MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS
POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT

RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions. Please contact the author for more information.

FIRE: K21644 Embleton Mountain Fire	**FIRE YEAR**: 2021	**DATE OF REVIEW**: September 1, 2021

AUTHOR: Tim Giles, P.Geo., Geoscientist, Westrek Geotechnical Services Ltd.

REPORT PREPARED FOR: BC Wildfire Service – Kamloops Fire Centre, Kamloops Fire Zone
Thompson Rivers Natural Resource District (FLNRORD)

FIRE SIZE, LOCATION, AND LAND STATUS:

The Embleton Mountain Fire was approximately 992 hectares in size. The Natural Hazard Assessment Map of the fire is attached (Figure 1).

The majority of the fire burned on Crown Land but there are portions of private land parcels close to or within the fire perimeter, including:

- several along the south side of fire above the Heffley-Louis Creek Road (HLC Road),
- on the east side of the fire above Whitecroft, and
- on the northeast side of the fire above the Louis Creek Road.

A preliminary vegetation burn severity map was provided by FLNRORD Thompson Okanagan Region (Figure 2).

VALUES AT RISK:

Private land surrounds the base of the fire on the south and east sides of the fire and numerous residences are present (Figure 1). Several small drainages run off the uplands to the south and east and large alluvial or fluvial fans are present along the base of the slopes above the HLC Road and the Louis Creek Road. The village of Whitecroft is located 200 to 300 m east of the fire perimeter.

The Louis Creek Road runs north up the Louis Creek valley (Plate 1) and was used as a fireguard to control the fire coming down into the valley bottom from the west. The HLC Road, which runs below the south edge of the fire (Plate 2), is the main access route to the Sun Peaks Ski Resort, the village of Whitecroft, and the south end of the Louis Creek valley.

Christian Creek flows east to join Louis Creek which flows north to join the North Thompson River near Barriere. Both creeks are high value fisheries watersheds.

WATERSHEDS AFFECTED: (Figure 1)		**VEGETATION BURN SEVERITY (Figure 2)**
• Two small watersheds drain the east facing slopes of the fire above Louis Creek. The lower slopes were selectively harvested prior to the 1970's and there are a few old roads and trails along the base of the slope on the east side of the fire.		Mostly low and moderate vegetation burn severity with patches of high and unburned.
• Three small watersheds drain off the plateau surface and into Christian Creek on the south side of the fire. The steeper slopes below the plateau were selectively harvested prior to the 1970's and there are a few roads and trails which cross the slope, one of which reaches the edge of the plateau surface. More recently, beginning in		A mix of moderate, low, high, and unburned vegetation burn severity.

2000, timber harvesting accessed the plateau surface from the north. Several cut-blocks were developed on the plateau surface between 2000 and 2015. • McLure Creek flows east outside the northern perimeter of the fire. The main access road to the upper watershed was opened in 2000 and numerous cut-blocks are now present in the upper McLure watershed.		A mix of low, moderate, high, and unburned.

SUMMARY OF HAZARDS AND RISKS:	**HAZARD** [1]	**RISK** [2]
• **East Facing Watersheds -** The east side of the fire above Louis Creek Road has two small creeks (WE1 and WE2 on Figure 1). WE1 has a mix of low, moderate, and high burn severities and the upper reaches have been heavily impacted by the fire (Plate 3). The WE1 watershed has a Melton Ratio of 0.72 which indicates that debris flows are the expected geohazard. At the base of the slope the alluvial fan is quite broad and is crossed by the Louis Creek Road. One residence is located on the south edge of the fan. The WE2 watershed is less well defined, and the watershed has a lower overall burn severity than WE1.	Moderate	**Moderate**
• **South Facing Watersheds -** Three small tributary drainages of Christian Creek are mapped on the south side of the fire (WS1, WS2, and WS3 on Figure 1). Within the largest drainage, WS2, a debris flood landslide occurred in the spring of 2017 (Sentinel Hub imagery) and ran out onto the alluvial fan above the HLC Road. The debris flood track passed between the three houses on the fan and deposited the majority of its sediment above the HLC Road. It is expected that there was a strong surge of water which impacted the HLC Road. The Melton Ratio (a predictor of the dominant hydrogeomorphic process influencing the fan, i.e., flood, debris flood, debris flow) of the WS2 creek is 0.58 which indicates that debris floods are the expected geohazard. The shape and topography of the watershed suggest that this Melton Ratio might underestimate the geohazard and a debris flow is possible. The WS2 drainage has a low to moderate vegetation burn severity on the face and low, moderate, and high vegetation burn severities on the plateau surface (Plates 4 and 5). On the plateau surface, water repellent soils were observed to be widespread and strongly persistent. Watersheds WS1 and WS3 are smaller and have lower burn severities.	Moderate	**Moderate**

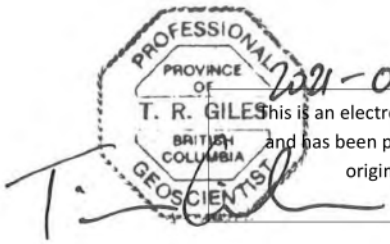
1. Hazard = P(H), the probability of occurrence of a hazardous event
2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk

FURTHER ACTIONS:

A further review of watershed WE1 is recommended. The Embleton Mountain fire burned the majority of the WE1 watershed across the steep face and it is expected that an increase in the rapidity of snowmelt runoff in the spring in the next 3 years has the potential to initiate a landslide from the upper slopes in the watershed.

A further review of watershed WS2 is recommended. A previous landslide (believed to be a debris flood) occurred in the spring of 2017, likely related to removal of the timber on the plateau surface between 2001 and 2017. The Embleton Mountain fire burned the majority of the WS2 watershed across the plateau surface and down the steep face and it is expected that an increase in the rapidity of snowmelt runoff in the spring in the next 3 years may initiate a similar landslide from the upper slopes in the watershed.

POTENTIAL MITIGATION:

SIGNATURE: Tim Giles PGeo, September 7, 2021	**ATTACHMENTS:**
 2021-09-07	

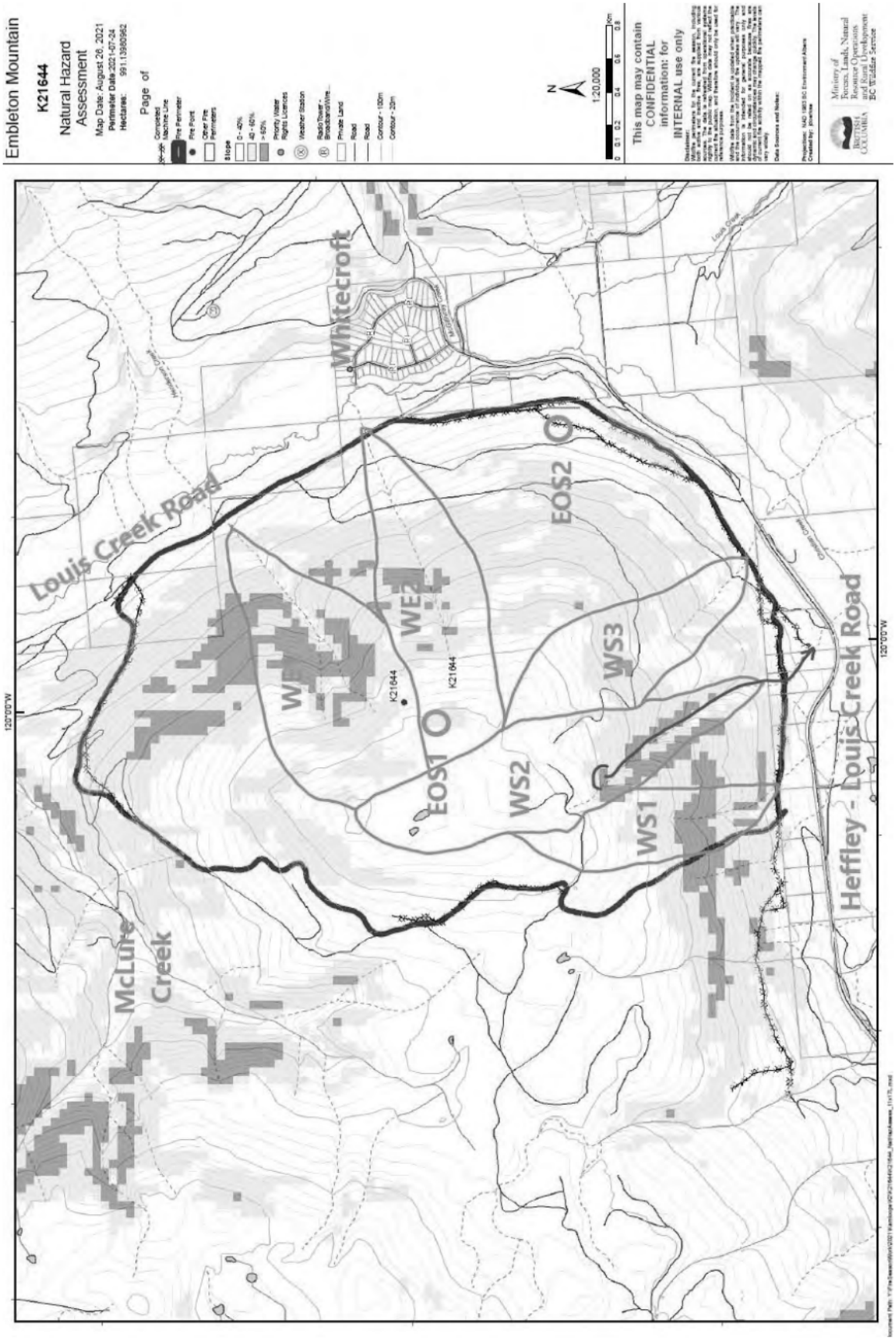


Figure 1: Natural Hazard Assessment Map for the Embleton Mountain Fire (K21644). Observation sites are the orange circles, watersheds outlined in green and the debris flood track and headscarp in blue.

Figure 2: Burn Severity Map for the Embleton Mountain Fire (K21644).

Plate 1: Looking south along the east facing slopes above the Louis Creek Road. The upper slopes are moderate to gently sloped and burned at a moderate or high vegetation burn severity.

Plate 2: Looking northwest at the south facing slopes above the Heffley-Louis Creek Road. Watershed WS2 is the mostly clearly defined draw in the centre of the image.

Plate 3: Watershed WE1 on the east facing slope of Embleton Mountain. The upper slopes have moderate to high vegetation burn severity. The creek runs out across Louis Creek Road and only the faintest trace of a watercourse was observed on the north side (right) of the fan

Plate 4: Headscarp of the 2017 landslide (debris flood) which ran out through watershed WS2. The upper plateau surface is quite gentle, moderately burned and was harvested between 2001 and 2017.

Plate 5: Looking upslope along watershed WS2. The debris flood from 2017 cleared trees along the margins of the draw making the channel wider. The trace of the creek can be seen at lower centre.

MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT
POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT

RECONNAISSANCE REPORT (REVISED)

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions.

FIRE: K71086 Lytton	**FIRE YEAR**: 2021	**DATE OF REVIEW**: September 2, 8 and 17, 2021 **DATE OF REPORT**: September 17, 2021

AUTHOR: Tim Giles, P.Geo., Geoscientist, Westrek Geotechnical Services Ltd.

REPORT PREPARED FOR:

BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development ("The Ministry") – *Thompson Okanagan Region* and *Cascades Natural Resource District*

BC Wildfire Service – *Kamloops Fire Centre* and *Cascades Fire Zone*

FIRE SIZE, LOCATION, AND LAND STATUS: The fire was approximately 83,671 hectares in size.

The fire covers an area from Lytton in the southwest to Spences Bridge in the north, west along the Fraser River and east along the Highway 8 corridor toward Merritt. The Ministry produced Natural Hazard Assessment map is attached for reference.

The land status is a mix of private, municipal, First Nations reserves, Provincial Parks and Crown land.

VALUES AT RISK:

The fire burned the village of Lytton and impacted other small settlements and numerous First Nations reserves.

The fire burned along both sides of the Trans Canada Highway (Highway 1) and Highway 8 as well as the east side above Highway 12. Numerous other paved and gravel roads were impacted by the fire but are generally not considered in this review.

The fire burned adjacent to the CP and CP Rail tracks from Lytton to Spences bridge.

A transmission line from the Kwoiek hydroelectric plant runs north-easterly through the fire towards Logan Lake.

WATERSHEDS AFFECTED:

On the western edge of the fire, several small watersheds leading west into the Fraser River were partially or completely burned.

Between Lytton and Spences Bridge numerous watersheds tributary to the Thompson River were heavily burned, including the Lytton, Botanie, Gladwin, Nicoamen, Sackum, Sleetsis, Squianny and Skoonka drainages.

Along the Nicola River valley, the tributary watersheds of Skaynaneichst, Skeikut, Shakan, Manning and Gordon Creeks were partially or completely burned.

BURN SEVERITY (map attached)

The preliminary burn severity map was provided by the Ministry. The vegetation burn severity map uses satellite images to estimate the change to vegetation canopy. For the Lytton Fire the images compared were taken June 29 and August 3. The map is incomplete on the west edge due to lack of satellite coverage and much of the fire appears unburned (green) because the fire had not yet burned across that area. A more complete vegetation burn severity map will be produced in the fall by the Ministry when there are clear skies to collect better post-fire satellite imagery.

SUMMARY OF HAZARDS AND POTENTIAL RISKS ASSOCIATED WITH FIRE:	**POST-FIRE HAZARD** [1]	**POST-FIRE RISK** [2]
• The Trans Canada Highway (TCH) and the Canadian Pacific (CP Rail) rail line runs along the east side of the Thompson River Valley between Lytton and Spences Bridge. The slopes above the river as well as the larger watersheds were heavily affected by the wildfire. Recent rainfalls in mid-August initiated	High	**High**

erosional sedimentation events in numerous small watersheds leading down to the highway. The Ministry of Transportation and Infrastructure (MOTI) have been cleaning and repairing culverts along much of this stretch of highway. It is unknown if CP Rail has reviewed their tracks since the events.		
• Highway 12 (Lytton to Lillooet) has several small, steep watersheds leading down to it from the east side of the Fraser River (including Spintlum, Conte, Seven Mile, and Hull Arden Creeks). These watersheds are naturally quite responsive to rain events as evidenced by alluvial fans at the base of the slope. These are not expected to have increased activity as a result of the fire as the vegetation burn severity is low and sporadic across these watersheds.	Low	**Low**
• Highway 8 connects Spences Bridge to Merritt along the Nicola River valley. The fire crossed the Nicola Valley near Agate, and the Gordon and Poison Creek watersheds are extensively burned at moderate to high vegetation burn severities. Some moderately steep slopes are located directly above the highway corridor in this area and some erosional sedimentation events have already occurred between Skuhun and Poison Creeks. The event is believed to have occurred on September 15 when the Environment Canada climate station at Merritt recorded 6 mm of rain and the Environment Canada Lytton RCS climate station recorded 3.2 mm. Further northwest several tributary watersheds were burned (Skaynaneichst, Skeikut, Shakan, and Manning Creeks), but the highway is located on the north side of the Nicola River and should not be affected by any fire-related events northwest of Shakan Creek.	Moderate	**Moderate**
• Canadian National (CN Rail) rail lines along the west side of the Thompson River between Lytton and Spences Bridge are at slightly increased risk from post-wildfire landslide events. These slopes are bedrock controlled and covered with sparse to moderate tree cover. Many of the existing landslide, avalanche and erosion prevention and protection structures show signs of activity from previous events. The vegetation burn severity map shows that is a mix of low, moderate, and high vegetation burn severity with large areas that appear unburned.	Moderate	**Moderate**
• Several of the tributaries of the Nicoamen River were extensively burned at moderate or high vegetation burn severity. Several rainfall events (17-, 8.3- and 8.1-mm daily rainfall totals measured by Environment Canada at the Lytton RCS climate station) through mid-August initiated surface erosion throughout two northern tributaries. Overland flow concentrated into the main channels and debris floods impacted the floodplain of Nicoamen River about 2.5 km upstream from the Thompson River. The majority of the coarse sediment deposited across the floodplain and may have briefly impounded the flow in the Nicoamen River. Downstream flooding and sedimentation appears to have passed safely under bridges on the Nicomen River Road which accesses the Nicomen #1 Indian Reserve, the TCH and the CP rail line. One small tributary channel, located just upstream of the Nicomen River Road bridge crossing appears to have experienced a small debris flow which impacted a structure on the north side of the river. Runoff through the Nicomen #1 Indian Reserve has deposited sediment near residential structures at the base of the slope, including on what is believed to be a playground. Two channels appear to be active on the upper slope and where the water passes under the CP Rail track and the TCH, but in the area of the community the channels do not appear to be well connected.	Moderate High	**Moderate for Nicoamen River** **High for Nicomen #1 IR**
• The Lytton Creek watershed defines the southern boundary of the Lytton Fire and the northern perimeter of the George Road Fire (K70804). The Village of	Moderate	**Moderate**

Lytton has a water treatment plant on Lytton Creek which has an increased potential to be impacted by a flood or debris flood. The upper elevations of the watershed were burned at moderate to high burn severity while much of the lower area was mixed low, moderate, and unburned. The overall channel gradient to the water treatment intake is 23% and the Melton Ratio is 0.49 which indicates a debris flood is the expected geohazard. *1. Hazard = P(H), the probability of occurrence of a hazardous event. It does not address the natural or pre-fire hazard that may already have existed.* *2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk*		

FURTHER ACTIONS:

Post-wildfire assessments are recommended for several areas of the Lytton wildfire to assess the potential impacts that the wildfire has had on the natural hazards and to present potential options that the stakeholder can consider to mitigate their risk. Specific sites are:

- Further investigation of the Nicoamen River watershed is recommended to determine the geohazard potential to the lower Nicoamen River, including the bridges on the Nicomen River Road, the TCH and the CP Rail track. A review of the small tributary watershed debris flow should be included in this review.

- The Nicomen #1 Indian Reserve is located on a glaciofluvial gravel terrace above the CP Rail track and the TCH. Drainage appears to pass through two culvert locations on the CP Rail track and then under the TCH. The drainage of the entire slope above the community should be investigated to determine suitable continuous channels to pass water through the community and ensure that these channels are of sufficient size to convey the expected increased flows from the watersheds above. This may require Indigenous Services Canada involvement.

- Further investigation of the Lytton Creek watershed is recommended to determine the geohazard potential to the Village of Lytton water intake. Downstream of the water intake the creek passes under the Trans Canada Highway, the south access road to the village of Lytton, plus the CP Rail and CN Rail tracks.

- MOTI should ensure that all drainage structures along the Lytton to Spences Bridge TCH corridor are cleaned and functional. MOTI may also want to further quantify the hazards and potential risks posed by watersheds and open slopes above the TCH.

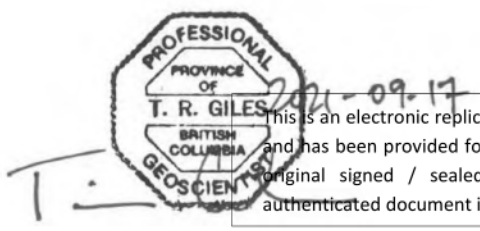
- MOTI should ensure that all drainage structures along the Highway 8 within the fire perimeter are cleaned and functional. MOTI may also want to further quantify the hazards and potential risks posed by watersheds and open slopes above Highway 8.

- CN Rail and CP Rail should independently assess all of their infrastructure within the fire perimeter.

POTENTIAL MITIGATION:

COMMENTS:

SIGNATURE: Tim Giles, September 17, 2021

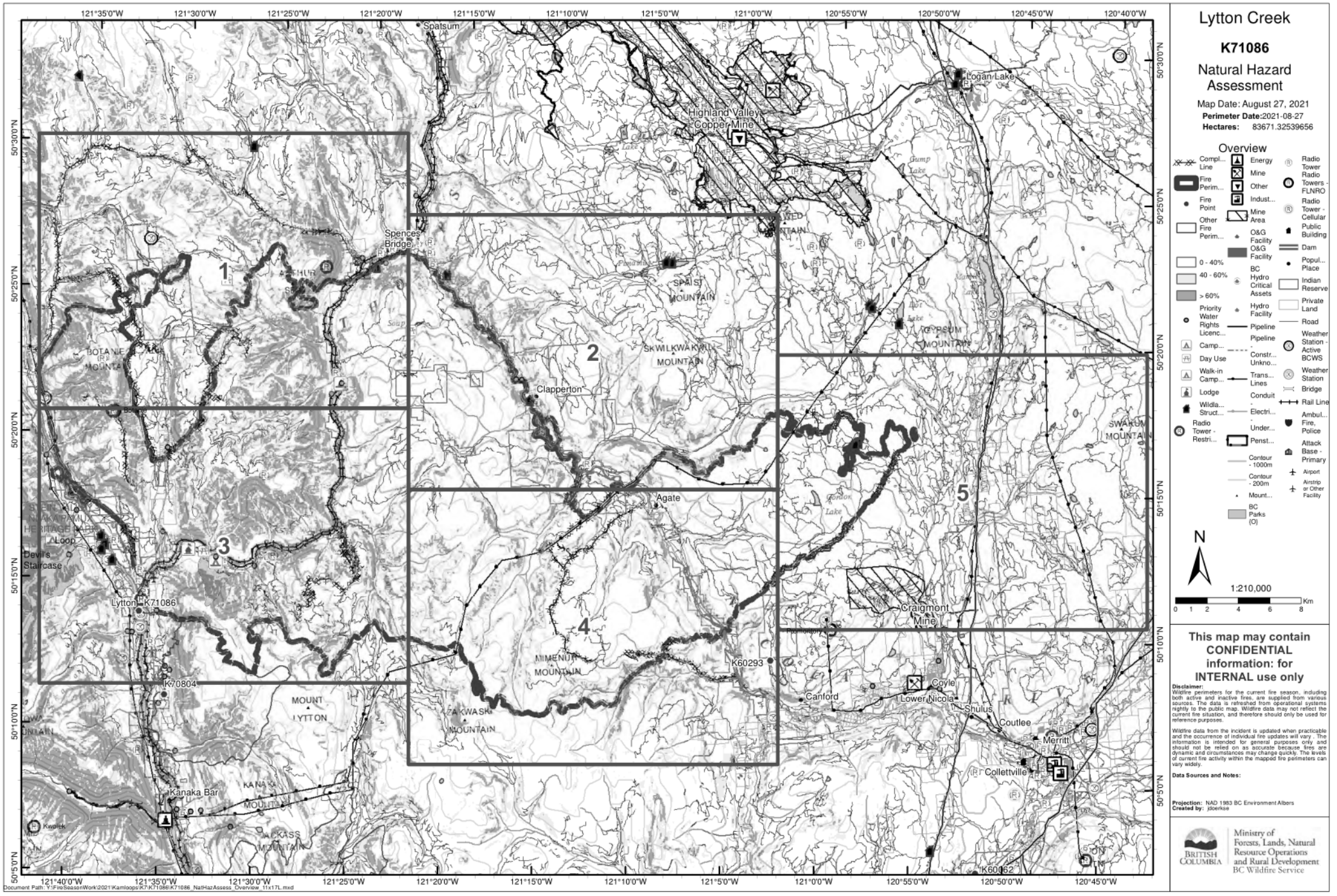


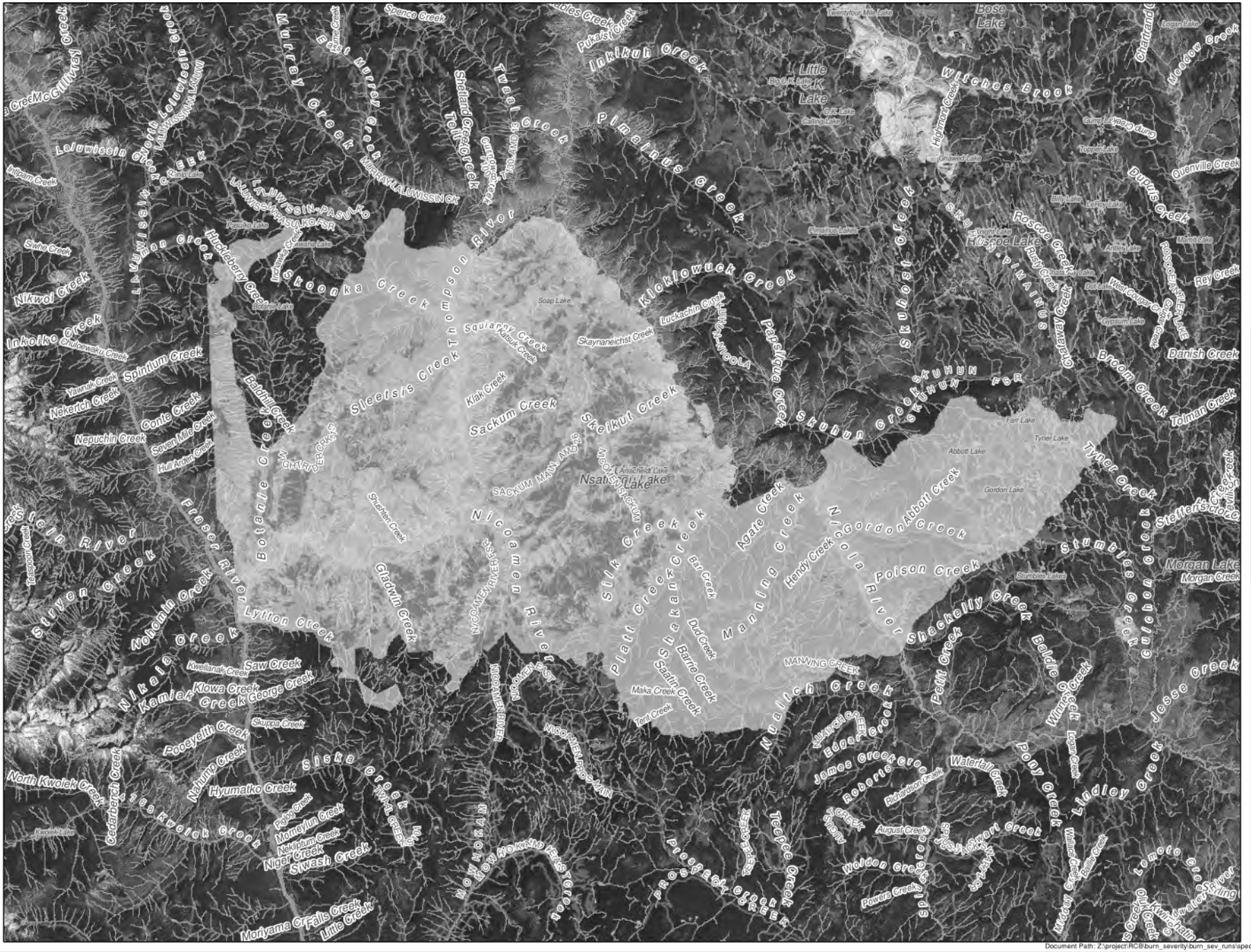
2021-09-17

This is an electronic replica of the original signed and sealed report and has been provided for convenience. Westrek has retained the original signed / sealed report on file and can provide an authenticated document if required.

