N A T U R A L R E S O U R C E S

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

2024 Pioneer Fire

Chelan County, Washington

by Josh Hardesty, Kate Mickelson,
Nancy Calhoun, and Kara Fisher

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
September 2024

WASHINGTON STATE DEPARTMENT OF
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WASHINGTON GEOLOGICAL SURVEY

Mailing Address:
MS 47007
Olympia, WA 98504-7007

Street Address:
Natural Resources Bldg., Rm 148
1111 Washington St SE
Olympia, WA 98501

Phone: 360-902-1450; Fax: 360-902-1785
E-mail: geology@dnr.wa.gov
Website: http://www.dnr.wa.gov/geology

Publications List:
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PLATES

(Plates are located at the end of this document)

Wildfire-Associated Landslide Emergency Response Team Report for the Pioneer Fire

by Josh Hardesty[1], Kate Mickelson[1], Nancy Calhoun[1], and Kara Fisher[1]

[1] Washington Geological Survey
MS 47007
Olympia, WA 98504-7007

INTRODUCTION

A Wildfire-Associated Landslide Emergency Response Team (WALERT) assessment was conducted to evaluate the potential risk posed by flash floods and debris flows from the Pioneer Fire in Chelan County, Washington. Wildfires can significantly change the hydrologic response of a watershed so that even modest amounts of rainfall can produce dangerous flash floods and debris flows. Increased runoff, flash floods, and debris flow hazards may remain elevated for several years after the fire.

WALERT assessed areas downstream of slopes burned by the wildfire to determine whether debris flows or flooding could impact infrastructure, structures, and other areas where public safety is a concern. We looked for historical evidence of debris flows using field reconnaissance, lidar interpretation, and orthoimagery. Further information about these hazards is provided in Appendix A.

This report is primarily a qualitative assessment of post-wildfire landslide hazards based on our professional judgment and experience. The assessment was performed as part of emergency response with the intent to produce a rapid report for decision-makers, land managers, landowners, and other partners.

WILDFIRE OVERVIEW

The Pioneer Fire started on June 8, 2024. As of September 18, 2024, the fire had burned 38,735 acres along the shores of Lake Chelan (INCI Web, 2024). The fire perimeter is almost completely coincident with four past fire burn scars: Rex Creek Fire (2001), Flick Creek Fire (2006), Rainbow Bridge Fire (2010), and Moore Point Fire (2013). Due to this past fire activity, abundant snags, heavy accumulations of downed woody material, young conifer growth, grass, and shrub patches exist across the landscape. The burn area is on United States Forest Service (USFS), National Park, and private lands. Both public and private infrastructure are within and in close proximity to the burn area.

HISTORIC DEBRIS FLOW OVERVIEW

Historic debris flow activity was observed on several fans inside the burn scar using lidar derivatives, aerial orthoimagery, and field observations. Some of these debris flow events are also documented in greater detail by other sources (Riedel and Sarrantonio, 2021).

LITTLE BOULDER, IMUS, HAZARD, AND FOURMILE CREEKS

In August of 2010, a storm over the Stehekin Watershed deposited 37 mm (1.46 in.) of precipitation over an 11-hour period with a peak intensity of 6.9 mm/hr (0.27 in./hr). This generated debris flows in the Little Boulder Creek, Hazard Creek, and Fourmile Creek drainages. Subsequent events occurred in Little Boulder Creek in 2012 and in the Little Boulder Creek and Imus Creek drainages in September of 2013, with the latter following a storm with a precipitation peak intensity of 8.9 mm/hr (0.35 in./hr) and a total rainfall accumulation of 24 mm (0.94 in.) over 4 hours (Riedel and Sarrantonio, 2021). Events from this 2013 storm resulted in significant damage on the Imus Creek alluvial fan, burying cars and inundating property with rocks and debris (Bartley, 2013; Richard, 2013).

From August 23–24, 2024, a slow-moving, longer-duration storm of almost 24 hours triggered a debris flow in Hazard Creek after the Pioneer Fire burned the drainage. Based on radar and weather station data in Stehekin, approximately 25–35 mm (1–1.4 in.) of rain fell in 24 hours with a maximum one-hour total of 6 mm (0.24 in.). This debris flow occurred three weeks after Pioneer Fire activity had burned the Hazard Creek watershed, according to local residents.

