Detailed Terrain Stability Review

Of Proposed harvesting of Blocks 3 and 4 CP 404 in the Laird Creek Area for Cooper Creek Cedar Ltd.

W. Halleran P. Geo, L.Eng.

Contents

1. Summary

If the recommendations contained within this report are implemented timber harvesting will not significantly increase the low incremental increase in Partial Risk to water quality at the intakes along Laird Creek. Currently there is a low likelihood of landslide initiation within the proposed blocks.

2. Introduction

Mr. Bill Kestell RPF of Cooper Creek Cedar Ltd, requested Apex Geoscience Consultants Ltd. to conduct a detailed terrain stability field assessment of proposed blocks 3 and 4 of CP 404 on the east side of the Laird Creek Watershed. This assessment was conducted concurrent with the road assessment (TA20CC01). As part of this DTSFA, a Partial Risk Analysis for water quality/intake along the lower reaches of Laird Creek was completed.

Mr. Kestell requested this review because portions of the proposed blocks are within or upslope of terrain mapped at level B intensity as Class V (unstable) and Class IV (Potentially unstable) by Greg Utzig P.Ag. (1997) as shown in Figure #1.

3. Methods, Limitations and Reliability

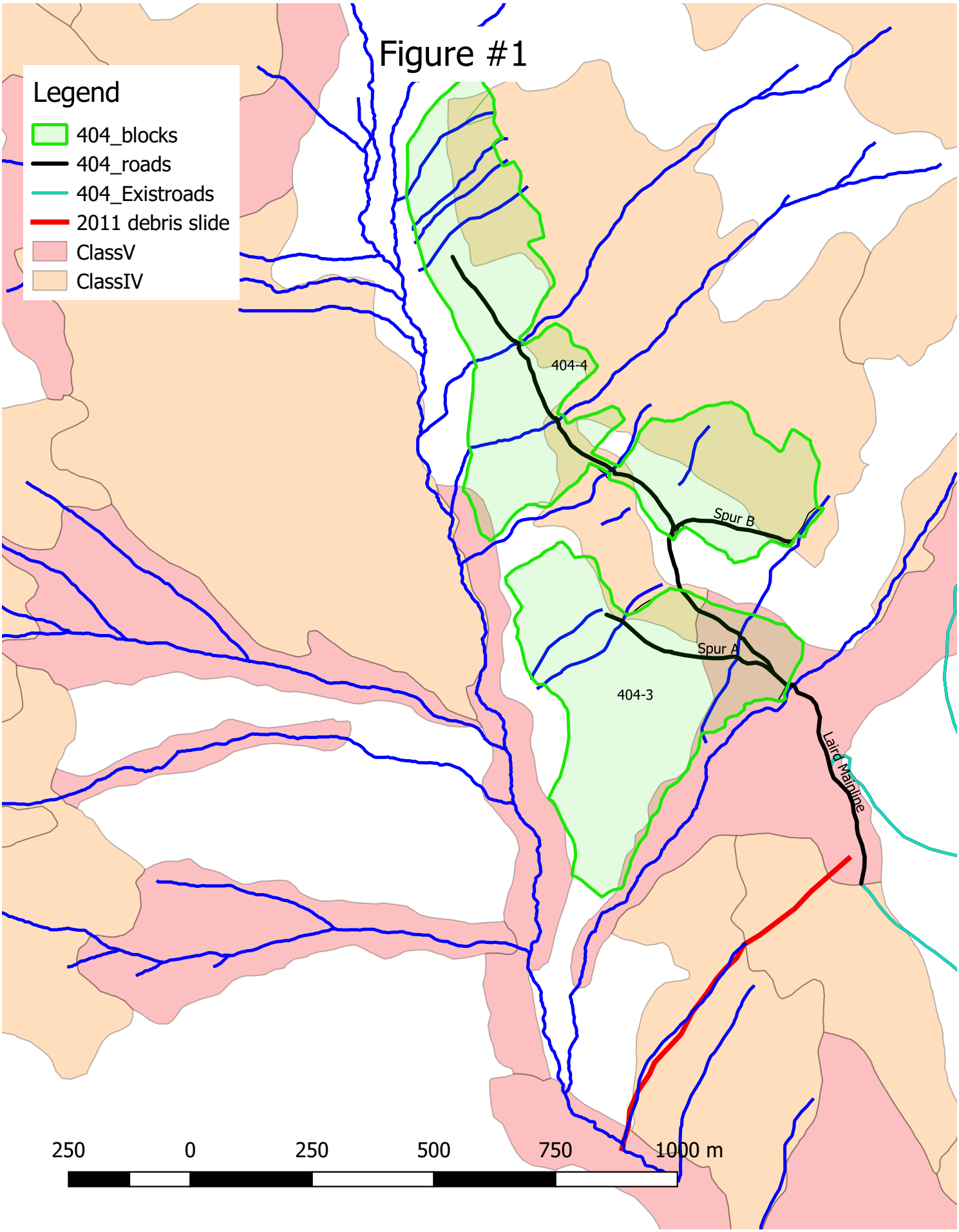
Google earth imagery; Bing maps satellite imagery; historical air photos; and previous reports were reviewed prior to the field assessment.

CCC supplied Lidar DEM files; and development and hill shade maps with the proposed development, previous development and terrain stability polygons marked on it. A Samsung android tablet with the Avenza maps program with the imported hill shade map was used for navigation and note taking.

Mr. Bill Kestell RPF. of Cooper Creek Cedar conducted field visits of the road, blocks, and adjacent slopes (areas of possible concern) with W. Halleran of Apex in late 2019 and early 2020.

The field assessment was completed by W. Halleran P. Geo L. Eng. on June 17th, 18th, 23rd, and 25th, the weather was warm and dry. Inferences are made from observations of materials in soil pits, tree churns, scarps, and watercourse channels within and adjacent to the proposed blocks during the field review.

Figure #1


Legend
404_blocks
404_roads
404_Existroads
2011 debris slide
ClassV
ClassIV
404-4
Spur B
Spur A
404-3
Laird Mainline
250
0
250
500
750
1000 m

The terrain stability assessment made in this report is based on generally accepted practice described in "Guidelines for Terrain Stability Assessments in the Forest Sector-October 2010" published by APEG of BC. The risk assessment presented in this report is based the conventions outlined in Land Management Handbook 56 "Landslide Risk Case Studies in Forest Development Planning and Operations".

This review assumes timber harvesting standards are met. Even if all standards are met there is still a possibility of landslides. Terrain assessment can reduce the likelihood of landslides, not eliminate it.

3.1 Previous Reports and Assessments

This assessment was conducted concurrently with the DTSFA for the proposed roads and spurs (TA20CC01), information gathered during that assessment is incorporated into this assessment.

