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

POST-WILDFIRE NATURAL HAZARDS RISK ANALYSIS BILL NYE FIRE (N11629)

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1. Introduction and Objectives

The Bill Nye wildfire (N11629) started on July 8th, 2021 and burned 7,195 ha within and between Lakit Mountain and Lazy Lake (Figure 1). The fire started on a westward face unit near Grundy Creek. From there it progressed in all directions (Photos 1 through 4). Because the fire includes or is adjacent to several populated areas, it was considered by the Ministry of Forests, Lands, Natural Resource Operation and Rural Development (MFLNRORD) to be a high priority to conduct a Post-Wildfire Natural Hazards Risk Analysis (PWNHRA). SNT Geotechnical Ltd. (SNTG) was retained by the Ministry of Forests Lands Natural Resource Operations (BC Wildfire Service) to complete this work. SNTG collaborated with Sitkum Consulting Ltd. (SCL) to complete the risk analysis and reporting.

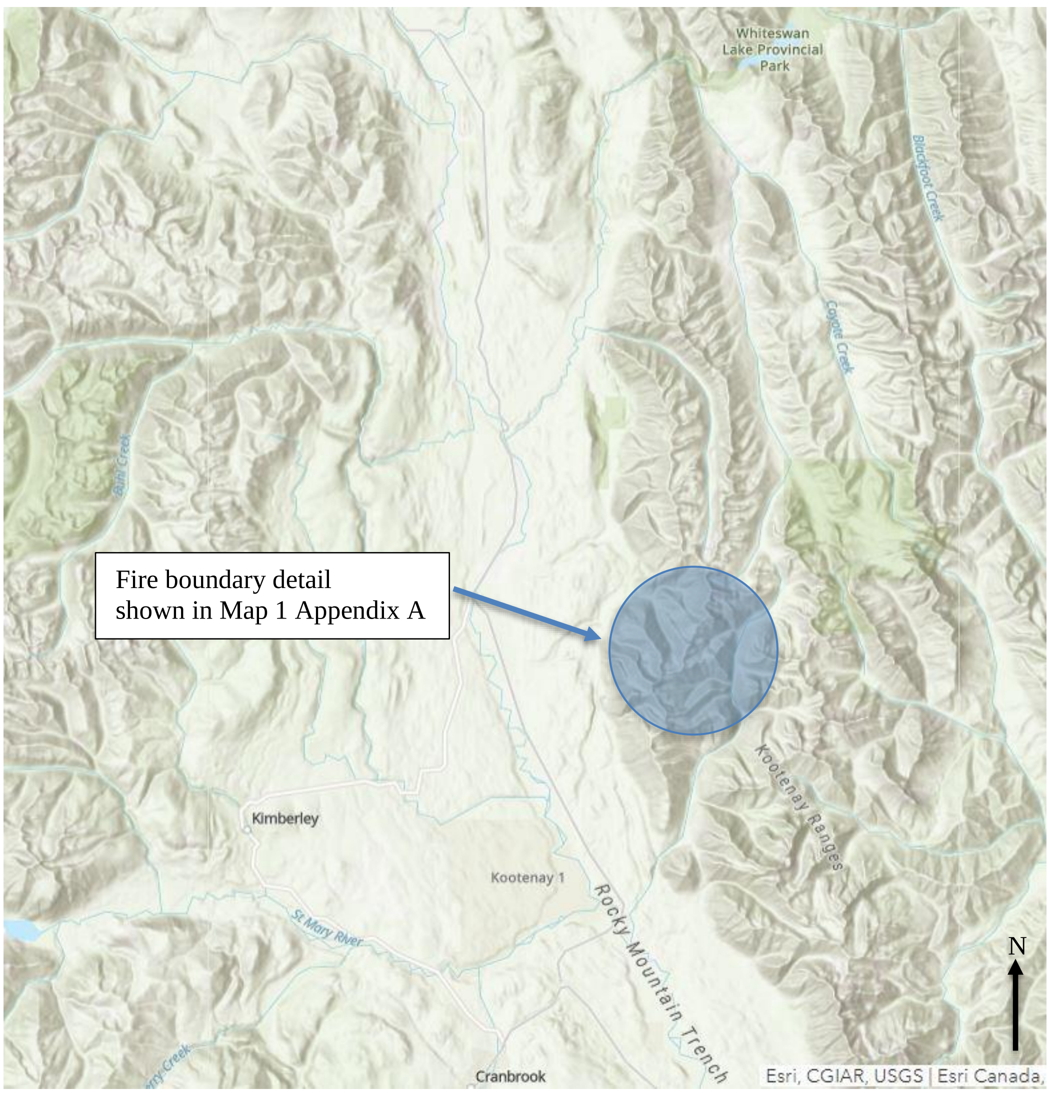

Figure 1. N11629 Fire location map

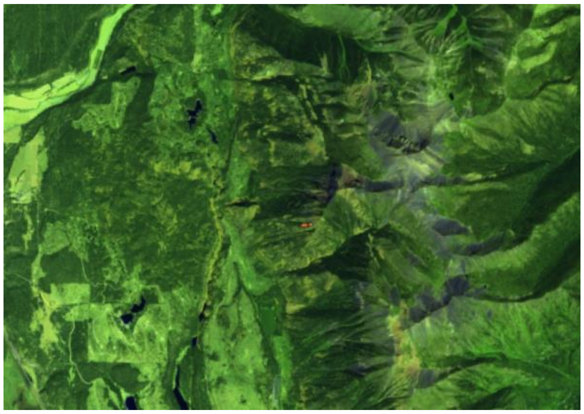

Photo 1. July 15th, 2021, Sentinel -2L1C Satellite Imagery

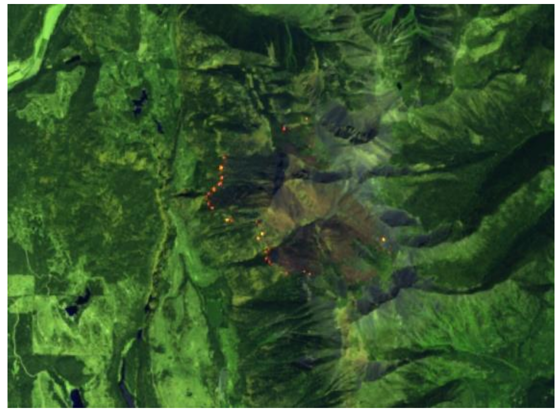

Photo 2. July 18th, 2021, Sentinel -2L1C Satellite Imagery

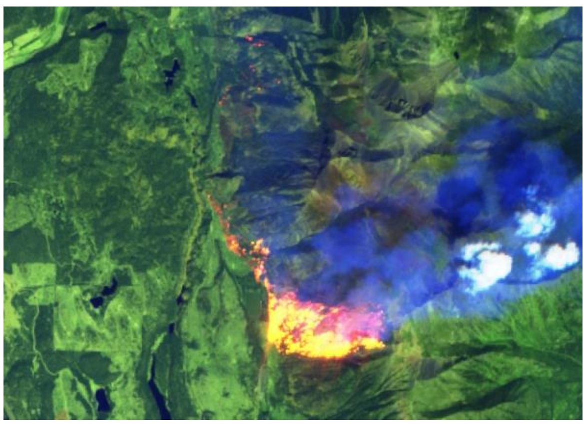

Photo 3. July 25, 2021, Sentinel -2L1C Satellite Imagery

Photo 4. July 30th, 2021, Sentinel -2L1C Satellite Imagery

A preliminary reconnaissance was conducted for BC Wildfire Service by Tim Giles, P.Geo., of Westrek Geotechnical Services Ltd. on August 12th, 2021 with a preliminary assessment report completed on August 25th, 2021. The results of the review indicated a moderate hazard relating to roads and drainage structures in the watershed. In particular some roads were observed to divert water northward into the North Face Units (renamed as various Lewis Creek Tributaries in this assessment). In addition, 6 residences were identified as being at risk.

A detailed risk analysis was conducted based on field inspections of elements at risk, as identified in the reconnaissance phase of the study. The 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 one to two years after the fire, and some debris flows attributable high intensity summer rains following the Bill Nye fire occurred in August 2021 (refer to Section 5 for additional information). 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 Bill Nye Fire, potential debris flow and flood hazards are possible both 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.

Field work in the burned areas was conducted on October 19 through October 21 by Michael Burnett, P.Eng. SNTG and Marc Deschenes, Geotechnical & Avalanche Specialist, SCL.

The October 19th field work included a helicopter reconnaissance with select landings to confirm the results of the BARC mapping and to compare the Vegetation Burn Severity (VBS) with the Soil Burn Severity (SBS). The field work was focused on the residences at risk below drainages Lewis West 1, Lewis West 2, Tracy Creek, and Herbert Face and the high elevation mine access road at the north end of the burn area on the westward facing slopes, as these areas had 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 Bill Nye fire area is situated in the Hughes Range of the western Rocky Mountains. The general physiography of the region consists of serrated ridges and peaks above approximately 2200 m with steep valley sides and broad terraces at valley bottom. Summit levels generally lie between 2200 m and 2600 m, and local relief of approximately 1300 m to 1600 m is typical with elevations ranging from approximately 900 m near Lewis Creek to approximately 2600 m along the alpine ridgetops near Mt. Bill Nye (2645 m).

