Burned Area Emergency Response (BAER)

Norse Peak and American Fires

Geology: Landslides

Snoqualmie Ranger District - Mount Baker-Snoqualmie National Forest, Washington

Naches Ranger District - Okanogan-Wenatchee National Forest, Washington

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Introduction

A rapid Burned Area Emergency Response (BAER) assessment was conducted to evaluate the public hazard from landslides and debris flows from the Norse Peak and American Fires. Hazards assessed include landslides, debris flows, and flooding that may adversely impact public safety and (or) infrastructure. Of these potential hazards, debris flows and flash flooding pose the greatest risk to public safety and infrastructure. Wildfire can significantly change the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash floods and debris flows. Areas downstream of slopes burned by fire were assessed for historic evidence of debris flow impacts using field reconnaissance, GIS interpretation of lidar (when available), and informed by local knowledge of past post-fire erosional events. Field observations were performed to evaluate the characteristics of surficial deposits, hillslope conditions, and channel bed material, gradient, and confinement. This is a qualitative assessment based on our professional judgement and experience and was performed as part of the emergency response efforts of the U.S. Forest Service.

Geologic observations, interpretations, and recommendation are summarized herein. The focus of this assessment is to the fire's overall effect across all ownerships and to the potential downstream impacts of debris flows. The objectives of this report are to:

1. Identify debris flow hazards potential affected by the fire.
2. Identify both emergency and long-term actions that could mitigate potential hazards.

Background

Thirteen fires were ignited by lightning on August 10th and 11th, in the vicinity of the William O. Douglas and Norse Peak Wilderness Areas on the Naches Ranger District of the Okanogan-Wenatchee National Forest. The fires were burning in steep rocky terrain, with difficult access. Two of the fires reached significant size: the Norse Peak Fire (north of State Route (SR) 410 near Union Creek) and American Fire (between SR410 and Bumping Lake).

Methods

Assessment of past evidence of debris flows and the potential impacts from debris flows at locations intersecting infrastructure and public safety were reliant upon observations in the field, lidar (where available) interpretation, unsupervised Burned Area Reflectance Classification (BARC) mapping, and ortho imagery. Field assessments were performed on October 2 and 9, 2017 and focused exclusively on impacts to areas outside of the Norse Peak and American Fires. Observations were focused on areas downstream of the fires where a channelized debris flow may travel and intersect campgrounds, highways, buildings and structures, and other areas where public safety is a concern. Our observations were compared to the USGS website Emergency Assessment of Post-Fire Debris-Flow Hazards[1] mapping to further evaluate where debris flows may be a concern. Though in some areas we briefly discuss flooding and soils, a detailed description of fire effect on soils and hydrology can be found in the related narratives in the final BAER report.

Hillslope Processes

Soils impacted by fire, especially those on steep slopes and in areas of high burn severity, are prone to surface erosion by water and wind when bare of a protective vegetative cover. Hydrophobic (water

[1] https://landslides.usgs.gov/hazards/postfire_debrisflow/index.php

repellant) soil conditions from fire can increase water runoff potential by repelling water from infiltrating into the subsurface, thus intensify the amount and rate of runoff produced during a storm event. When effective ground cover has been denuded after intense fire, soils are exposed to erosive forces such as raindrop impact, runoff can become rapid and erosion accelerated, and overland flow can result in rills and gullies that signify an accelerated rate of surface erosion. The steepest slopes are most prone, particularly where soils are shallow, are somewhat hydrophobic, or where there is a restrictive subsurface layer such as bedrock. Soils that have developed in volcanic ash and glacial till are easily detachable, having low cohesion and structure, and relatively low amounts of organics and moderately thin topsoil horizons.

On the steepest of slopes, the risk of debris flows can be high when runoff is channelized. Shallow soils on steep slopes in first- and second-order (Strahler stream order) headwater drainages are most prone to debris flows. The probability of debris flows is typically relative to hillslope gradient, channel convergence, available fine sediments, severity of hydrophobic soil conditions, the removal of a protective canopy and diminished root strength by fire, and the occurrence of a notable storm or precipitation event(s). Weather events that generate heavy precipitation and runoff in the area typically are associated with seasonal convective thunderstorms. Culmination of debris flows are usually associated with steep drainages and channels where sediment is routed downslope. If a debris flow does initiate, it will likely transform to a flash flood due to decreasing channel gradient, less convergent channel, or entraining sufficient water – all effectively decreasing the amount of sediment within the moving mass and changing the physical attributes of the debris flow.

Debris flows and flash floods

Debris flows have a specific, geologic definition that is often misused by media, the public, and scientists. Most observed “debris flows” are actually debris-laden flash floods or “hyperconcentrated flows.” In the following sections, we attempt to explain the differences between a debris flow and a sediment-laden flash flood.