Previous reports reviewed include: West Arm Demonstration Forest: Sediment Budget by Peter Jordan MoF 2001; Hydrological Assessment of the Laird Creek Study Area by Henderson Environmental Consulting Ltd. (2004); Forest Harvesting and Road Building in the Laird Creek Watershed by Forest Practices Board Complaint Investigation 040598 (2005); May 2011 Laird Creek landslide Event Geotechnical Assessment by Sitkum Consulting Ltd. (2011); May 22 Technical memorandum regarding the May 2011 Laird Creek Landslide summarising the April 2012 field review (2012); Laird Creek landslide Complaint Investigation 111006 by the Forests Practices Board (2013); Various Bioremediation reports and assessments by Pierre Raymond of Terra Erosion in collaboration with W. Halleran of Apex Geoscience Consultants Ltd. (2012-2013); Laird Creek Hydrogeomorphic Assessment by Apex Geoscience Consultants Ltd (2018).

Laird Creek Hydrogeomorphic Assessment (2018):

The Laird Creek Hydrogeomorphic reports made specific comments and recommendations regarding CP 404 some of which have been summarized and commented on here. Where appropriate, the recommendations have been incorporated into this assessment.

Blocks 404-3 and 404-4 are located on the eastern side of Laird Creek Watershed and have a west to southwest aspect below the H_{60} line (1600m). The size of both blocks has been reduced since this 2018 Hydrogeomorphic assessment, which calculated that, with the addition of these blocks, the ECA for the watershed would be 11% above Beggs road. With the reduction of the size of the blocks, the ECA will be a lower. The Hydrogeomorphic Assessment determined that the proposed blocks have "a low likelihood of detectable increase to the frequency of floods capable of causing sedimentation at the water intakes on Laird Creek". This implies that the snow melt from these blocks will not contribute to the peak flows in Laird Creek.

The report further states "a portion of one of the blocks of CP 404 borders a headscarp to a major debris flow tributary that has experienced a debris flow within the past 50 years". This was a portion of block 404-3, which, on the advice of Chris Perdue P. Geo, had already been deleted prior to this DTSFA[1].

The hydrogeomorphic assessment recommended a DTSFA on the blocks to assess the terrain stability because the blocks are upslope of terrain mapped as unstable, also suggesting that to reduce an increase in slope drainage flowing to the "unstable" area, one possible management strategy is to limit harvesting to ~25% ECA of total slope length above area of concern.

3.2 Likelihood of Landslide Determination

In this report the annual likelihood (Pa) of an event occurring is estimated by considering the age of the event (in this case, landslide). Slide reports, previous reports and field observations are used to determine the age, cause, distribution, type, size, and materials of both natural and development related landslides. In the absence of other information; and for purposes of this report, the age of the landslide is assumed to be equal to the return period of the conditions/climatic event that triggered the slide, i.e. a 500-yr. old event is associated with a 1 in 500-year return period (Pa). This precautionary approach results in a higher estimate of the annual likelihood of an event occurring than is present.

[1] Personal communication with B. Kestell of CCC.

For the natural terrain stability, field evidence for events that occurred less than 20 years ago, (Pa >0.05) will be obvious and likely appear relatively fresh (i.e. exposed mineral soil, broken and/or scarred timber, etc.). These areas are deemed to have a very high annual likelihood of landslides.

Field evidence for events that occurred between 20 and 100 years ago, (Pa = 0.05-0.01) should be obvious (i.e. change in vegetation, sharp slide scarps, scarred trees, buried soil horizons, absence of developed soil profile in the scar and scarp, etc.). These areas are deemed to have a high annual likelihood of landslides.

Field evidence associated with events that occurred between 100 and 500 years ago, (Pa=0.01-0.002) are usually more subdued (muted slide scars, multiple and/or thicker buried soil horizons, less developed soil profile within the scar compared to the adjacent slope, lack of burnt snags within the slide path if present on the adjacent slope). These areas are deemed to have a moderate annual likelihood of landslides.

Unless very large, field evidence for events associated with greater than 500-year-old events (Pa < 0.002) can be hard to notice (muted slide scars, old gullies, may have deep thick buried soils horizons). These areas are thought to have a low annual likelihood of landslides.

Debris slide paths are most likely U-shaped swales, debris slides can transition to debris flows if the slide enters a gully or is otherwise channelized. Along lower gradient reaches and/or in unconfined sections, debris deposition often occurs as levees or debris lobes. Trimlines (scoured side slopes), scarred trees adjacent to the channel, and buried soil horizons on levees or deposition sites can indicate the age and frequency of events. Observations of how previous development has influenced terrain stability, experience and professional judgment are used to determine how the proposed development will influence terrain stability.

The following formula is used to <u>estimate</u> the likelihood of an event occurring during the lifetime of a specific structure/element (long-term likelihood).

$Px=1-[1-(Pa)]^x$

Where Pa is the annual probability, x is the lifespan of the roads and/or the hydrological recovery of the stand, and Px is the probability during the lifetime of these structures.

For this report, the likelihood of an event occurring during the lifetime of the structure (Px) is defined as:
Greater than 50% is deemed Very High likelihood; from 50% to 20 % is a High likelihood; from 20% to 5% is a Moderate likelihood; less than 5% is a Low likelihood of landslide initiation.

3.3 Partial Risk Determination

This Partial Risk rating is a function of the likelihood of a potentially hazardous landslide and the likelihood that the sediment will reach Laird Creek. It does not relate to the severity of impacts to the water quality at the water intakes nor the vulnerability of the infrastructure, and therefore is not a complete estimate of risk[2].

For debris floods in Laird Creek triggered by increased flood frequency, the 2018 Hydrogeomorphic Assessment determined that the proposed blocks have "a low likelihood of detectable increase to the frequency of floods capable of causing sedimentation at the water intakes on Laird Creek". Debris floods are not considered a potentially hazardous event that can be influenced by the proposed development.

Based on the Hydrogeomorphic assessment and for the purposes of this report, debris slides and debris flows (Landslides) are deemed the potentially hazardous event.
For this assessment, where possible, the runout characteristics of past slides were used to predict the runout distance of future slides, and ultimately the likelihood that the slides would reach Laird Creek. Where no information was noted, an estimate of a slide reaching Laird Creek can also be determined via Table 3.3.1.

[2] LMH56

The relative rating for landslides is shown in Table 3.3.1.

Table 3.3.1. Likelihood of a Debris slide or Debris Flow Reaching or Affecting Laird Creek.

