Clarke Geoscience Ltd.

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CGL Project: 24-0103

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Attention: **Mr. Trevor Bohay, Director, All Hazards Response Coordination-ADM's Office**
Mr. Gareth Wells, Research Geomorphologist

CC: **Ms. Kathleen Louie, Title and Rights Natural Resource Manager, Lower Similkameen Indian Band**

Reference: **Shoudy Creek Watershed Post-Wildfire Natural Hazard Risk Analysis – 2024 Update**
Similkameen Valley, BC

1. Introduction

Clarke Geoscience Ltd. (CGL) was retained by the Ministry of Forests - BC Wildfire Service (MOF-BCWS) to complete a detailed Post-Wildfire Natural Hazard Risk Analysis (PWNHRA) for the 2023 Crater Creek Wildfire (K52125) under the Consulting and General Services Contract #CS25WHQ0131. The scope of work is defined in Schedule A – Services of that contract (Section 1 d) and specified that a report, under separate cover, be prepared to update the post-wildfire natural hazards, and current condition, of the Shoudy Creek watershed.

The Shoudy Creek watershed was burned in the 2018 Snowy Mountain Wildfire (K51238) and was part of a detailed PWNHRA report completed by Westrek Geotechnical Services Ltd. (2018).

1.1 Objectives and Scope of Work

The primary objective of this PWNHRA update is to describe the current (i.e., 2024) post-wildfire natural hazard conditions in the Shoudy Creek watershed. The scope of work is to re-assess post-wildfire natural hazards in the watershed, with reference to the 2018 PWNHRA report findings. The scope of work will also re-evaluate partial risk to Elements at Risk that are located on the fan for the identified hazards.

The study approach generally follows that which is outlined in *Land Management Handbook (LMH) No. 69 – Post-Wildfire Natural Hazards Risk Analysis in British Columbia* (Hope, et al., 2015). In addition, further clarification on study tasks and the risk analysis approach was provided in the MOF Contract, Schedule A – Services, and by communication with MOF-BCWS (G. Wells, *personal communication*, 2025).

1.2 Study Tasks and Approach

The study approach is comprised of the following tasks:

Task 1: Preparation for site work, including background information review and base map preparation.

Task 2: Collect GIS-Derived Watershed Parameters for the Hazard Assessment.

Task 3: Aerial reconnaissance and ground-based field assessment of the slopes, creek banks, and fan areas.

A helicopter overview flight documenting conditions at higher elevations was completed on August 1, 2024, by J. Clarke, P.Geo., of Clarke Geoscience Ltd., accompanied by B. Scott, of Ecora Engineering and Environmental Ltd., and K. Louie, Title and Rights Natural Resource Manager of the Lower Similkameen Indian Band (LSIB). Ground-based (foot and vehicle) field assessment was completed between July 29 and Aug. 1, 2024, by J. Clarke, B. Scott, and members of the LSIB Natural Resources Field Crew (Rick Kruger and RJ Edward)[1]. Photos and field notes were collected using a tablet on georeferenced maps.

Due to limited access into the watershed, the ground-based field assessment focused on the fan area and lower reaches. The field observations are considered in context with other background information to assess the likelihood of post-wildfire natural hazards, and to further identify the spatial likelihood of impact to identified Elements at Risk.

Task 4: Update the natural hazard assessment and partial risk analysis. This task is an update of the qualitative hazard assessment to determine the likelihood of post-wildfire natural hazards. Clarification of hazard criteria and the qualitative partial risk analysis approach is presented in Appendix A. Partial risk analysis does not quantify the degree of impact (i.e., vulnerability) it is a combination of the likelihood of an event occurring, and the likelihood of that event reaching or otherwise affecting a specified Element at Risk.

Task 5: Prepare a Report. This report includes maps (see Appendix B) and select photographs (see Appendix C) that document field observations, post-wildfire natural hazard conditions, and the results of the partial risk analysis.

2. Elements at Risk

Elements at Risk are defined as the population, building or engineering works, utilities, infrastructure in the area potentially affected by the hazards being assessed (Wise, et al., 2004). Other elements, such as fish and fish habitat and water quality are not specifically considered for this study.

Elements at Risk that are identified on the Shoudy Creek fan include the following, and are shown on Map 002 and Map 003 (Appendix B):

1. Chopaka Road, the only route providing vehicle access to properties in the area;
2. Civic Address: 557 Chopaka Road, located on the west (upslope) side of Chopaka Road (within Chopaka 7 & 8 IR);
3. Civic Address: 525 Chopaka Road, located on the west (upslope) side of Chopaka Road (within Chopaka 7 & 8 IR);

[1] Additional field observations were made in June 2024 during work completed for the Regional Similkameen Geohazards Project, by Ecora, on behalf of the USIB and LSIB (work in progress)

4. Civic Address: 560 Chopaka Road, located on the east (downslope) side of Chopaka Road (within Chopaka 7 & 8 IR);
5. Rodeo Grounds, located at the north end of the fan on the east side of Chopaka Road; and,
6. Two (2) domestic water intakes (mapped) on Shoudy Creek, one at the top end of the fan (damage observed) and another further downstream on a relict channel.

The 2018 wildfire affected lands within the LSIB Chopaka 7 & 8 IR, and within the nearby traditional territory. The surrounding lands hold special significance and value, providing cultural, archaeological, social, and economic resources to the Sməlqmix peoples. Further engagement with LSIB is recommended for a more robust analysis of risk.

3. Watershed Characteristics

3.1 Watershed Location

The Shoudy Creek watershed is located on the east-facing slopes of the Similkameen River valley, south of Keremeos and north of the US border (see Figure 3-1). Figure 3-1 also shows the perimeters for the 2018 Snowy Mountain Wildfire (Snowy Wildfire) and the 2023 Crater Creek Wildfire (Crater Wildfire) with respect to the study area location. Shoudy Creek was not affected by the Crater Wildfire.

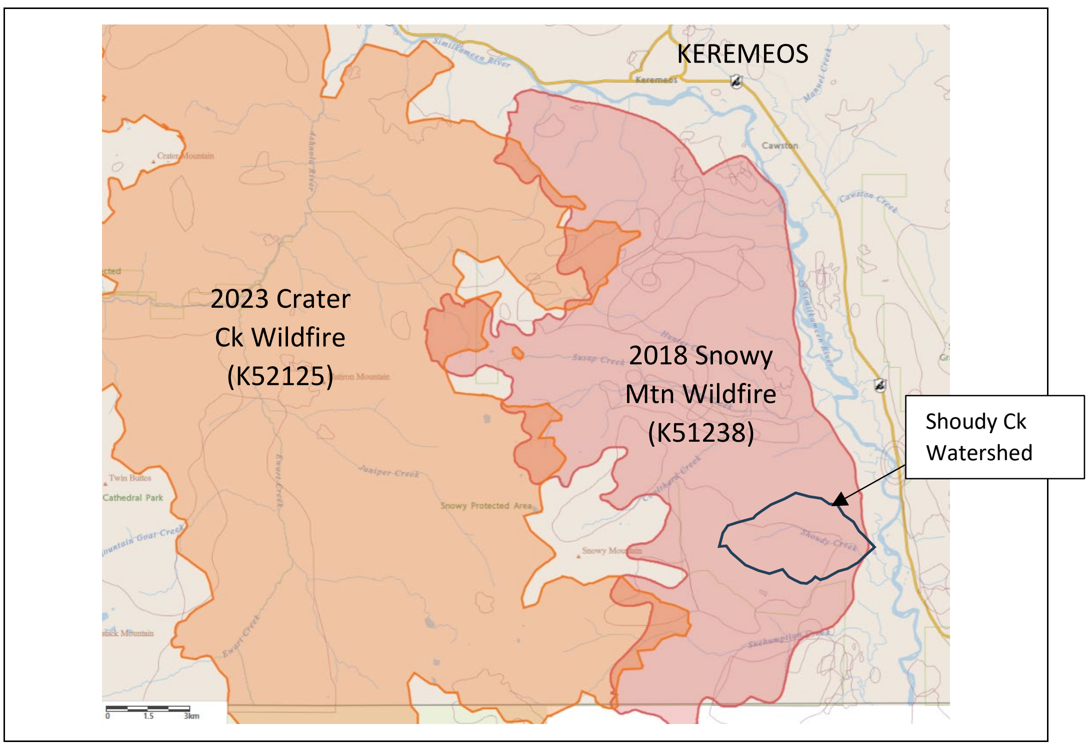


Figure 3-1: Location of the Study Area

3.2 Watershed Physiography and Terrain Conditions

The Shoudy Creek watershed has an area of 13.4 km^2. The watershed headwaters are located on the southeastern ridge of Snowy Mountain at ~2,235 m a.s.l., and the creek enters side channels of the Similkameen River at ~450 m a.s.l., representing an overall relief of ~1,785 m (see Map 001; Appendix B).