Flash floods, especially those that originate from recently burned areas, are often described as “debris flows” due to the appearance of sediment-laden water transporting woody and vegetative debris, trash, and carrying gravel, cobbles, and occasionally boulders. Though “debris flow” may be an observer’s description of the event, a true debris flow has specific properties, behaviors, and characteristics that significantly differentiate them from flash floods. What are often describe as a “debris flow” are actually a sediment-rich flash flood called a hyperconcentrated flow (HCF). A HCF is the transition between a flash flood and debris flow. One way geologists differentiate the three is by the percent of sediment (by volume) carried by the flowing water, so a flood contains less than 5 percent sediment by volume, a HCF is around 5 to 60 percent sediment by volume, and a debris flow exceeds 50 percent sediment by volume.

Debris flows are often described as appearing similar to flowing, wet concrete and travel quickly in steep, convergent channels. Debris flow speed may exceed that of the water flowing in the same channel. A moving debris flow can be very loud because they can buoy cobbles, boulders, and debris to the front and sides of the moving debris flow. The sound is often described as similar to that of a freight train and may cause the ground to vibrate. In the post-fire situation, a debris flow may start as a flash flood surge that entrains (picks up) sufficient sediment to transform into a HCF and, if conditions are suitable, (typically very steep and convergent slopes with significant, unconsolidated sediments) can transform into a debris flow.

Evidence of debris flow deposits tend to be distinct and include channel-adjacent levees of gravel, cobbles, and boulders; channel-adjacent trees display upslope damage such as scarring to bark from rock or debris impact; mud and gravel may be splashed onto trees and other channel adjacent objects; and (or) debris flow deposits that display coarse gravel, cobbles, and boulders "suspended" in fine-grained sediments (sand and finer).

The USGS provided models of post-fire debris-flow likelihood, volume, and hazard for the fire and this data can be downloaded or viewed on the USGS website Emergency Assessment of Post-Fire Debris-Flow Hazards[2]. The modeling calculates debris flow hazards with a range of precipitation storm scenarios and we opted to analyze the 15 minute, 24 millimeters (0.94 inches) storm intensity, the same storm event that the USGS displays on their webpage.

Debris flow and flooding hazards

Because of the ability of a debris flow to buoy cobbles, boulders, and woody debris to the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure. The hazard is typically limited to first and second order channels, so exposure by the public may be limited in wilderness areas and forestlands. The hazard of HCF and flash floods should not be discounted because they are not debris flows. Both flash floods and HCF can mobilize large volumes of woody debris and HCF can transport large volumes of coarse sediment. Both flash floods and HCF can inundate areas not typically wetted by regular flows, so channel-adjacent roads, trails, building, and other infrastructure can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation.

Alluvial Fans

Alluvial fans are low-gradient, cone-shaped deposits built by deposition of sediment and debris that accumulate immediately below a significant change in channel gradient and (or) valley confinement, such as a canyon or steep channel that drains from mountainous terrain and emerges onto a low gradient area such as a flood plain. Sediment on the alluvial fan is deposited by streams, floods, HCF, and (or) debris flows and are typically sourced from a single channel. Over time the alluvial fan stream will migrate across the fan surface to occupy many areas. The migrating stream commonly form distributary channels that branch across the surface and do not rejoin as water flows down the fan. On varying time scales, the channel(s) will change location on the fan, seeking a lower elevation away from where it has most recently been depositing sediment. Due to the low gradient of alluvial fans, the capacity of the channel to move sediment is reduced and channels will fill with sediment, forcing the channel to change direction. In extreme events these changes in channel can occur quickly, during a single storm. Over time, this gradual accumulation of sediment and channel migration builds and maintains the characteristic shape of a fan or cone.

Alluvial fans are attractive locations to build cabins and homes due to the slight elevation above river flood plains and (or) the occasion to have a view of the flood plain (Figure 1). However, alluvial fans are there because they are active depositional areas that accumulate sediment over time. The sediment can be deposited both slowly, such as during a spring melt when high streamflow during spring runoff transports and deposits fine sediment on the fan or quickly, when a flash flood, HCF, or debris flow transports sediment and debris to the fan. As stated above, both flash floods and HCF can inundate areas not typically wetted by regular streamflow, so channel-adjacent roads, trails, building, and other infrastructure can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. In addition, a debris flow can be very destructive due to the ability of a debris flow to buoy

[2] https://landslides.usgs.gov/hazards/postfire_debrisflow/index.php

cobbles, boulders, and woody debris at the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure.

Observations and Interpretations

American Fire

FS Road 18, Bumping River Road

Sunrise Creek crosses Road 18 on an alluvial fan and there were no signs of historic debris flow levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels. While we did not observe evidence of historic debris flow events, this area could be impacted by flash flood events depending on hydrological modeling and burn severity. A small portion of the watershed headwaters was impacted by the fire. The basin above the road contains deep landslides that could shed sediment from over steepened toes; however, the channel becomes relatively flat and unconfined approximately 700 feet upstream of the road. If a major storm impacts the drainage and a debris flow initiates in the headwaters of the basin or from one of the existing deep landslides, the low gradient alluvial fan will allow the debris flow to drop sufficient material to transform into a HCF or flood. The road could be impacted by from debris, sedimentation, water erosion, and (or) water inundation. The USGS Debris-flow combined relative debris flow hazard model ranks the drainage above Sunrise Creek as "low" for a storm intensity of 24mm (0.94in) in 15 minutes.