Above approximately 1700 m elevation the biogeoclimatic mapping indicates that the fire area is located within the Engelmann Spruce – Subalpine Fir zone. Between approximately 1200 m and 1700 m elevation the biogeoclimatic mapping indicates that the fire area is located in the Montane Spruce zone, and below approximately 1200 m the fire area is located within the Interior Douglas Fir zone. Based on the precipitation modeling available from ClimateBC_Map, the mean annual precipitation (MAP) within the burn area ranges from approximately 400 mm to 1000 mm, generally increasing with elevation. This is generally consistent with reference data available from weather stations throughout the region (MAP is 385.3 mm based on the Cranbrook A station Environment Canada data).

The available regional geology mapping referenced in iMapBC indicates the burn area is underlain by the Proterozoic aged Fort Steele Formation of the Purcell Supergroup, consisting of primarily quartzite which is consistent with field observations.

While the major drainages within the Bill Nye fire perimeter have had some level of reconnaissance terrain stability mapping (RTSM) previously completed, the terrain stability mapping is generally incomplete, with many areas having no or little terrain stability mapping. No details about the previous RTSM were found during the preliminary investigation. The areas that are mapped potentially unstable are generally associated with moderately steep to steep terrain in the gully headwall and gully sidewall areas. The areas mapped as unstable are associated with the western side of the Lewis Creek headwall and small areas of steep to very steep gradient slopes with exposed bedrock in the Grundy Creek and Herbert Creek drainages.

5. Watershed Hazards and Burn Severity Mapping

Watershed boundaries in the area were delineated using a combination of LiDAR data (LidarBC-Open LiDAR Data Portal and Canfor sourced), TRIM derived 20 m contours using topographic maps produced at a scale of 1:15,000 (note that TRIM data is published at 1:20,000 scale), and air photos (low resolution colour stereo pairs from 2000[1]). In areas where flood and debris flow hazards might be present, the watersheds were subdivided into smaller units to delineate drainage basins above alluvial and colluvial fans and cones (note: fans and steeper colluvial cones collectively referred to as fans on report maps). 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 still a valuable addition to help

[1] 30BCC00058 Nos. 55-57, 157-159, 30BCC00057 Nos. 159-160

confirm the field assessment of watershed hazards in this assessment. The relief ratio is included in Table 2 for relevant watersheds.

Table 2. Select Watershed Characteristics

Watershed	Herbert Creek	Tracy	Lewis Tributary 1	Lewis Tributary 2
Area (ha)	599	627	36	181
Length (km)	3.3	4.8	1.5	2.5
Elevation Range (m)	1120-2500	1020-2600	1000-1820	920-2100
Melton ratio	0.54	0.59	1.67	0.83
Typical channel slope, mid-watershed	40%	22%	55%	35%
Typical channel slope, headwaters	65%	50%	50%	50%
Terrain stability "V" or "U"	0%	0%	-	-
Terrain stability "IV" or "P"	4%	10%	-	-
"Gentle-over-steep" (burn on plateau draining into steep channels)	No	No	No	No
Main channel riparian zone severely burned	Yes	Yes	Yes	Yes
Burn Severity: H	33%	14%	45%	67%
Burn Severity: M	38%	28%	44%	24%
Burn Concentrated in:	Whole watershed	Whole watershed	Whole watershed	Whole watershed
Fan or Deposition Slope	6% to 30%	5% to 15%	5% to 20%	2% to 22%

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 form 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 the regional map. 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 0.50 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, including the helicopter reconnaissance flight, 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. 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 rating have been assigned for select drainages identified on the Post-Wildfire Risk Analysis with Burn Severity Map in Appendix A. The estimated hazard by drainage is shown in Table 3 below.

Table 3. Hazard estimate by drainage **for select drainages**

Drainage Name	Hazard	Burn Severity Description	Process	Value at Risk
Lewis East 1 (upper)	Moderate	32% moderate, 13% high	Debris Flow	House 7, private property, domestic and irrigation water infrastructure, Lewis Creek FSR
Lewis East 2	High	17% moderate, 66% high	Debris Flow	House 7, private property, domestic and irrigation water infrastructure, Lewis Creek FSR
Lewis East 3	High	15% moderate, 56% high	Debris Flow	House 7, private property, domestic and irrigation water infrastructure, Lewis Creek FSR
Lewis Tributary 2	High	17% moderate, 66% high	Debris Flow/flood	House 1, private property, domestic water infrastructure
Lewis West 1	High	22% moderate, 46% high	Debris Flow	House 1, private property, domestic water infrastructure
Lewis West 2 (upper)	High	33% moderate, 30% high	Debris Flow	House 1, private property, domestic water infrastructure
Lewis West 3	High	57% moderate, 26% high	Debris Flow	House 2, private property,
Lewis Tributary 1	High	44% moderate, 45% high	Debris Flow	House 2, private property,
Tracy North	High	67% moderate, 21% high	Debris Flow/flood	
Tracy Creek	Moderate	28% moderate, 14% high	Debris Flow/flood	House 3, private property, Irrigation water infrastructure
Tracy South 1	High	51% moderate, 40% high	Debris Flow	House 3, private property, Irrigation water infrastructure
Herbert Creek	Moderate to High	38% moderate, 33% high	Debris Flow/flood	House 5, House 6, private property, irrigation water infrastructure
Herbert Face	High	55% moderate, 27% high	Debris Flow/Debris Avalanche	House 5, private property
Herbert Tributary 1	High	44% moderate, 40% high	Debris Flow/flood	House 5, private property
Herbert Tributary 2	High	25% moderate, 48% high	Debris Flow/flood	House 5, private property
Herbert Tributary 3	Low	13% moderate, 12% high	Debris Flow/Flood	House 6, private property

Additional drainages with an estimated moderate incremental post wildfire likelihood of landslides but not included in Table 3 because of lack of significant values at risk include Grundy, Grundy Lower, Grundy South Face, Grundy Upper, Grundy-Tracy Face, Herbert Grundy South Face, Lewis East, Lewis North Face, Tracy Creek and Tracy North - Lewis Tributary 1 Face.

Photos 5 through 8 are example photos of high and moderate burn severity areas.

Photo 5. View looking north of high and moderate burn severity areas located in the mid-Tracy Creek drainage.

Photo 6. View looking down slope into a high burn severity area

located in the Lewis Tributary-2 drainage.

Photo 7. High burn severity area located in the lower Herbert Creek drainage.

Photo 8. High burn severity area located in the upper Tracy Creek drainage near the mine site.

Some post wildfire landslides have already occurred in the Herbert Tributary 1, Herbert Tributary 2, Lewis Tributary 2, Lewis West 1 and Lewis West 2 drainages as shown on Photos 9 through 14.

The post wildfire debris flow events likely occurred following two significant rainstorm events based on weather records (Env. Canada – Cranbrook) that indicated 29.2 mm and 21.4 mm of precipitation on August 8 and 17, 2021 respectively.

Photo 9. Helicopter overview of a recent post-wildfire debris flow located in the Herbert Tributary 2 drainage and south of House 5.

Photo 10. Recent post-wildfire debris flow located in the Herbert Tributary 1 drainage which reached the valley bottom upslope of property near House 5.

Photo 11. View looking downslope of a post-wildfire debris flow located in the Lewis Tributary 2 drainage which reached the Lewis Creek FSR.

Photo 12. View looking upslope at a post-wildfire debris flow confined in a gully located in the Lewis Tributary 2 drainage; the landslide reached the Lewis Creek FSR.

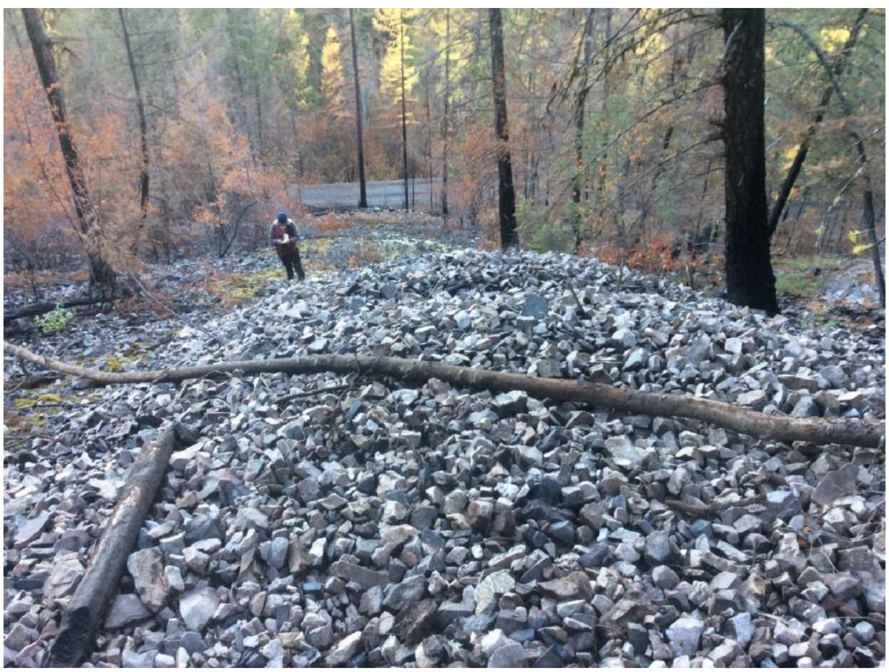

Photo 13. View looking downslope at a post-wildfire debris flow located in the Lewis West 2 drainage located upslope of House 1. The landslide terminated just above the Lewis Creek FSR.

Photo 14. View from the Lewis Creek FSR at a post-wildfire debris flow located in the Lewis West 2 drainage located upslope of House 1.

6. Elements at Risk and Partial Risks 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 such as outbuildings
- private property
- resource roads and non-status roads
- domestic and irrigation water supply infrastructure
- electrical distribution lines

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 RDEK web mapping service). Houses and other structures were considered to be at risk if they are located on alluvial fans, colluvial 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.