Melton Ratio is the dimensionless ratio of watershed relief and area that approximates the steepness of a watershed. Wilford, et al. (2004) found that the combination of watershed length and Melton Ratio could reasonably predict the dominant hydrogeomorphic hazard in a watershed. Class boundaries are <0.3 (flood), 0.3-0.6 (debris flood), and >0.6 (debris flow), with watersheds >2.7 km long (debris floods) and <2.7 km long (debris flow). The Shoudy Creek watershed has a Melton Ratio of 0.49, and a watershed length >2.7 km, which indicates that the dominant hydrogeomorphic process is debris flood. It is noted, however, that depending upon the trigger mechanism, the watershed can experience a range of processes, from clear-water flood to the potentially more destructive debris flood.

Shoudy Creek has few contributing tributaries. The mainstem channel is relatively confined within a steep sided valley and flows from sub-alpine bowl-shaped headwaters (avg. channel gradient 20%) before reaching a bedrock canyon (avg. channel gradient 26%) just upstream of the fan. Figure 3-2 illustrates the longitudinal stream channel profile of Shoudy Creek. The broad alluvial fan (avg. channel gradient 10%) radiates out from the canyon, extending into the Similkameen River Valley. The distal edge of the fan is bounded by Chopaka Road and an abandoned railway embankment (see Map 002 and Map 003; Appendix B).

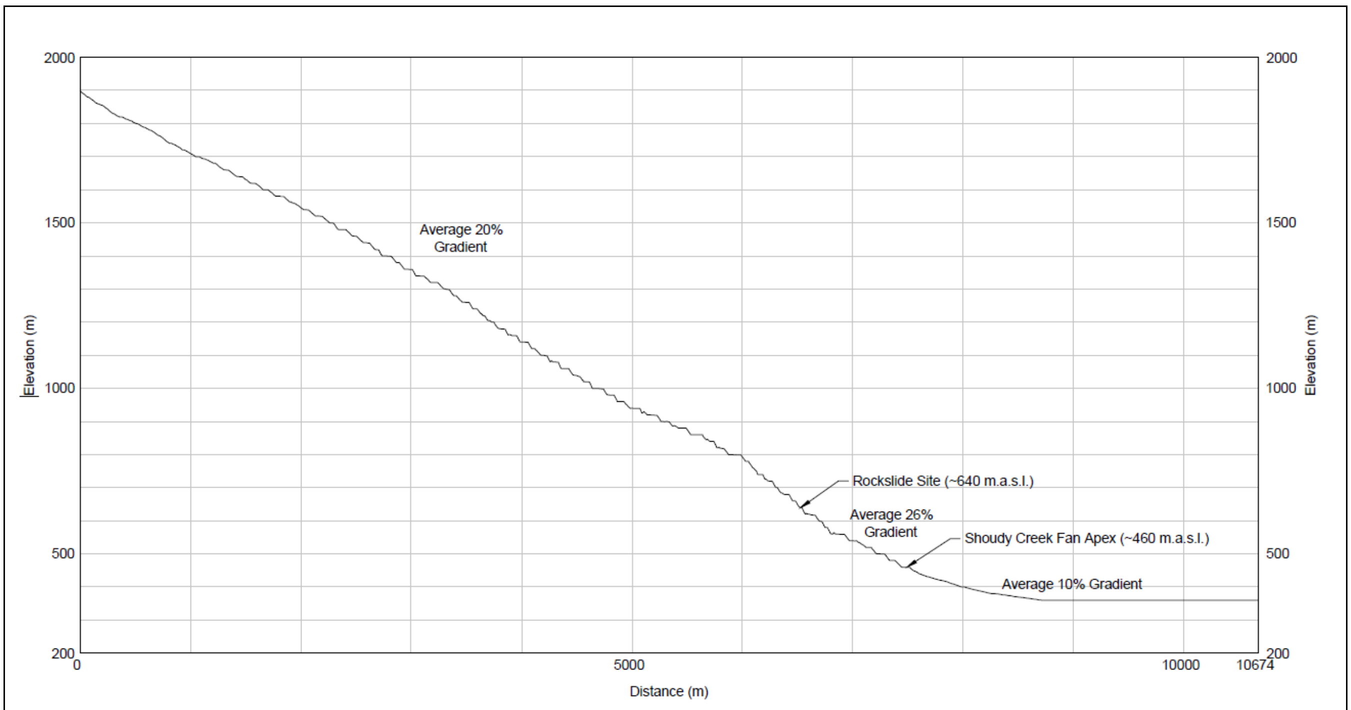


Figure 3-2: Longitudinal Profile of Shoudy Creek

Bedrock geology within the watershed is comprised of intrusive igneous rocks of the Similkameen Batholith, characterized as medium-grained granodiorite (BC EMPR; MapPlace). This rock type is subject to weathering and degradation by freeze-thaw and breaks down to coarse sandy materials. The rapid to well-drained sandy soils are readily apparent across the fan area.

Historic forest harvest development activity in the watershed predates the 1969 air photos. Cutblocks are not mapped on iMAP BC, but an extensive skid trail network is mapped and faintly visible on the north side of the middle watershed. Stability issues associated with the overgrown trail network are not obvious.

Reconnaissance-level terrain stability mapping was obtained from iMAP BC for the Shoudy Creek watershed and is shown in Figure 3-3. The mapping indicates that the steeper valley side slopes along the mainstem channel are potentially-unstable, or unstable. Sediment that is generated by landslide or debris flow activity along the valley side slopes will enter the mainstem channel. The likelihood for sediment to mobilize and become transported downstream to the fan is dependant upon meteorological inputs as well as channel gradient, confinement, and the presence or absence of barriers (such as colluvium, landslide debris, or woody debris).

Based on the hazard criteria (Appendix A), terrain that is most conducive to post-wildfire instability are the potentially-unstable and unstable slopes that are also burned at moderate to high burn severity. In the Shoudy Creek watershed, areas of moderate and high burn severity are primarily located in the upper elevation headwaters; areas that are mapped as "stable".

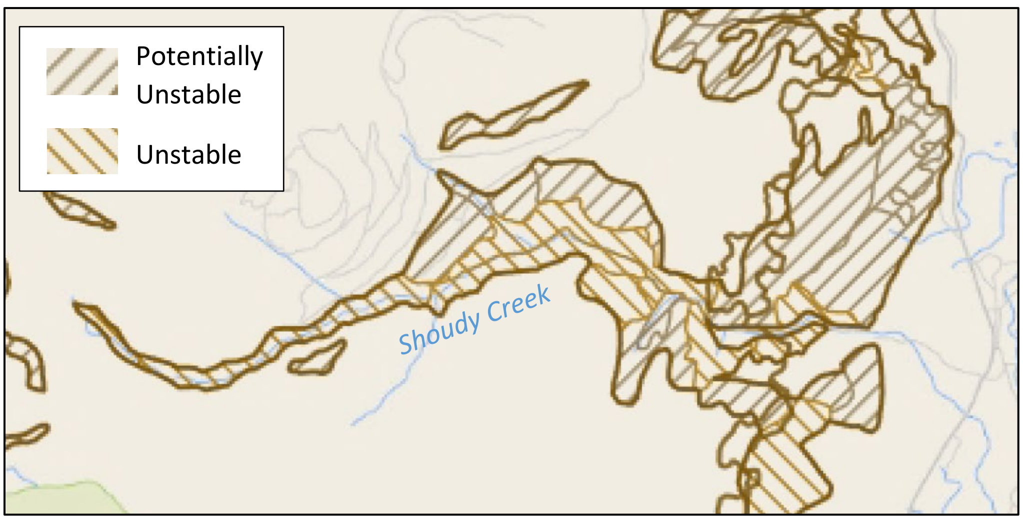


Figure 3-3: Reconnaissance-Level Terrain Stability Mapping for Shoudy Creek Watershed (Source iMAP BC)

4. 2018 Snowy Mountain Wildfire PWNHRA Results

The Snowy Wildfire burned an area of approx. 177 km^2, affecting watersheds draining north and east into the Similkameen River. The Shoudy Creek watershed was one of 13 watersheds (and 13 face units) examined as part of the 2018 PWNHRA prepared by Westrek (2018).

Vegetation burn severity mapping for the Snowy Wildfire (and for the Crater Wildfire) is shown on Map 001 (Appendix B). Based on field testing, vegetation burn severity was found to be relatively well-correlated with soil burn severity. The Westrek report also indicated that soil-water repellency was present, regardless of the degree of burn severity. This may indicate a natural condition that occurs in areas with a hot, dry climate. Soil burn severity within the Shoudy Creek watershed was not field tested for this 2024 update due to access issues into the upper watershed[2]. However, field testing done as part of the 2023 Crater Creek PWNHRA was relatively consistent with the previous findings.