ATTACHMENTS:

K71086 Lytton Natural Hazard Assessment Map
K71086 Lytton Vegetation Burn Severity Map


Lytton Creek
K71086
Natural Hazard Assessment
Map Date: August 27, 2021
Perimeter Date:2021-08-27
Hectares: 83671.32539656
Overview
1
2
3
4
5
Spatsum
Logan Lake
Highland Valley Copper Mine
Spences Bridge
Clapperton
Agate
Lytton
K71086
K70804
K60293
K60062
Kanaka Bar
Devil's Staircase Loop
Craigmont Mine
Canford
Coyle
Lower Nicola
Shulus
Coutlee
Merritt
Collettville
Kwoiek
SPAHAT MOUNTAIN
SKWILKWAKWIL MOUNTAIN
GYPSUM MOUNTAIN
SWAKUM MOUNTAIN
MOUNT LYTTON
ZAKWASKI MOUNTAIN
MINENUT MOUNTAIN
KANAKA MOUNTAIN
ALKASS MOUNTAIN
N
1:210,000
0 1 2 4 6 8 Km
This map may contain CONFIDENTIAL information: for INTERNAL use only
Disclaimer:
Wildfire perimeters for the current fire season, including both active and inactive fires, are supplied from various sources. The data is refreshed from operational systems nightly to the public map. Wildfire data may not reflect the current fire situation, and therefore should only be used for reference purposes.
Wildfire data from the incident is updated when practicable and the occurrence of individual fire updates will vary. The information is intended for general purposes only and should not be relied on as accurate because fires are dynamic and circumstances may change quickly. The levels of current fire activity within the mapped fire perimeters can vary widely.
Data Sources and Notes:
Projection: NAD 1983 BC Environment Albers
Created by: jdoerkse
Ministry of Forests, Lands, Natural Resource Operations and Rural Development
BC Wildfire Service
Document Path: Y:\FireSeasonWork\2021\Kamloops\K7\K71086\K71086_NatHazAssess_Overview_11x17L.mxd



K71086

Burn Severity Mapping For Natural Hazard Assessment

Burn Severity 2021 (Same-Year Classification)

- High
- Medium
- Low
- Unburned
- Unknown

This burn severity mapping is created using a Differenced Normalized Burn Ratio (DNBR) calculation on pre- and post-fire imagery which is classified into four Burned Area Reflectance Classification (BARC) categories. Default breakpoints are used for all timber types across BC and therefore may not accurately reflect field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CONTAINS A SIGNIFICANT AMOUNT OF SMOKE HAZE WHICH MAY ADVERSELY AFFECT BURN SEVERITY VALUES. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

"Same-Year Classification" means that the burn severity mapping has been completed the same year the fire occurred (i.e. in summer/fall 2018 for 2018 fires).

Pre-Fire Scene Identifier: T10UFA_20210629T190919

Post-Fire Scene Identifier: T10UFA_20210803T190921

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

Last updated: 2021-08-23
Updated by: camahood
Coordinate System: NAD 1983 BC Environment Albers

Document Path: Z:\project\RCB\burn_severity\burn_sev_runs\specialty_runs\2021\distribution_work\burn_severity_for_nat_haz_assessments.mxd

K21644 Embleton Mountain Fire – Supplement to the September 7, 2021 PWNHRA Reconnaissance Report

Prepared for:

Ministry of Forests, Lands, Natural Resource Operations and Rural Development
441 Columbia St.
Kamloops, BC V2C 2T3
Attention: Trevor Bohay, PGeo

Prepared by:

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October 12, 2021
File No. 021-155

1 Introduction and Scope

A *Post-wildfire Natural Hazard Risk Assessment Reconnaissance Report of the K21644 Embleton Mountain Fire*, published by Westrek Geotechnical Services Ltd. (Westrek) on September 7, 2021, indicated there were two issues requiring further field investigation.

- *A further review of watershed WE1 is recommended. The Embleton Mountain Fire burned the majority of the WE1 watershed across the steep face and it is expected that an increase in the rapidity of snowmelt runoff in the spring in the next 3 years has the potential to initiate a landslide from the upper slopes in the watershed.*
- *A further review of watershed WS2 is recommended. A previous landslide (believed to be a debris flood) occurred in the spring of 2017, likely related to removal of the timber on the plateau surface between 2001 and 2017. The Embleton Mountain Fire burned the majority of the WS2 watershed across the plateau surface and down the steep face and it is expected that an increase in the rapidity of snowmelt runoff in the spring in the next 3 years may initiate a similar landslide from the upper slopes in the watershed.*

As part of the Post-wildfire Natural Hazard Risk Assessment (PWNHRA) Services contract dated July 21, 2021, between the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (the Ministry) and Westrek, Westrek was requested to complete the further field investigation. An additional small watershed, WE2, was reviewed in the field to assess if a culvert might be required on the Louis Creek Road.

The services provided by Westrek are subject to the terms and conditions set out in the attached *Interpretation and Use of Study and Report and Limitations* (Appendix A), which is incorporated herein by reference.

2 Background

Moderate to high intensity wildfires can result in significant hydrologic change at both the stand and watershed scales. Noticeable effects may be observed on downstream values, such as water quality and quantity, stream channel stability, infrastructure, public safety and aquatic ecosystem health. The magnitude of post-wildfire hydrologic change is affected by numerous factors, including burn severity, watershed characteristics (forest cover, aspect, slope, geology, and soils) and timing and magnitude of rainfall or snowmelt.

The loss of forest cover following wildfire generally results in increased precipitation (both rain and snow) reaching the ground, decreased transpiration, increased soil moisture and increased surface runoff. Soil properties can be altered and, depending on soil burn severity, a water repellent layer may form in the soil. The water repellent layer reduces the permeability of the soil, which increases the surface runoff and erosion potential.

For small watersheds within the Embleton Mountain Fire, watershed scale effects may include an increase in streamflow, more rapid and earlier snowmelt generated flows and degradation of the water quality. Streamflow timing and magnitude are most significantly altered:

- in smaller watersheds where runoff concentration times are short,
- where hydrophobic soil conditions occur,
- where runoff is concentrated from gentle onto steep slopes, and
- during intense rainstorms or during rapid snowmelt.

Increase in, and perhaps flashier, snowmelt runoff is expected within these small watersheds draining off Embleton Mountain. This may result in elevated streamflow within the creeks, which may impact the road systems at the base of the slope.

3 Methods

Tim Giles MSc PGeo, representing Westrek, conducted a ground-based assessment of the K21644 Embleton Fire on September 21, 2021. The weather at the time was sunny and warm.

The watersheds WE1, WE2 and WS2 (Figure 1) were reviewed in the field to determine:

- if they showed signs of previous landslide activity,
- what effects on natural hazards, including peak flows, the fire might have on the watersheds, and
- if the drainage structures in the roads at the base of the slope (Heffley – Louis Creek Road or Louis Creek Road) were present and well maintained.

Information on surficial deposits, slopes, geomorphological processes, and drainage was obtained from site observations, exposures in windthrown trees, scarps and/or hand-dug excavations. Elevations provided in this report have been obtained from 1:20,000 scale TRIM topographic mapping.

Subsequent to the completion of the *Post-wildfire Natural Hazard Risk Assessment Reconnaissance Report of the K21644 Embleton Mountain Fire*, Westrek revised the Burn Severity Map using improved satellite imagery (Figure 2).

4 Results

4.1 Watershed WE1

This watershed (Photo 1) drains east into the Louis Creek valley from the peak of Embleton Mountain, roughly elevation 1610 m (Figure 1). The Burn Severity Map (Figure 2) indicates that there is a mix of unburned, low, moderate and high burn severity. The creek extends upslope to 1440 m and joins the main channel of Louis Creek on the floodplain at 745 m. A longitudinal profile of the creek (Figure 3) indicates the upper channel has a 65% gradient above a

Photo 1: *View of the WE1 watershed which drains from the peak of Embleton Mountain down to the Louis Creek Road (LCR) and Louis Creek. The solid blue line is the well-defined original channel, and the dotted blue line is the approximate location of the water diversion pipe and ditch. The old LCR alignment is shown in black.*

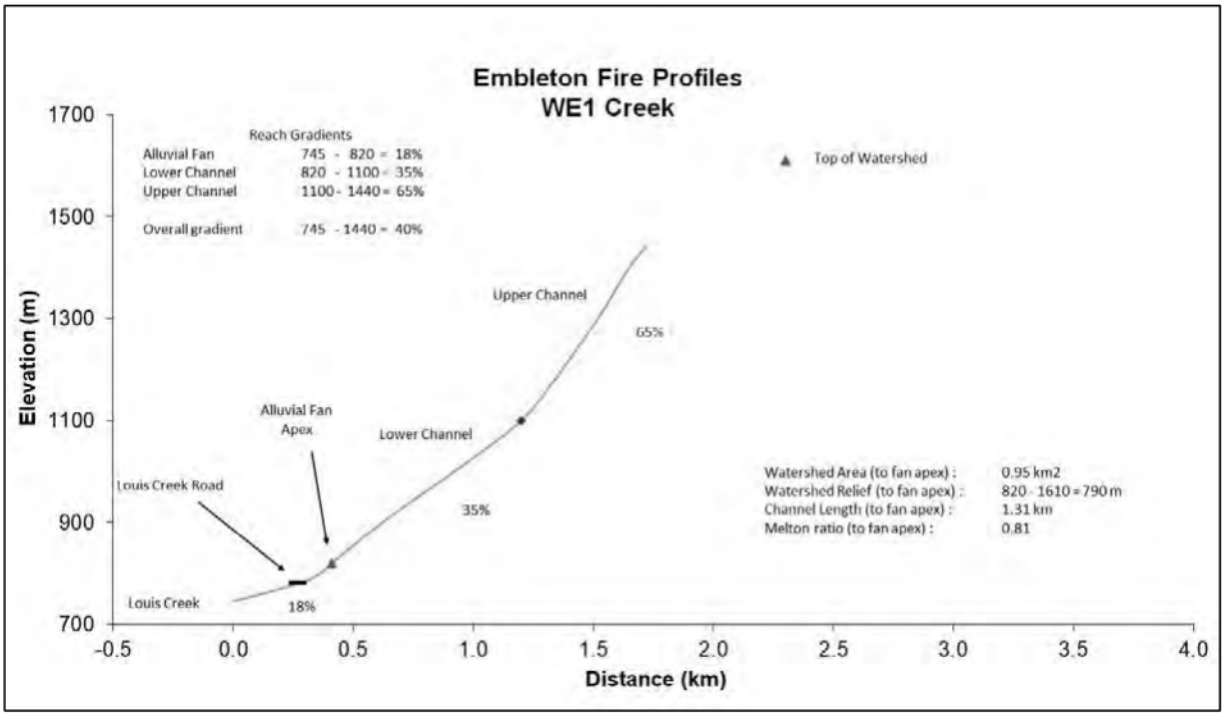


Figure 3: *Longitudinal profile of the watershed WE1 within the Embleton Mountain Fire. The profile has a vertical exaggeration of 2:1.*

moderately graded mid-slope channel (35%). The creek runs out across an alluvial fan sloped at 18%. The small area (0.95 km^2 or 95 hectares) and steep gradient means that this watershed has a relatively high Melton ratio at 0.81. This indicates that the expected geomorphological process in this watershed is a debris flow (Church and Jakob, 2020[1]).

Despite the relative steepness of the watershed, no sign of debris flow levees were observed on the channel or alluvial fan (Photo 2). The lower channel was an incised draw, 8 to 10 m wide, 3 to 5 m deep, with a very small stream within it. Streamflow disappeared gradually downslope and had completely infiltrated about 50 m upslope from the LCR. At the LCR, the draw is still 5 to 10 m wide and 2 to 3 m deep, but no culvert is present. Further downslope, the draw crosses an old road alignment (Photo 1, likely the original LCR alignment) which also has no culvert. This watershed now has significant areas of moderate and high burn severity (Figure 2). It is expected that for the next 3 to 5 years there will be increased streamflow and associated sediments off the slopes above due to the effects of the fire and this may impact the LCR.

Partial diversion of water in the creek is presently occurring about 175 to 200 m upstream from the LCR. This diversion consists of a 1-inch plastic pipe embedded in the stream which runs southeast into a cistern located about 60 m upslope from the LCR. The plastic pipe has burned, or otherwise ruptured, in at least 3 places between the creek and the cistern. The cistern drains downslope through a small drainage ditch, passes under the LCR through a culvert about 50 m south of the actual creek draw. A shallow swale carries water down to an old road alignment, which it passes under in a second culvert before being discharged into the field below.

Photo 2: *View up the channel on the alluvial fan of the WE1 watershed.*

[1] Church, M and M Jakob. 2020. *What is a debris flood?* Water Resources Research, 56, e2020WR027144. https://doi.org/10.1029/2020WR027144

For watershed WE1, it is recommended that the Ministry of Transportation and Infrastructure (MOTI) review the drainage where the creek intersects the LCR and, if appropriate, install a culvert. Further downslope, the draw crosses an old road alignment which should be culverted or cross-ditched as needed to provide appropriate drainage.

For watershed WE1, it is recommended that the Ministry of Forests, Lands, Natural Resource Operations and Rural Development determine the status of the water system and direct the owner to repair or remove it.

4.2 Watershed WE2

This watershed drains east into the Louis Creek valley from the slopes of Embleton Mountain (Figure 1). The Burn Severity Map (Figure 2) indicates that there is a mix of unburned, low and moderate burn severity. A view of the slope looking north along the LCR suggests it was mostly unburned and low burn severity (Photo 3). The creek draw has a well-defined V-shape, with a 1 to 2 m wide channel and 5 to 8 m deep sidewalls. No water was flowing in the channel, but some sediment accumulation was observed indicating ephemeral (freshet) flow likely occurs. It is expected that for at least the next 3 years there will be slightly increased streamflow off the slopes above due to the effects of the fire and this may impact the LCR.

For watershed WE2, it is recommended that MOTI review the LCR drainage and, if appropriate, install a culvert.

Photo 3: *View of the WE2 watershed on the east-facing slope of Embleton Mountain. The blue line is the approximate channel. The LCR is at lower right and Louis Creek can be seen at far right.*

4.3 Watershed WS2

This watershed drains to the south into Christian Creek from the peak of Embleton Mountain (Figure 1; elevation 1610 m). A longitudinal profile of the channel (Figure 4) indicates the channel has a 39% gradient which runs out across an alluvial fan sloped at 15%. The upper reaches of the watershed are on the gently plateau surface. From around 1500 m, the creek descends the steeper slopes down to the apex of the alluvial fan around 950 m (Photo 4). From the fan apex downslope, the creek is gently sloped until it joins Christian Creek at 820 m. The small area (1.32 km^2 or 132 hectares) and moderate gradient means that this watershed has a moderate Melton ratio at 0.57. This indicates that the expected geomorphological processes in this watershed are debris floods or debris flows (Church and Jakob, 2020). This watershed now has significant areas of moderate and high burn severity (Figure 2). It is expected that for the next 3 to 5 years there will be increased streamflow and associated sediments off the slopes above due to the effects of the fire and this may impact the Heffley - Louis Creek Road (HLCR).

In May 2017, a landslide initiated at the top of the south-facing slope and deposited debris through the private land, down to the HLCR. A review of landslide by Westrek in 2017 (unpublished field investigation) concluded that the event was a debris flow. Debris fanned out on the alluvial fan surface and lobes of sedimentary debris were deposited amongst the trees. Further downslope, culverts in the residential access road, two driveway accesses and under the HLCR, were impacted by sediment-laden streamflow (Figure 5 and Photo 6).

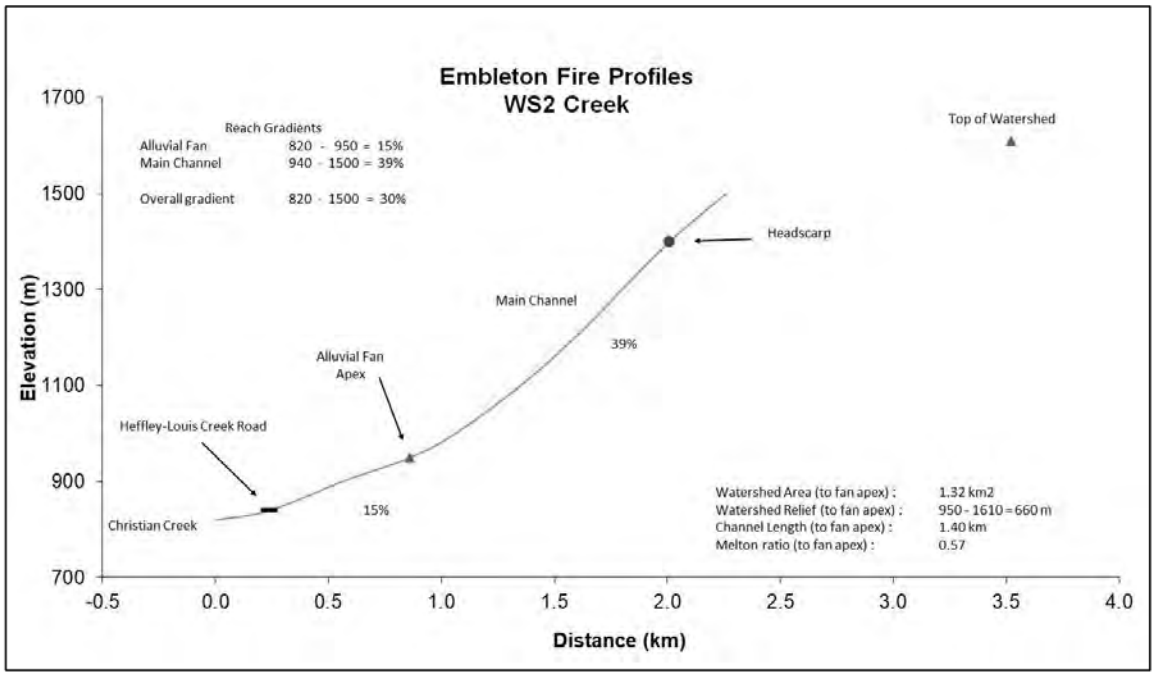


Figure 4: *Longitudinal profile of the watershed WS2 within the Embleton Mountain Fire. The profile has a vertical exaggeration of 2:1.*

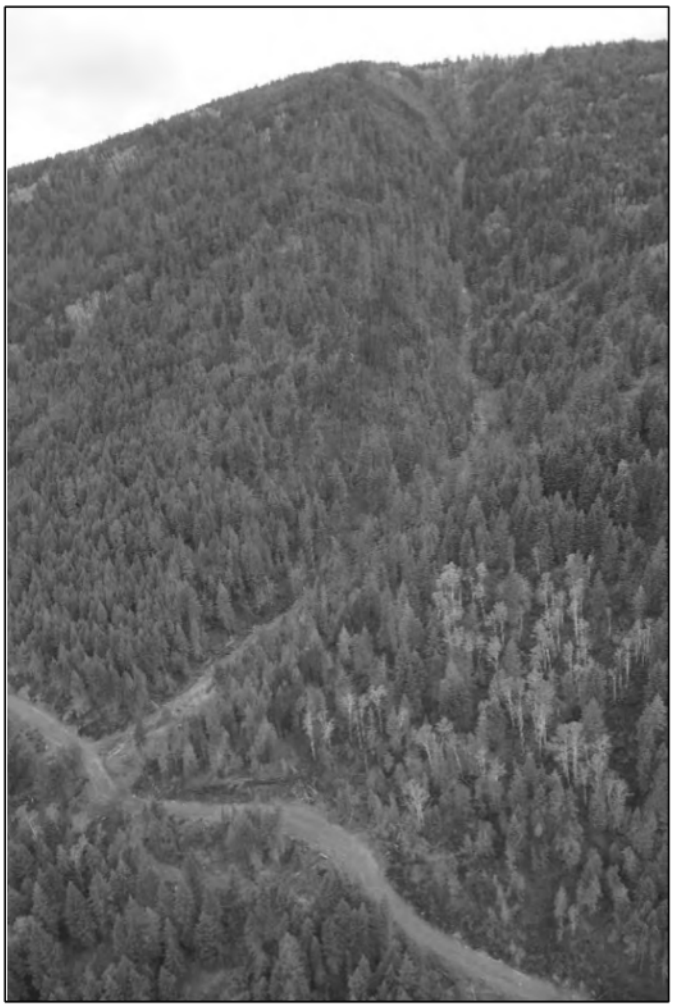


Photo 4: *View of the lower half of the WS2 Creek on the south-facing slope of Embleton Mountain. A fireguard constructed during firefighting crosses the creek just below the apex of the alluvial fan.*

For watershed WS2, it is recommended that, prior to the 2022 spring freshet, MOTI review the drainage where the creek intersects the HLCR and, if appropriate, install a culvert. Existing culverts and ditch-lines along the HLCR should also be cleaned and properly maintained.

For watershed WS2, it is recommended that the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, rehabilitate the fireguard (visible in Photos 4 and 5) through the creek draw. Removal of all the sediment and woody debris used to construct the fireguard through the channel is required. The natural channel at the crossing should be re-established to be of similar width and depth as it is upslope. The base of the channel should be lined with a layer of larger rocks (>25 cm diameter) to armour the channel base and reduce erosion from the area of the fireguard crossing.