FLICK CREEK

A small debris flow track in Flick Creek was observed in the 2013 orthoimage that was not visible in 2011 imagery or on any earlier imagery. While exact event timing cannot be determined, it is likely that a debris flow occurred in this drainage system between 2011 and 2013. More recently, a debris flow was triggered by the storm on August 23–24, 2024, after Flick Creek's watershed was burned during the Pioneer Fire.

MEADOW CREEK

Field observations indicated that a recent debris flow occurred in a deeply incised channel on the Meadow Creek fan. Aerial imagery from 2011 displayed a debris flow track upstream from and on the Meadow Creek fan. The debris flow track was not present in 2009 aerial imagery, however. Thus, we interpret that debris flow activity occurred between 2009 and 2011, most likely during the 2010 storm event.

PRINCE CREEK AND CANOE CREEK

In both the Prince Creek and Canoe Creek basins, evidence of debris flow activity was visible in a 2006 orthoimage. While the exact timing of these events is unknown, a review of aerial photographs and satellite images suggest they occurred between 1998 and 2006. In 1948, a flooding/debris flow event in Prince Creek destroyed a Forest Service guard station, barn, and a campground.

OBSERVATIONS AND INTERPRETATIONS

WALERT conducted a limited field assessment from September 9–11, 2024. We specifically focused on areas where wildfire effects on watershed hydrology could put life and property at risk. These areas included slopes within and downslope of the Pioneer Fire perimeter and along Lake Chelan (Plates 1 and 2). Alluvial fans along Lake Chelan's shoreline were primary areas of focus. Public safety is of concern at all locations discussed below. When structures, campgrounds, and trails are discussed, safety for people occupying or using the infrastructure mentioned is the primary concern.

Soil burn severity data

The Burned Area Reflectance Classification (BARC) data, a satellite-derived data layer of changes between pre- and post-fire vegetation conditions, were provided and field validated by the US Forest Service and National Park Burned Area Emergency Response (BAER) teams to generate a Soil Burn Severity (SBS) map. If you need assistance accessing or analyzing these data, please contact us and we can provide some support.

SBS mapping shows that 3,300 acres—9 percent of the area affected by the Pioneer Fire—were either unburned or had very low soil burn severity. Approximately 20,808 acres (53%) experienced low soil burn severity, 12,080 acres (31%) were moderate in severity, and 2,834 acres (7%) were shown to have experienced high burn severity.

Post-wildfire debris flow hazard assessment

MODELING RESULTS

The USGS provided a debris flow modeling assessment for the Pioneer Fire that incorporates the SBS data provided by the US Forest Service. The modeling data are typically available on their website within a few weeks of being generated (https://usgs.maps.arcgis.com/apps/dashboards/c09fa874362e48a9afe79432f2efe6fe). However, if access is needed prior to these data being made available please contact us and we can provide some support.

There are various outputs and ways to view these data. Here we will discuss the combined relative debris flow hazard for hydrologic basins, which combines both probability and volume from the USGS model to provide three different hazard ratings: Low, Moderate, and High. The USGS also models the combined relative debris flow hazard for stream channel segments within basins using the same hazard ratings. We focus our assessment on locations where public safety and infrastructure could be impacted. If you need assistance accessing or analyzing the debris flow assessment data, please contact us and we can provide support.

The USGS debris flow modeling is based on a modeled storm event with a peak rainfall intensity of approximately 0.25 inches of rain in a 15-minute period or 1 inch of rain in a 60-minute period (6 mm/15 mins or 24 mm/hr, respectively). Of note, this model also does not consider the effect of rain-on-snow or rapid snowmelt events in a recently burned area. Debris flows and flash floods may occur during rain-on-snow or rapid snowmelt events that do not meet the predicted rainfall threshold.

INTERPRETATIONS

The USGS modeling indicates that there are Low, Moderate, and High debris flow hazard ratings in drainages throughout the burned area. Some basins are dominated by drainages with Moderate and High debris flow hazard ratings. Along the fire boundary, several alluvial fans are present at basin outlets along generally steep slopes edging Lake Chelan (Plates 1 and 2). Remote and field observations revealed that many of these alluvial fans have experienced debris flows and flooding in the past.

Even in areas without historical evidence for debris flows, the fire likely impacted the basin's hydrologic response to future storm events. Increased runoff and increased potential for flash floods may persist for several years after the fire. Below we outline areas that we reviewed during this assessment where flash flooding or debris flows could impact property and infrastructure.

