

Springer Creek Fire Number 50372 Post-Wildfire Risk Analysis

Prepared for B.C. Ministry of Forests and Range
Southern Interior Forest Region - September 1, 2007*



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Executive Summary

The Springer Creek Fire burned extensive areas of the Enterprise Creek, Allen Creek, Cory Creek, Van Tuyl Creek, and Memphis Creek watersheds in addition to several face units. It has been well documented that wildfires can create soil and slope conditions that can increase the likelihood of debris flows, debris slides, debris floods, floods and snow avalanches. In order to assess the likelihood of these events occurring, the vegetation burn severity was estimated for each watershed (via high level photographs) with ground checks. Spot testing of soil burn severity and water repellency was also conducted. A ground review of the hill slope gullies, streams, slopes, and values at risk at the base of the slopes was completed, along with a partial assessment of some of the adjacent roads, trails and landings.

The review found the following vegetation burn severities, hazards and values at risk:

Creek	Watershed Area (hectares)	High and Moderate Vegetation Burn Severity	Primary Hazard Type	Hazard Level	Value at risk	Partial Risk Residents ¹	Partial Risk Highway Users ²
Enterprise	12000	4%	Debris Flood	Low	Highway Crossing of Enterprise Creek	n/a	Low
Enterprise 1	49	83%	Debris Flow	High	Highway and perhaps new crossing location	n/a	High
Allen Creek	70	27%	Debris Flow	Moderate to high	Houses, private property, highway	Moderate to high	Moderate to high
North Cory Creek	91	39%	Debris Flow	High	House, private property, highway	High	High
South Cory Creek	48	34%	Debris Flow	High	Building Site, House, private property, highway	High	High
South South Cory Creek	45	38%	Debris Flow	High	House, private property, highway	High	High
North Van Tuyl Creek	80	73%	Debris Flow	High	Highway, private property	Low	High
Mid Van Tuyl Creek	26	43%	Debris Flow	High	Highway, private property	Low	High
South Van Tuyl	86	57%	Debris Flow	High	Highway, house, private property	Low to Moderate	High
Memphis Creek North Ridge			Debris Slide	Low to moderate	Houses, private property, highway	Low ³	Low ³
Memphis Creek	539	52%	Debris Flow (or floods)	Moderate to High	Highway	n/a	Moderate
South Memphis	211	29%	Debris Flow	Moderate	Highway	n/a	Moderate
R1 Unit	85	16%	Debris Flow	Low	Highway	n/a	Low
Face units R3,R5,R6	43 to158	34% to 66%	Debris slide, or small debris flow	Low	Highway, residences below highway	Low	Low
Face Unit R5 – South End			Debris slide, or small debris flow	Moderate to high	Highway, residences at Allen Creek Fan	Moderate to high	Moderate to high

Table 1 Vegetation burn severities, hazards and values at risk

1 Partial Risk or P(HA) is the probability of occurrence of a specific hazardous landslide and the probability of it reaching or otherwise affecting the site occupied by a specific element; n/a = not applicable.

2 Actual partial risk to highway users will depend on a number of factors including highway configuration, stopping distances, available storage volume upstream of highway, highway users per day, and drainage control. Risk to highway users and infrastructure should be confirmed by MOT.

3 Risk at Memphis Creek north ridge depends on deactivated condition of Old Mining Road.

Many of these watersheds have a documented history of debris flow and debris slide activity and now, due to the wildfire effects on the vegetation and soil, the likelihood of landslides has substantially increased for the next 3 to 5 years. In order for landslides to initiate, a significant rainfall event must occur over the next several years. Because of the uncertainty related to the magnitude of rainfall events required to initiate post wildfire landslides, it is not possible to accurately predict and determine whether landslides will occur. Instead a qualitative estimate of landslide occurrence is made based on past experience (2003 Southern Interior Fires and elsewhere) and judgment. The short-term risk is primarily due to high intensity rainfall events on drier soils in summer and early fall. However, other longer and shorter term risks may be present related to snowmelt, rain-on-snow and long duration rainfall events and will require further investigation. Recommendations have been made for each watershed and include the following:

1. Communicate hazards and risks to local residents, landowners and stakeholders.
2. Consideration should be given to an evaluation of various early warning systems and the monitoring of local weather data.
3. Conduct a ground review of all mining, forestry roads and trails located in and above high risk areas, and fire protection guards and adequately deactivate them to ensure they do not result in further concentrations or diversions of surface or overland flow. The ground reviews will include recommendations for mitigative measures where required.
4. Produce a mitigation plan that prioritizes treatments based on the possible effectiveness of various treatment options to reduce erosion and promote water infiltration in the burn areas at the headwaters of the high hazard gullies above high

consequence locations. Further hydrologic and erosion modeling may assist with this evaluation.

5. Evaluate the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above houses, private property, and Highway 6.
6. A Ministry of Transportation review of existing and proposed highway infrastructure and signage in light of potential increased peak flows below high burn severity areas, and possible debris flow, debris flood and flood activity.
7. Complete the Landsat imagery comparisons of pre- and post-fire images and revise the vegetation burn severity map.
8. Complete an avalanche risk assessment with regards to avalanche magnitude, frequency and potential impacts to Highway 6 and private land.
9. Regenerate the forest by planting trees as soon as possible in the potential starting zones of snow avalanches.
10. No salvage logging should proceed in the moderate or high hazard watersheds located above elements at risk unless a further detailed study indicates that such harvesting will not further increase surface water or overland flows or result in a further concentration or diversion of surface water or overland flows. While distributing branches and limbs on the ground will increase ground cover, this has to be balanced by the necessary roads and trails and their potential impact.
11. Conduct an assessment of the long-term hydrologic and slope stability effects due to the wildfire with recommendations relating to possible long-term mitigative measures. The assessment should include a summary for local governments for consideration with respect to the issuance of rezoning, subdivision, and building permit approvals.
12. Monitor weather conditions, erosion events, re-vegetation, and the effects of any mitigative treatments in the burned areas for the next several years, to assist with the ongoing assessment of risk to downslope elements and to improve the predictive capabilities with regards to landslide initiation in interface burn areas.

Introduction

At the request of the Ministry of Forests and Range, South East Fire Centre and Southern Interior Forest Region, an emergency Post-Wildfire Risk Analysis was completed for the Springer Creek Fire (fire number 50372). The purpose of the analysis was to:

1. Identify the consequences that might be at risk.
2. Estimate the percent of area burned within each priority watershed.
3. Estimate the vegetation burn severity (produce a burn severity map) with ground checks.
4. Evaluate soil burn severity and determine the likelihood for increased overland flow and soil erosion potential, with a focus on areas with complete duff consumption and/or soil water repellency.
5. Evaluate debris flow, debris flood, debris slide, and flooding potential within each watershed. Identify and comment on other slope related hazards that may be present, including snow avalanches.
6. Make a preliminary inspection of the condition of roads, trails, fire access structures, guards and other human caused disturbances within each watershed that may contribute to landslides, erosion, and flooding as a result of the fire.
7. Complete a risk analysis and identify specific problem areas.
8. Make recommendations.

Following a wildfire, the likelihood of occurrence of landslides, erosion, floods and snow avalanches within or downslope of the burned area can increase. The degree of hazard increase depends on various factors including the burn area, vegetation burn severity, soil burn severity, development of water-repellent soil, slope attributes, local hydrology, and local geomorphic conditions. The trigger for an event is often a significant high intensity rainfall.

Elevated landslide and flooding hazards are both short-term (3 to 5 years) and long-term (until full forest regeneration). Short-term hazards relate to soil burn severity, development of water-repellent soil layers, increased overland flows, and sediment bulking. Longer-term hazards relate to increased Equivalent Clearcut Areas (ECA's) as a result of loss of overstory and possible effects of loss of tree root strength. This emergency analysis is focused on describing the elevated short-term hazards.

This emergency analysis was completed in a short time frame following allowable ground access in order to quickly determine if there was an increased risk from landslides, erosion,

flooding and snow avalanches due to the Springer Creek Fire and to appropriate communicate that risk to stakeholders with recommendations. The analysis is not intended to be an exhaustive review of the hazards, burn area, roads and trails, or consequences but rather as a tool to focus further reviews and actions to lower the risks, as is deemed appropriate by the stakeholders.

Methodology

During the week of Aug 13, while the burn area was still inaccessible to detailed ground reviews due to fire behavior, efforts were focused on collecting relevant background information including terrain stability mapping, historical landslide information (in the area), bedrock geology, TRIM maps, slope maps, and orthophotos. In addition, field information regarding the elements at risk (and their location to debris flow channels) were collected and a vegetation burn severity map was completed via oblique high level helicopter photography. During the week of August 20, ground reviews were conducted with an effort on confirming the burn severity map, identifying the degree of duff consumption and soil water-repellency, identifying potential areas of slope instability, and identifying potentially problematic roads and trails. The risk analysis, identification of recommendations for further evaluation and possible mitigative measures, and this report were completed during the week of August 27th. This schedule was consistent with the objective of having a risk analysis report completed within 10 days of having safe ground access.

Information Reviewed

Air Photos

Orthophotos

Terrain Stability Maps – TSIL B

Topography Maps – 1:20,000 TRIM Maps

Fire Perimeter Maps

RDCK 1:10000 Cadastral Map

MSRM 1:50000 2004 Flood Hazard Map

Bedrock Geology and Soil Maps

Various reports and studies – as referenced

Definitions

Consequence ¹	The effect on human well-being, property, the environment, or other things of value; or a combination of these. Conceptually, consequence is the change, loss, or damage to the elements caused by the landslide.
Hazard ¹	A source of potential harm, or a situation with a potential for causing harm, in terms of human injury; damage to property, the environment, and other things of value; or some combination of these.
Landslide ¹	A movement of rock, debris or earth down a slope. Includes debris flows, debris slides, and rockfalls. A debris flood is transitional between a debris flow and a flood.
Risk ¹	The chance of injury or loss as defined as a measure of the probability and the consequence of an adverse effect to health, property, the environment, or other things of value.
Risk Analysis ¹	The systematic use of information to identify hazards and to estimate the chance for, and severity of, injury or loss to individuals or populations, property, the environment, or other things of value.
Risk Assessment ¹	An assessment that combines risk analysis and risk evaluation to determine if a risk is acceptable or tolerable.
Soil Burn Severity ²	A relative measure describing the effects the wildfire had on soil hydrologic function through observations of the remaining woody debris, forest floor litter, duff, and the surface mineral soil.
Vegetation Burn Severity ²	Also referred to as Fire Severity. Describes the effects a wildfire has on the overstory and understory. Used to predict the potential effects wildfire could have on local hydrology, snowpack accumulation, soil erosion, and needle casting. Data usually collected by aerial visual means or remote sensing (satellite imagery) of a burned area.