Figure 5: *Google Earth view of the WS2 Creek alluvial fan from 2017. The track of the debris flow can be clearly seen coming off the upper slopes, running through the residential area, before reaching the HLCR. The creek currently follows the highway ditch-line east for 400 m to a 600 mm culvert, which passes it into the field below and then into Christian Creek.*

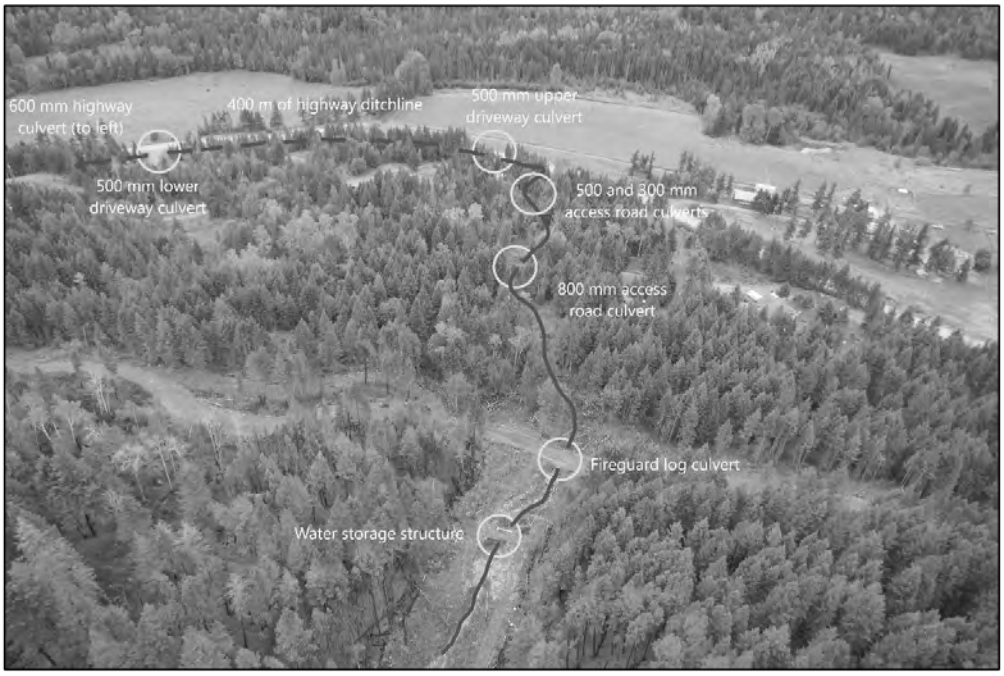


Photo 5: *View looking south of the WS2 Creek alluvial fan above the HLCR. The creek passes through a number of culverts and then follows the highway ditch-line to the east before draining south into Christian Creek.*

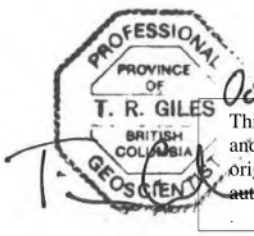
Residents on the alluvial fan should be advised of the potential impacts that the wildfire may have on the stability of the creek channel. Each owner should retain specialized expertise to better assess the risks to their safety and property and develop risk mitigation measures where appropriate to mitigate the risk.

5 Closure

We trust that this report is complete for your present requirements. Please contact the undersigned if you have any questions.

Yours truly,

Westrek Geotechnical Services Ltd.
Permit to Practice Number: 1002522



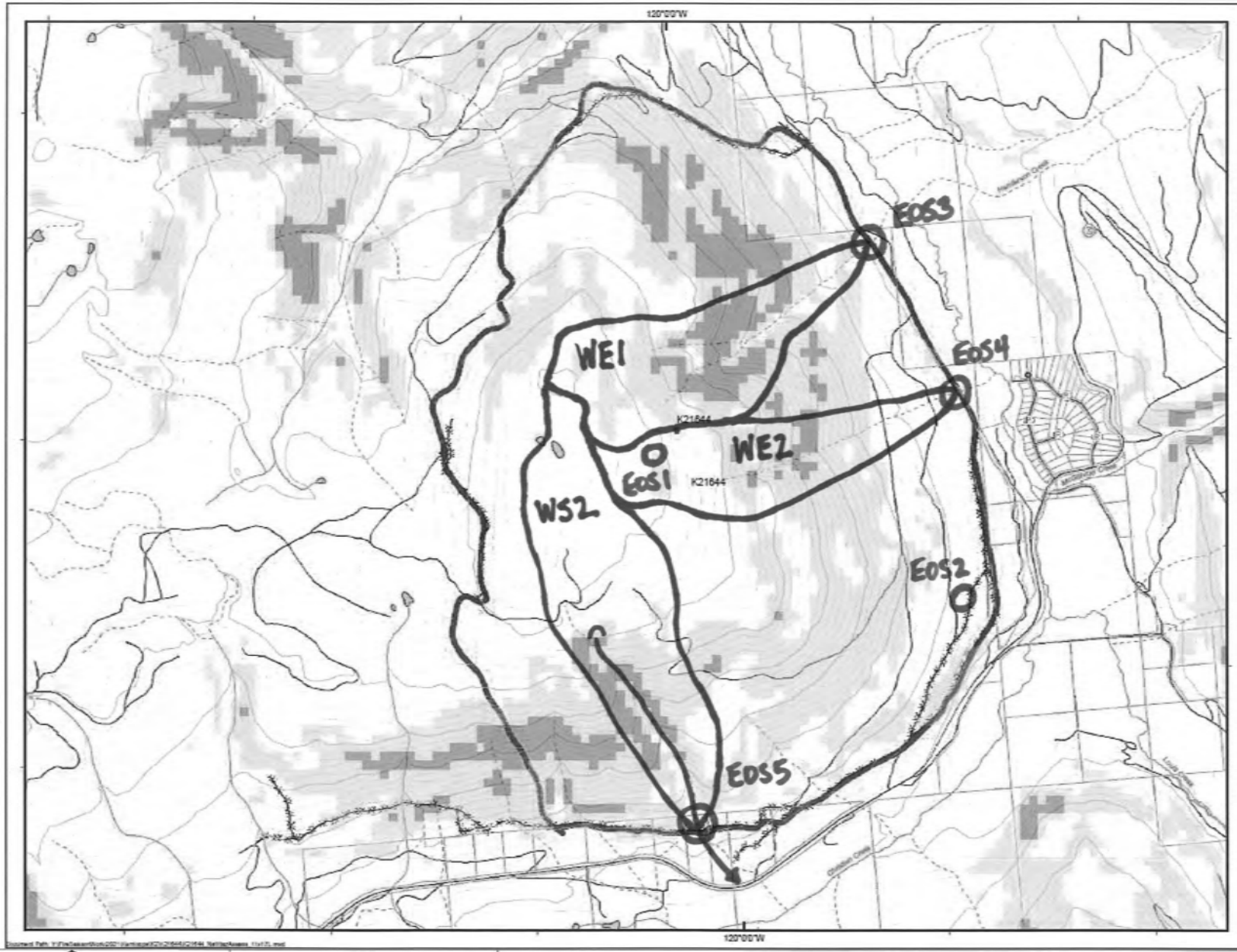
Oct 12, 2021

This is an electronic replica of the original signed and sealed report and has been provided for convenience. Westrek has retained the original signed / sealed report on file and can provide an authenticated document if required.

Per:
Tim Giles MSc PGeo
Senior Terrain Geoscientist

Reviewed by:
Kevin Turner, PEng
Senior Geotechnical Engineer

Attached: Figure 1 – *Natural Hazard Assessment Map, Embleton Mountain Fire K21644*
Figure 2 – *Burn Severity Map, Embleton Mountain Fire K21644*
Appendix A – *Interpretation and Use of Study and Report and Limitations*



Embleton Mountain

K21644

Natural Hazard Assessment

Map Date: August 26, 2021
Perimeter Date:2021-07-04
Hectares: 991.13980962

Page of

Completed Machine Line
Fire Perimeter
Fire Point
Other Fire Perimeters

Slope
0 - 40%
40 - 60%
> 60%

Priority Water Rights Licences
Weather Station
Radio Tower - Broadband Wire...
Private Land
Road
Road
Contour - 100m
Contour - 20m

N

1:20,000

0 0.1 0.2 0.4 0.6 0.8 Km

This map may contain CONFIDENTIAL information: for INTERNAL use only

Disclaimer:
Wildfire perimeters for the current fire season, including both active and inactive fires, are supplied from various sources. The data is refreshed from operational systems nightly to the public map. Wildfire data may not reflect the current fire situation, and therefore should only be used for reference purposes.

Wildfire data from the incident is updated when practicable and the occurrence of individual fire updates will vary. The information is intended for general purposes only and should not be relied on as accurate because fires are dynamic and circumstances may change quickly. The levels of current fire activity within the mapped fire perimeters can vary widely.

Data Sources and Notes:

Projection: NAD 1983 BC Environment Albers
Created by: jcarlow

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

westrek geotechnical services ltd.

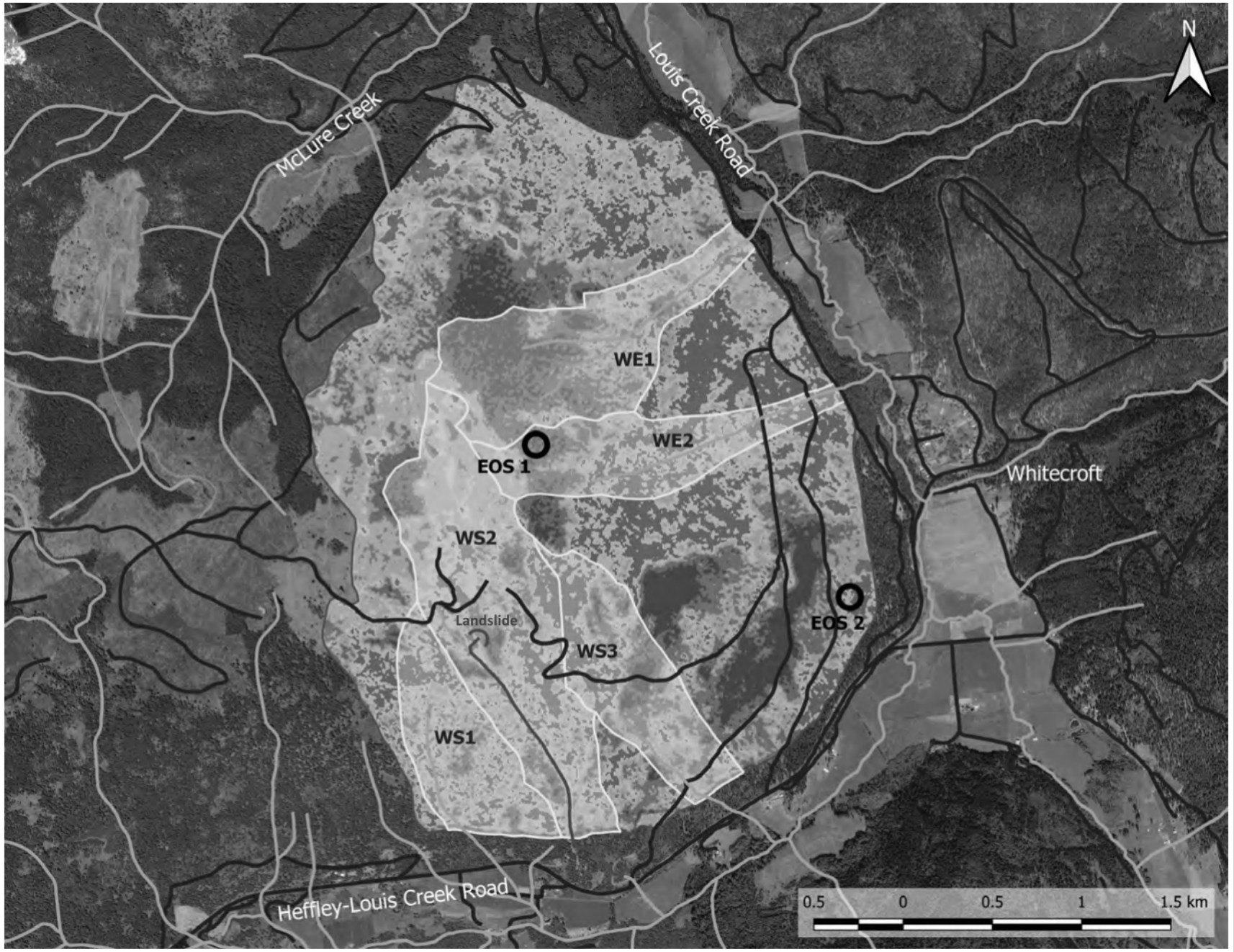
SCALE: AS SHOWN

Project: 021-155

NATURAL HAZARD ASSESSMENT MAP

EMBLETON MOUNTAIN FIRE K21644

FIGURE 1



EMBLETON MOUNTAIN
K21644

Burn Severity Map for Natural Hazard Assessments
1 : 50 000

Fire Boundary

Burn Severity 2021
(Year-Over-Year Classification)*

<= -550	UNKNOWN
-550 - 99	UNBURNED
99 - 269	LOW BURN
269 - 439	MOD-LOW BURN
439 - 660	MOD-HIGH BURN
> 660	HIGH BURN

This burn severity mapping is created using a Differenced Normalized Burn Ratio (dNBR) calculation on pre- and post-fire imagery as described by Key and Benson, 2006. The map is classified into five burned area reflectance classification (BARC) categories. Default breakpoints for burn severity classifications are used for all timber types across BC and therefore may not accurately reflect the forest type or field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CAN CONTAIN SMOKE AND/OR CLOUDS WHICH COULD ADVERSELY AFFECT THE BURN SEVERITY ANALYSIS*. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESSMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

*"Year-over-Year classification", means that the burn severity mapping was done using satellite scenes approximately (as close to) a year apart to capture similar vegetation and moisture levels.

Data Sources:
Pre-fire scene: Sept 09, 2020; Modified Copernicus Sentinel data [2021]/Sentinel Hub
Post-fire scene: Sept 07, 2021; Modified Copernicus Sentinel data [2021]/Sentinel Hub

Map produced by: JSchafer, 2021
Coor System: NAD 1983 BC Environment Albers

westrek
geotechnical services ltd.
100 -1383 McGill Road, Kamloops, BC V2C 6K7
Tel: 778-765-9525

Figure 2

APPENDIX A
INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek's liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the "Claim"), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

ii. if the Claim cannot be satisfied by the re-performance of the Services and:

1. if Westrek's professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek's total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

2. if Westrek's professional liability insurance applies to the Claim, shall be limited to the coverage amount available under Westrek's professional liability insurance at the time of the Claim. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in the amount of $2,000,000 per occurrence, $2,000,000 in the aggregate, for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client's expense.

It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek's liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

i. Substantial performance of the Services,

ii. Suspension or abandonment of the Services provided under this agreement, or

iii. Termination of Westrek's Services under the agreement,

whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
Suite 500 - 980 Howe Street
Vancouver, BC Canada V6Z 0C8
Telephone (604) 684-5900
Fax (604) 684-5909

October 14, 2021
Project No.: 1114016

Trevor Bohay, P.Geo.
Director of Special Projects-ADM's Office, South Area
Ministry of Forests, Lands, Natural Resource Operations and Rural Development
441 Columbia Street
Kamloops, BC

Dear Trevor,

Re: Post-wildfire Debris Flow Assessment Devil's Creek at Nicomen 1 I.R.

1.0 INTRODUCTION

BGC Engineering Inc. (BGC) was contacted by the BC Ministry of Forests, Lands, Natural Resources Operations and Rural Development (MFLNRORD) on September 16, 2021, to formulate a proposal for post-fire hazard assessments for three creeks draining onto the Nicomen 1 Indian Reserve (I.R.) on the east side of Thompson River some 15 km east of Lytton, B.C. One of the three creeks is named "Devil's Creek" and is located directly upstream of portions of the Nicomen 1 I.R. In the aftermath of the wildfire, BGC has identified this creek, to have the potential to generate destructive debris flows which could reach and travel through the Nicomen 1 I.R. on its path to the Thompson River. Currently, there is no infrastructure in place to protect the Nicomen 1 I.R. from debris flows.

The purpose of this letter is to inform MFLNRORD, prior to the issuance of BGC's complete geohazard report, of the substantial and immediate hazard posed by Devil's Creek to residences at Nicomen 1 I.R. and downstream infrastructure (Canadian Pacific Rail and Highway 1). "Substantial" is defined as a hazard of sufficient intensity (velocity, depth and impact force) to pose life loss threat to people outside and inside of buildings and to damage or destroy culverts, roads, and buildings. "Immediate" is defined as a hazard (debris flow or debris flood) that can occur without warning in response to a high-intensity rainfall or rain-on-snow event, and that in our opinion has greater than a 60% chance of occurring within the next 5 years.

This letter is intended to provide MFLNRORD, Emergency Management BC, Nicomen Band, and other stakeholders with relevant information to guide appropriate measures to safeguard residents and other infrastructure from the adverse consequences of a debris flow.

This work is completed under the MFLNRORD contract number 10005-40/RH22483-002 dated September 27, 2021.

2.0 FIELD OBSERVATIONS

On September 29, BGC Engineering (Dr. Matthias Jakob, P.Geo. P.L. Eng., Carie-Ann Lau, P.Geo. and Hazel Wong, P.Geo.) visited the Devil's Creek and adjacent watersheds upstream of Nicomen 1 I.R (Figure 2-2). The locations of the debris damage incurred by the August 16 and September 17, 2021 post-wildfire debris flow events on the Nicomen 1 I.R. were examined (Figure 2-2). The field work was followed by a helicopter flight on September 30. Due to high winds in the burned area, ground observations in the watershed were limited to elevations below 450 m.

Figure 2-1 is an aerial image showing the burn severity in the upper Devil's Creek watershed showing the Nicomen Earthflow[1], the forest service road (FSR), the outline of the Devil's Creek watershed and Devil's Creek with some of its main tributaries. The side slopes and tributaries, especially in the eastern and eastern and southern portions of the Devil's Creek watershed, were burned at moderate and high severities (Figure 2-1). Post-wildfire debris flows on August 16 and September 17, 2021 have emanated from moderate to highly burned tributaries.

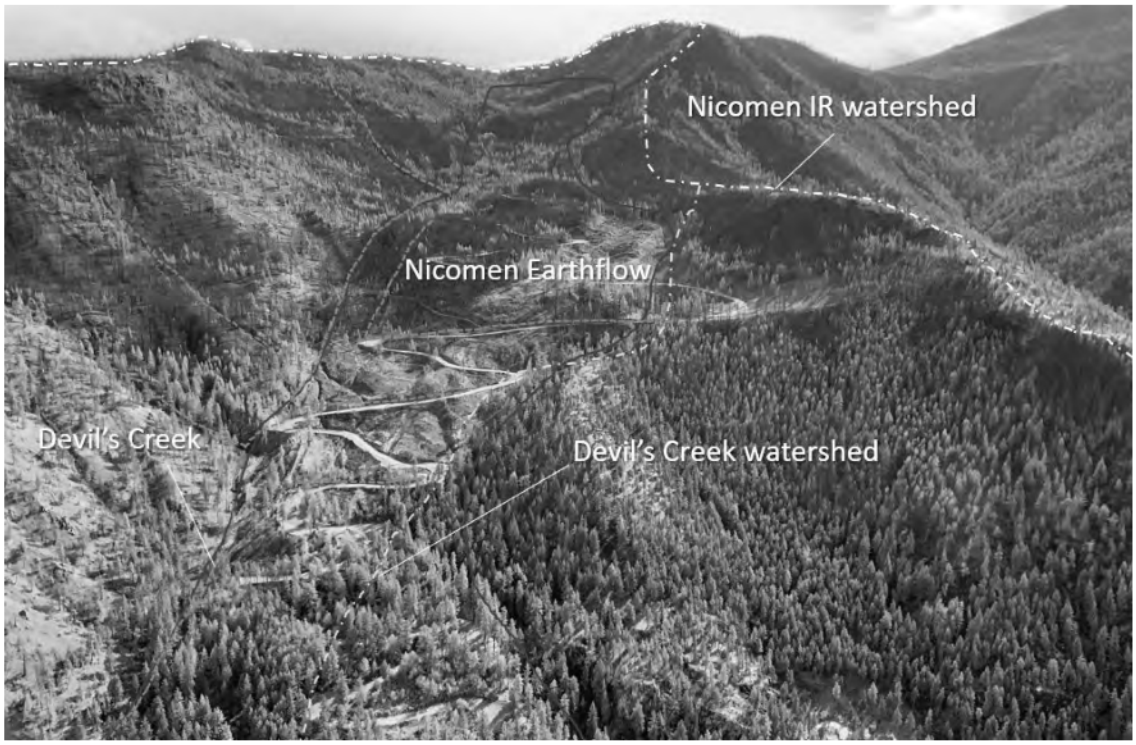


Figure 2-1. Upper Devil's Creek watershed on September 30, 2021 showing the different burn severities. The earthflow is located in the centre of the photo delineated in red and partially logged. Photo by BGC looking towards the South.

[1] An earthflow is a type of landslide and is defined as a downslope viscous flow of fine-grained, often clay-rich, sediments saturated with water that moves by gravity and internal deformation. The present state of the Nicomen earthflow is presumed to be inactive as no signs of ongoing movement were detected.

Post-wildfire debris flows and debris floods on August 16 and September 17, 2021 in Devil's Creek avulsed approximately 250 m upstream of Nicomen River Road. The resultant flows entered the playground adjacent to the Nicomen Band Office and deposited 0.1 to 0.2 m of sediment into the playground area (Figure 2-2). The unnumbered building directly downstream of the playground had water and sediment less 0.1 m deep deposit into the yard surrounding the building during the September 17, 2021 event.

Figure 2-2. Panoramic view towards the north from upstream of the Nicomen 1 I.R. playground looking downstream. The foreground shows debris coverage of approximately 20 cm height thinning towards the distal portions of the playground. The Nicomen Band office is the white building on the right side of the image. Photograph: BGC, September 29, 2021.

At Nicomen River Road, Devil's Creek is conveyed through a 1 m diameter corrugated steel pipe culvert (Figure 2-3). BGC observed a travel trailer parked on the road directly beside the culvert intake. The stream flows out of the culvert and into an incised drainage ("North Gully") on the east side of the property at 1027 Nicomen River Road.

Figure 2-3. Culvert intake for Devil's Creek at Nicomen River Road. Note the travel trailer parked in the foreground and two houses downstream of the culvert in the background of the photo. Photo: BGC looking downstream (north). September 29, 2021.

3.0 HAZARD INTERPRETATIONS

BGC made the following key interpretations based on the field assessment and review of air photographs and satellite images:

- Post-wildfire debris flows triggered from burnt tributaries could have sufficient momentum to travel down Devil's Creek to Nicomen 1 I.R. and further to the Thompson River. Post-fire debris flows are expected to carry large amounts of organic debris prone to forming log jams in the channel and increase avulsion potential.
- The dominant landform upstream of the Nicomen 1 I.R. is a presumably inactive earthflow. Earthflows are clay rich. Devil's Creek runs along the eastern portion of the Nicomen Earthflow. Entrainment of sediment and debris may introduce clay-rich sediments which increase the mobility (runout behaviour) of a debris flow.
- The FSR ascending the Nicomen Earthflow intercepts the various drainage paths across the earthflow and feeds them, in part towards Devil's Creek, thereby concentrating flow in Devil's Creek. These ditches will likely fill during future rainstorms, making runoff pattern

less predictable. High runoff is likely to incise the road fill and add sediment to the debris flow.

- The current channel of Devil's Creek upstream of buildings on Nicomen 1 I.R. does not have sufficient capacity to transport post-wildfire debris flows within the confines of its channel and is likely to avulse.
- Debris flows could occur in the next heavy rainstorm or rain-on-snow event whose timing is unknown. While the exact debris-flow initiation threshold is not known, literature on post-wildfire debris flows suggests that it could be as little as the rainfall intensities associated with a 1-year or 2-year return period event[2]. Given that post-wildfire debris flows can be triggered at comparatively low rainfall intensities compared to non-wildfire related debris flows, the probability of a debris flow occurring in the next five years (during which time the effects of wildfire induced changes to the watershed hydrology are highest) is very high.
- Since debris flows can transport gravel, boulders and debris, the culverts underneath Nicomen River Road will almost certainly be blocked by debris flows and debris will spill over Nicomen River Road.
- Post-wildfire debris flows are expected to have sufficient intensity (velocity, depth and impact force) to pose life loss threat to people outside and inside of buildings and to damage or destroy culverts, roads, and buildings.
- Post-wildfire debris flows will travel downstream of Nicomen River Road via two gullies ("North Gully" and "South Gully"). Given the relative steepness of these features, debris flows are very likely to travel downstream to the Canadian Pacific Railway and Highway 1.

The rationale for the above interpretations will be described in greater detail in BGC's forthcoming geohazard report.

4.0 CONCLUSIONS

Post-wildfire debris flows may be of sufficient impact intensity to severely damage the buildings and result in life loss. Three residential buildings and the Band Office are particularly subject to potential destructive impact by post-wildfire debris flows (Figure 4-1). This translates into a high to very high relative risk[3] for three buildings adjacent to Devil's Creek. At the Nicomen Band office, which is in an area interpreted to be less susceptible to Devil's Creek debris flows due to being further away from the creek and at higher elevation, impact forces are interpreted to be lower, hence resulting in moderate to high risk.

[2] Staley, D.M., Kean, J.W., Rengers, F.K. (2020) The recurrence interval of post-fire debris-flow generating rainfall in the southwestern United States. Geomorphology 370. https://doi.org/10.1016/j./geomorph.2020.107392

[3] Definitions of risk ratings will be provided in BGC's complete geohazard report.