On an alluvial fan that Road 18 passes over, we observed a pre-fire, high streamflow event that impacted the road and culverts, specifically at Cougar Flat Campground. While the area appears to be impacted by past flooding, the American Fire didn't burn the drainage above and won't affect these flooding problem areas.

Camp Fife: Boy Scouts of America (BSA)

Camp Fife is located on coalescing alluvial fans for Strawberry Creek and two unnamed creeks above the camp (Figure 2). Field evidence revealed that the western side of the BSA camp has experienced recent floods or HCF deposition of gravel and cobbles, likely within the past year (Figure 3 and image on title page). A crude levee has been constructed to prevent floodwaters from affecting adjacent structures at the camp. It appears that flood deposition behind the levee have accumulated sufficient sediment to be higher elevation than the adjacent structures, so flooding will be a continuing concern at the camp. We expect that the camp will continue to be impacted by flood waters as experienced in the recent past and this may be difficult to parse from fire-induced flash flooding in the future. Results of the post-wildfire hydrologic modeling are included in the final BAER report and should be consulted for this site.

The USGS modeled the debris-flow potential in the drainages above the BSA camp as "low" for a 12mm (0.47in) in 15-minutes storm event and "moderate" for a 24mm (0.94in) in 15-minute storm event (see Figures 4 and 5). While it is unlikely that debris flows would reach the camp, existing channels on the alluvial fan and adjacent to the camp could convey debris and flood water and impact the camp. Overall, all creeks that flow into the vicinity of the BSA camp should be further evaluated for flash flooding, HCF, and impacts by debris. Though there is a low likelihood of a significant flooding event that may impact the camp, the consequence could be high.

Bumping Lake

We did not visit Bumping Lake because we do not expect impact from the fire to the lake. The fire did not burn drainages that will affect the lake.

Norse Peak Fire

Hells Crossing Campground

We visited Hells Crossing Campground and do not believe that there are hazards posed by debris flows and flash flooding from the adjacent uplands to the north. We did not observe a drainage channel or past deposition suggestive of previous events that may convey sediment to the campsites. The USGS model indicated a “low” combined relative debris flow hazard in the drainage above the campground from the 12mm (0.47in) and 24mm (0.94in) in 15-minute storm intensity.

Union Creek Trailhead

The headwaters of Union Creek experienced areas of high and moderate burn severity. In the event of a significant storm and runoff event, the headwaters may experience debris flows and it is likely that downstream areas may experience flooding, which may include erosion, sedimentation, and overbank flooding. Where Union Creek exits the mountain front, the channel was approximately 50 feet wide and appears to be confined in bedrock. In this area there were no signs of historic debris flow levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels. Where the creek exits the bedrock channel, an alluvial fan has formed near the confluence with the American River. On the alluvial fan there are at least five cabins east of Union Creek (observed from across the creek) and these cabins appear to be located out of the active channel. However, depending on the magnitude of a flash flooding event(s), the cabins could be impacted. The occupants of the cabins should be notified of potential flash flood hazards associated with alluvial fans. Property owners and forest managers may need additional review and study of these cabins with respect to the associated flooding hazard. Results of the post-wildfire hydrologic modeling are included in the final BAER report.

In addition to the cabins on the alluvial fan, Union Creek flows under a wooden drivable foot bridge and adjacent to public parking, pit toilet, and day-use picnic area. Evaluate closure of picnic table and parking area depending on results of hydrological modeling.

Union Creek goes under SR410 at a newer bridge. Results of the hydrological modeling should be forwarded to WSDOT or Federal Highways to evaluate impacts to the bridge from flooding and debris.

The USGS debris flow model depicts some channels in the headwaters of Union Creek to have a “moderate” combined hazard potential of debris flow initiation during a 12mm (0.47in) in 15-minute storm intensity and dominantly “moderate”, with rare “high” potential in the 24mm (0.94in) in 15-mintue storm intensity. As stated earlier, if debris flows initiate in the headwaters of Union Creek, we expect that they would transform into flood or HCF at or before the alluvial fan, reducing the potential damage to infrastructure.

Wash Creek

At Wash Creek we observed dry channels with mature conifer trees growing within. There were no signs of historic debris flow levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels. While we did not observe evidence of historic debris flow events, this area could be impacted by flash flood events depending on hydrological modeling and burn severity. The USGS debris flow model indicates “moderate” combined relative debris flow hazard under a 12mm (0.47in) and 24mm (0.94in) in 15-minute storm events.

Silver Creek Drainage between SR410 and Chrystal Mountain Ski Resort

The Silver Creek drainage was only partially impacted by moderate burn severity along the upper portions of the eastern valley wall; however, because of the resort and cabins in the area, we assessed portions of the drainage for debris flow hazards.

We visited an unnamed drainage east of the Sand Flats Horse Camp, along FS410. The headwaters of this channel contained a small area of high burn intensity. The drainage exits the mountain front at FS410 and forms an alluvial/debris fan made of boulders and debris. There is little evidence of recent activity in this channel but future activity is possible. Depending on the hydrological modeling this area could be impacted by flooding and debris, potentially impacting both FS410 and FS7190 below. This unnamed drainage is modeled by the USGS to have a “low” combined relative debris flow hazard at 12mm (0.47in) in 15-minute storm event and “moderate” for the 24mm (0.94in) storm events.