Relative Rating of a Landslide Affecting Laird Creek.	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect Laird Creek.
Moderate	There is a run-out slope of<20^{o} (36%) gradient and <200 m in length, or another terrain configuration which could possibly intercept or dissipate a potential landslide debris and/or sediment from erosion (e.g. irregular or benched rock-controlled terrain) below and between the development and Laird Creek.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect Laird Creek at the time of an event. There is a run-out slope of <20^{o} gradient for >200 m, or another terrain configuration which would likely intercept or dissipate sediment or landslide (e.g. irregular or bench rock-controlled terrain), below and between the development and Laird Creek.
Negligible	Landslide deposition will not impact the considered elements.

The ranking of a Partial Risk is a product of the likelihood of a landslide occurring and the likelihood of that landslide reaching Laird Creek as illustrated in the matrix below.

Table 3.3.2 Matrix for determining Hazardous slide, P (HA).

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Laird Creek given that the Landslide/Soil Erosion Occurs			
		High	**Moderate**	**Low**	**Negligible**
Likelihood of Occurrence of Landslide	**Very High**	Very High	Very High	High	(Low)
	High	Very High	High	Moderate	Low
	Moderate	High	Moderate	Low	Very Low
	Low	Moderate	Low	Very Low	Very Low

4. Observations and Interpretations:

Block 404-3:

Prior to this assessment, on the verbal recommendations[3] of a site review by Mr. Chris Perdue P.Geo, a large portion of the southern part of this block was deleted to reduce the potential impact on a debris flow gully.

Portions of the proposed extension of Laird Main road and Spur A are within the upper part of Block 404-3 (Figure #2), which is within terrain mapped as Class IV and Class V terrain stability. This portion of the block has 50% slope gradient and is underlain by loose sandy boulder gravel with no evidence of instability. The southeastern boundary follows close to the slope break of a gully (S6 3-1) mapped as Class V. The steep side slope of the gully is mostly rock, there is a small boulder ridge at the top of the break that the boundary follows. Surface drainage will mostly flow southwest, parallel to the gully.

Spur A is located just downslope of proposed Laird Main on 30 to 55% gradient slope underlain by well drained, loose, sandy gravel to boulder gravel. Just past the junction with Laird Main, the Spur crosses a creek (S6 3-2), confined by 2 to 3 m high 60% boulder sideslopes. The channel gradient is 45%, with small woody debris and mossy cobbles and no evidence of debris flows.

Near the termination of the spur, the proposed road crosses an old debris deposit, currently the small stream (NCD 3-1) is caught in a small swale that conveys it across the southern edge of the deposit. The channel gradient is 30%, upslope of the Spur the channel hosted a small debris flow (25yrs, slide #3, Pa=0.04, Naturally High Likelihood) that terminated just upslope of Spur A.

The proposed block has been stratified into a conventional portion and a cable[4] portion (Figure #2 shows the original block configuration). The slope gradient of the conventional portion is from 15 to 30%, the cable portion is between 50 and 75% underlain by loose sandy gravel with numerous large boulders scattered across the slope.

[3] Bill Kestell CCC personal communication.
[4] This portion has been deleted as per recommendations contained in this report.

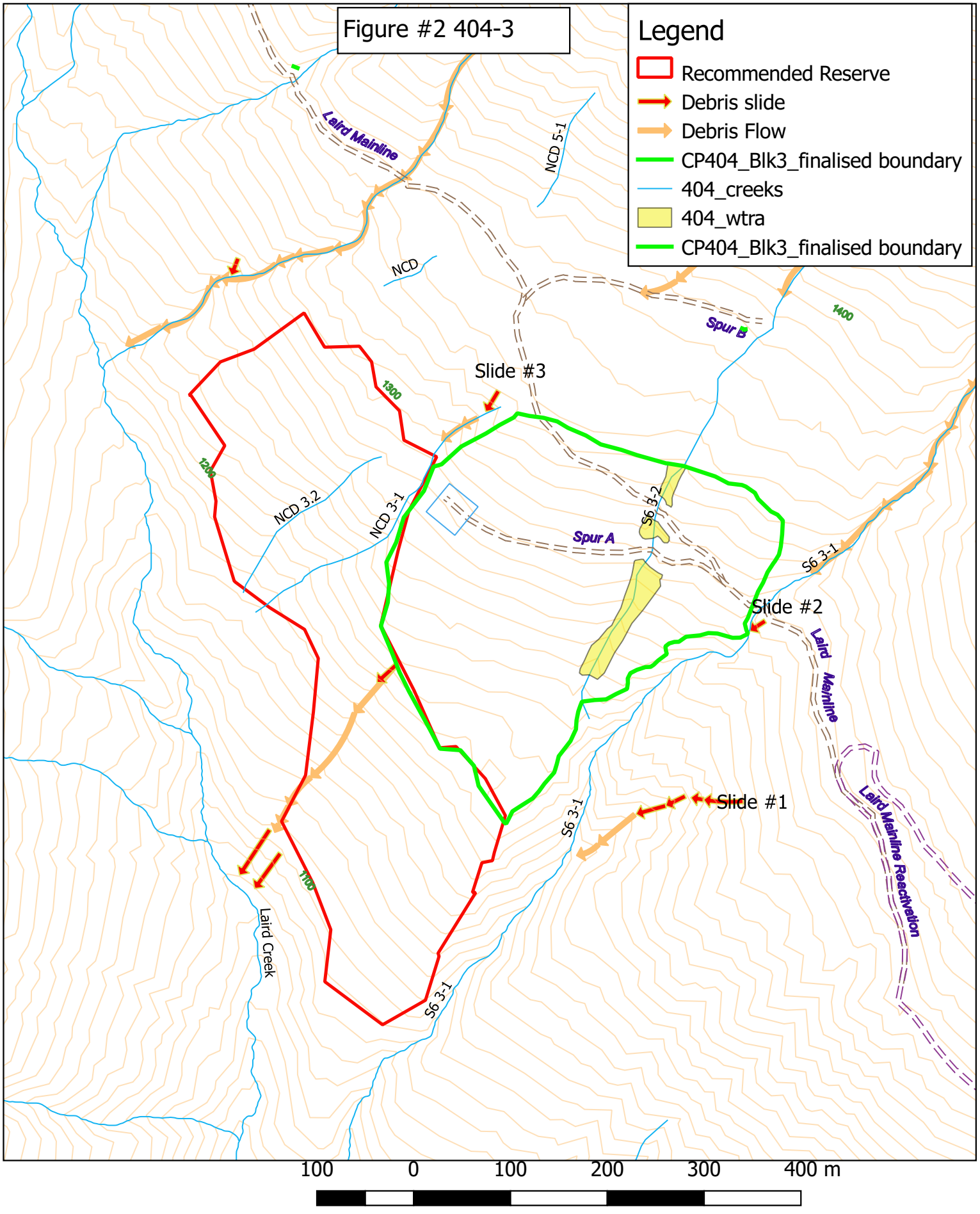


Figure #2 404-3
Legend
Recommended Reserve
Debris slide
Debris Flow
CP404_Blk3_finalised boundary
404_creeks
404_wtra
CP404_Blk3_finalised boundary
Laird Mainline
NCD 5-1
NCD
Spur B
1400
Slide #3
1300
1200
NCD 3.2
NCD 3-1
S6 3-2
Spur A
S6 3-1
Slide #2
Laird Mainline
Laird Mainline Reactivation
Slide #1
S6 3-1
1100
Laird Creek
S6 3-1
100
0
100
200
300
400 m

Just below the slope break, on 75% slope, near the centre of the block, there is an ~ 100 yr. old, debris slide scarp and debris flow channel (Pa=0.01, naturally High Likelihood).

