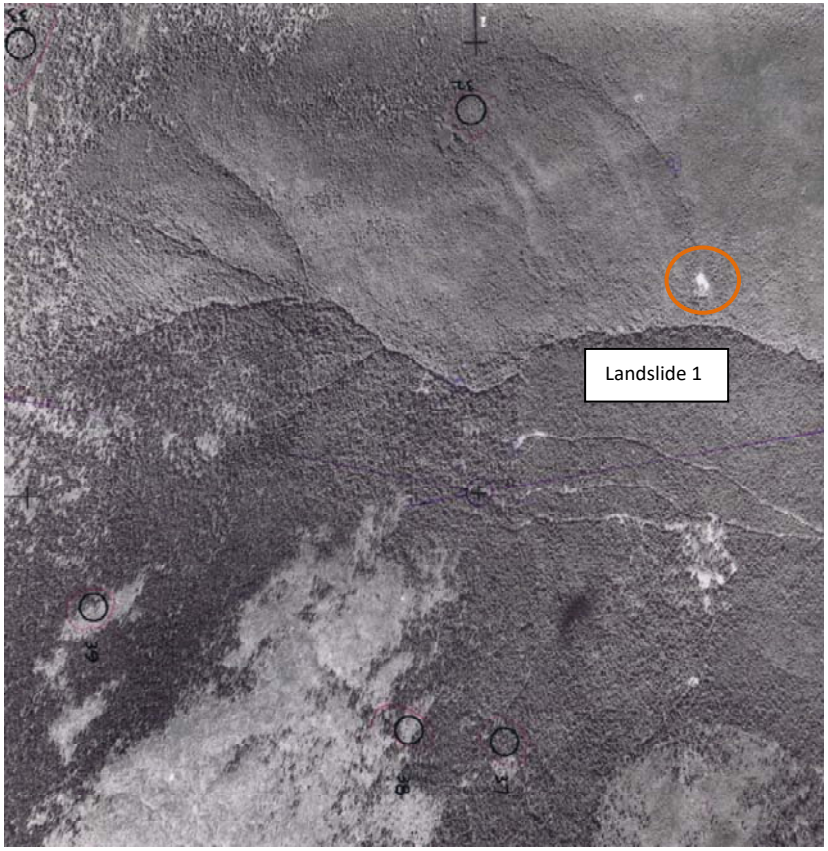


Photo 2 – 1959 airphoto of study area. Landslide 1 remains similar in size, shape, and vegetation cover. Note the trails beginning to extend across the south sidewall of the valley.