BOULDER CREEK (POINT 1 ON PLATE 2)

Portions of Boulder Creek's basin, in relatively close proximity to its alluvial fan, were burned in the Pioneer Fire. Burned drainages within this basin are modeled as both Moderate and Low debris flow hazards. We were unable to visit the Boulder Creek alluvial fan. However, a review of aerial imagery and lidar derivatives indicates that structures exist within 175–600 ft of the currently active channel. The Stehekin Valley Road also crosses the alluvial fan. Lidar derivatives reveal avulsion channels where past debris flows and floods have occurred near these structures and near the road. Based on past activity indicated in the lidar and the modeled debris flow hazard, there is an increased risk of flooding and debris flows impacting the structures and road.

LITTLE BOULDER CREEK (POINT 2 ON PLATE 2)

The Pioneer Fire burned a portion of the basin above the Little Boulder Creek alluvial fan. The drainage has a history of debris flows including events in 2010, 2012, and 2013. Past debris flows were composed of silt, sand, cobbles, and boulders 1–3 ft in diameter. Keller Park Drive cuts across the middle of the alluvial fan. Due to the existing debris flow potential indicated by several events in the last 14 years and the modeled Moderate debris flow hazard, this alluvial fan could be impacted by future flash flooding and debris flows.

IMUS CREEK (POINT 3 ON PLATE 2)

The upper basin and source area for the Imus Creek alluvial fan appears to contain highly jointed bedrock, which could provide abundant sediment to the channel. Purple Point campground is positioned on the northwestern edge of the alluvial fan and several structures exist on the western edge. Stehekin Valley Road cuts across the distal edge of the alluvial fan and the Imus Creek trail crosses the apex. The 2013 debris flow inundated a large portion of the alluvial fan, impacted Stehekin Valley Road, and buried several cars with rocks and debris. The basin is modeled as Moderate debris flow hazard; there is an existing baseline debris flow hazard that was likely exacerbated by the Pioneer Fire.

UNNAMED CREEK (POINT 4 ON PLATE 2)

This unnamed creek and its alluvial fan are located directly between Imus and Purple Creeks. Its basin is modeled as Moderate debris flow hazard. Several structures are present on the alluvial fan, Stehekin Valley Road cuts across the distal edge of the fan, and the Imus Creek trail crosses the apex of the fan. Although the contributing basin is not as large as the Imus or Purple Creek basins, flooding or debris flows resulting from post-wildfire conditions may impact this alluvial fan.

PURPLE CREEK (POINT 5 ON PLATE 2)

Drainages within the Purple Creek basin are modeled as Moderate debris flow hazards. Currently, the most likely flow path for an event is from the apex toward the middle and northern sides of the alluvial fan. At the apex, we noted that a large event, however, could send material to the southern portion of the alluvial fan. Structures are present in the current preferential flow path and several of them are excavated into the distal deposits of the alluvial fan, increasing the risk to those structures. The Stehekin Valley Road cuts across the distal edge of the fan and the ferry dock is located toward the middle of the alluvial fan. The Purple Point Campground is located on the southern portion of the fan. Based on the debris flow modeling, lidar-based observations, and field reconnaissance, flash flooding and debris flows could impact this alluvial fan and infrastructure located on it. Public safety is a high concern at this site.

HAZARD CREEK (POINT 6 ON PLATE 2)

The Hazard Creek basin is modeled as a High debris flow hazard. The Hazard Creek alluvial fan experienced a debris flow in 2010 and during a storm on August 23, 2024, as the Pioneer Fire was still burning. A resident on the alluvial fan communicated that the most recent event lasted over 90 minutes and the resident estimated the flow was 15 ft deep as it ran through the main channel. A small footbridge from the Lakeshore Trail that crossed the channel was swept away during this event. The resident also stated that the 2010 event was bigger than the recent event. Boulder levees from the 2010 event are still present near the fan apex. The current channel is deeply incised at the apex (approximately 35 ft deep) and it is unlikely that debris flows or flooding would jump out of the channel at this location and impact structures on the southern portion of the alluvial fan. A historic cabin is located near the active channel on a surface that is approximately 14 ft above the channel at its lowest point. This cabin may be impacted during larger debris flow events. Given the recorded debris flow activity and the modeled High debris flow hazard, debris flows and flash flooding are likely to impact the alluvial fan following the wildfire.