The 2018 wildfire burned almost the entire watershed area (96.5%), with 36% at low burn severity, 38% at moderate, and 22% at high severity. Westrek (2018) concluded that there was a high likelihood for post-wildfire debris flood[3] and moderate likelihood for peak flow (i.e., clear water flood) effects for Shoudy Creek. The spatial likelihood of impact by debris flood and peak flow effects was estimated to determine the partial risk rating for three (3) residences and the rodeo grounds located on the fan area. The 2018 partial risk analysis, summarized in Table 4-1, found that two residences located on the west (upslope) side of Chopaka Road had a high partial risk rating.

Table 4-1: Summary of 2018 Partial Risk Analysis Results (from Westrek, 2018)

Site	Hazard Type	Hazard Rating P(H)	Spatial Likelihood Rating P(S:H)	Partial Risk Rating
560 Chopaka Road & Rodeo Grounds	Debris Flood	High	Low	Moderate
	Flood / Debris-laden runoff	Moderate	Low	Low
525 Chopaka Road 557 Chopaka Road	Debris Flood	High	Moderate	High
	Flood / Debris-laden runoff	Moderate	High	High

5. May 2023 Post-Wildfire Sediment-Laden Flood Event

On May 3, 2023, just less than 5 years after the fire, a landslide-generated debris flow occurred on Roberts (aka Moonshine) Creek, which resulted in sediment deposition onto Chopaka Road. Roberts Creek is a small catchment located immediately north of Shoudy Creek. The Roberts Creek event was investigated by G. Wells, MOF (2023) and was determined to have triggered during a period of warm temperatures resulting in rapid melt of a mid-elevation snowpack. At the time, the assessment did not specifically reference a debris flood on Shoudy Creek. However, the helicopter photos taken on May 12, 2023, and a review of Sentinel satellite imagery on May 4th and May 12th indicate that sediment deposition onto the road at the south side of Shoudy Creek alluvial fan had taken place.

The event on Shoudy Creek was a sediment-laden flood that entered multiple channels across the east and southeast side of the fan (see Map 002 and Map 003). Flows branched out from the fan apex and occupied what is now the current channel along the southern edge of the fan. It is understood that floodwaters were directed around the residence at 557 Chopaka Road by a previously constructed shallow earthen berm, and that floodwaters did not directly impact the residence at 525 Chopaka Road because of local variations in ground topography (K. Louie, *personal communication*, 2025).

[2] There are no accessible roads into the upper watershed area, nor were there any opportunities to land the helicopter during the aerial reconnaissance flight.

[3] Debris flood is defined as type of flood process described as a hybrid between a flood and a debris flow. The event involves the transport of large volumes of sediment and woody debris down gully/stream systems by large volumes of water.

The sediment-laden flood event resulted in sediment deposition on the surface of Chopaka Road in at least four places, and any existing culverts and ditch lines were plugged with sediment. Clean up and repair work was required to clear the road and to clear sediment from the culverts.

6. Updated Natural Hazard Risk Analysis

6.1 Field Observations

Field observations from June 2024 & August 2024 are documented in photographs (Appendix C) and summarized below. Due to limited access into the upper watershed, ground-based field observations were focused on the fan area.

Upper Watershed Conditions (Photos 1 and 2) indicate that the wildfire-affected headwaters remain sparsely vegetated. Gullied channels are visible but do not appear to be scoured by runoff and have not generated any debris flow activity. Upper reaches of the mainstem channel are partly incised within unconsolidated glacial drift deposits. Exposed sediment along the crest of the slope indicates small-scale instability.

Middle Watershed Conditions, shown in Photos 3 and 4, indicate that the mainstem stream channel is well-confined within a narrow valley, incised within and flanked by steep side slopes. The steep valley side slopes are relatively short (200 to 400 m long) compared to the overall width of the catchment (~3 km). Of note, and of particular significance from a natural hazard perspective, is a large debris slide located approx. 800 m upstream of the fan apex on the south side of Shoudy Creek. The debris slide is visible on all historic imagery (predating 1969) and appears to be part of an active slide complex in bedrock, characterized by shallow, chronic slide activity with direct connectivity to the channel. This is a major source of sediment to Shoudy Creek that is readily transported downstream, and because the slide is so close to the fan, sediment reaches the fan in a short period of time.

Fan Conditions (Photo 5) observed from an overview level, indicate that the relatively large fan (~70 ha) extends into the Similkameen Valley. The fan is sparsely vegetated grassland and there are multiple channels extending across the fan. Evidence of the recent (2023) sediment-laden flood activity is indicated by fresh sediment deposition and multiple scoured channels. The location of the residences and culvert washout locations on Chopaka Road are shown in Photo 5 and on Map 002 and Map 003.

At the fan apex (Photo 6) the stream channel splits, with the current active flow directed southwards. The channel is wide and shallow with abundant coarse (sand, gravel and cobble) bedload. Deciduous shrub vegetation has grown in place of the burned forest and may influence the flow pattern through the reach. Overall, the channel is aggraded and unconfined, with a high level of instability.

Downstream from the apex, the historic stream channel is deeply incised within unconsolidated sandy fan deposits (Photos 7 and 8). Although currently inactive, this channel, as well as other relict channels across the fan were activated in May 2023; a time of elevated flow.

The fan gradient ranges from ~10% near the top of the fan, to 5% mid-fan, and <5% along Chopaka Road. As the fan, and stream channels on the fan, lose gradient, the ability to transport sediment diminishes. At the top of the fan, where gradients are closer to 10%, there is evidence that cobbles and small boulders (up to 0.3 m diameter) were deposited. Closer to the road, where gradients are less than 5%, the sediment being transported by stream flows is coarse sand and small sized gravels (Photo 9). The gradient and corresponding transport capacity dictates the nature of the hazard (i.e., size of material being transported and diminishing flow depth).

Chopaka Road and Downstream Conditions are shown in Photos 10 to 17. The current channel is flowing along the south edge of the fan and at Chopaka Road there are two (2) 600 mm diameter steel culverts. These culverts were plugged during the 2023 flood event, and it is apparent that some road repairs have been completed. The inlets of the culverts remain partly inundated with sediment and damaged from the clearing activity. Downstream from the culverts, Shoudy Creek flows through a 900 mm concrete culvert within an abandoned railway embankment. The stream channel downstream from the embankment is heavily aggraded, with high erosion and instability of the embankment fill materials. GoogleEarth imagery indicates that the channel flows parallel to the embankment for ~1.4 km before reaching an irrigation ditch that eventually enters the Similkameen River.

A second stream crossing on Chopaka Road on the south side of the fan is a 600 mm diameter steel culvert that is partly inundated with sand and gravel sediment. Upstream from the culvert the channel is completely infilled with sediment associated with the 2023 event. Downstream from the culvert, the channel passes through a 900 mm concrete culvert within the old rail embankment.

6.2 Post-Wildfire Natural Hazard Assessment and Partial Risk Analysis

6.2.1 Post-Wildfire Natural Hazards

Hydrologic hazards such as debris flood and clear-water flood activity are the dominant post-wildfire natural hazards affecting the Shoudy Creek fan area.

Sixty percent of the watershed burned at moderate and high burn severity in 2018, representing a complete loss of forest cover and understory vegetation. These moderate and high burn severity areas are mostly located above ~1,400 m elevation, within the Montane Spruce and Englemann Spruce Sub-Alpine Fir biogeoclimatic zones. These elevations are characterized by a seasonal snowpack. It is the spring melt of the snowpack that drives the dominant hydrologic processes occurring in the watershed. Debris floods and floods may also occur at different times of the year and may be triggered by short-duration high-intensity convective rainstorms, by debris flows or landslides entering the mainstem stream channel, or as a result of long-duration periods of low intensity rainfall.

Wildfire effects on watershed hydrology are comparable to the effects of any large-scale disturbance such as insect attack (i.e., mountain pine beetle) and forest harvesting. The measurement of “equivalent clear-cut area (ECA)” is used as an indicator of hydrologic change and is used to estimate effects on water yield and peak flow (Winkler and Boon, 2017). ECA is defined as the cumulative area of disturbance, as a percentage of watershed area, adjusted to account for forest regrowth, or recovery. Research by Winkler and Boon (2017) indicates that watersheds with a snowmelt-dominated peak flow are highly influenced by forest cover changes that influence snow accumulation and rates of snow melt. There is an assumption that as ECA increases, so does the potential for hydrologic change. Figure 6-2, from Winkler and Boon (2017) illustrates the corresponding hydrologic effect of ECA on peak streamflow for two creeks in the Upper Penticton Creek watershed. The figure shows that a 100% ECA represents a 50% increase in the 10-yr return period daily peak flow.

For Shoudy Creek, using this same relationship, a 60% ECA (corresponding to the % area burned at moderate and high severity) corresponds with a ~22% increase in the 10-yr return period daily peak flow in the first year following the fire. Compounding the hydrologic effects associated with loss of forest, are increased solar warming due to blackened tree trunks, and the effects of fire-induced soil-water repellency on runoff rates.

