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BC Ministry of Forests, Lands, and Natural Resource Operations
and Rural Development

POST-WILDFIRE NATURAL HAZARDS RISK ANALYSIS
AKOKLI FIRE (N71686)

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1. Introduction and Objectives

The Akokli wildfire (N71686) started on July 9, 2021 and burned 3,795 hectares within and between the Akokli Creek and Lockhart Creek drainages in southeastern B.C. (refer to Figure 1 and insert map on Map 1, Appendix A). The fire started in the Akokli Creek drainage and progressed westward through the Charles Creek, McGregor Creek, Holiday Creek, and Mack Creek drainages finally moving northward into Lockhart Creek drainage (Photos 1 through 4). Because the fire includes or is adjacent to several populated areas along the east shore of Kootenay Lake near the community of Boswell, it was considered by the Ministry of Forests, Lands, Natural Resource Operation and Rural Development (MFLNRORD) to be a high priority and a Post-Wildfire Natural Hazards Risk Analysis (PWNHRA) should be conducted. SNT Geotechnical Ltd. (SNTG) was retained by BC Wildfire Service to complete this work. SNTG collaborated with Sitkum Consulting Ltd. (SCL) to complete the risk analysis and reporting.

Figure 1. N71686 General fire location

Photo 1. July 13th, 2021 - Sentinel -2L1C Satellite Imagery

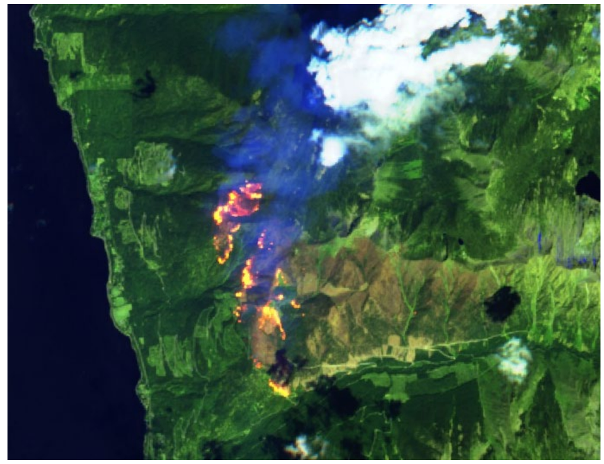

Photo 2. July 20th, 2021Sentinel -2L1C Satellite Imagery

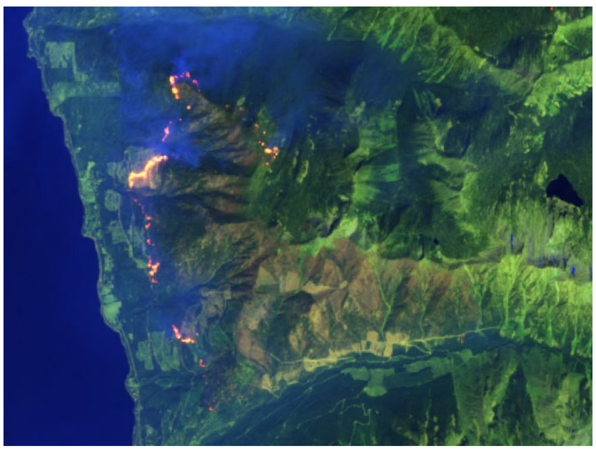

Photo 3. July 25th, 2021Sentinel -2L1C Satellite Imagery

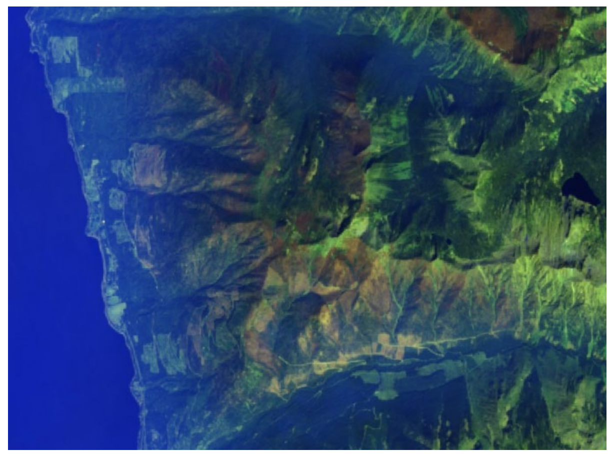

Photo 4. August 12th, 2021Sentinel -2L1C Satellite Imagery

While for many fires a reconnaissance risk analysis is conducted, which involves a review of operational maps and other information from the Southeast Fire Centre, preliminary burn severity maps (Rapid Burned Area Mapping (RBAM)) and a review of aerial imagery on Google Earth, a written reconnaissance risk analysis was not completed for the Akokli Fire as the resource values warranted a more detailed risk analysis.

The detailed risk analysis with field work was supported by burn severity mapping, with polygons representing unburned, low, moderate, and high burn severity areas. The detailed risk analysis includes, where relevant, recommendations for mitigation measures.

2. Potential Hazards as a Result of the Fire

Debris flows and floods following wildfires can occur as a result of high-intensity rainfall on severely burned and/or water-repellent soils, typically in mid to late summer. Examples in B.C. include the 2004 Kuskonook Creek and Jansen Creek debris flows near Creston, debris floods and flows following the 2017 Elephant Hill Fire (91 events, one causing a fatality on Highway 1) and debris floods in Kelowna and near Falkland, which followed the 2003 wildfires. This hazard is greatest in the first two to three years after the fire. Debris flows and floods can also occur during spring runoff as a result of rapid snowmelt in burned areas. Examples include several debris flows which followed the 2007 Springer fire near Slocan (one causing a fatality), and debris flows which followed a 2009 fire at Kelly Lake. They can also occur, although less commonly, during fall (2005 Mt. Ingersoll Fire with 15 channel failures and seven hillslope landslides) or early winter rain-on-snow events. The springtime hazards are due to increased snow accumulation, more rapid snowmelt, and higher groundwater levels in burned areas, and can persist for several years or decades until revegetation occurs.

In the area of the Akokli Fire, potential debris flow and flood hazards are possible due to short-duration high-intensity rainfall events, rain on snow events, or rapid snowmelt runoff events.

Water repellency was observed in areas of high soil burn severity and although not a necessary condition, water repellency makes it more likely that overland flow will be generated during high-intensity summer or early fall rains (generally following dry spells when water repellency is greatest). High soil burn severity also causes reduced infiltration capacity, even without water repellency, and therefore can increase susceptibility to overland flows even in areas where water repellency was not observed. In areas of moderate vegetation burn severity, needle fall from the dead trees can create an effective mulch, which tends to slow down surface runoff and promote infiltration. The partial or total loss of forest litter and duff layer in moderate and high soil burn severity areas results in a reduction in water storage capacity and increased surface run-off flow velocity.

In August 2018, in the area burned by the 2017 Elephant Hill fire near Cache Creek, there were several unusually intense, short-duration rainstorms which caused severe flooding and erosion in many small, steep creeks. Overland flow and flood damage occurred even in watersheds which drained moderate and low burn severity areas, including grassland. Some flooding also occurred in unburned watersheds, but it was much more extensive and severe in burned areas. These rainstorms were estimated to have a return period of 100 years or more in the most severely affected areas (that is, in any given year, the probability of occurrence is 0.01, based on historical data). Extreme rainstorm events are likely to cause widespread flooding and possibly landslides in all areas, burned or unburned; however, the Cache Creek events illustrate that burned areas are more susceptible to damaging events. In the post-wildfire risk analysis procedure, the hazard ratings are generally assumed to apply to flood or erosion events that may occur as a result of rainfall or snowmelt events that are likely in the two-to-five-year period after a fire. Although the risk analysis focuses on a two-to-five-year time horizon, lingering hazards can extend for decades until forest regeneration occurs.

Soil erosion can be a significant process in high soil burn severity areas, due to exposed bare soil and lack of a protective litter and duff layer. Increased sediment load during flood events can contribute to flood damage, by blocking culverts and ditches. It can also contribute to the likelihood of debris flows in steep watersheds. Erosion from burned areas may result in adverse impacts to water quality in the creeks affected by the fire. In addition, peak flow in some extensively burned watersheds could result in additional sediment entrainment from bank erosion or through tributary debris deposition. In the first few rainstorms and snowmelt events after the fire, ash and soot can be washed downstream and enter water intakes. In addition to ash and sediment entrainment there have been documented increases of other types of water contamination including an increase in heavy metal concentrations post wildfire (Silins et al 2016, Bladen et al 2014.)

3. Methods

The post wildfire assessment includes a review of available relevant reports of previous work in the burned watersheds, field work, mapping, and analyses.

Some of the available information reviewed includes geological and geotechnical reports (see references in Section 10). Also reviewed were local geological maps and watershed conditions (refer to Section 4). Debris flood and debris flow susceptibility maps were reviewed with some examples shown in Section 6. The susceptibility maps were prepared by BCG Engineering Ltd. for the RDCK to assess debris flood and debris flow hazards. The maps were commissioned by the RDCK to assist with the identification and prioritization of hazardous areas within the RDCK jurisdictional area (22,200 km^2). The maps were created using a combination of digital elevation model metrics (20 m contour intervals) used to identify potential debris source zones within creek channels/gullies and flow propagation modelling to plot potential down slope flow paths.

The authors of the BGC report and maps caution that the maps are not suitable to undertake site specific hazard assessments (Sturzenegger, M. et al, 2021, BGC Engineering, 2019). The hazard ratings (very low, low, moderate and high) do not have a physical meaning and the methodology does not compute or provide debris-flow or debris-flood volume, mass depth, velocity, peak discharge or impact forces. They are intended to be used for a regional comparison between sites to determine areas with higher hazard potential. Further, the debris-flow and debris-flood susceptibility ratings are not associated with any specific return period, but instead represent a range of possible outcomes. The BGC authors suggest that when using the maps for risk prioritization, higher weights should be attributed to the fan areas classified with higher susceptibility. While the maps are not intended to be used for detailed, site-specific hazard assessments, they do provide an indication of where debris-flood or debris-flow hazards may be of concern.

Field work in the burned areas was conducted on October 20 by Doug Nicol, P.Eng. (SNTG), Pete Wittstock, P.Eng. (SNTG), Dwain Boyer, P.Eng. (SNTG), Tedd Robertson, P.Geo. P.L.Eng. (SCL), and Caitlin Tatham, G.I.T. (SCL), on October 21 by Doug Nicol, Tedd Robertson, and Caitlin Tatham, and on November 10, by Dwain Boyer and Sarah Crookshanks, P.Geo. (MFLNRORD).

Previous field work (including an August 19 helicopter reconnaissance) was conducted by Doug Nicol for the purposes of reviewing the deactivation of guards and trails constructed by BC Wildfire Service.

The October and November field work included truck accessed foot traverses and soil plots to confirm the results of the BARC mapping and to compare the Vegetation Burn Severity (VBS) with the Soil Burn Severity (SBS) and to make observations of the resource values at risk and key creek fan attributes.

The field work was focused on the Akokli Creek, McGregor Creek, Holiday Creek, and Mack Creek drainages as these areas were thought to have the highest risk (the combination of steep slopes with significant burned areas and downslope values).

Mapping of potential post-wildfire hazards and the analysis of risks followed the general methodology outlined in Hope et al. (2015). In the simplest terms, risk is the product of hazard and consequence. For the purpose of post-wildfire risk analysis, usually only partial risk is considered; this is the probability that a hazardous event (e.g., a debris flow) will occur and that it will reach or affect the site of the element at risk (e.g., a house or highway) with consideration to the spatial and temporal probability but not the value or vulnerability of the elements at risk. Detailed risk analysis generally involves ground inspections of high value elements exposed to considerable hazards. Subjective terms (low, moderate, high) are used to describe hazard and risk, based on generally accepted definitions (Wise et al 2004). The qualitative risk matrix used for the determination of partial risk in this study is shown Table 1. The risk was considered in an incremental context and not as an absolute risk which would also consider pre-existing natural hazards. For example; an element at risk may have been considered to be at high partial risk pre-fire, but if there is no significant increase in the assessed risk at the location of the element considered, the post wildfire risk would be assessed as low or non-existent.

Table 1. Qualitative risk matrix for partial risk (Wise et al, 2004. Land Management Handbook 56)

P(HA), annual probability (likelihood) of occurrence of a specific hazardous landslide and it reaching or otherwise affecting the site occupied by a specific element		**P(S:H) × P(T:S) Probability (likelihood) that the landslide will reach or otherwise affect the site occupied by a specific element, given that the landslide occurs**		
P(HA) = P(H) × P(S:H) × P(T:S)		**High**	**Moderate**	**Low**
P(H), annual probability (likelihood) 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*

4. Terrain and Watershed Conditions

The Akokli Fire is situated in the Purcell Mountains, part of the Columbia Mountains within southeastern British Columbia. The general physiography of the region consists of consists of serrated ridges and peaks above approximately 2100 m elevation and with rounded ridge crests and steep valley sides below 2100 m. Local summit levels generally lie between 2300 m and 2800 m, and local relief of approximately 1200 m to 1800 m is typical with elevation ranging from approximately 660 m at Lockhart Creek to approximately 2385 m at the summit of Mt Davies.

Below approximately 1100 m to 1200 m elevation within the fire perimeter the biogeoclimatic mapping has identified the West Kootenay variant of the Dry Warm subzone of the Interior Cedar – Hemlock zone. Between approximately 1100 m to 1200 m and 1600 m elevation on the west facing slopes south of Lockhart Creek and the south facing slopes within the Akokli Creek drainage is the dry mild subzone of the Interior Cedar – Hemlock zone, and within Lockhart Creek is the moist warm subzone of the Interior Cedar – Hemlock zone. Upslope of approximately 1600 m elevation lies the wet mild subzone of the Engelmann Spruce – Subalpine Fir zone. Based on the precipitation modeling available from ClimateBC_Map, the mean annual precipitation within the burn area ranges from approximately 800 mm to 1200 mm, generally increasing with elevation. This is generally consistent with reference data available from weather stations throughout the region.

The regional geology mapping as viewed in iMapBC indicates the burn area is underlain by primarily Proterozoic aged sedimentary and some metamorphic bedrock. The entire west facing slope between Lockhart Creek and Akokli Creek is mapped within the Horsethief Creek Group consisting of primarily phyllite, quartzite, and grit; this is consistent with field observations of phyllite and quartzite bedrock. Within Akokli Creek other sedimentary rock formations in the burn area include the Toby Formation of the Windermere Supergroup (conglomerate) and the Dutch Creek Formation and Creston Formation of the Purcell Supergroup (siltstone, argillite, quartzite, and dolomite).

Reconnaissance terrain stability mapping has been previously completed in the Akokli Drainage and on the west facing slopes and drainages between Lockhart Creek and Akokli Creek, but there is no available terrain stability mapping within the Lockhart Creek drainage. The majority of the main gully systems are classified as Potentially Unstable, but no Unstable terrain has been mapped (refer to Table 1 for more detailed area analysis).

5. Watershed Hazards and Burn Severity Mapping

Watershed boundaries in the area were delineated using LiDAR (LidarBC-Open LiDAR Data Portal sourced) derived 5 m contours for small drainages, and TRIM based 20 m contours for the large watersheds of Akokli Creek and Lockhart Creek. In areas where flood and debris flow hazards might be present, the watersheds were subdivided into smaller units to delineate drainage basins above alluvial fans. Many streams are not named on published maps, so some names used for watershed identification in this report are arbitrary.