The Class V polygon downslope of the block, adjacent to Laird Creek, is underlain by sandy boulder gravel with ancient to recent debris slides (75 yr., Pa= 0.013, naturally High Likelihood) and occasional ancient to old slumps. The primary trigger for the slides is slope undercutting by Laird Creek (resulting an over steepened slope). Seeps and wet soil in the slide's scars indicate that a secondary trigger is high pore pressure within the slide scarp and/or along the toe (reduces soil strength).

Block 404-4:

The southern portion of the block is located mostly upslope of the proposed Mainline and Spur B. Within this part of the block ground skidding is proposed for the small portion of the block downslope of the mainline and Spur B, the remainder of the block will be cable yarded (Figure 3). Both Spur B and this portion of the mainline are located on colluvial cones that formed at the base of gullies and draws that drain the 65 to 85% gradient slope that typifies the upper portion of this block.

There is an approximately 50 years old layer of sediment deposited on the colluvial cone associated with stream 3-2 (the stream is within a WTRA #2), likely related to debris flows associated with debris slides further upstream (Pa=0.02, Naturally High Likelihood).

The boundary heads up adjacent to stream 3-2 then heads north across the slope, cutting across the headwall of next gully to the north (unnamed). This headwall is an old (~250yrs, Pa=0.004, Moderate Likelihood) debris slide scarp. At the base of the gully there are old levees and debris lobes forming part of a colluvial cone (by Spur B).

The boundary then cuts across a series of ancient debris slide scarps to a deep gully (NCD 5-1) that appears to host snow avalanches (25yrs? Pa = 0.04, High Likelihood). The headscarp of this gully is within a WTRA #1. This gully terminates at a large ancient colluvial cone traversed by the proposed road.

The boundary then dips down to the proposed road to exclude a debris flow gully (stream S6 4-1).

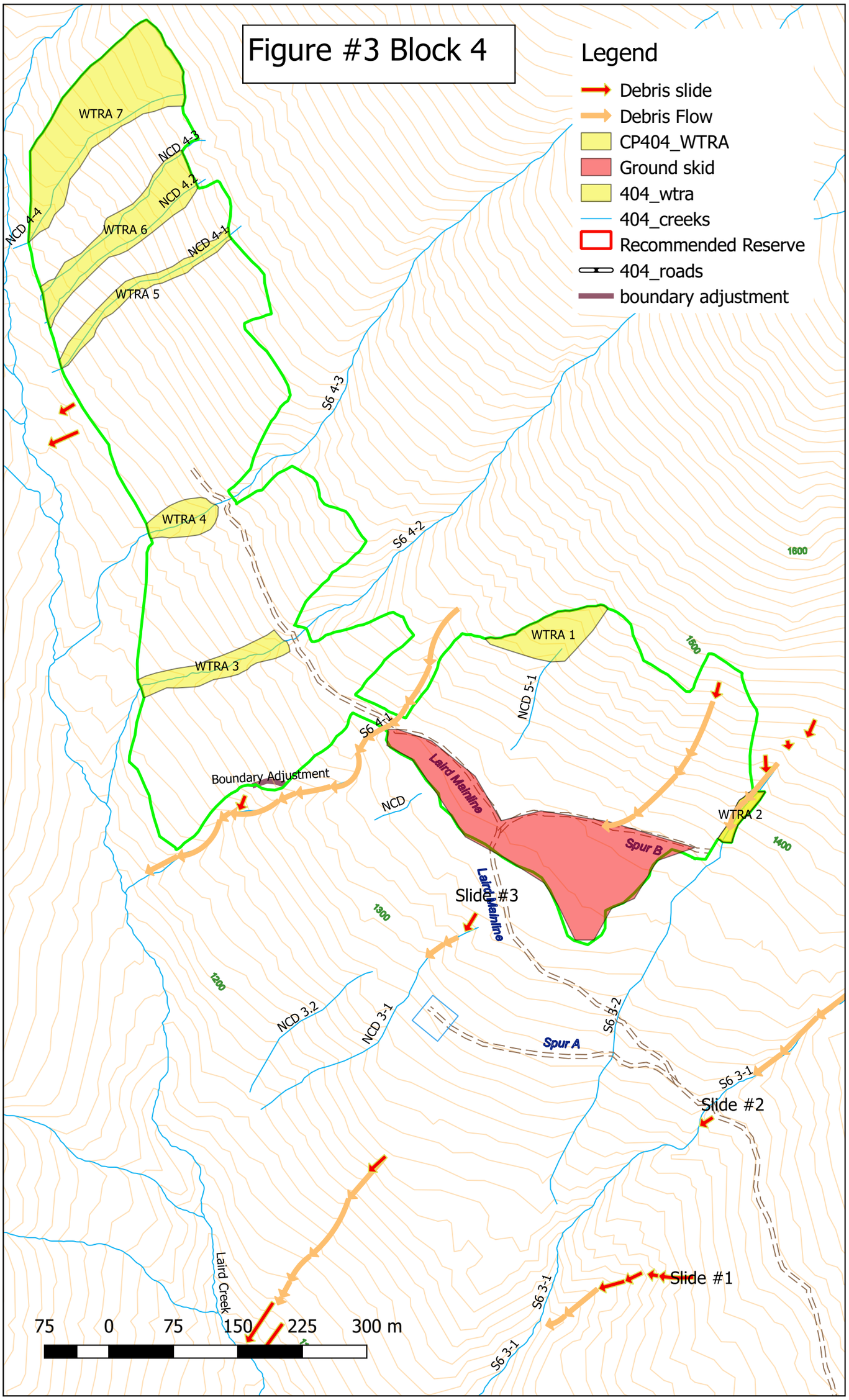


Figure #3 Block 4
Legend
Debris slide
Debris Flow
CP404_WTRA
Ground skid
404_wtra
404_creeks
Recommended Reserve
404_roads
boundary adjustment
WTRA 7
WTRA 6
WTRA 5
WTRA 4
WTRA 3
WTRA 1
WTRA 2
NCD 4-3
NCD 4-2
NCD 4-1
NCD 4-4
S6 4-3
S6 4-2
S6 4-1
NCD 5-1
NCD
Boundary Adjustment
Laird Mainline
Spur B
Spur A
Slide #3
Slide #2
Slide #1
NCD 3.2
NCD 3-1
S6 3-2
S6 3-1
Laird Creek
1600
1500
1400
1300
1200
75 0 75 150 225 300 m

North of stream 4-1 the boundary jogs up and then back down to the road, avoiding the steep sideslopes of a deep gully (Stream 4-2). Debris from a small recent debris slide off the side slope has not been mobilized down the channel. This gully is within WTRA #3 in the block. This gully shows no evidence of hosting debris flows.