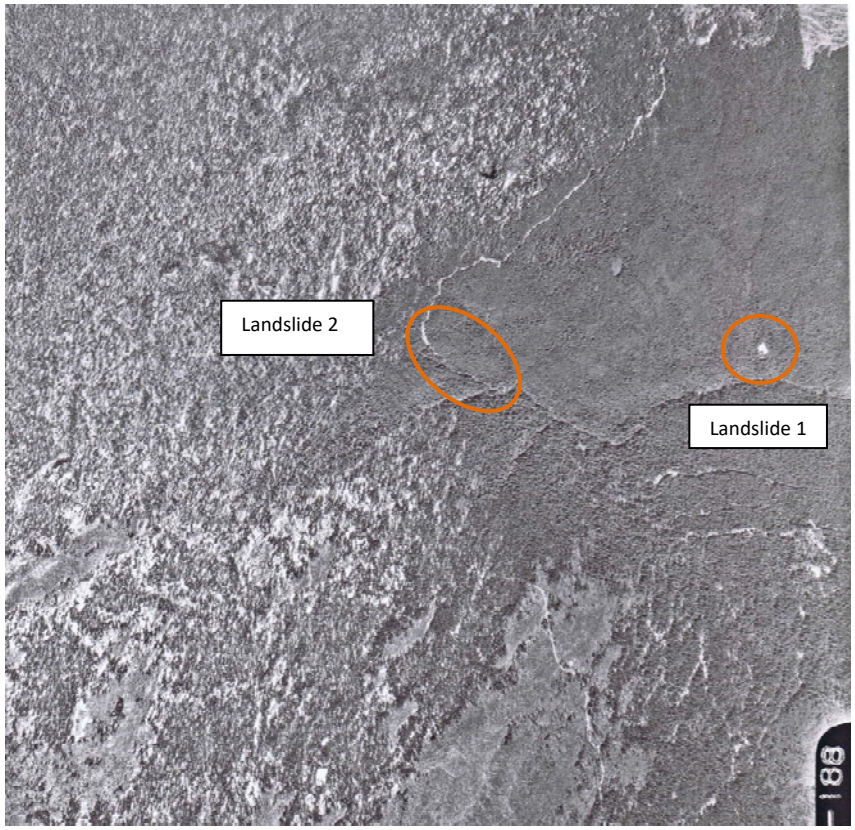


Photo 3 – 1967 airphoto of the study area. Note that Landslide 1 remains static in size, shape, and vegetation cover. Landslide 2 originates on a recently constructed road near the headwaters of Bastion Creek.

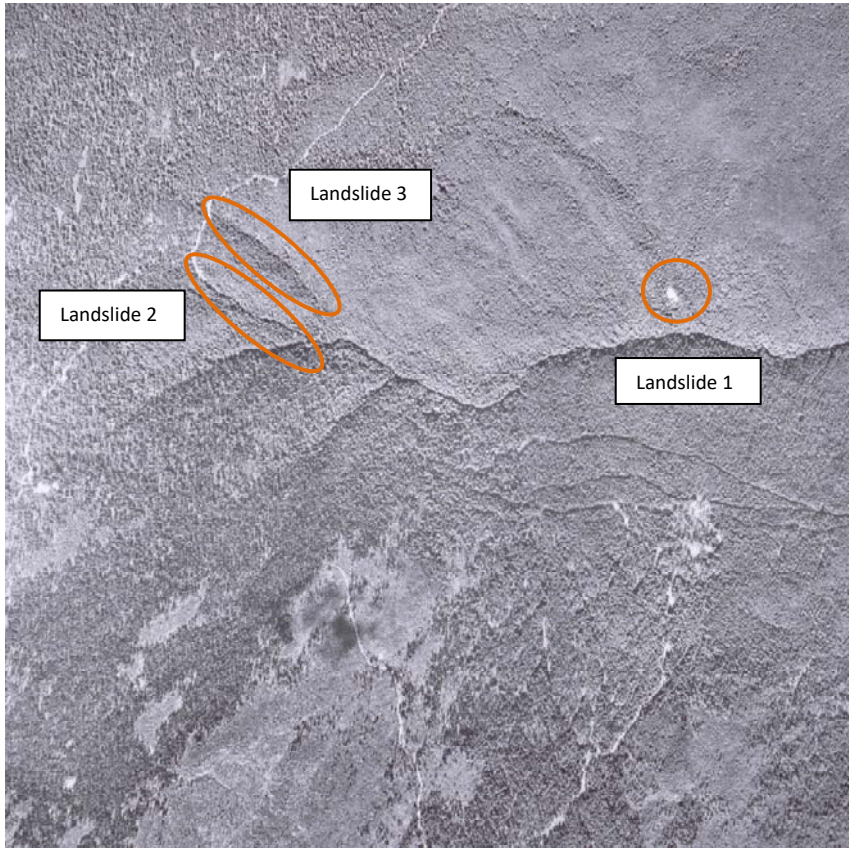


Photo 4 – 1974 airphoto of the study area. Landslide 1 remains static in size, shape, and vegetation cover. Landslide 2 is clearly visible and vegetation has not begun to regrow. Landslide 3 originates immediately downslope of the precursor to the 450.000 road.