There are four buildings between FS410 and FS7190 northeast of Chrystal Mountain Resort (Figure 6). These building may need additional review due to their proximity to avalanche chutes and intermittent streams. Based on lidar interpretation, at least three of the buildings appear to be sited in areas where streams may have historically occupied. In addition, northeast and east of the buildings are landslides that are evident in the lidar topographic data. These landslides appear to be deep and are not expected to reactivate based on short term changes to hydrology due to the fire; however, the steep portions of these landslides could initiate shallow landslides that could impact the structures below. It is likely that the landslides provided the material that the current buildings are built. The USGS combined relative debris flow hazard modeling suggest “low” hazard for both the 12mm (0.47in) and 24mm (0.94in) storm events.

Goat Creek Drainage

There were no signs of historic debris flows levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels where Goat Creek exits the mountain front and immediately upstream of NF7176 culvert over Goat Creek. The Goat Creek area may experience additional flooding and at least two cabins near the creek could be impacted by minor flooding upstream of the NF7176 culvert. Currently the creek is incised and may be able to accommodate some additional water where it goes under SR410; however, it is moderately unconfined where it exits the mountain front near the culvert. There the channel may migrate during large events and could impact nearby cabins, the access road, and the 5 foot diameter NF7176 culvert.

The USGS combined relative debris flow hazard modeling depicts portions of the headwaters of Goat Creek as “low” and “moderate” hazard during 12mm (0.47in) in 15-minute storm events and mostly “moderate” in the 24mm (0.94in) in 15-minutes storm events. Based on this modeling, the basin may produce debris flows during extreme storm events, and we expect any debris flow to transform into a flood or HCF as they transition onto the alluvial fan.

Working with and notifying cabin owners in the Goat Creek area of potential flood hazards is important. Consider options for maintaining or removing the NF7176 culvert so it does not exacerbate flooding problems if plugged by debris.

Deep Creek Drainage

Where Deep Creek exits the canyon, it appears to have incised into the 5,000 year old Osceola Mudflow terrace. In this area, there were no signs of historic debris flows levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels. Alta Crystal Resort buildings are located on high terraces away from Deep Creek; however, they should be notified of the BAER hydrological modeling and potential for flash flood hazards in Deep Creek. Also, Deep Creek flows under SR410 and passes through an approximately 5 foot concrete box culvert. This culvert is placed within approximately 20 feet of fill where SR410 passes over Deep Creek and the culvert has a slight bend near the outlet. The box culvert could be impacted by debris and may need regular inspection before and after storm events. The USGS combined relative debris flow hazard depicts the Deep Creek basin as “moderate” hazard for both the 12mm (0.47in) and 24mm (0.94in) in 15-minute storm events.

Ranger Creek

Observations at Ranger Creek include boulders and logs upstream of the culvert that lacked vegetation, suggesting deposition within the past year, likely from a flood event. There were no signs of historic debris flows levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels. The concrete culvert at Deep Creek (MP 54.3) may be at risk of plugging due to debris during storm events. The USGS combined relative debris flow hazard model indicated the basin is at “moderate” hazard during both 12mm (0.47in) and 24mm (0.94in) storm events.

Minnehaha Creek

There were no signs of historic debris flows levees, channel deposits, or damage to the upslope side of trees in or adjacent to the channels where the creek exits the mountain front. During our site visit to Minnehaha Creek we noted recent repairs to NF7150 road near the creek and recently deposited debris in the channel. A low footbridge crossing Minnehaha Creek to a cabin appeared undamaged by this recent flooding. Results of the hydrological model should be used to evaluate the flooding potential to the drainage and used to evaluate the safety of people accessing the cabin via the footbridge.

We did not visit the Dalles Campground or the picnic areas to evaluate potential impacts of flooding, additional review of the flood hazards at this site may be necessary.

Upper portion of the Minnehaha Creek watershed are modeled by the USGS as “low” combined relative debris flow hazard for both the 12mm (0.47in) and 24mm (0.94in) storm events. We expect that if debris flows initiate in the upper watershed, they will transform into HCF or flood by the time they make it to SR410 and The Dalles Campground located downstream.

Recommendations

The primary depositional process we observed suggest that flooding and HCF are the most-likely hazards that may impact the areas we evaluated in the field. The reduced likelihood of debris flows is primarily due to either the areas being adjacent to higher order (third) streams where debris flows are unlikely or in areas where the basin experience low burn severity and a lower likelihood of hydrophobic soil conditions that can drive debris flow initiation.

The most significant potential impact at all visited sites is flash flooding and associated damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. Residents of cabins and homes built on alluvial fans and (or) adjacent to streams flowing from burned areas should be informed of potential post-fire flash flooding hazards. Managers of transportation networks such as counties, WSDOT, and FHWA should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion to highways/roads, as well as potential issues with blocked culverts. We suggest reminding transposition network managers that before and after storm events to inspect culverts and bridges from channels draining areas impacted by the fires.