Residences at risk have been numbered one through seven (refer to Maps 1, 2 and 3 in Appendix A). Most of the houses and infrastructure that could be at risk are located on the fans of Lewis Creek, the Lewis Tributaries, Tracy Creek and the Herbert Tributaries 1 and 2. The fan boundaries of these creeks were delineated based on LiDAR data interpretation where coverage was available, available air photos along with TRIM data 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 domestic water licenses on Lewis Creek and Lewis Tributary 2 Creek, in addition to some irrigation, and general use licenses (refer to Water License Summary Table 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 hazards relating to any one water intake.

A BC Hydro distribution line is located along the Lazy Lake Road. For the most part, the distribution line is situated outside of the burn area with the exception of a section on the Lewis Tributary fan which is located in a low to moderate burn severity area. Based on the location of the power poles on the fan the likelihood of a 10-15 year return period landslide impacting the poles is estimated at Low.

6.1. House 1

House 1 and out-buildings are situated on a relatively flat bench comprised of fluvial materials interspersed throughout bedrock outcrops. The house and outbuildings are located downslope of Lewis Creek FSR to the east and upslope of Lazy Lake Road to the west. House 1 and outbuildings are situated near the bottom of the Lewis West 2 drainage and to the south of the Lewis West 1 drainage and Lewis Tributary 2.

Lewis West 2

The Lewis West 2 drainage area includes a face unit located upslope of House 1 and outbuildings. The face unit consists of steep to very steep slopes that are typically comprised of relatively thin layers of colluvium and talus overlying bedrock. Bedrock bluffs were identified on the lower slopes near the Lewis Creek FSR and immediately upslope of House 1 and are likely present throughout the face unit. Rockfall processes are active in the face unit and have the potential of impacting House 1, outbuildings, and the property. Recent post-wildfire debris flows that likely initiated in the steeper shallow gullies near the top of the face unit with high burn severity were identified; it appeared that the debris flows terminated at the upslope ditch line of the Lewis Creek FSR and on talus slopes above the Lewis Creek FSR (refer to Photo 15).

Lewis Creek FSR, situated between the property and steeper segment of the face unit, would likely create a barrier where debris flow deposition would occur; however, potential nuisance flooding could still reach the house.

Photo 15. Debris flow deposition above Lewis Creek FSR.

As per Table 3 Lewis West 2 drainage has a high incremental post wildfire debris flow hazard.

The likelihood of a debris flow directly impacting House 1 is considered low resulting in a MODERATE PARTIAL RISK.

Lewis West 1

Lewis West 1 is a face unit located immediately to the north-east of House 1, the private property, and outbuildings. The face unit consists of steep to very steep slopes that are typically comprised of relatively thin layers of colluvium and talus overlying bedrock. Bedrock bluffs were identified on the lower slopes near the Lewis Creek FSR and are likely present throughout the face unit. Rockfall processes are active in the face unit and have evidence of impacting to the lower extents of the face unit. A post-wildfire debris flow that likely initiated in the steeper shallow gullies near the top of the face unit with high burn severity was identified; it appeared that the debris flow terminated at the upslope ditch of Lewis Creek FSR.

The Lewis Creek FSR and a flat bedrock bench are situated between House 1 and the steeper face unit. Lewis Creek FSR would likely create a barrier where debris flow deposition would occur; however, potential nuisance flooding could still reach the house.

As per Table 3, Lewis West 1 drainage has a high post wildfire incremental debris flow hazard.

The Likelihood of a debris flow directly impacting House 1 is considered low resulting in a MODERATE PARTIAL RISK.

Lewis Tributary 2

Lewis Tributary 2 is a drainage unit located to the southeast of Lewis West 1 face unit. There are several gullies located at the upper extent of the drainage that converge to make three main gullies that become unconfined at multiple apex points along a fan complex. Lewis Creek FSR traverses across the lower extent of the fan complex. Downslope of the FSR it appears that the flows become re-channelized through eroded post-glacial fluvial deposits constrained by bedrock outcrops that extend to the valley bottom.

Post-wildfire debris flows occurred in the northern and southern most gully features above the fan complex. They likely initiated in the steeper gullies near the top of the drainage unit with high burn severity. The northern gully debris flow dispersed over the fan complex at the apex of the fan and then appeared to become rechannelized below the Lewis Creek FSR depositing debris in the form of fine sediment across the access road leading to House 7. It is noted that a fire guard in the channel above the House 7 access road likely contributed to the amount of material deposited by channelizing the debris flow. The southern gully debris flow extended from the apex of the fan to the Lewis Creek FSR; at the Lewis Creek FSR it appears that the debris flow was directed south-west down the Lewis Creek FSR (the FSR was clear of debris at the time of the review). It appeared that at an undetermined location along Lewis Creek FSR the debris transitioned from coarse angular rock to a finer sand deposit, the sand deposits extended downslope from Lewis Creek FSR along a bedrock-controlled drainage that becomes undefined approximately 40 m to the southwest of House 1.

There is an intervening gently sloped bedrock shelf, including the FSR, situated between House 1 and the apex of the fan feature where debris flow deposition would likely occur. It is possible nuisance flooding could extend to the house location, similar to what apparently happened in August 2021.

As per Table 3, Lewis Tributary 2 drainage has a high post-wildfire incremental debris flow/flood hazard.

The likelihood of a debris flow directly impacting House 1 is considered low resulting in a MODERATE PARTIAL RISK.

6.2. House 2

House 2 and out-buildings are situated on the Lewis Tributary Fan 1 situated upslope of the Lazy Lake Road that crosses the fan. The residence and outbuildings are situated along the southern edge of the fan approximately 250 m downslope of the apex of the fan. The southern extent of the fan is bounded by bedrock bluffs situated approximately 20 m to the south of the house.

The base of the gully of Lewis Tributary 1 appears to be comprised of talus rock that was likely deposited from actively raveling bedrock bluffs located throughout the tributary. The talus obscures the presence of a stream channel along the base of the draw (Photo 16). It is likely that seasonal runoff flows through the talus below the surface and possibly results in seeps at unidentified locations near the fan apex. The fan has slope gradients ranging between 15% and 28% near the vicinity of House 2 where the fan appears to be dominated by historical debris flow processes with an event frequency estimated to be on the order of centuries. There is no evidence of large debris flow activity in recent history. Boulders were identified on the fan and likely originated from the actively raveling rock bluffs located throughout the unit.

Rockfall processes are active in the face unit and prior to the wildfire there was an existing rock fall hazard upslope of House 2. Typically, there is a small increase to the rock fall hazard after wildfire events. The increase in rockfall hazards is typically due to the removal of vegetation that is otherwise supporting fallen rocks and which can act as rockfall barriers. As a result, rockfall processes have the potential of impacting House 2, outbuildings, and the property.

Photo 16. Talus located along base of draw within the Lewis Tributary 1 drainage.

As per Table 3, Lewis Tributary 1 drainage has a high post-wildfire incremental debris flow hazard.

Given the location of the house from the fan apex (250 m) and presence of the significant in-channel talus the likelihood of a debris flow directly impacting House 2 is considered low resulting in a MODERATE PARTIAL RISK.

6.3. House 3:

Tracy Creek

Private property including a residence (House 3) and out-buildings are situated on the Tracy Creek fan, upslope of the Lazy Lake Road which crosses the lower portion of the fan. The residence and out-buildings are situated in the middle of the fan approximately 300 m downslope of the apex of the fan (Photo 17). There is one water license in Tracy Creek for irrigation purposes (PD22959) that is situated near the apex of the fan (Photo 18). From the apex of the fan, Tracy Creek currently flows in a southwesterly direction away from House 3 and out-buildings (Map 2). The majority of the fan is located in an un-burned area.

Photo 17. View looking west at House 3 situated in the middle of the Tracy Creek fan.

Photo 18. View looking upstream at Tracy Creek and the location of the POD (irrigation) situated near the apex of the Tracy Creek fan.

The Tracy Creek drainage is naturally subject to periodic debris flow events with a frequency estimated to be on the order of centuries and which has not had a large debris flow event in recent history. Sediment within the channel has likely built up over this time resulting in the potential for a large debris flow event if initiated. Tracy Creek is sufficiently contained within a gully throughout the middle to lower reaches of the drainage; however, the creek has variable confinement across the fan and avulsion is possible in the event of a debris flow or flood. The creek channel was modified to accommodate the water intake for the POD, resulting in a shallow confinement of the creek channel, which could potentially result in water and debris spilling out of the gully in the event of a debris flow. Furthermore, there is an access trail which leads from the water intake and down towards House 3 (Photo 18).

Tracy Creek has an overall moderate burn severity, with 28% Moderate and 14% High. The majority of the moderate and high burn severity areas are situated in the southern portion of the lower Tracy Creek watershed where several steep linear drainage patterns are connected to Tracy Creek (Photos 19 and 20). The Tracy South-1 Tributary has a significantly higher burn severity with 51% Moderate and 40% High. The extent of moderate and high burn severity connected to the gully headwall areas in the Tracy South-1 Tributary where debris flows could occur results in an increase in debris flow hazard with the potential to temporary block Tracy Creek flows. These landslides, if they were to occur, would be approximately 3 km upstream from the Tracy Creek fan with potential for debris to continue downstream and reach the fan. House 3 is located in the middle of the fan which has a slope gradient ranging between 10% and 18%. The fan appears to be dominated by fluvial processes as opposed to debris flow processes. Based on field observations of the fan, past debris flow deposits in the form of boulders, debris lobes or debris levees are not apparent in the vicinity of House 3.