FOURMILE CREEK (POINT 7 ON PLATE 2)

Fourmile Creek contains a relatively large basin, most of which was burned during the Pioneer Fire. The basin is modeled primarily as a Moderate debris flow hazard. Most of Fourmile Creek's alluvial fan was also burned during the fire. The upper portion of the fan exhibited multiple surfaces associated with past channel avulsion. At the time of our visit, the active channel was positioned along the south side of the fan. Abundant boulders are located near and just downstream from the fan's apex. As detailed above, this alluvial fan was impacted by a debris flow in 2010, suggesting that the boulders near and just downstream from the fan's apex were deposited during the debris flow event that impacted the fan in 2010. Topographic surface characteristics indicated that avulsion within one of the upper, secondary (currently abandoned) channels could occur in the future. Two residential structures were observed on the fan. The northernmost structure was located within one of the abandoned channels that appears to contain potential for stream reoccupation. If this were to occur due to post-fire debris flow events, this structure may be at risk of being impacted.

FLICK CREEK (POINT 8 ON PLATE 2)

The Flick Creek basin is modeled dominantly as a High debris flow hazard. At the time of our visit, Flick Creek's active channel cascaded over bedrock surfaces just above the alluvial fan's apex and continued through the northern portion of fan. Flick Creek and its alluvial fan have a history of debris flow events as detailed above. More recently, a storm from August 23–24, 2024 triggered a debris flow that impacted the northern portion of the fan. This event deposited material near a private residence positioned on the northern, distal edge of the fan. During our site visit, we observed a newly deposited debris dam upstream from the residence. It appears this debris dam has rerouted the active channel slightly to the south. However, the proximity and orientation of the debris dam, the configuration of the active channels, the location of the residence, and the modeled High debris flow hazard indicate that the residential structure is at an elevated risk of being impacted by future post-fire debris flow events.

UNNAMED STREAM (POINT 9 ON PLATE 1)

An unnamed stream with an alluvial fan at its confluence with Lake Chelan is located approximately 2,000 ft north of Hunts Creek. The stream's basin is modeled as Moderate debris flow hazard. A private residence and dock are located on the stream's alluvial fan and near the stream's active channel. Given that no natural barriers or deflection points were observed directly above the private residence, it appears the residential structure and associated infrastructure are at an elevated risk of being impacted by post-fire debris flow activity if such activity were to occur.

FISH CREEK/MOORE POINT (POINT 10 ON PLATE 1)

Fish Creek flows through a large alluvial fan, known as Moore Point, before entering Lake Chelan. Fish Creek's basin has been modeled primarily as Moderate and High debris flow hazard. The alluvial fan contains at least three surfaces with older, elevated surfaces located on its northern and southern portions and younger, lower surfaces extending from the apex to Lake Chelan through its middle portion. The active channel and multiple secondary channels are present on the lower active fan surface. Most of the residential structures are positioned on an elevated, middle surface to the north of the active surfaces. However, a small cabin, located to the south of the other residences, is positioned near and just north of the lower, active fan surface. It is elevated above the active channel but appears to be at risk of inundation from flooding or debris flow activity related to post-fire conditions. Additionally, the Moore Point campground is located on the western side of the fan on its lower, more active surface. The campground's facilities appear to be at an elevated risk of inundation from post-fire flooding/debris flow events. A bridge associated with the Lakeshore Trail spans Fish Creek within the upper, narrower section of the alluvial fan. This bridge and the Lakeshore and Fish Creek trails are at an elevated risk of being impacted if post-fire flooding/debris flow events occur.

MEADOW CREEK (POINT 11 ON PLATE 1)

Meadow Creek experienced a debris flow recently, most likely in 2010 based on remote sensing and personal communication with a person familiar with the trail repair. This recent debris flow deposited large boulders and logs, destroyed the US Forest Service footbridge and trail tread, and nearly overtopped the channel onto the terrace above. Meadow Creek watershed was burned at a mostly low SBS at lower elevations, with significant moderate SBS and patchy high SBS in the upper portion of the basin. The modeling indicates this basin has a Moderate debris flow potential which extends down to the fan. Due to the existing debris flow potential indicated by a significant debris flow less than 10 years ago, there is now an exacerbated hazard on this fan.