Stream 4-3 is confined within a rock canyon upslope of the proposed road, the gully (canyon) sideslope is excluded from the block. The stream flows over large rocks sourced from rockfall from the canyon sideslopes, large trees growing in the bottom of the canyon indicate no evidence of recent debris flows or flooding. Downslope of the proposed road the stream and canyon are within WTRA #4.

North of stream 4-3, below the block boundary there are two ~ 25-year-old debris slides south of FC #17, neither of which reached Liard Creek. The slides initiate on what appears to be an ancient slump scarp, the displaced material of the slump is still at the toe of the slope, indicating no mobilization down Laird Creek. It is likely that the triggering mechanism for the debris slides is increased pore pressure related to upslope drainage.

Streams and swales in the northern portion of the block are all within WTRA's, there is no obvious evidence of instability.

The southern boundary of this portion of the block is adjacent to the steep side slope of a stream 4-1 which hosts debris flows. Just west of FC 13 the boundary dips below the headscarp of a small slide (150 yrs.?) into the stream. A small slough (10 yr. old) at the base of the slide appears to be associated with a seep.

Cumulative:

As currently proposed, 43% of the slope linearly above a portion of the Class V adjacent Laird Creek is downslope of portions of blocks 3 and 4. In addition, Laird Main and Spurs A and B are also within this area.

5. Implications, Recommendation and Risk Analysis

Block 404-3

This block, combined with the southern portion of Block 404-4, would result in ~ 43% ECA upslope of the unstable slope adjacent to Laird Creek (Class V, Pa=0.013). There is also a small ~ 100-year-old (Pa=0.01) slide within the central portion of the block at or near the boundary between cable and conventional yarding.

Recommendations in the Hydrogeomorphic Risk Assessment included limiting the ECA linearly above these unstable slopes to 25% or less and to adjust the block boundary to exclude slide headscarps. To meet these objectives, it is recommended that the lower steep portion (roughly coincides with the proposed cable portion) be reserved (figure 2), this would exclude the 100 yr. old slide headscarp and reduce the linear ECA to ~25%.

To reduce the hydrological impact of Spur A, the spur should be constructed as a short-term road or forwarding trail and reclaimed after silviculture requirements are met (ex. Planting) or within three years whichever is sooner.

Currently, assuming a 60 year hydrological recovery, and $Px=1-[1-(Pa)]^x$; $P_{60} = 1-[1-(0.013)]^{60}= 0.46$, there is a High Likelihood of a landslide occurring, but if the recommendations are implemented, the proposed harvesting will not significantly increase the likelihood of landslides. Any slide that did occur will reach Laird Creek, resulting in a Very High Partial Risk, if the recommendations are implemented, the proposed harvesting poses a low incremental increase in the Risk.

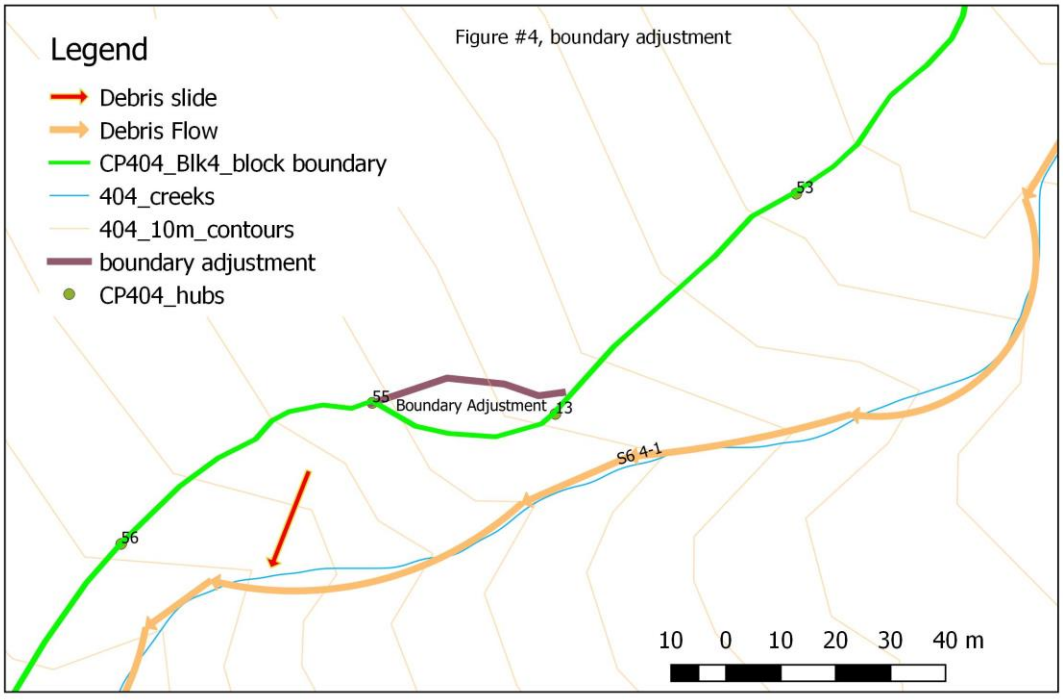
Block 404-4

The upper portion of the block falls partially within class IV terrain. The boundary has been placed to avoid the steep side slopes of the gullies and WTRA's have been situated to exclude slide headscarps, stream gullies/canyon sideslopes and potential avalanche initiation zones.

The proposed block is less than ~10% on linear slope length upslope of the slides by FC 17 and is unlikely to significantly increase the slope drainage contributing to the small slides.

Spur B should be constructed as a temporary road and reclaimed within three years to reduce the hydrological impact on downslope terrain stability. Do not construct a landing at the end of the spur near stream 3-2 (debris flow channel). The landing can be constructed anywhere west of road hub #9.

