APEX GEOSCIENCE CONSULTANTS LTD.

Detailed Terrain Stability Field Review

Proposed Road and portions of proposed blocks in the McFarlane Creek Watershed
For
Kalesnikoff Lumber Company Ltd.

W. Halleran P. Geo, L.Eng.

2020-04-08

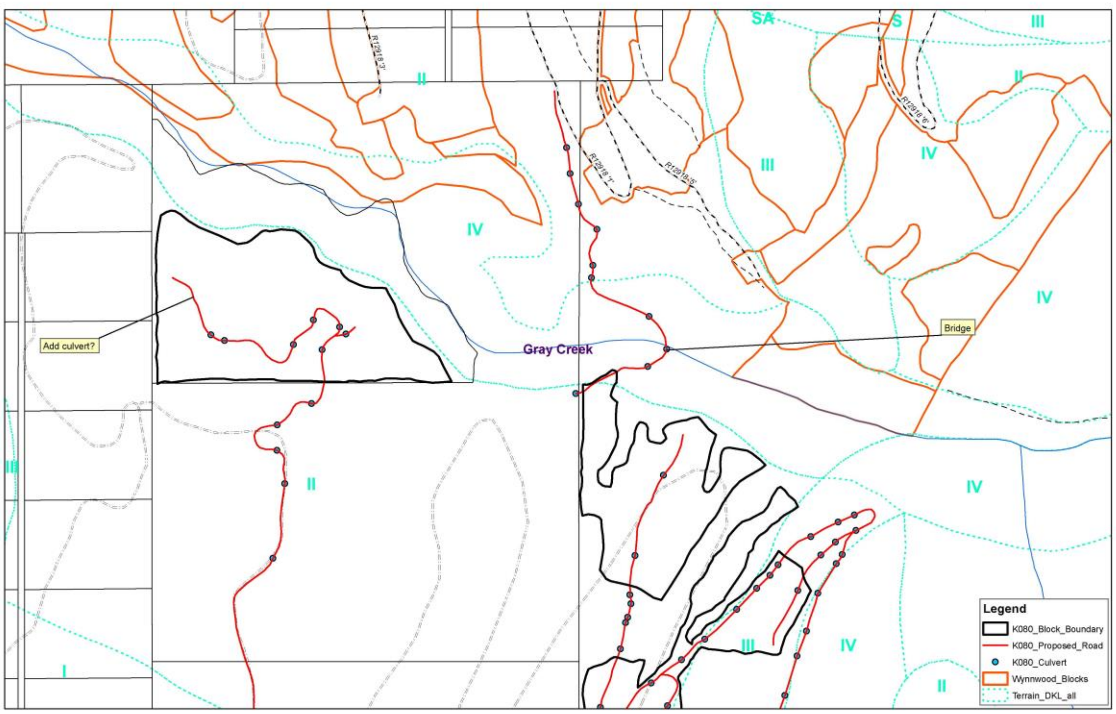
1. Summary

If the recommendations contained in this report are followed, the proposed development will not increase the low likelihood of landslide initiation, the proposed development poses a low to very low risk to water quality, water intake infrastructure, micro hydroelectric generation infrastructure, fish habitat, and private land.

2. Introduction

On October 18th, 2018, an email was sent to Mr. W. Halleran P. Geo L. Eng. of Apex Geoscience Consultants Ltd. by Mr. Gerald Cordeiro of Kalesnikoff Lumber Company (KLC) requesting a Detailed Terrain Stability Assessment of a proposed road and various blocks in the Macfarlane Creek watershed (figure #1).

Figure 1



It should be noted that the label Gray Creek is incorrect, that stream is McFarlane Creek. The email stated that "A lot of the terrain within the harvest areas is relatively benign" there is however a proposed new crossing over McFarlane Creek, which is in a Class IV gully. The proposed road crosses two gullies which drain into Class IV terrain". The road then crosses Class IV side slopes above the creek. From there the road connects to existing roads in private property. There will be an engineered crossing of McFarlane Creek.

Mr. Cordeiro requested a field investigation and recommendations for the following:

- The access road and crossing from the existing road (R12918 ‘1’ on the map).
- A review of McFarlane gully from the east end of the proposed development to the west end. Some portions of the planned blocks are adjacent to Class IV terrain along McFarlane “gully”.
- Assess the suggested additional culvert placed to avoid ditch run draining onto the ridge near the PoT of the road (see label).

And if the proposed development poses a hazard, assess the risk for the following elements:

- Water quality at several points of diversion downstream. Possibly one of the infrastructures has a micro hydroelectric unit integrated into it.
- Possible spawning habitat along the lower reach of McFarlane Creek.
- In the unlikely event of a dam-burst flood, there are several private properties on the fan, including the Lakeview Resort and Marina.

3. Methods, Limitations and Reliability

Google earth imagery, Bing maps satellite imagery and historical air photos were reviewed. KLC supplied hill shade and slope maps with the roads, blocks, proposed culvert locations and terrain stability polygons marked on them. A Samsung android tablet with the Avenza maps program with the imported hill shade map was used for navigation and note taking.

The field assessment was completed by W. Halleran P. Geo L. Eng. on October 23rd, 2018, the weather was cool with periods of light rain and snow on the higher summits.

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 and Guidance for Flat over Steep (2004). The risk assessment presented in this report follows the conventions outlined in Land Management Handbook 56 “Landslide Risk Case Studies in Forest Development Planning and Operations”.

For determination of the likelihood of a dam burst flood reaching the lower fan of McFarlane, and for information regarding the flood history of the stream, the report "Terrain Stability Inventory Alluvial and Debris Torrent Fans, Kootenay region, completed by Klohn Crippen for the ministry of Environment 1998" was consulted. This report determined that there is a low hazard of debris floods or floods at McFarlane Fan.

Inferences are made from observations of materials in soil pits, road cuts, and tree churns within and adjacent to the proposed block and road during the field review.

This review assumes road good construction 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 Likelihood of Landslide Determination

In this report the annual likelihood (Pa) of an event occurring is estimated by considering the age of the event. Slide 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 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 will likely result in a higher estimate of the annual likelihood of an event occurring than is present.

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) is 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 exceptionally 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.

Areas with no evidence of historic instability are deemed to have a very low (to nil) likelihood of landslide initiation.

If a debris slide enters a "low order stream channel" a debris flow may result. The following assumptions are made:

- A landslide entering a low-order channel of gradient less than 10^o (17.5%) stops
- A landslide entering a low-order channel of gradient greater than 10^o at an intersection angle of 45^o or less becomes a debris flow.
- Debris flows are erosive in channels of gradient greater than 10^o; they continue downstream but start depositing material at gradients less than 10^o.
- At channel junctions, if the gradient of the receiving channel is less than 20^o (36%), but greater than 3.5^o (6%), a debris flow continues if the junction angle is less than 70^o, otherwise it deposits on a fan.
- A debris flow entering a channel of gradient greater than 20^o will continue downstream, no matter what the junction angle.