An approximate index of potential debris flow hazard is the Melton or relief ratio (which is the elevation range divided by the square root of watershed area). Based on research completed in B.C. (Wilford et al. 2009), if the relief ratio is greater than 0.6, then the watershed is likely to be susceptible to debris flows; if between 0.3 and 0.6, to debris floods. This is a very rough guideline and debris flow susceptibility depends on many other geologic and hydrologic factors, but the relief ratio is useful to help confirm the field assessment of watershed hazards. The relief ratio is included in Table 2 for relevant watersheds.

Table 2. Watershed Characteristics

Watershed	Mack	Holiday	McGregor	Charles	Akokli	Lockhart
Area (km^2)	3.5	2.5	3.6	1.3	52.1	37.4
Length (km)	3.5	2.7	3.0	2.2	12.8	9.8
Elevation Range (m)	625-2070	660-2100	620-2200	640-1600	560-2600	600-2380
Melton ratio	0.74	0.92	0.80	0.84	0.22	0.29
Typical channel slope, mid-watershed	30%	55%	30%	35%	15%	8%
Typical channel slope, headwaters	50%	50%	55%	50%	15%	35%
Terrain stability "V" or "U"	0%	0%	0%	0%	2%	-
Terrain stability "IV" or "P"	44%	32%	48%	23%	44%	-
"Gentle-over-steep" (burn on plateau draining into steep channels)	No	No	Yes	No	No	No
Main channel riparian zone severely burned	No	No	Yes	No	No	No
Burn Severity: H	1%	3%	3%	0%	3%	2%
Burn Severity: M	38%	50%	52%	12%	11%	10%
Burn Concentrated in:	Mid-upper elev.	Upper elev.	Upper elev.	Mid-upper elev.	Mid-elev. south aspect	Mid-elev. North aspect
Fan or Deposition Slope	10% to 21%	13% to 25%	13% to 16%	15% to 25%	5% to 20%	7% to 10%

Burn severity maps are used to assess the potential hydrologic effects of the fire in each watershed due to forest cover and soil changes. The definitions of high, moderate, and low vegetation burn severity (VBS) are given in Hope et al. (2015) and Parsons et al. (2010), as well as the procedure for preparing a burn severity map. Briefly, the vegetation burn severity categories are:

- High – trees dead (black); needles, twigs, and understory consumed
- Moderate – trees dead (orange); scorched needles remain on trees, understory burned
- Low – trees live (green); canopy mostly unburned, understory lightly burned.

Soil burn severity (SBS) is similarly classified as high, moderate, or low, and is based on the extent of consumption of the forest floor and fuels on the ground, and on the extent of exposed bare soil:

- High – forest floor and near-surface roots consumed, mineral soil structure altered
- Moderate – litter consumed, duff partly consumed or charred, mineral soil unaltered

- Low – litter scorched or partly consumed, often with patchy forest floor burn.

Vegetation and soil burn severity are usually, but not always, fairly well correlated. For example, a high VBS site most commonly has a high SBS, though may have moderate SBS and is unlikely to have a low SBS. Water repellency is often, but not always, present on high SBS sites. Where SBS is high, the infiltration capacity of the soil and storage capacity of the forest floor is often greatly reduced, and overland flow may be generated during heavy rain. If this occurs over large areas, soil erosion and downstream flooding can occur. If water repellency is present, the amount of overland flow can be considerably greater. Where VBS is moderate, dead needles remain on the trees. These soon fall, often covering the ground with an effective mulch which promotes infiltration and reduces erosion and the likelihood of overland flow. Therefore, fire related flood and debris flow hazards from rainstorms are generally high only where both VBS and SBS are high.

Increased flood hazard during spring snowmelt is due to loss of the forest canopy, which results in both a higher winter snowpack and more rapid snowmelt. The effect is similar to that of clearcutting. However, in the first one or two years, the effect of fire may be greater than clearcutting, due to the black colour of burned tree trunks and the soot and debris which falls on the snow. The reduced water storage and run-off attenuation from the loss of the litter and/or duff may also contribute to increased freshet related flood hazard although this is less of a factor during freshet as the litter/duff storage capacity is typically reduced in the during freshet. Also, because there is no longer transpiration from trees and understory vegetation, the water table and soil moisture may be higher when winter comes. The flood hazard in a watershed is a function of the area burned at high and moderate VBS; low VBS sites (in which many trees and shrubs have survived) generally do not contribute significantly to flood hazard.

A burn severity or Burned Area Reflectance Classification map (BARC) was prepared by FLNRORD both at the provincial and regional level, based on Sentinel 1 and Landsat 8 satellite images (pre and post fire). The two maps differed slightly in the classification of and extent of VBS. The authors compared the map results with their ground and aerial surveys and determined the most representative map was a combination of the two created by filling in the unburned area of the provincial map with the data from the regional map which included more low burn severity in these areas. Some additional edits to the burn severity polygons were made in some cutblocks in the Akokli Creek drainage where BARC mapping appeared to misrepresent ground conditions based on field observations. The burn severity map used in this report and believed to be suitably representative of the Soil Burn Severity for the purpose of this assessment is shown in Map 1 Appendix A.

A complete table of burn severities by watershed along with the watershed boundaries are shown on Map 1 Appendix A. In addition to the low, moderate, and high drainage VBS categorization, a weighted burned area classification (referred to as the effective burn severity index (EBSI)) was also used to assess the landslide hazard. The EBSI is calculated as the sum of 100% of the area of the high burn severity plus 50% of the area of moderate burn severity divided by the drainage area. If an area with an EBSI of greater than approximately 50% is situated at or above potential landslide initiation locations, then there is likely to be a significant increase in landslide hazard. Landslide occurrence is not only a function of the extent of moderate or high burn severity within a drainage area, but also depends on where the burn occurs within a watershed. High burn severity areas within the upper steep portions of small watersheds can be more hazardous than a similar burn severity located at the lower parts of a drainage where debris flow initiation is lower due to decreased sediment availability and increased channel stability.

Field data on vegetation and soil burn severity were collected at a limited number of ground plots, with more general visual observations made throughout the field assessments. The field observations were used to check the accuracy of the high, moderate, low, and unburned categories on the BARC map. The field observations were found to correspond reasonably well to the BARC map categories; however, some adjustments to the map were required as previously noted. Water repellent soils were found at most plots with high SBS.

Based on the above factors relating to the incremental increase in likelihood of landslides and flooding hazards, in addition to the watershed conditions, hazard ratings have been assigned for select drainages identified on Map 1 Appendix A. The estimated hazard by drainage is shown in Table 3 below.

Table 3. Hazard estimate by drainage

Drainage Name	Hazard	Burn Severity Description	Process	Value at Risk
Akokli Overall	Low	13% moderate and 3% high	Flood, stream blockage outflow	Highway 3A, Houses, Domestic, Irrigation, Industry Water Licenses
A1	High	58% moderate, 18% high overall but concentration in upper drainage	Debris Flow	FSR
A2	High	58% moderate, 20% high	Debris Flow	FSR
A3	High	59% moderate, 33% high	Debris Flow	FSR
A4	High	50% moderate, 21% high overall but concentration upper drainage	Debris Flow	FSR
A5	High	65% moderate, 30% high	Debris Flow	FSR
Charles Upper	Low	22% moderate, 0% high	Debris Flow	Houses, Highway 3A
Charles McGregor Face	Low	39% moderate, 2% high	Debris Slide	Houses, Highway 3A, Domestic and Irrigation Water Licenses
McGregor All	Moderate to High	52% moderate, 3% high overall but MacGregor Tributary 1 has 73% moderate burn severity and 12% high and located in upper drainage	Debris Flow	Houses, Highway 3A, Domestic, Irrigation, Livestock Water Licenses
McGregor - Holiday Face	Low	26% moderate, 0% high	Debris Slide	Houses, Highway 3A, Domestic, Irrigation Water Licenses
Holiday	Moderate	50% moderate and 3% high overall and Holiday Upper has 55% moderate and 5% high	Debris Flow	Houses, Highway 3A, Domestic, Irrigation, Commercial Water Licenses
Mack	Moderate	38% moderate, 1% high overall but Mack upper has 47% moderate, 2% high	Debris Flow	Houses, Highway 3A, Domestic, Irrigation, Commercial Water Licenses
L1	High	36% moderate, 35% high	Debris Flow	
Lockhart Overall	Low	10% moderate, 2% high	Flood, stream blockage outflow	Highway 3A, Houses, Provincial Campsite, Cabins, Domestic, Irrigation, Commercial Water Licenses

Photos 5 through 8 are heli-overview photos of the site while Photos 9 through 11 are example photos of high burn severity areas at ground sites.

Photo 5. Mack Creek and Holiday Creek

Photo 6. McGregor Creek

Photo 7. Lower Akokli

Photo 8. Upper Akokli

Photo 9. Example of high burn severity area - Akokli Drainage

Photo 10. Example of high burn severity area

Photo 11. High burn severity in drainage A1

5.1. Comparison with Kuskonook and Jansen Creek drainages (2004 debris flows)

On August 7, 2004 debris flows occurred in the Kuskonook Creek and Jansen Creek watersheds as a result of an intense summer rainstorm and the 2003 Kuskonook wildfire effects. The estimated debris flow volume at Kuskonook was 25,000 m^3. The estimated burn severity in the Kuskonook Creek drainage (area 4.59 km^2) was 31% moderate and 17% high, and in the Jansen Creek drainage (area 3.66 km^2) 18% moderate and 10% high. Figure 3 shows the location of the high burn in the upper part of the watershed where the burn severity (combination of moderate and high) approached 80% to 90% with a significant proportion of this high burn severity. Most of the overland flow was produced in fairly gently sloping areas near the top of the watershed at about 1800 m to 2050 m elevation.

Table 4 is a summary of characteristics of the Kuskonook Creek and Jansen Creek.

Table 4. Characteristics of the Kuskonook Creek and Jansen Creek drainages

Watershed	Kuskonook	Jansen
Area (ha)	504	351
Elevation range (m)	560-2130	560-2120
Relief (m)	1570	1560
Melton ratio	0.70	0.83
Typical fan slope	17%	26%
Typical channel slope, mid-watershed	35-50%	35-65%
Typical channel slope, headwaters	20-65%	60-70%
Terrain stability "U"	0	0
Terrain stability "P"	22%	43%
Fan identified in previous mapping as subject to debris flows	yes	yes
Historical or air photo record of recent debris flows	no	no
"Gentle-over-steep" (burn on plateau draining into steep channels)	yes	yes
Mainstem channel riparian zone severely burned	no	no
Fan/channel morphology	subject to avulsion	subject to avulsion
Elements at risk	houses on fan (~6), highway, marina, water intakes	houses on fan (~2), highway
Burn severity: H	15%	10%
Burn severity: M	29%	19%
Burn concentrated in:	headwaters	headwaters

Kuskonook and Jansen Creek are located 15 km south of the Akokli Fire along similar (west) aspects. A comparison of the Kuskonook Creek and Jansen Creek watersheds with Mack Creek, Holiday Creek, and McGregor Creek indicates similarities in drainage size (all 2.5 km^2 to 5 km^2), Melton ratio's (0.70 to 0.92), fan slopes (17% to 25%) and typical headwaters channel slopes (50% to 70% excluding gentle above steep at Kuskonook); refer to Table 1, Table 3, Figure 2, Figure 3. However; Kuskonook Creek and Jansen Creek have more gentle-over-steep terrain in the upper watersheds.

Mack Creek, McGregor Creek and Holiday Creek are underlain by Proterozoic aged metamorphic rocks including phyllite and quartzite, while Kuskonook Creek and Jansen Creek are underlain by Mesozoic aged granodiorite intrusive rocks (granite, granodiorite, monzonoite) of the Mid-Cretaceous-Bayonne Assemblage (iMapBC). In general, there are coarser-textured (sandy) soils in the Kuskonook Creek and Jansen Creek watersheds, compared to Mack Creek, Holiday Creek and McGregor Creek. All drainages are considered debris flow prone based on these watershed characteristics and confirmed with evidence of past debris flows observed in the field (reforested debris flow deposits).

The burn severity comparison is somewhat different for McGregor Creek, Holiday Creek, and Mack Creek with significantly less high burn severity compared with Kuskonook Creek and Jansen Creek 2003 burn severity (see Table 2, 4, 5, Figure 2, 3).

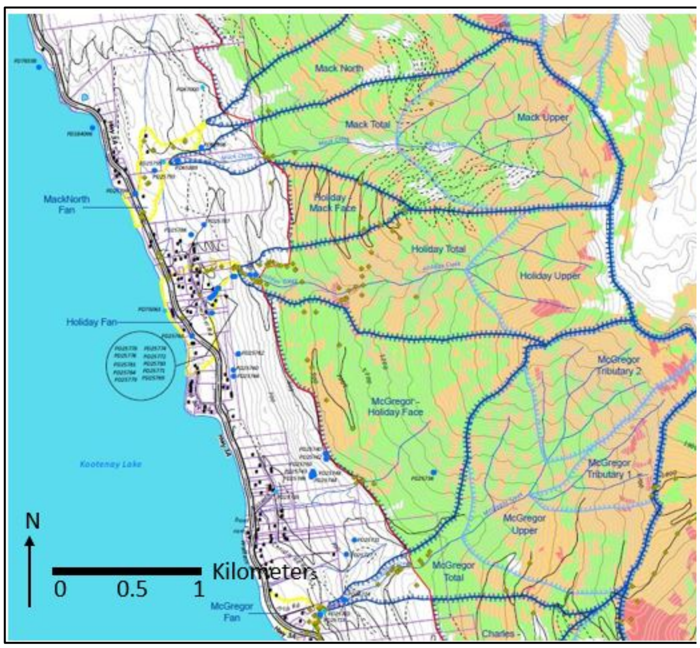

Figure 2. McGregor Creek, Holiday Creek, and Mack Creek Burn Severity Map

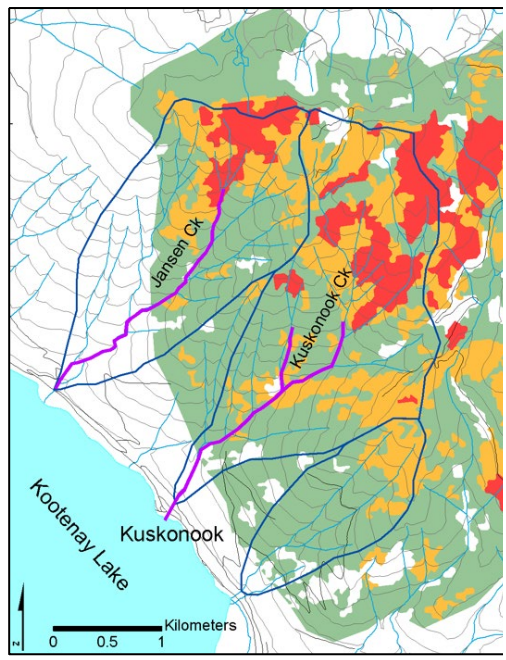

Figure 3. Kuskonook Creek and Jansen Creek burn severity (Jordan and Covert 2009)

Table 5. Comparison of drainages overall burn severity

Watershed	% High burn severity	% Moderate burn severity
McGregor	3	52
Holiday	3	50
Mack	1	38
Kuskonook	15	29
Jansen	10	19

The degree of high burn severity area especially when it occurs at the upper part of the watershed (as was the case in Kuskonook and Jensen drainages) would be expected to result in significantly increased surface runoff when compared to moderate burn severity area (McGregor, Holiday, and Mack drainages). While the hazard of debris flow initiation is estimated to be lower for these drainages, a significant rain event could still initiate debris flows.