West of FC #13, upslope of stream 4-1, the boundary dips into an ancient debris slide scarp, yarding trees out of this scarp will gouge the headscarp resulting in an over steep slope and a significant increase in landslide initiation. Pull the boundary out of the slide scar onto the slope adjacent to the slide, from hub 55 to just past FC 13 (Figure 3).



If these recommendations are implemented, timber harvesting of the proposed blocks will not significantly increase the likelihood of landslides nor the incremental Partial Risk to water quality at the intakes.

Respectfully Submitted,
Apex Geoscience Consultants Ltd.

Will Halleran P.Geo. Eng. L.

Will Halleran

Digitally signed by Will Halleran
DN: cn=Will Halleran, o=Apex Geoscience Cons., ou=Geotech, email=apexgeo@shaw.ca, c=CA
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Appendix I Tabulated Field Notes and Map

Title	Description
4-01	small stream, burnt snags, no evidence of slides this far, 50% step to trib flats.
4-02	boundary on 40% slope, break to 70% to laird flats, seeps, and spring at toe, or at least looks wet, bouldery, no evidence of instability, to avoid sedimentation designated crossings on streams.
4-03	open swale to valley flats, boulders in bottom, water flowing, trees scarred on side, 25 yrs, open portion starts at 50/70 break, draw into block, check bottom. hard to tell may just be seeps, there are old sand deposits.
4-04	photos of laird from here.
4-05	20m wide 3m deep 30m long debris slide to flats, currently springs and seeps, top half of scarp treed, scar not treed mostly devils club, age is difficult, there is a 50cm spruce scarred on side about half way in, 25cm, another spruce about the same size slightly knocked swept, scar is 40% organics and boulders and micaceous silty sand. scarp is 70% 6m long, seeps out of base
4-06	crown is 45% bouldery between swales sta. 71 just to south, dead fall on crown, older scarp to north treed, scarp underlain by coarse sand and gravel, guess slide is 25 yrs? did not make it to laird.
4-07	crossed swale in sand onto 45% slope.
4-08	to here 40% slope, bouldery, no obvious step to laird, stable.
4-09	deeply incised, lots of wood debris spanning channel below, huge boulders likely bed rock, no evidence of debris flows 80% sideslope, 1sideslope m high.
4-10	stream, here channel 30%, boulder and small woody debris steps, upstream I can see a waterfall at least 50m above this elevation.
4-11	boundary just below break in 65% slope, keep off this slope, crests about 10m ahead onto 35% bouldery slope.
4-12	old debris slide gullies not well treed but large cedar vets near bottom not scarred, 500? slope 40%
4-13	on to irregular terrain, flats, and mounds, just before gully, 25%.
4-14	100% sideslopes, huge boulders or rounded bed rock, large vet cedars (1m) in bottom.
4-15	on 40% slope at edge of gully sideslope 90% bouldery material.
4-16	deeply incised in start of 20% cone.
4-17	in block 20%, here -80% to creek, old slide scarp, forested, likely from creek undercutting, just ahead there is an elevated terrace at the toe to the slope about 5m above current stream level, likely same time as slide, ancient.
4-18	ancient scarps onto step off terrace, likely when stream was down cutting, in block 25%, ancient scarps 55%, bouldery.
4-19	75% slope to creek boulder zone, underlain by boulders, ancient slides likely when creek undercut.
4-20	to here the boundary was just on the 55% portion of the 70% sideslope to stream, here up on 45% slope at 80% break to creek, no sign of instability, old broken vets at bottom along stream. possible trim line 2m upside, steeper part, likely snow avalanche.
4-21	up 60% slope, beside ancient slide scarp, very large vets so at least a few fires,

Title	Description
4-22	90 to 100% scarp, large scarp is very old, large vets, smaller feature half way up (sand) looks like it went after the last fire, newer one at base, very small with seep looks 10yrs?, could just be seep. actually, small wet rock step that the material sloughs off, rock step in adjacent creek at same level. minor seep off rock.
4-23	top of scarp lines up with edge of small rock canyon.
4-24	boundary cuts across very top of scarp. pull boundary out of scarp, aboutm15m upslope. start just before sta. 55 where boundary is heading upslope, go 15 to 20m more then go across. to fc 13, which is just on the slope to the creek
4-25	onto small gravel bench. could be head of ancient slump feature.
404-3 26	60% slope, loose sand 25%, silt 10%, well graded sub angular gravel 65%
404-3 27	slope 60 to 70% here, small ancient shallow sloughs, loose sandy gravel.
404-3 29	two ancient small headscarps feed narrow debris slide swales, 65% slope, boulders in headscarp, 2m wide, 2m deep, second one 15m to east similar size and age, looks like a bench just upslope (ancient slump head). large burnt rotten "stumps" in scar, predated fire, <500 yrs. loose boulder gravel, steeper below, just on old boundary.
404-3 30	eastern slide is newer, less developed bm, layer of weathered black rock (black sand) 15cm deep in pit on side of scarp, then rusty slabby rock, two 0.5m steps up 10m to break, in older scarp?, 5m wide, 2.5m deep, slide likely post dates fire 100 yrs? Broad scar down, not to channelized. 70%, steps seem to have rock in scarp, crown at 55 70 slope break. slightly swept trees on crown on 70% slope, large boulders at top.
404-3 31	poorly developed bm in scar, silty sandy moist gravel, lots of coarse on surface, signs of old erosion, debris and log levee on sides, secondary scarp on side and just below 70% slope. older larger scarp scar on east side, sharp ridge (levee?) between where this log debris on.
404-3 32	on bouldery debris, mossy, in scar, dead standing tree. below boulders about 1m fill swale at jct of this scar and one to east, swale continues down, old dead burnt logs lying across, trees knocked down by this slide knocked adjacent trees down, swale below 10m high cedar, forest floor intact. photo of scarred tree material on upslope side as well. scar caused by tree knocked down.
404- 33	followed down, sides trimline loose sandy gravel in draw poor mixed bm no large trees in it some up on ridge crest, scar from east no vets, scar from west has large trees in it, just above west junction and just below east junction scarred 25cm cedar on east side, scar 10m deep. most active was one I went down, likely 25 yrs, slope break just below, likely main draw.
404-3 34	hit stream, just below boulder or rock step, lots of deposition , small sloughs on sideslope of creek just up, stream gradient 30% down, looks like small debris flow ran down creek from here, larger trees though so didn't fill draw.
404-3 35	most of the coarse debris stopped here, to here bouldery material 1 to 2 meter elevated from valley flat, trees adjacent scarred, toe here against large fir broken 2m high, 2m snout, 40% gradient up 30% down, still cleared below but not consistently elevated, likely debris slide to here, or very coarse debris flow. full of downed timber just before junction with main creek. Older debris piles,