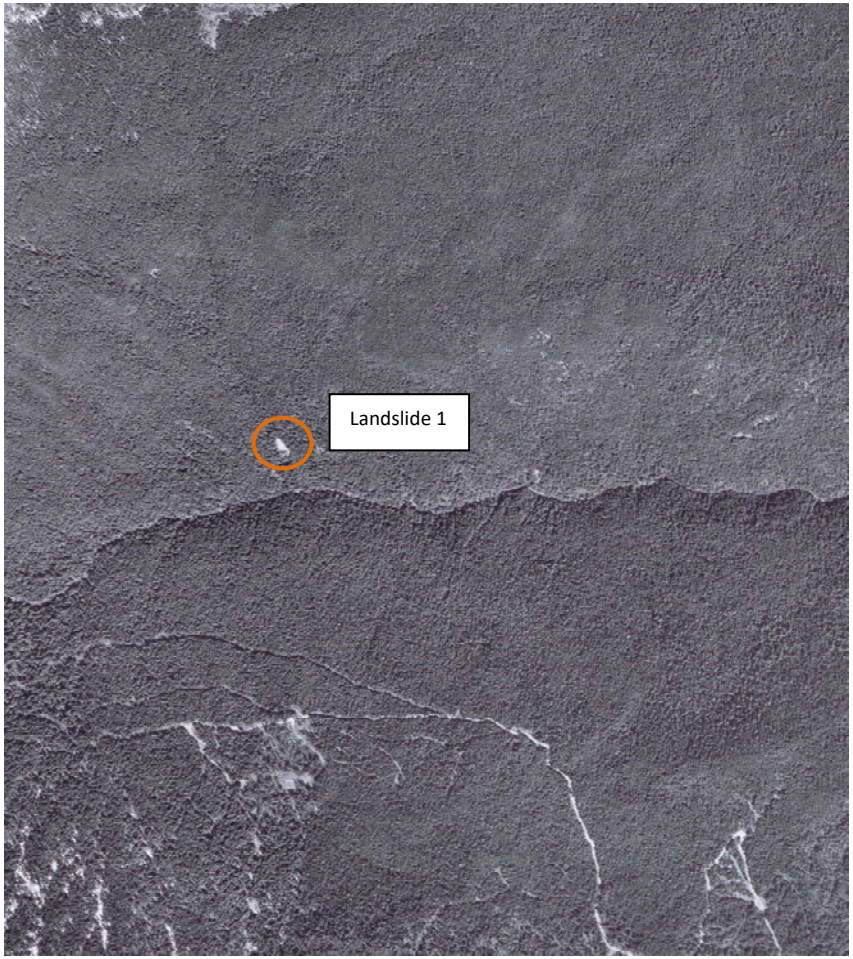


Photo 5 – 1978 airphoto of study area. Landslide 1 has remains static in size, shape, and vegetation cover. The headwaters of Bastion Creek as not included in the airphoto set.