There is a group of structures built on the far northern portion of the alluvial fan and just to the north of the fan. The northernmost structure of this group is located beyond the mapped fan, indicating that past debris flow and alluvial processes have not deposited material or reached this location. However, there are historic cabins (that do not appear to be occupied at the time of writing) that are closer to the active channel surface and that are exposed to potential debris flow impacts. In particular, near where Meadow Creek exits the confined gorge, there are locations at which Meadow Creek could avulse in a given debris flow if the channel were to be dammed by log jams or debris. The avulsion potential is not well understood. However, if avulsion occurred, debris could flow on the elevated terrace and impact the historic structures.

CASCADE CREEK (POINT 12 ON PLATE 1)

Cascade Creek has a small alluvial fan adjacent to Lake Chelan. Several modeled Moderate hazard drainages and one High hazard drainage are in close proximity to the alluvial fan. We observed boulder levees which we interpret to be associated with past debris flow deposition. The alluvial fan's surface area is relatively small and there is little cross-sectional elevation difference between the active stream channel and the rest of the fan surface. This fan geometry and the modeled hazard ratings suggest that debris flow or flooding events may occur with potential to impact the entirety of the fan surface. Thus, the Forest Service campground on the alluvial fan is at risk from debris flow inundation.

PIONEER CREEK (POINT 13 ON PLATE 1)

Pioneer Creek does not have a mapped alluvial fan at its confluence with Lake Chelan. However, the modeling indicates this basin as having Moderate debris flow hazard. In addition to the steep, somewhat confined channel that continues to the lake, the upper drainages are also very steep. A residential structure is positioned near the channel, which could be impacted by future debris flows or flooding events.

REX CREEK (POINT 14 ON PLATE 1)

The Pioneer Fire burned just the lower portion of the Rex Creek basin, with patchy moderate severity and predominantly low burn severity. However, the modeling indicates a Moderate debris flow hazard. Rex Creek basin exhibits a confined channel and very steep drainages and slopes. There is a ~15-ft-deep channel confining the current streamflow that would likely contain small debris flow events. However, a larger magnitude (large volume) debris flow event could continue straight across the fan and inundate the upper surface of the alluvial fan. Residential structures in close proximity to the active channel may also be impacted during larger debris flow events.

PRINCE CREEK (POINT 15 ON PLATE 1)

Prince Creek has a large alluvial fan and a relatively large basin feeding it (approximately 36 square miles). There are no structures on this alluvial fan and the land ownership is entirely USFS. The USFS has a campground and pit toilets located on an elevated, older alluvial fan surface. During our site visit, we interpreted this surface to be abandoned alluvial fan terrain. We observed a lower elevation, active-channel surface, strewn with boulder-cobble levees and inactive, former channels. The lower surface has been active historically and is interpreted to have been inundated by a flood (or debris flow) in 1948 that destroyed several USFS structures, including a guard station, barn, and campground.

Much of Prince Creek's basin was moderately–severely burned (about 2.5 sq mi or 6.85 sq km), including several steeply sloped drainages. In the modeling, the burned portion of the Prince Creek basin exhibits Moderate to High debris flow hazard. The USFS campground is on an elevated section of the alluvial fan and is less likely to be impacted. The lower, more active portion of Prince Creek fan, across which the USFS Lakeshore and Prince Creek Wilderness trails traverse, is vulnerable to potential debris flows and flooding events.

CANOE CREEK (POINT 16 ON PLATE 1)

Canoe Creek and its alluvial fan are the southernmost point of interest in association with the Pioneer Fire. A residential structure is located on the northern, distal portion of Canoe Creek's alluvial fan and in relatively close proximity to Canoe Creek's active channel. Remote review suggests that geologic conditions (apparent heavy rock jointing and alteration) in the basin may be a source of abundant sediment to the channel. Remote sensing imagery also indicated a debris flow had inundated the area around the present-day active channel sometime between 1998 and 2006.

The Pioneer Fire did not burn the entirety of the Canoe Creek basin, but about one third of its lowest portion burned at low severity and a few patchy areas burned at moderate burn severity. The modeling shows several Moderate debris flow hazard drainage basins that feed into Canoe Creek close to the alluvial fan, indicating that the existing debris flow hazard has likely been exacerbated by the fire. The structures on Canoe Creek fan are at an elevated risk of debris flow and (or) flooding hazard.