Title	Description
	large Doug fir at junction adjacent to channel 35cm diameter, scarred 10cm in., debris fan at junction, coarse sand.
404-3 36	fan, 10cm of sand and fine gravel, then old thin forest floor then gravel, trim line no la4ge trees 2m up on sides 10cm cedar on bottom, up slope stream flowing over rock step, 45% stream gradient up, 20% gradient here for 30m then looks steeper again, valley trim line 10m across, canyon walls upstream. mainstream mossy boulder steps, lots of fine gravel and sand mobile. less wide flat down stream, flat here likely due to debris from side trib, rock exposed in steep sideslopes.
404-3 37	90%/70% break, old scarps at break, hard to get soils due to tree churns, lots of deadfall, about third way up to here rust small outcrops, now rare feldspar porphyry outcrop gneissic, loose sandy bouldery gravel on slope, here sand gravel, to south large ancient scarp goes up through break, likely associat3d with stream down cutting. lots of dead pine down, new growth is mostly Doug fir, 15cm, scattered larch vet.
404-3 38	boundary on ridge like feature here, esker? lots of boulders just down, loose bouldery gravel -70% to creek, - 55% to block.
404-3 39	sta. 54, just off ridge o to 75% slope, pops back out again just ahead. ridge becomes more of an antiscarp, 50% in block, 90% to creek, boulders at break, dry, boundary just over break for 10m then follows break,
404- 40	boundary just over onto 65% slope 10m back from 90% to creek, likely rock, boulder or rock steps in block, dry stable.
404-3 41	sta. 51, to here boundary just at steep break to creek, block will not drain on surface to slideslope, creek is against south side, looks like rock or large boulders, tightly confined, no evidence of debris floods. 45 to 50 % slope in block, coarse soils.
404-3 42	30% to flatter ground, +50% in block, loose sandy gravel.
404-3 43	-85% to creek, +35% in block, ancient slide scarps into creek, likely from undercutting.
404-3 44	to here along 85% boulder break, then onto ancient boulder cone, here 75% slide scarp, mossy rock suggest water, slide 8m wide, 2m deep, large vets adjacent on raised ground 15cm diameter cedar in scar, fire?, 75 yrs or has more water wet trees cant grow, directly into creek, say was associated with upslope burn, boulder gravel, not undercut.
404-3 45	ancient debris flow slide debris on slope, debris slide scars on both sides, large vets in scars, pre dates fire, lots of boulders, slide back likely related to the water the should flow here, may disperse under fan, say 1 in 250 event with fire.
404-3 46	debris flow this rotation, scarred large cedars, boulder field here. 55% slope, looks weird, almost like a trench. 100 yrs.
404-3 47	60% slope, mostly large boulders.
404-3 48	60%, subangular boulders, tree churns some sandy gravel.
404-3 49	65%, open sub angular to sub rounded boulder steps.
404-3 50	ancient shallow debris slide, mossy boulders peak out.65%.
404-3 51	boulder levee, then +60/-50% sandy boulder gravel.

Title	Description
404-3 52	stream, discontinuous channel, mostly organic, no trim, large trees adjacent no scarring, no evidence of debris flows. 35% gradient.
404-3 53	stream mod confined no evidence of recent debris flows, large trees flowing around, 45% slope, possible top of terrace below to south, check below.
404-3 54	stream, sand mobile, flows into ancient slide scarp to creek, scarp 90%, scar 55%, ends at 2m step to creek, large vets on sidescarps, bottom wet no trees in transport slump but in front looks like terrace south, undercut.
404-3 55	coarse sandy gravel, ridge like, step down to small bench, either ancient slump or step off feature, separated from block by broad bowl swale on inside of this feature.
404-3 56	feature is sandy gravel, here 110% wet sandy gravel, sloughs, some large trees scattered on slope, could be saturated from frothy creek, or undercut, original downcutting left really steep, wet here, no obvious deep failures, during extreme flows may undermine, 200 yr. so step off could be old slump with material left behind, prior to last rotation at least.
404-3 57	boundary starting to skirt around ancient slide scarp, -75%/+55%, loose sandy bouldery gravel.
404-3 58	here, swale feeds scarp, looks likes on side of cobble gravel cone, pits in scarp gave coarse sand, possibly crudely bedded cone. laird has undercut when down cutting, slides appear ancient. +40%/-75%. the crown has slumped 1m 10m wide, 6m long, trees straight, no evidence of recent movement.
404-3 59	35% slope. deep bm, sand 30%, silt 5%, sub angular gravel 65%. 15m back from 80% slope to creek, no obvious scarps.
404-3 60	ancient scarp 85%, loose gravel with boulders.
404-3 61	no stream draw cut through slope, 65% gradient 40% upslope, no channel or evidence of instability.
404-3 62	Still dry, well confined, ancient debris flow channel. 45% slope.
404-3 63	boulder slope, swale very shallow, floored in mossy boulders, 60% slope. 1m boulder (or rock) step across slope, shallow broad swale above.
404-3 64	shallow swale, small outcrops, scattered across slope, 60% slope. base of short 80% rock step.
404-3 65	top of step, short unconfined section of swale, partially confined up slope, 60% slope.
404-3 66	patch of devil's club, swale upslope, off break, only partially confined here, 60% here, looks like 45lik 10m upslope falling corner likely water driven to surface due to rock, boundary across slope looks moist. boundary on 60% slope just below break, sandy bouldery gravel, may have occ rock.
404-3 67	broad devils club seep, lots of birch and aspen on slope. small stream, broad shallow swale upslope.
404-3 68	65%, wet, lots of coarse in soil pits, hard to dig, likely close to rock, boundary heads up to break.
404-3 69	just on 65% slope below,35%, lots of small boulders on surface, silt 5%, sand 25%, cf 70%, rain is starting.
404-3 70	head across and down large ancient slump scarp onto head of slump, ancient debris slide below.