Water repellency²

The degree to which soil resists the infiltration of water. A water repellent layer can be formed when the forest floor is almost completely or totally consumed by wildfire.

¹ Adopted from 2004 LMH 56 Landslide Risk Case Studies in Forest Development Planning and Operations 2004 MOFR .

² Modified from Curran et al 2006.

Site Location and Landslide History

The Springer Creek Fire was bounded by the Highway 6 to its west, Enterprise Creek drainage to the north, and Springer Creek Drainage to the south (see Figures 1 and 2).

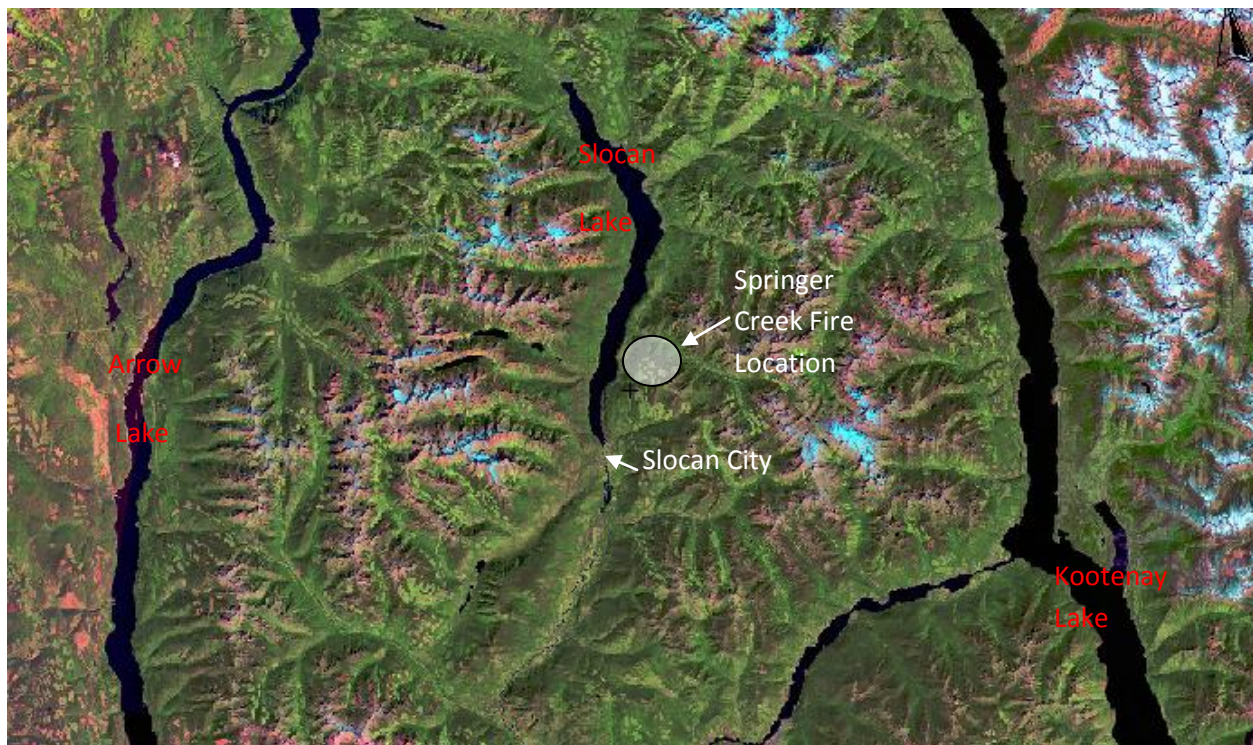


Figure 1 Site Location

Mining in the Slokan Valley has occurred since the late 1800's. Mining roads between Memphis and the Van Tuyl creeks existed in 1952 (VanDine 1990) and in 1966 the mining road extended to the upper slopes. Airphoto reviews (VanDine 1990) indicate that in 1939 much of the steep westward slopes of North Van Tuyl creek was recovering from a forest fire. Logging of some of

the fans began prior to 1939 (Curran et al 1990) and logging of the plateau areas of Ottawa Hill began in 1976.

A history of previous slope failures primarily collected from airphoto reviews was summarized by Curran et al 1990 and confirmed and unconfirmed debris flow events were summarized (VanDine 1990) with a total of 12 debris flows between 1958 and 1990 spread between the Cory, Van Tuyl, and Memphis Creeks. Several debris slides have also been documented throughout these drainages (Curran et al 1990).

Private development over the last several decades has centered on the flatter slopes between 800m elevation and Slocan Lake and is comprised of rural style properties and homes.

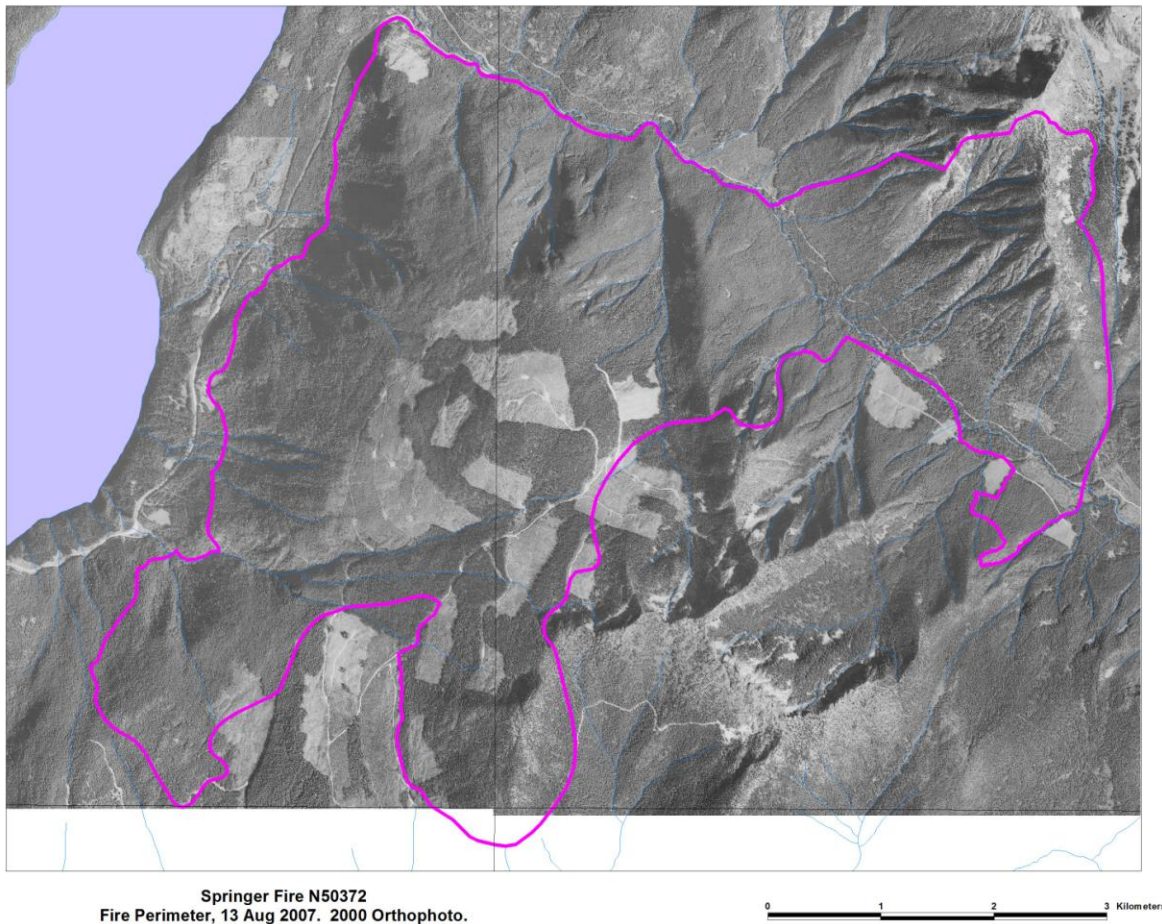


Figure 2 Fire Boundary

Site Physiography, Surficial Materials, and Bedrock Geology

General Physiography

The Springer Creek Fire occurred in the Kokanee Range located within the Selkirk Mountains of the Columbia Mountain System. The general physiography of the region consists of serrated ridges and peaks above 2000m and rolling topography with rounded ridge crests and steep valley sides below 2000m. Summit levels in the nearby area lie near 2200m, Slocan Lake lies at approximately 550m and local relief between 600m to 1000m is typical. The Biogeoclimatic zones include the Interior Cedar Hemlock at low elevations and the Engelmann Spruce Subalpine Fir at higher elevation.

The area is situated between approximately 550m (Slocan Lake) and 1930 m (Ottawa Hill) elevation on generally west to northwest facing slopes above Highway 6 and Slocan Lake. Highway 6 extends in a north-south direction at approximately 700m elevation along the edge of a bedrock controlled bench-like feature located at the base of the steeper slopes to the east.

In general, the terrain is dominated by a prominent rounded mountain top (Ottawa Hill) with a slightly convex slope configuration on the west side. Slopes drain north into Enterprise Creek, west into Allen Creek, Cory Creek and Van Tuyl Creek, and south into Memphis Creek. All of these creeks drain into Slocan Lake. Post-glacial erosion has developed present day drainage patterns which tend to follow bedrock jointing and flow generally east to west.