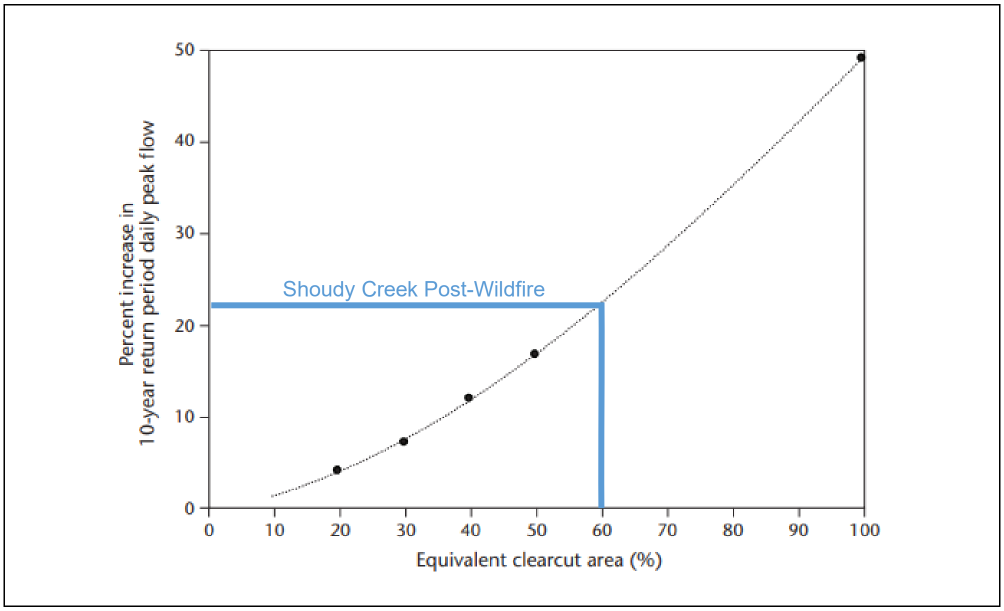


Figure 6-1: Equivalent Clearcut Area (%) Effects on Hydrology (adapted from Winkler and Boon, 2017)

Based on the high percentage area burned (96%), the high percentage area burned at moderate to high severity (60%), and the higher elevation location of these moderate/high burn areas, post-wildfire effects on hydrology are anticipated to remain high until the forest recovers.

Geomorphic hazards influencing sediment delivery and downstream sediment transport continue to be significant for Shoudy Creek because they have a profound impact on downstream channel stability across the fan. The large, bedrock debris slide located ~800 m upstream of the fan apex, is a chronic and unmitigable source of sediment to Shoudy Creek. Sediment from the slide, and from the slopes adjacent to the slide, is deposited into the channel along a confined reach with an average channel gradient of 26%. Through this reach at the slide site, higher than usual post-wildfire stream flows will undercut and incise slide deposits. This represents an unlimited source of sediment to the fan.

Along the fan, which has an average gradient of 10% near the apex, the aggraded stream channel is shallow and wide. As a result, the channel can easily lose confinement and can more easily avulse or rapidly shift pattern. There is a high degree of uncertainty with respect to future channel pattern and this uncertainty starts at the fan apex, continuing downstream across the fan area. Currently, the active channel flows along the southern fan edge towards Chopaka Road. However, sediment delivery into the channel at the top of the fan could change the alignment very quickly, resulting in a completely different channel alignment in a very short period. Historic and currently inactive (dry) channels on the fan may become active during high flows, delivering water and sediment downstream.

Based on the review of watershed conditions, the current post-wildfire natural hazard levels for both flood and debris flood hazards are considered to be HIGH.

6.2.2 Spatial Likelihood of Impact and Partial Risk Analysis

The 2023 flood event confirms that the two residences located on the west (upslope) side of Chopaka Road were, and continue to be, exposed to flood and debris flood hazards. Previous flood impacts, and the re-evaluated spatial likelihoods of impact at the identified Elements at Risk are as follows:

- At 557 Chopaka Road – floodwaters were directed around the residence by a shallow earthen berm. The level of protection offered by the berm is not well understood. Thus, the spatial likelihood of impact by clear-water flood remains HIGH. Because coarse sediment and debris associated with debris flood are likely to have settled out before reaching the residence located at the downslope part of the fan, the spatial likelihood of impact from debris flood at this site is rated MODERATE;
- At 525 Chopaka Road – floodwaters were directed around the residence by topographic variation. Because the previous flood has altered minor topographic variation across the fan, more information is required to assess the current level of exposure to flood hazard. For the reasons stated above, the spatial likelihood of impact by clear-water flood remains HIGH and the spatial likelihood of impact from debris flood is rated MODERATE;
- All culverts along Chopaka Road were plugged with sediment, and the road was rendered impassible in at least two locations due to sediment-laden flow overtopping the road. The spatial likelihood of flood impact to Chopaka Road and associated drainage structures remains HIGH; and,
- 560 Chopaka Road and the rodeo grounds, located on the east (downslope) side of Chopaka Road were not impacted by the 2023 flood. Due to their location at the distal extent of the fan, the spatial likelihood of impact by flooding and debris flood is rated LOW.

The updated partial risk analysis is presented in Table 6-1. The updated analysis indicates a high to very high partial risk of impact by debris flood or flood hazard to the properties located on the upslope side (west) of Chopaka Road. There is also a very high partial risk rating assigned to Chopaka Road and the associated drainage structures. For properties located on the downslope side (east) of Chopaka Road, the partial risk rating is moderate.

Table 6-1: Updated (2024) Partial Risk Analysis for Shoudy Creek

Site	Hazard Type	Hazard Rating P(H)	Spatial Likelihood Rating P(S:H)	Partial Risk Rating
560 Chopaka Road & Rodeo Grounds	Debris Flood	High	Low	Moderate
	Flood / Debris-laden runoff	High	Low	Moderate
525 Chopaka Road & 557 Chopaka Road	Debris Flood	High	Moderate	High
	Flood / Debris-laden runoff	High	High	Very High
Chopaka Road & Drainage Structures	Debris Flood	High	High	Very High
	Flood / Debris-laden runoff	High	High	Very High

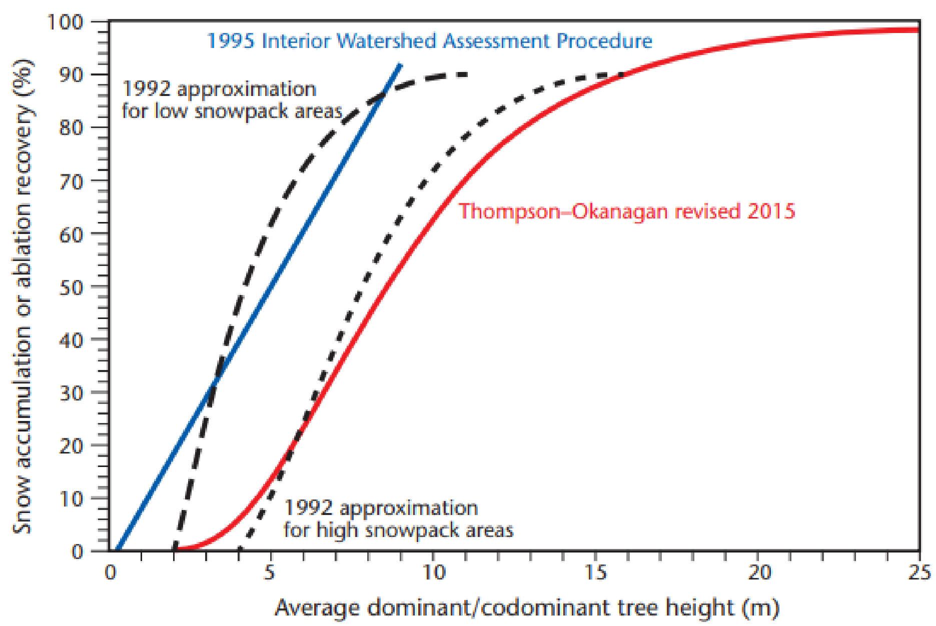
6.3 Expected Duration of Post-Wildfire Effects on Natural Hazards

6.3.1 Hydrologic Recovery

Hope, et al. (2015) indicate that post-wildfire effects on hydrology increase in the first two to three years following wildfire and then decrease in time after that. Hydrologic effects are expected to persist beyond 5 years until vegetation in the watershed approaches a state of recovery, or when the structure of the new forest approaches a pre-wildfire condition, which could be several decades post wildfire (Hope, et al., 2015; Jordan, 2016).

As the forest recovers from disturbance the effect on peak flow diminishes. Winkler and Boon (2015) provide a "recovery curve" for the Southern Interior (see Figure 6-2), which indicates that for a spruce-fir and lodgepole pine forest, 90% recovery is expected once regrowth is ≥65% of the original stand height of 25 m, which corresponds to approx. 16 m.

For Shoudy Creek, based on approximate rates of recovery and rates of tree growth for the Southern Interior, the time to reach a 15 m stand height, representing ~20% ECA, is in the order of 50-60 years.