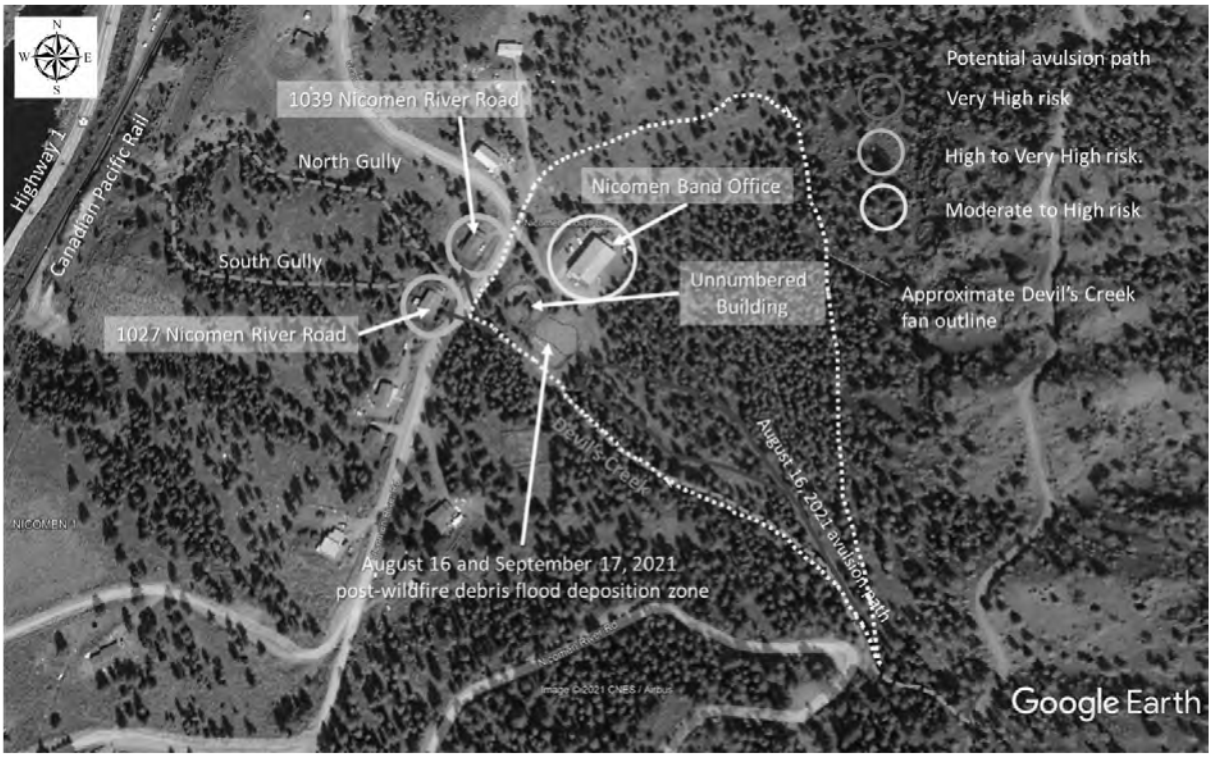


Figure 4-1. Lower Devil's Creek watershed with key infrastructures and exposed buildings on Nicomen 1 I.R. Base imagery: Google Earth, August 8, 2018.

5.0 RECOMMENDATIONS

Given the very high risk that three homes are subject to, BGC recommends that immediate steps are taken to reduce risk to the residents of those properties. Such risk reduction could be either through evacuations during time of inclement weather or by structural measures. The latter require time to conceptualize, engineering and construct. Hence, it may be favourable to implement a real-time weather forecast based system to notify and possibly evacuate residences when specific rainfall thresholds are exceeded.

Another option would be to provide temporary housing for the three properties at the highest risk of debris flow impacts until structural mitigation can be completed, or the watershed has recovered from the wildfire and poses a lesser risk.

6.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD). This letter contains BGC's opinions on the specific issues identified herein. BGC based its opinions and conclusions in this letter upon the information made available to BGC at the time of preparation of the letter, including that information provided to it by MFLNRORD. If local conditions change in any material respect, then MFLNRORD should engage BGC to re-evaluate BGC's opinions and conclusions in this letter. While preparing this letter, BGC exercised the prevailing level of care, skill, and diligence normally expected of a qualified professional performing similar services under comparable circumstances at the same or a similar location. BGC expressly disclaims all express or implied warranties in connection with this letter.

BGC suggests that MFLNRORD provide copies of this letter to relevant federal, provincial and local authorities having jurisdiction over the areas identified herein. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

Matthias Jakob, Ph.D., P.Geo., P.L. Eng.
Principal Geoscientist

Carie-Ann Lau, M.Sc., P.Geo.
Geoscientist

Reviewed by:

Joseph Gartner, Ph.D., P.Eng.
Senior Geotechnical Engineer

CAL/JG/mjp/mm

MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT
POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT

RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions.

FIRE: K61884 White Rock Lake	**FIRE YEAR**: 2021	**DATE OF REVIEW**: September 9 and 24, 2021 **DATE OF REPORT**: October 14, 2021

AUTHOR: Tim Giles, MSc, PGeo, Geoscientist, Westrek Geotechnical Services Ltd.

REPORT PREPARED FOR:

BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development ("The Ministry") – *Thompson Okanagan Region, Cascades, and Okanagan Shuswap Natural Resource Districts*

BC Wildfire Service – *Kamloops Fire Centre, Merritt, Vernon, and Penticton Fire Zones*

FIRE SIZE, LOCATION, AND LAND STATUS: The fire was approximately 83,342 hectares in size.

The Ministry-produced Natural Hazard Assessment map is attached for reference.

The land status is a mix of private, municipal, First Nations reserves, Provincial Parks and Crown land.

VALUES AT RISK:

Much of the White Rock fire was on the Thompson Plateau, encompassing a large part of the Salmon River watershed as well as reaching watersheds tributary to Okanagan Lake.

It advanced north into the community of Monte Lake and burned several residences. Around the Monte Lake area there are impacted slopes above residences and outbuildings, highways, other roads, and the CN Rail line.

On the western shore of Okanagan Lake, large areas of burned slopes exist above the residential communities of Ewing and Killiney Beach. Several small creeks pass through these communities as they enter Okanagan Lake and there is potential for elevated streamflow impacting the residential areas as well as Westside Road.

The watersheds of Whiteman-Bouleau, Naswhito and Equesis Creeks are all significantly burned and there is potential for elevated streamflow as a result of the wildfire. Large communities on the fluvial fans of these watersheds are potentially at risk from flooding.

WATERSHEDS AFFECTED:

South Thompson River - The White Rock Fire burned across much of the upper Salmon River watershed above Westwold which enters Shuswap Lake and the South Thompson River drainage. Small parts of the Monte and Paxton creek watersheds were also burned.

Nicola River – A small part of the upper Chapperon drainage was burned.

Okanagan Basin - on the east side of the fire, the watersheds of Irish, Newport, Bradley, Equesis, Naswhito and Whiteman-Bouleau Creeks were all extensively burned.

- Whiteman-Bouleau: 56% moderate and high burn severity
- Naswhito: 45% moderate and high burn severity
- Equesis: 21% moderate and high burn severity

BURN SEVERITY (map attached)

A burn severity map was compiled by Westrek Geotechnical Services Ltd. The vegetation burn severity map uses satellite images to estimate the change to vegetation canopy. For the White Rock Fire, the images compared were taken September 9, 2020, and September 24, 2021.

HAZARDS AND POTENTIAL RISKS ASSOCIATED WITH FIRE:	POST-FIRE HAZARD [1]	POST-FIRE RISK [2]
• A small portion of the Paxton Creek watershed burned north of Highway 97. Paxton Creek flows west through a culvert under Highway 97 into the Monte Creek system which flows north into the Thompson River. A mix of unburned, low, moderate, and high burn severities were observed within the watershed and the effects of the fire are expected to be incremental increases in sediment movement and channel degradation. The flow in the creek is expected to increase during spring freshet and after rainfall events. Landslides are not expected and any that do occur should be of limited size and only impact short reaches within the creek channel. Properties and structures along Paxton Creek may be impacted by increased flooding as a result of the fire.	Low for flooding along Paxton Creek Low for landslides within the Paxton Creek watershed	Low for flooding along Paxton Creek Low for landslides within the Paxton Creek watershed
• A small area of the Monte Creek watershed (not Monte Lake) burned south of Highway 97. A mix of unburned, low, moderate, and high burn severities were observed, and effects of the fire are expected to be incremental increases in sediment movement and channel degradation. Landslides are expected on the steeper slopes, but they should be of limited size and only impact short reaches within the creek channels. Properties and structures downstream of the fire on Monte Creek are unlikely to affected by the effects of the fire.	Low for flooding along Monte Creek	Low for flooding along Monte Creek
• The Salmon River watershed was extensively burned upstream from the Highway 97 corridor at Westwold. Numerous smaller watersheds, including, Rush, Goodwin, Cain, Weyman, Random, Ingram and Twig Creeks were heavily impacted. It is anticipated that the effects of the fire might be noticed during the next 2 or 3 spring freshets as snowmelt occurs earlier and freshet flows may be flashier. Increased sedimentation is expected along these creeks which may cause increased degradation of the channels. Landslides are expected but will be limited to steep-sided valley-sidewall events which will impact relatively short reaches within the creek channels. Properties and structures along the lower Salmon River (as far downstream as Westwold) may be impacted by flooding as a result of the fire.	Low for flooding on Salmon River Low for landslides within the Salmon River watershed	Low for flooding on Salmon River Low for landslides within the Salmon River watershed
• Monte Lake drains into the Salmon River watershed west of Westwold. On the south side of the lake are numerous creek draws which were extensively burned at moderate to high burn severities. One small erosional sedimentation event was observed on the south side of Monte Lake during the overview flight. There was no clear initiation landslide and it appeared that the event was primarily sediment-laden streamflow. The majority of sediment was deposited above the CN Rail line, but water did reach the tracks. Drainages on the south side of the lake are expected to see further small erosional sedimentation events. Above Highway 97 on the north side of the lake are numerous small creek draws which were extensively burned at moderate to high burn severities. These creek draws are expected to respond rapidly to rainfall events, and nuisance sedimentation events are expected to impact the highway. Properties and structures on both sides of Monte Lake may be impacted by nuisance sedimentation and overland flows as a result of the fire.	Moderate for flooding around Monte Lake High for landslides around Monte Lake	Moderate for flooding around Monte Lake High for landslides around Monte Lake

• A small portion of the northeastern headwaters of the Chapperon Creek watershed was burned and there was a mix of unburned, low, moderate burn severities. The watershed was extensively harvested prior to the fire. Effects of the fire are expected to be incremental increases in sediment movement and channel degradation. Landslides are not expected and any that do occur should be of limited size and only impact short reaches within the creek channels.	Low for flooding on Chapperon Creek	Low for flooding on Chapperon Creek
• The small watersheds of Newport and Bradley Creeks and the face units beside them were extensively burned. They are expected to have increased streamflow and associated sedimentation. Sediment aggradation may occur in the creek channels on the alluvial fan surfaces. This may cause overbank flooding and potential migration of the channel appears possible across much of the very gently sloped, lower fan surfaces. Numerous residences are present along the shoreline of Okanagan Lake below Newport Creek, some of which could be inundated if the main creek migrated laterally across the lower fan surface.	High for flooding on the Newport and Bradley Creek fans	High for flooding on the Newport and Bradley Creek fans
• Several west-flowing tributary drainages in the Irish Creek watershed were burned. These creek draws are expected to respond to rainfall events with increased streamflow and associated sedimentation. These nuisance sedimentation events may impact properties and structures on the upper floodplain of Irish Creek which has been developed primarily for agricultural use	Moderate for flooding on upper Irish Creek	Moderate for flooding on upper Irish Creek
• Around 32% of the Equesis Creek watershed was burned, but of the areas that burned 65% were moderate or high burn severity. The Equesis Creek fan did not burn during the wildfire. McGregor and Musgrave creeks were both extensively and severely burned and are expected to have increased streamflow and sedimentation. The upstream floodplain of Equesis Creek has been developed for agricultural use with numerous residences present. The increased streamflow and sediment movement along upper Equesis Creek has the potential to cause overbank flooding along the upper creek. Downstream from the wide floodplain reach the creek has a narrower incised channel down to the large coalescent fluvial fan which it shares with Naswhito Creek. From the fan apex down to Westside Road, there are several residential structures adjacent to the creek. The creek is constricted at Westside Road where passes it through an arch culvert onto the lower fan surface. Downstream of the highway, at least two water diversions for agricultural irrigation purposes are visible. Increases in sediment transport from the upper watershed and delivery to the fan is expected. Sediment aggradation in the creek on the fan surface may cause overbank flooding and potential migration of the main channel appears possible across much of the very gently sloped, lower fan surface. Numerous residences are present along the shoreline of Okanagan Lake, some of which could be inundated if the main creek migrated laterally across the lower fan surface.	Moderate for flooding on the Equesis Creek fan Moderate for landslides in the tributary watersheds.	Moderate for flooding on the Equesis Creek fan Moderate for landslides in the tributary watersheds.
• The Naswhito Creek watershed had a mix of unburned, low, moderate, and high burn severity patches (45% moderate and high); the fluvial fan was partially burned during the fire. The creek follows a confined valley down to the apex of the large coalescent fluvial fan	Moderate for flooding on the Naswhito Creek fan	Moderate for flooding on the Naswhito Creek fan

it shares with Equesis Creek. Upstream of the fan apex there is no development along the tight valley floodplain. There are a few residences upstream of Westside Road on the upper fan surface. At Westside Road, the creek passes through an arched culvert and then crosses undeveloped agricultural land before entering Okanagan Lake through a narrow outlet with residences on both sides of the channel. It is expected that there will be a minor increase in streamflow and sediments delivered to the apex of the fan. Minor sediment aggradation in the creek on the fan surface has the potential to cause some overbank flooding.		
• The Whiteman-Bouleau Creek watersheds had high burn severities along the deeply incised, steep-sided valleys leading to the plateau surface (56% moderate and high). The creeks join once they leave the hills and the lower 6 km passes through a confined valley with several private land parcels, some with what appear to be residential structures. The Whiteman-Bouleau fan is a large, low gradient fluvial fan which has been extensively developed for residential and recreational use; the fan was not burned during the wildfire. The creek passes under a bridge on Westside Road in a confined channel. A residential area exists on the north bank of the creek downstream of the highway and numerous residences are present along the shoreline of Okanagan Lake. It is expected that there will be a significant increase in streamflow and sediments delivered to the apex of the fan above the highway. Sediment aggradation in the creek on the fan surface may cause rapid overbank flooding and potentially lateral migration of the creek could occur across much of the gently sloped lower fan surface.	High for flooding on lower Whiteman Creek and on the Whiteman Creek fan High for landslides in the tributary watersheds	High for flooding on lower Whiteman Creek and on the Whiteman Creek fan High for landslides in the tributary watersheds
• The Killiney Beach area (Westside Road between Morden Creek to Sugar Loaf FSR) was extensively burned, and numerous residences were destroyed. Topographic maps indicate that there are several small watersheds which drain through the residential areas. There is an expected increase in surface flows through the creeks leading through the residences and into Okanagan Lake. Properties and structures in the Killiney Beach area may be impacted by nuisance sedimentation and overland flows as a result of the fire.	High for flooding + landslides in the Killiney Beach area	High for flooding + landslides in the Killiney Beach area
1. Hazard = P(H), the probability of occurrence of a hazardous event. It does not address the natural or pre-fire hazard that may already have existed. *2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk*		

FURTHER ACTIONS:

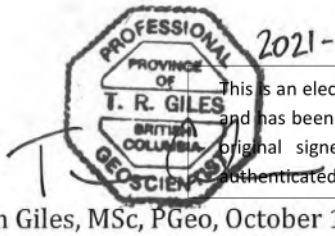
Post-wildfire assessments are recommended for several areas of the White Rock wildfire to assess the potential impacts that the wildfire has had on the natural hazards and to present potential options that the stakeholder can consider for mitigating their risk. Specific sites are:

- Paxton Creek – MOTI are recommended to review their drainage structures along Paxton and North Paxton Creeks upstream from Highway 97.
- Monte Lake – MOTI are recommended to review ditch lines and culverts on Highway 97 between the Paxton Valley Road and the CN Rail track crossing east of Monte Lake. Residents around Monte Lake should also be warned of the increased potential for nuisance sedimentation and overland flows as a result of the fire.
- A watershed review of the Newport, Bradley and Irish Creek watersheds. This review should include an understanding of the potential impacts to the Newport and Bradley Creek fluvial fans of the increase in streamflow and sedimentation from the upper watersheds. A review of the west-facing tributary creeks in

the Irish Creek watershed should determine the potential impact of increased streamflow and sedimentation to the properties in upper Irish Creek watershed.

- A watershed review of the Whiteman (and Bouleau) Creek watersheds and the fluvial fan. This review should include an understanding of the potential impacts to the creeks of the increase in streamflow and sedimentation from the upper watershed down to Okanagan Lake.
- A watershed review of the Equesis and Naswhito Creek watersheds and their coalescent fluvial fan. This review should include an understanding of the potential impacts to the creeks of the increase in streamflow and sedimentation from the upper watershed down to Okanagan Lake.
- A review of the drainages in the Killiney Beach area. This review should include the area upslope to the height of land from Morden Creek in the south to the start of the Sugar Loaf Forest Service Road in the north.
- CN Rail should independently assess all of their infrastructure within the fire perimeter.

SIGNATURE:



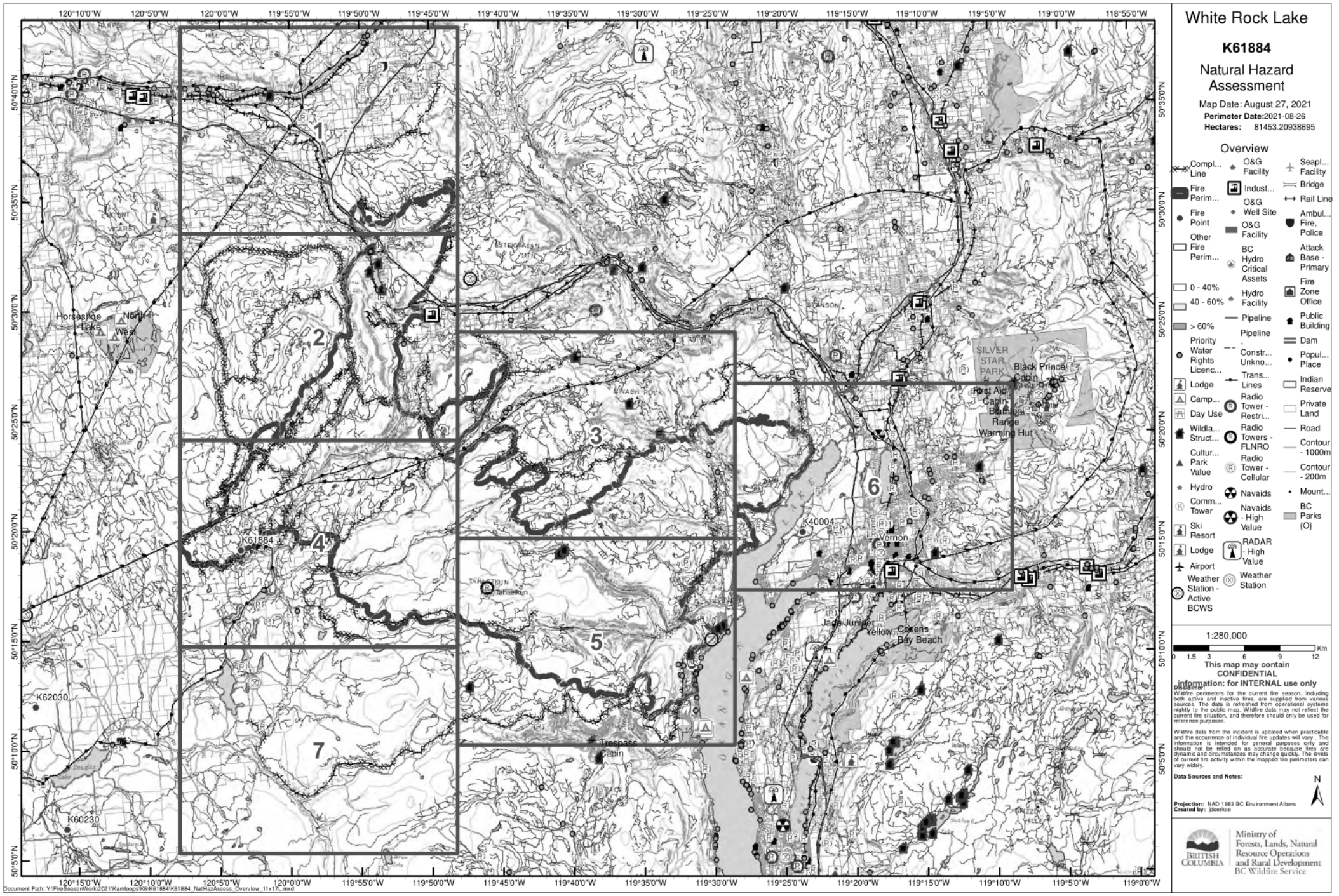
2021-10-14

Tim Giles, MSc, PGeo, October 14, 2021
Senior Geoscientist

Westrek Geotechnical Services Ltd.
Permit to Practice Number: 1002522

ATTACHMENTS:

K61884 White Rock Lake Natural Hazard Assessment Map
K61884 White Rock Lake Vegetation Burn Severity Map


White Rock Lake
K61884
Natural Hazard Assessment
Map Date: August 27, 2021
Perimeter Date:2021-08-26
Hectares: 81453.20938695
Overview
1:280,000
0 1.5 3 6 9 12 Km
This map may contain CONFIDENTIAL information: for INTERNAL use only
Disclaimer:
Wildfire perimeters for the current fire season, including both active and inactive fires, are supplied from various sources. The data is refreshed from operational systems nightly to the public map. Wildfire data may not reflect the current fire situation, and therefore should only be used for reference purposes.
Wildfire data from the incident is updated when practicable and the occurrence of individual fire updates will vary. The information is intended for general purposes only and should not be relied on as accurate because fires are dynamic and circumstances may change quickly. The levels of current fire activity within the mapped fire perimeters can vary widely.
Data Sources and Notes:
Projection: NAD 1983 BC Environment Albers
Created by: jdoerkse
N
Ministry of Forests, Lands, Natural Resource Operations and Rural Development
BC Wildfire Service
Horseshoe Lake
North West
SILVER STAR PARK
Black Prince Cabin
First Aid Cabin
Biathlon Range Warming Hut
Vernon
Tahaetkun
Jade Juniper
Yellow Cosens Bay Beach
Trespass Cabin
K61884
K40004
K62030
K60230
1
2
3
4
5
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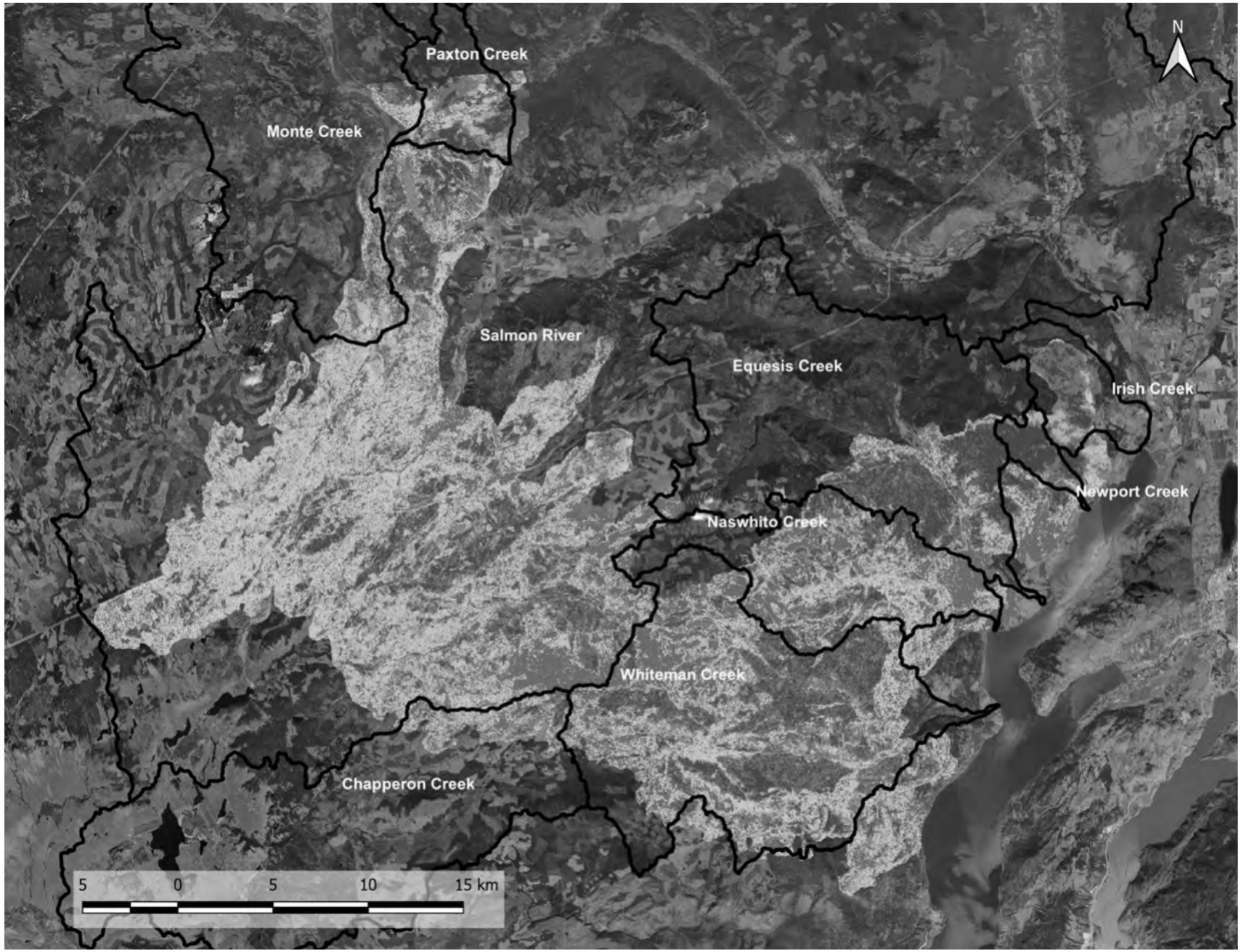

WHITE ROCK LAKE
K61884

Burn Severity Map for Natural Hazard Assessments
1 : 180 000

Fire Boundary

Burn Severity 2021
(Year-Over-Year Classification)*

<= -550	UNKNOWN
-550 - 99	UNBURNED
99 - 269	LOW BURN
269 - 439	MOD-LOW BURN
439 - 660	MOD-HIGH BURN
> 660	HIGH BURN

This burn severity mapping is created using a Differenced Normalized Burn Ratio (dNBR) calculation on pre- and post-fire imagery as described by Key and Benson, 2006. The map is classified into five burned area reflectance classification (BARC) categories. Default breakpoints for burn severity classifications are used for all timber types across BC and therefore may not accurately reflect the forest type or field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CAN CONTAIN SMOKE AND/OR CLOUDS WHICH COULD ADVERSELY AFFECT THE BURN SEVERITY ANALYSIS*. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESSMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

*"Year-over-Year classification", means that the burn severity mapping was done using satellite scenes approximately (as close to) a year apart to capture similar vegetation and moisture levels.