6. Elements at Risk and Partial Risk for Drainages of Interest

Property, infrastructure, and water supplies are often at risk from post-wildfire hazards, such as flooding or landslides. These areas or sites are referred to as “elements at risk” and include the following:

- houses and other occupied structures
- highways and other transportation infrastructure (forest access roads)
- domestic water supplies
- linear infrastructure including hydro transmission lines
- campgrounds and parks

Some general information on potential risks is given here and more specific analyses of risks are described in the following sections and the accompanying tables. If any particular elements are not given any further mention, it is because no moderate or high risks were identified.

Houses and other buildings are shown on maps, based on TRIM data with additional information added from available imagery (Google Earth and RDCK web mapping service). Houses and other structures were considered to be at risk if they are located on alluvial or debris flow fans, near stream channels, or at the base of steep slopes below burned areas. Such sites comprise most of the risk elements in this study.

Most of the houses and infrastructure that could be at risk are located on the fans of Akokli Creek, McGregor Creek, Holiday Creek, Mack Creek, and Lockhart Creek. The fan boundaries of these creeks were delineated based on LiDAR data interpretation combined with limited field checking and comparison with previous mapping completed in the area.

Water license information was obtained from the BC Government water license query page, and from the POD (points of diversion) shown on iMap BC. There are several domestic licenses on smaller creeks, with a summary table presented in Appendix B. A partial risk assessment was not completed for every water intake or point of diversion. Instead, Table 3 should be referenced to determine the hazard relating to any one water intake.

A Fortis BC transmission line is located adjacent to Highway 3A. The location/risk relating to individual power poles were not reviewed as part of this assessment.

6.1. Akokli Creek

Akokli Creek has a large drainage area (52 km^2) with a Melton ratio of 0.22, a length of 12.8 km, and fan slope of 5%. The creek is not considered prone to debris flows and the overall burn severity (11% moderate and 3% high) is not considered enough to elevate the incremental post wildfire flood hazard above low. However, there are several steep drainages on the north side of Akokli Creek (A1 through A9 - See Map 1) that were burned up to 95% (combined moderate and high severity). Many of these drainages have a high likelihood of post wildfire debris flow initiation. Should a large debris flow occur in one of these drainages it has potential to transport debris all the way to Akokli Creek and cause a temporary blockage - which could result in one or more pulses of sediment laden flow that would have the potential to flood the fan. In fact, it is understood that in 2019 a landslide that occurred in a tributary drainage caused such a temporary blockage and the resulting outwash flows were as high as the lower part of a bridge girder log (Photo 12).

The MoTI Highway 3A bridge crossing Akokli Creek has good clearance with local bedrock outcrops near the footing locations (Photos 13 and 14).

Old levees and berms on private land were observed along some portions of the Akokli Creek channel particularly between the small bridge on the fan and the fan apex (Photo 15); however, there appears to be some low freeboard areas near the fan apex where high flows or a creek blockage could redirect flows onto the left portion of the fan (Photo 16). Typical development on the fan is shown in Photos 17 to 19 and consists of recreational trailers. There are also a couple of houses with year-round occupancy.

While the incremental post wildfire hazard is considered low for flooding and debris floods, if a large event were to occur the potential for the creek flows to be diverted out of the creek channel is considered high resulting in a MODERATE PARTIAL RISK to the buildings. The natural hazard of potential flooding/debris floods should be reviewed in light of what appears to be relatively low freeboard at the fan and the previous known events which nearly caused damage to the local bridge (refer to Recommendations Section 8.2).

Photo 12. Local bridge across Akokli Creek on the fan

Photo 13. MoTI Highway 3A Bridge

Photo 14. Akokli Creek Channel below MoTI Highway 3A Bridge

Photo 15. Berms constructed or reinforced on the Alokli Creek Fan

Photo 16. Low point near fan apex

Photo 17. Akokli Creek at distal end of fan

Photo 18. Typical development on the Akokli Creek fan

Photo 19. Typical development on the Akokli Creek fan

6.2. Charles Creek and Historical Landslides

In 1997 several landslides occurred in the Charles Creek drainage and to the south (Photos 20 and 21). Several site investigations were conducted with recommended works (Kokanee Forest Consulting Ltd. 1998, EBA 1997, EBA 1998, Skaha Consultants 2006). The details of these investigations will not be repeated here. Instrumentation (slope inclinometers and stand pipes) and horizontal drains were installed and monitored for about 15 years. The MFLNRORD no longer actively monitors the site.

There is very little burned area above these landslide locations and there is little increase in hazard due to the wildfire. However, the area has historical instabilities and in fact a recent landslide (not wildfire related) was reviewed by one of the authors during the review of fire guards. The landslide is located below the McGregor FSR on the south side of the Charles Creek drainage (see Photos 22 and 23).

Based on the above observations, the partial risk to residences and Highway 3A on the Charles Creek fan is estimated to be LOW.

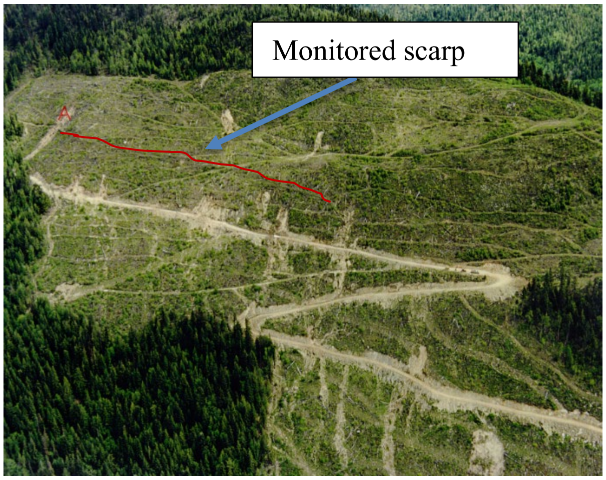

Photo 20. 1997 Charles Creek Landslides

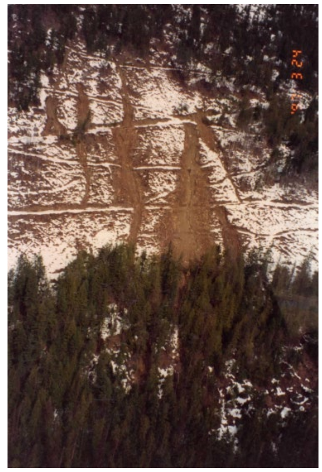

Photo 21. 1997 Charles Creek Landslides

Photo 22. 5 km McGregor FSR landslide

Photo 23. 5 km McGregor FSR landslide

6.3. McGregor Creek

McGregor Creek has a drainage area of 3.6 km^2. The McGregor Creek fan is a relatively steep debris flow prone fan. The Melton ratio for the watershed is 0.80. Refer to Appendix B for a profile of the main creek channel from the apex of the fan to the lake. This cross section through the fan indicates that the creek channel and fan surface gradient from the apex of fan to the lake varies from 15% to 25% and has an average total gradient as 20% (see Table 3). It also indicates that there are no significant grade breaks in the mainstream channel or on the fan surface, from the apex to Hwy 3A, that would serve to slow down the flow of a significant debris flow.

Upstream of the road crossing the channel is well incised with a 25% to 30% channel gradient. Adjacent to the channel the soil burn severity is predominantly low, with some areas of moderate soil burn severity. Thick colluvial deposits alongside of the channel with boulders to 60 cm diameter in the channel are a result of past debris flow activity older than the life of the forest. Considering likely debris flow scour rates and landslide volumes based on observations of past events in similar drainages within the region, with no bedrock in the channel and thick sediment deposits, entrainment rates are estimated to be on the order of 6 m^3/m in the event of a significant debris flow.

Figure 4 shows the debris flow susceptibility mapping available from the BGC Cambio Community Application (2020).

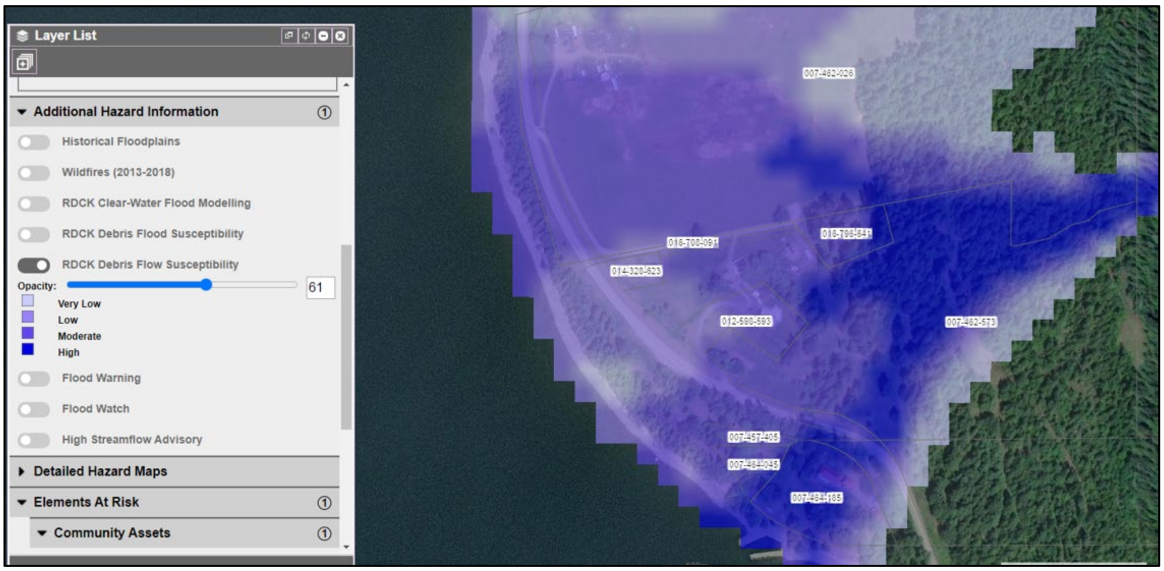

Figure 4. Debris Flow Susceptibility Map for McGregor Creek fan – Source: BGC Cambio Community Mapping.

Figure 5 shows four houses and a cemetery on the fan. The creek channel is well incised from the apex of the fan to Hwy 3A (Photo 24). However, there is man-made obstruction in the gulley at the apex of the fan in the form of a road crossing and water intake pond (Photo 25).

During a debris flow event there is a moderate likelihood that water and debris will be forced out of the gulley by this obstruction resulting in overland flow down the south or north side of the fan towards the houses resulting in a MODERATE TO HIGH PARTIAL RISK TO THE HOUSES/RESIDENTS. The likelihood of this occurring can be reduced with the removal of the road crossing and water intake pond. In addition, the likelihood of a channel avulsion at this location could be reduced by the construction of a berm across the road on the south side of the channel and an excavation of material on the north side as shown in Photo 25. The berm on the south side would reduce the likelihood of debris flow material flowing down the fan towards the house at 12185 Hwy 3A. The excavation on the north side would encourage overflow from the gulley on the north side to flow to the north into an open field away from the three houses (12260, 12220 & 12252) and the cemetery. Photo 26 is a photograph of the open field on the north side of the fan.

Individual home owners may be able to further mitigate the hazard by constructing a debris flow deflection berm or berms upslope of their house provided the berm(s) does not re-direct flows or debris towards other residences on the fan (refer to Recommendations Section 8.3).

Figure 5. McGregor Creek fan elements at risk

Photo 24. View of McGregor Creek channel mid slope on fan

Photo 25. Water intake pond and road crossing at apex of McGregor Creek fan

Photo 26. View looking north west to runout area for debris flowing to the north from the apex of the fan

6.4. Holiday Creek

Holiday Creek has a drainage area of 2.5 km^2. The fan is a steep debris flow prone landform with an average gradient of 23% (refer to profile in Appendix B). The Melton ratio for the watershed is of 0.92. The stream remains confined upslope of fan apex, with debris flow deposits near the apex of the fan including boulders up to 1.5 m diameter. There are well defined debris flow levees adjacent to the channel near 700 m elevation, but mature timber at edges of channel throughout the lower and mid elevations of the gully system which indicate there have been no destructive debris flow events within the life of the forest. Soil burn severity is predominantly low near the gully bottom, with some areas of moderate soil burn severity. Based on channel properties and in comparison with past debris flow events in similar drainages within the region, entrainment rates on the order of 3 m^3/m to 8 m^3/m are estimated to be possible in the event of a significant debris flow, with local variability based on extent of bedrock control at and adjacent to the channel.

Figure 6 shows the debris flow susceptibility mapping available from the BGC Cambio Community Application (2020).

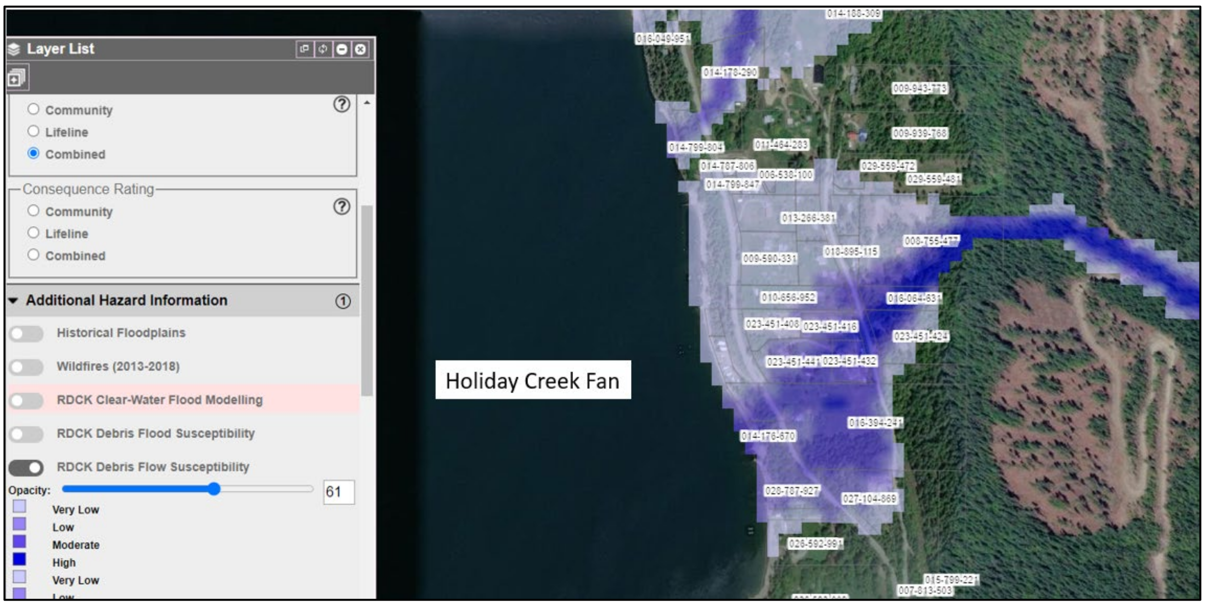

Figure 6. Debris Flow Susceptibility Map for Holiday Creek fan – Source: BGC Cambio Community Map (2020)

Figure 7A, taken from the RDCK webmap, indicates that there are eight houses on the east (upslope) side of Hepher Road, 14 houses between Hepher Road and Hwy 3A and three houses between Hwy 3A and the lake. The fan boundaries estimated using LiDAR imagery (Figure 7B) shows similar house numbers except for 9 houses (instead of 3) between Hwy 3A and the lake. The exact fan boundary was not located in the field. The boundaries presented in Figures 7A and 7B should be taken as approximations - houses located near the boundary could still be at risk even if shown to be located outside the delineated fan boundary.