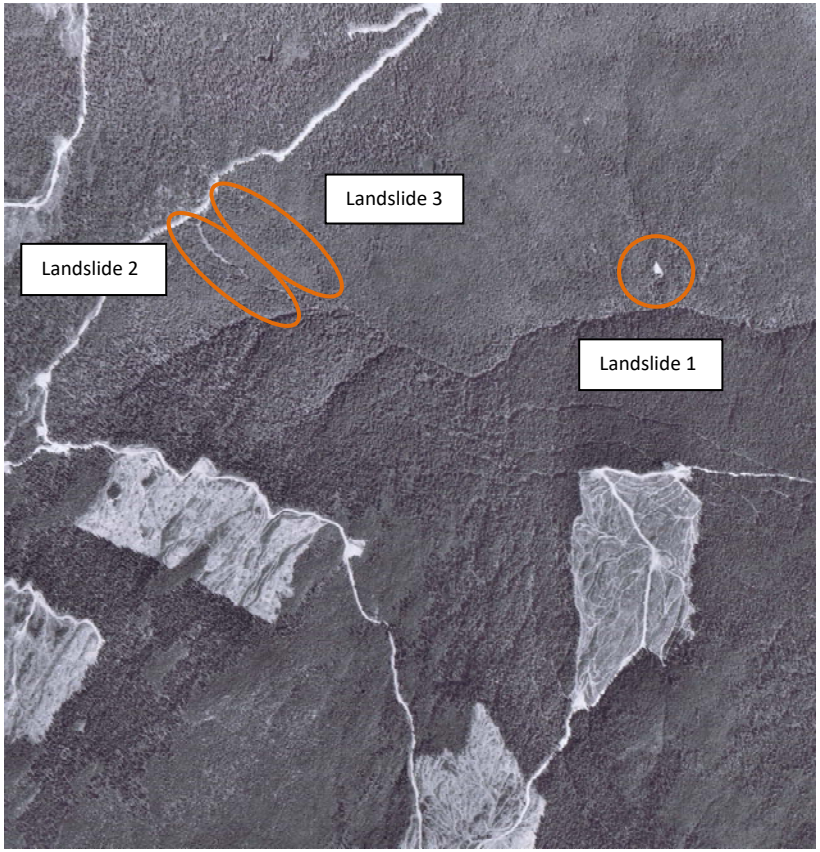


Photo 6 – 1984 airphoto of study area. Landslide 1 has remains static in size, shape, and vegetation cover. Landslides 2 and 3 are visible in the headwaters area. A series of large cutblocks begin to appear throughout the headwaters area.

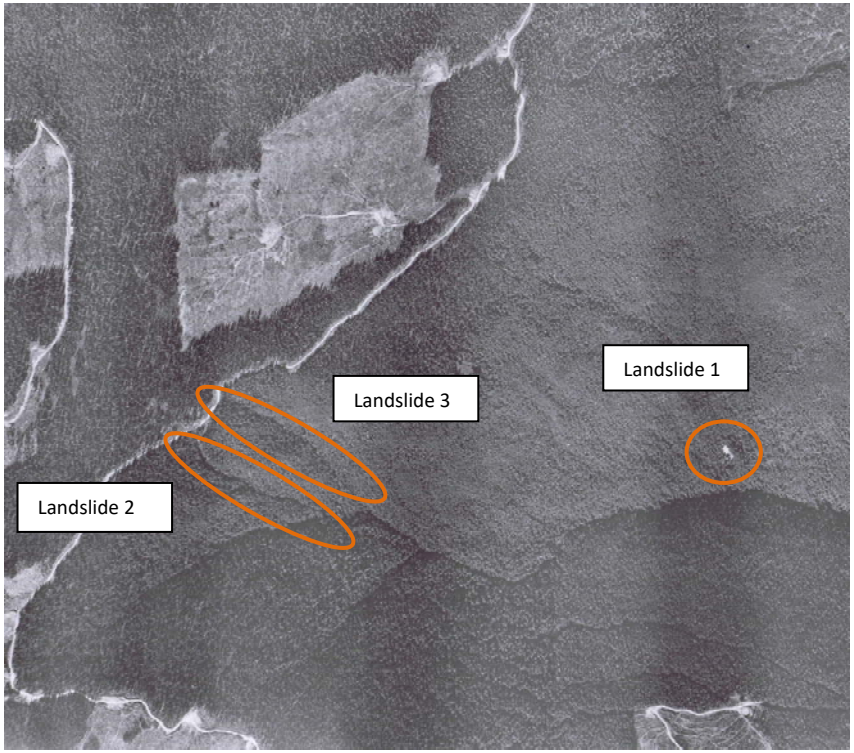


Photo 7 – 1989 airphoto of study area. Landslide 1 remains static in size, shape, and vegetation cover. Landslide 2 and 3 are visible in the headwaters area but are beginning to revegetate.

Photo 8 – 1994 airphoto of study area. Landslide 1 remains static in size, shape, and vegetation cover. Landslide 2 and 3 are visible in the headwaters area but are beginning to revegetate.