Debris flow channels are most likely broadly U shaped, trimlines (scoured side slopes) can indicate the age and frequency of events. Scarred trees adjacent to the channel, along lower gradient reaches and/or unconfined sections debris deposition often occurs as levees or debris lobes.

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 estimate 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 "structure" and Px is the probability during the lifetime of the structure.

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 greater than 5% is a Moderate likelihood; 5% to 1% is a Low likelihood of landslide initiation; less the 1% is Very Low likelihood.

3.2 Hazard Determination

A hazard is a defined as a source for potential harm in terms of human injury, property, or environmental values. For this report, an event is deemed to be a hazard, if the it can materially adversely affect the element(s) at risk (specific hazardous event –P (H)). The relative hazard rating for landslides are shown in Tables 3.2.1 and 3.2.2.

Table 3.2.1. Likelihood of a Debris slide/ Debris Avalanche or Sediment Reaching or Affecting MacFarlane Creek.

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly impact McFarlane Creek.
Moderate	There is a run-out slope of<20º (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 McFarlane Creek . Some secondary transport of suspended sediment and small wood debris by accompanying water runoff may reach McFarlane Creek.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect McFarlane Creek at the time of an event. There is a run-out slope of <20º 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 McFarlane Creek.

Table 3.2.2. Likelihood of a Debris Flow or flood Affecting McFarlane Creek Fan

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	Description of Activity and/or Geomorphic Conditions
High	Debris flood or flow reaches McFarlane Fan. The channel gradient of McFarlane Creek is greater 10º or greater from initiation to the apex of the fan.
Moderate	Debris Flood or Flow occurs in McFarlane Creek but does not reach the fan. There is a 50m reach of McFarlane Creek less than 10º.
Low	Debris slide into McFarlane Creek does not transition into a debris flow or flood.

A Dam burst flood could only occur if a debris slide was of enough volume to completely block McFarlane Creek allowing enough volume of water to pond behind the blockage. Variables such as volume of the ponded water and the erosion rate of the breach are difficult to estimate. Evidence of past events can be used to determine the likelihood and/or frequency of dam burst floods.

The Hazard posed by a landslide is determined via the matrix shown in Table 3.2.3.

Table 3.2.3 Matrix for determining Hazardous slide, P (H).

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect McFarlane Creek or Fan, given that the Landslide/Soil Erosion Occurs		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

1) Modified from Wise et al (2004), Table 8, page 26.

3.3 Partial Risk Analysis

The risk analysis presented in this report is qualitative and is based on information gathered during this project and from information provided in the report "Terrain Stability Inventory Alluvial and Debris Torrent Fans, Kootenay region, completed by Klohn Crippen for the ministry of Environment 1998".

Elements to be assessed for risk are water quality/infrastructure (including possible micro hydro plant) at the domestic intakes lower down McFarlane Creek, Fish Habitat and private property on the fan.

For this report, the landslide risk is defined as hazard x consequence. Hazard has been defined in section 3.2, and consequence is the effect of the event.
Consequences are defined in tables 3.3.1 to 3.3.3.

Table 3.3.1: Water quality, water supply infrastructure, and hydro generation infrastructure.

Consequence	***Effect***
High	Long-term or permanent deterioration of water quality. Complete destruction of water intake structures.
Moderate	Short-term deterioration of water quality, repairable damage (1 week) to water intake structures.
Low	Short-term (less then 1 week) deterioration of water quality, "damage" to water intake structures repairable during regular maintenance.

For water quality and water supply infrastructure the P(H) would be a landslide that reaches McFarlane Creek.

Table 3.3.2: Private property on Fan

Consequence	**Effect**
High	Structural property damage to the structures.
Moderate	Minor to moderate damage to infrastructure due to flooding.
Low	Flood on fan restricted to stream channel.

The P(H) would be a debris flow or Dam burst flood occurring in McFarlane Creek that reaches the fan.

To determine risk the following matrix is used.

Table 3.3.4 Matrix for determining partial risk.

		Consequence		
		High	**Moderate**	**Low**
Likelihood of Occurrence of a Specific Hazardous Landslide/Sediment Delivery	**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

4. Observations:

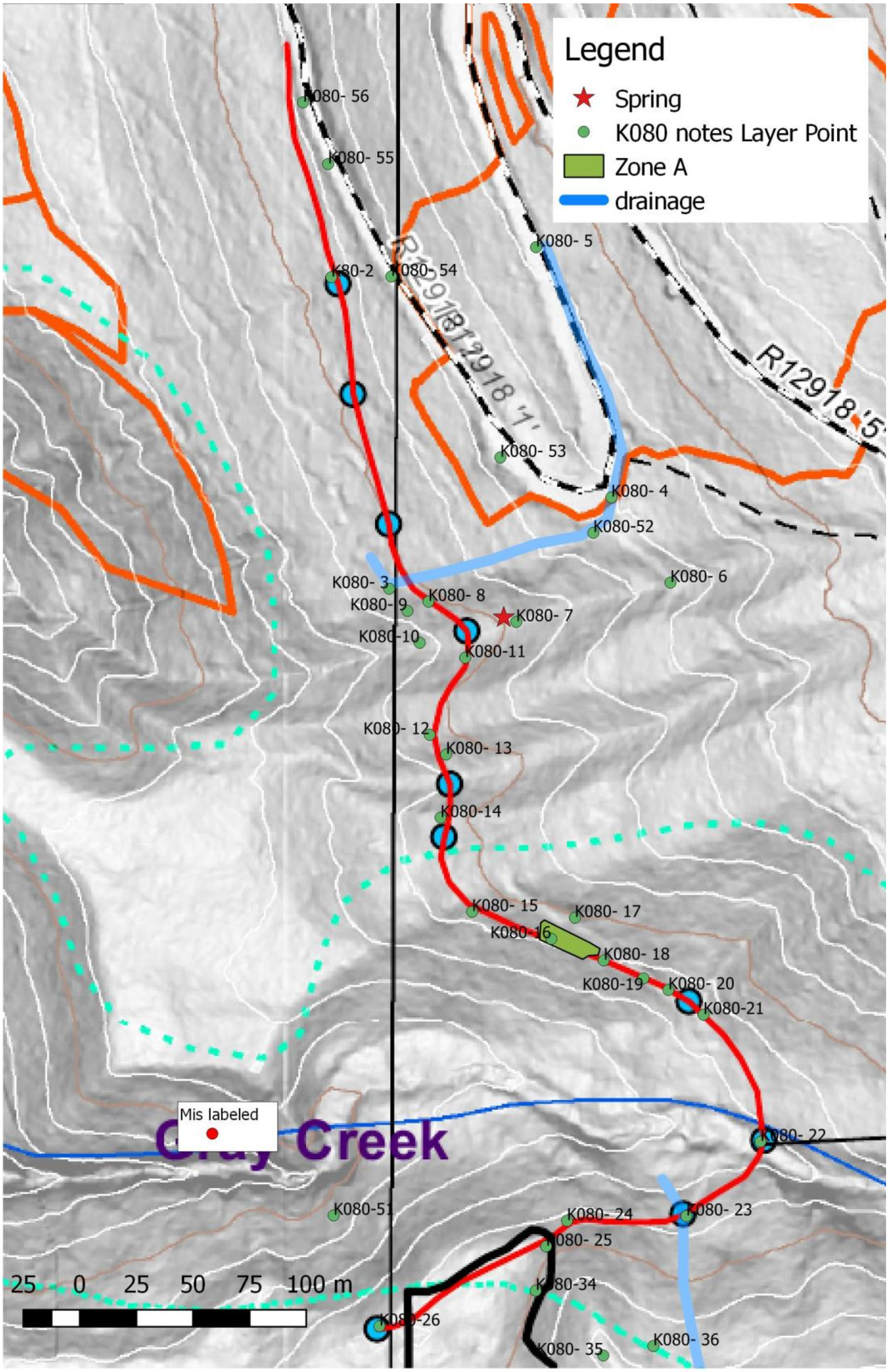
The proposed block, roads, observations sites and culvert locations are shown on Figure #A (Gray Creek label is located on MacFarlane Creek) at the back of this report, observations are tabulated in the table at the back of this report.

