NATURAL RESOURCES

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

Sourdough and Blue Lake Fires

Whatcom and Chelan Counties, Washington

by Josh Hardesty and Kara Fisher

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
October 2023

WASHINGTON STATE DEPARTMENT OF
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Wildfire-Associated Landslide Emergency Response Team Report for the Sourdough and Blue Lake Fires

by Josh Hardesty[1] and Kara Fisher[1]

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INTRODUCTION

A Wildfire-Associated Landslide Emergency Response Team (WALERT) assessment was conducted to evaluate the potential risk posed by landslides and debris flows from the Sourdough and Blue Lake Fires in northwest Washington State.

Wildfires can significantly change the hydrologic response of a watershed so that even modest rainstorms can produce dangerous flash floods and debris flows. In coordination with the U.S. Forest Service (USFS), WALERT assessed areas downstream of slopes burned by wildfires to determine whether debris flows or flooding could impact roads, structures, and other areas where public safety is a concern. Further information about these hazards is provided in Appendix A.

WALERT looked for debris flow potential and historical evidence of debris flows using field reconnaissance, lidar interpretation, Burned Area Reflectance Classification (BARC) maps, and orthoimagery. We also mapped alluvial fans using lidar data and can provide the detailed mapping to interested parties and emergency managers to assist in preparation for potential future flooding and debris flow impacts.

This report is primarily a qualitative assessment of post-wildfire slope stability 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 OVERVIEW

Sourdough Fire

Lightning strikes on July 29 ignited the Sourdough Fire, which continues to burn to the north and northwest of the Diablo Lake area in Washington. As of September 21, the fire is approximately 25 percent contained and has burned 6,369 acres, primarily in brush, timber litter, and timber (INCI Web, 2023). The majority of the burned land is federal and falls within North Cascades National Park.

Blue Lake Fire

The Blue Lake Fire started on August 14 near Washington Pass, approximately 13 miles southwest of Mazama, Washington. As of September 26, the fire is approximately 80 percent contained and has burned 1,074 acres, primarily in timber and brush (INCI Web, 2023). Much of the burned land is federal and falls within the Okanogan–Wenatchee National Forest.

OBSERVATIONS AND INTERPRETATIONS

WALERT field assessments were performed on September 13, while fire suppression efforts were still occurring. The work focused on areas where wildfire effects on watershed hydrology could put life and property at risk. Relating to the Sourdough Fire, areas of interest included a residential community (Hollywood Hills) and its infrastructure, as well as facilities, roads, and structures near and along the north side of Diablo Lake (Plate 1). Areas of interest near the Blue Lake Fire included portions of State Route 20 and the Bridge Creek parking lot (Plate 2).

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

USFS Burned Area Emergency Response (BAER) teams assessed the soil burn severity for each fire using BARC data, a satellite-derived data layer of post-fire vegetation conditions. Following guidance from the report of Parsons and others (2010), the BARC data were field checked and calibrated by the BAER teams. Finalized soil burn severity maps and short reports for the two fires will be available online, most likely by the end of the month.

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

MODELING RESULTS

The USGS provided a debris flow assessment for the Sourdough Fire and Blue Lake Fire using soil burn severity data provided by the USFS. Their assessment relies on empirical models to estimate likelihood of debris-flow generation and flow volume where debris flows initiate.

The USGS debris flow modeling is based on a modeled storm event with a peak rainfall intensity of approximately one-quarter inch of rain in a 15-minute period. Of note, this model does not consider the effect of rain-on-snow events in a recently burned area. Debris flows and flash floods may occur during rain-on-snow events that do not meet the predicted rainfall threshold. The preliminary hazard assessment and data used to complete this assessment are posted on the USGS website[1]. There are various outputs and ways to view the data using the website. If you need assistance analyzing or accessing the debris flow assessment data, please contact us and we can provide support.

Here we'll discuss the combined relative debris flow hazard, which uses both probability and volume from the USGS model to provide three different hazard ratings: Low, Moderate, and High.

Sourdough Fire

The USGS modeling suggests that there are Low, Moderate, and High debris flow hazards in drainages coincident with and emanating from the Sourdough Fire perimeter. Notably, all the High debris flow hazards are within the Stetattle Creek watershed. As such, areas with the highest apparent risks of debris flows and flooding are within and at the mouth of the Stetattle Creek watershed. Tributary streams and associated fans in the upper reaches of Stetattle Creek watershed were not observed during our field assessment, as the fire was actively burning in this area. Considering the fire is actively burning, results of the soil burn severity and debris flow modeling may not accurately reflect conditions once the fire is eventually extinguished.

Blue Lake Fire

The USGS modeling suggests that there are Low and Moderate debris flow hazards in drainages within and emanating from the Blue Lake Fire perimeter. No modeled high debris flow hazards are associated with this fire. Modeled moderate debris flow hazards nearest to SR 20 are located within two drainage basins positioned on Whistler Mountain's southeast side, one drainage basin on Whistler Mountain's southwest side, and within three basins on west-facing slopes to the east of the highway. The basin outlet nearest to public-use infrastructure appears to be associated with the basin off Whistler Mountain's southwest side and above the Bridge Creek parking area.