Slopes above approximately 1600m elevation are typically slightly irregular to irregular in slope configuration with moderate slope gradients (30-50% gradients). Natural drainage patterns are infrequent but occasional swales and shallow gullies are incised into the slopes. This area was significantly logged over the past 30 years and as a result an extensive network of logging roads and trails covers the area. Slopes between approximately 750m and 1600m elevation, located above the highway, are typically uniform to slightly irregular in slope configuration with moderately steep to steep slope gradients (55-120% gradients). The terrain is characterized by steep slopes, several deeply incised V-shaped gullies and isolated rock cliffs. Cone-shaped deposits of colluvial material are commonly found at the base of the gullies and talus deposits are typically found at the base of rock exposures. All of the previously mentioned creeks flow within these gullies and most have a history of debris flows and have potential to develop future debris flows.

One old mining road extends up slope through a series of switchbacks along a broad ridge feature dividing Van Tuyl Creek and Memphis Creek and has a history of road-related slope failures. Slopes between approximately 600m and 750m elevation, located between Slocan Lake and the highway, are typically slightly irregular to irregular in slope configuration with gentle to moderate slope gradients (10-50% gradients). The terrain is characterized by a wide bench-like feature with gentler slopes occasionally incised by swales and shallow gullies, and isolated bedrock controlled hummocks. The bench extends 500-800m in width between Cory Creek and Enterprise Creek and 200-300m in width between Cory Creek and Memphis Creek.

The lower slopes west of the benchy terrain and above Slocan Lake are dominated by steep rocky exposures incised by steep-sided gullies.

Surficial Materials

Surficial materials are dominated by morainal and colluvial deposits with lesser amounts of glaciofluvial deposits.

Morainal deposits left by the glaciers are characterized by a discontinuous till mantle of variable thickness (<1m to 2m) overlying irregular and hummocky bedrock on the upper slopes as well on the lower slopes in proximity of the highway. The till is generally a loose (due to weathering) to compact gravelly sand (medium to fine) with some silt (<20%), cobbles and occasional boulders. The coarse fragment content ranges from 30-45% and consists of sub-rounded to sub-angular clasts (dominantly granitic). A thin deposit (up to several centimetres thick) of volcanic ash is found at the mineral soil surface in some locations. Soil drainage is generally moderately well to well drained, with some imperfect to poor drainage found in the bottom of swales, gullies and other depressions.

Colluvial deposits occur within the study area and are products of erosion and mass wasting derived primarily from bedrock in-situ. They are found where eroded bedrock is near the surface; at the base of rock exposures (talus) as a result of rockfall and ravelling processes; and at the mouth of deeply-incised gully systems as a result of erosional and depositional processes. The colluvial deposits are generally a loose sandy rubble with 50-65% angular to sub angular coarse fragments. Soil drainage is generally well to rapidly drained, with some imperfectly drained soils found in the bottom of gullies. These deposits dominate on the steep middle slopes above the highway and are also spatially distributed on the upper slopes (above 1600m) where bedrock is near the surface. Bedrock is also generally near the surface at the midslope elevations and the thin colluvial deposits are prone to debris slides when surface flows or overland flows become concentrated.

Glaciofluvial deposits and remnant terraces are found mainly in isolated areas below the highway along the benchy terrain. These deposits generally consist of weakly to well-stratified material with a sand to gravelly sand with 20-60% coarse fragments (rounded to sub-rounded clasts). Lenses of sand and silt are common. Soil drainage is generally well to rapidly drained.

Bedrock Geology

Geological mapping indicates the local bedrock is predominantly part of Lower Cretaceous Nelson plutonic Rocks comprised of porphyritic granite rocks. The highway corridor between Memphis Creek and just south of Slocan City is comprised of augen gneiss rocks of early Mesozoic age.

The general structural trend follows a north-south direction which correlates with the major geologic fault in the Slocan Valley. Rock cliffs and ridges are a result of near-vertical jointing in the rocks which trends both north-south and east-west. The jointing is apparent in the deeply incised gullies above the highway and along the steep rocky cliffs above Slocan Lake.

Bedrock tends to fracture easily and therefore rock particles are typically fragmental in nature. Soils derived from these rocks typically develop a sandy matrix. Sporadic occurrences of saprolite (weathered bedrock) can occur near seepage areas and consist of unconsolidated angular fragments of gravel. The coarse textured nature of the bedrock in the area contributes to the high percentage of sand and gravel in the soil.

Vegetation and Soil Burn Severity

Vegetation burn severity was estimated for each watershed (via high level photographs) with ground checks.

Vegetation burn severity, or fire severity, refers to the effects of the fire on the forest canopy and understory. For this analysis, a preliminary severity map was prepared by taking oblique aerial photographs from a high altitude, identifying areas (or polygons) of high, moderate, and low severity on the photos, and transferring the polygons to a base map. The following classification is used (after Curran et al, 2006):

High – trees blackened and dead, needles consumed, understory consumed;

Moderate – Trees burned and dead, needles remain, understory mostly burned;

Low – Canopy and trunks partially burned, understory lightly or patchily burned.

A more detailed and accurate map of vegetation burn severity can be prepared from Landsat satellite imagery, which is currently in progress.

Soil burn severity refers to the effects of the fire on soil hydrologic function and includes the removal of protective forest floor cover and/or the creation of a water-repellent layer. A water repellent layer can be formed when the forest floor is partially or totally consumed by wildfire. During combustion, the waxes, lipids, and other compounds vaporize and diffuse both into the atmosphere above the ground and into the soil profile where the compounds can condense when they reach a lower temperature, coating mineral soil particles (after Curran et al, 2006).

The following classification is used (after Curran et al, 2006):

- High – forest floor consumed, mineral soil has altered porosity and structure;
- Moderate – litter consumed; duff consumed or charred, mineral soil unaltered;
- Low – litter scorched or consumed, duff and mineral soil unaltered.

Soil burn severity may, but not necessarily, be correlated with vegetation burn severity. In areas of high and moderate soil burn severity, the soil may be water repellent, increasing the likelihood of overland flow during heavy rain. Soil burn severity can only be determined by observations on the ground. For this analysis, two teams of 2-3 people spent two days doing ground traverses in the areas considered to be of greatest concern. Soil burn Severity was assessed on a field form, using subjective ratings of six indicators: litter, duff, fine fuel, large fuel, mineral soil exposure, and presence/absence of live roots. Water repellency was assessed using the water drop penetration test: the mineral soil is exposed along a shallow trench, and water drops are applied at various depths. Strong repellency is present if the drops stay on the surface longer than 40 seconds.

The vegetation burn severity map (reduced in scale) is shown in Figure 3. The field checking showed that soil and vegetation burn severity were highly correlated in this fire. About 80% of plots in “High” vegetation burn severity polygons had strong water repellency, and all had high soil burn severity. In “Moderate” and “Low” polygons, about 45% of plots had strong water repellency, although these plots were usually located in more heavily burned patches. These results indicate that, in the “High” severity polygons, there is a high likelihood of overland flow during heavy rain. In large, continuous areas of high burn severity, there could

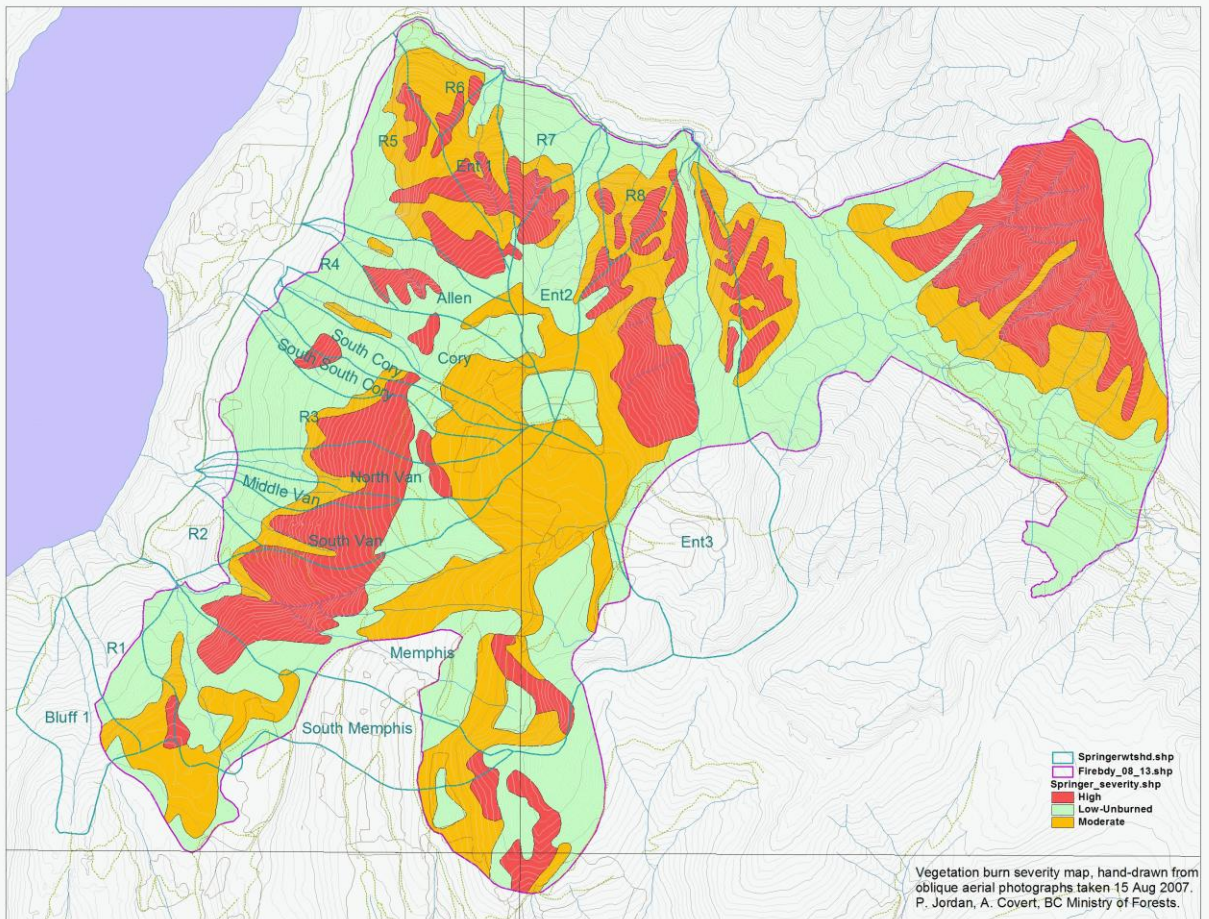
be sufficient overland flow to cause debris flows or flooding in the channels below. This hazard may exist, to a lesser extent, in some areas of moderate burn severity; however, it is likely that the patchy nature of the burn in these areas, combined with natural mulching from needle fall, will reduce the hazard.