<u>4.1 Proposed road (figure #2):</u>

At the POC, the existing road (R12918 ‘1’) is excavated into sub-vertically foliated Schist overlain by about 1m of silt (25%) sand (15%) gravel (60%). From the POC off the existing Forest Service road to K080 -03 the proposed road crosses a 35 to 45% gradient slope underlain by silty gravel, likely close to rock. At station K80 -03 there is an eroded channel (0.25m deep, 15m wide) on an old trail that heads up along the edge of the north gully. Water is intercepted and diverted along the existing upslope road (R12918 ‘1’), from about K080-05 and is directed around the switch at K080-04 onto the old trail, water can be safely directed off the trail at station K080-52 (marked with a small rock cairn).

From K080-03 to K080-14 the proposed road crosses two ancient debris flow/slide gullies (North Gully and South Gully). Neither gully has an obvious watercourse, although there is a spring in the North Gully just above the proposed road crossing (station K080-07). The northern sideslope of the north gully is underlain by sub-angular

Figure 2


Legend
Spring
K080 notes Layer Point
Zone A
drainage
K080- 56
K080- 55
K80-2
K080- 54
K080- 5
R12918 '1'
R12918 '5'
K080- 53
K080- 4
K080-52
K080- 3
K080- 9
K080- 8
K080- 7
K080- 6
K080-10
K080-11
K080- 12
K080- 13
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K080- 17
K080-16
K080- 18
K080-19
K080- 20
K080-21
Mis labeled
Creek
K080- 22
K080-51
K080- 24
K080- 23
K080- 25
K080-34
K080-26
K080- 35
K080- 36
25 0 25 50 75 100 m

gravel (shallow to rock) with a slope gradient of up to 65%, the south sideslope has a slope gradient of 55% and is underlain by moderately compact silty sandy gravel.

The South Gully (K080-12 to 14) has an ~ 6m 65 to 75% drop at the bottom (rock), the remainder of the slope is 55% and underlain by loose sandy gravel. There is no evidence of instability.

The road then goes onto a 35% gradient slope before heading onto McFarlane Creek gully sideslope (65 to 75% gradient). The slope is underlain by silty sandy gravel along the upper sections to boulder gravel along the lower section. An old road cuts across this slope. The old road has no drainage control, an oversteep cutslope and an oversteep fillslope which contains organic debris. The cutslope of the old road has sloughed to 75% with a 1-2m sub vertical cut at the top. There are small fillslope failures (Zone A figure #2) along a portion of this road, the failures did not progress to debris slides.

From stations K080-15 to 17 the proposed road is just downslope of an old road (including a portion of Zone A). From station K080-17 to 20 the proposed follows the existing old road to the valley flat.

Station K080-20 is just above the valley flats on 50% slope gradient, station K080-21 is just past a draw on a small colluvial cone deposited on a much larger ancient cone, the road then heads across mounded sandy gravel “flats” to the stream crossing. At the crossing (K080-22) the stream gradient is 15% with lot of functioning woody debris, (the old road crossing is 5m downstream). The channel here is confined by rock (small canyon).

The proposed road aligns with the old road just out of the stream channel, which climbs up the southern sideslope. At station K080-23 the old road intercepts a stream out of a 40% gradient draw, the stream flows down the road, a culvert was marked by the road layout crew (the slope is 50%). The slope is predominantly rock, colluvium and coarse gravel. To station K080-24 the terrain is mostly rock and coarse colluvium with slope gradients less than 65%. The high cut on the existing road is stable at 80%. The road then angles onto a 60% gradient slope underlain by loose sandy gravel to gravelly sand upslope of a broad flat that separates the road from the slope to McFarlane Creek. From Station K080-25 to 26 (POT) the road follows the old road on gravel flats just set back from the 70% slope above the broad flat (step off terrace). The road is located on mounded and hummocky loose gravel.

Existing road R12918 '1' upslope of the proposed road, stations K080-53 to 56, was checked for drainage, the drainage appears to be well managed. One additional culvert is proposed at station K080-05.