Areas of specific concern include:

- Deep Creek (~MP 55.5) passes under SR410 through a five foot box culvert with a bend at the end. A flash flood event magnified from hydrophobic soil conditions could mobilize large volumes of woody debris that could block the intake of the box culvert, potentially impacting the state highway from flash flooding, deposition, and (or) erosion. Provide WSDOT with hydrological model for Deep Creek. The box culvert could be impacted and need additional maintenance.
- Notify Alta Crystal Resort of potential flash flood hazards in Deep Creek below their resort.
- The Goat Creek community along FS7174 should be notified of potential flood hazards. At least two building near the creek, escape routes, and a culvert could be impacted.
- Four buildings at Crystal Mountain Resort may need additional review as they are built near small drainages that may be unstable.
- The cabins near Union Creek should be notified of potential flash flood hazards associated with alluvial fans. Landowners and forest managers may need additional review and study of these cabins and the associated flood hazard.
- Provide hydrologic model of Union Creek to highway mangers for evaluation of the bridge.
- Notify transportation maintenance crews to safely monitor conditions between FS7190 and FS410 after large storm events.
- Evaluate safety of accessing cabin via foot bridge on north side of Minnehaha Creek during flood events.
- Agencies with jurisdiction over roadways, campgrounds, infrastructure, and local emergency managers should be notified of these findings.

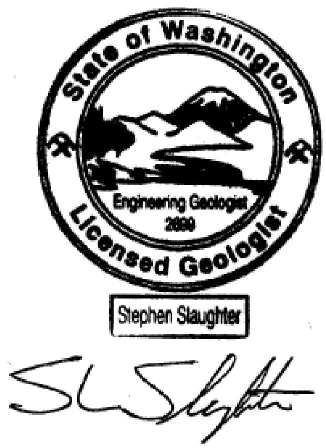
Areas of concern identified by USGS post-fire debris flow modeling:

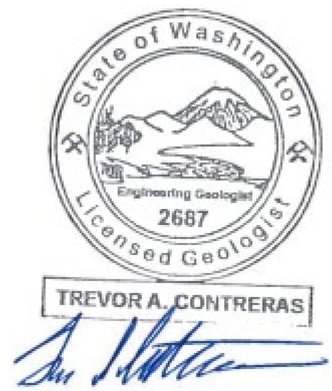
- Boy Scouts of America Camp Fife is located below areas the USGS modeled as "moderate" combined relative debris flow hazard during storm events of 24mm (0.94in) in a 15-minute storm intensity. The camp administration should be notified of this and seek appropriate professional consulting services to help them identify the potential impacts to the camp safety and operations.

Limitations

This report was written as part of emergency operations of the Burned Area Emergency Response (BAER) assessment to quickly assess and identify geological hazards associated with the Norse Peak and American fires. It is intended to help the USFS focus efforts and make decisions regarding post-wildfire geological hazards. Limited fieldwork was accomplished to assess hazards presented by landslides, and not all areas or hazards were evaluated, and we did not assess flooding issues. Hydrological professionals with the USFS provided that analysis and their report should be consulted. We encourage the USFS, WSDOT, Federal Highways, landowners and others to consult qualified professionals for site specific analysis of geological hazards and flood risk due to the wildfires.

We presented limited results of the USGS preliminary assessment of post-fire debris-flow hazard modeling, choosing to present both the 12mm (0.47in) and 24mm (0.94in) in 15-minute storm intensity. There is additional modeling of 40mm (1.6in) in 15-minute storm intensity that models more extreme precipitation events. The modeling can be accessed at: https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=149





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Figures

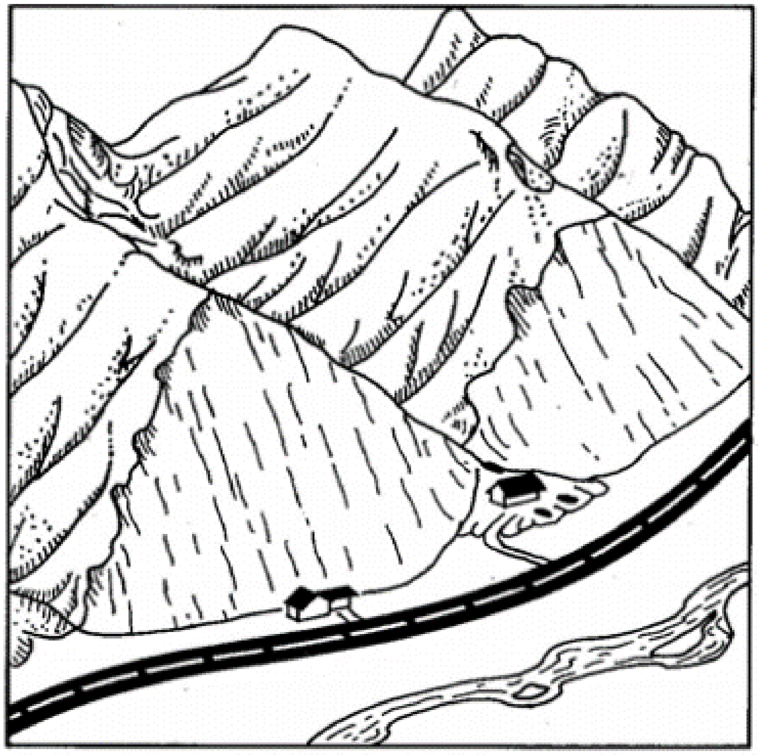

Figure 1. Homes and road in debris flow-prone locations on alluvial fans. Courtesy of Oregon Dept. of Forestry.