Photos 19 and 20. View looking south at the south side of the lower area of Tracy Creek drainage upper and lower with mostly moderate and high vegetation burn severity.

Taking into consideration the post-wildfire conditions within the Tracy Creek drainage as well as the upslope relief within the gully system, the likelihood of incremental post wildfire landslides and flooding within the Tracy Creek drainage is estimated as moderate (Table 3).

In the event of a significant debris flow event there is a high likelihood of a direct impact and damages to the POD (irrigation) and related infrastructure. In addition, there is a moderate to high likelihood that water and debris will be forced out of the gulley at the location of the water intake due to the shallow confinement.

Taking this into consideration along with the uniform shape of the fan, as well as the approximate 300 m distance (apex to house), in the event of a debris flow the likelihood of directly impacting House 3 is considered low resulting in a LOW PARTIAL RISK. However, potential nuisance flooding could still reach the house.

6.4. House 4

House 4 is situated west of the Bill Nye Fire along the Lazy Lake Road and was originally identified as being possibly at risk of post wildfire landslides or flood hazard (Map 1). However, due to the significant intervening distance of approximately 2.5 km west of Tracy Creek across gentle and convoluted terrain, the incremental partial risk of post wildfire debris flows or flooding is considered VERY LOW.

6.5. House 5:

Herbert Creek / Herbert Face /Herbert Tributary 1/ Herbert Tributary 2

Private property including a residence (House 5) and out-buildings are situated between the Herbert Creek fan to the north and the Herbert Fan 1 to the south (Map 3). There is one water license in Herbert Creek for irrigation purposes (PD22979) and is situated near the apex of the fan. From the apex of the fan, Herbert Creek flows in a southerly direction through the private property and adjacent to House 5 and out-buildings (Photo 21). The house is located approximately 800 m south of the apex of the Herbert Creek fan. There are potential fire related hazards to the house associated with the Herbert Creek drainage and the Herbert Face. While not a significant risk to the house, Herbert Tributary 1 and the Herbert Tributary 2 drainages have the potential to impact the private lands to the south of House 5.

Photo 21. View looking north at House 5 and private property situated in the Herbert Creek watershed. Note the recent post-wildfire debris flows located just south of the property.

Herbert Creek

Herbert Creek is a drainage that is naturally subject to periodic debris flow events with a frequency estimated in the order of centuries and does not appear to have experienced a large debris flow event in recent history. Sediment within the channel has likely built up over this time resulting in the potential for a large debris flow event if initiated. Herbert Creek is sufficiently contained in a gully throughout the drainage; however, the gully loses confinement at the apex of the fan and avulsion would be possible in the event of a flood or debris flow. The Herbert Creek fan appears dominated by debris flow processes.

Herbert Creek has a moderate to high burn severity, with 38% Moderate and 33% High. The majority of the high burn severity areas are situated in the central portion of the watershed in steep gullied terrain converging into Herbert Creek. Bedrock bluffs are common in the watershed and are subject to active rockfall processes. The extent of moderate and high burn severity areas connected to the gully headwall results in the debris slides and debris flows potentially temporarily blocking Herbert Creek flows. These landslides, if they were to occur, would be more than 2 km upstream from the Herbert Creek fan and could result in debris flows or debris floods affecting the fan.

The estimated incremental likelihood of post-wildfire landslides and flooding within the Herbert Creek drainage is estimated as moderate to high (Table 3).

In the event of a significant debris flow event there is a high likelihood of a direct impact and damages to the POD (PD22979) and related infrastructure due to their location near the top of the Herbert Creek fan.

Taking into consideration the approximate distance of 800 m to House 5 across the gentle to flat terrain (approximately 330 m beyond the toe of the fan), there is a very low likelihood of a debris flow event reaching House 5; however, there is potential for debris flood or other flood related hazardous events such as bank erosion, channel avulsion, or clearwater flooding impacting private property, House 5 and out-buildings due to their proximity to Herbert Creek which flows through the property.

As a result, the likelihood of flood related impacts to House 5 is considered low to moderate resulting in a MODERATE TO HIGH PARTIAL RISK with respect flooding related impacts to House 5 (Table 4).

Herbert Face

The Herbert Face drainage is located upslope of House 5 and private property. Herbert Face forms a broad shallow basin and consists of moderately steep to very steep slopes, including large talus slopes. Bedrock bluffs are common in the upper portion of the face unit and are subject to active rockfall processes, as well as the potential for open slope debris avalanches or possibly debris flows in the shallow gully within the center of the drainage. It does not appear that rock fall events extend beyond the gentle gradient bedrock shelf including a subtle cross-slope bedrock ridge feature situated up slope of the private property.

Approximately 82% of the Herbert Face drainage includes moderate and high burn severity areas. The extent of moderate and high burn severity connected to the steep terrain in the Herbert Face drainage where debris flows could result in an increase in debris flow hazard. These landslides, if they were to occur, would have the potential to reach the valley bottom. The primary hazards to House 5 and private property consists of debris flows and debris avalanches originating in the higher steeper terrain of the Herbert Face drainage.

Taking into consideration the post-wildfire conditions within the Herbert Face drainage, the likelihood of debris flow and debris avalanche hazards is estimated as high (refer to Table 3).

There is an intervening gently sloped bedrock shelf, including a subtle cross-slope bedrock ridge feature, situated along the northeastern property boundary which would likely create a potential buffer from possible impacts to House 5 and private property in the event of a significant debris flow. Existing colluvium from past upslope landslides does not appear to extend beyond this lower slope onto the gentle terrain where House 5 is located. In addition, House 5 is situated near the south edge of the Herbert 5 face unit, with a relatively small upslope catchment consisting of mostly Moderate burn severity. As a result, the potential for a hazardous debris flow or debris avalanche within the Herbert Face unit is estimated to be Moderate.

The likelihood of a debris flow or debris avalanche directly impacting House 5 is considered low based on the terrain descriptions above, resulting in a LOW PARTIAL RISK for House 5 with respect to debris flows or debris avalanches initiating within the Herbert Face drainage (Table 4).

Herbert Tributary 1

Herbert Tributary 1 is a smaller drainage located upslope of private property to the south of House 5 and consists of moderately steep to very steep gullied terrain. There are two steep-sided gullies in the upper drainage area which converge at mid-slope. The stream is sufficiently contained in a gully throughout the drainage; however, the gully loses confinement within the upper portion of the Herbert Fan 1. Based on field observations the fan is dominated by debris flow processes. The mid-portion of the drainage includes shallow dry gullies and common bedrock bluffs which are subject to active rockfall processes, as well as to the potential for open slope debris avalanches; this area has been included within a terrain polygon mapped as unstable. The drainage is naturally subject to periodic debris flow events with a frequency estimated to be on the order of decades. Recent post-wildfire debris flows have occurred in the steeper gullies with high burn severity and have reached the middle of the Herbert Fan 1 along the eastern edge of the private property (Photo 21). These events likely occurred following two significant rainstorms events based on weather records (Env. Canada – Cranbrook) which indicated 29.2 mm and 21.4 mm of precipitation on August 8 and 17, 2021 respectively.

Approximately 84% of the Herbert Tributary 1 drainage includes moderate and high burn severity areas which are associated with moderately steep to very steep gullied terrain. Taking into consideration the post-wildfire conditions within the Herbert Tributary 1 drainage, the upslope relief within the gully system, as well as the recent occurrence of post-wildfire debris flows, the likelihood of debris flow hazards within the Herbert Tributary 1 drainage is estimated as High (Table 3).

Given the location of House 5 upstream to the north of the toe of the fan, it is not at significant risk from debris flows originating in the Herbert Tributary 1 drainage. Debris flow deposits could reach the private land to the south of House 5 in the area identified as Herbert Fan 1 on Map 3, and sediment–laden flow could reach Herbert Creek located further downslope near the base of the Herbert Fan 1 flowing in a southerly direction across the private property.

Herbert Tributary 2

The Herbert Tributary 2 drainage is located upslope between House 5 and House 6 and consists of moderately steep to very steep gullied terrain. There are several steep-sided stream gullies in the upper drainage area which converge at mid-slope. Further downslope, the stream gully appears to lose confinement at the apex of the Herbert Fan 2. The drainage is naturally subject to periodic debris flow events with a frequency estimated to be on the order of decades and based on field observations the fan is dominated by debris flow processes. The Herbert Fan 2 which forms at the base of the drainage merges with the Herbert Fan 1 to the north; avulsion is possible in the event of a flood or debris flow directed towards the private property to the south of House 5 and runout could occur onto either Herbert Fan 2 or Herbert Fan 1. Bedrock bluffs are common in the upper to mid-portion of the drainage and are subject to active rockfall processes, as well as to the potential for open slope debris avalanches; this area has been included within terrain polygon mapped as unstable. Recent post-wildfire debris flows have occurred in the steeper gullies with high burn severity and have reached the lower portion of the Herbert 2 fan as well as spilling over onto the mid-portion of the Herbert Fan 1 along the southeastern edge of the private property to the south of House 5 (Photo 21). These events likely occurred during the same period as described for the Herbert Tributary 1.

Approximately 73% of the Herbert Tributary 2 drainage includes moderate and high burn severity areas which are associated with moderately steep to very steep gullied terrain. Taking into consideration the post-wildfire conditions within the Herbert Tributary 2 drainage, the upslope relief within the gully system, as well as the recent occurrence of post-wildfire debris flows, the likelihood of debris flow and flooding hazards within the Herbert Tributary 2 drainage is estimated as high (Table 3).