Title	Description
404-3 71	ancient debris slide, scarp,off front of head, boundary start on lower slump, scarp, head 6m below.
404-3 72	off slumps, large scarp like feature ahead, ancient debris slide scar below, I just passed a devil's club seep at base of scarp, silty sandy gravel. ra8ng good now, patches of devils club ahead.40% stepped slope, devils club was a stream.
404-3 73	another small stream, 40% slope.
404-3 76	revised sta. 104, 70% slope, 90% slope to creek, 6m, scatter3d large trees on east side, large trees at top of sideslope on west side, ancient boulder cone. start of devil's club on sideslope on west side. large mossy boulders in bottom of draw. lots of angular rock on slope.
404-4 113	small stream broad swale, entrenched 0.25wide, 0.25 deep, flows over boulder or rock below, 60%, burnt snags right beside, so wide seepage zone to east.
404-4 121	sloughs and rock,ravel off scarp, hit large trees at toe, did not progress to slides, 90% scarp with large boulders. small bench of ancient debris catches material before it enters draw, small spring just below at base of this step. may want to have a reserve as trees can reduce sliding. check out draw.
404-4 94	90% possible debris slide, wet, pit gives loose brown coarse sand in scar,
404-4 100	+45%-55%, coarse gravel, 85% sub angular large cobble, hard to dig.
404-4 101	fc24, just went through small swale, seasonal seeps likely, ancient feature, 60% here, seems moist, coarse silty sandy gravel, another swale just ahead.
404-4 102	broad seepage zone just upslope, small stream here, 65%, seeps here as well. coarse gravel, slope break just upslope, mostly brush here.
404-4 103	seeps to here, separated from creek slope by small rise, bouldery on top, but I can see rock at break just up. yes, rock controlled, rock at lip, granite.
404-4 104	stream flowing over boulders from rock fall off canyon sides, 75% up, 45% down, small gravel bed load. large trees 8n bottom not scarred.
404-4 105	90% boulders blocks,
404-4 106	85%, coarse sandy gravel.
404-4 107	boundary on 60% slope, coarse bouldery gravel 10m from break to stream sideslope.
404-4 108	small mossy outcrop, seasonal seep, cedar, +65%/-55%. coarse gravels, no swale down.
404-4 109	small spring, devils club, open, draw or scarp just ahead.
404-4 110	large boulders beside open draw.
404-4 111	65% lots of boulders.
404-4 112	seasonal springs, very bouldery, devils club 60%, swale to west now more of a small bowl.
404-4 114	60% slope, devils club seeps, here dry stream confined by boulders, shallow, swale below, lots of devil's club adjacent, coarse sandy gravel.
404-4 115	stream over mossy bedrock or large boulders, springs scattered on slope usually at rock steps
404-4 116	drier slope, 60%, rock step downslope, large Doug firs. coarse gravel.
404-4 117	lots of outcrop to here, dry, here junction of two small stream, flowing over rock step, recent scour, slough from western one, no obvious large slides burnt

Title	Description
	trees lying in channel, partially buried, but recent high flows, very angular material, 70%. trees not scarred.
404-4 118	stream, flowing over rock step just upslope, channel swale, is treed to bottom. 60% slope, do not yard down creeks.
404-4 119	bench, possible ancient slump head, but it is rock controlled now, slope, bouldery (large) gravel.
404-4 120	ancient large slide scarp, removed bench, at least partial, could also, be wash of gravel off rock step, springs start of creek at toe of scarp, 1m diameter spruce in middle of step. few other trees, but they grow on side scarp, head scarp 10m high 100%, head 15 % 10m wide, then slope 60%, I see burnt snags beside it,
404-4 122	washed to boulders
404-4 123	v shaped gully 3m deep, to here no obvious signs of debris flows or floods, possible even though on outside bends no trees there is a good soil. and now 80cm spruce in bottom.
404-4 74	stream, incised 0.5m into cone, 3m above elevation, channel 0.2m wide, mossy cobbles, on cone layer of gravely sand over coarser material, poor bm, recent deposition 50 yrs, 40% channel gradient, cone is brushy, trees at toe 10m down.
404-4 75	just before apex of cone creek flows under trees, at apex confine on east side by cobble levee has bm, only slightly confined on west side by debris, sharp swale upslope, creek flows through center of cone elevated up to 4m above slope.50 % channel gradient, loose sandy gravel, lots of very rotten wood on top,, possible debris deposited at top of cone, vets 7m either side of center, this is likely part of the cone.
404-4 77	60% slope, coarse sub angular gravel.
404-4 78	sta 13, fc 4, 60% slope, dry
404-4 79	debris slide scarp, large 85%, good bm throughout, large trees on top portion of scarp, debris deposit below trees in scarp scar, pits give moist coarse sand, bm developed, large scarp ancient debris likely 250 or more but not treed, large maples, ancient feature.
404-4 80	deep sandy gravel, very deep bm, 65% slope, aspen grove on other side, boundary heads down.
404-4 81	loose sandy gravel, sub angular, moist, ancient slide scarp, debris flow channel just below, treed across, +80%/-70%.
404-4 82	complex of ancient debris slides, good soil throughout, loose sandy sub angular gravel, 75 to 85t%, angular blocks in scars.
404-4 83	70%, coarse sub angular gravel.
404-4 84	just into scarp beside draw, seems wet, large mossy boulders sticking out, or bedrock, wtp boundary just out of it trees, possible snow avalanche, possible flagging 4m up trees across draw. -70+80%.
404-4 85	boundary came down just in draw, 75%, lots of blocks, here 65%, possible seep, extremely large, house sized block in middle of draw, broken snags on side of draw, no obvious slides.
404-4 86	bottom of draw is cleared, but still has good soil on sides, possible snow dirt avalanche path 70%-60%, rotten trees (aspen maple) parallel to draw in bottom.

Title	Description
404-4 87	broad draw, no trees on east side , but burnt snags on west side, not a debris slide but possible snow avalanche, 55%.
404-4 88	55% slope, blocky gravel, 20m back from draw.
404-4 89	45% gradient channel, large mossy boulders, on sides old debris on boulders 250 yrs? opens below, lower gradient.
404-4 90	-55%+45%, blocky gravel,
404-4 91	broad wash zone ancient, floored in large cobble small blocks, sides sandy blocky gravel.
404-4 92	boundary just on stream sideslope, here 70%, but becomes sub vert just below, I can see rock on the other side.
404-4 93	95%, scattered outcrops. devils club, lots of trees down, upper 3m coarse bouldery gravel, lower mostly rock.
404-4 95	material get coarser down, mossy stream channel, rotten woody debris, debris from slide still partially at base of slide in stream, no obvious significant mobilisation, 35% channel gradient. trees possibly from side of slide still 10m up. 90% slope on west side sems drier, 10m high rock just upstream.
404-4 96	band of outcrop, rusty, some water showing.
404-4 97	granite outcrops near top of sideslope, no evidence of instability, 85%.
404-4 98	boundary just over break on 75%, in block looks about 55%, loose sand 25%, silt 10%, mostly small subrounded gravel 65%, boulders scattered on slope.
404-4 99	5m over break, on 65%, sandy gravel, areas of granite boulders or outcrops.
404-3 28	lots of boulders -55%, +65%, 10m below 55% break, boulder zone? or close to rock?

Observation sites