RESOURCES

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

NATURAL

Bolt Creek, Suiattle River, Boulder Lake, and Lake Toketie Fires

King and Snohomish Counties, Washington

by Kate Mickelson and Mitch Allen

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
October, 2022

WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

Bolt Creek, Suiattle River, Boulder Lake, and Lake Toketie Fires

King and Snohomish Counties, Washington

by Kate Mickelson and Mitch Allen

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
October, 2022

WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES
Hilary S. Franz—*Commissioner of Public Lands*

WASHINGTON GEOLOGICAL SURVEY
Casey R. Hanell—*State Geologist*
Jessica L. Czajkowski—*Assistant State Geologist*
Ana Shafer—*Assistant State Geologist*

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:
https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/publications-and-maps#publications-list

Washington Geology Library Catalog:
https://www.dnr.wa.gov/programs-and-services/geology/washington-geology-library#search-the-library-catalog

Washington State Geologic Information Portal:
https://www.dnr.wa.gov/geologyportal

Published in the United States of America

Contents

PLATES

(Plates are located at the end of this document)

Wildfire-Associated Landslide Emergency Response Team Report for the Bolt Creek, Suiattle River, Boulder Lake, and Lake Toketie Fires

by Kate Mickelson and Mitch Allen

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 Bolt Creek Fire near Skykomish, Washington and the Suiattle River, Boulder Lake, and Lake Toketie Fires near Darrington, Washington. Wildfires can significantly change the hydrologic response of a watershed so that even modest rainstorms can produce dangerous flash floods and debris flows. Increased runoff, flash floods, debris flows, and rockfall hazards may remain elevated for several years after the fires.

In coordination with the U.S. Forest Service (USFS) Burned Area Emergency Response (BAER) team, WALERT assessed areas downstream of slopes burned by the wildfires to determine whether debris flows or flooding could impact infrastructure, structures, and other areas where public safety is a concern. Further information about these hazards is provided in Appendix A. We mapped alluvial fans using lidar data, 10-meter digital elevation models, and orthoimagery and looked for historic evidence of debris flows in the field. This mapping is at a much finer scale than the map shown in Plates 1 and 2, and can be provided to interested parties in a variety of formats if requested.

Areas downstream of slopes burned by fire were assessed for historic evidence of debris flow impacts using field reconnaissance, GIS interpretation of lidar, and 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 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 stakeholders.

WILDFIRE OVERVIEWS

Bolt Creek Fire

The Bolt Creek Fire started on September 10, 2022. At the time of this report, the cause of the fire was still under investigation, but thought to be human induced. As of September 30, 2021, the fire has burned 12,070 acres, primarily in timber, closed timber litter, and hardwood litter (INCI Web, 2022). The majority of the land that burned is on USFS land.

Suiattle River, Boulder Lake, and Lake Toketie Fires

The Suiattle River, Boulder Lake, and Lake Toketie Fires started around August 30, 2022. These fires burned in timber (litter and understory) (INCI Web, 2022). The suspected cause of these fires was lightning. The fires burned entirely on USFS land. At the time of this assessment these fires had the following approximate perimeters: Suiattle River: 115 acres; Boulder Lake: 959 acres; Lake Toketie: 807 acres.

OBSERVATIONS AND INTERPRETATIONS

Field assessments were performed September 27–29 while fire activity was still occurring, limiting access to many sites. As all four of the fires were still actively burning, the burn perimeters grew during and after our field visit and this assessment does not take into account those areas. The work focused on areas where wildfire effects on watershed hydrology could put life and property at risk along portions of State Route 2 and areas along Forest service (FS) road 6510 for the Bolt Creek Fire. For the Suiattle River, Boulder Lake, and Lake Toketie Fires, we focused on areas below the fires along FS 2600.

Satellite-derived data in the form of a calibrated Soil Burn Severity map was available for all four fires and was provided by the USFS BAER team. They reviewed it for the federal lands and calibrated it for application throughout the burned area.