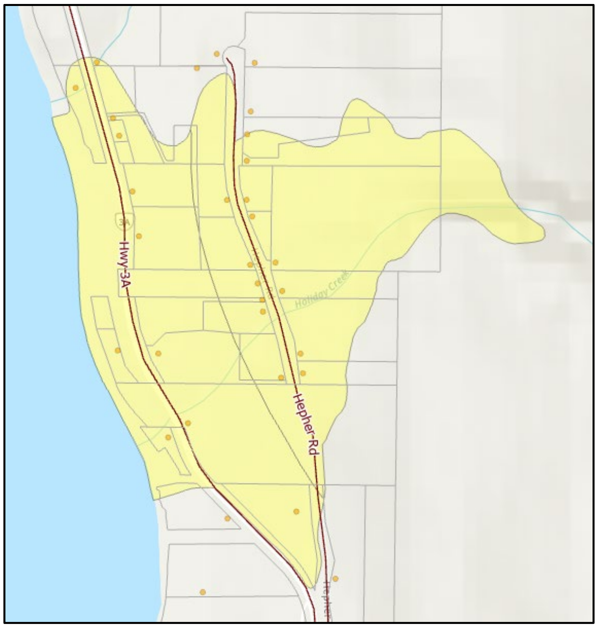

Figure 7A. Source RDCK webmap

Figure 7B. LiDAR based delineation

As shown on the fan profiles in Appendix B, the channel and fan surface gradient from the apex of the fan to Hepher Road is 20% to 25%. Channel obstructions, both anthropogenic (Photo 27) and natural (Photo 28), render it difficult to impossible to predict where debris will flow on the fan surface during a significant event. Consequently, if a debris flow were to occur, there is a moderate to high likelihood that overland flow would reach and impinge upon any of the eight houses on the fan upslope from Hepher Road. Downslope of Hepher Road the gradient to the lake is significantly lower (15%). There is a moderate likelihood (if a debris flow were to occur) that overland flow will reach any of the 19 houses downslope of Hepher Road.

Based on the above observations and interpretations, there is estimated to be a MODERATE TO HIGH PARTIAL RISK TO THE HOUSES/RESIDENTS located above Hepher Road and a MODERATE PARTIAL RISK TO THE HOUSES/RESIDENTS below Hepher Road.

Photo 27. View looking downslope (west) at water intake on Holiday Creek

Photo 28. View looking downslope (west) at natural low confinement

Given the level of PWNHRA study, it is not possible to predict where debris material would flow on the surface of the fan during an extreme event. The only apparent method to reduce the hazard on the fan would be to construct a debris flow containment structure or structures. Due to the high costs associated the design, land acquisition, construction and maintenance of these structures they have typically only been constructed to protect large communities.

It may be possible to protect individual houses by constructing relatively small berms and/or site grading at or near the houses to deflect and encourage overland flow away from the houses. However, the level of effort required to estimate the size and location of these berms and grading efforts for the number of houses on the fan is beyond the scope of this study. As described above, obstructions in the main gulley that currently conveys Holiday Creek from the apex of the fan to the Lake. At each of these sites, the low channel confinement increases the likelihood of debris flowing out of the main gulley and down the fan surface in one or more, difficult to predict, pathways. Consequently, without detailed investigations, it is not possible to accurately predict the volume and impact forces of debris flows that could reach a particular house to enable the design of a berm or berms and/or site grading efforts. In addition, each of these measures would have to be designed to ensure that it did not redirect debris flow towards another house and result in an increased hazard rating for that house.

As a result, no physical mitigation works are recommended at this time considering the scope of this assessment. However, it is recommended that further geotechnical assessment be considered by stakeholders to determine if there are any additional risk mitigation options available that don't at the same time increase the hazards to adjacent homeowners.

6.5. Mack Creek

Mack Creek has a drainage area of 3.5 km^2 and a Melton ratio of 0.74. The Mack Creek fan is also debris flow prone. The overall gradient from the apex of the fan to the lake is 19% (refer to profile in Appendix B). There are reforested debris flow deposits in the lower channel near 910 m elevation where the stream gradient is 15% to 20%, with evidence of varied ages of deposits. Colluvial boulders in the channel typically range from 0.2 m to 0.6 m diameter but are up to 1.3 m diameter. Based on channel properties and in comparison with past debris flow events in similar drainages within the region, entrainment rates on the order of 5 m^3/m to 7 m^3/m have been estimated for an estimate of the size of a possible debris flow event considering on material availability and expected scour depths within the channel.

Figure 8 shows the debris flow susceptibility mapping available from the BGC Cambio Community Application (2020). Figure 9 shows the houses on the fan.

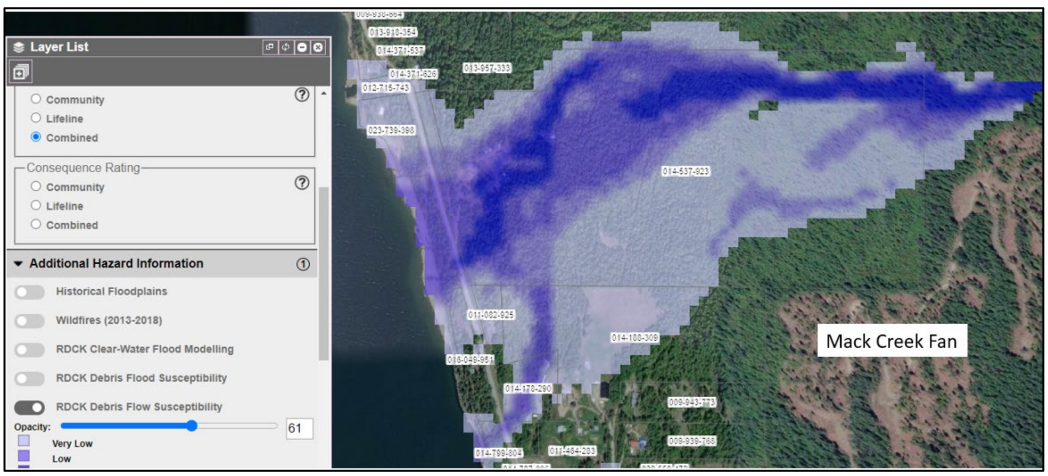

Figure 8. Debris Flow Susceptibility Map for Mack Creek fan – Source: BGC Cambio Community Map (2020)

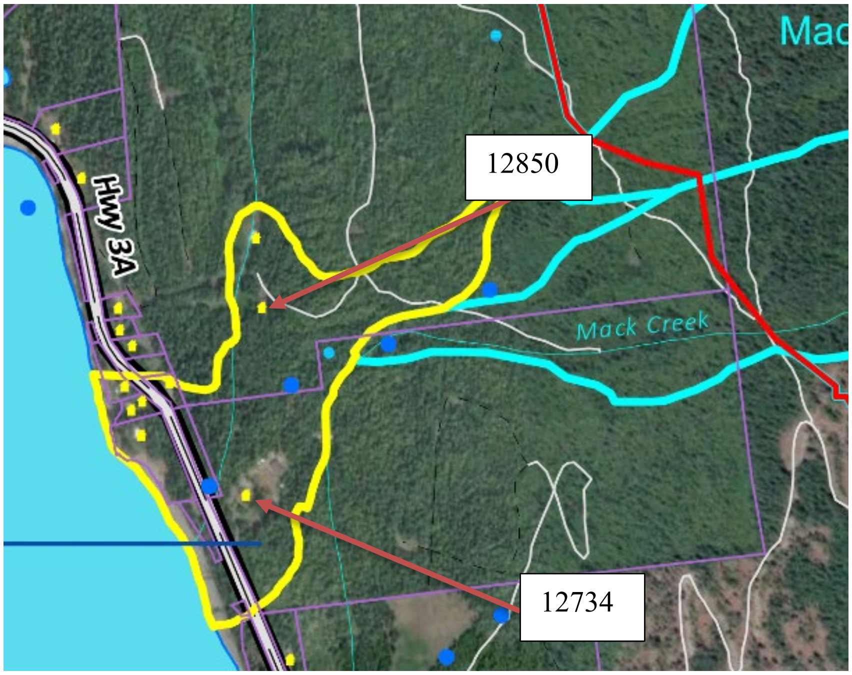

Figure 9. Mack Creek Fan showing houses on the fan – fan area is shown in yellow

While the overall fan surface gradient from the apex to the lake is 19%, the gradient from the apex to just above Hwy 3A is 15%. The dwelling at 12734 Hwy 3A is located approximately 400 m from the apex of the fan. The fan surface gradient upslope and proximal to the dwelling ranges from 8% to 14%. The PARTIAL RISK IS CONSIDERED LOW for this house location. This lower gradient and distance between the house and the apex of the fan, as well as the absence of gully features (Photo 29) that could direct flow towards the house renders the likelihood of debris flow material other than shallow slow moving sediment laden floodwaters reaching the houses as low.

The dwelling at 12850 Hwy 3A (Photo 30) located approximately 240 m from the apex of the North Mack Creek is also assessed with at LOW PARTIAL RISK. The fan surface gradient at the house is 16% and there are no gully features to direct flow towards the house.

Photo 29. View looking north at house at 12734 Hwy 3A. The fan slopes east to west. The house is located approximately 400 m from the apex of the fan.

Photo 30. View looking south at house at 12850 Hwy 3A. The fan slopes left to right. The house is 240 m from the apex of the North Mack Creek fan.

6.6. Lockhart Creek

Lockhart Creek has a large drainage area (37 km^2) with a Melton ration of 0.29, a length of 9.8 km, and fan slope of 5%. The creek is not considered prone to debris flows and the overall burn severity (10% moderate and 2% high) is not considered enough to elevate the incremental post wildfire flood hazard above low. However, there are some steep drainages on the south side of Lockhart Creek (L1, L3, L4a - See Appendix A Map 1) that have burn severities of 71%, 60%, and 99% respectively (combined moderate and high burn severity). These drainages have a high likelihood of post wildfire debris flow initiation. Should a large debris flow occur in one of these drainages it has potential to run-out all the way to Lockhart Creek and cause a temporary blockage - which could result in one or more pulses of sediment laden flow that would have the potential to flood the fan.

The MoTI bridge over Lockhart Creek had clearance of 1.5 m at the time of the field review. On the downstream side of the left footing some erosion was occurring adjacent to the footing (Photos 31 and 32).

At the Lockhart Creek fan apex there is less than 2 m freeboard (Photo 33) and it is possible extreme flooding with debris could overtop at this location and flow over the left side of the fan (further upstream Lockhart Creek is incised in bedrock). There are five cabins (Photo 34) and an office/ house (Photo 35) between the creek and the access road that would be exposed to flooding and a marina business/restaurant below the highway (Photo 36).

While the incremental post wildfire hazard is considered low, if a large event were to occur the potential for the creek flows to be diverted out of the creek channel at the fan apex is considered high resulting in a MODERATE PARTIAL RISK to the local buildings. Consideration should be given by BC Parks to increase the freeboard at the fan apex to reduce the likelihood of the creek being diverted down the left side of the fan towards the cabins and houses (refer to Recommendations Section 8.2).

Photo 31. MoTI bridge over Lockhart Creek

Photo 32. MoTI bridge over Lockhart Creek

Photo 33. Lockhart Creek fan apex

Photo 34. Cabins left bank Lockhart Creek

Photo 35. Cabins and office/dwelling on Lockhart Creek fan.

Photo 36. Restaurant/business below Highway 3A on Lockhart Creek fan.

6.7. Partial Risk Summary for Select Drainages of Interest

The following table (Table 6) summarizes partial risk estimates for the select drainages of interest in terms of hazards and high value elements at risk.

Table 6. Partial Risk summary table for select drainages in the Akokli Fire.

Drainage Name	Hazard	Process	Value at Risk*	Likelihood of Spatial Effect P(S:H) x P(T:S)	Partial Risk (prior to any mitigation works)
Akokli Creek	Low	Flood, stream blockage outflow (Debris Flood)	Highway 3A, Houses, Cabins, RV's	High	Moderate
A1	High	Debris Flow	FSR	High	Very High
A2	High	Debris Flow	FSR	High	Very High
A3	High	Debris Flow	FSR	High	Very High
A4	High	Debris Flow	FSR	High	Very High
A5	High	Debris Flow	FSR	High	Very High
Charles Upper	Low	Debris Flow	Houses, Highway 3A	Moderate	Low
Charles McGregor Face	Low	Debris Slide	Houses, Highway 3A	Low	Very Low
McGregor	Moderate to High	Debris Flow	Houses, Highway 3A	Moderate	Moderate to High
McGregor - Holiday Face	Low	Debris Slide	Houses, Highway 3A	Low	Very Low
Holiday	Moderate	Debris Flow	Houses, Highway 3A	Moderate to High	Moderate to High (above Hepher Road) Moderate (below Hepher Road)
Mack	Moderate	Debris Flow	Houses, Highway 3A	Low	Low
Lockhart Overall	Low	Flood, stream blockage outflow (Debris Flood)	Houses, Highway 3A, Provincial Campsite, Cabins	High	Moderate

*Most of these drainages also have Domestic and Irrigation water licenses with many Commercial and Livestock licenses as well. Individual water license infrastructure was not reviewed. The Hazard ratings can be used to assess individual infrastructure risk.

7. Watershed Management Considerations

Salvage harvesting of burned areas has the potential to increase the associated hazards and risks associated with flooding and landslides. It is recommended that no salvage harvesting take place within the drainages where there is a Moderate or High likelihood of post wildfire landslide or flooding hazards without due consideration of the potential cumulative effects on hydrogeomorphic hazards within the watershed resulting from the wildfire, existing harvesting and resource roads, as well as planned forest development. The potential impacts to high value downslope elements at risk should be evaluated as part of this assessment.

8. Summary of Recommendations

The recommendations are not intended as an evaluation of the acceptability of either the present risk or residual risk given the implementation of a risk reduction strategy. In addition, some risk reduction strategies may result in increased risks for other downslope values so any measures implemented must consider the potential for both positive and negative consequences.

8.1. General Recommendations; all affected drainages

1. Residents and businesses located adjacent to the creeks and drainages discussed should be provided an electronic copy of this report. During periods of elevated risk: high flows during spring runoff (precipitation or snow melt driven), summer rain storm events, and fall storms with significant precipitation (generally with rain on snow events), residents should be diligent with regards to work/travel adjacent to the local creeks and be aware of any sudden changes to creek flows (rapid increase or decrease in flows, or flow pulses), colour, or debris (logs, boulders, sediment) transport. Residents should familiarize themselves with the creeks, their location relative to the creeks, and where damages would be sustained if flooding/debris flows were to occur. If changes are observed, they should be reported promptly to Emergency Management BC at 1 (800) 663-3456.
2. Residents should be vigilant by monitoring the creeks for turbidity and Environment Canada weather forecasts, and local weather conditions as spatial variability of precipitation rates can be significant in mountainous terrain and should be prepared to evacuate on short notice during times of elevated risk.
3. Residents should familiarize themselves with the *Landslide and Flooding Risks due to Wildfires* and the *Debris Flow Hazard Awareness in the Kootenay Region* brochures published by MFLNRORD, both of which are attached in Appendix D.

8.2. Akokli Creek

1. Akokli Creek fan berm condition/height/extent should be reviewed and raised/extended given what appears to be relatively low freeboard near the fan apex and the previous known events nearly causing damage to the local bridge.

8.3. McGregor Creek

1. Consideration be given to the removal of the road crossing and water intake pond and construction of a berm across the road and excavation of material on the north side near the fan apex.

2. Individual homeowners may be able to further mitigate the hazard by constructing a debris flow deflection berm or berms upslope of their house provided the berm(s) does not re-direct flows or debris towards other residences on the fan.

8.4. Holiday Creek

1. There are no simple, low-cost risk reduction strategies available for the houses/residents of the Holiday Creek fan; however, it is recommended that further geotechnical assessment be considered by stakeholders to determine if there are any additional risk mitigation options available that don't at the same time increase the hazards to adjacent homeowners

8.5. Lockhart Creek

1. MoTI should inspect and repair scour under left bank footing of Highway 3B crossing of Lockhart Creek.
2. BC Parks should consider adding a berm at the fan apex (left side) to reduce likelihood of Lockhart Creek being diverted to the left side of the fan towards cabins and houses.