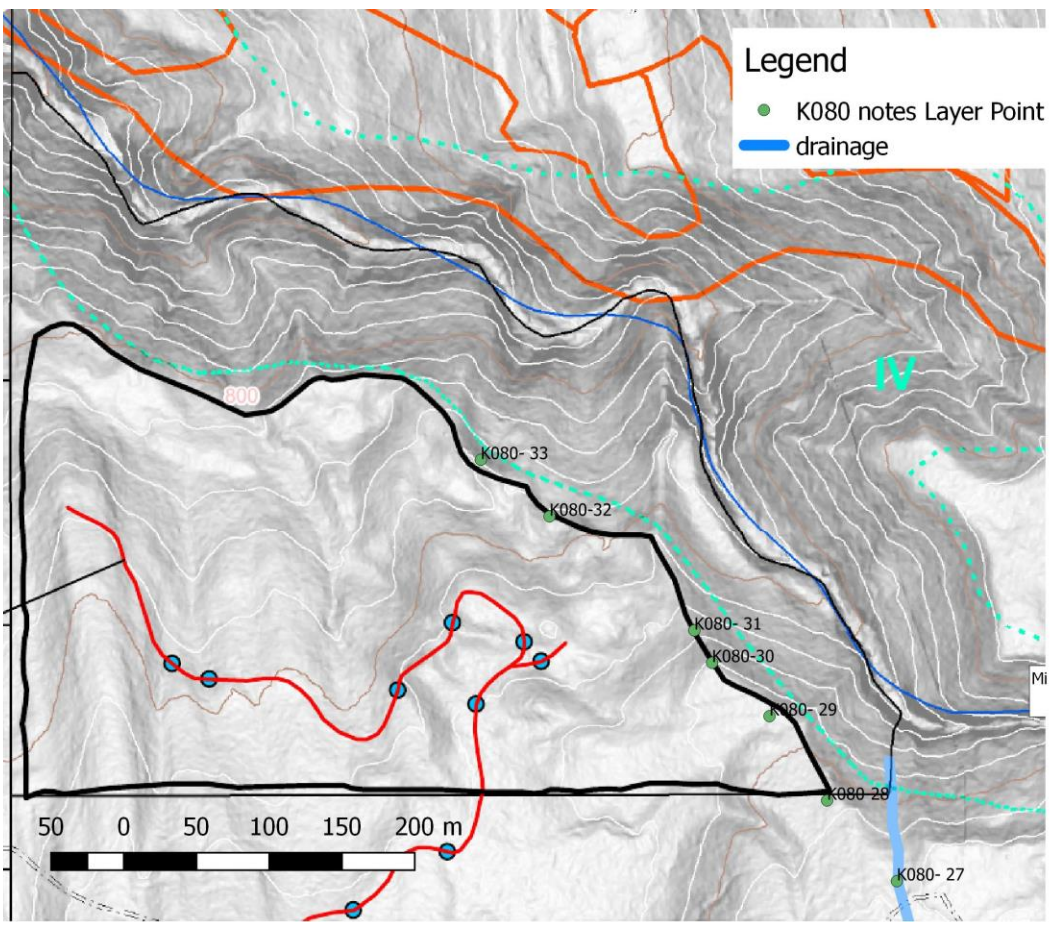
4.2 Proposed Blocks.

The block boundaries of two proposed blocks (West and East Blocks) that impinge on or are close to the slope to McFarlane Creek were reviewed.

There is a small stream at station K080-27 that flows out of the "flats" onto the steep slope above McFarlane Creek, there is no instability associated with the stream.

4.2.1 Western Block (Figure #3)

Figure 3

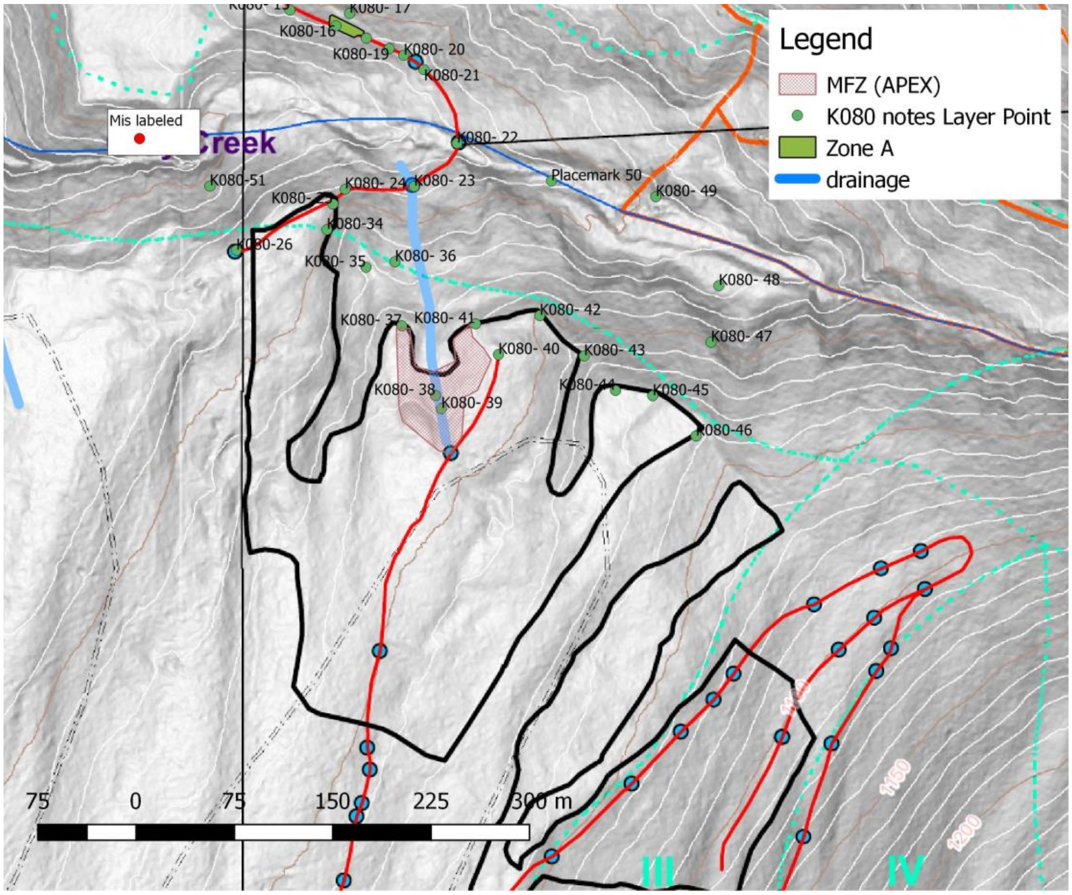


Stations K080-28 to K080-33 are along the northern boundary of the western block, most of the boundary is along a ridge that separates the block from the sideslope to the creek. The terrain is hummocky loose sandy gravel, there appear to be large ancient slumps along the slope break. There is little direct connectivity between the block and the slope to the creek.

4.2.2 Eastern Block (Figure #4)

Stations K080-34 to 46 is along the northern edge of the eastern block. Like the western block the terrain is typified by ridges and hummocks of sandy gravel. It is likely that in places this material only thinly caps rock. At stations K080-37, and 39 there are pools of water, station K080 – 38 is in a broad wet area. This wet area is likely that result of an impermeable layer close to surface (the layer is likely rock). Station K080-47 (below the block) is on a steep rock slope, station K080-48 is on a large rubble rock fall cone, the stream has cut down through it, with a 500 to 1000-year-old smaller cone on top.

Figure 4



4.3 McFarlane Creek:

At stations K080-49 and Placemark 50 there are slides into the creek, likely the result of the stream undercutting the slope during a high flood event. The debris from both slides spanned the stream channel, erosion on the higher flats indicates the stream was ponded behind the debris deposit, then diverted around onto the valley flat, eventually the stream eroded through the debris dams. There is no evidence of dam burst flood events or debris flow/flood downstream of the debris deposits. The slide at K080-49 appears to be 25 to 50 years old, at station K080-50 the slide deposit has 30 cm diameter cedar on it and is possibly 75 to 100 years old. The debris deposits are for the most part still present, indicating mobilisation of large debris deposits is rare in this stream. The photo below shows the stream eroded through the debris pile station Placemark 50.