Table 2 summarises the results of the vegetation burn severity.

Watershed	Vegetation Burn Severity Area (ha)					Percent Area Burned			
	High	Moderate	Low or Unburned	Outside fire perimeter	Total Watershed Area	High	Moderate	Low or Unburned	Outside fire perimeter
Allen	11.3	8.1	47.5	3.4	70.3	16%	11%	68%	5%
Bluff 1		5.7	4.0	80.5	90.2	0%	6%	4%	89%
Cory	4.6	31.2	53.3	1.6	90.8	5%	34%	59%	2%
Ent 1	15.9	24.4	8.5	0.1	48.8	33%	50%	17%	0%
Ent2	14.9	31.5	62.7	0.1	109.2	14%	29%	57%	0%
Ent3	90.1	95.0	102.3	186.8	474.2	19%	20%	22%	39%
Memphis	87.8	192.6	170.5	87.8	538.7	16%	36%	32%	16%
Middle Van Tuyl	5.1	5.9	12.3	2.7	26.0	20%	23%	47%	10%
North Van Tuyl	29.0	29.6	18.6	3.1	80.3	36%	37%	23%	4%
R1	2.6	11.5	24.5	46.7	85.4	3%	13%	29%	55%
R2	0.4	1.4	6.2	35.1	43.1	1%	3%	14%	82%
R3	29.2	18.3	65.1	27.1	139.6	21%	13%	47%	19%
R4	0.9		16.5	21.1	38.5	2%	0%	43%	55%
R5	36.8	42.2	47.8	31.3	158.1	23%	27%	30%	20%
R6	5.4	22.8	12.3	2.4	42.8	13%	53%	29%	6%
R7	10.7	7.3	42.0	2.1	62.1	17%	12%	68%	3%
R8	11.5	22.2	16.6	1.3	51.7	22%	43%	32%	3%
South Cory	4.5	11.9	31.0	0.7	48.1	9%	25%	65%	1%
South Memphis	15.0	47.2	79.0	69.2	210.5	7%	22%	38%	33%
South South Cory	5.7	11.0	26.1	1.6	44.5	13%	25%	59%	4%
South Van Tuyl	38.0	10.8	32.7	4.5	86.0	44%	13%	38%	5%
Grand Total	419	631	880	609	2539	17%	25%	35%	24%

Table 2

Note: These areas represent only the watersheds shown on the map. Additional areas in the Enterprise Creek and Springer Creek watersheds are not included in the table.



Springer Fire N50372
Preliminary Burn Severity Map, 16 Aug 2007

Figure 3 Vegetation Burn Severity Map

Table 3 provides a summary of the some of the characteristics of various creeks and drainage areas within the fire boundary and above Highway 6.

Summary of Watershed Characteristics	Bluff 1	South Memphis	Memphis	South VanTuyl	Middle VanTuyl	North VanTuyl
Area (ha)	90	211	539	86	26	80
Elevation range (m)	720-1350	770-1980	770-2150	740-1820	740-1660	740-1930
Melton ratio ¹	0.66	0.83	0.59	1.16	1.80	1.33
Fan or Deposition Slope ²	-	27%	27%	-	-	21%
Typical channel slope, mid-watershed	45%	60%	50%	60%	70%	70%
Typical channel slope, headwaters	30%	20%	20%	35% ⁵	45% ⁵	25% ⁵
Terrain stability "V"	-	13%	18%	42%	71%	22%
Terrain stability "IV"	-	9%	17%	17%	23%	29%

Summary of Watershed Characteristics	Bluff 1	South Memphis	Memphis	South VanTuyl	Middle VanTuyl	North VanTuyl
Historical or air photo record of debris flows	-	Yes	No	no	yes	yes
"Gentle-over-steep" (burn on plateau draining into steep channels)	no	yes	yes ⁴	yes	yes	yes
Main channel riparian zone severely burned	no	no	yes	yes	no	no
Burn severity: H	0	7%	16%	44%	20%	36%
M	6%	22%	36%	13%	23%	37%
Burn concentrated in:	mid-elevation	mid-elevation	mid-elevation	mid-elevation	mid-elevation	mid-elevation
Avulsion Potential	-	No	No	Yes	Yes	Yes

Summary of Watershed Characteristics (continued)

Watershed	South South Cory	South Cory	Cory	Allen	Ent 1
Area (ha)	45	48	91	70	49
Elevation range (m)	710-1900	740-1900	740-1930	700-1800	720-1660
Melton ratio ¹	1.77	1.67	1.25	1.31	1.34
Fan or Deposition slope ²	-	7% to 27%	12% to 25%	20% to 40%	-
Typical channel slope, mid-watershed	60%	70%	75%	75%	60%
Typical channel slope, headwaters	30% ⁵	30% ⁵	30% ⁵	25%	50%
Terrain stability "V"	32%	37%	24%	-	-
Terrain stability "IV"	29%	33%	15%	-	-
Historical or air photo record of debris flows	Yes	Yes	Yes	no	-
"Gentle-over-steep" (burn on plateau draining into steep channels)	yes	yes	yes	no	no
Main channel riparian zone severely burned	no	no	no	no	yes
Burn severity: H	13%	9%	5%	16%	33%
M	25%	25%	34%	11%	50%
Burn concentrated in:	mid-elevation	mid-elevation	mid-upper elev.	mid-elevation	mid-upper elev.
Avulsion Potential	Yes	Yes	Yes	Yes	-

Table 3

Footnotes:

- 1 Melton Ratio = relief / $\sqrt{\text{area}}$. It is an index of average watershed slope. A study by Wilford et al (2004) in northwestern B.C. concluded that watersheds subject to debris flows and debris floods typically had Melton ratios of >0.6 and 0.3-0.6 respectively.
- 2 Fan slopes from field measurements and 1990 Van Dine.
- 3 - = no information available.
- 4 On Memphis Creek, most of the severe burn is below the break in slope.
- 5 No channel in upper part of watershed; number refers to typical ground slope.

Individual Watershed Discussion and Risk Analysis

Enterprise Creek Watershed

The Enterprise Creek watershed is a large watershed (approximately 105 km²) with creek gradients in the lower 7.5km (total 20km drainage length) of less than 10% and a Melton Ratio of 0.18.

The lower 8km of the drainage was burned above and upstream of Highway 6 with the burn area predominately on the south side of Enterprise Creek for the westerly 4km of the burn (see Photo 1) and predominantly on the north side of Enterprise Creek for the easterly 3.5km of the burn (see Photo 2).



Photo 1 Burned slopes on the south side of Enterprise Creek



Photo 2 Burned slopes on the north side of Enterprise Creek

The total burn area within the Enterprise Creek watershed is about 8% with about half of that being high and moderate burn severity. The Enterprise Creek watershed was not ground reviewed as part of the post wildfire risk analysis because of the lack of residences and private property below the Enterprise Creek tributaries and because of the lack of debris flow activity within Enterprise Creek itself. As such soil burn severity was not assessed.

Identified Hazards

Possible hazards relating to post wildfire effects within the Enterprise Creek drainage include rockfall activity (particularly on the steep, rocky north slopes), debris flow activity within the creeks and gullies on the south and north slopes in and below the burn areas and open slope debris slides. It is possible a debris flood could initiate within Enterprise Creek if significant debris flow activity (from the side tributaries) occurs at a time when Enterprise Creek flows are high, however, the likelihood of a debris flood is considered low. Significant side tributary debris flow activity could also cause a temporary blockage of Enterprise Creek which would result in additional erosion potential downstream. In addition, the debris flows entering Enterprise Creek from the tributary drainages could significantly add to bedload and wood debris to Enterprise Creek.

It is unlikely that peak stream flow discharges will be significantly increased by the burn.

There is a gully (unit Ent 1) located above the highway (near the bridge site) that has a watershed area of 49 hectares of which 16 hectares has a high vegetation burn severity and 24 hectares has a moderate vegetation burn severity. The combined high and moderate vegetation burn severity comprises 83% of the drainage. The Melton ratio for the drainage is 1.34 which is indicative of its steepness and small drainage area and its potential for debris flow activity.

Values at risk

On the north slope of the western portion of Enterprise Creek (1km length) Highway 6 passes below the burn area. A debris flow originating from the gully in unit Ent 1 could deposit debris at and adjacent to the highway and/or remove the highway subgrade.

It is understood (personal communication with MOT) that the highway bridge (crossing Enterprise Creek) will soon be replaced with an 18m wide multiplate arched culvert. Should a debris flood initiate within Enterprise Creek there is potential for erosion of the creek banks and blockage of a bridge or culvert opening (from trees and debris carried within the debris flood). In addition the new arched culvert may be closer to the debris flow hazard in Unit Ent 1.

The remainder of Enterprise Creek has a gravel surfaced Forest Service Road and Ministry of Highways Road that could be damaged from debris flows (tributaries), debris slides or a debris flood (Enterprise Creek).

Risk

The likelihood of a debris flow within watershed Ent 1 given the vegetation burn severity, and gully size and steepness is considered high. The partial risk to Highway 6 and highway users is considered high as a debris flow within Ent 1 would almost certainly reach the highway. In addition the gulley may be close to the proposed new Enterprise Creek crossing location.

The likelihood of a debris flood occurring within Enterprise Creek is considered low as it is unlikely that debris flow activity (as a result of the wildfires) will occur at the same time as very high stream flows. The partial risk to highway users is considered low. The consequences of a debris flood are estimated as moderate (depending on the design and passage abilities of the new crossing).