8.6. MFLNRORD and Forest Licensees

1. It is recommended that no salvage harvesting take place within the drainages where there is a Moderate or High likelihood of post wildfire landslides without due consideration of the potential cumulative effects on hydrogeomorphic hazards within the watershed resulting from the wildfire, existing harvesting and resource roads, as well as planned forest development. The potential impacts to high value downslope elements at risk should be evaluated as part of this assessment.
2. Increased inspection frequency of roads and culverts is required for the next three to five years - at least twice per year and following significant rain events.
3. Existing non-status road and trail systems within the Mack Creek, Mack North, and MacGregor Creek drainages should be reviewed for potential drainage diversions or terrain stability concerns which could be heightened by the wildfire, with mitigation works considered if sufficient concerns are identified.

9. Closure – Report Use and Limitations

This report was prepared for the exclusive use of the MFLNRO. The material in it reflects SNT Geotechnical Ltd.'s best judgment and professional opinion in light of the information available to it at the time of preparation. Any use which a third party makes of this report or any reliance on or decision to be made based on it are the responsibility of such third parties. SNT Geotechnical Engineering Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decision made or action based, or lack thereof, on this report. No other warranty is made, either expressed or implied.

The report and assessment have been carried out in accordance with generally accepted professional practices in B.C. The discussion and recommendations presented are based on available information and limited field investigation and inferences from surficial features. No subsurface investigation was carried out as part of this assessment or development of conclusions or recommendations. Inherent variability in local precipitation, run-off conditions, soil and vegetation burn severity, surface and subsurface conditions may create unforeseen situations. Property boundaries (private, municipal, reserve, crown) referred to on maps and in the text were obtained via publicly available cadastral layers overlain onto orthoimagery and is approximate and may not be accurate for the purposes of locating risk mitigation strategies. Boundaries should be confirmed prior to design and implementation of risk mitigation strategies.

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Appendix A

Maps

Drainage Name	Total Drainage Area (ha)	Modified Vegetation Burn Severity			
		Area Unburned within drainage (%)	Area Low burn severity within drainage (%)	Area Moderate burn severity within drainage (%)	Area High burn severity within drainage (%)
A1	376	2	22	58	18
A2	32	0	23	58	20
A3	38	0	8	59	33
A4	43	0	30	50	21
A5	51	0	5	65	30
A6	147	0	31	57	12
A7	83	3	28	65	4
A7 Upper	65	4	23	68	5
A8	25	1	63	37	0
A9	55	37	29	33	1
Akokli South Face	1226	6	32	47	14
Akokli Total	5207	78	8	11	3
Charles – McGregor Face	59	12	47	39	2
Charles Total	126	40	48	12	0
Charles Upper	53	8	70	22	0
Holiday – Mack Face	40	1	42	57	0
Holiday Total	231	7	40	50	3
Holiday Upper	96	11	29	55	5
L1	61	0	29	36	35
L2	46	0	58	39	3
L3	89	14	26	54	6
L4	636	42	19	33	7
L4a	50	1	0	63	36
Lockhart North Face	213	25	49	26	0
Lockhart Total	3744	78	9	10	2
Mack North	101	15	52	32	0
Mack North – Lockhart Face	92	22	66	12	0
Mack Total	259	11	50	38	1
Mack Upper	162	6	45	47	2
McGregor – Holiday Face	201	2	72	26	0
McGregor Total	342	5	39	52	3
McGregor Tributary 1	59	0	15	73	12
McGregor Tributary 2	90	0	31	65	4
McGregor Upper	282	0	35	60	4

PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS;
BC WILDFIRE SERVICE

AKOKLI FIRE #N71686
MAP 1:
AKOKLI FIRE ADJUSTED VEGETATION BURN SEVERITY

CONTOUR (LIDAR DERIVED): INDEX/INTERMEDIATE — 100m 20m
STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
POWERLINE
WATERSHED BOUNDARY
WATERSHED SUB-BASIN BOUNDARY
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
STRUCTURES
FIRE PERIMETER
MODIFIED VEGETATION BURN SEVERITY RATING
HIGH
MODERATE
LOW
UNBURNED
FIELD OBSERVATION SITE
PROVINCIAL PARK / RECREATION SITE

PREPARED BY:
SNT GEOTECHNICAL LTD.
&
SITKUM CONSULTING LTD.

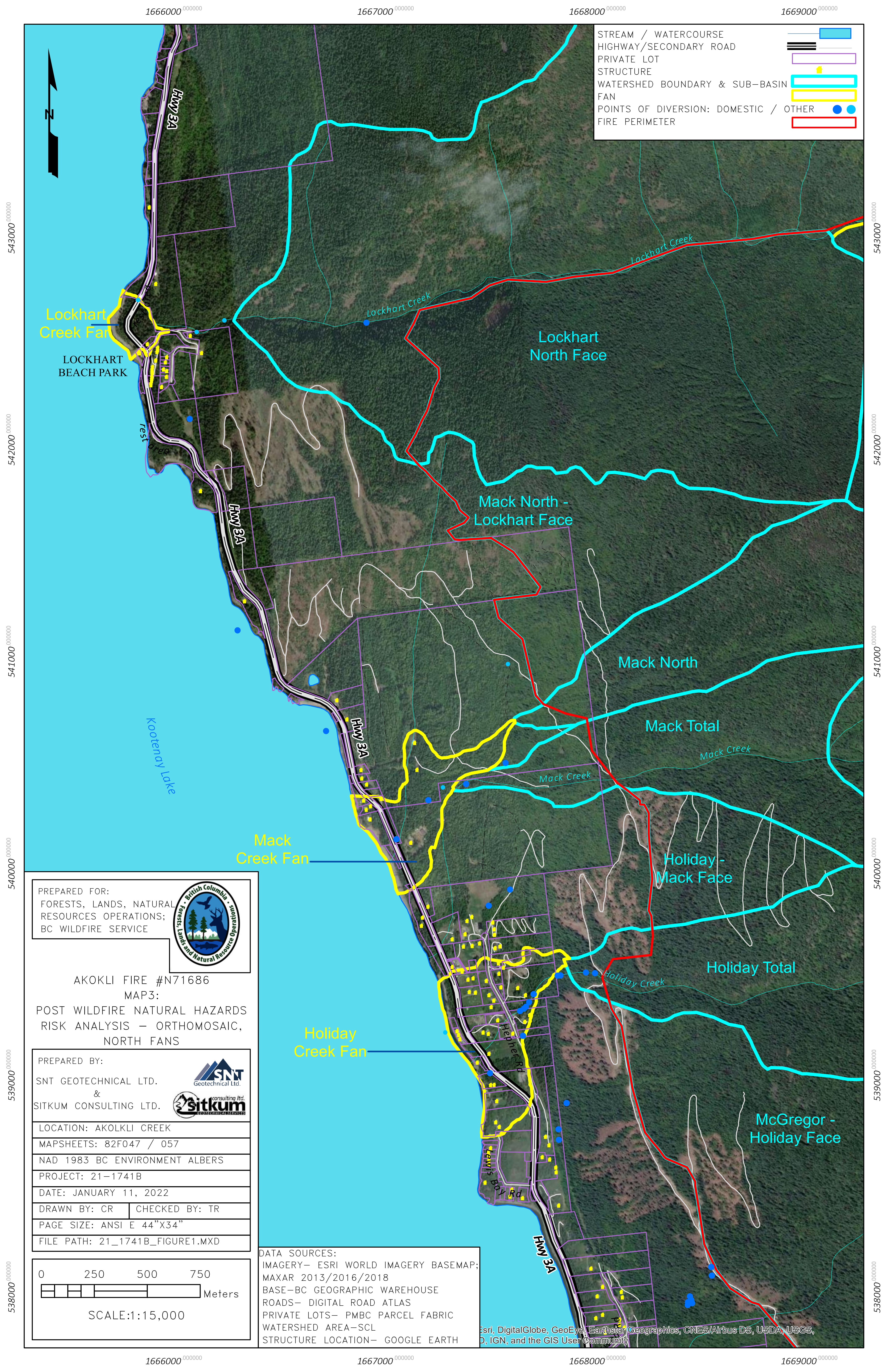
FIELD WORK IN THE BURNED AREAS WAS CONDUCTED ON OCTOBER 20 BY DOUG NICOL, P.ENG. (SNTG), PETE WITTSTOCK, P.ENG. (SNTG), DWAIN BOYER, P.ENG. (SNTG), TEDD ROBERTSON, P.GEO. P.L.ENG. (SCL), AND CAITLIN TATHAM, G.I.T. (SCL), ON OCTOBER 21 BY DOUG NICOL, TEDD ROBERTSON, AND CAITLIN TATHAM, AND ON NOVEMBER 10TH, BY DWAIN BOYER AND SARAH CROOKSHANKS, P.GEO. (MFLNRORD).
PREVIOUS FIELD WORK (INCLUDING AN AUGUST 19TH HELICOPTER RECONNAISSANCE) HAD BEEN CONDUCTED BY DOUG NICOL FOR THE PURPOSES OF REVIEWING THE DEACTIVATION OF GUARDS AND TRAILS CONSTRUCTED BY BC WILDFIRE SERVICE.

LOCATION: AKOKLI CREEK	
MAPSHEETS: 82F047 / 057	
NAD 1983 BC ENVIRONMENT ALBERS	
PROJECT: 21-1741B	
DATE: JANUARY 11, 2022	
DRAWN BY: CR	CHECKED BY: TR
PAGE SIZE: ANSI E 44"X34"	
FILE PATH: 21_1741B_FIGURE1.MXD	

DATA SOURCES:
LIDAR- LIDAR BC PORTAL
BASE-BC GEOGRAPHIC WAREHOUSE
ROADS- DIGITAL ROAD ATLAS
PRIVATE LOTS- PMBC PARCEL FABRIC
WATERSHED AREA-SCL
STRUCTURE LOCATION- GOOGLE EARTH
BURN SEVERITY POLYGONS- MODIFIED FROM MOF BARC LAYERS BASED ON FIELD OBSERVATIONS; REFER TO REPORT FOR METHODS

0 250 500 750 Meters
SCALE:1:15,000


PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS; BC WILDFIRE SERVICE
AKOKLI FIRE #N71686
MAP2 :
AKOKLI FIRE BARE EARTH MODEL
STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
POWERLINE
WATERSHED BOUNDARY
WATERSHED SUB-BASIN BOUNDARY
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
STRUCTURES
FIRE PERIMETER
FIELD OBSERVATION SITE
PROVINCIAL PARK / RECREATION SITE
PREPARED BY:
SNT GEOTECHNICAL LTD. & SITKUM CONSULTING LTD.
LOCATION: AKOKLI CREEK
MAPSHEETS: 82F047 / 057
NAD 1983 BC ENVIRONMENT ALBERS
PROJECT: 21-1741B
DATE: JANUARY 11, 2022
DRAWN BY: CR
CHECKED BY: TR
PAGE SIZE: ANSI E 44"X34"
FILE PATH: 21_1741B_FIGURE1.MXD
0 250 500 750 Meters
SCALE:1:15,000
FIELD WORK IN THE BURNED AREAS WAS CONDUCTED ON OCTOBER 20 BY DOUG NICOL, P.ENG. (SNTG), PETE WITTSTOCK, P.ENG. (SNTG), DWAIN BOYER, P.ENG. (SNTG), TEDD ROBERTSON, P.GEO. P.L.ENG. (SCL), AND CAITLIN TATHAM, G.I.T. (SCL), ON OCTOBER 21 BY DOUG NICOL, TEDD ROBERTSON, AND CAITLIN TATHAM, AND ON NOVEMBER 10TH, BY DWAIN BOYER AND SARAH CROOKSHANKS, P.GEO. (MFLNRORD).
PREVIOUS FIELD WORK (INCLUDING AN AUGUST 19TH HELICOPTER RECONNAISSANCE) HAD BEEN CONDUCTED BY DOUG NICOL FOR THE PURPOSES OF REVIEWING THE DEACTIVATION OF GUARDS AND TRAILS CONSTRUCTED BY BC WILDFIRE SERVICE.
DATA SOURCES:
LIDAR- LIDAR BC PORTAL
BASE-BC GEOGRAPHIC WAREHOUSE
ROADS- DIGITAL ROAD ATLAS
PRIVATE LOTS- PMBC PARCEL FABRIC
WATERSHED AREA-SCL
STRUCTURE LOCATION- GOOGLE EARTH
BURN SEVERITY POLYGONS- MODIFIED FROM MOF BARC LAYERS BASED ON FIELD OBSERVATIONS; REFER TO REPORT FOR METHODS
Lockhart Creek Fan
LOCKHART BEACH PARK
L1 Fan
L2 Fan
L3 Fan
L4 Fan
Lockhart Total
Lockhart North Face
L2
L3
L4a
LOCKHART CREEK PROVINCIAL PARK
Mack North Lockhart Face
Mack North
Mack Total
Mack Upper
Mack Creek Fan
Holiday Mack Face
Holiday Total
Holiday Upper
Holiday Creek Fan
McGregor Tributary 2
McGregor Holiday Face
McGregor Tributary 1
McGregor Upper
McGregor Total
McGregor Creek Fan
Kootenay Lake
Charles McGregor Face
Charles Upper
Charles Total
Charles Creek Fan
Boswell
Destiny Bay
Akokli Creek Fan
Hwy 3A
REC2114 BAKER LAKE
REC2305 SHERMAN LAKE
Akokli Mountain
Mount Goodwin
A1
A1 Fan
A2 Fan
A3 Fan
A4 Fan
A6 Fan
A7 Fan
A9 Fan