Data Sources:
Pre-fire scene: Sept 09, 2020; Modified Copernicus Sentinel data [2021]/Sentinel Hub
Post-fire scene: Sept 24, 2021; Modified Copernicus Sentinel data [2021]/Sentinel Hub

Map produced by: JSchafer, 2021
Coor System: NAD 1983 BC Environment Albers

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Figure 1

MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT
POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT

RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions.

FIRE: K70804 George Road	**FIRE YEAR**: 2021	**DATE OF REVIEW**: September 2 and 28, 2021 **DATE OF REPORT**: October 25, 2021

AUTHOR: Tim Giles, MSc, PGeo, Geoscientist, Westrek Geotechnical Services Ltd.

REPORT PREPARED FOR:
BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development ("The Ministry") –
Thompson Okanagan Region and Cascades Natural Resource District
BC Wildfire Service – *Kamloops Fire Centre, Merritt Fire Zone*

FIRE SIZE, LOCATION, AND LAND STATUS: The fire was approximately 5,017 hectares in size. The Ministry-produced Natural Hazard Assessment map is attached for reference. The land status is a mix of First Nations reserves, private land and Crown land.

VALUES AT RISK:
The George Road Fire burned from the Fraser River upslope over several watersheds south of Lytton. The southern boundary is located on the south slopes of the Siska Creek watershed. The northern boundary is located roughly along Lytton Creek.

The watersheds of Siska, Skuppa, George, Saw and Lytton Creeks have creeks leading down through residential areas, the Trans Canada Highway #1 (TCH), the Canadian Pacific rail line and into the Fraser River. Skuppa, George and Saw Creek are smaller watersheds and their creeks are much shorter and steeper. Numerous other small face units with very small creeks exist between the named creeks.

WATERSHEDS AFFECTED:

Siska Creek – a large watershed (7090 ha) with a moderately sloped upland area, which drains through a narrow bedrock-controlled canyon directly into the Fraser River.

South Skuppa Creek –a short, steep watershed (366 ha), which joins North Skuppa Creek just above the CP Rail tracks.

North Skuppa Creek – a short, steep watershed (120 ha), which joins South Skuppa Creek just above the CP Rail tracks.

George Creek – a small watershed (511 ha) with a moderately steeply sloped upland, which has cut a deep and steep bedrock canyon.

Saw Creek – a small (117 ha) but long and thin, face unit watershed.

Lytton Creek – a larger watershed (1062 ha) with a moderately sloped upland area, which drains through a bedrock-controlled canyon onto a moderately sloped lower bench.

BURN SEVERITY (map attached)

A burn severity map was compiled by Westrek Geotechnical Services Ltd. The vegetation burn severity map uses satellite images to estimate the change to vegetation canopy. For the George Road Fire, the images compared were taken September 9, 2020, and September 7, 2021.

SUMMARY OF HAZARDS AND POTENTIAL RISKS ASSOCIATED WITH FIRE:	POST-FIRE HAZARD [1]	POST-FIRE RISK [2]
<u>Siska Creek</u> – A large portion of the upper watershed burned at a moderate or high vegetation burn severity. Several sidewall failures were observed along the lower creek valley. This creek passes under the TCH and the CP rail tracks in a tunnel excavated through rock. The diameter of the tunnel is estimated to be at least 4 m. There are no residences or other structures within the watershed; the TCH and the CP Rail tracks are the only two elements at risk. It is expected that this watershed will see a marked increase in streamflow as a result of the fire. This will also lead to increased volumes of sediment and large woody debris moving through the channel. It is recommended that the Ministry of Transportation and Infrastructure (MOTI) complete periodic reviews and appropriate maintenance of the inlet to the Siska Creek tunnel under the TCH, beginning in the fall of 2021, and at least annually thereafter.	High for flood Low for debris flow	**Moderate risk to tunnel**
<u>South Skuppa Creek</u> – Much of this watershed has a moderate or high vegetation burn severity rating. The watershed has a steep upper channel (over 50% gradient) leading down to a long moderately sloped bench (around 20% gradient) above the TCH. The majority of the tributary watersheds on the south side of the watershed were burned at moderate to high vegetation burn severities. Watershed morphometrics indicate that the expected geomorphic process in this watershed is a debris flow. The upper watershed is bedrock controlled with large talus accumulations and there is no clear channel. A defined continuous channel with flow was first observed downslope of the talus slope, around 550 m elevation. From there down, the creek was confined in a broad valley until it reached the TCH at 270 m elevation. There were no signs of debris flows or debris floods within the creek draw below 600 m elevation. The creek is small (<1.5 m wide) and has cobble-step pool morphology at lower gradients and boulder-step pool morphology where the gradients are over 20%. The south tributary creeks are slightly steeper than the main stem, but they plateau on a mid-slope bench. This creek passes under the TCH through a 650 mm perforated, vertical drop structure, which flows into a horizontal culvert. An increase in streamflow is expected through South Skuppa Creek, primarily from the southern tributaries. This increase is expected to transport more sediment down to the TCH drainage structures. Increased maintenance of the vertical drop structure and inlet sump is recommended. Cleanout of the sediment basin above the TCH might be required in the first 3-5 years after the fire.	Moderate for flood Low for debris flow	**Moderate risk to TCH drainage structures**
<u>North Skuppa Creek</u> – Two elevation bands were burned at moderate to high vegetation burn severity: a portion of the upper watershed (over 1400 m elevation) and one mid-slope (approximately between 500 and 800 m elevation). The watershed has a steep upper channel (over 50% gradient) leading down to a long, moderately sloped bench (around 20-25% gradient) above the TCH. Watershed morphometrics indicate that the expected hydrogeomorphic process in this watershed is a debris flow. The upper watershed is bedrock controlled with thick talus accumulations and no clear channel. A defined continuous channel with flow was first observed downslope of the talus slope, around 575 m elevation. Downslope, the creek is confined in a broad valley until it reaches the TCH at 270 m elevation. There were no signs of debris flows or debris floods within the creek draw below 600 m elevation. The creek is narrow (<1m wide) and has cobble-step pool morphology. This creek crosses the TCH through a 450 mm culvert. No flow was observed at the	Moderate for flood Low for debris flow	**Moderate risk to TCH drainage structures**

culvert, but minor sediment accumulation was observed in the inlet sump. The culvert outlet has a rust line (at <5% capacity), which indicates flow does pass through the culvert. A slight increase in streamflow is expected through North Skuppa Creek, which is expected to transport more sediment down to the TCH culvert; increased maintenance of the inlet sump and culvert is recommended. **<u>George Creek</u>** – Two thirds of this watershed is unburned or has a low vegetation burn severity rating. One small tributary on the upper plateau was burned at a high vegetation burn severity. This watershed has a moderately sloped upper channel (average 28% gradient) leading down to a short, steep reach across bedrock (average 47%) onto a long, moderately sloped bench (around 22% gradient) above the TCH. The watershed morphometrics indicate that the expected hydrogeomorphic process in this watershed is a debris flow. On the plateau, the watershed has several tributary streams, which feed into a bedrock-controlled channel with thick talus accumulations. A well-defined 3-4 m wide boulder-step pool channel was observed near the water intake system, which is located on the moderately sloped bench (around 350 m elevation). There were no signs of debris flows or debris floods within the creek draw. George Road, which is the highest crossing on the creek, has a 1200 mm culvert. Under the TCH, this creek enters a 950 mm, perforated vertical drop structure, which flows into a horizontal culvert. A sediment trap and screen with a flume is located on the creek above the inlet. No flow was observed at the time of the field investigation, but sediment accumulation in the trap indicates that there is potential for movement through the creek. A slight increase in streamflow is expected through George Creek. This increase is expected to transport more sediment down to the George Creek water intake, the George Road culvert and the TCH drainage structures. Increased maintenance of the George Road culvert and the TCH sediment trap, flume and vertical drop structure is recommended. Cleanout of the sediment basin at the TCH might be required in the first 3-5 years after the fire. The owners/operators of the George Creek water system should be advised that increased streamflow and associated sedimentation is likely for the next few years and they should develop strategies to manage this appropriately. **<u>Saw Creek</u>** – The upper reaches of this watershed have a moderate to high vegetation burn severity rating. The watershed has a steep upper channel (over 55% gradient) leading down to a long, moderately sloped bench (around 20% gradient) above the TCH. The watershed morphometrics indicate that the expected hydrogeomorphic process in this watershed is a debris flow. The upper watershed is bedrock controlled with very steep bedrock cliffs and chutes leading down to a thick talus accumulation at the transition between the steeper and gentler slopes (around 520 m elevation). A broad draw (over 100 m wide and having an average slope around 20%) runs across the bench and has numerous small debris flow tracks running through it. Well defined, steep-sided flow paths with clear marginal levees were observed above 350 m elevation. An old road or fireguard cuts across the draw and deflects flows northwards. Downslope of the old road, the flows are less linear and deposits appear to be more waterborne than gravity driven. Sediment splays and sediment wedges behind log jams are common to about 300 m elevation. From there down to the TCH (at 270 m elevation), there are several small, incised ephemeral channels, which come together where they intersect an	Moderate for flood Low for debris flow High for flood High for debris flow	**Moderate risk to George Road and TCH drainage structures** **Low risk to George Creek water system** **High risk to TCH drainage structures**

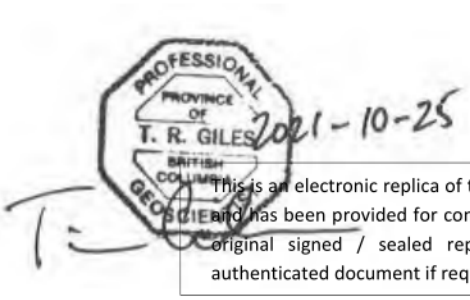
old access trail and eventually reach the TCH. An increase in streamflow is also expected through Saw Creek. This increase is expected to transport more sediment down to the TCH. There is no culvert presently installed where the creek reaches the TCH. Approximately 100 m south of where Saw Creek reaches the TCH, a 450 mm culvert passes under the TCH; this culvert is believed to be upslope, so none of the Saw Creek drainage reaches this culvert. It is recommended that MOTI review the drainage where Saw Creek intersects the Trans Canada Highway and, if appropriate, install a culvert. Cleanout of the ditch-line at the TCH might be required in the first 3-5 years after the fire. **<u>Lytton Creek</u>** – Lytton Creek is a water source for the Village of Lytton. Around 40% of the watershed burned at moderate or high vegetation burn severity. Most of this occurred in the upper areas of the watershed above 1150 m elevation. The upper south-facing slopes are lightly treed and covered in thick coalescent talus cones, which reach down to the valley floodplain and through which the creek flows. The lower reaches of the creek are deeply incised into a post-glacial, sand and gravel glaciofluvial bench and the creek has developed a broad valley leading down to the Fraser River. The watershed morphometrics indicate that the expected hydrogeomorphic process in this watershed is a debris flood. The creek has a very consistent gradient between 15 and 25% from the upper watershed to the Fraser River. Lytton Creek has numerous structures along its path into the Fraser River. The most upstream structure is a water intake dam and pond. The creek then passes: • under Loring Way in two culverts (1200 and 1300 mm), • ~60 m under the TCH through an oval 2300 mm (horizontal) by 2700 mm (vertical) culvert, • ~40 m under Highway 12 (Main Street) in a 2200 mm culvert, • ~100 m under the CP Rail track through a rectangular concrete box culvert, 1000 mm (horizontal) and 2000 mm (vertical) at the inlet, and out under the Environment Canada access road through a 1200 mm culvert, • under the upper section of River Road through two 1200 mm culverts, • ~45 m under the CN Rail track in an 1800 x 1800 mm concrete box culvert, and • under the lower section of River Road through a 2300 mm (horizontal) by 2000 mm (vertical) culvert. Lytton Creek then enters the Fraser River. The most limiting structure is the CP Rail-Environment Canada access road tunnel-culvert combination. How the rectangular concrete box culvert connects to the round metal culvert is unknown. An increase in streamflow is expected through Lytton Creek and has the potential to initiate debris floods, which may impact infrastructure. The water system already experiences high levels of turbidity during spring freshet and this will likely increase as a result of the fire. Increased maintenance of the water intake infrastructure and the numerous culverts on Lytton Creek is recommended. *1. Hazard = P(H), the probability of occurrence of a hazardous event. It does not address the natural or pre-fire hazard that may already have existed.* *2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk*	Moderate for flood Low for debris flow	**Moderate risk to numerous road and rail structures** **Moderate risk to Lytton Creek water system**

FURTHER ACTIONS:

Increased maintenance of the drainage structures on the Trans Canada Highway below the George Road Fire is recommended. This includes

- Siska Creek – It is recommended that MOTI and CP Rail evaluate the capacity and resiliency of the tunnel. It is recommended that MOTI and CP Rail complete periodic reviews and appropriate maintenance of the inlet to the Siska Creek tunnel, beginning in the fall of 2021, and at least annually thereafter.
- South Skuppa Creek – It is recommended that MOTI evaluate capacity and resiliency of the inlet sump and vertical drop structure. Cleanout of the sediment basin above the TCH might be required in the first 3-5 years after the fire.
- North Skuppa Creek – It is recommended that MOTI maintain the inlet sump and culvert.
- George Creek – It is recommended that MOTI maintain the George Road culvert and the TCH sediment trap, flume and vertical drop structure. Cleanout of the sediment basin at the TCH might be required in the first 3-5 years after the fire. The owners/operators of the George Creek water system should be advised that increased streamflow and associated sedimentation is likely for the next few years and they should develop strategies to manage this appropriately.
- Saw Creek – It is recommended that MOTI review the drainage where Saw Creek intersects the Trans Canada Highway and, if appropriate, install a culvert. Cleanout of the ditch-line at the TCH might be required in the first 3-5 years after the fire. A further evaluation of the debris flow risk in Saw Creek should be completed. Collection of lidar mapping is recommended to help guide evaluation of this watershed as well as the reminder of the slope between Siska and Lytton Creeks.
- Lytton Creek – It is recommended that MOTI and/or the Village of Lytton evaluate and maintain or improve the numerous culverts on Loring Way, the TCH, Main Street and River Road. CP Rail and CN Rail should inspect and maintain the concrete box culverts under their infrastructure. The owners/operators of the Lytton Creek water system should be advised that increased streamflow and associated sedimentation is likely for the next few years and they should develop strategies to manage this appropriately.

SIGNATURE:



Tim Giles, MSc, PGeo, October 25, 2021
Senior Geoscientist

Westrek Geotechnical Services Ltd.
Permit to Practice Number: 1002522

ATTACHMENTS:

K70804 George Road - Selected Site Photographs
K70804 George Road - Natural Hazard Assessment Map
K70804 George Road - Vegetation Burn Severity Map

Photo 1 *– View looking south of moderate to high vegetation burn severity along the lower Siska Creek watershed just above the Trans Canada Highway. Note the sidewall failures on the south side of the creek valley.*

Photo 2 *– View of North and South Skuppa Creeks, outlined left and right respectively. The upper watershed areas have moderate to high vegetation burn severities; the lower watershed is mostly unburned.*

Photo 3 *– View of George Creek watershed (outlined). The watershed has mostly low to moderate vegetation burn severities. The water system intake is close to the blue roofed building (circled) in the centre of the image.*

Photo 4 *– View of the Saw Creek watershed (outlined). The upper watershed above the steep chutes has moderate to high vegetation burn severity; the remainder of the watershed is a mix of unburned and low vegetation burn severity. The broad active debris flow draw can be seen leading down towards the Trans Canada Highway.*

Photo 5 *– View looking down mid-Lytton Creek towards the Fraser River. Coarse talus deposits on the south-facing slopes (right) reach the valley floodplain.*

Photo 6 *– View looking up Lytton Creek. The Village of Lytton water system buildings (circled) are at the end of the road on the north (left) side of the creek. Loring Way crosses the creek at lower right.*

westrek geotechnical services ltd.	Project No: 021-155 Date: October 22, 2021	**MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT**	**K70804 GEORGE ROAD FIRE POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT**	**SELECTED SITE PHOTOGRAPHS**

Photo 7 – *View of the lower end of Lytton Creek. Image includes the Fraser River at the bottom, the six road crossings and two rail crossings.*

Photo 8 – *View of South Skuppa Creek around 475 m elevation. Note the coarse rubbly nature of the ground, predominantly glaciofluvial gravels at this location but transitioning into colluvial deposits upslope.*

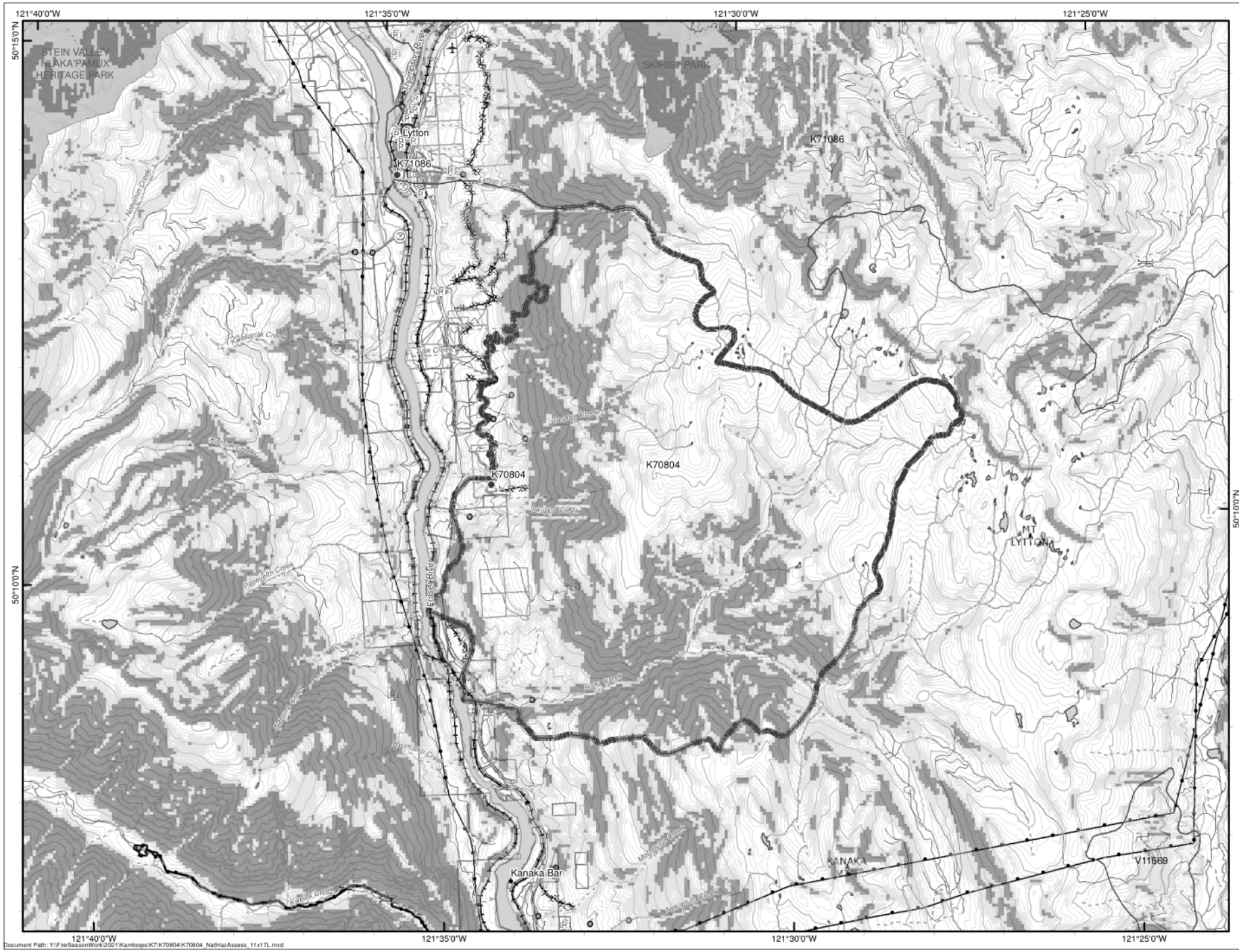
Photo 9 – *View of North Skuppa Creek around 525 m elevation. The creek has incised into the coarse angular rubbly talus deposits which fill the broad valley of North Skuppa Creek.*

Photo 10 – *Looking downstream on George Creek at around 375 m elevation. The water system buildings are located approximately 50 m to the north (to the right of image). The creek is an open boulder-step pool with limited wood framework.*

Photo 11 – *View of debris flow track with 2-3 m high levees on the margins in the broad draw that defines mid-Saw Creek around 350 m elevation. Trees growing on the levee tops are even aged and approximately 10-12 years old. No streamflow was observed at the time of inspection.*

Photo 12 – *Log jam, sediment lobes and distributary splays of sediment in the broad draw of Saw Creek, approximately 325 m elevation. Small creek channels develop downstream of where the sediment lobes and splays deposit.*

westrek geotechnical services ltd.	Project No: 021-155 Date: October 22, 2021	**MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT**	**K70804 GEORGE ROAD FIRE POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT**	**SELECTED SITE PHOTOGRAPHS**



George Road

K70804

Natural Hazard Assessment

Map Date: August 27, 2021
Perimeter Date: 2021-08-21
Hectares: 5017.1374992

Page of

- Completed Line
- Fire Perimeter
- Fire Point
- Other Fire Perimeters

Slope

- 0 - 40%
- 40 - 60%
- > 60%

- Priority Water Rights Licences
- Transmission Lines
- Penstock
- Weather Station
- Weather Station
- Radio Tower - Restricted
- Radio Tower
- RadioTower - Broadband/Wire...
- Radio Tower - Cellular
- Radio Tower
- Radio Tower
- Airstrip or Other Facility
- Bridge
- Rail Line
- Station
- Ambulance, Fire, Police
- Attack Base - Primary
- Public Building
- Populated Place
- Indian Reserve
- Private Land
- Road
- Road
- Contour - 100m
- Contour - 20m
- Mountain
- BC Parks (O)

N

1:60,000

0 0.3 0.6 1.2 1.8 2.4 Km

This map may contain CONFIDENTIAL information: for INTERNAL use only

Disclaimer:
Wildfire perimeters for the current fire season, including both active and inactive fires, are supplied from various sources. The data is refreshed from operational systems nightly to the public map. Wildfire data may not reflect the current fire situation, and therefore should only be used for reference purposes.

Wildfire data from the incident is updated when practicable and the occurrence of individual fire updates will vary . The information is intended for general purposes only and should not be relied on as accurate because fires are dynamic and circumstances may change quickly. The levels of current fire activity within the mapped fire perimeters can vary widely.