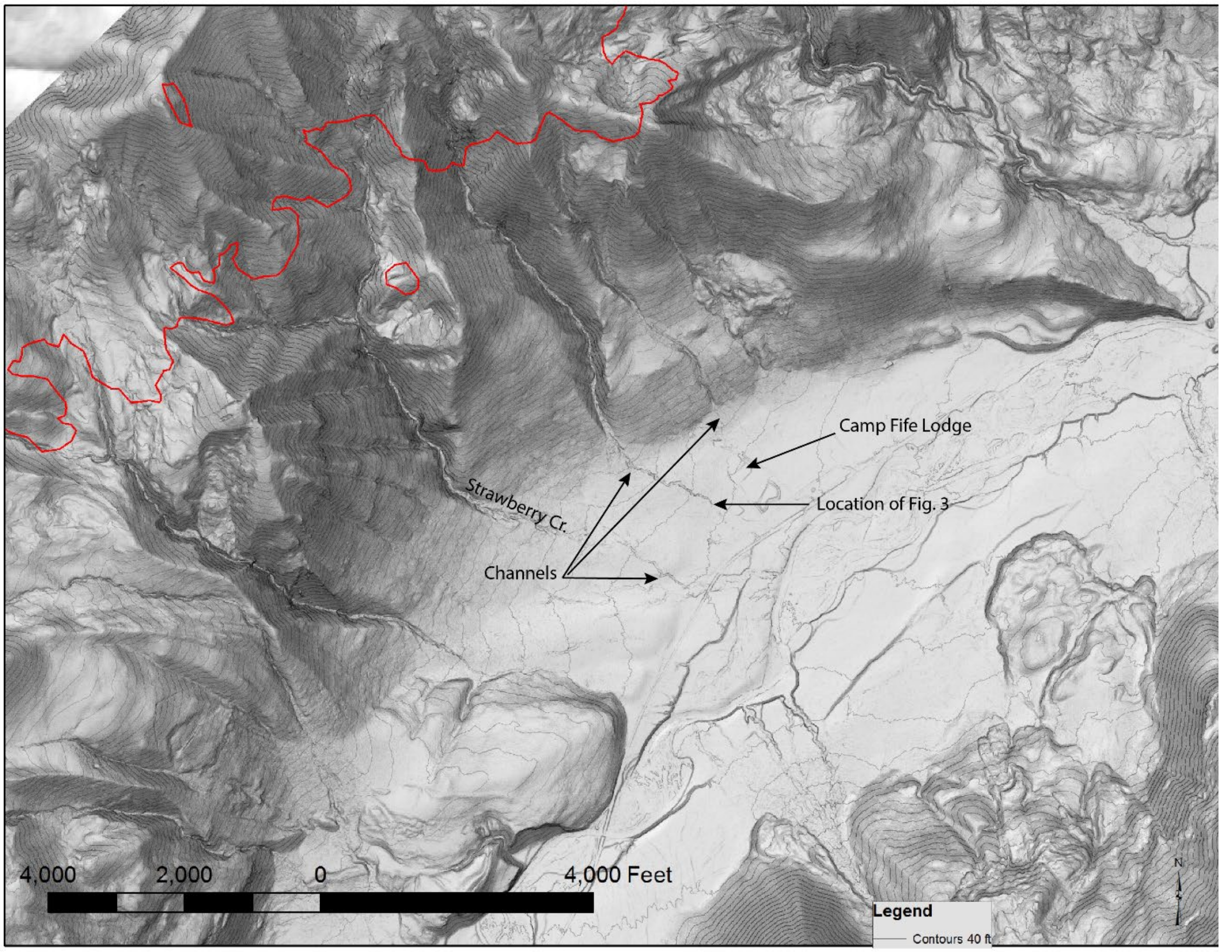

Figure 2. Camp Fife Lidar based topographic map showing location of alluvial channels and the main camp lodge. Fire perimeter in red.

Figure 3. Channel at Camp Fife showing bridge and recent alluvial deposition in channel. Channel is unconfined below this where sediment deposits spread out on the alluvial fan.