Soil burn severity and Burned Area Reflectance Classification (BARC) data

OBSERVATIONS

The soil burn severity was assessed by the USFS BAER team using Burned Area Reflectance Classification (BARC) data provided by the USFS. The BARC data were field checked and calibrated using guidance from the report of Parson and others (2010) and were calibrated and posted online (https://inciweb.nwcg.gov/incident/article/8429/72413/). In their report the BAER team outline burn severity in acres. We encourage interested parties to consult the BAER team report and maps if they have questions about burn severity in their area. If you need assistance accessing or analyzing the data, please contact us and we can provide some support.

According to the USFS BAER report, 5,918 acres or 51 percent of the area affected by the Bolt Creek fire was either unburned or had low soil burn severity. Approximately 3,790 acres (32%) were marked as moderate burn severity and 1,803 acres (16%) were marked as high burn severity.

For the Suiattle River, Boulder Lake, and Lake Toketie Fires, 1,260 acres or 67 percent of the area affected by the fire was either unburned or had low soil burn severity. Approximately 432 acres (23%) were marked as moderate burn severity and 187 acres (10%) were marked as high burn severity.

U.S. Geological Survey (USGS) post-fire debris flow hazard assessment

MODELING RESULTS

The USGS provided a debris flow assessment for the four fires based on the field-validated soil burn severity data provided by the USFS. The data will be available on their website (https://landslides.usgs.gov/hazards/postfire_debrisflow/).

There are various outputs and ways to view the data. Here we will discuss the combined relative debris flow hazard for basins, which uses 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 channel segments within basins using the same hazard rating. We will focus on locations where public safety and infrastructure could be impacted.

The USGS debris flow modeling is based on a modeled storm event with a peak rainfall intensity of approximately one quarter of an inch of rain in a 15-minute period. These models were not developed with data that take into account climate on the western side of the Cascades in the Pacific Northwest. Of note, this model does not take into account the effect of rain-on-snow in a recently burned area. Debris flows and flash floods may occur during rain-on-snow events and not meet the predicted rainfall threshold.

Interpretations

The USGS modeling suggests that there is Low, Moderate, and High debris flow hazard in drainages throughout the burned areas. Below we outline the various drainages where debris flows and flash flooding could impact the property and infrastructure that we reviewed during the limited reconnaissance field work.

BOLT CREEK FIRE

Unnamed fan along FS 6024 (Point 1 on Plate 1)

The FS 6024 road traverses several mapped fans along the west-facing slopes east of Barclay Creek, at the west end of the burned area. This road provides access to the Barclay Lake trailhead. Basins associated with these fans are modeled as having Low to Moderate debris flow hazard after the Bolt Creek fire. These fans were not observed in the field during our assessment, as the fire was actively burning in this area. Additionally, since the fire was still burning during the time of this assessment, results of the soil burn severity and debris flow modeling may not accurately reflect conditions once the fire is eventually extinguished. While debris flow hazards may be modeled as Low and Moderate, flash flooding, debris flows, and increased rockfall could impact infrastructure on the fans during heavy precipitation or rain-on-snow events.

Unnamed fan east of Baring (Point 2 on Plate 1)

The basin above this fan is modeled as High debris flow hazard. Hummocky topography and several channels were observed on the fan surface, although heavy vegetation obscured much of the fan. Several tributaries converge above this fan's surface and the confined channel immediately upslope of it. An additional mid-slope fan has been deposited at this convergence, and it exhibits evidence that past events have episodically been diverted southward, away from the fan surface associated with Point 2. Residential property and structures, and Bonneville Power Administration (BPA) access roads, transmission lines, and towers are located on and adjacent to the mapped extent of the fan. While much of this infrastructure is located outside of the mapped fan, flash flooding and debris flows could impact infrastructure during heavy precipitation or rain-on-snow events given its relative proximity.

Unnamed fan southeast of Baring (Point 3 on Plate 1)

The basin above this fan is modeled as Moderate debris flow hazard. Hummocky topography, apparent debris lobes, boulders up to 1.5 feet in diameter, and multiple channels were observed on this fan's surface both remotely and in the field. A BPA transmission line access road traverses the middle of the fan, and the railroad and State Route 2 traverse the distal edge of the fan. An additional mid-slope fan has been deposited at the convergence of several tributaries upstream, where these tributaries lose confinement and the main channel then takes a sharp turn to the northeast. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact the above infrastructure. However, this mid-slope fan and the turn in the channel may partially arrest the movement of a debris flow on its way downslope.