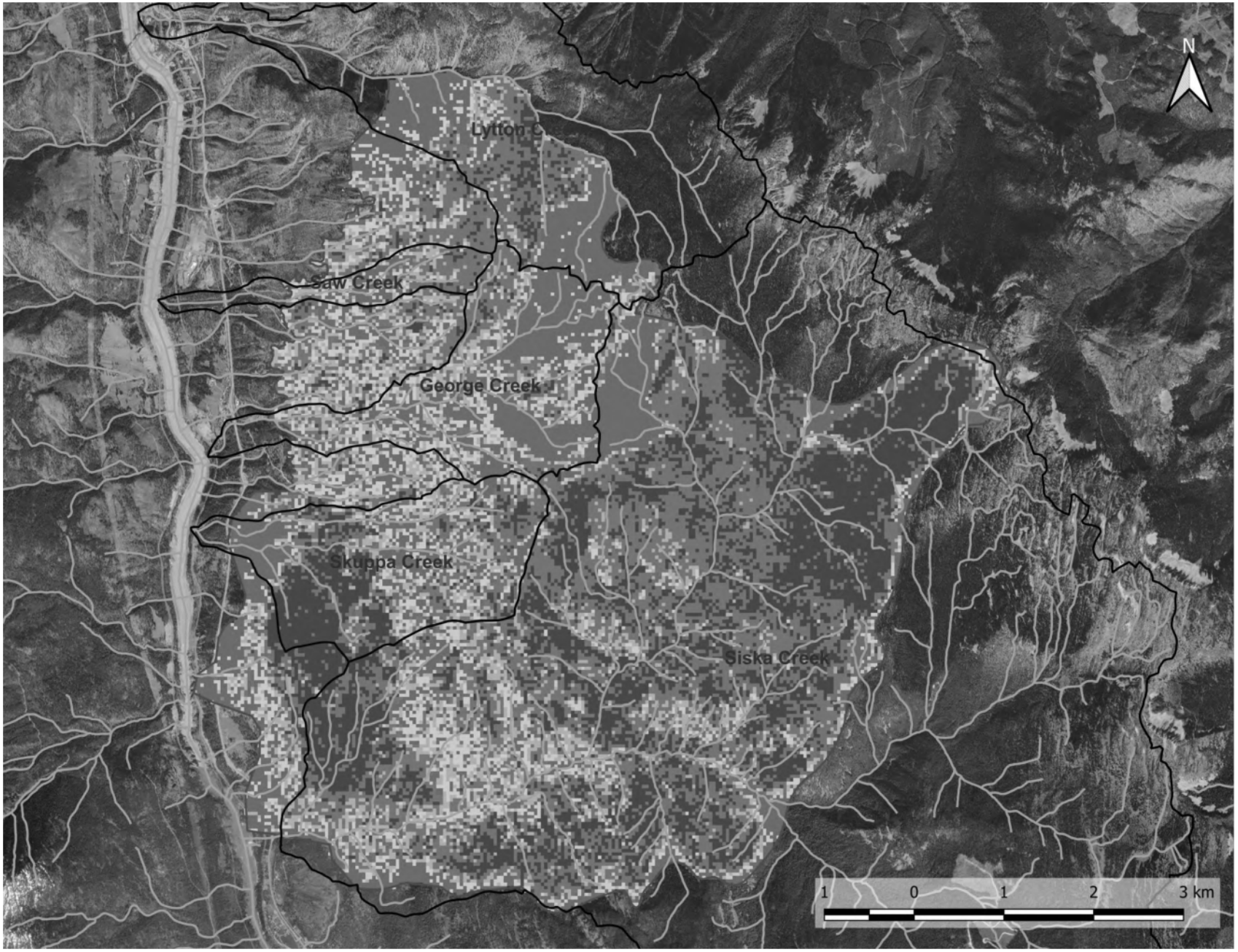
Data Sources and Notes:

Projection: NAD 1983 BC Environment Albers
Created by: jdoerkse

BRITISH COLUMBIA

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

Document Path: Y:\FireSeasonWork\2021\Kamloops\K7\K70804\K70804_NatHazAssess_11x17L.mxd



GEORGE ROAD
K70804

Burn Severity Map for Natural Hazard Assessments
1 : 40 000

Fire Boundary

Burn Severity 2021
(Year-Over-Year Classification)*

<= -550	UNKNOWN
-550 - 99	UNBURNED
99 - 269	LOW BURN
269 - 439	MOD-LOW BURN
439 - 660	MOD-HIGH BURN
> 660	HIGH BURN

This burn severity mapping is created using a Differenced Normalized Burn Ratio (dNBR) calculation on pre- and post-fire imagery as described by Key and Benson, 2006. The map is classified into five burned area reflectance classification (BARC) categories. Default breakpoints for burn severity classifications are used for all timber types across BC and therefore may not accurately reflect the forest type or field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CAN CONTAIN SMOKE AND/OR CLOUDS WHICH COULD ADVERSELY AFFECT THE BURN SEVERITY ANALYSIS*. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESSMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

*"Year-over-Year classification", means that the burn severity mapping was done using satellite scenes approximately (as close to) a year apart to capture similar vegetation and moisture levels.

Data Sources:
Pre-fire scene: Sept 09, 2020; Modified Copernicus Sentinel data [2021]/Sentinel Hub
Post-fire scene: Sept 07, 2021; Modified Copernicus Sentinel data [2021]/Sentinel Hub

Map produced by: JSchafer, 2021
Coor System: NAD 1983 BC Environment Albers

westrek
geotechnical services ltd.
100 -1383 McGill Road, Kamloops, BC V2C 6K7
Tel: 778-765-9525

Figure 1

polargeoscience ltd.

TECHNICAL MEMORANDUM

To:	**Trevor Bohay**, PGeo, Director of Special Projects, BC FLNRORD **Andy Oetter**, Post Wildfire Natural Hazards Assessment, BC FLNRORD	**Date:**	November 3, 2021
Cc:		**Polar File:**	850701
From:	**Lars Uunila**, PGeo & **Robbie Johnson**	**Client File:**	

Re:	**Preliminary Findings: Field review of Hydrologic Impact Following the Sparks Lake Wildfire in the Deadman River Watershed**

Hi Trevor and Andy,
This memo briefly documents preliminary findings following a field review of the hydrologic risks of the Sparks Lake Wildfire in the Deadman River watershed. These notes are provided as in interim deliverable for consideration prior to our office analysis and reporting, and should be considered preliminary and are subject to revision.

Field review
Between October 19 and 22, 2021 Polar Geoscience Ltd. (Polar) conducted a field review to assess hydrologic hazards following the Sparks Lake Wildfire (K21001) in the Deadman River watershed. On October 19, 2021, Lars Uunila and Robbie Johnson of Polar and Mike Anderson of the Skeetchestn Natural Resources Corporation, flew the burned area of the watershed by helicopter. Due to a low cloud ceiling, the helicopter reconnaissance was limited to the lower portions of the watershed, generally below the plateau (i.e., below elevations of approximately 1,000 m). On October 20 through 22, 2021, a ground review was conducted by Lars Uunila and/or Robbie Johnson in order to assess the extent and severity of the wildfire effects on the hydrology across the Deadman River watershed. In addition, the review provided the opportunity to identify and review key watershed values that may be at increased risk to flooding and erosion following the wildfire. On the morning of October 21, 2021, Robbie Johnson and Mike Anderson focussed further review on properties and areas of flooding and/or erosion concern to the Skeetchestn Band.

Burn severity and wildfire observations
Supplementary to this memo is an attached PDF illustrating the burn severity of the Sparks Lake Wildfire, however, during our field review we noted the following:

<u>Deadman River</u>

- From 8 km upstream of the mouth of Deadman River to 4 km south of Mowich Lake, slopes on the east side of the river display lower severity and patchy areas of burn.
- A high severity valley-wide burn is noted from 4 km south of Mowich Lake to near the south end of Vidette Lake. Some areas of lower severity burn were observed along the northeast end of Skookum Lake and throughout the Deadman River floodplain, between Skookum and Vidette Lakes. The remainder of Vidette Lake and the timber in the portion of the watershed to the northwest of the lake is largely unaffected by the wildfire. The northeast slopes of Vidette Lake and portion of the watershed north of the lake experienced patchy mixed severity burns.

- The area immediately surrounding Deadman River Falls experienced a high severity burn.
- Above Deadman River Falls, burn severity is mixed and the extent of burn is patchy and scattered throughout remaining timber between cutblocks.

Criss Creek

- The riparian area along the first 2 km of Criss Creek experienced a partial burn.
- The lower 6 km of Criss Creek experienced a valley-wide, high severity burn, except for the first 2 km of riparian area.
- From 6 km to 8.5 km upstream of the mouth of Criss Creek experienced patchy areas of burn and severity was mixed.
- From 8.5 km to 15.5 km upstream of the mouth of Criss Creek experienced a high severity burn.
- The remaining upstream area experienced mixed severity and patchy areas of burn, dominantly in the mature timber between cutblocks.

Observed hydrologic impacts

Watershed scale:

Soils were tested in several locations throughout the watershed for the presence of a hydrophobic (water repellent layer), induced by the wildfire. A hydrophobic layer was detected in high severity burned areas in all locations tested, and was present just below the ash layer and as deep as 5 cm below the soil surface. Evidence from recent rainstorms following the wildfire suggest that the hydrophobic layer is spatially continuous throughout high severity burned areas. The presence of a water repellent layer increases the efficiency of delivery of water from hillslopes to streams, causing the watershed to have a flashier stream response, particularly from rainfall events.

Surface runoff and significant sediment transport was evident in gullies downstream of high severity burned areas. Several landslides, including debris floods or flows have already occurred following the fire, including one large landslide into Snohoosh Lake. These events are expected to continue in response to future rainfall events and will directly contribute sediment to streams where the hillslopes are coupled to the channel. Additional contributions of sediment are expected from increased sediment delivery to roads, drainages along roads, and indirectly from increased bank erosion associated with higher flows.

On the upper plateau, expected hydrologic impacts from the wildfire include an increase in snowpack due to suppressed snow interception with tree loss, and accelerated melting from an increase in solar radiation and lower snowpack albedo. This causes an increased likelihood of earlier and higher magnitude peak flow events during the spring freshet. Risk of increased sediment delivery from debris flows and slope failures is lower on the plateau due to relatively low gradient rolling terrain. However, sediment delivered directly from runoff in burned blocks and sediment contributions from increased bank erosion are expected to increase.

In general, it is expected that rainstorms and spring snowmelt conditions (snowpack depth, antecedent soil moisture, warming rate, etc.) that would normally generate moderate flows, can now be expected to produce faster responding and higher magnitude flood events. The incremental increase in flood severity and frequency is difficult to quantify, but it is expected to be significant. We plan to examine this topic further in our report.

Sub-basin scale

Unlike in the Deadman River, Criss Creek does not have a series of lakes and reservoirs which act to attenuate flow and allow sediment to fall out of suspension. Criss Creek is a flashy system capable of transporting significant sediment volumes due to the adjacent steep coupled slopes and lack of lakes along its main channel.

Significant runoff and sediment transport was noted in gullies along the first 7 km of the Criss Creek Forest Service Road (FSR) on the northwest slopes above Criss Creek. Along this section of road, even relatively small gullies that previously have not conveyed measurable flow, show evidence of significant flow and sediment transport, and have scoured, incised channels. Many culverts along this section of FSR are buried with sediment, and water has overtopped the road in several locations. Each location where a gully crosses a road is at an increased risk of road failure, which may be triggered by even modest rainstorm- or snowmelt-runoff.

Tobacco Creek appears to be an active system with evidence of aggradation above the mouth, where it crosses the Deadman Vidette Road. There are three 900 mm diameter culverts at this crossing, two of which act as overflow. The main culvert is partially filled with sediment and only able to convey 2/3 flow capacity. Increased flows and sediment delivery will increase the risk of a road failure.

Specific areas at risk of flooding

An increase in hydrologic hazard from the wildfire can occur from higher water levels causing areas to be inundated and/or from increased erosion along the channel banks, compromising roads and buildings in close proximity to the channel. It is important to note that increased flooding as a result of the wildfire is contingent upon the necessary weather conditions. Additionally, an increase in the abundance of large woody debris is expected in the channel system, particularly downstream of severely burned riparian areas. This debris is likely to build up in front of stream crossings and lower the conveyance capacity of bridges and culverts.

Residences, structures and sections of road considered to be an an increased risk of flooding and/or erosion as a result of the wildfire are listed in TABLE 1.1 (in upstream order). The locations of the areas of concern listed in TABLE 1.1 are provided as an attached KMZ file and are labelled based on the placemark number. TABLE 1.2 provides a qualitative description of the hazard ratings used in TABLE 1.1.

TABLE 1.1 *Summary of hydrologic risks in the Deadman River Watershed following the Sparks Lake wildfire.*

Placemark #	Element at Risk	Dominant hazard	Description	Pre-fire hazard[1,2]	Incremental change in hazard due to wildfire[3]		Total hazard due to wildfire
1	CN Rail bridge	Erosion	CN Rail bridge constricts flow on the alluvial fan near the mouth of the Deadman River. West bank on upstream side of the bridge is currently experiencing erosion.	Very low	Not at an imminent risk, however, increased erosion to the west bank could compromise the bridge in the future. Incremental flood-related risk at this location is low.	++	Low
2	Unnamed Road	Erosion	Deadman River is encroaching and eroding banks adjacent to unnamed road on the east side of the river. No riprap was observed at this location.	High	Increased erosion rate with higher flows. Incremental flood risk at this location is low.	++	Very High
3	Unnamed Road	Erosion	Deadman River is encroaching and eroding banks adjacent to unnamed road on the east side of the river.	High	Increased erosion rate with higher flows. Incremental flood risk at this location is low.	++	Very High
4	Fish counting weir	Flooding	We understand that the fence is removed during winter, however, remaining structure is at risk of damage during high flows.	Low	Increased flows could increase the likelihood of damage.	++	Moderate
5	Deadman Vidette Road	Erosion	Erosion risk along the Deadman Vidette Road.	Low	Section of road is currently protected by riprap, although road fill may be lost with increased erosion rates.	+	Low
6	Trailer Park	Flooding/erosion	Several residences within the trailer park are in the floodplain and at risk of being inundated. Properties in proximity to the channel are at risk of erosion.	Low	Increased flood risk to residences in low lying areas within the trailer park. Increased rates of erosion with higher flows.	++	Moderate
7	Fish counting weir	Flooding	Weir is susceptible to damage during high flows.	Low	Increased flows could increase the likelihood of damage.	++	Moderate
8	Residence	Flooding	Residence and surrounding structures are located in the floodplain and are at flood risk.	Moderate	Incremental increase in flood risk.	++	High

[1] Refer to TABLE 1.2 for definitions of qualitative ratings.
[2] Pre-fire hazard represents conditions immediately before the Sparks Lake wildfire.
[3] Relative ratings are as follows: - decrease, ø negligible increase, + minor increase, ++moderate increase, +++ major increase. A change of one (e.g., +) contributes up to a one-step increase in the total hazard level, a two-step change (++) contributes a one-step jump in total hazard (e.g., moderate to high), and a change of +++ contributes to around a two-step jump in total hazard (moderate to very high).

Placemark #	Element at Risk	Dominant hazard	Description	Pre-fire hazard[1,2]	Incremental change in hazard due to wildfire[3]		Total hazard due to wildfire
9	Deadman Vidette Road	Flooding/erosion	Section of road is currently armoured with riprap, although at risk to increased erosion. Road surface is less than 3 m above channel and at risk to flooding.	Low	Increased erosion rate and flood risk with higher flows.	++	Moderate
10	Deadman Vidette Road	Erosion/flooding	Section of road is currently armoured with riprap although at risk to increased erosion.	Low	Increased erosion rate with higher flows. Incremental flood risk at this location is low.	+	Low
11	Residence	Flooding	According to Anderson (pers. comm., 2021) s.22 house on north bank was almost lost during 1990 flood.	Moderate	Incremental flood risk with increased flows.	++	High
12	Pow wow arbour	Flooding	Pow wow arbour has been previously inundated during high flows, but has not sustained any damage (Anderson, pers. comm., 2021)	High	Incremental flood risk with increased flows.	++	Very high
13	Residence	Flooding	Residence and surrounding structures located within the floodplain. Relatively low-lying floodplain noted in this area.	Low	Incremental flood risk with increased flows.	++	Moderate
14	Fish hatchery	Flooding	Fish hatchery located adjacent to the main river channel was damaged during the 1990 flood event (Anderson, pers. comm., 2021)	Moderate	Incremental flood risk with increased flows.	++	High
15	Residence	Flooding	Residence located within the floodplain.	Low	Incremental flood risk with increased flows.	+	Low
16	Residence	Flooding	Several residences are located on the Criss Creek alluvial fan.	Moderate	The channel banks near the Criss Creek FSR bridge crossing at the apex of the fan are likely sufficient to contain an increase in flows, however, channel banks between bridge and mouth are subject to inundation during a large flood event.	++	High
17	Residence	Erosion/flooding	Channel is relatively narrow and incised at this location. Erosion and undercut banks are encroaching on a property and shed. Homeowner s.22 has reported high flows approaching within approximately 1 m of her lawn. Bank on the east side has been armoured	High	Erosion is the greatest concern at this location. Increased erosion, incision and an undercutting of the banks is expected to occur. Incremental flood risk associated with higher flows.	++	Very high

Placemark #	Element at Risk	Dominant hazard	Description	Pre-fire hazard[1,2]	Incremental change in hazard due to wildfire[3]	Total hazard due to wildfire
			with riprap, although it appears under-protected on the downstream end of the property.			
18	Residence	Flooding	Several buildings and structures are located in the floodplain and in close proximity to the channel. Residence (homeowner: s.22 is located at a higher elevation than the surrounding buildings and is at a lower flood risk.	Moderate	Incremental flood and erosion risk with increased flows to structures and buildings within close proximity of the river. Private bridge susceptible to damage from increased flows. ++	High
19	Residence	Erosion/flooding	According to Mike Anderson, channel is relatively narrow and incised at this location and property is at flood risk. Residence (homeowners.22 and surrounding structures are located in the floodplain and at flood risk.	Moderate	Incremental flood and erosion risk with increased flows. ++	High
20	Residence	Erosion/flooding	According to Mike Anderson, the channel is relatively narrow, incised and banks are experiencing erosion at this location. Residence (homeowner: s.22 Farmer) and surrounding structures are located in the floodplain and at flood risk.	Moderate	Incremental flood and erosion risk with increased flows. ++	High
21	Deadman Vidette Road	Erosion/flooding	Erosion and flood risk along the Deadman Vidette Road. Section of road is currently riprapped, although road fill may be lost with increased erosion rates. Road surface is approximately 2 m above channel level and at a risk of being flooded.	High	Incremental flood and erosion risk with increased flows. ++	Very high
22	Residence	Erosion/flooding	Several buildings and structures located in the floodplain and in close proximity to the channel.	Low	Incremental flood and erosion risk with increased flows. ++	Moderate
23	Private bridge	Flooding	Bridge span is quite narrow and at crossing is at risk of being washed out during high flows.	Moderate	Incremental flood risk with increased flows. ++	High
24	Residence	Flooding	Residence located on the floodplain.	Low	Incremental flood risk with increased flows. ++	Moderate
25	Deadman Vidette Road		Erosion risk along the Deadman Vidette Road in multiple locations, each identified by the same placemark number.	Moderate	Sections of road are currently armoured with riprap, although road fill may be lost with increased erosion rates. Road is relatively low and susceptible to flooding from increased flows. ++	High

Placemark #	Element at Risk	Dominant hazard	Description	Pre-fire hazard[1,2]	Incremental change in hazard due to wildfire[3]		Total hazard due to wildfire
26	Residence	Flooding	Residence located on the floodplain.	Low	Incremental flood risk with increased flows.	++	Moderate
27	Residence	Flooding	Residence and surrounding structures located on either side of Tobacco Creek near the mouth are at risk of being flooded. Deadman Vidette Road stream crossing is compromised by sediment and at risk to flooding and a potential road washout.	High	Residences along the channel are at an increased flood risk. The stream has a history of flooding and the crossing was damaged in recent years due to high flows and sediment inputs. The newly replaced culverts (within the last 2-3 years) are currently partially filled with sediment. Both the channel along the fan and the culverts below the Deadman Vidette Road are not expected to be able to convey increases in flows from the wildfire.	++	Very high
28	Residence	Flooding	Residence located on the floodplain. Evidence of a recently new drainage systems along road and surrounding property suggest flood concerns.	Moderate	Incremental flood risk with increased flows.	++	High
29	Deadman Vidette Road	Flooding	The channel at the Deadman River bridge below Vidette Lake has been heavily aggraded. Flow upstream of the bridge has been re-routed through a small drainage ditch to the north of the bridge, and passes through two 1,200 mm diameter culverts.	High	Both the new diverted channel culvert system and the bridge crossing over the pre-existing channel are at an increased flood risk due to increased flows. There is an increased risk of a road washout with increased flows.	++	Very high
30	Recreation campsite	Flooding	Two picnic tables at a recreation site on a steep fan adjacent to Vidette lake tributary channel.	Low	Incremental flood risk with increased flows.	++	Moderate

It is important to recognized that the findings presented in this memo are preliminary and include only the major issues we have thus far identified as part of our assessment. The findings and potential increases in risk are subject to revisions pending further review. Additionally, several small bridges and channel crossings located on private property were not observed during the field visit. These elements are expected also to be at risk of sediment and debris build-up, and potential damage during high flow events.

Risk Management Options:

There are several elements at risk, and some elements are at high or very high risk. As such, it would be prudent to initiate steps to manage these risks. The following are suggested actions for those responsible parties to manage or mitigate increased flood and erosion risks in the Deadman River Watershed as a result of the Spark Lake Wildfire of 2021.

- Criss Creek Forest Service Road should be frequently monitored and temporarily closed in advance of large rain events. This is particularly important along the lower sections of the road along the slopes to the west of Criss Creek. Mitigative actions could include clearing culvert intakes, replacing crossings with larger culverts, or removing the culverts and leaving armoured swales to allow debris and water to travel overtop during large runoff events.
- All stream crossings (i.e., culverts and bridges) should be regularly monitored and any build up of debris should be cleared.
- Riprap should be stockpiled in anticipation of increased erosion along sections of road near the channel or residences and structures in proximity to eroding channel banks.
- Similarly, sandbags should be stockpiled in advance, to be readily deployed to protect residences and structures during peak flow events.
- Snowpack and weather conditions should be monitored in the late-winter and early spring to provide an early warning for potential flooding during the freshet. This should be accompanied by communication to the public (i.e., signage).
- Where feasible, consider construction of armoured berms/dikes or installation of riprap (or other bank protection) at locations where increased flood and/or erosion risks are noted. The location and details of such works would require site-specific engineering assessment, planning, and construction, preferably prior to freshet in 2022.

TABLE 1.2 *Generic qualitative ratings used for the likelihood of hazard occurrence. Adapted from Wise et al. (2004)*[4].

Rating for likelihood of hazard occurrence	Description	Approximate range of annual probabilities of occurrence, Pa	Approximate range of probabilities of occurrence over a 20-year period, Px[5]
Very high	**Imminent**, the event or sustained change to the watershed process would almost certainly occur.	>5.0%	>64%
High	**Likely**; the event or sustained change to watershed process will probably occur.	1.0% to 5.0%	18% to 64%
Moderate	**Possible**; the event or sustained change to watershed process could occur.	0.2% to 1.0%	3.9% to 18%
Low	**Unlikely**; the event or sustained change to watershed process might occur.	0.04% to 0.2%	0.8% to 3.9%
Very low	**Rare**, the event or sustained change to watershed process is only a remote possibility.	<0.04%	<0.8%

[4] Wise, M.P., G.D. Moore, and D.F. VanDine (editors). 2004. Landslide risk case studies in forest development planning and operations. B.C. Min. For., Res. Br., Victoria, B.C. Land Manage. Handbook No. 56. http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh56.htm.