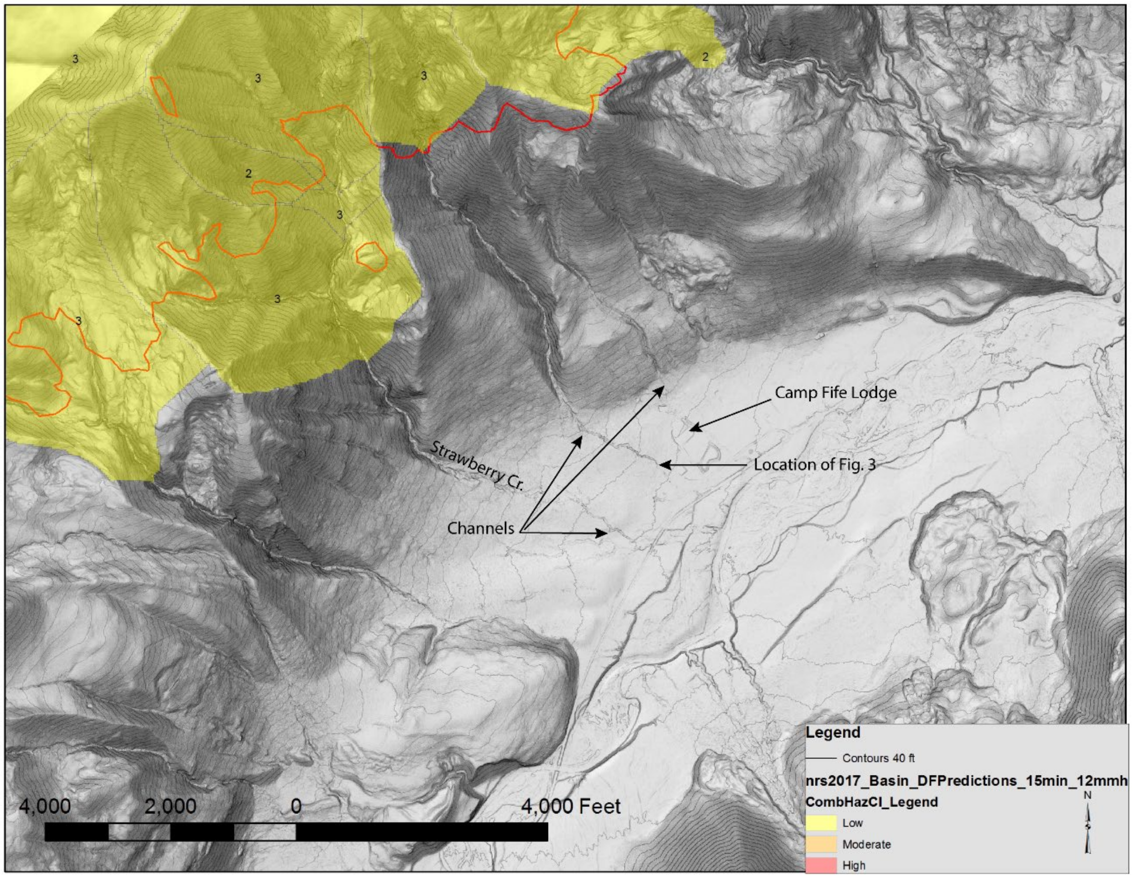

Figure 4. USGS Debris flow prediction model for a 12mm (0.47in) in 15 minutes storm intensity above Camp Fife BSA.