Unnamed fan at mile point 3.75 (Point 4 on Plate 1)

The basin above this fan is modeled as High debris flow hazard. Hummocky topography, several channels, and boulders up to 1 foot in diameter were observed on the fan's surface during our field reconnaissance, suggesting past debris-flow activity. A BPA transmission line access road traverses the upper portion of the fan, and State Route 2 and the railroad have been excavated into portions of the fan. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact the access road, State Route 2, and the railroad. However, a mid-slope fan has been deposited upstream of this fan where the steep channel partially loses confinement, suggesting that some debris flows may be deposited mid-slope before they reach the fan that intersects the State Route 2 downstream.

Unnamed fan at mile point 44.25 (Point 5 on Plate 1)

The basin above this fan is modeled as High debris flow hazard. Excavations into the fan along Highway 2 expose boulders up to 1 foot in diameter in the fan deposit, and several adjacent culverts under the highway were observed during our field reconnaissance, suggesting past debris-flow activity. BPA transmission line towers and an access road traverse the fan. State Route 2 and the railroad have also been excavated into portions of the fan. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact transmission line infrastructure, State Route 2, and the railroad.

Grotto fan (Point 6 on Plate 1)

The basins above this fan complex are modeled as High debris flow hazard. The community of Grotto, BPA transmission line infrastructure, State Route 2, and the railroad are all located within the mapped extent of this fan. Field access was limited to the residential roads at the distal end of the fan, where development has obscured topographic features. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact the community of Grotto, transmission line infrastructure, State Route 2, and the railroad.

Bolt Creek fan (Point 7 on Plate 1)

The basin above the Bolt Creek fan is modeled as Moderate debris flow hazard, with the majority of the modeled stream segments within the basin modeled as High debris flow hazard. A dispersed campsite exists near the active channel and Beckler Road traverses the fan downslope of the campsite. In the active channel and near the dispersed campsite, boulders approximately 4 feet in diameter were observed, suggesting past debris-flow activity. The channel loses confinement where the FS 6510 road crosses the channel. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact the FS 6510 road crossing, the dispersed campsite, and where Beckler Road crosses the fan.

Unnamed fan below FS 6510 (Point 8 on Plate 1)

The basin above this fan is modeled as High debris flow hazard. At the apex of the fan, the channel loses confinement where the FS 6510 road crosses the channel. A review of the lidar data shows that the channel is steep and confined until it exits onto the valley floor. Flash flooding and debris flows could impact the FS 6510 road crossing at the apex of the fan during heavy precipitation and rain-on-snow events.

Debris flows and flash floods also could deposit material in the Beckler River. The Beckler River Campground is on the other side of the Beckler River directly across from the fan. Campsites are not directly at risk but debris flows and flash floods could impact any recreation in the Beckler River adjacent to and below the fan.

2020 debris flow fan (Point 9 on Plate 1)

The basin above the 2020 debris flow fan is modeled as Moderate debris flow hazard. A debris flow occurred in this drainage in 2020. The mapped alluvial fan is based on lidar and from the runout visible in the 2021 orthophoto. Much of the modeled basin appears to have been clearcut harvested sometime between the 2015 and 2017 orthophotos.

A review of the 2021 othrophoto shows that the event possibly started as a road failure along a private road. The event continued downstream and impacted three road crossings downstream, including crossings at the FS 6514 and 6510 roads. The FS 6510 road is still closed from the 2020 failure.

At the FS 6514 crossing, the channel was scoured up to 15 feet. The channel walls consist of loose, unconsolidated colluvium with boulders up to 3 feet in diameter. Looking from the Beckler River campground across the Beckler River, the debris flow deposit consists of logs and boulders up to 2 feet in diameter.

Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation and rain-on-snow events could impact roads crossing this channel. Debris flows and flash floods also could deposit material in the Beckler River. The Beckler River Campground is on the other side of the Beckler River directly across from this fan. Campsites are not directly at risk but debris flows and flash floods could impact any recreation in the Beckler River adjacent to and below the fan.