House 5 is not considered at risk from debris flow or flood events originating in Herbert Tributary 2 because of its location upstream to the north of both Herbert Fan 2 and Herbert Fan 1. The undeveloped private land to the south of House 5 could be impacted by debris flow runout or flood processes originating in Herbert Tributary 2 (as already occurred in August 2021), and sediment–laden flow could reach Herbert Creek located further downslope near the base of the Herbert Fan 2 of Herbert Fan 1.

6.6. House 6:

Herbert Creek

Private property including a residence (House 6) and out-buildings are situated at valley bottom in the Herbert Creek watershed downstream of the southern boundary of the Bill

Nye fire. Herbert Creek flows in a southerly direction through the private property and adjacent to House 6 (Photo 22). House 6 is situated approximately 2.4 km from the apex of the Herbert Creek fan across gentle to flat terrain within the valley bottom and approximately 600 m south of the southern boundary of the fire.

Herbert Creek

The Herbert Creek watershed in addition to Herbert Tributary 1, Herbert Tributary 2, and Herbert Tributary 3 all drain into Herbert Creek upstream of House 6. Burn severity and debris flow and/or debris flood hazards for each of these drainages are described above in Section 6.5, except for Herbert Tributary 3 which is described below.

Herbert Tributary 3

Herbert Tributary 3 is a smaller drainage located in the southernmost portion of the burned area. Based on the burn severity mapping approximately 27% of the total Herbert Tributary 3 drainage was impacted by the fire which includes a narrow band of the northern portion of the drainage. The drainage consists of moderately steep to very steep slopes incised by a few gullies, most of which converge in the middle portion of the drainage. The main stream gully appears to lose confinement near the apex of the Herbert Fan 3. Based on field observations the fan is dominated by debris flow processes. The gullies are naturally subject to periodic debris flow events with a frequency estimated to be on the order of decades. There is no evidence of recent debris flows. Bedrock bluffs are common in the upper to middle portion of the drainage and are subject to active rockfall processes, as well as the potential for open slope debris avalanches; this area has been included within terrain polygon mapped as unstable. House 6 is situated approximately 450 m south from the base of the Herbert Fan 3 and is not considered to be at risk from debris flow events originating in Herbert Tributary 3.

Approximately 25% of the Herbert Tributary 3 drainage includes moderate and high burn severity areas which are associated with moderately steep to very steep gullied terrain. Due to the relatively small burned area within the drainage, the effects of the wildfire are likely to be limited to higher-than-normal sedimentation and/or ash present in the stream potentially affecting water quality, but significant changes to stream flows or debris flow magnitude or frequency is not expected.

Taking into consideration the post-wildfire conditions within the Herbert Tributary 3 drainage, the upslope relief within the gully system, the incremental post-wildfire likelihood of landslides and flooding hazards within the Herbert Tributary 3 drainage is estimated as low (Table 3).

Photo 22. View looking northwest at House 6 and private property situated in the Herbert Creek watershed south of the Bill Nye Fire which can be seen in the upper right corner of the photo.

In the event of a significant debris flow in any of Herbert Creek or the Herbert Tributaries the debris would likely deposit across the respective fans; however, turbid flood flow and other flood related hazards such as bank erosion and channel avulsion within Hebert Creek could potentially affect House 6. While there is a high likelihood of debris flows and increases in runoff in each of the affected Herbert drainages except for Herbert Tributary 3, the potential for hazardous flood process to occur in Herbert Creek downstream of all these drainages is tempered by the extent of gentle gradient fans separating the upslope streams from the main valley bottom creek where much runoff is likely to disperse into subsurface flow. As a result, there is a moderate likelihood for flood related hazards to impact the vicinity of House 6 resulting in a MODERATE TO HIGH PARTIAL RISK (flood related hazards) to House 6.

6.7. House 7

House 7 and out-buildings are situated on the Lewis Creek fan. The majority of the fan is located in an un-burned area. The residence and out-buildings are situated in the middle of the fan approximately 250 m downslope of the apex of the fan which has a slope gradient ranging between 15% and 20%. The fan appears to be dominated by fluvial processes as opposed to debris flow processes. Based on field observations of the fan, past debris flows deposits in the form of boulders, debris lobes or debris levees are not apparent in the vicinity of House 7. There are multiple water licenses in Lewis Creek for irrigation and domestic purposes. From the apex of the fan, Lewis Creek flows in a northwesterly direction towards House 7 and out-buildings. House 7, outbuildings, and related private land and access are potentially affected by the Lewis North Face, Lewis Main, and Lewis Tributary 2.

Lewis North Face and Lewis Main

Lewis North Face and the much larger Lewis Main drainages both flow into lower Lewis Creek. Based on the burn severity mapping approximately 5% of the total Lewis Main drainage was impacted by the fire. A recent debris flow event was identified at the upper bridge crossing of Lewis Creek FSR; however, it is important to note that the recent debris flow was not caused by the fire as the drainage area upstream of the debris flow was not affected by the fire. There is no evidence of recent debris flows at the lower FSR crossing of Lewis Creek or at the apex of the Lewis Creek fan. The three smaller Lewis East subbasins do have significant burn areas in their upper watersheds and represent a moderate or high incremental likelihood of post wildfire debris flows which could impact water quality in the main Lewis Creek channel. However, due to the minimal burned area in the overall Lewis Creek drainage, the effects of the wildfire would be limited to higher-than-normal sedimentation and/or ash present in the stream and potentially affecting water quality. Significant changes to flood related hazards (including increased peak flows, channel avulsion, bank erosion, or debris floods) on the Lewis Creek Fan are not expected as a result of the fire.

Lewis Tributary 2

House 7 is not considered at risk due to Lewis Tributary 2. The house access road identified in Figure 1 could be impacted by nuisance flooding and/or minimal debris deposition associated with the distal effects of a debris flows.

6.8. MoTI Lazy Lake Road

The section of the Lazy Lake Road located between Lewis Creek and Tracy Creek has been assessed for risks of post wildfire landslides or flood hazard due to its proximity to the western boundary of the fire including a short section across the Lewis Tributary Fan located within a burned area of the fire.

Areas of concern along the Lazy Lake Road include the section between the Tracy Creek Fan and the Lewis Tributary Fan where the road is located at the base of the Tracy North-Lewis Tributary 1 Face. This face unit includes mostly moderate burn severity areas with some high burn severity areas which are associated with moderately steep to steep terrain, including some shallow dry gullies, where debris flows could initiate (Photo 23). The intervening gentle to moderate slopes between the base of the steeper terrain and the road would likely limit the potential for debris flow impact to the road and so the likelihood of road damage is considered moderate.

There is a segment of the Lazy Lake Road which accesses House 1 and House 2 where the road is located at the base of the Lewis Tributary 1 drainage, the Lewis West 3 face unit, the Lewis West 2 face unit, and the Lewis West 1 face unit. A significant proportion of the area upslope was burned to moderate and high burn severity. The intervening gentle slopes, including the Lewis Tributary Fan, between the base of the steeper terrain and the Lazy Lake Road, including the location of the Lewis Creek FSR situated up slope of the road would likely limit the potential for a spatial effect such that the likelihood of debris flows damaging the Lazy Lake Road has been estimated to be low.

It is noted the recent debris flow events reached or terminated in close proximity to the Lewis Creek FSR which is situated a short distance upslope of the Lazy Lake Road.

Photo 23. View looking east from the Lazy Lake Road at the Tracy North – Lewis Tributary 1 Face showing moderate to low burn severity areas.

6.9. Lewis Creek FSR

The Lewis Creek FSR crosses the lower extents of the Lewis West 3, Lewis West 2, Lewis West 1, and Lewis Tributary and through areas of moderate burn severity. There are areas with moderate to high burn severity above the FSR. Post wildfire debris flows have already impacted the road in multiple locations. Works to re-establish culverts and ditch lines have been completed at the sites impacted. The FSR is generally in good condition and there were no observed signs of instability in the form of fill slope failures or tension cracks.

Some of the existing culverts are susceptible to plugging in the event of additional debris flows events and the crossing grades increase the likelihood of redirecting debris flows (and creek flows) downgrade. Recommendations for the FSR are included in Section 8.6 and 8.8.

6.10. Non-Status Roads:

Lewis Creek (segment between the drainage divide of Lewis East 1 and Lewis North Face and the Mine site)

The road passes through the Lewis Tributary 2, Tracy North and Tracy Creek drainages through areas burned at moderate to high severity. The are no culverts; however, the road is in relatively good condition with no signs of significant instabilities in the form of fill slope failures or tension cracks. There are some local sites where the road intercepts and has redirected water (seepage) down the road grade resulting in some road surface erosion. Recommendation to deactivate the road is included in section 8.7.

6.11. Partial Risk Summary for Select Drainages of Interest

The following table (Table 4) summarizes partial risk estimates for the select drainages of interest in terms of hazards and high value elements at risk.