Source: Winkler and Boon (2015)

Figure 6-2: Hydrologic Recovery associated with Tree Growth

6.3.2 Duration of Wildfire Effects on Soils

Research on the persistence of wildfire-induced water repellent soils indicates that it is site specific, dependent upon the strength and extent of hydrophobic chemicals in the soil and the physical and biological factors affecting the breakdown of these chemicals. MacDonald and Huffman (2004) showed rapid deterioration of soil-water repellency after 1 year, particularly when there is prolonged contact with moisture, while others found that conditions may persist for up to 6 years, recurring in subsequent dry seasons (DeBano, 1981) (Curran, et al., 2006).

For Shoudy Creek, water repellent soils were most likely to occur in conjunction with the areas burned at moderate and high burn severity. These areas are located at mid- to upper elevations, where a seasonal snowpack provides moisture and where there is some observed vegetation (grasses) recovery. Thus, it is anticipated that, over the past 6 years, the wildfire-induced soil-water repellency in Shoudy Creek has diminished to the point where effects on surface runoff have also lessened. Ground-based data is required to further refine what is known about current soils conditions.

6.4 Climate Change Considerations

Changes in climate are already being experienced within the study area. These observed changes are considered in the post-wildfire hazard assessment. For example, temperature-induced snowmelt and localized precipitation events in the previous few years have resulted in debris flood and sediment-laden flows reaching fans of watersheds impacted by wildfire.

The *Climate Projections for the Okanagan Region* document (RDNO, RDCO, RDOS and Pinna Sustainability, 2020), projected climate changes for the South Okanagan for the 2050s (2040-2069) in comparison to a 1961-1990 baseline period. The results indicate the following:

- Total precipitation is expected to **increase by 10% to 13%** for the spring and autumn seasons, but summer precipitation expected to **decrease (-14%)**.
- Of relevance to this study, the frequency of intense precipitation is expected to increase, as is the associated precipitation amount. Namely, the 1 in 20 wettest-day of the year[4] is expected to **increase by 18%**, from an average of 33 mm to 39 mm.

Similar increases in precipitation are shown in model results examined using the PCIC Climate Explorer[5]. The maximum 1-day precipitation increases from the historical (1981-2010) to the modelled (2040-2069) by **8%** and the 5-year annual maximum 1-day precipitation increases by **4%**.

The effects of a changing climate, including warmer temperatures and increased frequency and magnitude of short-duration high intensity precipitation, are anticipated in the near-future. Provisions for a changing climate should be incorporated into future designs for mitigative measures, culverts, and other drainage structures.

7. Summary and Conclusions

The Shoudy Creek watershed was extensively burned (96% of total area), with a high (60%) proportion that burned at moderate and high burn severity, representing complete loss of forest cover and understory vegetation. Based on an updated review of watershed conditions, the current post-wildfire natural hazard levels for both flood and debris flood hazards in the Shoudy Creek watershed are rated HIGH. High hazard is defined as “an event is probable under adverse conditions” with a corresponding estimated annual probability of occurrence of 0.01 to 0.2 (or between a 1 in 5-year to a 1 in 100-year return period).

[4] 1 in 20 wettest day is an indicator of extreme weather. The likelihood of a single-day rainfall of this magnitude occurring in any given year is 1 in 20, or 5% chance.
[5] Pacific Climate Impacts Consortium URL: services.pacificclimate.org/pcex

Although it is estimated that the effects of wildfire-induced soil-water repellency in Shoudy Creek have diminished, the loss of mid- to high-elevation forest cover represents an ongoing hydrologic hazard. The hydrologic effects are anticipated until the forest recovers. Based on a rough estimation of recovery rates, it is estimated that it may take 50-60 years for the watershed to fully recover.

Ongoing instability of a large debris slide along the canyon reach of Shoudy Creek upstream of the fan apex continues to affect channel stability across the fan. A recent (May 2023) snowmelt-driven flood event on Shoudy Creek resulted in sediment-laden flows occupying multiple channels on the fan, many of which were pre-existing historic avulsion channels. Due to low channel confinement and high sediment load, the updated analysis indicates a high to very high partial risk of impact by debris flood or flood hazard to the properties located on the upslope side (west) of Chopaka Road, and to Chopaka Road and its associated drainage structures.

The following measures will reduce the spatial likelihood of impact to a low level, which would reduce the partial risk to a moderate level. These measures include the following:

1. Install measures such as protective berms near the affected structures at 525 and 557 Chopaka Road. Protective berms are most easily designed and effective when placed near the structures that are located further down the fan. Upslope, towards the fan apex, mitigation measures would require considerable design and construction effort and would require frequent maintenance due to the high sediment load.

2. Improve drainage along Chopaka Road. Better defined roadside ditches along Chopaka Road and oversized cross-drains that accommodate increased flows and allow sediment transport are recommended. The oversized culverts, or arch culverts, would replace the existing structures shown on Maps 002 and 003 and additional cross-drains may be suitable at the other avulsion sites located to the north along the fan. It is recommended that a Qualified Professional be engaged to determine appropriate sizing and placement. Annual inspection and monitoring are recommended after significant rainfall or snowmelt events, with subsequent maintenance of drainage structures as required to ensure clear passage.

   The concrete culverts along the abandoned railway embankment do not appear to constrict flows and, although erosion and undercutting of the embankment is taking place, there is little rationale to remove them at this time.

3. Complete hydrologic analysis and inundation modeling. In the long-term, it may be beneficial to understand the hydrology and flow across the fan. Further analysis is required to determine the design flows and inundation flow depths and velocities. However, this work is probably not required if the purpose is only to protect the two structures located on the fan.

8. Closure and Limitations

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The assessment has been carried out in accordance with generally accepted professional practices in BC. Professional judgment has been applied in the interpretations provided in this report. The conclusions and recommendations presented in this report are based on available information, limited field investigation, and professional opinion. Inherent variability in local precipitation, runoff, soil and vegetation burn severity, surface and subsurface soil conditions, may create unforeseen situations.

This report is subject to the CGL General Conditions and Terms of Use, presented in Appendix D.

Prepared by:

CLARKE GEOSCIENCE LTD.

Jennifer Clarke, M.Sc., P.Geo.
Project Manager and Geomorphologist
Permit to Practice #1000143

In accordance with Professional Practice requirements, this report has been reviewed by Tim Giles, P.Geo., Senior Geoscientist with SNT Geotechnical Ltd.

Enclosures:

Appendix A CGL Partial Risk Analysis Approach for Post-Wildfire Natural Hazards
Appendix B Map 001, Map 002, and Map 003
Appendix C Select Photographs
Appendix D CGL General Conditions and Terms of Use

References

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Appendix A CGL Partial Risk Analysis Approach for Post-Wildfire Natural Hazards

Appendix A – CGL Partial Risk Analysis Approach for Post-Wildfire Natural Hazards

The following describes the risk analysis approach used for post-wildfire natural hazards and provides definitions of the technical terms used. The approach is adopted from, and described in more detail in, Land Management Handbook No. 69 (Hope, et al., 2015), Land Management Handbook No. 56 (Wise et al., 2004), and the EGBC Landslide Assessment Guidelines (2023).

The term "partial risk" refers to the probability of a specific hazardous event affecting an element at risk. Partial risk analysis differs from a Total Risk analysis as it does not estimate the damages that may occur because of an impact (i.e., vulnerability). Partial risk assumes that any encounter is undesirable.

Partial risk is expressed as:

$$P(HA) = P(H) \times P(S{:}H) \times P(T{:}S)$$

where:
$P(HA)$ is the partial risk;
$P(H)$ is the likelihood of a hazardous event occurring;
$P(S{:}H)$ is the spatial likelihood that the hazardous event will reach the element at risk;
$P(T{:}S)$ is the temporal likelihood that the element at risk will be at the site if the hazard event occurs.

For fixed or stationary structures such as buildings and roads, the temporal probability [$P(T{:}S)$] is equal to 1 and the above equation is reduced to:

$$P(HA) = P(H) \times P(S{:}H)$$

Partial Risk = **Hazard** (likelihood of a hazardous event) x **Spatial Likelihood** (likelihood that event reaches and otherwise affects the Element at Risk)

Each component of risk is defined below.

Hazard P(H) – is defined as a process that has the potential to damage, harm, or cause other adverse effects to human health, property, the environment, or other things of value (CSA, 1997). With respect to post-wildfire natural hazards, these may include landslides, soil erosion, rockfall, debris flow, debris flood, sediment-laden flow, or other natural geological processes.

Hazard levels that pertain to specific hazardous events may be expressed in qualitative, or relative, terms. For the purposes of this project, qualitative descriptors and corresponding probability ranges for post-wildfire natural hazard likelihood (P(H)) are provided in Table A1 below. For each hazard level, there is corresponding annual probability of occurrence (Pa) and an associated return period in years (1/Pa).