SUIATTLE RIVER, BOULDER LAKE, AND LAKE TOKETIE FIRES

The sections below provide information on alluvial fans with infrastructure along FS 2600. Note that we did not evaluate the portion of FS 2660 that runs below the Boulder Lake Fire. Please see the USFS BAER team report for possible impacts to this road.

Tenas Creek fan (Point 10 on Plate 2)

The basin above the Tenas Creek fan has sub-basins that are modeled as Low and Moderate debris flow hazard. The majority of the drainage above the fan and the area where the Boulder Lake Fire burned does not have lidar topographic data available. The first modeled debris flow hazard basin (Low hazard) is approximately 2.5 miles upstream of the apex of the fan and 3.6 miles upstream of where Tenas Creek crosses under the FS 2600 road. In a review of the limited lidar data and the 10-meter DEM, Tenas Creek does not appear to be confined for the majority of the channel downslope of the fire. The FS 2600 road crossing is far enough away from where the channel exits the mountain front that flooding is more likely than debris flows during heavy precipitation and rain-on-snow events.

Unnamed fan along FS 2600 (Point 11 on Plate 2)

The basin above this fan has sub-basins that are modeled as Low debris flow hazard after the Suiattle River Fire. The channel floor and sides of the active channel where it crosses FS 2600 are composed of subrounded boulders up to 5 feet in diameter, indicating past debris flow activity. A review of the lidar data shows that the channel is steep and confined until it exits onto the valley floor. One home exists on the alluvial fan and the FS 2600 road crosses the fan. Both the road and the home are near the active channel. While debris flow hazard may be modeled as Low, flooding and debris flows could impact infrastructure on the fan during heavy precipitation or rain-on-snow events based on evidence of past events.

Buck Creek Campground fan (Point 12 on Plate 2)

We conducted a rapid visual assessment of the Buck Creek Campground. Boulders ranging from 2–15 feet in diameter and apparent debris lobes were observed on the alluvial fan, suggesting past debris flow activity. The campsites closest to Buck Creek are approximately 4–8 feet above the active channel. Boulders up to 10 feet in diameter were observed in these sites. Towards the apex of the fan, we observed strand lines, water scour, and other signs of seasonal high flooding from this past year.

At the apex of the fan and directly above the campground, a 20-foot-high log jam spans the entire active channel. Unconsolidated sediment composed of silt, sand, and cobbles has filled in the channel behind the log jam.

The majority of the drainage above the fan and the area where the Lake Toketie Fire burned does not have lidar topographic data available. Above the Buck Creek fan the majority of the sub-basins are modeled as Moderate and High debris flow hazard. The first modeled debris flow hazard basin (Moderate hazard) is approximately 5 miles upstream of the Buck Creek Campground fan.

We mapped two alluvial fans directly below the fire scar. The extent of these is approximate due to the lack of detailed lidar data. A review of the 2019 orthophoto shows past debris flow and snow avalanche scars within the burn perimeter, suggesting past activity along the slope.

Debris flows need steep, confined channels to continue moving downstream. In a review of the limited lidar data and the 10-meter DEM, the channel loses confinement in several areas downstream of the fire. However, field reconnaissance showed that debris flow events capable of transporting large boulders deposit on the fan at the campground regardless of the effects of wildfire. The log jam at the apex of the fan also increases the likelihood of channel avulsion, which could cause inundation on a large part of the fan. Based on the modeling and field reconnaissance, flash flooding and debris flows could impact the campsites, a 1930s picnic shelter, and other campground infrastructure at Buck Creek Campground.

RECOMMENDATIONS

Our assessment suggests that areas downstream of the fires could be impacted by flash flooding and debris flows. These hazards may remain elevated for several years after the fires. In drainages where High and Moderate debris flow hazards exist, debris flow activity may occur during periods of intense precipitation (approximately one quarter of an inch of rain in a 15-minute period). Atmospheric river events or rain-on-snow events could also trigger debris flows. All of the fires discussed in this report are within mapped rain-on-snow zones. More information and maps for rain-on-snow zones in Washington State can be found here: https://data-wadnr.opendata.arcgis.com/datasets/4a8339bfe8ca46b8a0a674195827e6d3_6/about.