Photo 1 Eroded Slide Debris at Placemark 50 (note the difference in tree diameter of the tree in foreground and trees on debris).

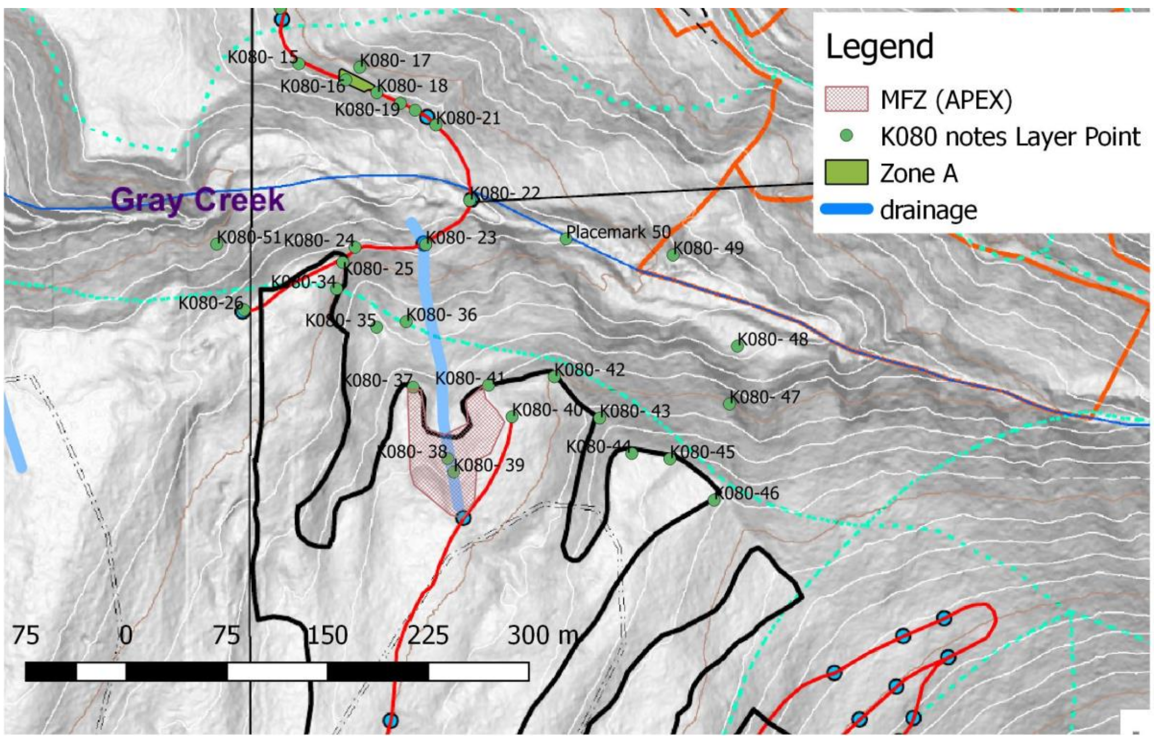
5. Implications and Recommendation

5.1 Proposed Harvesting:

The proposed harvesting is mostly located on mounded and ridged gravel with little direct linkage between surface drainage and the sideslope above McFarlane Creek. One stream was noted at station K080-27, this stream is located between the two proposed blocks and is unlikely to be significantly impacted.

The "wet land" at stations K080-38 to 40 is likely the source of the stream at station K808-23. To avoid rutting and disrupting the drainage patterns this area should either be harvesting on snow/frozen conditions, low ground pressure machinery or delineated as a no machine zone (marked on figure 5).

Figure 5



Timber harvesting will not increase the low likelihood of landslide initiation.

5.2 Road Construction:

The fillslope failures along the old existing road on the north side of the stream crossing did not progress to debris slides, a major drainage diversion along the road on the south side of the crossing did not trigger a debris slide. This would suggest the slope is relatively resilient and that slides are unlikely. Proposed culverts located and marked on the provided road plan are enough to avoid significant diversion and drainage concentration.

Specific recommendations are tabulated in following tables 5.1-5.2.

If the recommendations contained within this report are implemented, timber harvesting and road construction as proposed will not significantly increase the Low Likelihood of Landslide Initiation.

5.3 Additional Culvert:

The additional culvert that is proposed near the end of the proposed road in the western block is unlikely to receive significant slope drainage. It is however preferable to place a culvert along that section of road to discharge into the draw rather then to carry water along the ditch to discharge onto the ridge interfluve.

5.4 Debris flood or Dam Burst:

Evidence noted in this assessment such as slide debris deposits still within the stream channel and large old woody debris in the channel indicates that debris floods have not occurred or are rare events. The narrow-eroded channel through debris slide deposits and no evidence of major disturbance downstream of the debris dams indicates the Dam Burst floods do not occur in this channel, which supports Klohn Crippen's assessment of the fan.

Table 5.1 Road

From/to Site	Slope	material	Prob landslide	Cut/fill	Comments	Recommendations	Residual Prob
K080-01 to 03	35% to 45%	Compact Silty sandy Gravel (GM)	L	1.3:1			L
K080-03	45%	Silty sandy gravel	L		Eroded channel on a trail that parallels gully. Water from diverted drainage down existing road.	Direct down ditch to culvert at K080-2. (marked proposed culvert on existing road to reduce the flow here)	L
K080-08 to 15	50-65%	Compact Silty sandy gravel to loose gravelly sand	L	1.3:1	Crossing two “Gullies”. The Gullies are ancient large debris slides.		L
K080-15 to 20	60-75%	Loose Sandy Gravel	L	1.3:1	South aspect sideslope upslope of McFarlane.		L
K080-16	75%	Loose sandy gravel	M	1.3:1	Small fillslope failure from upslope.	Cut will partially remove oversteep fill.	L
K080-17	70%	Loose sandy gravel to silty gravel	M	1.3:1	The proposed road is on the old trail, zone of small fillslope failures.	Clean fill of organics, scale fill back to 85%. Improve ditchline.	
K080-20 to 22	25%	Sandy gravel	L				L
K080-22	15%				Creek Crossing. Confined by rock.		
K080-23 to 25	60%	Coarse colluvium and rock	L	1:1	Follows old road, north aspect sideslope		L
K080-23					Stream	Culvert	

6: Partial Risk Analysis

Elements assessed for risk are:

- Private properties on the fan, including the Lakeview Resort and Marina in the event of a dam burst flood.
- Water quality at points of diversion downstream
- Infrastructures of a micro hydroelectric unit and water intakes.
- Spawning habitat along the lower reach of McFarlane Creek.

As stated in section 5, if the recommendations contained in this report are implemented the development will not significantly increase the low likelihood of landslide initiation. A partial risk analysis will be completed on those elements that potentially impacted by a hazardous event (greater than Low).