RECOMMENDATIONS

Our assessment identifies and corroborates that flash flooding and debris flows have occurred in this area in the past. The Pioneer Fire very likely exacerbated the existing flash flooding and debris flow hazard in this area. Debris flows, flash flooding, and increased runoff could impact infrastructure during periods of intense precipitation (approximately 0.25 inches of rain in a 15-minute period or 1 inch of rain in a 60-minute period), during rapid snowmelt events, or during rain-on-snow events.[1]

Residents and occupants of structures built on steep slopes, alluvial fans, and (or) adjacent to streams flowing from burned areas should be informed about potential post-fire rockfall, flash flood, and debris flow hazards. The Stehekin area is also frequented by tourists that may not be aware of associated risks. Warning signs and evacuations plans should be prepared for residents and tourists. Property owners and (or) residents in locations of elevated hazards should consider seeking appropriate professional consulting services for site-specific evaluations of the potential threats to their life, safety, and property.

Trails and camping areas on alluvial fans subject to the hazards discussed herein should be signed to warn the public of flash flood, debris flow, and rockfall hazards. We recommend signs be placed at strategic locations, particularly at campgrounds and trailheads. Some campsites and trails may need to be temporarily closed due to the elevated hazard. Drainages and canyons within basins with elevated hazards should be avoided during rain events given the risk of rockfall, debris flow, and flooding events.

Landowners and land managers may choose to take action to prevent excessive soil erosion and promote revegetation to help mitigate flooding and meet their management and economic goals. The soil burn severity map created and field-validated by the USFS and NPS BAER teams can be a useful tool to evaluate areas for re-planting. We are willing to help direct users to this map product or provide the data in various formats as needed.

Managers of road networks and private landowners should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion impacts to roads following wildfires, as well as potential issues with blocked culverts. We recommend inspecting any culverts within channels draining areas impacted by the fire both before and after storm events. Blocked culverts can cause additional flooding and exacerbate damages by increasing the amount of erosion during an event. The damage to roads and infrastructure can be minimized by proactively clearing these culverts prior to storms or seasonal snowmelt.

For more information on how to stay safe when at risk from debris flows, please consult our Floods After Fire pamphlet and the USGS fact sheet with safety tips relating to post-fire debris flows (links in the footnote at the bottom of this page).[2]

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LIMITATIONS

WALERT aims to quickly identify and assess geologic hazards associated with wildfires to inform decision making and help focus the efforts of local officials and residents who may be impacted by post-wildfire hazards. All observations and interpretations are based on empirical evidence and local knowledge. Not all areas or hazards, such as rockfall, were evaluated. Site conditions are subject to change as a result of flash flooding and debris flow events. The inherent unpredictability of such events can drastically alter surfaces that appeared to be at lower risk of inundation during our assessment. Future modifications to

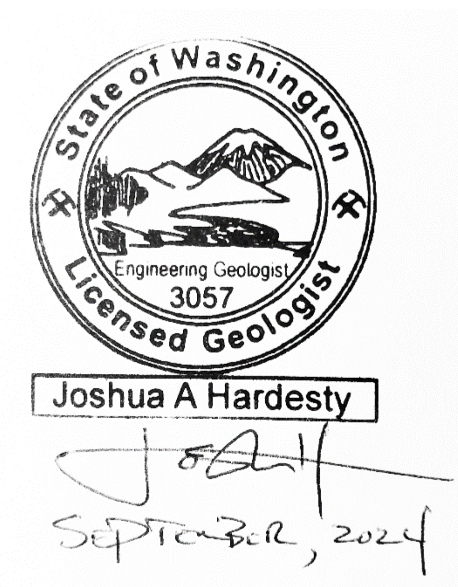
[1] More information and maps for rain-on snow zones in Washington State can be found at https://data-wadnr.opendata.arcgis.com/datasets/8203e7253e8d44a6bad1a76e92436cbe_6/explore