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N
STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
STRUCTURE
WATERSHED BOUNDARY & SUB-BASIN
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
FIRE PERIMETER
Hwy 3A
Lockhart Creek
Lockhart Creek Fan
LOCKHART BEACH PARK
Lockhart North Face
rest area
Mack North - Lockhart Face
Mack North
Mack Total
Mack Creek
Kootenay Lake
Mack Creek Fan
Holiday - Mack Face
Holiday Total
Holiday Creek
Holiday Creek Fan
Hepher Rd
Lewis Bay Rd
McGregor - Holiday Face
PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS; BC WILDFIRE SERVICE
British Columbia Forests, Lands and Natural Resource Operations
AKOKLI FIRE #N71686
MAP3:
POST WILDFIRE NATURAL HAZARDS RISK ANALYSIS – ORTHOMOSAIC, NORTH FANS
PREPARED BY:
SNT GEOTECHNICAL LTD.
&
SITKUM CONSULTING LTD.
SNT Geotechnical Ltd.
sitkum consulting ltd.
LOCATION: AKOLKLI CREEK
MAPSHEETS: 82F047 / 057
NAD 1983 BC ENVIRONMENT ALBERS
PROJECT: 21-1741B
DATE: JANUARY 11, 2022
DRAWN BY: CR
CHECKED BY: TR
PAGE SIZE: ANSI E 44"X34"
FILE PATH: 21_1741B_FIGURE1.MXD
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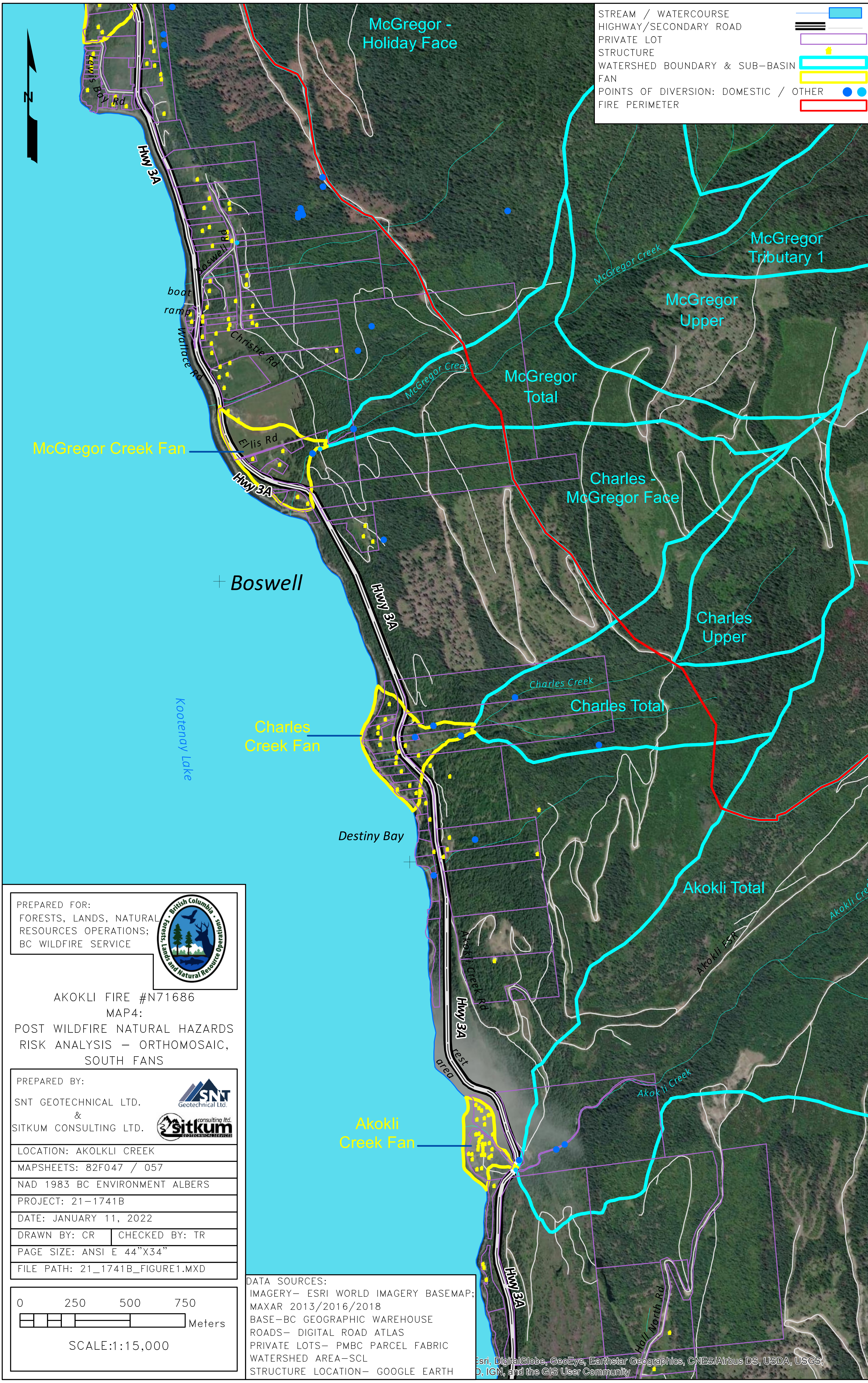
Meters
SCALE:1:15,000
DATA SOURCES:
IMAGERY– ESRI WORLD IMAGERY BASEMAP; MAXAR 2013/2016/2018
BASE–BC GEOGRAPHIC WAREHOUSE
ROADS– DIGITAL ROAD ATLAS
PRIVATE LOTS– PMBC PARCEL FABRIC
WATERSHED AREA–SCL
STRUCTURE LOCATION– GOOGLE EARTH
Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IGN, and the GIS User Community



PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS; BC WILDFIRE SERVICE

AKOKLI FIRE #N71686
MAP4:
POST WILDFIRE NATURAL HAZARDS RISK ANALYSIS – ORTHOMOSAIC, SOUTH FANS

PREPARED BY:
SNT GEOTECHNICAL LTD.
&
SITKUM CONSULTING LTD.

LOCATION: AKOLKLI CREEK
MAPSHEETS: 82F047 / 057
NAD 1983 BC ENVIRONMENT ALBERS
PROJECT: 21-1741B
DATE: JANUARY 11, 2022
DRAWN BY: CR | CHECKED BY: TR
PAGE SIZE: ANSI E 44"X34"
FILE PATH: 21_1741B_FIGURE1.MXD

0 250 500 750 Meters
SCALE:1:15,000

DATA SOURCES:
IMAGERY– ESRI WORLD IMAGERY BASEMAP; MAXAR 2013/2016/2018
BASE–BC GEOGRAPHIC WAREHOUSE
ROADS– DIGITAL ROAD ATLAS
PRIVATE LOTS– PMBC PARCEL FABRIC
WATERSHED AREA–SCL
STRUCTURE LOCATION– GOOGLE EARTH

Appendix B

McGregor Creek, Holiday Creek and Mack Creek Fan Profiles

AKOKLI FIRE
MACK NORTH CREEK FAN

CROSS–SECTION | FIGURE: 1A

LOCATION: Boswell, B.C.
MAPSHEET / OPENING NO: 082F047
UTM ZONE & COORDINATES (POC cross–section): 11 516778E 5481760 N NAD: 83

PAGE SIZE: Ansi B 11"x17"
PROJECT: 21-1741b
FILENAME: Akokli-Fans-xSecs.dgn

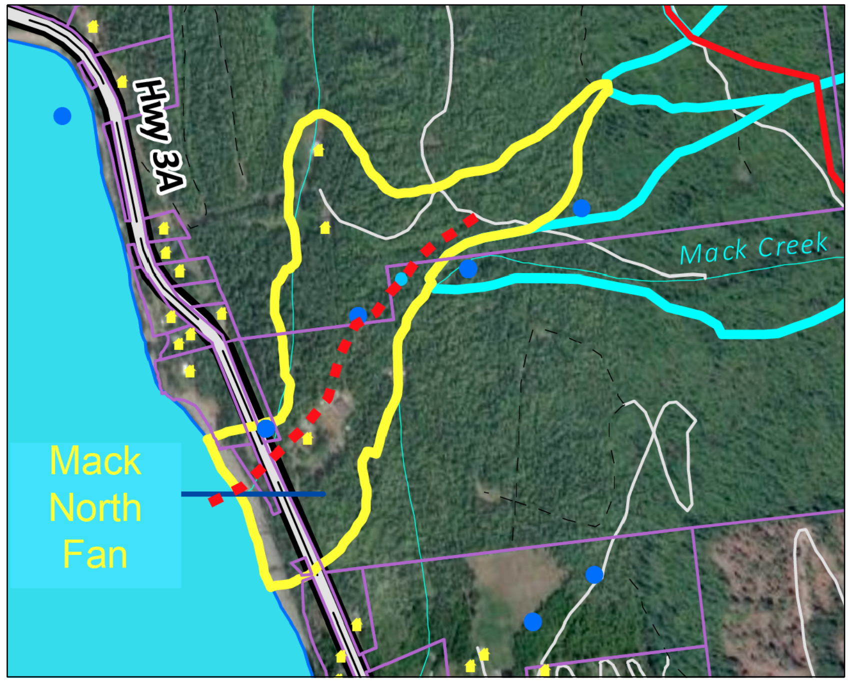
DATE: JAN.12, 2022
DRAWN: KA
CHECKED: TR

PRODUCED BY: SNT Engineering Ltd.; Sitkum consulting ltd. Geotechnical Services

0 — 100 Metre
SCALE 1:2000

PRODUCED FOR: Forest Service British Columbia; British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development

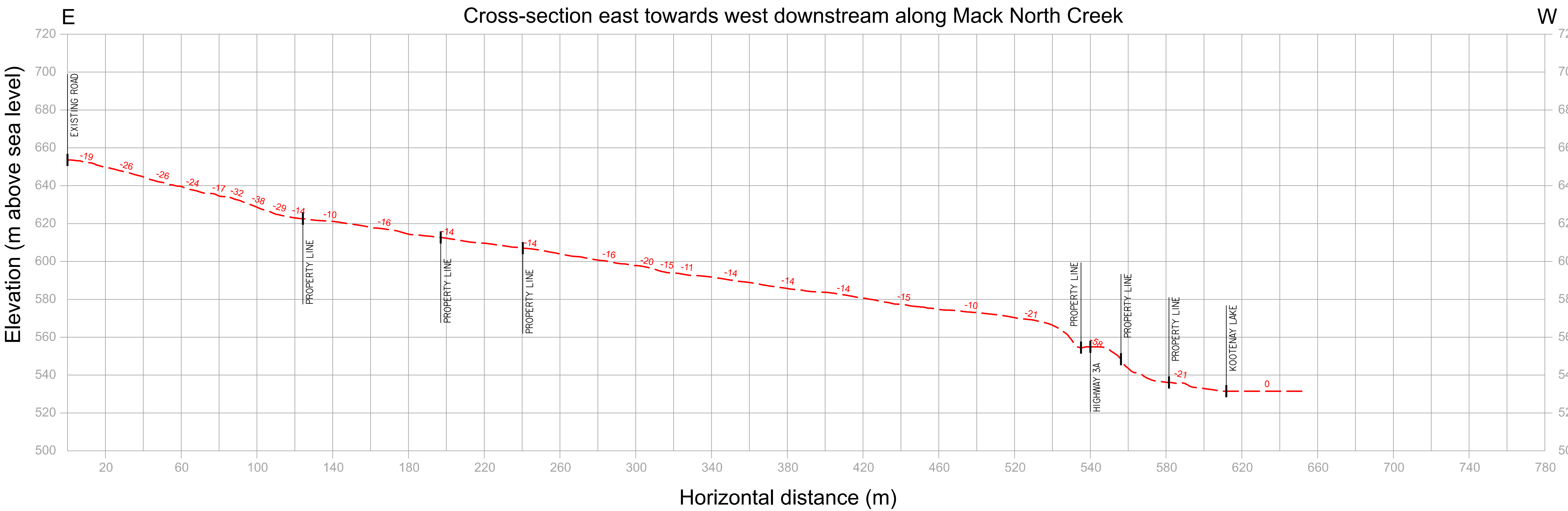
DATA SOURCE(S): LidarBC, TRIM



INSET IMAGE:
THE RED-DASHED LINEWORK IN THE IMAGE TO THE LEFT INDICATES THE APPROXIMATE LOCATION OF THE CROSS-SECTION.
IMAGE IS NOT TO SCALE.

LEGEND:

STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
STRUCTURE
WATERSHED BOUNDARY & SUB–BASIN
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
FIRE PERIMETER



AKOKLI FIRE McGREGOR CREEK FAN	LOCATION: Boswell, B.C.	PAGE SIZE: Ansi B 11"x17"	DATE: JAN.12, 2021
	MAPSHEET / OPENING NO: 082F047	PROJECT: 21-1741b	DRAWN: KA
	UTM ZONE & COORDINATES (POC cross-section): 11 517443E 5478073 N NAD: 83	FILENAME: Akokli-Fans-xSecs.dgn	CHECKED: TR
CROSS–SECTION	FIGURE: 1C	PRODUCED BY: SNT Engineering Ltd.; Sitkum consulting ltd. Geotechnical Services	

SCALE 1:2000 (0 – 100 Metre)

N

PRODUCED FOR: Forest Service British Columbia; British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development

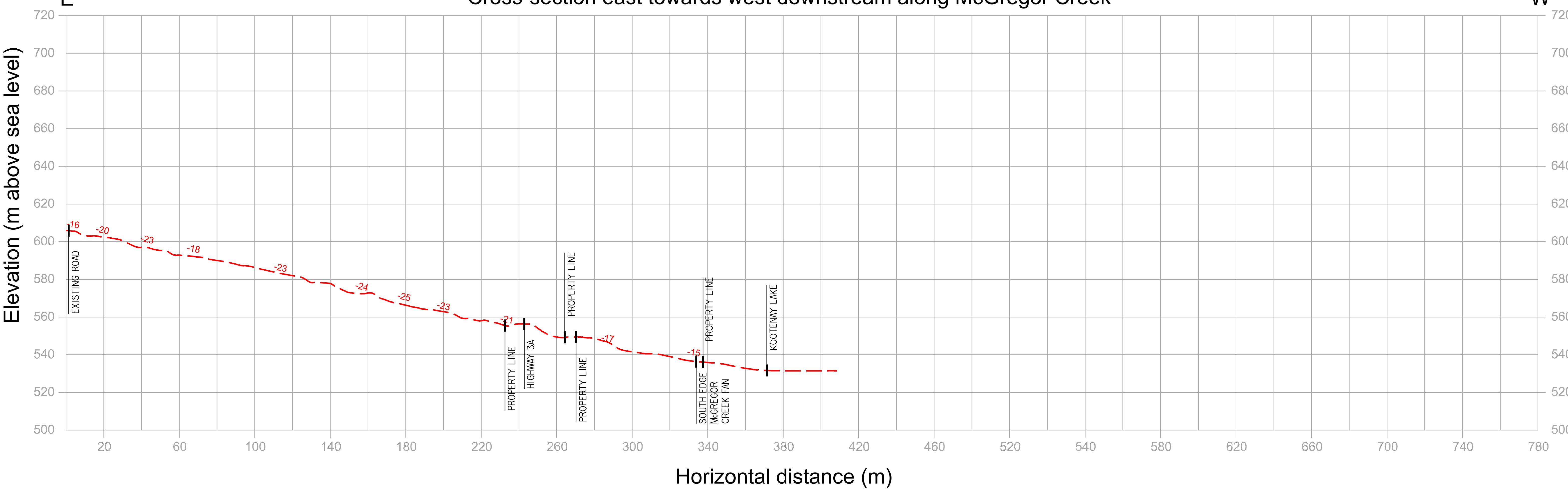
DATA SOURCE(S): LidarBC, TRIM

INSET IMAGE:
THE RED-DASHED LINEWORK IN THE IMAGE TO THE LEFT INDICATES THE APPROXIMATE LOCATION OF THE CROSS-SECTION.
IMAGE IS NOT TO SCALE.