Table A1: Natural Hazard Levels (Likelihood of a Hazardous Event) Defined

Hazard Level P(H)	Qualitative Description	Hazard Criteria	Annual Probability of Occurrence (Pa), or Return Period
Very High	An event is expected to occur over a 5-year period.	• Most of the catchment has burned with a significant proportion burned at moderate and/or high severity. • Evidence of pre-fire terrain instability within stream channels, on fans or face units. • Post-fire instability observed on similar terrain nearby.	>0.20 (greater than 1 in 5 yr)
High	An event is probable under adverse conditions.	• Most of the catchment has burned with a significant proportion (i.e. >50%) of terrain conducive to post-wildfire natural hazard initiation burned at moderate and/or high severity. • Indicators of pre-fire terrain instability within stream channels, on fans or face units.	0.01-0.20 (1 in 5 yr to 1 in 100 yr)
Moderate	An event could occur under adverse conditions – it's not probable, but possible over a several year period.	• More than 20% of the terrain conducive to post-wildfire natural hazards in the catchment area was burned with moderate and/or high severity. • Historic geomorphic indicators of instability are present.	0.002-0.01 (1 in 100 yr to 1 in 500 yr)
Low	An event could occur under very adverse conditions – it's considered very unlikely to occur over a several year period.	• Only a limited proportion of the catchment was burned during the fire. • Few or no signs of pre-fire instability are present within stream channels, on fans, or face units.	0.0004-0.002 (1 in 500 yr to 1 in 2,500 yr)
Very Low	An event will not occur; or is conceivable though considered exceptionally unlikely over a several year period.	• A limited proportion/none of the catchment was burned during the fire. • No terrain instability indicators are present.	<0.0004 (less than 1 in 2,500 yr)

from PWNHRA Contract Schedule A – Services, modified from Wise, et al., 2004; and EGBC, 2023

Spatial Likelihood P(S:H) – is defined as the likelihood that a specific hazardous event reaches and otherwise affects the identified Element at Risk. Relative levels of spatial likelihood are expressed in qualitative, or relative, terms as defined in Table A2 below.

Table A2: Spatial Likelihood Levels (Likelihood that the Hazardous Event Reaches or Affects the Specified Element at Risk) Defined

Spatial Likelihood Level P(S:H)	Probability Range	Qualitative Description (*from PWNHRA Contract Schedule A – Services, modified from Wise, et al., 2004*)
High	>0.5	It is probable that the Element at Risk will be impacted by the hazard. The Element is located within the zone of impact of the hazard being evaluated.
Moderate	0.5-0.1	It is possible that the Element at Risk will be impacted by the hazard. The Element at Risk is located at the distal end of the runout zone or zone of impact of the hazard being evaluated.
Low	<0.1	It is unlikely that the Element at Risk will be impacted by the hazard being evaluated.

Elements at Risk – are defined as the population, building or engineering works, utilities, infrastructure, water quality, and environmental features such as fish and fish habitat in the area potentially affected by the hazards being assessed.

Partial Risk P(HA)- is defined as the probability that a specific hazard, such as a landslide, debris flow, or rockfall event, will occur and the probability of it impacting a site occupied by a specific Element at Risk. Partial risk may be evaluated quantitatively using probabilities, or, as in the case for this assessment, qualitatively using relative ratings and a partial risk matrix (Table A3).

Table A3: Qualitative Post-Wildfire Natural Hazard Partial Risk Matrix

Partial Risk P(HA): the probability that a specific hazard will occur and the probability of it impacting a site occupied by a specific Element at Risk (i.e., P(HA) = P(H) x P(S:H))		Spatial Impact Likelihood P(S:H) – the probability (likelihood) that the hazard will reach or otherwise impact the site occupied by an Element at Risk (see Table A2).		
		High	**Moderate**	**Low**
P(H) – the annual probability (likelihood) of occurrence of a post-wildfire natural hazard (i.e. landslide, debris flow) (see Table A1)	**Very High**	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low
	Very Low	Low	Very Low	Very Low

There are five possible outcomes, or partial risk levels, from the partial risk analysis (see Table A4). These risk levels do not imply a threshold level of risk acceptability or tolerance, as this may vary depending on the element being considered. General implications of the qualitative partial risk ratings are derived from LMH 69 (Hope, et al., 2015) and adapted from LMH 56 (Wise et al., 2004). Ultimately, risk acceptability is to be determined by the land manager or owner. This task is referred to as risk evaluation.

Table A4: Implications of Qualitative Partial Risk Ratings

Partial Risk Rating	**Evaluation** **(*from PWNHRA Contract Schedule A – Services*)**
Very High	Unacceptable risk typically requiring site-specific detailed investigation, planning and implementation of mitigative treatments recommended to reduce the partial risk to a more acceptable level. May be very expensive or impractical. Consider avoidance.
High	Usually unacceptable and typically requiring site-specific detailed investigation, planning and implementation of mitigative treatment recommended to reduce the partial risk to a more acceptable level.
Moderate	This risk may or may not be tolerable, depending on the risk acceptability criteria of the stakeholder or decision maker. The risk may be accepted and monitored. Treatment plans may be developed to reduce the hazard. Additional investigation and planning for treatment or mitigation options may be pursued.
Low	Usually acceptable, treatment or additional investigation may still be pursued at the discretion of the stakeholder or decision maker.
Very Low	Acceptable.

References:

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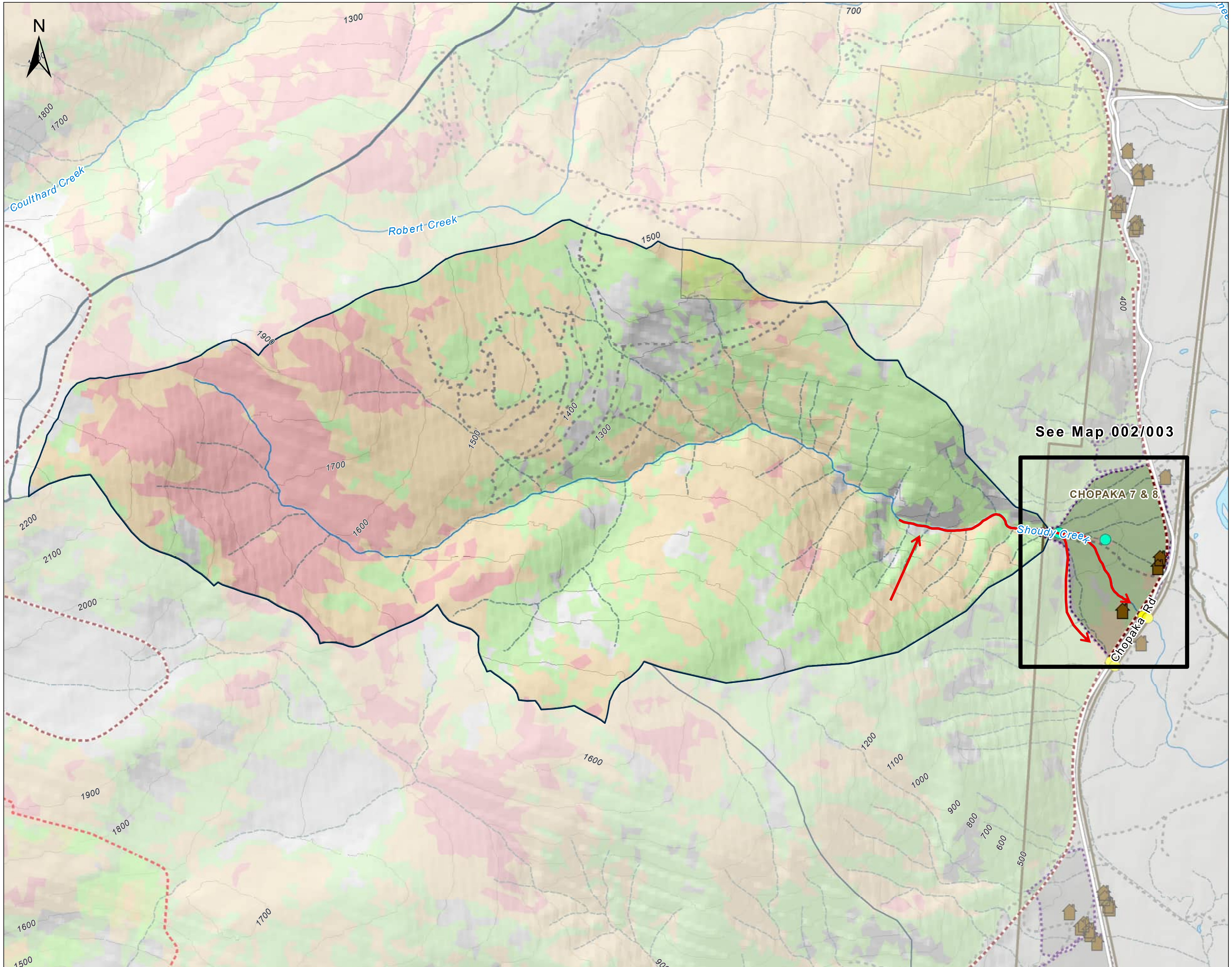
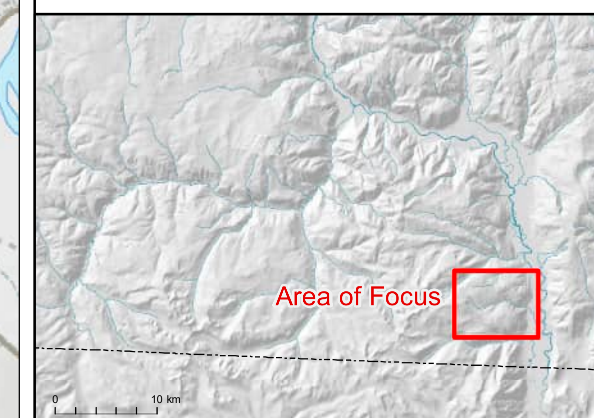
Appendix B Maps