The likelihood of debris flows occurring upstream of the Highway 6 location within tributaries of the Enterprise Creek watershed is considered high. The consequences to infrastructure is considered low to moderate (replacement of local culverts and/or bridges and road repairs) upstream of Highway 6. It is possible that public safety could be impacted by these events, however, the number of users per day is low compared with Highway 6. The partial risk is considered low.

Recommendations – Enterprise Creek

- E1. MOT should confirm design, location, and construction of proposed new crossing of Enterprise Creek is compatible with the risk (relative to debris flood activity).
- E2. MOT should confirm the location and construction of proposed new crossing of Enterprise Creek relative to the identified debris flow hazard in Ent 1 watershed. This includes the presence of construction workers within the debris flow transportation and deposition zone.
- E3. The gravel roads (MOT and MOF) located upstream of Highway 6 should be reviewed in the locations below the burn area to ensure gully and creek crossings are sufficiently robust to pass debris flows.
- E4. Fire protection constructed guards and structures, and any old roads and trails located upslope of the highway should be inspected and adequately deactivated.
- E5. No salvage logging should proceed upslope of the highway unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows, or overland flow from high burn severity areas.

Allen Creek Watershed

Allen Creek is a 70 hectare watershed draining to the west down to Highway 6 where it turns north and drains into Slocan Lake. The headwaters of Allen Creek are very steep with bedrock cliffs. No flowing surface water was observed (walked down channel to 1500m elevation and up channel from Highway 6 to 1100m) and no alluvial channel was observed. With the steep

rocky side slopes, the Allen Creek gully consists of coarse colluvium and from 1000m to 800m the colluvium forms a broad cone which becomes unconfined at 800m (to Highway 6) where the slopes break to 20% to 40% (from 60% to 70%). The Melton ratio of Allen Creek is 1.31 and possible old debris flow levees were observed between the fire guard and Highway 6.

The vegetation burn severity was mapped as 11 hectares high and 8 hectares moderate (27% combined high and moderate burn severity). The high vegetation burn severity is located primarily between 1100m and 1500m elevation (see Photo 3). Part of the mapped high vegetation burn severity was reviewed on the ground to check soil burn severity and soil water-repellency. The results confirm the presence of water repellent soils along with the removal of the forest floor litter and duff, and the resulting exposure of mineral soil (see Photos 4 and 5). In addition, some of the area mapped as low vegetation burn severity (area upslope of the mapped high burn severity) is considered to have a moderate to high soil burn severity (likely as a result of a creeping ground fire).



Photo 3 High Burn Severity in Allen Creek Watershed

An old harvested block is located between 1700 and 1800m near the upper drainage divide. The road into the block was walked and cross ditches were observed. Trails within the block were not reviewed.



Photos 4 and 5 Water drops sitting on soil trench (left) dug to test for water-repellency, demonstrating non-infiltrating water. Right - water trapped above water repellent layer after small recent rainfall in Allen Creek – Allen Creek Watershed

Identified Hazards

The identified hazards within the Allen Creek watershed include rockfalls, debris flows, and debris slides. The ability for a debris flow to initiate will partly depend on the available water supply and the ability of the coarse colluvium to allow infiltration of any overland flows that come from the burned soils above. Observations below local rock outcrops (two days after local rainfall of 10mm at Slocan fire weather station) indicated that water was trapped in a shallow layer of ash above a water-repellent soil layer, suggesting that local runoffs will be high during a more significant rainfall event. Given the degree of burn severity, the gully characteristics, lack of alluvial channel, abundant supply of debris flow volume and possible historical debris flow lobes, the likelihood of a debris flow event or debris slide event in or above the Allen Creek gully is considered moderate to high.

Elements at risk

Two houses and two building sites (with footings) are located on or adjacent to the colluvial cone between the fire guard and Highway 6, and thus the consequences to public safety are considered high. In addition, Highway 6 is located below the houses and private property.

Risk

If a debris flow is initiated within the Allen Creek gully, it could travel to the highway and beyond. Because the gully is unconfined below the 800m elevation, the variability in the possible debris flow path is high and it is possible that a debris flow could pass through the area without impacting any of the houses. Thus, the partial risk (hazard occurring and affecting residents) is considered moderate to high. Given the occurrence of a debris flow it is considered likely that its run out would extend to the highway and thus the partial risk to highway users is also considered moderate to high.

Recommendations – Allen Creek

- A1. It is recommended that an evaluation be conducted of the possible effectiveness of various treatment options to reduce erosion and promote water infiltration (reduce overland flow) in the burn areas at the headwaters of the Allen Creek gully.
- A2. It is recommended that an evaluation be conducted of the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above houses, private property, and Highway 6.
- A3. The existing operational forest road, fire protection constructed guards and structures, and old roads and trails located in the headwaters of Allen Creek should be reviewed and, if required, adequately deactivated to ensure they do not promote any concentration or diversion of surface flows or increased overland flow from burned areas.
- A4. No salvage logging should proceed in the Allen Creek watershed unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows or overland flow from burned areas.

Cory Creek Watersheds

The Cory Creeks are actually 3 watersheds referred to as North Cory Creek, South Cory Creek, and South South Cory Creek (one of these is locally known as Angel Creek). The drainage areas are 91 hectares, 48 hectares, and 45 hectares respectively. The creeks cross the highway at three separate locations, merge and head south around a large bedrock knoll before entering Slocan Lake. All three creeks were flowing at the highway guard location and at Highway 6 (through 500mm and 600mm culverts) at the time of the field reviews. The Melton ratio of the Cory Creeks vary from 1.25 to 1.77.

Possible debris flow levees were observed adjacent to all the Cory Creeks and the creek gradients between the fire guard and Highway 6 drop as low as 20%, with poorly defined channels at some locations. Discussions with local residents indicate the channel locations have been modified over the years. An area of flood hazard has been identified via a 1:50,000 MSRM flood hazard map (see Figure 4) that encompasses all three Cory Creek watersheds for a distance of about 300m upstream and downstream of Highway 6 in the region of low stream gradients. The flood hazard area extends to the bend of Allen Creek as it heads to the north.

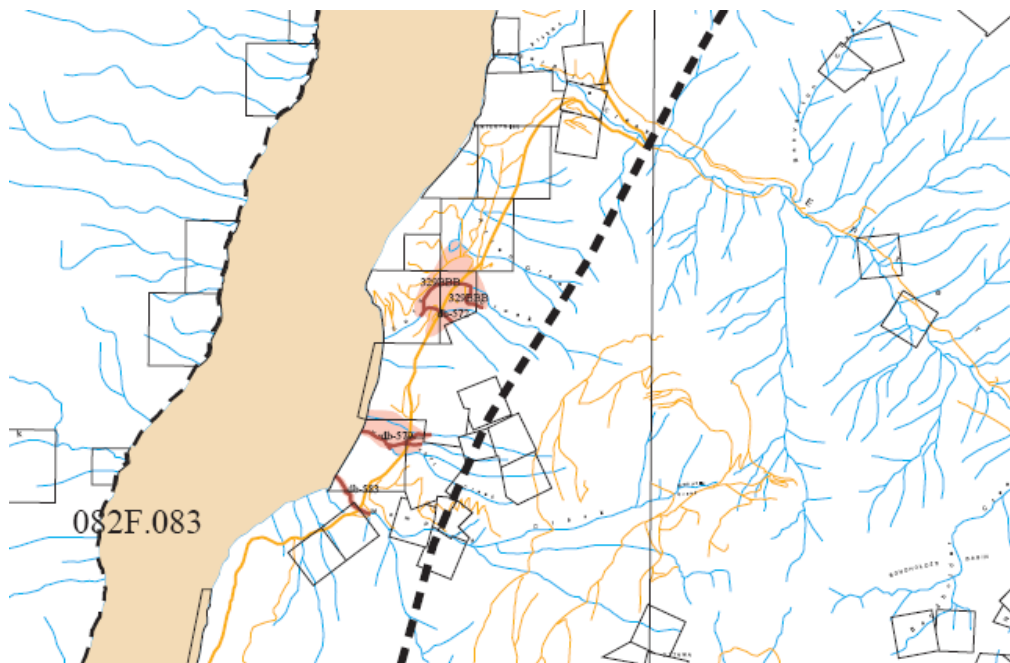


Figure 4 MSRM 1:50000 2004 Flood Hazard Map

On May 30th, 1990 debris flows occurred in the North Cory and South Cory Creeks following a significant rain on snow precipitation event (see Curran et al). The North Cory debris flow was initiated by a small sidewall slump at the 1580m elevation. Slide deposition began at the 1100m elevation and continued to and across the highway and onto private property below (debris flowed up against a house [that is still occupied today] causing minor damage – see Photos 6 and 7). Slide debris at the highway coalesced with slide debris from South Cory to form a deposit over 200m wide. Slide volumes were estimated at between 10,000m³ and 12,500m³ for North Cory and between 7,500m³ and 10,000m³ for South Cory (VanDine 1990).

The 1990 review by Curran et al. concluded that there was a 170% increase in drainage area as a result of harvesting operations (roads), which contributed to the slide initiation. During the 1990 review, older terraces, levees and lobal features were noted indicating a history of debris flow activity (before 1990).



Photo 6 Debris against house after 1990 Slide



Photo 7 Debris from 1990 Cory Creek Slides

The South Cory debris flow was initiated by two debris slides at the 1370m elevation, which were initiated by overland flows from roads and cutblocks at higher elevations, and merged at the 1180m elevation in the gully system. Deposition initiated at the 770m elevation and continued to Highway 6 and below onto private property (narrowly missing a house). The 1990 review by Curran et al concluded that there was an 86% increase in drainage area as a result of harvesting operations (roads and landings) which contributed to the slide initiation.

The 1990 reports concluded that considerable debris occupies the debris flow tracks, the banks have been considerably oversteepened and destabilized, future debris flow paths could wander over the old colluvial fans and further debris flow activity is likely. The report by VanDine noted the house is at risk from future debris flows and/or flooding.

In 1977 South South Cory experienced a debris flow which blocked the highway (Curran et al 1990).