LEGEND:

- STREAM / WATERCOURSE
- HIGHWAY/SECONDARY ROAD
- PRIVATE LOT
- STRUCTURE
- WATERSHED BOUNDARY & SUB–BASIN
- FAN
- POINTS OF DIVERSION: DOMESTIC / OTHER
- FIRE PERIMETER

Cross-section east towards west downstream along McGregor Creek



AKOKLI FIRE
HOLIDAY FAN

CROSS–SECTION | FIGURE: 1B

LOCATION: Boswell, B.C.	PAGE SIZE: Ansi B 11"x17"
MAPSHEET / OPENING NO: 082F047	PROJECT: 21-1741b
UTM ZONE & COORDINATES (POC cross–section): 11 517183E 5480731 N NAD: 83	FILENAME: Akokli-Fans-xSecs.dgn
DATE: JAN.12, 2022	DRAWN: KA
CHECKED: TR	

PRODUCED BY: SNT Engineering Ltd. / Sitkum consulting ltd. GEOTECHNICAL SERVICES

0 — 100 Metre
SCALE 1:2000

N

PRODUCED FOR: Forest Service British Columbia / British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development

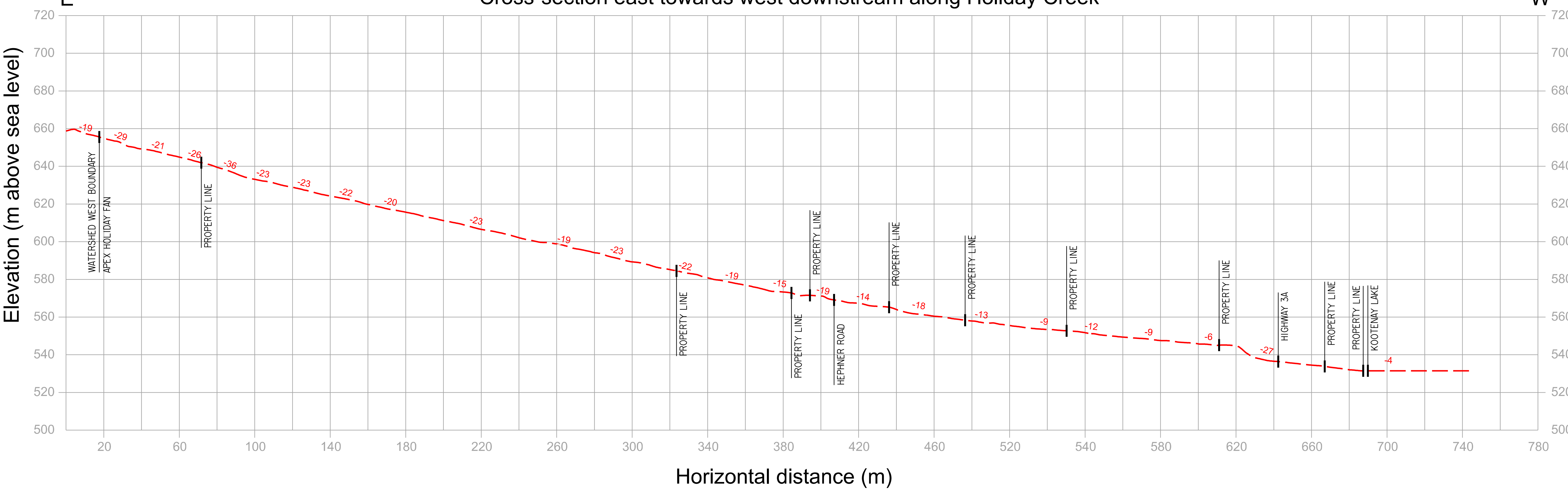
DATA SOURCE(S): LidarBC, TRIM

INSET IMAGE:
THE RED-DASHED LINEWORK IN THE IMAGE TO THE LEFT INDICATES THE APPROXIMATE LOCATION OF THE CROSS-SECTION.
IMAGE IS NOT TO SCALE.

LEGEND:

- STREAM / WATERCOURSE
- HIGHWAY/SECONDARY ROAD
- PRIVATE LOT
- STRUCTURE
- WATERSHED BOUNDARY & SUB–BASIN
- FAN
- POINTS OF DIVERSION: DOMESTIC / OTHER
- FIRE PERIMETER

Cross-section east towards west downstream along Holiday Creek



Appendix C

Water License Reports

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Lockhart Creek	Lockhart Creek	PD25804	C037145	Irrigation	49.5074879	-116.77122799
Lockhart Creek	Lockhart Creek	PD25804	C037145	Domestic	49.5074879	-116.77122799
Lockhart Creek	Lockhart Creek	PD25802	C114058	Local Waterworks	49.508362	-116.780384
Lockhart Creek	Lockhart Creek	PD25802	C114058	Commercial Enterprise	49.508362	-116.780384
Lockhart Creek	Lockhart Creek	PD74842	C114058	Local Waterworks	49.508024	-116.782278
Lockhart Creek	Lockhart Creek	PD74842	C114058	Commercial Enterprise	49.508024	-116.782278
Lockhart Creek	Lockhart Creek	PD192832	500542	Misc. Industry	49.509694	- 116.785786
Lockhart North Face	Johnson Spring	PD25797	F020439	Domestic	49.5044071	-116.78344599
Mack North - Lockhart Face	Frances Creek	PD6700	C105753	Irrigation	49.492325299	-116.764993
Mack North - Lockhart Face	Kootenay Lake	PD76598	C116982	Domestic	49.4952436	-116.782139
Mack North - Lockhart Face	Kootenay Lake	PD184096	C130057	Commercial Enterprise	49.4905162	-116.777294999999
Mack North - Lockhart Face	Kootenay Lake	PD184096	C130062	Commercial Enterprise	49.4905162	-116.777294999999
Mack Creek	Mack Creek	PD66996	C105751	Domestic	49.4881715	-116.765970999999
Mack Creek	Mack Creek	PD66996	C105752	Irrigation	49.4881715	-116.765970999999
Mack Creek (Mack North Fan)	Mack Creek	PD25795	C052397	Irrigation	49.4881715	-116.770219999999
Mack Creek (Mack North Fan)	Mack Creek	PD25793	F044503	Domestic	49.4870414	-116.771264
Mack Creek (Mack North Fan)	Mack Creek	PD25793	C100494	Domestic	49.4870414	-116.771264
Mack Creek (Mack North Fan)	Mack Creek	PD25799	F040389	Domestic	49.4855742	-116.77365
Mack Creek (Mack North Fan)	Mack Creek	PD25799	F040389	Domestic	49.4855742	-116.77365

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Mack Creek (Mack North Fan)	Mack Creek	PD25799	C130457	Domestic	49.4855742	-116.77365
Mack Creek (Mack North Fan)	Mack Creek	PD25799	C130551	Domestic	49.4855742	-116.77365
Mack Creek (Mack North Fan)	Mack Creek	PD25799	C113052	Domestic	49.4855742	-116.77365
Mack Creek (Mack North Fan)	Mack Creek	PD25799	C112289	Domestic	49.4855742	-116.77365
Mack Creek	Mack Creek	PD25799	F040387	Domestic	49.4855742	-116.77365
Mack Creek	Castro Spring	PD65889	C101135	Domestic	49.48751089999	-116.768697
Mack Creek	Castro Spring	PD65889	C103880	Domestic	49.48751089999	-116.768697
Mack Creek	Castro Spring	PD65889	C100446	Domestic	49.48751089999	-116.768697
Mack Creek	Castro Spring	PD65889	C101136	Domestic	49.48751089999	-116.768697
Mack Creek	Castro Spring	PD65889	C113365	Commercial Enterprise	49.48751089999	-116.768697
Holiday-Mack Face	Bains Spring	PD25787	C057990	Domestic	49.482823	-116.766760
Holiday-Mack Face	Bains Brook	PD25786	C058768	Domestic	49.482259	-116.768266
Holiday-Mack Face	Bains Brook	PD25786	C040913	Domestic	49.482259	-116.768266
Holiday Creek	Holiday Creek	PD25784	C051501	Domestic	49.478826	-116.761990
Holiday Creek	Holiday Creek	PD25784	C051501	Irrigation	49.478826	-116.761990
Holiday Creek	Holiday Creek	PD25783	C041245	Domestic	49.478902	-116.762555
Holiday Creek	Holiday Creek	PD25781	C058889	Irrigation	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	C134003	Irrigation	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	C134009	Domestic	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	F020484	Domestic	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	F020484	Domestic	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	C134004	Domestic	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	C051892	Domestic	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25781	C051892	Irrigation	49.478926	-116.764230
Holiday Creek	Holiday Creek	PD25779	F014152	Domestic	49.478924	-116.764413
Holiday Creek	Holiday Creek	PD25779	F014152	Irrigation	49.478924	-116.764413
Holiday Creek	Holiday Creek	PD25778	C110415	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C061946	Domestic	49.478293	-116.766115

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Holiday Creek	Holiday Creek	PD25778	C061946	Irrigation	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C060024	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C061947	Irrigation	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C110416	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C041089	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C041243	Irrigation	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	F014152	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	F014152	Irrigation	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C041138	Domestic	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25778	C041244	Irrigation	49.478293	-116.766115
Holiday Creek	Holiday Creek	PD25774	C032679	Irrigation	49.477973	-116.766471
Holiday Creek	Holiday Creek	PD25774	C128551	Domestic	49.477973	-116.766471
Holiday Creek	Holiday Creek	PD25774	C128551	Irrigation	49.477973	-116.766471
Holiday Creek	Holiday Creek	PD25776	F014152	Domestic	49.477799	-116.766727
Holiday Creek	Holiday Creek	PD25776	F014152	Irrigation	49.477799	-116.766727
Holiday Creek	Holiday Creek	PD25771	C111887	Domestic	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25771	C111887	Irrigation	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25771	C117208	Commercial Enterprise	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25771	C111890	Domestic	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25771	C111890	Irrigation	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25771	C111886	Irrigation	49.477661	-116.767137
Holiday Creek	Holiday Creek	PD25772	C111889	Domestic	49.477733	-116.766856
Holiday Creek	Holiday Creek	PD25772	C111889	Irrigation	49.477733	-116.766856
Holiday Creek	Hyatt Creek	PD25769	C119914	Irrigation	49.476593	-116.767157
Holiday Creek	Hyatt Creek	PD25769	C119914	Domestic	49.476593	-116.767157
Holiday Creek	Hyatt Creek	PD25769	C111898	Domestic	49.476593	-116.767157
Holiday Creek	MacFarlane Spring	PD25768	C130043	Domestic	49.475200	-116.769605
Holiday Creek	Kootenay Lake	Kootenay Lake	PD75063	C114888	Commercial Enterprise	49.477163
McGregor-Holiday Face	Lewis Brook	PD25762	C107004	Domestic	49.473517	-116.764910

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
McGregor-Holiday Face	Lewis Brook	PD25762	C127008	Domestic	49.473517	-116.764910
McGregor-Holiday Face	Lewis Brook	PD25762	C070981	Domestic	49.473517	-116.764910
McGregor-Holiday Face	Lewis Brook	PD25762	C070981	Irrigation	49.473517	-116.764910
McGregor-Holiday Face	Simpson Spring	PD25760	C069692	Domestic	49.472455	-116.765663
McGregor-Holiday Face	Bell Spring	PD25766	C069691	Domestic	49.472017	-116.765718
McGregor-Holiday Face	Clearwater Springs	PD25740	C114437	Domestic	49.465819	-116.756968
McGregor-Holiday Face	Clearwater Springs	PD25740	C114452	Irrigation	49.465819	-116.756968
McGregor-Holiday Face	Clearwater Springs	PD25740	C067752	Domestic	49.465819	-116.756968
McGregor-Holiday Face	Clearwater Springs	PD25740	C108837	Domestic	49.465819	-116.756968
McGregor-Holiday Face	Clearwater Springs	PD25740	C108838	Domestic	49.465819	-116.756968
McGregor-Holiday Face	Clearwater Springs	PD25742	C114437	Domestic	49.465444	-116.757002
McGregor-Holiday Face	Clearwater Springs	PD25742	C114452	Irrigation	49.465444	-116.757002
McGregor-Holiday Face	Clearwater Springs	PD25742	C067752	Domestic	49.465444	-116.757002
McGregor-Holiday Face	Clearwater Springs	PD25742	C108837	Domestic	49.465444	-116.757002
McGregor-Holiday Face	Clearwater Springs	PD25742	C108838	Domestic	49.465444	-116.757002
McGregor-Holiday Face	Hepbeb Springs	PD25743	F040199	Domestic	49.464547	-116.758543
McGregor-Holiday Face	Hepbeb Springs	PD25743	C114426	Domestic	49.464547	-116.758543

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
McGregor-Holiday Face	Hepbeb Springs	PD25744	F040199	Domestic	49.464404	-116.758499
McGregor-Holiday Face	Hepbeb Springs	PD25744	C114426	Domestic	49.464404	-116.758499
McGregor-Holiday Face	Hepbeb Springs	PD25746	F040199	Domestic	49.464339	-116.758807
McGregor-Holiday Face	Hepbeb Springs	PD25746	C114426	Domestic	49.464339	-116.758807
McGregor-Holiday Face	Hepbeb Springs	PD25748	F040199	Domestic	49.464471	-116.758772
McGregor-Holiday Face	Hepbeb Springs	PD25748	C114426	Domestic	49.464471	-116.758772
McGregor-Holiday Face	Hepbeb Springs	PD25750	F040199	Domestic	49.464696	-116.758584
McGregor-Holiday Face	Hepbeb Springs	PD25750	C114426	Domestic	49.464696	-116.758584
McGregor-Holiday Face	Gordon Creek	PD25735	C051889	Irrigation	49.463630	-116.762798
McGregor-Holiday Face	Gordon Creek	PD25736	F070680	Irrigation	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C059071	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C051890	Irrigation	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	F008959	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C127758	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C127816	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C127823	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C063723	Domestic	49.463484	-116.745748

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
McGregor-Holiday Face	Gordon Creek	PD25736	F070679	Irrigation	49.463484	-116.745748
McGregor-Holiday Face	Gordon Creek	PD25736	C063139	Domestic	49.463484	-116.745748
McGregor-Holiday Face	Feininger Spring	PD25731	C100498	Domestic	49.459523	-116.755131
McGregor-Holiday Face	Mackie Brook	PD25727	C048313	Irrigation	49.458604	-116.756195
McGregor-Holiday Face	Mackie Brook	PD25727	C048314	Domestic	49.458604	-116.756195
McGregor Creek	McGregor Creek	PD25724	C100525	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C105962	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067695	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067695	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C054787	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C103779	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C103779	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C100583	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067708	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067696	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067696	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C109850	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C068136	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C068136	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C052543	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C052543	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C112628	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C068137	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C068137	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C063213	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067707	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C066095	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C063212	Domestic	49.455463	-116.757086

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
McGregor Creek	McGregor Creek	PD25724	C067693	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C063212	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C112627	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C112627	Irrigation	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25724	C067832	Domestic	49.455463	-116.757086
McGregor Creek	McGregor Creek	PD25722	C101567	Irrigation	49.454832	-116.759347
McGregor Creek	McGregor Creek	PD25722	C067679	Livestock watering	49.454832	-116.759347
McGregor Creek	McGregor Creek	PD25722	C067679	Irrigation	49.454832	-116.759347
McGregor Creek	McGregor Creek	PD25719	C102047	Irrigation	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C101568	Domestic	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C101568	Irrigation	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C067679	Livestock watering	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C067679	Irrigation	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C101578	Irrigation	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C112679	Irrigation	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C112679	Domestic	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C119933	Domestic	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C102048	Domestic	49.454690	-116.759824
McGregor Creek	McGregor Creek	PD25719	C102048	Irrigation	49.454690	-116.759824
Charles-McGregor Face	Sheila Spring	PD25717	C056557	Domestic	49.450811	-116.756117
Charles-McGregor Face	Agokay Spring	PD25716	C057987	Domestic	49.443021	-116.754557
Charles-McGregor Face	Agokay Spring	PD25716	C062776	Domestic	49.443021	-116.754557
Charles-McGregor Face	Agokay Spring	PD25716	C062776	Irrigation	49.443021	-116.754557
Charles-McGregor Face	Agokay Spring	PD25716	C064792	Domestic	49.443021	-116.754557
Charles-McGregor Face	Agokay Spring	PD25716	C057985	Domestic	49.443021	-116.754557