Residents of homes built on alluvial fans and (or) adjacent to streams flowing from burned areas should be informed of potential post-fire flash flood and debris flow hazards. Residents should seek appropriate professional consulting services for site-specific evaluations to help them identify the potential threats to their life safety and impacts to infrastructure. For more information on what to do if you live on an alluvial fan, please consult our Floods After Fires flyer (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf).

Landowners and land managers may choose to take action to prevent excessive soil erosion, reduce flooding, and promote revegetation to meet their management and economic goals. Utilizing the soil burn severity map provided by the USFS as a tool to find areas of high and moderate burn severity should assist in this evaluation. We are willing to help direct users to this map product, or to provide the data in various formats as needed.

The Buck Creek and Beckler River Campgrounds and the dispersed camp at Bolt Creek may need signs to warn the public of flash flood and debris flow hazards that could occur post-fire. The use of some campsites at Buck Creek Campground and the dispersed campsite at Bolt Creek may need to be restricted due to the hazard.

Private landowners and managers of transportation networks and power transmission corridors should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) road erosion following wildfires, as well as potential issues with blocked culverts. We recommend further inspecting culverts within channels draining areas impacted by the fires both before and after storm events. Blocked culverts could cause additional flooding and damage, which could otherwise be minimized.

REFERENCES

INCI Web, 2022, Bolt Creek Fire [webpage]. INCI Web. [accessed September 30, 2022 at https://inciweb.nwcg.gov/incident/8417].

INCI Web, 2022, Suiattle River Fire [webpage]. INCI Web. [accessed September 30, 2022 at https://inciweb.nwcg.gov/incident/8396].

Parsons, Annette; Robichaud, P. R.; Lewis, S. A.; Napper, Carolyn; Clark, J. T., 2010, Field guide for mapping post-fire soil burn severity: U.S. Department of Agriculture General Technical Report RMRS-GTR-243, 49 p. [https://www.fs.fed.us/rm/pubs/rmrs_gtr243.pdf]

LIMITATIONS

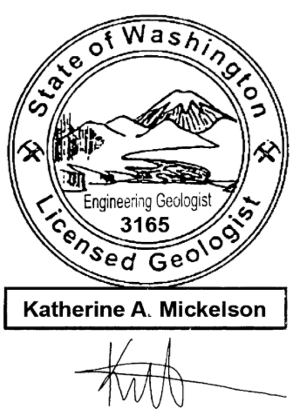
WALERT aims to quickly identify and assess geologic hazards associated with wildfires in order to inform decision-making and to help focus the efforts of local officials and residents who may be impacted by post-wildfire hazards. All observations and interpretations are based on empirical evidence and local knowledge. Not all areas or hazards were evaluated. 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.

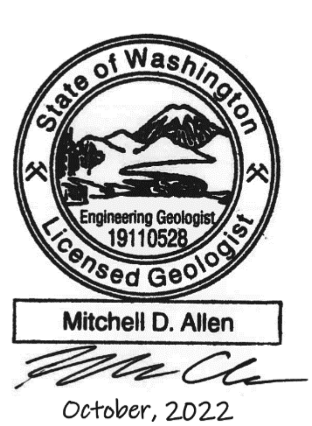
ACKNOWLEDGMENTS

We'd like to thank the USFS BAER team for their cooperation and sharing of data throughout the assessment process. We would also like to thank the diligent fire crews for providing resources and wisdom in a safe and timely manner while we were conducting this assessment during active fire conditions.

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

Mitch Allen
Licensed Engineering Geologist #19110528
Washington Geological Survey
Washington State Dept. of Natural Resources
Olympia, WA
Cell: 360-819-0436
E-mail: mitchell.allen@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. 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. 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 (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf) and Spanish (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans_esp.pdf).