All three drainages have similar vegetation burn severities with combined high and moderate vegetation burn severities varying from 34% to 39% (see Photo 8). To put these burn severities in perspective the 2004 Kuskonook Creek debris flow (as a result of the 2003 fire) had combined vegetation burn severities of 44% and the Jansen Creek debris flow (adjacent to Kuskonook Creek) had combined vegetation burn severities of 29%. If only the area above the

initiation point of the debris flow is considered, the Kuskonook combined vegetation burn severity is closer to 80% and the Jansen Creek combined vegetation burn severity is closer to 60% due to the concentration of burn in the headwaters. This is also the case with Cory Creeks where the vegetation burn severity above 1500m is about 60%. Thus the vegetation burn severity of the Cory Creeks is similar to other drainages that have experienced post wildfire debris flow events.

The soil burn severity was correlated with the vegetation burn severity in that those locations with a high vegetation burn severity also demonstrated a high soil burn severity with water-repellent soils (which was also the case at Kuskonook). In addition, the area of the high vegetation burn severity extended further across the slope of North Cory and into the gully than the preliminary vegetation burn severity map indicates (suggesting that the area of high severity is thus higher than the figures presented in this report).



Photo 8 Burned areas of the Allen Creek and Cory Creek watersheds

The channel of North Cory Creek was inspected (see Photo 9) at 1520m with evidence of alluvium and channel in-fill colluvium (however there were no surface flows at the time of the field review). The volume available for debris flow entrainment at the 1500m elevation is estimated at between 1m^3 and 2m^3 per linear metre. Over a length of 1200m (distance to deposition area) this volume would accumulate to 1200m^3 to 2400m^3 (actual debris flow volume would likely be much higher, perhaps 5000m^3 to $15,000\text{m}^3$, given additional potential bank erosion and the magnitude of the 1990 events and the resulting oversteepened banks; however, volume may be mitigated by segments scoured to bedrock.



Photo 9 Gully at top of Cory Creek



Photo 10 Infiltrometer Test – Cory Creek Watershed

Water-repellency and Infiltrometer testing in North Cory creek watershed confirmed the presence of highly water repellent soils (see Photo 10). Several old roads and trails criss-cross the Cory Creek from 1900m to 1650m. The lowest road was walked and some large (still effective) cross ditches were observed. Other roads and trails within the drainage were not reviewed.

Identified Hazards

The identified hazards include rockfalls, debris flows, and debris slides. Given the degree of burn severity, the gully characteristics, abundant supply of debris flow volume and historical debris flow lobes, the likelihood of a debris flow event in any of the Cory Creek gullies is considered high. A debris flow event could be initiated by a debris slide into one of the gullies

or channels, or by in stream sediment bulking and channel erosion during large peak flows. Deposition of debris would likely range from the 800m elevation to and beyond the highway.

Elements at risk

One building site and a camper with a snow roof are located above the highway and could be impacted by debris flow or debris slide activity, and/or rockfall, within and adjacent to Cory Creeks. One house (which was impacted by the 1990 debris flows) and possibly an unoccupied cabin located below the highway could also be impacted, as could private property located below the highway and thus the consequences to public safety are considered high. In addition, Highway 6 is located within the debris flow paths.

Risk

If a debris flow is initiated within the Cory Creek gullies, it could travel to the highway and beyond. Because the gullies are relatively unconfined below the 800m elevation, the variability in the possible debris flow path is high. The partial risk P(HA) is considered high for the residences, recreational vehicle, possible future residences (building sites) and Highway 6.

Recommendations – Cory Creek

- C1. It is recommended that an evaluation be conducted of the possible effectiveness of various treatment options to reduce erosion and promote water infiltration (reduce overland flow) in the burn areas at the headwaters of the Cory Creek gullies.
- C2. It is recommended that an evaluation be conducted of the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above houses, private property, and Highway 6.
- C3. The existing operational forest road, fire protection constructed guards and structures, and old roads and trails located in the headwaters of the Cory Creeks should be reviewed, and if required adequately deactivated, to ensure they do not promote any concentration or diversion of surface flows or overland flows from burned areas.
- C4. No salvage logging should proceed in the Cory Creek watersheds unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows.

Van Tuyl Creek Watersheds

The VanTuyl Creeks are actually 3 watersheds (where they cross the highway) and are referred to as North Van Tuyl, Middle Van Tuyl and South Van Tuyl. The drainage areas are 80 hectares, 26 hectares, and 86 hectares respectively. The creeks cross the highway through two 600mm culverts at North Van Tuyl, a 900mm culvert at middle Van Tuyl, and a 600mm culvert at South Van Tuyl. All three creeks had water flow at the highway location during the field assessment. In addition a small flow was entering a 600mm culvert located between middle Van Tuyl and North Van Tuyl.

The Melton ratio of the Van Tuyl Creeks vary from 1.16 to 1.80. Possible debris flow levees were observed adjacent to North Van Tuyl Creek. The portion of North Van Tuyl above Highway 6 appears to have been artificially trained and curved to the north, likely during reparations following the 1990 events.

On May 30th, 1990 a debris flow occurred in North Van Tuyl Creek (see Curran et al) following a significant rain-on-snow precipitation event. The North Van Tuyl Creek debris flow was initiated in channel at about 1470m elevation below a small waterfall. Deposition of debris occurred from 790m elevation to the Highway 6. The debris flowed fanned out on the highway over an 80m length (see Photo 11) and continued below the highway and into Slocan Lake. The estimated volume of the slide was 10,000m³ to 12,500m³ (VanDine 1990). It was concluded in 1990 that stream flow which contributed to the debris flow had been concentrated from an upper landing with a pond at the 1690m elevation. It was noted in 1990 that the passing debris flow left much of the creek banks oversteepened and there was sufficient debris supply that could enter the channel, such that a repeat event was likely.



Photo 11 – Debris on Highway from 1990 North Van Tuyl Creek Slide

A debris flow also occurred in 1983 down North Van Tuyl Creek. The 1983 event originated at about the 1550m elevation and deposited debris onto Highway 6. Reference was made at that time to the need to review the upslope drainage plans with respect to roads, landings, culverts and ditches. Other debris flows (unconfirmed) may have occurred in 1958, 1981, and 1987 (VanDine 1990). An area of flood hazard has been identified via the a 1:50000 MSRM flood hazard map that encompasses all three Van Tuyl Creek drainages from about 100m above the Highway to Slocan Lake.

The mapped vegetation burn severities (combined moderate and high) are 73% for North Van Tuyl, 43% for Middle Van Tuyl, and 57% (of which 44% is high) for South Van Tuyl. The high vegetation burn severities are typically concentrated between 1300m and 1650m elevation (the transition zone between the 25% upland slopes and the 70% gully headwalls).

The soil burn severity was correlated with the vegetation burn severity in that those locations with a high vegetation burn severity also demonstrated a high soil burn severity with water-repellent soils. There is a patchy burn area above the 1650m elevation, between the moderate vegetation burn severity area located at the height of land and the high vegetation burn severity located below 1650m elevation. It is believed that this patchy burn area may act as a zone that will allow any overland flows from above to infiltrate, and thereby reduce the effects of the areas of moderate burn. If this infiltration occurs it will reduce the effective area of the combined moderate and high burn severity. However, the likely initiation point for debris flows is between 1550m elevation and 1300m elevation. Since the burn was concentrated within this zone, the effective burn severity increases. For Middle Van Tuyl the drainage area does not extend into the patchy burn area above and thus 100% of its drainage area above 1300m has been mapped as having a moderate to high vegetation burn severity.

The channels of the Van Tuyl creeks were inspected down to the 1500m (see Photos 12 and 13) elevation and they were found to contain available volume of colluvium and alluvium that could be supplied in the event of a debris flow (0.5m^3 to 2m^3 per linear meter at the upper reaches, likely higher lower down). Possible debris flow events in the Van Tuyl creeks could range from 5000m^3 to $15,000\text{m}^3$. North Van Tuyl consists of 4 steep gullies (slopes 70% to 90%) that merge at about the 1400m elevation. Middle Van Tuyl is a 4m wide by 1m deep shallow gully at the 1500m elevation with a coarse sand channel infill. South Van Tuyl is comprised of 6 gullies at the 1500m elevation that merge downslope.



Photo 12 North Van Tuyl Creek



Photo 13 Burned gully at headwaters of Middle Van Tuyl

The largest gully is located at the southern side of the South Van Tuyl watershed and is a v-shaped 10m deep draw with sidewall slopes of 65% to 70% (see Photos 14 and 15). Soil in the South Van Tuyl drainage is very sandy and saprolitic. Soil depth to bedrock is deeper than the North Van Tuyl area.



Photo 14 South Van Tuyl Burn



Photo 15 South Van Tuyl Creek Gully

Several old roads and trails crisscross the Van Tuyl watershed from 1800m to 1500m (see Photo 16). Most of these trails and roads have been cross ditched and/or outsloped (see Photo 17).



Photo 16 Old road and trail network
Van Tuyl Creek Drainage



Photo 17 Cross ditch in old road in North Van
Tuyl Creek Drainage

A trail observed at the South Van Tuyl drainage boundary with Memphis Creek was deeply rutted with no observed cross ditching (see Photo 18). Post wildfire surface erosion was observed where water was collected by this trail and directed downslope.



Photo 18 Old rutted trail causing post wildfire erosion

Identified Hazards

The identified hazards include rockfalls, debris flows, and debris slides. Given the degree of burn severity, the gully characteristics, abundant supply of debris flow volume and historical debris activity, the likelihood of a debris flow event in any of the Van Tuyl Creeks is considered high. A debris flow event could be initiated by a debris slide into one of the gullies or channels, or by in stream sediment bulking and channel erosion during high peak flows. Deposition of debris would likely occur above, on, and below Highway 6 and into Slocan Lake.

Elements at risk

The primary element at risk is Highway 6 (public safety and infrastructure). A residence is located on the left bank of South Van Tuyl Creek about 6m above the confined gully. This residence was noted in the 1990 report (VanDine) as not appearing to be at risk from debris flows. The area between Highway 6 and Slocan Lake in the vicinity of the Van Tuyl Creeks is private property.