[5] The probability of occurrence over a specified number of years (Px) is based on (Wise et al., 2004) as follows:

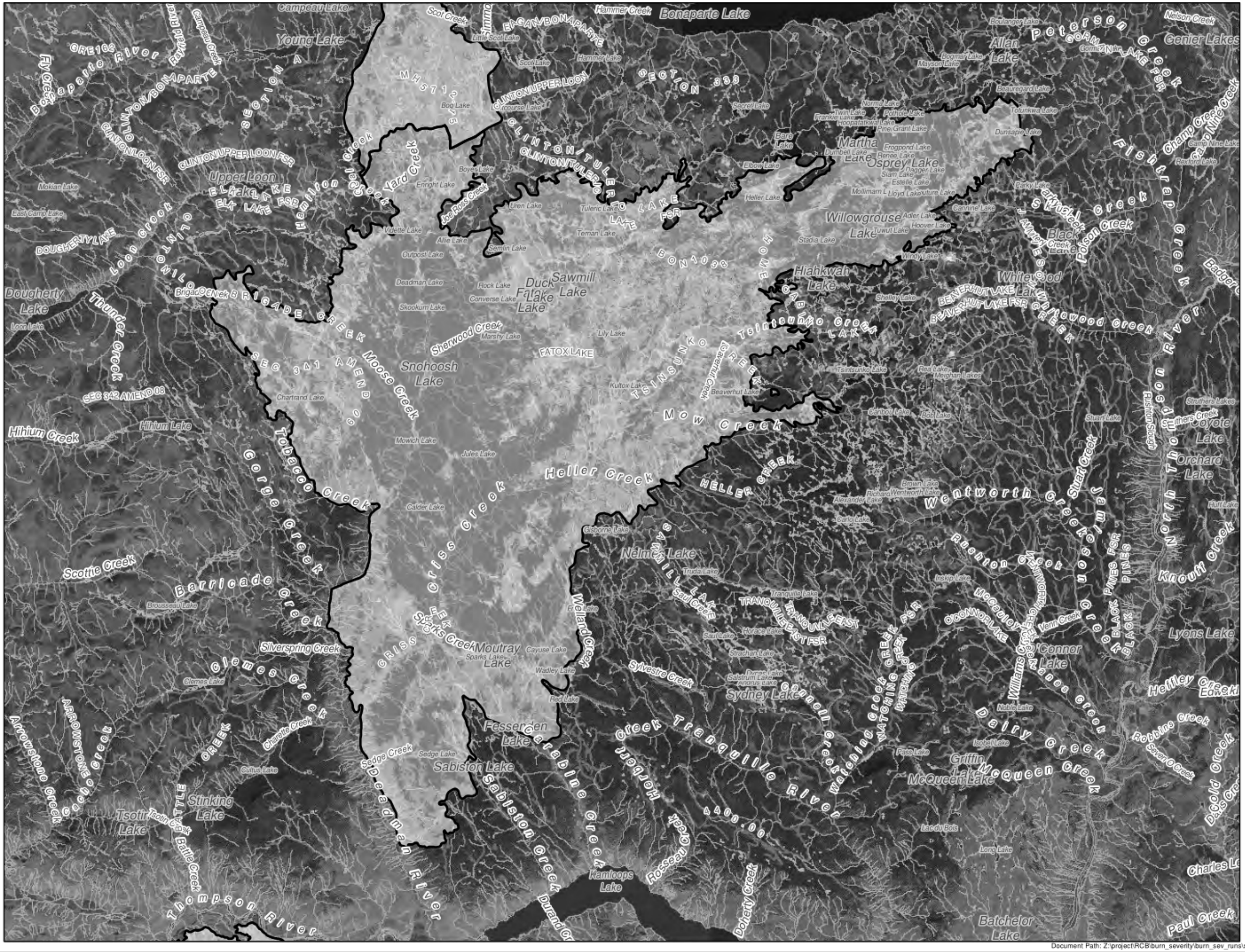
$Px = 1 - (1-Pa)^x$

where,

Px = Probability of at least one event over the specified number of years

Pa = Annual probability of occurrence

x = Number of years



K21001

Burn Severity Mapping

Burn Severity 2021 (Same-Year Classification)

- High
- Medium
- Low
- Unburned
- Unknown
- Mapped Fire Perimeter

This burn severity mapping is created using a Differenced Normalized Burn Ratio (DNBR) calculation on pre- and post-fire imagery which is classified into four Burned Area Reflectance Classification (BARC) categories. Default breakpoints are used for all timber types across BC and therefore may not accurately reflect field conditions.

"Same-Year Classification" means that the burn severity mapping has been completed the same year the fire occurred (i.e. in summer/fall 2021 for 2021 fires). Post-fire imagery obtained as soon as possible after the fire has stopped moving and fire activity is significantly decreased or non-existent.

0 2.75 5.5 11
Kilometers

British Columbia
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

Last updated: 2021-10-26
Updated by: camahood
Coordinate System: NAD 1983 BC Environment Albers

Document Path: Z:\project\RCB\burn_severity\burn_sev_runs\same_year_runs\2021\2021_hatfield_delivery\distribution_work\burn_severity.mxd

MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT

POST-WILDFIRE RISK ANALYSIS – RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions. Please contact the author for more information.

FIRE: Michaud Creek (N51765) | **FIRE YEAR: 2021** | **DATE OF REPORT:** November 3, 2021

AUTHOR: Sarah Crookshanks

REPORT PREPARED FOR: District Manager, Southeast Fire Centre

FIRE SIZE, LOCATION, AND LAND STATUS: 14032 ha. East shore of Arrow Lakes north of Renata. Mostly Crown land, with some parcels of private land scattered throughout.

VALUES AT RISK: Bowman Point Recreation Site, domestic water intakes (Dog, Renata and Bowman Creeks) and dwellings (at Bowman Point, Renata and Cinnamon Lake)

WATERSHEDS AFFECTED:	TOTAL AREA	AREA BURNED[1]	BURN SEVERITY[2]	
			% High	% Moderate
Cinnamon Creek	2745 ha	1345 ha (49%)	5	27
Michaud Creek	1436 ha	874 ha (61%)	6	35
Bowman Creek	6059 ha	1374 ha (23%)	1	9
Renata Creek	8613 ha	2446 ha (28%)	3	13
Dog Creek	19705 ha	598 ha (3%)	0	1
		[1] (% of watershed area)	*[2] % of watershed area*	

SUMMARY OF HAZARDS AND RISKS:	HAZARD [1]	RISK [2]
Hazards: The most significant hazards are flooding and water quality impacts.		
Risks:		
1. Flooding on Renata Creek impacting dwellings	VL	L
2. Flooding on Dog Creek impacting dwellings	VL	L
3. Flooding on Bowman Creek impacting dwellings or recreation site	L	L
4. Water quality impacts to domestic water users on Dog, Renata and Bowman Creeks	L	M

1. Hazard = P(H), the probability of occurrence of a hazardous event
2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk

FURTHER ACTIONS:
None recommended.

POTENTIAL MITIGATION:
None recommended.

SIGNATURE:
Original signed and sealed

ATTACHMENTS:
See attached report, map and photos for further details.

Southern Interior Forest Region, preliminary report form version 1.1, 2010

Michaud Creek Fire (N51765) 2021 – further details on the Post-Wildfire Risk Analysis

The Michaud Creek fire began on July 10, 2021 and burned a large area on the east shore of Arrow Lake north of Renata. Most of the fire was on Crown land, with a handful of parcels of private land. An aerial overview was completed for this fire on October 1. No field work was undertaken, because the post fire natural hazard risks were deemed to be low.

Burn severity mapping was produced for this fire in late September by regional geomatics staff. Provincially contracted burn severity mapping was released in early November and it appears to align more closely with the vegetation burn severity captured in the aerial photos. Therefore, the provincial burn severity data were used in this analysis.

As the attached map shows, the fire is primarily composed of low and moderate burn severity. The impacts on Renata Creek, Dog Creek and Bowman Creek will be minimal due to the low proportion of the watershed with moderate or high burn severity. A larger proportion of the Cinnamon Creek and Michaud Creek watersheds burned; however, there are no elements in these watersheds that are at risk due to postfire geohazard events.

Sarah Crookshanks, P.Geo.
November 3, 2021

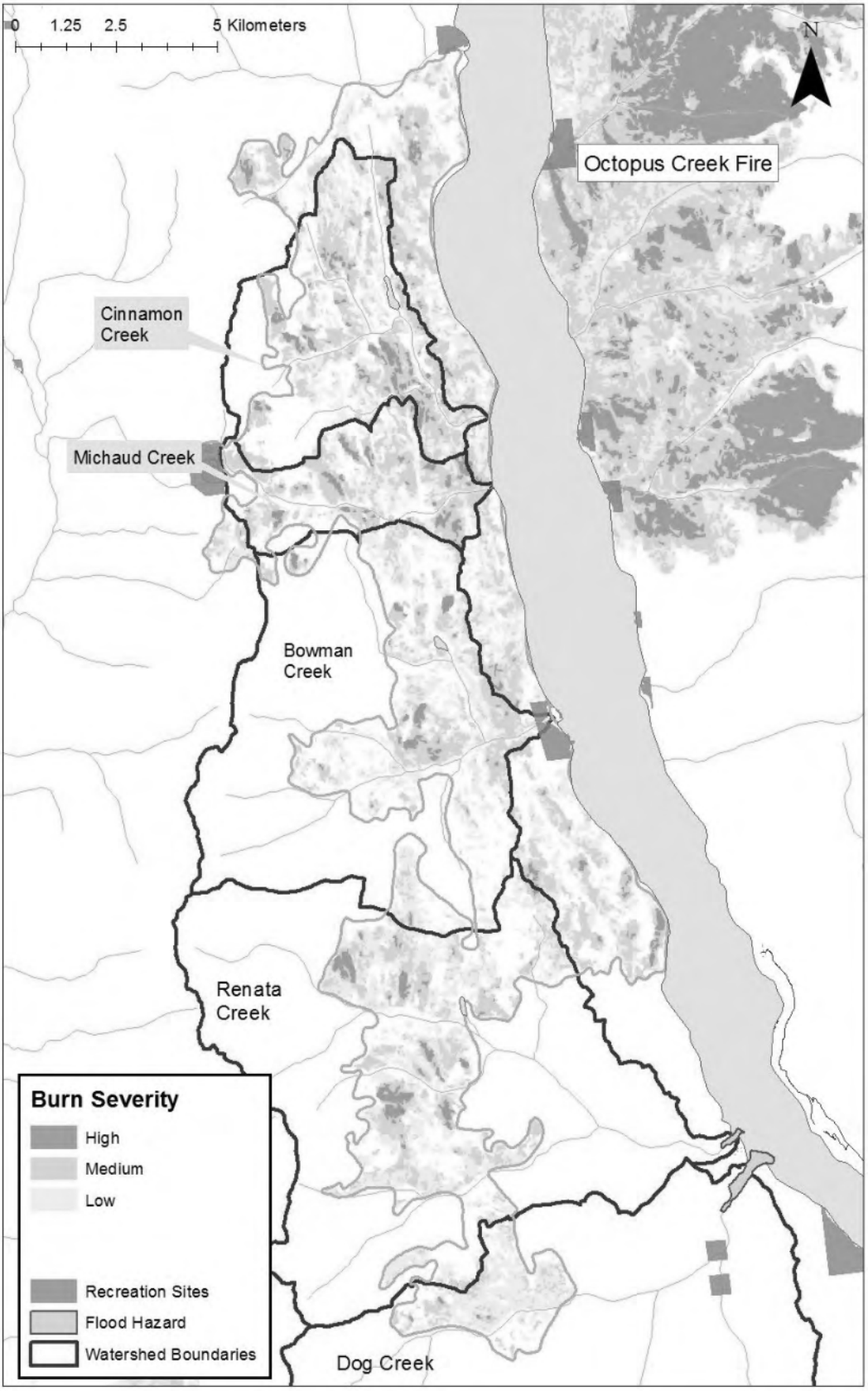

0 1.25 2.5 5 Kilometers
N
Octopus Creek Fire
Cinnamon Creek
Michaud Creek
Bowman Creek
Renata Creek
Dog Creek
Burn Severity
High
Medium
Low
Recreation Sites
Flood Hazard
Watershed Boundaries

Photo 1. North branch of Renata Creek (view from the South)

Photo 2. Bowman Creek

MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT

POST-WILDFIRE RISK ANALYSIS – RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions. Please contact the author for more information.

FIRE: Octopus Creek (N51800)	**FIRE YEAR: 2021**	**DATE OF REPORT:** November 3, 2021
AUTHOR: Sarah Crookshanks		
REPORT PREPARED FOR: District Manager, Southeast Fire Centre		
FIRE SIZE, LOCATION, AND LAND STATUS: 22049 ha. Fire is located along the west shore of Arrow Lake south of Fauquier. Crown land, with a few parcels of private property near Taite Creek and Hutchison Creek.		
VALUES AT RISK: Applegrove Road, Private Property, Recreation Sites		

WATERSHEDS AFFECTED:	**TOTAL AREA**	**AREA BURNED**	**BURN SEVERITY (% of watershed area)**
Taite Creek	8791 ha	3978 (45%)	23% H, 12% M
Octopus Creek	4616 ha	2291 (49%)	18% H, 23% M
Van Houten Creek	4208 ha	2597 (62%)	36% H, 20% M
Hutchison Creek	5919 ha	2056 (35%)	5% H, 19% M
Gladstone Creek	3041 ha	1870 (61%)	28% H, 27% M

SUMMARY OF HAZARDS AND RISKS	**HAZARD** [1]	**RISK** [2]
Hazards: The most significant hazards are debris floods, flooding and water quality impacts		
Risks:		
1. Risk of flooding on Taite Creek impacting Applegrove Road or Taite Creek Recreation Site	M	M
2. Risk of a debris flood on Octopus Creek impacting Applegrove Road or Octopus Creek Recreation Site	M	M
3. Risk of a debris flood on Octopus Creek impacting Octopus Hotsprings Recreation Site	M	H
4. Risk of a debris flood on Gladstone Creek impacting Gladstone Recreation Site	H	H
5. Risk of a debris flood on Van Houten Creek impacting Van Houten Recreation Site	H	H
6. Risk of water quality impacts to surface domestic water use on sources along Applegrove Road	L	M

1. Hazard = P(H), the probability of occurrence of a hazardous event
2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk

POTENTIAL MITIGATION AND FURTHER ACTIONS:

- Domestic surface water users on creeks that fall within the fire perimeter may want to consider additional water quality treatment measures.
- Recreation Sites and Trails BC may want to post information regarding post wildfire hazards at affected recreation sites depending on the site popularity and infrastructure
- Recreation Sites and Trails should consider closing Gladstone, Van Houten and Octopus Hotsprings Recreation Sites for at least the next 3 years due to high flood risk
- It is recommended that MFLNRORD regularly inspect and maintain Taite Creek and Octopus Creek bridges along Applegrove Road, particularly after significant rainstorms.

COMMENTS:

- Octopus Creek wildfire resulted in large swaths of high burn severity in debris flood prone watersheds. However, the elements at risk within the watersheds are limited to recreation sites, road/bridges and several parcels of private property. No dwellings were identified to be at risk from post fire natural hazards.

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SIGNATURE:	**ATTACHMENTS:**
Original signed and sealed	See attached report, map and photos for further details.

Southern Interior Forest Region, preliminary report form version 1.1, 2010

Octopus Creek Fire (N51800) 2021 – further details on the Post-Wildfire Risk Analysis

The Octopus Creek fire began on July 11, 2021 and burned a large area on the west shore of Arrow Lake south of Fauquier. Most of the land is Crown land, with a handful of parcels of private land along Arrow Lake. Several dwellings along Applegrove Road were lost in the fire. An aerial overview was completed for this fire on October 1. No field work was undertaken, since the elements at risk from post-wildfire geohazards are limited to recreation sites, Applegrove Road and several parcels of private property. No dwellings were identified to be at risk from post fire natural hazards.

Burn severity mapping was produced for this fire in late September by regional geomatics staff, and it closely aligns with the provincially developed burn severity mapping released in late October. The aerial overview confirmed that the burn severity mapping is generally accurate.

Watershed morphometrics suggest that Octopus, Gladstone, Hutchison and Van Houten Creeks are all potentially susceptible to debris floods, whereas Taite Creek is more likely to be susceptible to clearwater flooding. Because of the large proportion of high burn severity in the Gladstone and Van Houten watersheds, those creeks are considered to have a high debris flood hazard.

The recreation sites along the west shore of Arrow Lakes are located on the creek fans and are susceptible to post fire flooding hazards. Gladstone, Van Houten and Octopus Hotsprings Recreation Sites are not listed on the public government website, though they are listed as active on the publicly available spatial dataset. I would recommend posting information regarding post wildfire hazards at the recreation sites, depending on their popularity and infrastructure. The province has developed a brochure and sign on post-fire hazards that can be used for public communication. I would also recommend closing Gladstone, Octopus Hotsprings and Van Houten Recreation Sites for at least the next 3 years due the high flood hazard. The risk is higher at sites with overnight use, which should be considered when deciding on closures.

Applegrove Road is susceptible to flood damage where it crosses the Taite Creek and Octopus Creek fans. MFLNRORD should inspect and maintain the bridges regularly at these crossings. Domestic surface water users on creeks that fall within the fire perimeter may want to consider additional water quality treatment measures.

The private lot at the mouth of Hutchison Creek does not appear to have any structures or buildings. Local government confirmed that they are unaware of any dwelling on this lot. Therefore, it is assumed that the land is unoccupied and the water licence on Hutchison Creek is not currently in use.

Sarah Crookshanks, P.Geo.
November 3, 2021

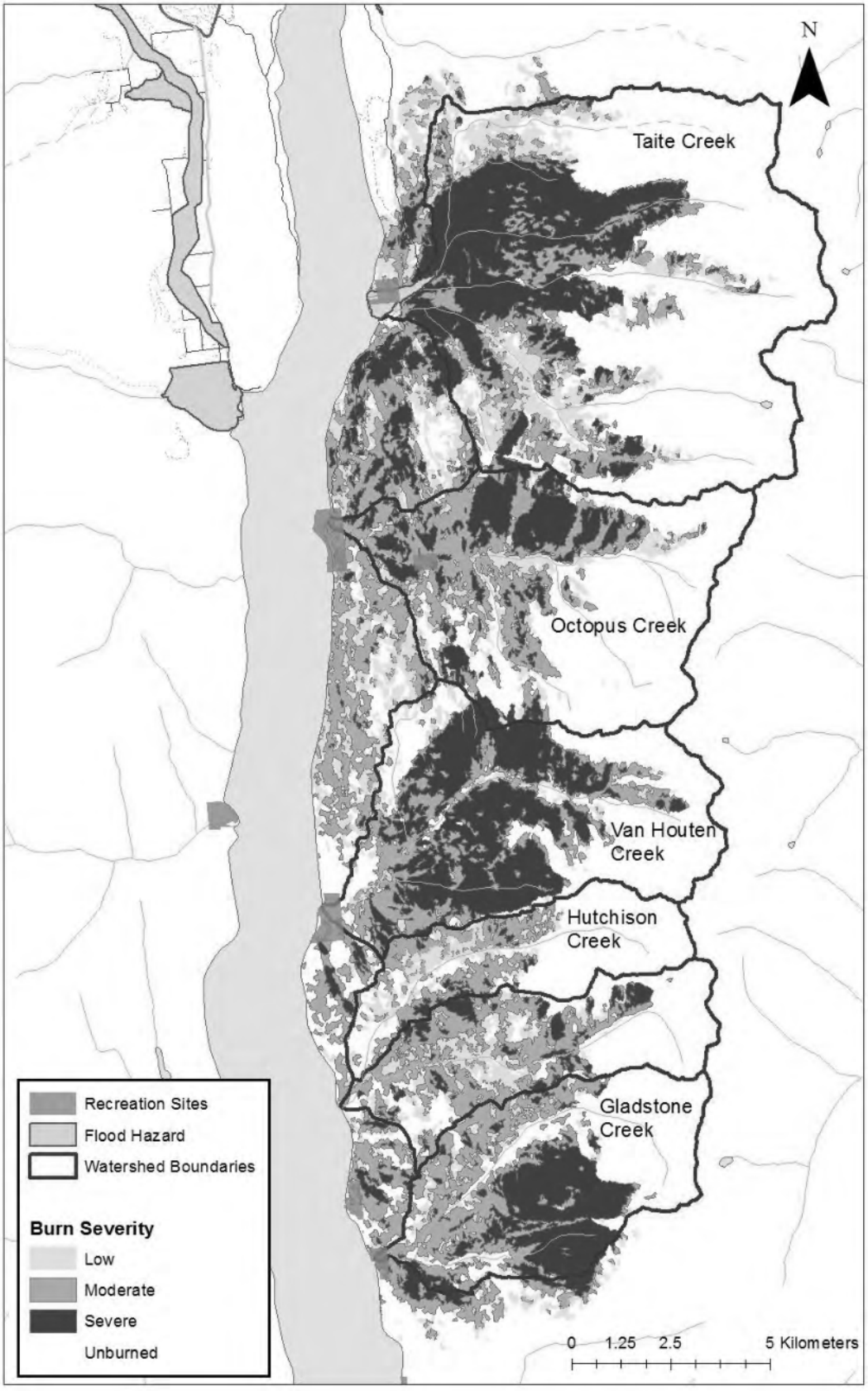

N
Taite Creek
Octopus Creek
Van Houten Creek
Hutchison Creek
Gladstone Creek
Recreation Sites
Flood Hazard
Watershed Boundaries
Burn Severity
Low
Moderate
Severe
Unburned
0 1.25 2.5 5 Kilometers

Photo 1. High burn severity in Van Houten Creek watershed.

Photo 2. Lower slopes of Taite Creek watershed.

Photo 4. Gladstone Creek.

BC MINISTRY OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT
POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT

RECONNAISSANCE REPORT

NOTE: The results given on this form are preliminary in nature and are intended to be a warning of potential hazards and risks. It is not a final risk analysis and further work may alter the conclusions.

FIRE: K61882 July Mountain	**FIRE YEAR:** 2021	**DATE OF REVIEW:** September 2 and 22, 2021 **DATE OF REPORT:** November 4, 2021

AUTHOR: Tim Giles, MSc, PGeo, Senior Geoscientist, Westrek Geotechnical Services Ltd.

REPORT PREPARED FOR:

- BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development – *Thompson Okanagan Region and Cascades Natural Resource District* (the Ministry)
- BC Wildfire Service – *Kamloops Fire Centre, Merritt Fire Zone*

FIRE SIZE, LOCATION, AND LAND STATUS:

The fire was approximately 19,335 hectares in size and included the K62615 Brook Creek Fire. The Ministry-produced Natural Hazard Assessment map (Figure 1) is attached for reference. The land status is a mix of private and Crown land, and the fire burned wholly within the Thompson-Nicola Regional District.

VALUES AT RISK:

The July Mountain Fire burned along and across, the Coquihalla Highway #5 (the Coquihalla), from Juliet Creek in the southwest to Voght Creek in the northeast. The Coquihalla forms the east boundary from the south end of the fire to Brookmere Creek. The western boundary roughly follows the height of land between Murray and Maka Creeks, before crossing near the confluence and heading southwest to northeast towards Voght Creek in the north. The northeast area extends from west of Brookmere across Shovelnose Mountain to Voght Valley.

The fire burned around Murray Lake and Fig Lake; several cabins are located on the shores of Murray Lake. Along Voght Creek and the Kane Valley Road, there are numerous residential and agricultural properties.

WATERSHEDS AFFECTED:

Coldwater River – this a very large watershed that extends south from Merritt to the heights of land with the Similkameen River watershed to the southeast and Fraser River watershed to the southwest. The Coldwater River joins the Nicola River at Merritt. The area of the Coldwater watershed that burned (i.e., 13,980 of 91,228 ha burned) was mostly forested uplands that extend to the alpine areas to the southwest on Maka and July Mountains. Of the 15% of the watershed that burned, almost half (~48%) burned at moderate and high vegetation burn severity. Fortunately, the riparian zone along the floodplain of the Coldwater River burned less severely and most of the channel was not heavily affected. The most noticeable downstream effect of the fire on the Coldwater River is anticipated to be a slight increase in streamflow during spring freshet.