Proposed Road

North Gully: It is unlikely that a slide into this gully would transition into a debris flow (insufficient stream). There is a low likelihood of landslide initiation, for 100m below the crossing the gully gradient is 36% (determined by lidar).

Table 6.1. Likelihood of a Debris slide/ Debris Avalanche or Sediment Reaching or Affecting MacFarlane Creek.

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect McFarlane Creek.
Moderate	There is a run-out slope of<20º (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 McFarlane Creek . Some secondary transport of suspended sediment and small wood debris by accompanying water runoff may reach McFarlane Creek.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect McFarlane Creek at the time of an event. There is a run-out slope of <20º 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 McFarlane Creek.

Table 6.2. Matrix for determining Hazardous slide, P (H).

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

Slides at this crossing are deemed a low hazard to the elements at risk.

South Gully: There is no evidence of a watercourse in this gully. It is unlikely that a slide into this gully would transition into a debris flow (insufficient stream). There is a low likelihood of landslide initiation, for >200m below the crossing the gully gradient is 35% (determined by lidar).

Table 6.3. Likelihood of a Debris slide/ Debris Avalanche or Sediment Reaching or Affecting MacFarlane Creek.

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect McFarlane Creek.
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Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect McFarlane Creek at the time of an event. There is a run-out slope of <20º 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 McFarlane Creek.

Table 6.4. Matrix for determining Hazardous slide, P (H).

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

Any slide that occurs at this crossing is deemed a very low hazard to the elements at risk.

North Approach to Macfarlane Creek: The northern approach to the creek crossing is just downslope or coincident to an existing older road. Fillslope failures along this older road did not progress to debris slides. There is a low likelihood of landslide initiation. If a slide did occur there is a 30m to 125m wide < 36% bench of irregular terrain that would reduce the likelihood that the slide would reach McFarlane Creek.

Table 6.5. Likelihood of a Debris slide/ Debris Avalanche or Sediment Reaching or Affecting MacFarlane Creek.

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect McFarlane Creek.
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Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect McFarlane Creek at the time of an event. There is a run-out slope of <20º 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 McFarlane Creek.

Table 6.6. Matrix for determining Hazardous slide, P (H).

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

A slide along this section of the road is deemed a low hazard.

Southern egress from McFarlane Creek: There is a low likelihood of landslide initiation along this section of road. Any slide that did occur is likely to directly enter McFarlane Creek Channel.

Table 6.7. Likelihood of a Debris slide/ Debris Avalanche or Sediment Reaching or Affecting MacFarlane Creek.

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek (P(H))	**Description of Activity and/or Geomorphic Conditions**
High	Landslide debris and/or sediment delivery would reach or directly affect McFarlane Creek.
Moderate	There is a run-out slope of<20º (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 McFarlane Creek . Some secondary transport of suspended sediment and small wood debris by accompanying water runoff may reach McFarlane Creek.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect McFarlane Creek at the time of an event. There is a run-out slope of <20º 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 McFarlane Creek.

Table 6.8. Matrix for determining Hazardous slide, P (H).

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

For this section of road, a debris slide is deemed to be a moderate hazard.

A debris slide along this section of road will intersect McFarlane at about 45^{o}, the stream gradient is ~15%, a debris slide is unlikely to transition into a debris flow. Stream erosion of the debris would likely result in detectable turbidity along the lower reaches of the stream for less than a week.

Table 6.9: Water quality, water supply infrastructure, and hydro generation infrastructure.

Consequence	***Effect***
High	Long-term or permanent deterioration of water quality. Complete destruction of water intake structures.
Moderate	Short-term deterioration of water quality, repairable damage (1 week) to water intake structures.
Low	Short-term (less then 1 week) deterioration of water quality, "damage" to water intake structures repairable during regular maintenance.

Table 6.10 Matrix for determining partial risk.

		Consequence		
		High	**Moderate**	**Low**
Likelihood of Occurrence of a Specific Hazardous Landslide/Sediment Delivery	**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

A slide along this section of road poses a low risk for water quality, water intake infrastructure, and the hydroelectric infrastructure.

For elements along the lower fan and lower reaches (fish habitat), a hazardous event would be a debris flow or flood down the channel.

As stated previously, a debris slide into McFarlane Creek is unlikely to transition into a debris flow or flood.

A dam burst flood is a potential hazard for elements on the fan and along the lower reaches. In 1998 Klohn Crippen, as part of a larger project, assessed the stability of this fan. McFarlane Creek fan (82F010-19) was determined to be an alluvial fan and assigned a low hazard for debris floods and flooding.

Evidence noted in this assessment (such as slide debris deposits still within the stream channel, a narrow eroded channel through the debris with no evidence of a dam burst flooding downstream of the constrictions) supports Klohn Crippen's assessment of the fan.

Table 6.11 Likelihood of a Debris Flow or flood Affecting McFarlane Creek Fan

Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek Fan	Description of Activity and/or Geomorphic Conditions
high	Debris flood or flow reaches McFarlane Fan. The channel gradient of McFarlane Creek is greater 10º or greater from initiation to the apex of the fan.
Moderate	Debris Flood or Flow occurs in McFarlane Creek but does not reach the fan. There is a 50m reach of McFarlane Creek less than 10º.
Low	Debris slide into McFarlane Creek does not transition into a debris flow or flood.

The determination of a hazardous flood is shown in Table 6.12

Table 6.12. Matrix for determining Hazardous flood, P (H).

		Relative Rating of Likelihood of a Landslide Affecting McFarlane Creek Fan		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**Very High**	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

Klohn Crippen's determination that the Fan of McFarlane is an alluvial fan indicates that the fan has been constructed by fluvial processes not colluvial (i.e. debris flows) processes. The low hazard and "Stable" rating of the fan indicates that there was little evidence of previous flooding and that there is a low probability that the stream will either overflow or jump out of the present channel under flood conditions.

Table 6.12: Private property on Fan

Consequence	Effect
High	Structural property damage to the structures.
Moderate	Minor to moderate damage to infrastructure due to flooding.
Low	Flood on fan restricted to stream channel.

Table 6.14 Matrix for determining partial risk.

		Consequence		
		High	**Moderate**	**Low**
Likelihood of Occurrence of a Hazardous Flood	**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

The proposed development poses a very low risk to private property on the fan.

Respectfully Submitted,
Apex Geoscience Consultants Ltd.