Risk

If a debris flow is initiated within the Van Tuyl Creek gullies, it would likely travel to the highway and beyond. The highway crossing at South Van Tuyl is comprised of about 6m of fill at the upstream side of the highway (deeper on the downstream side). It is possible that should a debris flow occur (or a series of multiple flows) within South Van Tuyl Creek, that it could become blocked by the highway, fill the volume behind the highway and be diverted towards the residence in a low energy flow (primarily water and suspended solids).

The partial risk to highway infrastructure is considered high. A debris flow hitting the highway has the potential to cause loss of life and injury if the highway is occupied at the time. The actual degree of risk to public safety (if a debris flow occurs) will depend on the size of debris flow, location of deposit, erosion of highway, time of day, volume of traffic and traffic patterns.

The risk (partial risk) of impact to the residence located on the left bank of South Van Tuyl is considered low to moderate (combined likelihoods of a debris flow occurring, being directed down the highway, flowing towards the house, and impacting the structure).

Recommendations - Van Tuyl Creek

- V1. It is recommended that an evaluation be conducted of the possible effectiveness of various treatment options to reduce erosion and promote water infiltration (reduce overland flow) in the burn areas at the headwaters of the Van Tuyl Creek gullies.
- V2. It is recommended that an evaluation be conducted of the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above Highway 6.
- V3. The existing operational forest road, fire protection constructed guards and structures, and the old roads and trails located in the headwaters of the Van Tuyl Creeks should be reviewed and if required adequately deactivated to ensure they do not promote any concentration or diversion of surface flows or overland flows from burned areas.
- V4. No salvage logging should proceed in the Cory Creek watersheds unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows.

Memphis Creek Watershed

The Memphis Creek watershed is a relatively large watershed (totaling 750 hectares) which is split between the main Memphis Creek Watershed (539 hectares) and South Memphis (211 hectares). The main Memphis Creek is comprised of 3 tributaries that join at approximately the 1200m elevation. South Memphis and Memphis Creeks join at the 780m elevation (80 metres above and 350 metres laterally from Highway 6).

The Melton ratio of South Memphis is 0.83 while the Melton ratio of Main Memphis Creek is 0.59 (implying Main Memphis Creek may be prone to debris flooding and debris flows). Before passing under Highway 6, Memphis Creek passes through a culvert located at an old highway location 100m upstream of the existing highway location.

On May 30th, 1990 a debris flow occurred in South Memphis Creek. The debris flow initiated at a slope break at the 1250m elevation and scoured much of the channel to bedrock. Debris deposition initiated at the 760m elevation above the old highway location (the existing highway was under construction when the debris flow occurred – see Photo 19). Slide volume was

estimated at between 12,500 m³ and 15,000 m³ (Vandine 1990). Culverts in the new highway were partially plugged and an excavator on site was able to remove debris from the culverts in order to allow stream flow resumption. In 1990 it was concluded that the effective drainage area of South Memphis was augmented by 41% due to forestry roads.



Photo 19 Old Highway 6 location after Memphis Creek 1990 Slide

The mapped vegetation burn severities (combined moderate and high) are 29% for South Memphis and 52% for main Memphis (see Photo 20). Some areas of high vegetation burn severity areas in Main Memphis were correlated with high soil burn severity and the presence of water-repellent soils. Soil burn severity was not confirmed in South Memphis. In addition, some areas of moderate and low burn severity in Main Memphis also have high soil burn severity and water-repellency, although natural mulching from needle fall is expected to partially offset the risk of overland flow from these areas.

Several active roads, old roads and trails cross the Memphis Creek Watershed. An old mining road with a history of landslides climbs the drainage divide between Memphis Creek and South

Van Tuyl Creek (see Photo 21) and an old road crosses the three tributaries of Main Memphis at about the 1500m elevation. Both of these roads have been deactivated. An active road passes through both the South Memphis watershed and main Memphis Watershed (culverted with no cross ditches).



Photo 20 Burned Areas of the Van Tuyl and Memphis Creek Watersheds



Photo 21 Old mining road on ridge between Memphis and Van Tuyl Creek

From 1400m to 1700m the South Memphis Watershed did not burn. However the watershed did burn above 1700m (to the top of the drainage near 2000m). Most of the roads and trails of South Memphis are located in this unburned zone and are thus not expected to pose a significant hazard increase as long as they can adequately disperse any extra water directed to them via the burn area above.

Identified Hazards

The identified hazards include debris flows and debris slides in South Memphis and debris flows, debris slides or debris flood, and flooding in Main Memphis. The mining road on the ridge between Memphis Creek and South Van Tuyl Creek has the potential to divert water and cause a debris slide; however, deactivation of this road (after a 1999 debris slide) will reduce the likelihood of this happening. Given the degree of burn severity, the location of the burn, gully characteristics, and historical debris activity, the likelihood of a debris flow event in South Memphis is considered moderate while the likelihood of a debris flow event or debris flood event in Main Memphis is considered moderate to high. Given adequate deactivation of the

mining roads (to be further confirmed) and trails the likelihood of debris slide initiation as a result of the mining road is considered low to moderate.

The high and moderate vegetation burn severities may have the effect of increasing the ECA's to above 50% which has the potential to increase the peak flows of Memphis Creek and to reduce the return period of flood events. Since the ECA will remain high (for decades) the flood hazard will also remain for decades.

Elements at risk

The primary element at risk (from debris flows and debris floods) is Highway 6 (public safety and infrastructure). The ridge between Memphis Creek has a residence and an unoccupied house above the highway and a residence (couple of houses) below the highway. These houses could be at risk from a debris slide resulting from the diversion of high overland flows by the mining road.

Risk

If a debris flow is initiated within Memphis Creek (Main or South) it is possible that the old highway fill with trash rack could provide the necessary volume capacity. However it should be noted that the 1990 event essentially filled the volume available and partially blocked the culverts in the new highway. Given the volume available behind the old highway, the partial risk to highway infrastructure is considered moderate. Given the height of the highway fills it is unlikely that a debris flow could pass directly over the highway, and thus a direct impact of a highway user is unlikely. However, it is possible that should the highway culverts block, that the highway fill could rapidly erode and result in a public safety issue. The likelihood of this occurring is a function of the size and location of the highway culverts and the ability of maintenance crews to respond to a blockage event.

The likelihood of a debris slide occurring on the slopes between Memphis Creek and Van Tuyl Creek – referred to as Memphis Creek north ridge (given the old road has been adequately deactivated, which needs to be further confirmed) and impacting the house above the highway is considered low. The likelihood of a debris slide passing over the highway and impacting the residence below the highway is considered low to very low.

Recommendations – Memphis Creek

- M1. It is recommended that the drainage system at the Highway 6 crossing of Memphis Creek be reviewed to ensure its ability to pass a large debris flow and debris flood (this includes cleaning out the trash rack and giving consideration to raising the old road elevation to provide additional volume storage).
- M2. The existing operational forest road, fire protection constructed guards and structures, and the old roads and trails located in the headwaters of the Memphis Creeks should be reviewed and if required adequately deactivated to ensure they do not promote any concentration or diversion of surface flows.
- M3. The deactivation of the old mining road between Memphis Creek and Van Tuyl Creek should be reviewed to ensure it can adequately disperse potentially high surface flows.
- M4. No salvage logging should proceed in the Memphis Creek watersheds unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows.

Scorpion Creek, Springer Creek, and Highway Corridor South of Memphis Creek

The southern extent of the burn extended into the Scorpion Creek watershed which is a tributary to Springer Creek. Because of the limited mapped high vegetation burn severity area, the very low creek gradients (Scorpion Creek below the burn) and lack of infrastructure or residences below the burn area, this area was not ground reviewed and is not considered to pose a moderate or high risk to public safety.

Springer Creek drains an area of 52.5 km², and is only about 4% occupied by the burn. It is extremely unlikely that stream flow on Springer Creek would be affected by the burn, although some small tributaries draining the burned area could experience some increased flow.

500m south of Memphis Creek, an unnamed creek (part of Unit R1) with a drainage area of 85 hectares and a Melton ratio of 0.65 crosses Highway 6. The mapped vegetation burn severity (combined moderate and high) is 16% (only 3% high). Given the low burn severities this

drainage was not ground reviewed and the likelihood of a debris flow or debris slide resulting from the wildfire effects is considered low.

Another 90 hectare watershed to the south of the unnamed creek ("Bluff 1" on the map and tables) was mapped with a vegetation burn severity of only 6% (moderate and high) and thus the likelihood of a debris flow and/or debris slide resulting from the wildfire effects is considered low.

Recommendations as follows:

- S1. All fire protection related guards, trails, and structures should be inspected to ensure they have been adequately deactivated in areas draining towards the highway.

Residual or Face Units

Three of the "residual" or face unit areas above Highway 6, R3, R5, and R6, have a substantial proportion of high and moderate severity burn. These areas could be subject to open-slope debris slides, or debris flows in minor gullies. R3 is located between Van Tuyl and Cory Creeks, R5 is located north of Allen Creek (west facing) and R6 is located north of R5 (north facing). The likelihood of slope failures on these face units is generally considered low. At the southern extent of unit R5 a larger watershed, above the steep face unit, and within a high vegetation burn severity could be classified as having a moderate hazard of landslides and if a slide were to initiate in this area it is possible that it could be directed towards the colluvial fan located at the base of Allen Creek (and the house and private property located at the north end of the Allen Creek fan). The partial risk to residents and highway users at the southern end of R5 is thus considered moderate to high. Elsewhere below the face units slide deposition would likely be onto the highway.

Recommendations as follows:

- R1. It is recommended that an evaluation be conducted of the possible effectiveness of various treatment options to reduce erosion and promote water infiltration (reduce overland flow) in the burn areas at south end of Face Unit R5.
- R2. It is recommended that an evaluation be conducted of the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above houses, private property, and Highway 6 at the south end of Face Unit R5.

- R3. Fire protection constructed guards and structures, and the old roads and trails located in or above the face units should be inspected and adequately deactivated.
- R4. No salvage logging should proceed in or above the face units unless a further detailed study indicates that such harvesting will not further increase surface water flows or result in a further concentration or diversion of surface water flows.