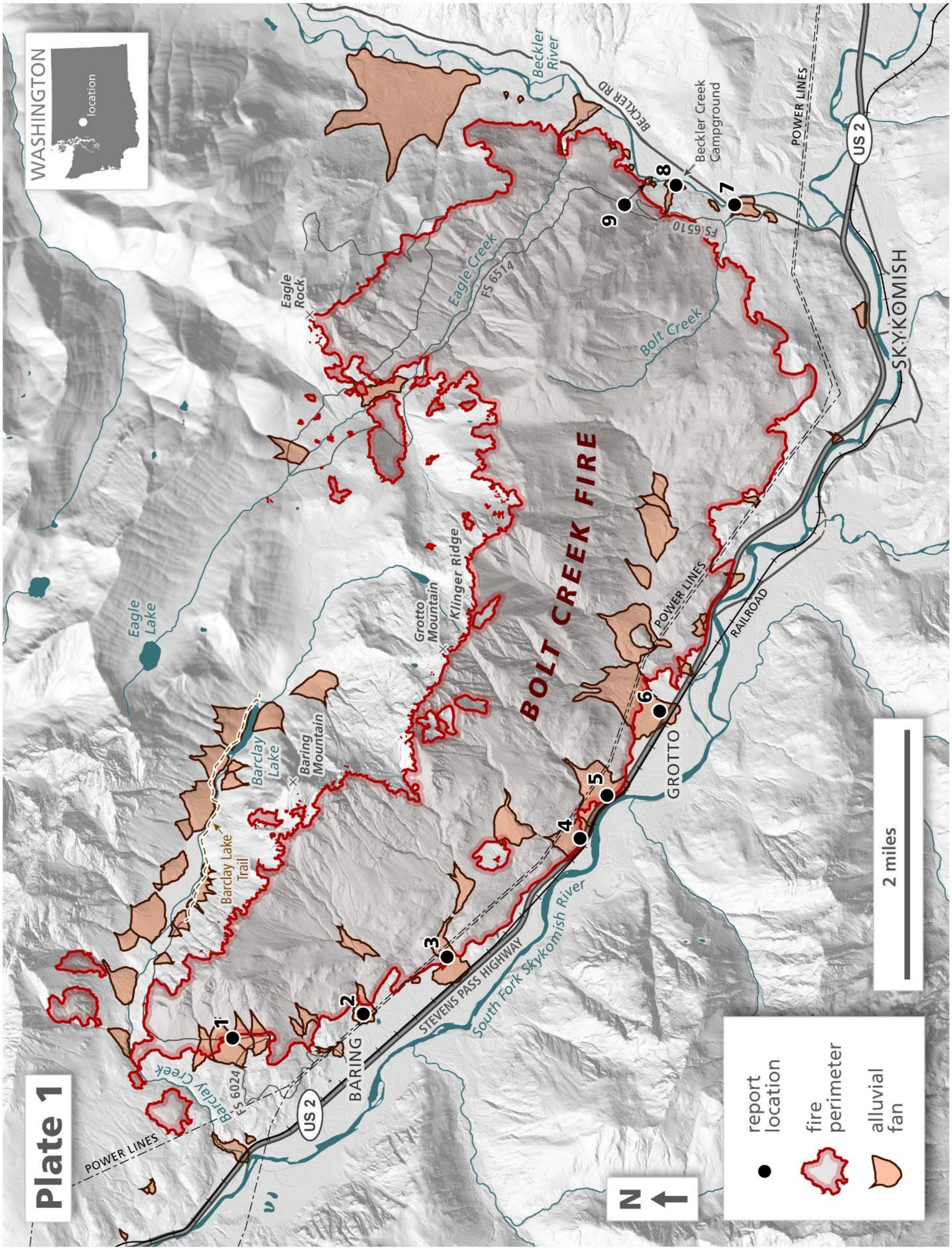


Plate 1
WASHINGTON
location
BOLT CREEK FIRE
Eagle Lake
Barclay Lake
Barclay Lake Trail
Baring Mountain
Grotto Mountain
Klinger Ridge
Eagle Rock
Eagle Creek
FS 6514
Bolt Creek
Beckler River
BECKLER RD
Beckler Creek Campground
FS 6510
POWER LINES
POWER LINES
POWER LINES
US 2
US 2
SKYKOMISH
RAILROAD
GROTTO
BARING
STEVENS PASS HIGHWAY
South Fork Skykomish River
Barclay Creek
FS 6024
1
2
3
4
5
6
7
8
9
2 miles
N
report location
fire perimeter
alluvial fan