Table 4. Partial Risk summary table for select drainages in the Bill Nye Fire

Drainage Name	Hazard	Process	Value at Risk	Likelihood of Spatial Effect (houses only) P(S:H) x P(T:S)	Partial Risk (houses only)
Lewis Tributary 2	High	Debris Flow	House 1, private property, domestic water infrastructure	Low	Moderate
Lewis West 1	High	Debris Flow	House 1, private property, domestic water infrastructure	Low	Moderate
Lewis West 2	High	Debris Flow	House 1, private property, domestic water infrastructure	Low	Moderate
Lewis Tributary 1	Moderate	Debris Flow	House 2, private property,	Moderate	Moderate
Tracy Creek	Moderate	Debris Flow/Flood	House 3, private property, irrigation water infrastructure	Low	Low
Herbert Creek	Moderate to High	Debris Flood/Flood	House 5, private property	Low to Moderate	Moderate to High (flooding hazards)
Herbert Face	Moderate to High	Debris Flow/Debris Avalanche	House 5, private property	Low	Low

Drainage Name	**Hazard**	**Process**	**Value at Risk**	**Likelihood of Spatial Effect (houses only)** P(S:H) x P(T:S)	**Partial Risk** (houses only)
Herbert Creek and Tributaries	Moderate to High	Flood	House 6, private property	Moderate	Moderate to High (flooding hazard)

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

Debris flows and debris slides are likely to occur (some have already occurred) as a result of the 2021 Bill Nye Wildfire. The locations of these landslides are limited to small steep drainages located in the upper watersheds of the Lewis Tributary 2, the Lewis West 1, the Lewis West 2, the Hebert Tributary 1 and the Herbert Tributary 2 drainages. Some of the houses and private property and the Lewis Creek FSR are directly exposed to these landslide hazards. Flooding may also occur (e.g., Herbert Creek).

8.1. General Recommendations; all affected drainages

Recommendation 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.

Recommendation 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.

Recommendation 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 C.

Recommendation 4: 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 below in drainages with moderate or high hazard ratings (Table 3).

8.2. Lewis West 1, Lewis West 2 and Lewis Tributary 2

House 1

Recommendation 5: The construction of a deflection berm and/or swale that would be designed by a qualified professional, should be considered above House 1. The berm/swale could extend from the bedrock outcrop on the north side of the natural bedrock-controlled gully to the northeast edge of the bench that House 1 is located (Photo 24).

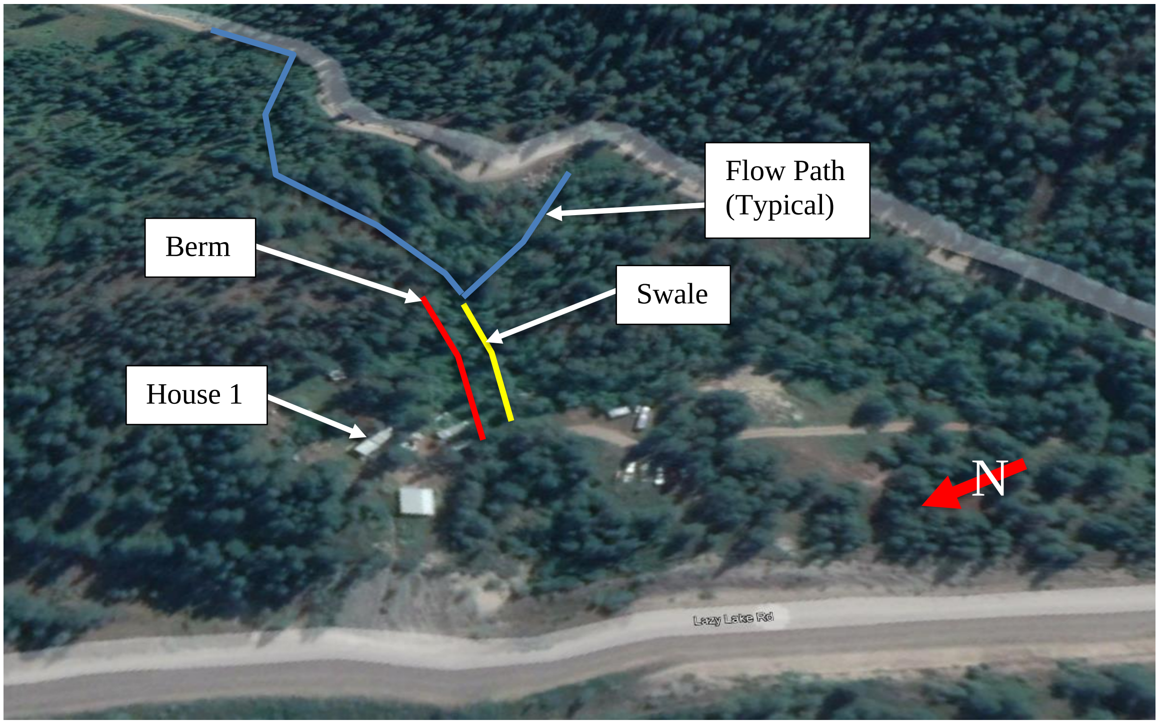

Photo 24. Proposed House 1 berm and swale locations (Google, 2018)

Recommendation 6: The homeowners informed the undersigned that no one currently lives on the property full time. At times of occupation the homeowners/residents should familiarize themselves with these creeks in relation to the recommendations listed in Section 8.1.

8.3. Lewis Tributary 1 and Lewis West 3

House 2

Recommendation 7: The construction of a deflection berm and/or swale, that would be designed by a qualified professional, should be considered up slope of House 2 extending from the rock bluffs to the downslope extent of House 2 (Photo 25).

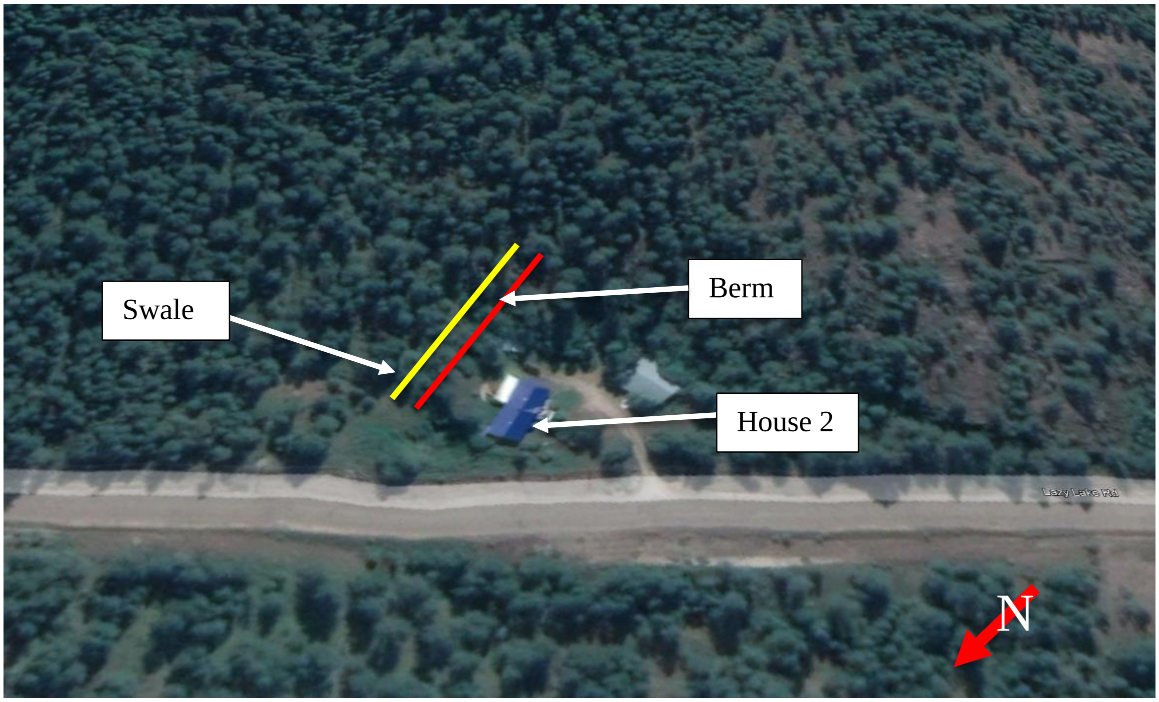

Photo 25. Proposed House 2 berm and swale locations (Google, 2018)

8.4. Tracy Creek

House 3

Recommendation 8: The likelihood of significant debris reaching the house is considered low; however, consideration should be given to mitigating the hazard of shallow nuisance flooding and sedimentation by constructing a small deflection berm and ditch up slope of the house approximately along the fence line. Given the distance from the House to the fan apex, a high (greater than 1m) berm would not likely be required

8.5. Herbert Creek

House 5

Recommendation 9: MFLNRORD should confirm that all of the machine guards upslope of House 5 are adequately rehabilitated to ensure slope stability and natural surface drainage patterns are maintained.

House 6

Recommendation 10: MFLNRORD should confirm that all of the machine guards upslope of House 6 are adequately rehabilitated to ensure slope stability and natural surface drainage patterns are maintained.

8.6. Lewis Creek Forest Road FSR (up slope of House 1 and House 7)

Recommendation 11: Enlargement of the ditch for catchment (~2.5 m wide x 1 m deep) along sections crossed by recent debris flows and construction of ~1 m deep catchment basin at culvert inlets is required.

Recommendation 12: Construction of a gentle swale in road surface at the culvert location to reduce potential for redirected water in the event of blockage; but that still allows access.

Recommendation 13: Installation of a culvert across Lewis Creek FSR at the southern end of Lewis Tributary 2 is required.

Recommendation 14: The FSR above the houses should be gently in-sloped.

8.7. Lewis Creek: Non-Status Road

Recommendation 15: Deactivation prescriptions should be completed for the full length of the non-status road (completed by qualified professional) and deactivation works implemented (including constructing swales at gully locations and cross ditches where required).

8.8. MFLNRORD and Forest Licensees

Recommendation 16: 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.

Recommendation 17: Increased inspection frequency of roads and culverts as required for the next three to five years - at least twice per year and following significant rain events.