Potential debris flow magnitudes

The four debris flows that occurred in 1990 had estimated volumes (or magnitudes) of 9000 to 14,000 m³, and channel yield rates (volume divided by channel length) of 8 to 13 m². Other debris flows inspected by the authors in the West Kootenay region have had yield rates in the range of 2 to 10 m². Inspection of some upper channels in the present investigation suggest available debris volumes in the order of 2 m²/m, but volume in the lower channels are likely to be greater. Based on this limited information, potential debris flow magnitudes in the Van Tuyt and Cory channels may be in the range of 5000 to 15,000 m³. For channels which experienced debris flows in 1990, magnitudes may be somewhat less, because the 1990 events removed much of the available debris from the channels. Observations in 1990 indicated that additional debris volume could enter the channel and supply future debris flow events. The potential debris flow volume in Memphis Creek may be greater, due to its longer length, and the probably larger volumes of alluvial sediment stored in its channel.

Landslide Trigger

Although a burn may increase the likelihood of the occurrence of landslides, erosion, and flooding by creating the necessary background conditions, a trigger is required that allows the events it initiate (snow avalanches are treated separately and are discussed below).

There are two types of rainfall events that can cause landslide or flood events following wildfire. These are:

Short duration, high-intensity rainstorms in the summer.

These convective storms may cover only a small area and so are often unrecorded by weather stations and are difficult to forecast. Examples of post-wildfire events caused by this type of event are the August 2004 Kuskonook Creek debris flows, the 2004 Lamb Creek debris flow/debris flood and the October 2003 floods at Kelowna. Most post-wildfire events documented in the western USA are of this type.

Long duration frontal rainstorms which typically occur in fall or early winter.

These can produce 50mm to 100mm of rain overall several days, and may fall on an early season snowpack at high elevations. An example of this type of event is the October 2005 debris flows in the 2003 Mt Ingersoll fire near Burton.

In the Springer fire, the first type of rainstorm is the most likely to cause hazardous events. The hazardous watersheds are small and steep, and a typical scenario would be a localized thunderstorm following a period of summer drought, which might affect the upper slopes of one or two watersheds, and generate overland flow which could trigger a debris flow in the steep channels below or debris slides on open slopes. Events caused by rainstorms of the second type are also possible, but based on past experience are less likely.

In comparison, peak runoff events caused by spring snowmelt or by late spring rain-on-snow rainfall have not been known to cause the same increase in landslide or flood likelihood following wildfire. This is apparently because water repellent layers in the soil become inactive following prolonged contact with the wet snowpack, and become reactivated as the soil dries out in mid-summer. However, in the Memphis Creek watershed, existing pre-fire Equivalent Clearcut Area (ECA), combined with a large area of moderate-severity burn, could cause an increase in the spring peak flow and will likely result in a decrease in the return period of flood events.

Events occurred 1 to 2 years after the 2003 fire season and it is generally acknowledged that the effects of a wildfire decrease significantly 3 to 5 years after the fire (due to water-repellency breakdown and revegetation).

Since the likelihood of the occurrence of landslides, erosion, and flooding following a wildfire is a function of the occurrence of a high intensity rainfall event within a certain time period following the fire (typically 3 to 5 years), the degree of hazard and risk cannot be considered in isolation of the probability of the occurrence of the required rainfall event. The rainfall event does not have to be significant (when compared with the rainfall required to initiate events in unburned areas) and in many instances in the literature “unremarkable” rainfall events have

resulted in post-wildfire erosion events. While the 1990 landslides events resulted from increasing the drainage areas by 1 to 2 times, post wildfire runoff can be several times this amount. For the purposes of this analysis it is assumed that rainfall events in the order of magnitude that occurred at the Kuskonook, Ingersol and Lamb Fires will occur at the Springer Creek Fire over the next 3 to 5 years.

To better quantify the required rainfall intensities to initiate landslide events from wildfires with similar burn severity and geomorphic characteristics to the Springer Creek Fire, four rainfall gauges were placed in the field during these assessments and will be monitored by the Forest Sciences Section staff.

While the effects of soil burn severity may decrease significantly over a 3 to 5 year time period, the hydrological effects of loss of tree canopy and the effects of root strength loss may persist for decades. The elevated ECA's and root strength loss may result in an increased likelihood of landslides over this time period, however, the long term incremental hazard is likely not as great as the short term incremental hazard resulting from the effects of the burn on the soil and associated overland flow. The determination of the long-term hazards are beyond the scope of this emergency analysis.

Snow Avalanche Hazard

The following section is a preliminary description and discussion with regards to the snow avalanche hazard within the terrain above Highway 6 between Memphis Creek and Enterprise Creek, based on a few field observations carried out on August 21 and 22, 2007.

Prior to the Springer Fire, the terrain above Highway 6, consisting of steep and gullied slopes, was not considered an area capable of producing large destructive avalanches mainly due to the densely forested nature of the slopes. However, following the severity of the Springer fire across this area, most of the timber has been destroyed particularly within the headwalls of the gullies which form Alan Creek, Cory Creek, Van Tuyl Creek and Memphis Creek (see Photo 22). Therefore the potential for the formation of avalanches and an impact to Highway 6 and private property down slope must now be considered.

Important contributing factors to the initiation of avalanches include:

Slope Angle

The potential starting zones for avalanche initiation are located approximately between 1400m and 1500m elevation within the headwalls of steep, deeply-incised gullies. Field measurements noted slopes angles ranging from 30 to 38 degrees, sufficient for the initiation of slab avalanches.

Terrain Configuration

The gully headwalls are typically broad concave, bowl-shaped features which commonly contain a few shallower gullies joining further down slope and forming the main, deeply-incised creek gully. These gully headwalls are common avalanche starting zones and are likely to increase the frequency of initiation or severity of avalanches due to the channelling effect of the gullies.

Snow Supply / Climate / Weather

The area of concern is located within the Moist Climatic Region, an area characterized by significant amounts of snowfall, relatively mild temperatures, and variable wind effect. Unusual snowpack conditions and weather events can combine to produce unusually large and destructive avalanches. The prevailing winds in this climatic region are predominantly from the west and southwest. Although snowpack depths may not always reach the threshold depths required to form large avalanches at the elevation of the starting zones, wind plays a significant role in transporting and depositing deep snow accumulations on the leeward side of the starting zones. The effect of wind loading results in increased snow depths and loads, thus increasing the avalanche hazard.

Loss of the forest canopy

The remaining burnt or severely damaged standing timber will likely fall to the ground as a result of decay and blowing winds. The loss of the forest canopy has a direct influence on the formation of avalanches via increased snow depths on the ground, increased wind effect in open areas, and increased solar radiation effect on the snowpack.



Photo 22 Area of potential snow avalanche (Van Tuyl Creek)

Snow Avalanche Recommendations

The following are initial recommendations based on preliminary field observations and a brief visual field assessment only.

- SA1. Complete an avalanche risk assessment with regards to avalanche magnitude, frequency and potential impacts to Highway 6 and private land.

- SA2. Regenerate the forest by planting trees as soon as possible in the potential starting zones

General Recommendations from this Post-wildfire Hazards Risk Analysis

1. Communicate hazards and risks to local residents, landowners and stakeholders.
2. Consideration should be given to an evaluation of various early warning systems and the monitoring of local weather data.
3. Conduct a ground review of all mining, forestry roads and trails located in and above high risk areas, and fire protection guards and adequately deactivate them to ensure they do not result in further concentrations or diversions of surface or overland flow. The ground reviews will include recommendations for mitigative measures where required.
4. Produce a mitigation plan that prioritizes treatments based on possible effectiveness of various treatment options to reduce erosion and promote water infiltration in the burn areas at the headwaters of the high hazard gullies above high consequence locations. Further hydrologic and erosion modeling may assist with this evaluation.
5. Evaluate the possible effectiveness of protection devices such as diversion berms, catch basins or other structures located above houses, private property, and Highway 6.
6. A Ministry of Transportation review of existing and proposed highway infrastructure in light of potential increased peak flows below high burn severity areas, and possible debris flow, debris flood and flood activity.
7. Complete the Landsat imagery comparisons of pre and post fire images and revise the vegetation burn severity map.
8. Complete an avalanche risk assessment with regards to avalanche magnitude, frequency and potential impacts to Highway 6 and private land.
9. Regenerate the forest by planting trees as soon as possible in the potential starting zones of snow avalanches.
10. No salvage logging should proceed in the moderate or high hazard watersheds located above elements at risk unless a further detailed study indicates that such harvesting will

not further increase surface water or overland flows, or result in a further concentration or diversion of surface water or overland flows. While distributing branches and limbs on the ground will increase ground cover, this has to be balanced by the necessary roads and trails and their potential impact.

11. This analysis is focused on the short term increase in hazards relating to the wildfire and slope instabilities. Over the longer term (beyond 5 years) an elevated hazard (above forested conditions) will persist due to changes in snowpack interception, increased snow melt rates, and ground cover and soil effects. The level of long term hazard has not been assessed, as such, it is recommended that the long-term hydrologic and slope stability effects due to the wildfire be assessed with recommendations relating to possible long-term mitigative measures. The assessment should include a summary for local governments for consideration with respect to the issuance of rezoning, subdivision, and building permit approvals.

12. Monitor weather conditions, erosion events, re-vegetation, and the effects of any mitigative treatments in the burned areas for the next several years to assist with the ongoing assessment of risk to downslope elements and to improve the predictive capabilities with regards to landslide initiation in interface burn areas.

Closure, Report Use, and Limitations

This report was prepared for the BC Ministry of Forests and Range, Southern Interior Forest Region. The material in it reflects the authors' best judgment and professional opinion in light of the information available to them 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. The authors accept no responsibility for damages, if any, suffered by any third party as a result of decision made or action based on this report.

The report and analysis have been carried out in accordance with generally accepted practice in B.C. with respect to natural hazard investigations (and specifically the analysis of wildfires and their influence on slope stability). The discussion and recommendations presented above are based on limited field investigation and inferences from surficial features. Shallow test pits and road cuts were examined - no further subsurface investigation was carried out as part of this analysis or development of conclusions or recommendations. Variability in surface and subsurface conditions may create unforeseen situations.

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