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Charles-McGregor Face	Agokay Spring	PD25716	C019840	Domestic	49.443021	-116.754557
Charles-McGregor Face	Agokay Spring	PD25716	C057986	Domestic	49.443021	-116.754557
Charles Creek	Charles Creek	PD25713	C042838	Domestic	49.443740	-116.749254
Charles Creek	Charles Creek	PD25712	C053873	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055018	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055025	Irrigation	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055016	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055016	Irrigation	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F056024	Irrigation	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055023	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055022	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	C056025	Irrigation	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	C053872	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	C125244	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055017	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055024	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055024	Irrigation	49.442462	-116.752936
Charles Creek	Charles Creek	PD25712	F055026	Domestic	49.442462	-116.752936
Charles Creek	Charles Creek	PD25709	F014156	Domestic	49.442659	-116.755799
Charles Creek	Hare Creek	PD25715	C100597	Domestic	49.441370	-116.744438
Charles-Akokli Face	Beaumont Spring	PD26265	C060035	Domestic	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C048791	Domestic	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C048791	Irrigation	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C112428	Domestic	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C112412	Domestic	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C112411	Lawn, Fairway & Garden	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C112411	Commercial Enterprise	49.438190	-116.752907
Charles-Akokli Face	Beaumont Spring	PD26265	C063824	Domestic	49.438190	-116.752907
Charles-Akokli Face	Creighton Spring	PD26266	F020884	Domestic	49.436956	-116.755753

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Akokli Creek	Akokli Creek	PD26268	C062572	Domestic	49.425362	-116.749831
Akokli Creek	Akokli Creek	PD26269	F016060	Domestic	49.425214	-116.750382
Akokli Creek	Akokli Creek	PD26269	F014157	Domestic	49.425214	-116.750382
Akokli Creek	Akokli Creek	PD26269	F014157	Irrigation	49.425214	-116.750382
Akokli Creek	Akokli Creek	PD26270	F014157	Domestic	49.424592	-116.753082
Akokli Creek	Akokli Creek	PD26270	F014157	Irrigation	49.424592	-116.753082
Akokli Creek	Akokli Creek	PD192870	500542	Misc. Industry	49.424592	-116.753082

Appendix D

Landslide and Flooding Risk Brochures

4 WHAT *should you do during a storm or heavy runoff event?*

- Pay attention to weather forecasts that include thunderstorm or heavy rainfall warnings.
- Check the current Environment Canada weather forecast at *http://weather.gc.ca/canada_e.html*
- Avoid driving in an area where a wildfire has recently occurred. Potential dangers include washed-out bridges and culverts. Roads running below steep banks are susceptible to landslides. If it's absolutely necessary to travel in the area, stay alert and watch the road ahead of you for collapsed pavement, mud, fallen rocks or other indications of debris flows.
- Never drive across a flooded road.
- If your home is in an at-risk area and severe weather is occurring or in the forecast, stay alert. Listen for any unusual sounds (e.g. tree trucks cracking or boulders knocking together) and watch for changes to water flows in local stream channels. Consider sleeping on an upper floor of your home and don't sleep in the basement.
- Do not enter water channels or hike upstream to inspect water lines or buildings. Consider leaving the area temporarily if you are concerned (and if it is safe to do so).
- On forested land where a wildfire has recently occurred, avoid camping on floodplains, beside small streams, on alluvial fans or at the base of burned slopes. Be aware that forest service roads or resource roads may wash out if a flood occurs and could cut off access to the area.

How long do post-wildfire risks last?

In areas that have been severely burned, post-wildfire risks may last for two years or more. However, the increased risk of floods or debris flows in severely burned areas may persist much longer.

After two or three years, the regrowth of vegetation and reduced water repellency of the soil should lower the risk considerably.

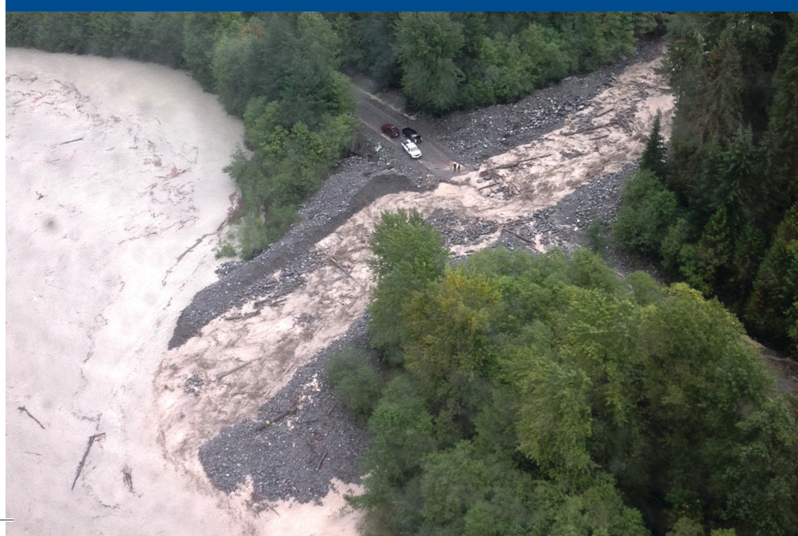
How can you get more information about potential risks to your property?

Consulting geotechnical specialists can provide specific information about your property and post-wildfire hazards, including potential risk-mitigation techniques.

This bulletin provides general information only and does not cover all potential hazards. Additional information resources are available online:

- Current wildfires: *www.bcwildfire.ca*
- Association of Professional Engineers and Geoscientists of B.C. (APEGBC): *www.apeg.bc.ca/Home*
- Environment Canada weather: *http://weather.gc.ca/canada_e.html*
- Current flood information, Emergency Management BC information and contacts: *http://www.embc.gov.bc.ca/index.htm*
- Ministry of Forests, Lands and Natural Resource Operations district offices and contacts: *www.gov.bc.ca/for*

The large Terminal Creek mudslide near Squamish occurred during a localized rainstorm in September 2015, stranding recreationalists.



There was widespread flooding on the Squamish River after a severe rainstorm in September 2015.

Landslide and Flooding Risks DUE TO WILDFIRES

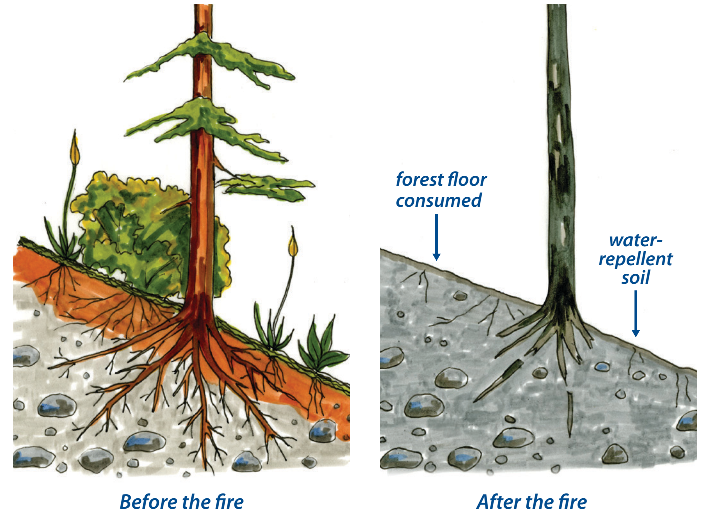
What you can do to recognize and deal with the hazards

British Columbia

Ministry of Forests, Lands and Natural Resource Operations

Part of the Elaho River drainage area was burned by wildfire in 2015.

This is the Elaho drainage area in June 2015, showing evidence of how severe the wildfire was in that area.



Wildfires remove the protective ability of vegetation, increasing runoff, erosion, debris flow and the potential for landslides.

INTRODUCTION

This pamphlet describes how wildfire activity may increase the risk of natural landslides and flooding, the warning signs you should watch for, and what you should do in an emergency. This information can help you and your family avoid a potentially dangerous situation.

1 HOW *does wildfire activity increase the risk of landslides and flooding?*

Periodically, British Columbia experiences severe wildfires near populated areas, such as those that occurred in 2003, 2009, 2010 and 2015.

A severe wildfire damages the forest canopy, as well as the smaller plants and soil below the trees. This can result in increased runoff after intense rainfall or a rapid snowmelt, putting homes or other structures below the burned area at risk of localized floods and landslides.

2 WHAT *specific hazards should you watch for after a wildfire?*

- *flooding*, especially after an intense rainfall
- *landslides*, which could include a:
  - debris flow (a specific type of fast-moving and powerful landslide, resulting from heavy water runoff and carrying large amounts of soil, rocks, wood debris and trees)
  - rockfall (resulting from the fire-induced cracking of rocks and the loss of stumps, logs and roots that would normally hold loose rocks in place)

What values could be put at risk?

- *Residential*, farm and industrial buildings that are downslope or downstream of the site of a severe wildfire could be affected by post-wildfire hazards, even if the fire was only one or two hectares in size.
- *Structures* that are located below a recent wildfire and are near a creek, gully or alluvial fan are most at risk.
- In an area that has experienced flooding or landslides in the past, there is an increased likelihood that a flood or landslide could happen there again.
- *Roadways*, railway lines, pipelines and other types of infrastructure (including bridges that are downslope or downstream of a wildfire) may be obstructed, inundated or washed out.
- *Domestic water lines*, irrigation water lines and water intakes (and other structures in gullies, streams or creeks) could be damaged or destroyed by a post-wildfire flood or landslide. These areas may be at risk during these events but also after them, due to water channel blockages.

What weather conditions trigger post-wildfire floods and debris flows?

The most common trigger is intense rainfall (e.g. 10mm of rain falling in under 30 minutes). The risk increases if the rainfall follows a prolonged dry period, because water can't soak into dry, fire-altered soils quickly. The water is repelled and flows over the land, instead of soaking into it.

In coastal areas, fall rainstorms are the most likely causes of post-wildfire floods or debris flows. A rapid spring snowmelt can also be a trigger in drainage areas that have experienced severe wildfires.

3 HOW *can you deal with post-wildfire hazards?*

- *Be informed. Be ready.*
- *Familiarize* yourself with the landscape and its normal drainage channels. Know where your home or property is situated with respect to natural drainage channels. Find out if any floods or landslides have occurred in the area in recent years.
- *Contact* local authorities to learn about any emergency response and evacuation plans for your area. Attend any meetings that are held to inform the public of local risks.
- *Develop* your own emergency plans for your family, property and/or business. Post-wildfire hazard events can occur with little advance warning, so it's important to be prepared.
- If a wildfire occurs on Crown (provincially owned) land, a post-wildfire risk analysis may be conducted to determine if the safety of nearby residential areas may be affected. *Contact your local government* office or Emergency Management BC (EMBC) to see if a risk analysis has been done in your area.

Debris Flow Hazard Awareness
in the Kootenay Region

Debris flows are fast-moving mixtures of water, sediment, boulders and logs that flow down steep mountain creeks. In recent years, debris flows have caused fatalities, near misses and significant property damage in the Kootenays.

This document is intended to help you understand this hazard in the Kootenay Region, identify some indicators that could be cause for concern and learn how to report a potential emergency.

Figure 1. Debris flow material that was deposited on the Kuskanook Creek fan after a rainfall event in August 2004.

Figure 2. Debris flood on Memphis Creek. Note the large volume of floating debris in the lake and the uncharacteristically turbid water.

Get to know your watershed:

- Learn the history of debris flow hazards on or near your property and the areas you visit often, especially near the mouths of creek channels and alluvial fans. Flood hazard mapping is available through your local government and is a good initial reference. For example, the Non-Standard Flooding and Erosion Areas (NSFEA) hazard map can be accessed through the Regional District of Central Kootenay's Property Information Mapping System (mapinfo.rdck.bc.ca/Pims/).
- Be aware of dikes or flood control structures that may be protecting your property from flooding and/or debris flows. Structures that were built many years ago and are not being maintained may no longer be providing the protection it was designed for. A dam upstream of your property may also pose a hazard, depending on its condition and maintenance history. Refer to www.env.gov.bc.ca/wsd/public_safety/index.html to identify the locations of any such structures.
- If you live near or visit areas prone to debris flows, you should become familiar with the terrain between your property and the creek channel and fan apex. During a major flood event, creeks may suddenly change course and flow along a new or abandoned flood channel, and debris flow material may run out onto the fan area. Terrain features to be aware of include: abandoned creek channels; levees; scarred trees; and lobal deposit features.
- If you have concerns about debris flows impacting your property, you may wish to hire a qualified professional to provide additional assistance.

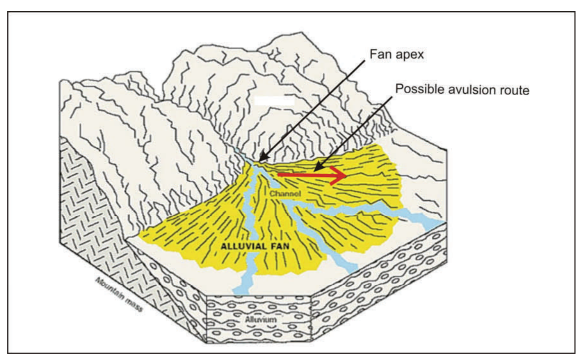


Figure 3. Schematic diagram of an alluvial fan, showing a possible flow route and geological features.

What you should do in an emergency:

- **To report a debris flow emergency that is occurring call 911.**
- **To report observations of these debris indicators, call the 24-hour provincial toll-free number: 1 800 663-3456**
- Local governments are responsible for responding to emergencies in their jurisdiction.
- The provincial government will provide technical expertise and assistance to local governments during emergencies. For more information, visit: www.embc.gov.bc.ca/index.htm

Debris flow hazard indicators:

- By monitoring the creeks near your property or the areas you visit frequently, you can become familiar with typical flow patterns and recognize any unusual events that may indicate a potential debris flow event.

- There are large natural variations in the water levels of creeks in the Kootenays associated with either snow-melt and heavy rainfall. Each creek responds differently, depending on the size and characteristics of its watershed.

  However, an unusually rapid increase or decrease in flow may indicate that the creek has been blocked by a landslide upstream or that a debris flow is about to occur. Call the provincial emergency number below to report your observations.

- Creeks in the Kootenays often flow dirty during spring runoff and after a major rainstorm. Dirty or turbid water does not necessarily indicate that a debris flow hazard exists.

  However, abnormally dirty water may signal that a landslide or bank failure has occurred up-stream. Pulses of sediment in a creek channel may also indicate that something unusual has occurred upstream. Call the provincial emergency number below to report your observations.

- A large volume of debris (logs, sediment, etc.) that accumulates in a creek channel or has recently been transported down the creek and is now floating near the mouth of the creek may indicate that a natural hazard event has occurred in the watershed.

  If you observe an unusually large and recent change in the accumulation of debris in a creek channel, call the provincial emergency number at 1 800 663-3456 to report your observations.

Figure 4. Turbid water in Gar Creek the day before the Johnson's Landing landslide on July 12, 2012.

Public Safety Advisory:

Use caution while spending time in a confined creek channel or gully that is prone to debris flows. Fatalities and close calls have occurred when people have been caught up in debris flows while working on their water intake systems.

To summarize, the following factors may indicate an upstream hazard:

- Abnormally dirty water
- Accumulation of large logs or debris in the creek
- Sudden changes in flow
- Pulses in flow (i.e. rapid changes in flow) or pulses of sediment
- Rapid accumulation of sediment or bedload along a flat section of a creek channel

Not all debris flows are preceded by these indicators.
Following the advice in this document does not ensure your safety.

To report the potential emergency, call the 24-hour toll-free number: 1 800 663-3456

BRITISH COLUMBIA

#4, 385 Baker Street
Nelson, BC, V1L 4H6
250 509-1009

February 15, 2022

Sarah Crookshanks, P.Geo., Research Geomorphologist, MFLNRO

Re: PWNHRA Akokli Fire N71686 Recommendations

A Post Wildfire Natural Hazards Risk Analysis was completed by the undersigned for the Akokli Fire (N71686). A report was completed and issued on February 8th, 2022. An additional recommendation should be included as part of the recommendations listed in Section 8.1 of the report as follows:

"Water quality could be affected by modified run-off conditions including changes to turbidity, biological contamination, flows (quantity and timing), and metal concentrations. It is recommended that periodic water quality testing be implemented near domestic use intakes located in/below significantly burned drainages."

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