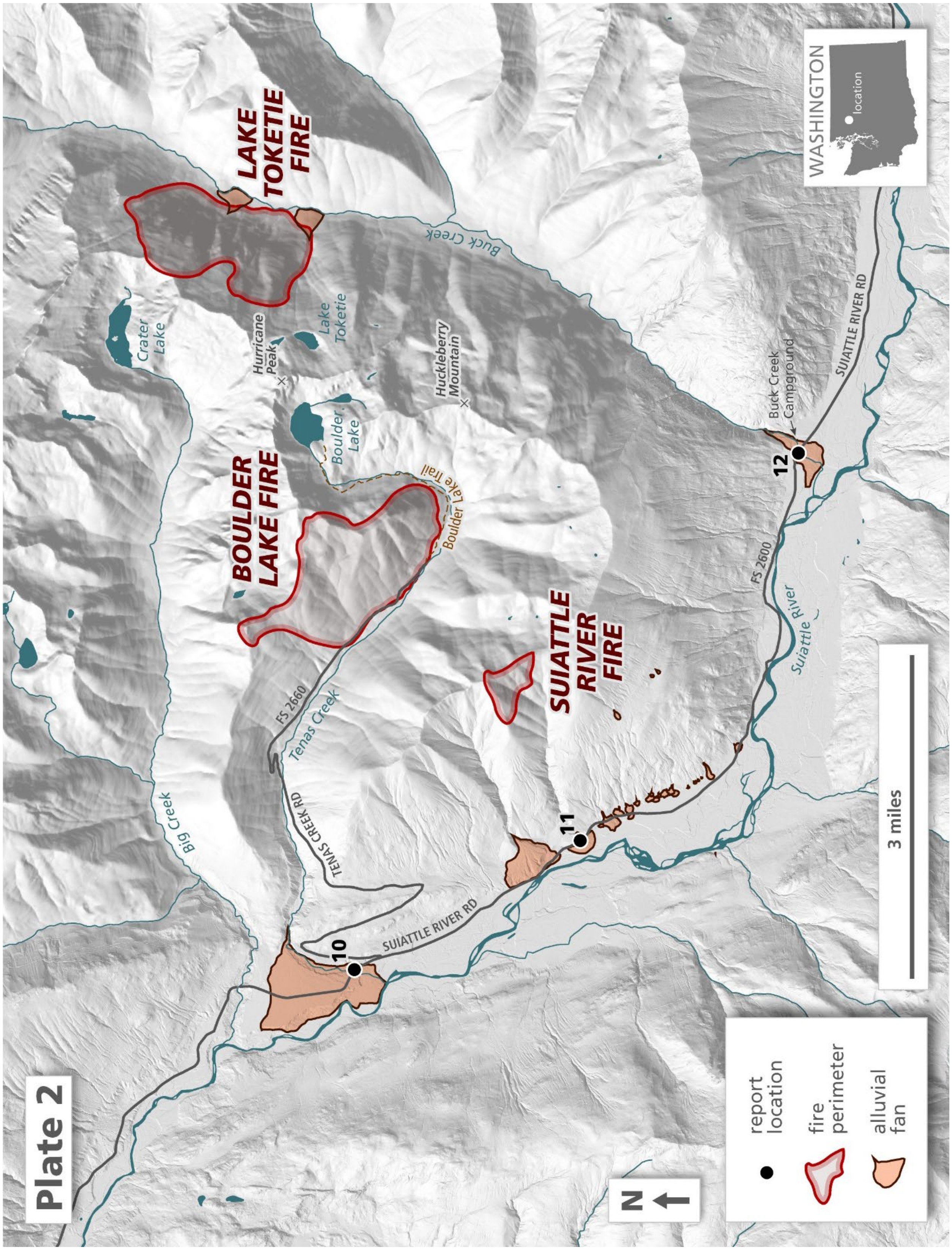


Plate 2
LAKE TOKETIE FIRE
BOULDER LAKE FIRE
SUIATTLE RIVER FIRE
Crater Lake
Hurricane Peak
Lake Toketie
Huckleberry Mountain
Boulder Lake
Boulder Lake Trail
Buck Creek
Buck Creek Campground
SUIATTLE RIVER RD
FS 2600
Suiattle River
FS 2660
Tenas Creek
TENAS CREEK RD
Big Creek
10
11
12
3 miles
N
WASHINGTON
location
report location
fire perimeter
alluvial fan