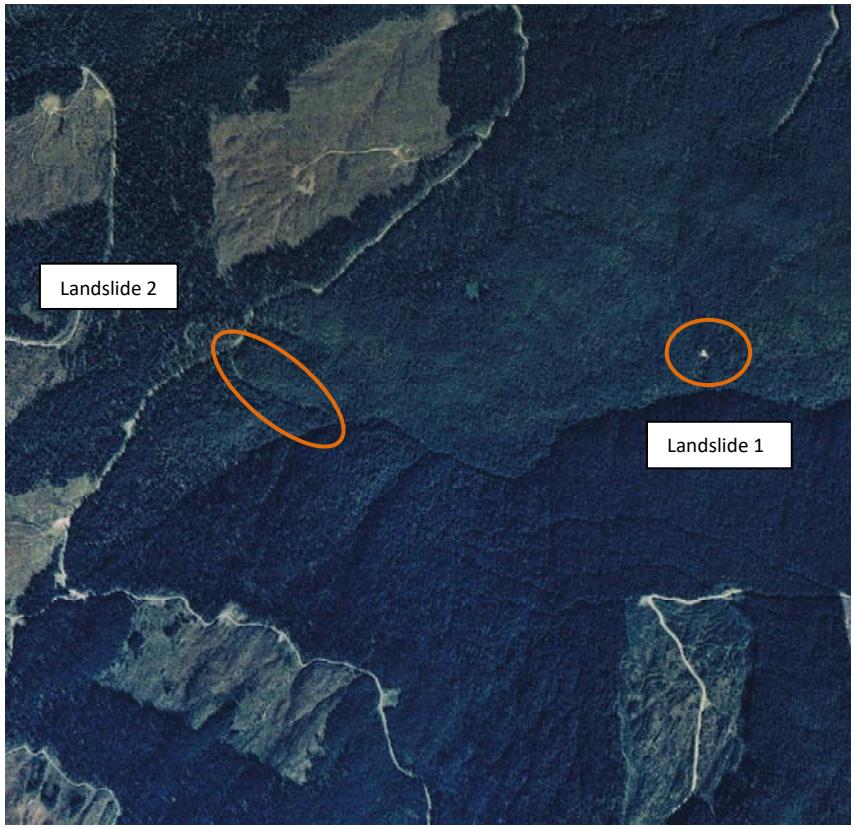


Photo 9 – 2001 airphoto of study area. Landslide 1 and 2 are visible but Landslide 3 appears to have fully revegetated.

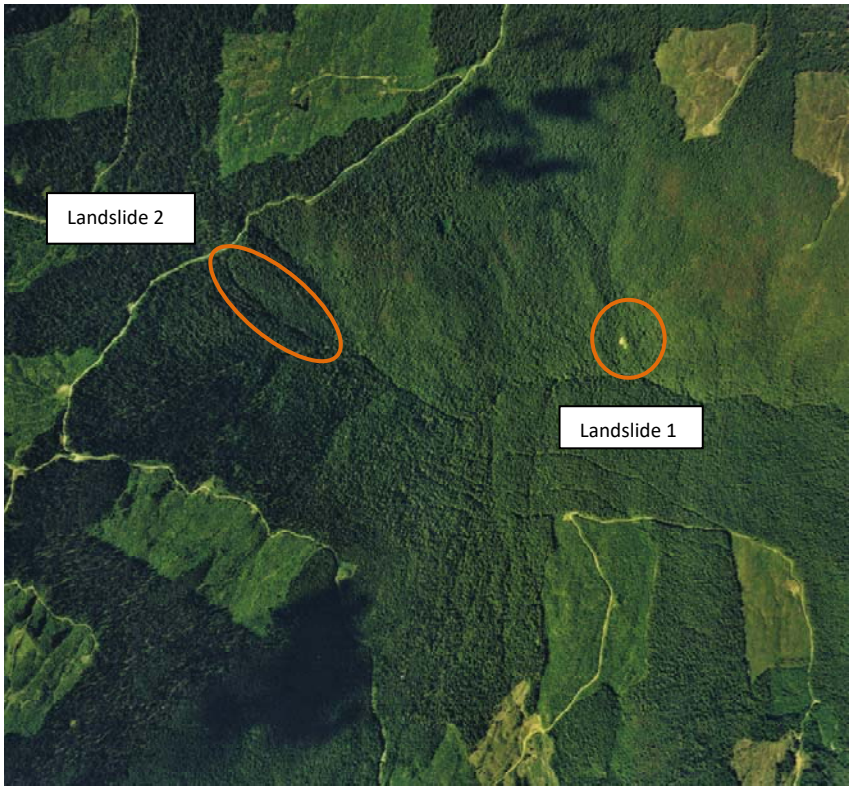


Photo 10 – 2007 airphoto of study area. Landslide 1 and 2 are visible but Landslide 3 appears to have fully revegetated.