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 and Sitkum Consulting 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. and Sitkum Consulting Ltd. accept 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.

Report prepared by:

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March 3/2022

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March 3/22

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2022-03-03

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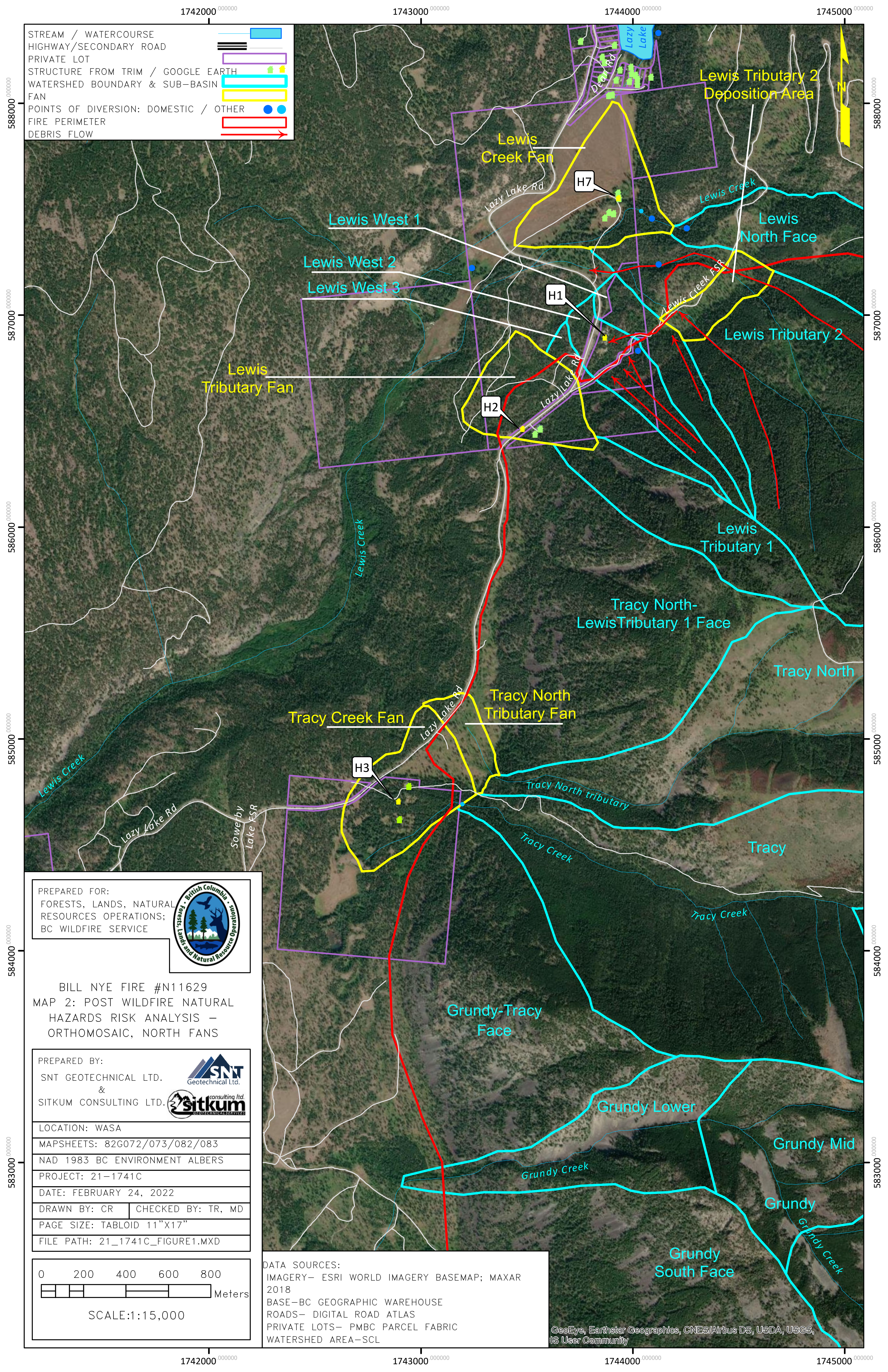
Appendix A

Maps

Drainage Name	Total Drainage Area (ha)	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 (%)
Grundy	360	17	27	33	23
Grundy Lower	50	9	34	35	23
Grundy Mid	70	0	5	32	63
Grundy South Face	319	1	19	69	12
Grundy South Tributary	126	1	9	61	30
Grundy Upper	241	23	32	33	12
Grundy-Tracy Face	124	1	34	63	2
Herbert	599	17	12	38	33
Herbert Face	144	1	17	55	27
Herbert Tributary 1	69	3	12	44	40
Herbert Tributary 2	116	16	11	25	48
Herbert Tributary 3	71	73	2	13	12
Herbert-Grundy South Face	188	0	22	76	3
Lewis East	12	42	14	32	13
Lewis East 2	27	11	6	17	66
Lewis East 3	33	22	7	15	56
Lewis Main	2571	96	1	1	2
Lewis North Face	59	48	0	29	23
Lewis Tributary 1	35	0	11	42	46
Lewis Tributary 2	181	7	2	24	67
Lewis West 1	18	30	2	22	46
Lewis West 2	19	34	3	33	30
Lewis West 3	13	13	1	54	32
Tracy	627	43	15	28	14
Tracy North	149	0	12	67	21
Tracy North – Lewis Tributary 1 Face	133	0	29	59	12
Tracy South-1	45	0	9	51	40


STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
STRUCTURE FROM TRIM / GOOGLE EARTH
WATERSHED BOUNDARY & SUB-BASIN
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
FIRE PERIMETER
DEBRIS FLOW
1742000
1743000
1744000
1745000
588000
587000
586000
585000
584000
583000
Lazy Lake
Lewis Tributary 2 Deposition Area
Lewis Creek Fan
H7
Lazy Lake Rd
Lewis Creek
Lewis North Face
Lewis West 1
Lewis West 2
Lewis West 3
H1
Lewis Creek FSR
Lewis Tributary 2
Lewis Tributary Fan
H2
Lewis Tributary 1
Lewis Creek
Tracy North-LewisTributary 1 Face
Tracy North
Tracy North Tributary Fan
Tracy Creek Fan
H3
Tracy North tributary
Tracy Creek
Tracy
Lewis Creek
Lazy Lake Rd
Sowerby Lake FSR
Grundy-Tracy Face
Grundy Lower
Grundy Mid
Grundy Creek
Grundy
Grundy South Face
PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS;
BC WILDFIRE SERVICE
BILL NYE FIRE #N11629
MAP 2: POST WILDFIRE NATURAL HAZARDS RISK ANALYSIS – ORTHOMOSAIC, NORTH FANS
PREPARED BY:
SNT GEOTECHNICAL LTD. & SITKUM CONSULTING LTD.
LOCATION: WASA
MAPSHEETS: 82G072/073/082/083
NAD 1983 BC ENVIRONMENT ALBERS
PROJECT: 21-1741C
DATE: FEBRUARY 24, 2022
DRAWN BY: CR
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PAGE SIZE: TABLOID 11"X17"
FILE PATH: 21_1741C_FIGURE1.MXD
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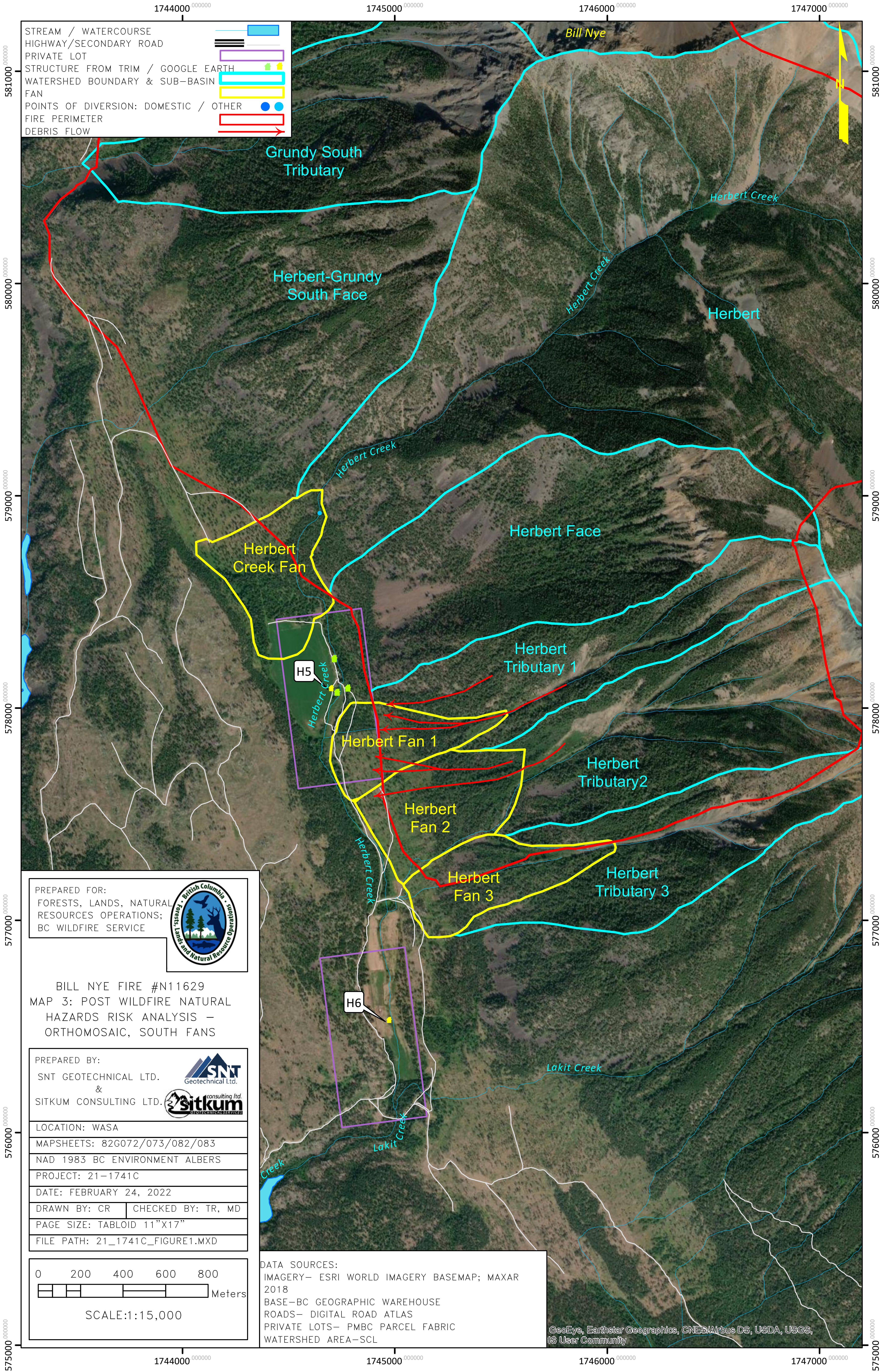
SCALE:1:15,000
DATA SOURCES:
IMAGERY- ESRI WORLD IMAGERY BASEMAP; MAXAR 2018
BASE-BC GEOGRAPHIC WAREHOUSE
ROADS- DIGITAL ROAD ATLAS
PRIVATE LOTS- PMBC PARCEL FABRIC
WATERSHED AREA-SCL
GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, GIS User Community