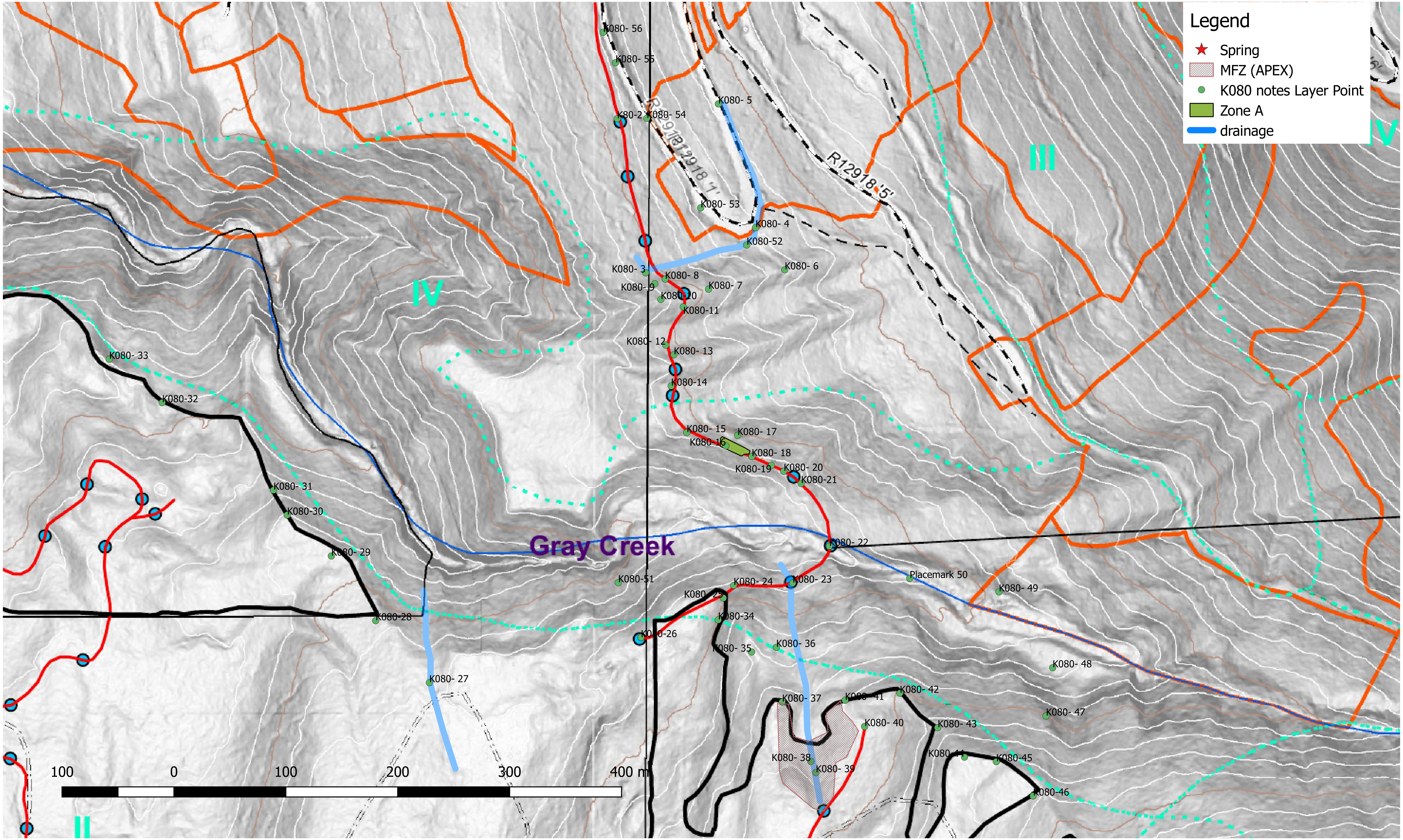
Will Halleran P.Geo.

Title	Description
K080- 1	road cut at poc is in schist sub very foliation topped with 1m of silt 25%, sand 15%, gravel 60%, from hillshade appears a large terrace occurs downslope at about 920m elevation, below road most has eroded off, matching the class IV polygon boundary. drove to switch, no obvious drainage draining towards proposed road.
K80-2	culvert lines up with road culvert, swale, no obvious scour, slope to here generally less than 35%.
K080- 3	to here up to 45% slope, silty sandy gravel, stacked large, trails, here beside sideslope to gully, trail parallels gully, eroded channel on trail, should we direct to bottom of gully (no, take off main road to avoid directing down road and possibly saturating fill.
K080- 4	followed, erosion up to switch, water is, directed off switch onto trail then confined by berms, eroded 0.25m in places, old trail off switch ditched through. so diverted and concentrated drainage from up road, would need to assess road to see where it came from.
K080- 5	followed ditch to here, appears some springs at switch but scoured ditch to here, here wet ditch small pool. sedges, not much scour further up. flag culvert at low end of seep, hopefully lines up with culvert along lower lift.
K080- 6	followed trail to first gully, not to deep here, old cut and fill slough, no obvious, erosion across, trail, likely wet, rotten wood in fill, about 15% gully gradient.
K080- 7	followed "gully" down, very broad bottom, silty sandy gravel 65% sideslopes with ancient slides, no obvious channel, here small spring just up stream of road, 20 to 25% gradient, ancient large failure off kame terrace.
K080- 8	60 to 65% sideslope, silt 30% sand 15%, sub rounded to sub angular gravel 55%, compact, 20cm silt Bm, push forward to fill gully crossing. could be till or close to weathered rock, slope likely variable, use this as most restrictive. if slide occurred unlikely to be carried as debris flow down gully, not enough water, control drainage on trail upslope. this is a short section, then onto 50% old slide deposit before bottom,
K080- 9	Old slide or skidding down slope, possible that the water caught by the old trail was at one time directed down here, now bermed.
K080-10	more v shaped, narrow bottom, more recent forest floor scour, cut stumps, I think gully was used to skid. some pits on sides give no bm others give good bm, don't think it is a trim line, old cut stumps right in bottom.
K080-11	55%, ancient slough, compact sandy silt till
K080- 12	crossed,35% slope, on edge of 75% sideslope about 6m to bottom of broad gully, ancient debris slide.
K080- 13	pit gives loose, silt 10%, sand 30%, small rounded gravel 70%, variable material.
K080-14	sideslope this side 6m 65%, loose sandy gravel with boulders upslope, broad u-shaped gully, 25% channel gradient (no channel), then onto 35% slope with ancient t shallow debris flow just ahead, these are ancient features. my guess is top of kame terrace at 1020m.
K080- 15	onto 60% slope, areas of bare earth, silt10%, sand 45%, gravel 45%, loose, ravelling, likely variable, small shallow slough, steeper downslope.
K080-16	to here 75% slope, loose sandy gravel, here small fillslope failure off trail just above, scar is mossy, debris piled against trees. cut of road will likely partially remove old