LEGEND

- First Nations Reserve
- Cadastral Fabric (Private Land)
- 2023 Crater Creek Wildfire (K52125)
- 2018 Snowy Mountain Wildfire (K51238)
- Catchment / Sub-basin
- Alluvial Fan
- Recent (post-2018 and post-2023) Post-Wildfire Hazard Events (Landslides, Debris Flows and Sediment-Laden Flooding)
- Structure
- Major Stream Crossing
- Active Water Point of Diversion (POD) (Domestic)

Vegetation Burn Severity (Source: BC Data Catalogue)

- High
- Medium
- Low

Roads (Source: Data BC Digital Roads Atlas)

- Highway / Road
- Resource Road / Trail
- Trail / Unclassified

300 150 0 300 600
metres

Client:
MINISTRY OF FORESTS - BC WILDFIRE SERVICE

Project:
POST-WILDFIRE NATURAL HAZARD RISK ANALYSIS UPDATE

Title:
SHOUDY CREEK WATERSHED

Scale: 1:25,000	NAD 1983 UTM Zone 11 U	Map No. 001
Project No: 24-0103	Date: June 17, 2025	

Clarke Geoscience Ltd.

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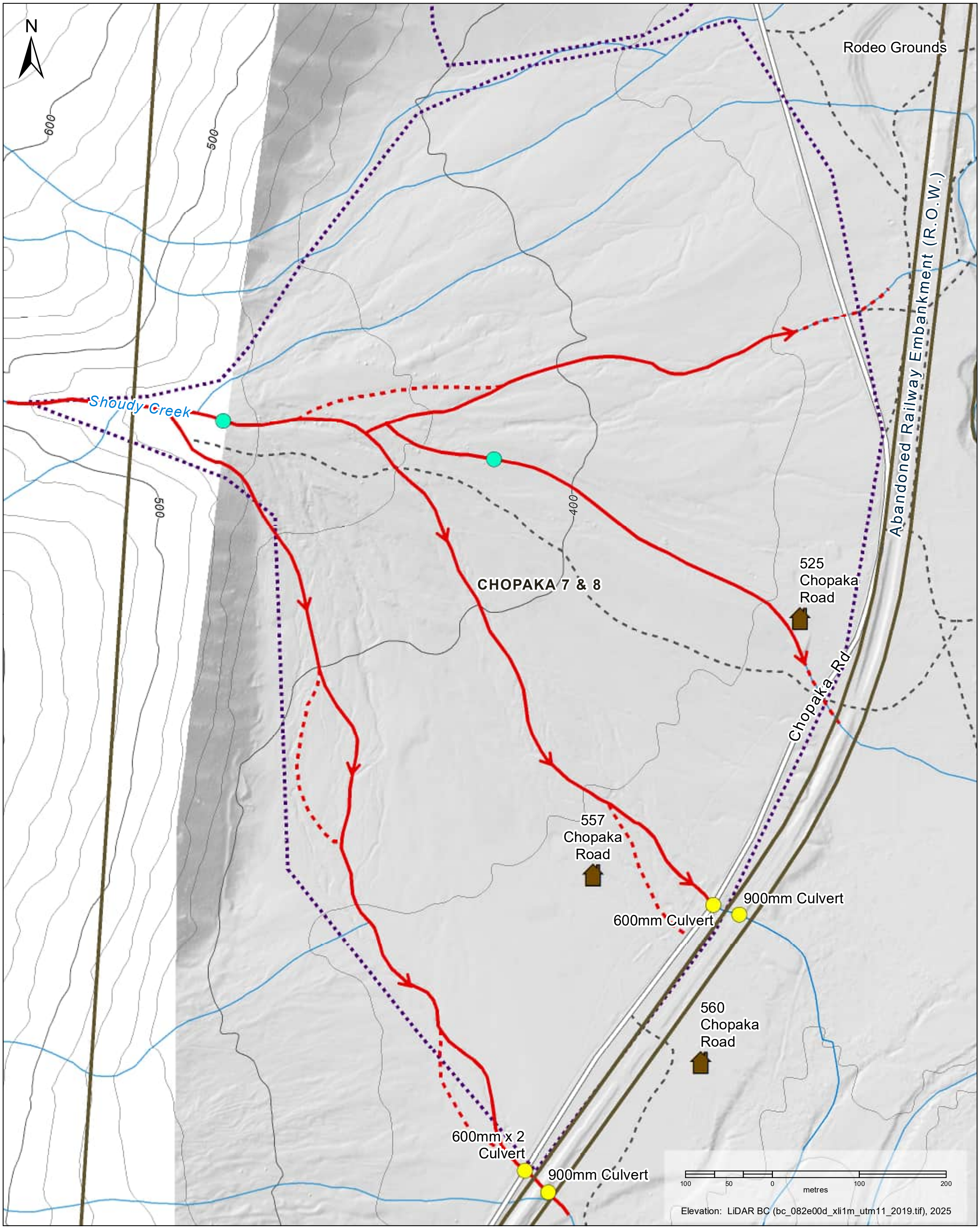

- First Nations Reserve
- Alluvial Fan
- Watercourse (Source: DataBC)
- Approximate Flow Path of the May, 2024 Sediment-Laden Flooding Event
- Trail (Source: DataBC)
- Structure
- Culvert
- Active Water Point of Diversion (POD) (Domestic)

Title:

SHOUDY CREEK FAN AREA

Scale: 1:6,000	NAD 1983 UTM Zone 11 U	Map No.
Project No: 24-0103	Date: June 17, 2025	002

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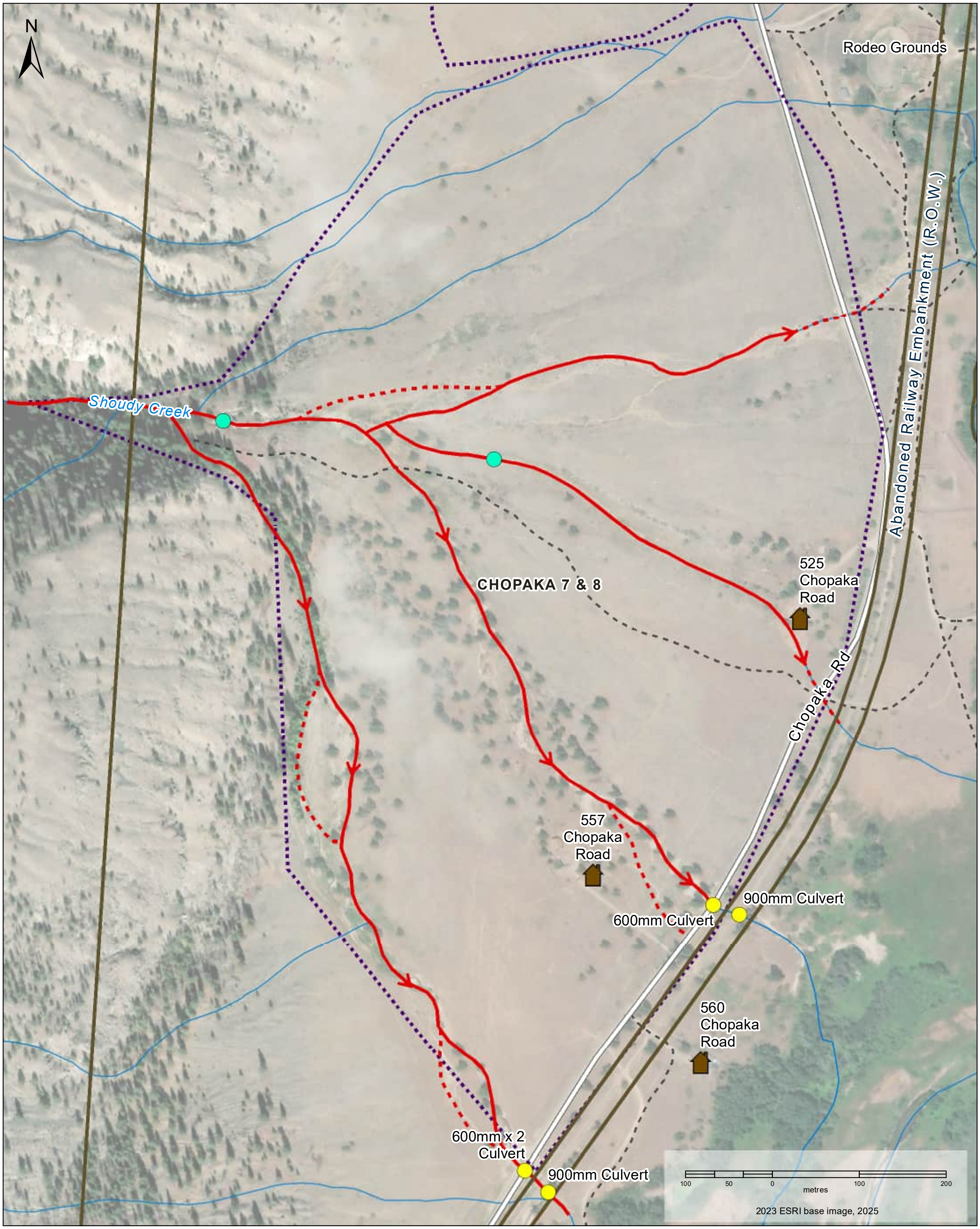