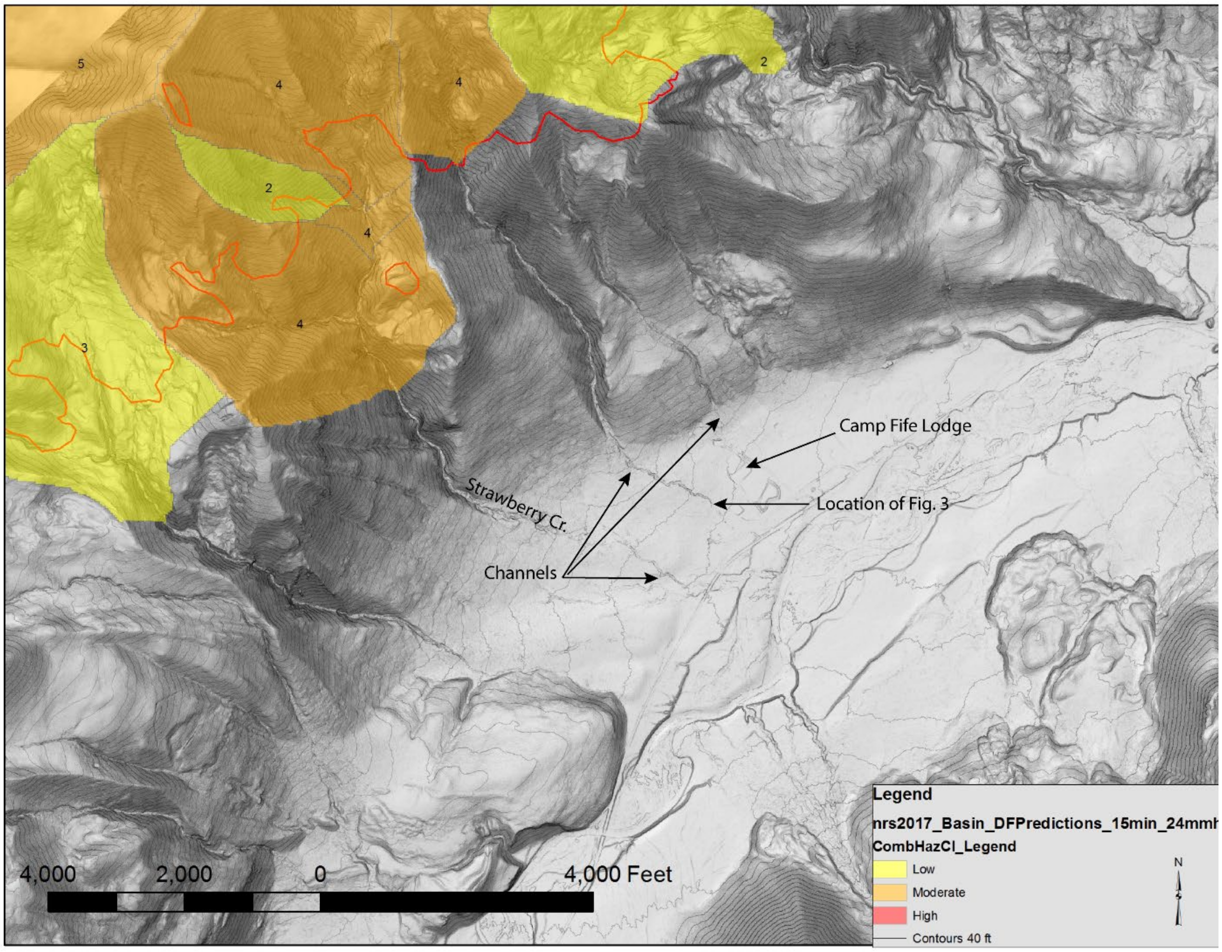

Figure 5. USGS Debris flow prediction model for a 24mm (0.94in) in 15 minutes storm intensity above Camp Fife BSA.

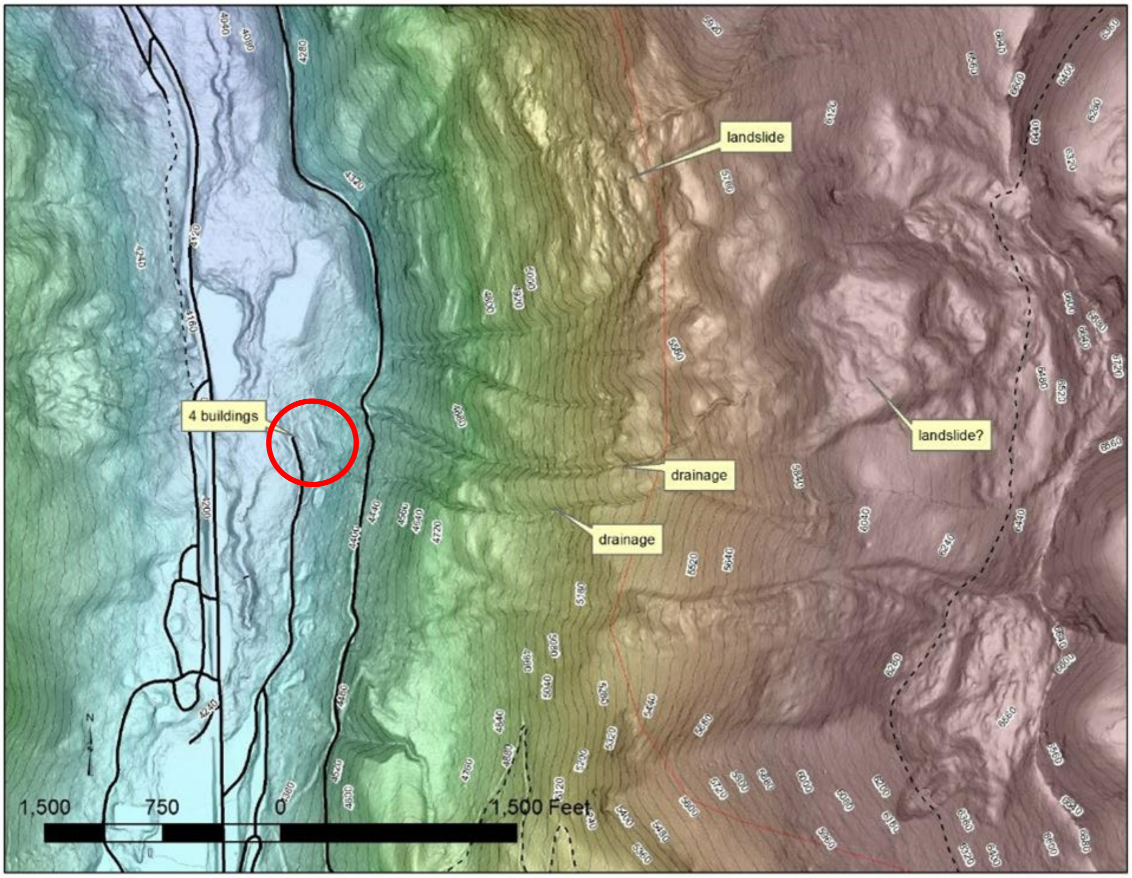

Figure 6. Crystal Mountain area with lidar topography showing location of buildings that may need additional review. Note landslide features to northeast and east of the site.