	road.
K080- 17	on old trail, broad zone of small fill failures, cut 4m high, top part 90%, cut sloughed onto road 70%, likely directing any water onto fill, loose sandy to silty sandy gravel. unsupported cut sloughed and travels to 70%, long term angle of stability.
K080- 18	to here slope about 70% (thick small hemlock makes it hard to see), just back onto 60% slope, larger rubble, pit difficult due to coarse material, may be soil from road.
K080-19	just higher gravel content up to 65%, old road on "bench", 1m cut in boulders gravel, slope, below 60, to 65%. hard to see.
K080- 20	+/-50%, broad flat below.
K080-21	past draw, old small cone, onto ancient large cone, relatively flat.
K080- 22	stream crossing, 15% stream gradient, lots of functioning woody debris, rock canyon on south side, 2m sub vertical drop on north side likely rock controlled, but crossed mounded zone of silty sandy gravel, erosion control to avoid sediment delivery, such as take off to, discharge onto forest floor, low gradient so unlikely to channel too much water here, old road crossing just downstream 5m.this cut will be in rock. or approach to bridge will be high enough.
K080- 23	Old road intercepts spring from 40% draw, may be stream, flows, down road, road, culvert flagged good, to here mostly rock, colluvium and coarse gravel, slope less than 50%
K080- 24	to here mostly rock and coarse colluvium, small rock, step below, slope less than 65%, sub vertical fill, high cut, here just into loose, sandy gravel, immediately below road 60%, then rock step then 65%, high 80% cut, stable.
K080- 25	+/-60%, loose sandy gravel to gravelly sand, broad flat or ridge separates slope from creek.
K080-26	to here follow old road, just back from 70% slope to flats, long term angle of stability, loose sandy gravel, rapidly drained, in block small kettle features, small depressions and knolls, here loin new road in loose sandy gravel, culvert is placed here, likely due to small depression breach, larger one just back, but not continuous, small rise, this culvert will discharge onto 70% slope but is unlikely to have water, likely subsurface due to loose gravel, likely variable at depth, didn't notice any springs on face along this section, likely goes deep. photos show variable loose sandy gravel to silty gravel, also small depression, which is the continuation of small depression culverted here, would be bett3r to culvert private road that heads south.
K080- 27	stream
K080-28	block corner on break of irregular flat generally pitches parallel to break and 80% slope break, ancient slump, loose sandy gravel.
K080- 29	to here series of moderate sized ancient slide scarp, good Bm and ae in soils mostly sandy gravel to silty sandy gravel but areas of angular (variable), 85% scarp, 65% slope below, likely formed soon after down cutting, irregular slope in block, here 65% slope, in block generally drains away from edge.
K080-30	head down sharp nose of step off terrace, 65% in block, 75% to creek flats, just back the slope was away from edge, possible swale.
K080- 31	off, steep part of step off now down 35% "ridge", -65% toward creek, 30% towards depression or swale parallel to break, in block hummock. Large boulders or small outcrops on crest. ridge ahead becomes a razor back. large bench and ridge below, no connection to creek.
K080-32	past two depression swale discharge no channel, mossym45% steps, devils club,

	boulder, between70%, now 45%, hummocky in block.
K080- 33	on ridge, large ancient slump on creek side, 85% scarp, 40% on other side to depression, head below mossy cedar, likely related to depression (ice melt), now small rise separates depression from parallel draw, boundary on ridge. I have seen enough, kettled terrain difficult to divert water, no sign of instability associated with forest fire deforestation, all ancient, okay, head back.
K080-34	65% loose gravel slope to depressions, not connected to creek.
K080- 35	esker
K080- 36	45%
K080- 37	just over on 65% break off flat topped knoll, below broad draw, 35% with a pool of water and moss.
K080- 38	on boundary in "draw", to, here on edge of short 60% slope to draw, draw was well confined, here confined 9n south, but broad wet flats on north and west, can see road flags, careful of redirection and routing/rutting. perhaps low ground pressure or frozen and snow unlikely to be diverted out of draw below, but resident time may be altered. not likely to have adverse effect.
K080- 39	areas of standing water, grassy, swallows, seeps, road near top end here.
K080- 40	pot road, small depression at base of slope and end of swale just ahead, small knoll ahead. do not breach rise to north, defines bowl, skid in from south.
K080- 41	short 55% slope, silty sandy gravel, to what appears to be an old slump head or a perched meander. top of ridge just up slope, no drainage. I am on the boundary but doesn't seem to match map. move placemats to match map.
K080- 42	to here just on 65% slope off ridge top, silty gravel, benches below, here benches appear to be gone, -75% slope to creek valley, boundary follows small ridge crest so still doesn't drain towards creek. to previous benches could have been slumps due to upslope wet zone and undercutting during down cutting.
K080- 43	Follow razor back ridge top, cobbles and boulders on top, -75% to 80% towards creek, 55% in block, boundary then heads along 55% slope in block, base of slope is irregular terrain, short slope. this is likely an esker.
K080-44	tree churns showing higher percent gravel up to 85%, with silt matrix, even slightly sticky, very grey, 70-75% towards creek. -5% on flat top, rises a bit ahead.
K080-45	shallow swale pitching into block at foot of 2m 40% rise to next flat. it appears that most of this block drains into the wet area, at least eventually.
K080-46	boundary follows foot of 45% slope, in block slope pitches 10% to southwest, -75% slope to creek, material is silt 10%, sand 10%, gravel (lots of cobbles and boulders) 80% (to 65% proportionally) different than kame material, must be till. head down to creek to check lower slopes and small stream that appears, to drain block.
K080- 47	+75%/-100%, steep is likely rock, large bench about 40m below.
K080- 48	yes, it was rock, as is the steep portion of the lower slope, I came down an ancient large rockslide, huge fan in bottom, small 10m high by 20m wide cone at base at least 500 to 1000 yrs. old. creek has cut down into, the ancient deposit.
K080- 49	slide into creek from north, down cutting due to flood, exposed snag.
K080-51	30% coarse colluvium to creek, upslope of road 40% broad swale.
K080-52	alternatively, can take water off here feeds broad swale below which joins gully at low gradient section. lost my flags, marked with flat rock and three smaller ones on top.

K080- 53	reverse waterbed (directs water onto fillslope).
K080- 54	culvert, low point in road, minor sedimentation along ditch, shallow swale upslope, no obvious cut erosion.
K080- 55	low point in road, rock in cut, no culvert, just ahead
K080- 56	crossditch, slight rise then steeper gradient road, rock in cut and ditch.



Legend
Spring
MFZ (APEX)
K080 notes Layer Point
Zone A
drainage
Gray Creek
IV
III
II
R12918 '5'
K080- 56
K080- 55
K080- 54
K080- 5
K080- 53
K080- 4
K080-52
K080- 3
K080- 8
K080- 6
K080- 7
K080-11
K080- 12
K080- 13
K080-14
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K080-28
K080- 27
K080-51
Placemark 50
K080- 49
K080- 48
K080- 47
K080- 42
K080- 37
K080- 40
K080- 43
K080- 38
K080- 39
K080-45
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