STREAM / WATERCOURSE
HIGHWAY/SECONDARY ROAD
PRIVATE LOT
STRUCTURE FROM TRIM / GOOGLE EARTH
WATERSHED BOUNDARY & SUB-BASIN
FAN
POINTS OF DIVERSION: DOMESTIC / OTHER
FIRE PERIMETER
DEBRIS FLOW
N
Bill Nye
Grundy South Tributary
Herbert-Grundy South Face
Herbert Creek
Herbert
Herbert Face
Herbert Creek Fan
Herbert Tributary 1
Herbert Fan 1
Herbert Tributary2
Herbert Fan 2
Herbert Fan 3
Herbert Tributary 3
H5
H6
Lakit Creek
Creek
PREPARED FOR:
FORESTS, LANDS, NATURAL RESOURCES OPERATIONS;
BC WILDFIRE SERVICE
British Columbia
Forests, Lands and Natural Resource Operations
BILL NYE FIRE #N11629
MAP 3: POST WILDFIRE NATURAL HAZARDS RISK ANALYSIS – ORTHOMOSAIC, SOUTH FANS
PREPARED BY:
SNT GEOTECHNICAL LTD.
&
SITKUM CONSULTING LTD.
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GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, IS User Community
1744000
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Appendix B

Water License Reports

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Lewis Creek	Lewis Creek	PD22936	F003776	Irrigation	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Incidental Domestic	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Irrigation	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Incidental Domestic	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Irrigation	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Incidental Domestic	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22936	F003776	Irrigation	49.811101	-115.624949
Lewis Creek	Lewis Creek	PD22935	F003776	Irrigation	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22935	F003776	Incidental Domestic	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22935	F003776	Irrigation	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22935	F003776	Incidental Domestic	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22935	F003776	Irrigation	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22935	F003776	Incidental Domestic	49.811715	-115.627112
Lewis Creek	Lewis Creek	PD22934	C041056	Land Improve: General	49.8120943	-115.627738
Lewis Creek	Lewis Creek	PD22934	C109117	Land Improve: General	49.8120943	-115.627738
Lewis Creek	Lewis Creek	PD22956	C046399	Irrigation	49.7796293	-115.687798
Lewis Creek	Lewis Creek	PD22956	C059384	Domestic	49.7796293	-115.687798
Lewis Creek	Lewis Creek	PD22956	C059384	Irrigation	49.7796293	-115.687798
Lewis Creek	Lewis Creek	PD22955	C046398	Irrigation	49.7709402	-115.693434
Lewis Creek	Lewis Creek	PD22955	C059384	Domestic	49.7709402	-115.693434
Lewis Creek	Lewis Creek	PD22955	C059384	Irrigation	49.7709402	49.7709402
Lewis Creek	Lewis Creek	PD22954	C059384	Domestic	49.7705719	-115.69516

Drainage	Source	PD number	License Number	Purpose	Latitude	Longitude
Lewis Creek	Lewis Creek	PD22954	C059384	Irrigation	49.7705719	-115.69516
Lewis Creek	Lewis Creek	PD22953	C046396	Irrigation	49.7673982	-115.712931
Lewis Creek	Lewis Creek	PD22953	C046397	Irrigation	49.7673982	-115.712931
Lewis Creek	Lewis Creek	PD22953	C059433	Domestic	49.7673982	-115.712931
Lewis Creek	Lewis Creek	PD22953	C059433	Irrigation	49.7673982	-115.712931
Lewis Creek	Lewis Creek	PD22952	C059433	Domestic	49.766039	-115.7203
Lewis Creek	Lewis Creek	PD22949	C035870	Irrigation	49.7657394	-115.721132
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Domestic	49.809747	-115.627121
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Livestock Stockwatering	49.809747	-115.627121
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Domestic	49.809747	-115.627121
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Livestock Stockwatering	49.809747	-115.627121
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Domestic	49.809747	-115.627121
Lewis Tributary 2	Rowena Creek	PD69258	C108071	Livestock & Animal: Stockwatering	49.809747	-115.627121
Lewis West 2	Marvel Spring	PD22945	C119664	Domestic	49.8062572	-115.629289
Tracy Creek	Tracy Creek	PD22959	C032303	Irrigation	49.78829	-115.645011

Appendix C

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.

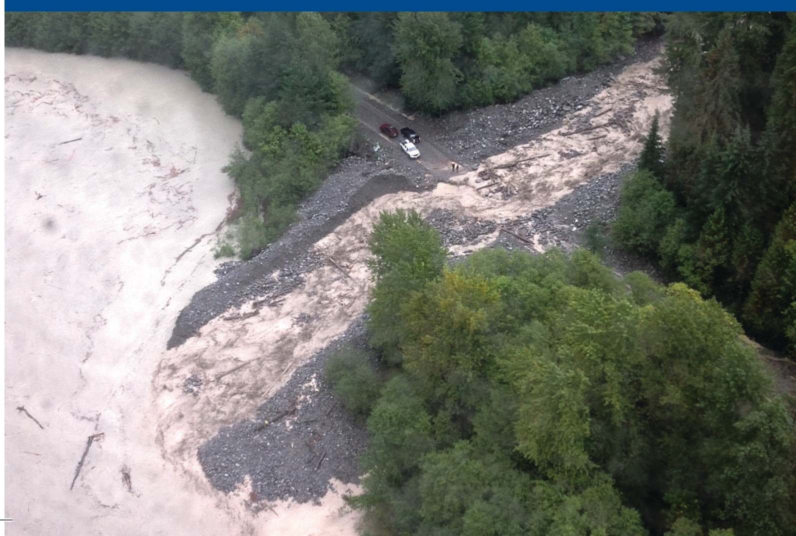
How can you get more information about potential risks to your property?

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

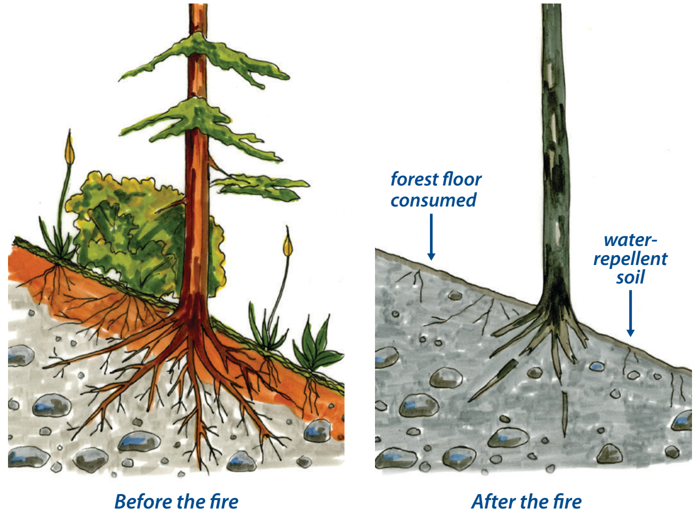
What you can do to recognize and deal with the hazards

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.

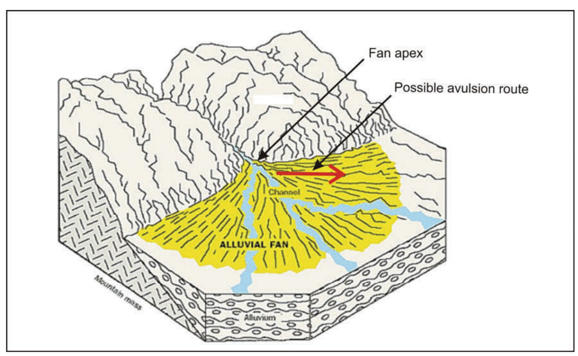


Figure 3. Schematic diagram of an alluvial fan, showing a possible flow route and geological features.

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 snowmelt 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 upstream. 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