Burned sub-basins within the Coldwater River watershed include:

- Juliet Creek – a high elevation sub-basin where 3268 of 9034 ha of forest was burned. It joins the Coldwater River 45 km south of Merritt. About 36% of the area affected by the fire was burned at moderate or high

BURN SEVERITY

A vegetation burn severity map was compiled by Westrek Geotechnical Services Ltd. (Figure 2, attached). These maps use satellite imagery to estimate the change to the vegetation. For the July Mountain Fire, the images compared were taken on September 9, 2020, and September 7, 2021.

vegetation burn severity. • Bottletop Creek – a small sub-basin that was extensively burned, i.e., about 696 of 721 ha. It drains south into the Coldwater River 44 km south of Merritt. About 35% of the area affected by the fire was burned at moderate or high vegetation burn severity. • Brook Creek – a north-draining watershed where 738 of 4229 ha was burned. It joins the Coldwater River 30 km south of Merritt. About 45% of the area affected by the fire was burned at moderate or high vegetation burn severity. • Shouz Creek – a small, west-draining watershed, which was completely burned, i.e., 868 of 868 ha. It which joins the Coldwater River about 27 km south of Merritt. About 75% of this sub-basin was burned at moderate or high vegetation burn severity. • Voght Creek – a large, west-draining watershed that was minimally burned, i.e., 2522 of 21,046 ha. It joins the Coldwater River 24 km south of Merritt. About 45% of the area affected by the fire was burned at moderate or high vegetation burn severity. Maka Creek – a large watershed that was minimally burned, i.e., 4801 of 21,606 ha. It drains north, parallel to the west of the Coldwater River and joins the Nicola River 20 km downstream from Merritt. About 41% of the area affected by the fire was burned at moderate or high vegetation burn severity. Spearing Creek – a headwater tributary to the Similkameen River watershed, and only 551 of 13,218 ha was burned. About 25% of the area affected by the fire was burned at moderate or high vegetation burn severity.		
SUMMARY OF THE POST-FIRE HAZARDS AND RISKS: **The Coquihalla Ditch** - North of Shouz Creek and the Brookmere interchange, the Coquihalla passes below a steep slope, which was extensively burned at moderate or high vegetation burn severity (Figure 3, Photos 1 and 2). The slope starts below the Shouz Creek FSR and is convex down and across, and there are no draws or watercourses on this face unit. It is less than 200 m long and extends down to the Coquihalla. The slope gradient exceeds 50% and is directly connected to the Coquihalla ditch. It is anticipated that there will be some shallow open-slope slides on this face that will extend down to the ditch. It is recommended that MOTI review and maintain the ditch and culverts for 2 km north of the Brookmere interchange to ensure they are clear of debris and remain functional. **Shouz Creek Sub-Basin**– this creek flows west from the north slopes of Shovelnose Mountain and joins the Coldwater River at the Brookmere interchange (Figure 3). Upslope, the Shouz Creek channel is 2-3 m wide, cobble-boulder plane bed to step pool channel morphology. The creek is constricted as it reaches the Shouz Creek FSR where it flows through a 900 mm diameter culvert (Figure 4 and Photo 3). As the creek reaches the floodplain of the Coldwater River, it flows through a 1700 mm diameter culvert under the Coldwater Road, which passes under a bridge below the Coquihalla. The creek is then directed under the Coquihalla off-ramp road through a second 1700 mm diameter culvert into the Coldwater River. It is anticipated that the Shouz watershed will see a marked increase in stream	**POST-FIRE HAZARD[1]** Moderate for flood and shallow slides Moderate for flood, and low for debris flood	**POST-FIRE RISK[2]** **Moderate risk to the Coquihalla ditch** **Moderate risk to the culvert on Shouz Creek at the Shouz Creek FSR**

flow as result of the fire. This will also lead to increased volumes of sediment moving through the channel. It is expected that the Shouz Creek FSR 900 mm diameter culvert will be too small for the projected increases in post-fire streamflow and sediment movement. It is recommended that: • The Ministry ensure the functionality of the culverts along the Shouz Creek FSR within this sub-basin. • MOTI ensure the functionality of the culverts along the Coldwater Road (UTM coordinates 10U 650760E 5527730N) and the Coquihalla off-ramp road (UTM coordinates 10U 650620E 5527840N).		**Low risk to the Coldwater Road and the Coquihalla off-ramp road**
Larson Hill Slopes – Three main creeks and several small ephemeral creeks drain to the Coquihalla from these slopes, including; 1. **East Fig Creek** – This small creek has moderately steep valley sidewalls (25 to 45%), but the channel gradient is mostly low gradient, between 15 and 25%. The entire watershed above the Coquihalla burned at moderate to high vegetation burn intensity. Elevated streamflow is expected along this creek, along with increased sedimentation. It is recommended that MOTI ensures the functionality of the culvert under the Coquihalla at UTM coordinates 10U 649500E 5525700N (Figure 3 and Photo 4). 2. **South Fig Creek** –A broad glaciofluvial bench is located above the Coquihalla and the creek has incised a deep, steep-sided valley. The channel gradient ranges from 5 to 10% for 1 km above the Coquihalla. The majority (~70%) of this watershed burned at moderate to high vegetation burn intensity. Elevated streamflow is expected along this creek, along with increased sedimentation. It is recommended that MOTI ensures the functionality of the culvert under the Coquihalla at UTM coordinates 10U 649320E 5523980N (Figure 3 and Photo 5). 3. **South Larson Creek** –A broad glaciofluvial bench is located above the Coquihalla into which this creek has incised a deep, steep-sided valley. The channel gradient ranges from 10 to 20% for 2 km above the Coquihalla. About half of this watershed burned at moderate to high vegetation burn intensity. Elevated streamflow is expected along this creek, along with increased sedimentation. It is recommended that MOTI ensures the functionality of the culvert under the Coquihalla at UTM coordinates 10U 648300E 5521550N.	High for flood and moderate for debris flood	**Moderate risk to the Coquihalla at several locations where creeks pass under the road**
Brookmere Road – This road leaves the Coquihalla at the Brookmere interchange and heads south for 6 km, before turning east and going a further 4 km to the small community of Brookmere (Figure 3). On the segment that heads south, the slopes above the road are gentle to moderate and the vegetation burn severity is mixed. On the eastern portion of the road, the slopes above can reach up to 50% and there are a few larger, moderate to high vegetation burn severity patches (Photo 6). Creeks appear to be ephemeral and flow is likely limited to spring freshet and after intense rainfall events. It is anticipated that there will be some creek flows or shallow open-slope slides which may impact the Brookmere Road. It is recommended that MOTI ensure the functionality of all ditches and	Moderate for flood and shallow slides	**Moderate risk to Brookmere Road**

culverts along the Brookmere Road for the next 3 to 5 years until ground cover on the burned slopes is re-established. *1. Hazard = P(H), the probability of occurrence of a hazardous event. It does not address the natural or pre-fire hazard that may already have existed.* *2. Risk = Partial risk P(HA) = P(H) × the probability of it reaching or affecting an element at risk.*		

FURTHER ACTIONS:

Increased review and maintenance of the drainage structures (culverts, ditches, and ditch-blocks) on the Coquihalla Highway and the Brookmere Road below the July Mountain Fire is recommended for the next 3 to 5 years until ground cover on the burned slopes is re-established. Culverts should be reviewed at inlets for impediments to flow and at outlets to ensure there is proper armouring to prevent downslope erosion. Ditches should be reviewed to ensure they are clear of debris and allow unobstructed flow of water to the nearest downslope drainage structure. Ditch-blocks at culvert inlets should be reviewed to ensure they are correctly located and well-maintained.

In the Brookmere interchange and Larson Hill areas, several small watersheds were extensively burned, and these will require extra attention during spring freshet or after intense rainfall events. Nuisance sediment-laden floods and shallow open-slope slides are expected along all road corridors within the fire.

All resource roads within the perimeter of the July Mountain Fire should have increased review and maintenance of drainage structures (bridges, culverts, ditches, ditch-blocks and cattleguards) for the next 3 to 5 years until ground cover has re-established on the burned slopes.

SIGNATURE:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
T. R. GILES
GEOSCIENTIST

2021-11-04

Tim Giles MSc, PGeo
Senior Geoscientist

Westrek Geotechnical Services Ltd.
Permit to Practice Number: 1002522

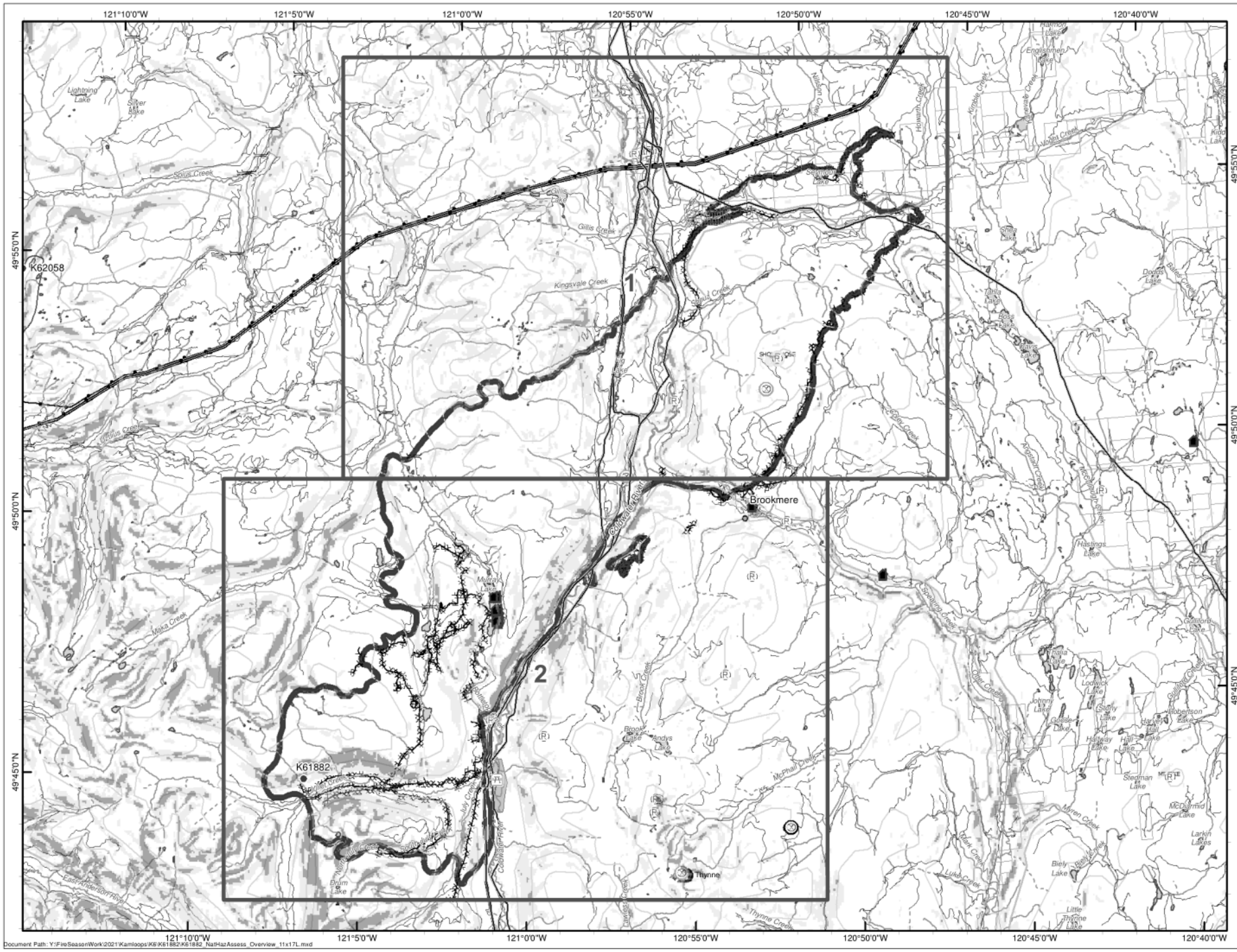
ATTACHMENTS:

Figure 1: K61882 July Mountain Fire - Natural Hazard Assessment Map

Figure 2: K61882 July Mountain Fire - Vegetation Burn Severity Map

Figure 3: K61882 July Mountain Fire - Notable Watersheds

Figure 4: K61882 July Mountain Fire - Selected Site Photographs



July Mountain

K61882

Natural Hazard Assessment

Map Date: August 27, 2021
Perimeter Date: 2021-08-21
Hectares: 19134.83079404

Overview

- Compl... Machine Line
- Fire Perim...
- Fire Point
- Other Fire Perim...
- Pipeline
- Pipeline - Constr... Unkno...
- Trans... Lines
- Weather Station - Active BCWS
- Weather Station
- Radio Tower - Restri...
- Radio Tower - Cellular
- Radio Tower
- Radio Towers - FLNRO
- Bridge
- Dam
- Popul... Place
- Indian Reserve
- Private Land
- Road
- Contour - 1000m
- Contour - 200m

Slope

- 0 - 40%
- 40 - 60%
- > 60%
- Priority Water Rights Licenc...
- Day Use
- Wildla... Struct...
- O&G Facility
- BC Hydro Critical Assets Mount...
- BC Parks {O}

N

1:125,000

0 0.5 1 2 3 4 Km

This map may contain CONFIDENTIAL information: for INTERNAL use only

Disclaimer:
Wildfire perimeters for the current fire season, including both active and inactive fires, are supplied from various sources. The data is refreshed from operational systems nightly to the public map. Wildfire data may not reflect the current fire situation, and therefore should only be used for reference purposes.

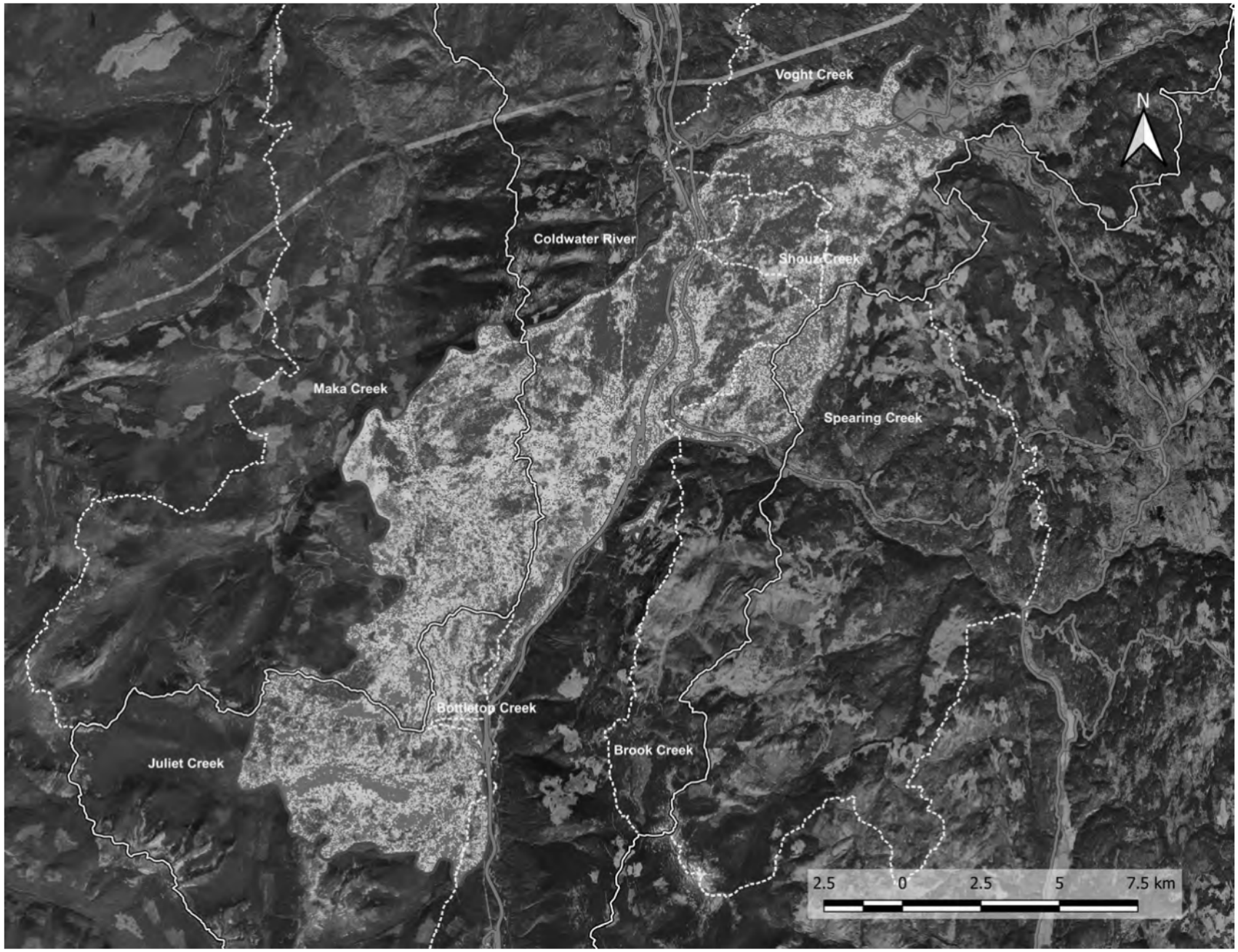
Wildfire data from the incident is updated when practicable and the occurrence of individual fire updates will vary. The information is intended for general purposes only and should not be relied on as accurate because fires are dynamic and circumstances may change quickly. The levels of current fire activity within the mapped fire perimeters can vary widely.

Data Sources and Notes:

Projection: NAD 1983 BC Environment Albers
Created by: jdoerkse

BRITISH COLUMBIA

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



JULY MOUNTAIN
K61882

Burn Severity Map 1 : 120 000

- Coldwater Watershed
- Major Road/Highway
- Fire Boundary

Burn Severity 2021
(Year-Over-Year Classifications)*

- Unclassified <= -550
- Unburned -550 - 99
- Low Burn 99 - 269
- Mod-Low 269 - 439
- Mod-High 439 - 660
- High Burn > 660

This burn severity mapping is created using a Differenced Normalized Burn Ratio (dNBR) calculation on pre- and post-fire imagery as described by Key and Benson, 2006. The map is classified into five burned area reflectance classification (BARC) categories. Default breakpoints for burn severity classifications are used for all timber types across BC and therefore may not accurately reflect the forest type or field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CAN CONTAIN SMOKE AND/OR CLOUDS WHICH COULD ADVERSELY AFFECT THE BURN SEVERITY ANALYSIS*. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESSMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

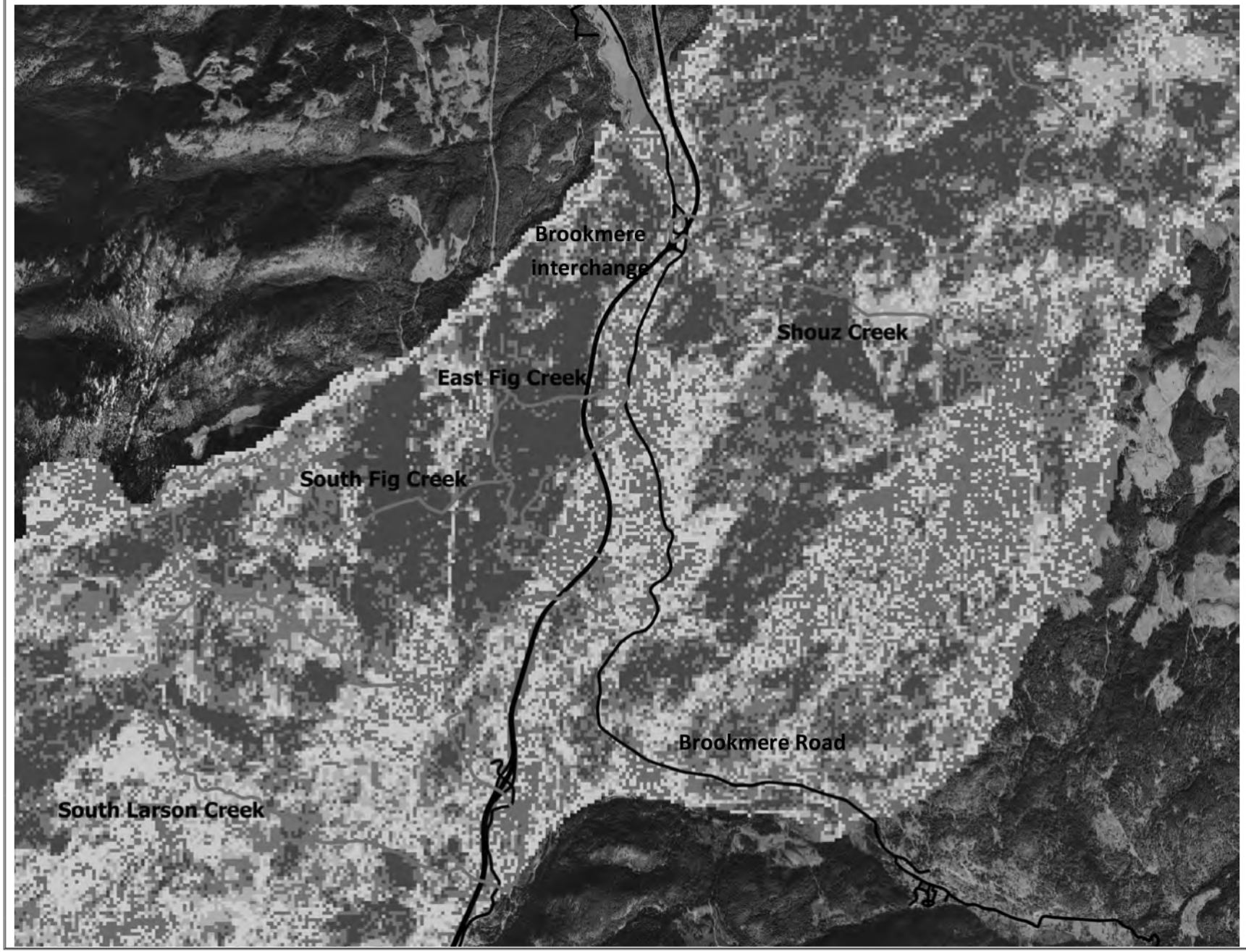
*"Year-over-Year classification", means that the burn severity mapping was done using satellite scenes approximately (as close to) a year apart to capture similar vegetation and moisture levels.

Data Sources:
Pre-fire scene: Sept 09, 2020; Modified Copernicus Sentinel data [2021]/Sentinel Hub
Post-fire scene: Sept 07, 2021; Modified Copernicus Sentinel data [2021]/Sentinel Hub

Map produced by: JSchafer, 2021
Coor System: NAD 1983 BC Environment Albers

westrek
geotechnical services ltd.
100 -1383 McGill Road, Kamloops, BC V2C 6K7
Tel: 778-765-9525

Figure 2



K61882 JULY MOUNTAIN FIRE Notable Watersheds

Burn Severity Map 1:40 000

- Watershed Boundary
- Major Road/Highway
- Fire Boundary

Burn Severity 2021
(Year-Over-Year Classifications)*

- <= -550
- -550 - 99
- 99 - 269
- 269 - 439
- 439 - 660
- > 660

This burn severity mapping is created using a Differenced Normalized Burn Ratio (dNBR) calculation on pre- and post-fire imagery as described by Key and Benson, 2006. The map is classified into five burned area reflectance classification (BARC) categories. Default breakpoints for burn severity classifications are used for all timber types across BC and therefore may not accurately reflect the forest type or field conditions.

IMPORTANT: THIS BURN SEVERITY RUN USES POST-FIRE IMAGERY THAT CAN CONTAIN SMOKE AND/OR CLOUDS WHICH COULD ADVERSELY AFFECT THE BURN SEVERITY ANALYSIS*. THIS MAP IS FOR EMERGENCY NATURAL HAZARD ASSESSMENT ONLY AND SHOULD NOT BE USED FOR ANY OTHER PURPOSES.

*"Year-over-Year classification", means that the burn severity mapping was done using satellite scenes approximately (as close to) a year apart to capture similar vegetation and moisture levels.

Data Sources:
Pre-fire scene: Sept 09, 2020; Modified Copernicus Sentinel data [2021]/Sentinel Hub
Post-fire scene: Sept 07, 2021; Modified Copernicus Sentinel data [2021]/Sentinel Hub

Map produced by: JSchafer, 2021
Coor System: NAD 1983 BC Environment Albers

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geotechnical services ltd.
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Tel: 778-765-9525

Figure 3

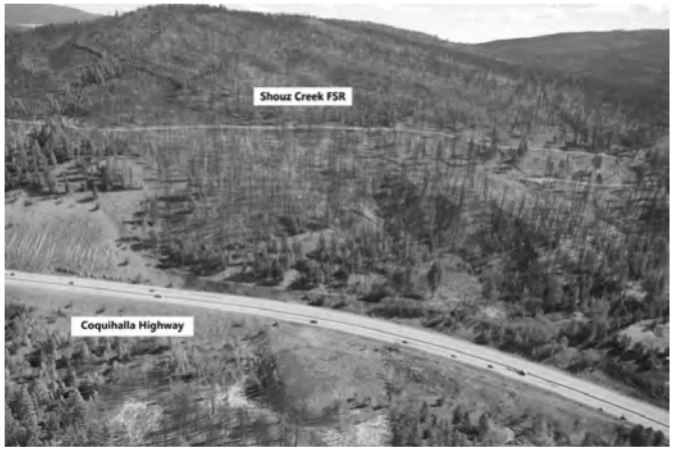

Photo 1 *– View looking east at the steep slope between the Coquihalla and the Shouz Creek FSR. Centre of image is approximately 1 km north of the Brookmere interchange.*

Photo 2 *– View looking south at the steep slope between the Coquihalla and the Shouz Creek FSR. Shouz Creek is shown as a blue line leading down to the Brookmere interchange. Shovelnose Mountain is the peak at centre of image.*

Photo 3 *–Looking downstream along Shouz Creek towards the 900 mm diameter culvert under the Shouz Creek FSR. The culvert constricts the creek as it passes under the road and at high flows will back up flow. This may cause sediment deposition above the inlet which may further restrict flow.*

Photo 4 *– View looking north along the Coquihalla north of Larson Hill. The trace of East Fig Creek is shown as a blue line leading down to the Coquihalla and further to join the Coldwater River.*

Photo 5 *- View looking north along the Coquihalla at Larson Hill. The trace of South Fig Creek is shown as a blue line leading down to the Coquihalla. Fig Peak is located at top centre of image.*

Photo 6 *- View looking north at a moderate to high vegetation burn severity patch on the south-facing slopes above Brookmere Road. Community of Brookmere is to the east (right) of image.*

westrek geotechnical services ltd.	Project No: 021-155 Date: November 4, 2021	**MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT**	**K61882 JULY MOUNTAIN FIRE POST-WILDFIRE NATURAL HAZARD RISK ASSESSMENT**	**FIGURE 4 - SELECTED SITE PHOTOGRAPHS**