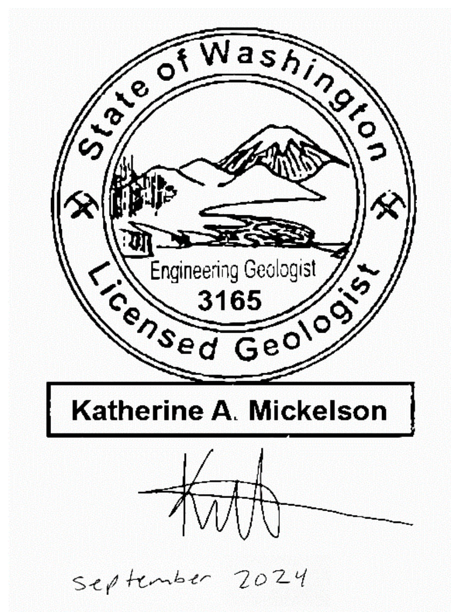
[2] The Washington Geological Survey's Floods After Fire pamphlet: *https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf*
The USGS's fact sheet on post-fire debris flows safety:
https://pubs.usgs.gov/fs/2022/3078/fs20223078.pdf

surfaces associated with flash flooding and debris flow events may need to be reevaluated to determine if the hazard assessment herein needs to be updated. We encourage landowners, land managers, and those potentially at risk from post-wildfire hazards to consult qualified professionals for site-specific analysis of geological hazards and flood risk and prepare accordingly.

Josh Hardesty
Licensed Engineering Geologist #3057
Washington Geological Survey
Washington State Dept. of Natural Resources
Olympia, WA
Cell: 564-669-1750
Email: josh.hardesty@dnr.wa.gov

Kate Mickelson
Licensed Engineering Geologist #3165
Washington Geological Survey
Washington State Dept. of Natural Resources
Olympia, WA
Cell: 360-810-0006
Email: kate.mickelson@dnr.wa.gov





APPENDIX A: GEOLOGICAL BACKGROUND

Hillslope processes

A variety of factors contribute to the probability of debris flows occurring in burned areas. These include hillslope gradient, channel convergence, availability of fine sediments, severity of hydrophobic (water repellant) soil conditions, burn severity, and the removal of a protective canopy and diminished root strength caused by fire.

Hydrophobic soil conditions in burned areas can increase water runoff potential on hillslopes during a storm by preventing water from infiltrating into the subsurface. Overland flow can result in rills and gullies that further channel water downhill.

When effective ground cover has been denuded after intense fire, soils are also exposed to erosive forces such as raindrop impact and wind. The steepest slopes are most prone to erosion, particularly where soils are shallow 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 contain relatively low amounts of organics, resulting in moderately thin topsoil horizons.

Flash floods and debris flows

Debris flows have a specific geologic definition that is often misused by the media, the public, and scientists. Most observed “debris flows” are actually sediment-laden flash floods known as hyperconcentrated flows (HCFs). In the following sections, we explain the differences between these two types of flows.

FLASH FLOODS

Flash floods, especially those that originate from recently burned areas, are often described as “debris flows” due to the sediment-laden water transporting woody and vegetative debris, trash, 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 differentiate it from a flash flood. An HCF is the transition between a flash flood and a debris flow. One way geologists differentiate the three is by the percent of sediment (by volume) carried by the flowing water. A flood contains less than 5 percent sediment by volume, an HCF carries around 5 to 60 percent sediment by volume, and a debris flow exceeds 50 percent sediment by volume.

DEBRIS FLOWS

Debris flows are often described as having the appearance of flowing, wet concrete. These flows travel quickly in steep, convergent channels. A moving debris flow can be very loud because it can buoy cobbles, boulders, and debris to the front and sides of the flow. The sound is often compared to that of a freight train and may cause the ground to vibrate. In a post-fire situation, a debris flow may start as a flash flood surge that picks up sufficient sediment to transform into an HCF and, if soil and slope conditions are suitable, can transform into a debris flow.

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 on bark from rock or debris impact. Mud and gravel may be splashed onto trees and other channel-adjacent objects. Because of the ability of a debris flow to buoy these materials to the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure.

Alluvial fans

Alluvial fans are low-gradient, cone-shaped deposits that consist of sediment and debris. These features often accumulate immediately below a significant change in channel gradient and (or) valley confinement. This might occur at the mouth of a canyon or steep channel that drains from mountainous terrain and emerges onto a low gradient area such as a flood plain or lakeshore. Sediment on the alluvial fan is deposited by streams, floods, HCFs, and (or) debris flows and is typically sourced from a single channel.

Alluvial fans are attractive locations to build cabins and homes due to the slight elevation above the flood plain or lakeshore. However, alluvial fans 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 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.

An information flyer about alluvial fan hazards is available on our website in both English and Spanish

- https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf
- https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans_esp.pdf