Legend	
First Nations Reserve	Trail (Source: DataBC)
Alluvial Fan	Structure
Watercourse (Source: DataBC)	Culvert
Approximate Flow Path of the May, 2024 Sediment-Laden Flooding Event	Active Water Point of Diversion (POD) (Domestic)

Title:

SHOUDY CREEK FAN AREA

Scale: 1:6,000	NAD 1983 UTM Zone 11 U	Map No.
Project No: 24-0103	Date: June 17, 2025	003

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Appendix C Selected Photographs

APPENDIX C – SELECT PHOTOS (Shoudy Creek Watershed)

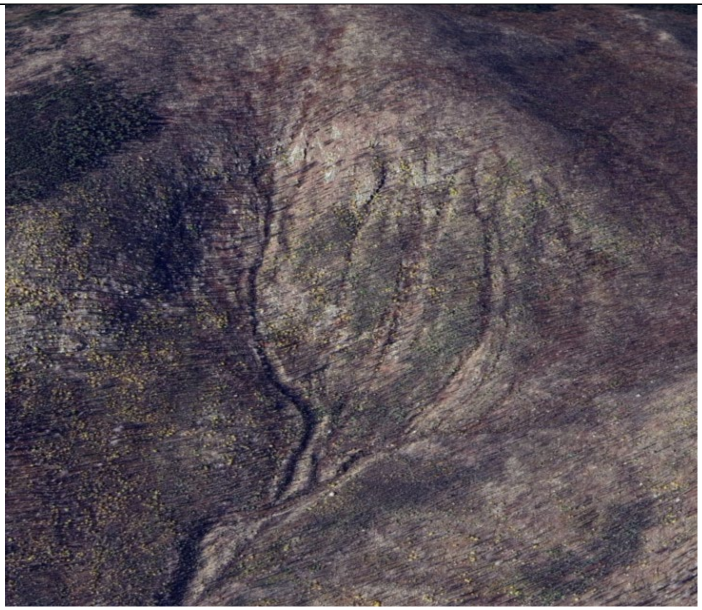

Photo 1: Overview of upper Shoudy Creek watershed, looking northeast. Note burned forest and gullied channels. (from GoogleEarth)

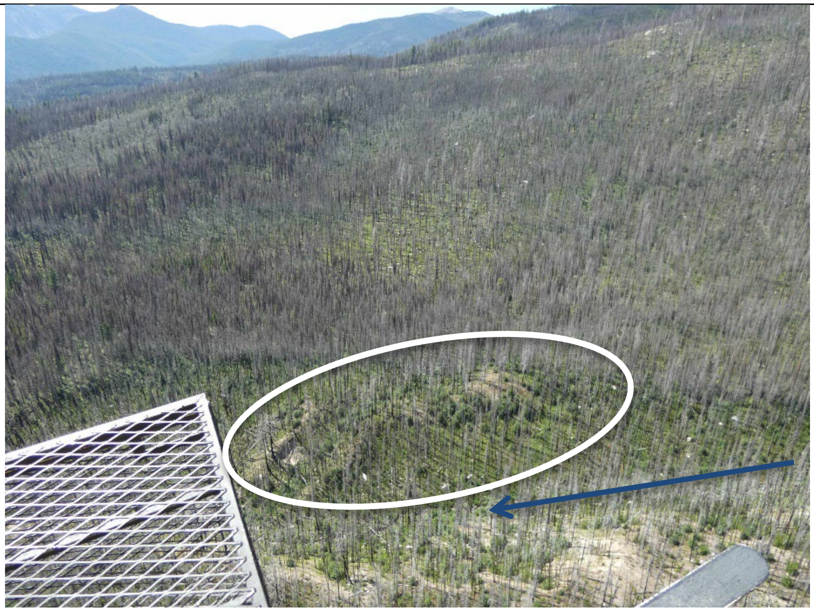

Photo 2: Burned headwaters of Shoudy Creek and observed terrain instability (circled) along incised reaches. Note, channel is visible at the bottom of photo (arrow).

Photo 3: View of mid-slope areas of Shoudy Creek showing tight connection of valley side slopes.

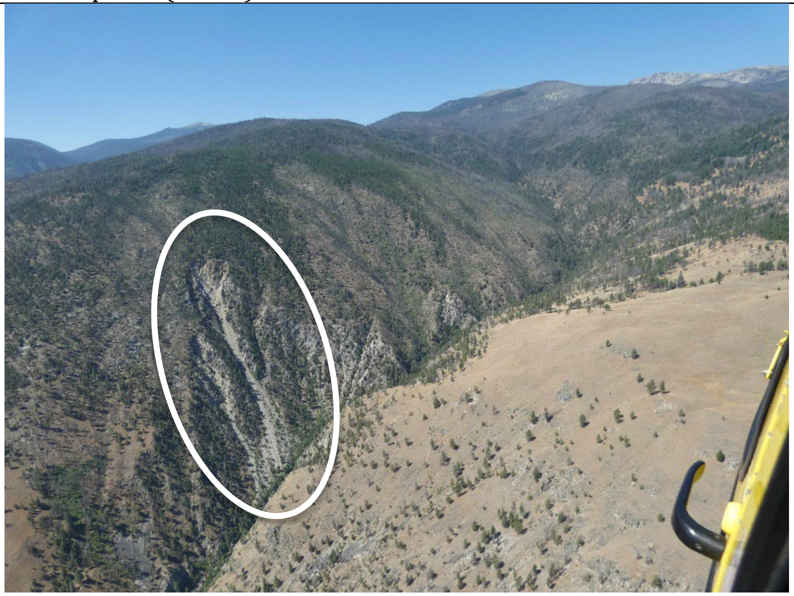

Photo 4: View of large debris slide located ~800 m upstream of Shoudy Creek fan (circled). Recent instability indicated by fresh rock exposure.

Photos taken in August 2024

Photo 5: Shoudy Creek fan area showing multiple channels (arrows) that experienced recent sediment-laden flooding resulting in impacts to Chopaka Road. Note residences and rodeo grounds (white circles). May 2023 washout locations shown in Photos 6 to 9 are circled in red. Source image from GoogleEarth. See area mapped in Map 002 and Map 003.

Photo 6: Shallow stream channel at fan apex with abundant sediment (sand, gravel and cobble) and deciduous vegetation. Mature forest burned by 2018 fire. Photo taken at flow split at top of fan.

Photo 7: View downstream along dried up channel in upper part of fan. Note deep incision, vertical unconsolidated stream banks, and severed irrigation pipe.

Photo 8: View upstream along historic channel on fan area. Note incised banks and abundant coarse bedload material.

Photo 9: View upslope along fan showing shallow, sediment-laden, unconfined avulsion channel attributed to 2023 washout at Chopaka Road from Shoudy Creek. Southern-most washout location.

Photo 10: Current path of dominant flow (photo taken in June 2024). At 2023 washout location, inlet of two 600 mm diameter culverts on Chopaka Road.

Photo 11: Outlet of two 600 mm diameter culverts on Chopaka Road.

Photo 12: View upslope along Shoudy Creek fan showing shallow, sediment-laden channel at Chopaka Road (June 2024). Note sandy gravel soils.

Photo 13: Immediately downstream from Chopaka Road, Shoudy Creek flows through a 900 mm diameter concrete culvert passing through old rail embankment.

Photo 14: Downstream side of rail embankment (left) on Shoudy Creek showing high erosion and instability.

Photo 15: View of 600 mm diameter culvert at Chopaka Road along abandoned channel that was inundated during 2023 flood event.

Photo 16: View upstream from 600 mm culvert. Note abundant sediment (gravely sand) associated with 2023 debris flood event.

Photo 17: 900 mm diameter concrete culvert under old railway embankment downstream from culvert in Photo 17.

Appendix D CGL General Conditions and Terms of Use

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