In the sections below we outline the areas of interest where debris flows and flooding could impact the property, infrastructure, and areas of public-use that we reviewed during the limited reconnaissance field work.

Sourdough Fire

STATE ROUTE 20 CORRIDOR

Mile Point 124 (Sourdough 1 on Plate 1)

Modeling for the basin above the fan mapped at this site indicates Low debris flow hazard given the modeled storm event. That said, site observations suggest previous debris flow or flooding has occurred in the past, and there is currently debris present in the channel (boulders and woody debris). The existing culverts have been slightly damaged (Fig. 1), possibly from falling debris. Review of aerial photographs suggests debris flow activity occurred during the 1990s that impacted the portion of State Route 20 coincident with Sourdough 1. This is further supported by a stand of even-aged (~30 years old) alders seen on the fan, which indicates a channel-clearing event occurred roughly 30 years ago. Additionally, our Recently Reported Landslides website[2] reports slide activity in this area during 2017, which closed the highway and temporarily stranded 89 people.

Mile Point 124.3 (Sourdough 2 on Plate 1)

The modeling results in the basins above the fan mapped at Sourdough 2 show a Moderate debris flow hazard given the modeled storm event. As with Sourdough 1, aerial imagery review indicates that past debris flow activity in this drainage has impacted the portion of State Route 20 coincident with Sourdough 2. At the time of our field review, the channel was relatively clean and

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

[2] https://wadnr.maps.arcgis.com/apps/webappviewer/index.html?id=ef7ea514f7e54dde8cf1e8eefd2037b4

predominantly comprised of exposed bedrock. While State Route 20 road culverts appeared to be in good condition, future debris flows have potential to pass over and impact the road surface. Additionally, flash flooding due to increased soil hydrophobicity upslope could result in flooding of the highway at this location, especially if culverts become obstructed.

STETATTLE CREEK DRAINAGE

The hottest part of the fire burned within the Stetattle Creek watershed, resulting in several drainages with High debris flow hazards. Future debris flows in this watershed would likely deposit abundant material into the Stetattle Creek drainage system. In addition, the size of the watershed indicates that flooding may occur where Stetattle Creek loses confinement. This area is home to recreation destinations such as the Stetattle Creek Trail and the Sourdough Campground and is located north of the Hollywood Hills residential area. Due to burn restrictions and safety concerns, we were not able to access upper portions of the drainage during our field assessment. WALERT mapped alluvial fans that may contain elevated debris flow hazards but did not do an exhaustive assessment of all the post-fire hazards in the area. We can provide alluvial fan maps at appropriate scale for emergency managers and communities planning for post-fire flooding and debris flows.

Stetattle Creek Fan (Sourdough 3 on Plate 1)

The Stetattle Creek fan is located at the confluence between Stetattle Creek and the Skagit River. The Hollywood Hills community is located on the Stetattle Creek fan. The basins draining into Stetattle Creek are modeled as Low, Moderate, and High debris flow hazard areas given the modeled storm event. Considering High debris flow hazards are present upstream from the fan, this site contains an elevated risk of being impacted by debris flow or flooding activity. There is a 35-foot wide and 10–15-foot-tall manmade levee that runs along the eastern bank of the creek. Much of the levee was covered with vegetation, which masked most of its surface. Where visible, boulders and concrete grout were observed on the water side of the levee. However, its internal composition and therefore competency is unknown. Past storm events, such as one that occurred in 2007, have an ability to reposition the active channel and mobilize large boulders (over 5 feet diameter), as observed currently in the stream. The post-fire elevated risk of flooding and scour presents a hazard to the residential community and its access bridge (Fig. 2), which are both located on the Stetattle Creek fan. In addition, there are debris flow hazards to this community associated with streams, such as Rumsey Creek, coming off slopes to the east of the Stetattle Creek fan.

Rumsey Creek Fan (Sourdough 4 on Plate 1)

The Rumsey Creek basin is modeled as Moderate debris flow hazard. The Rumsey Creek channel is steep and relatively straight. Because the steep channel quickly loses confinement on low gradient ground in close proximity to residential structures and a road, this site presents a public safety concern. We were informed by onsite Seattle City Light staff that Rumsey Creek has a history of flooding, with the catchment often clogging with leaves/channel debris and overflowing into the street during the rainy season. At the time of our field investigation, the culvert grate at Rumsey Creek Street was clear, although we were informed that it had recently been cleaned out. Notably, a wedge of alluvium has accumulated behind an in-channel rock wall immediately upstream from the culvert, which appears to have reduced the size of the catchment.

DIABLO LAKE AREA

Boat Launch/Diablo Dam Parking (Sourdough 5 on Plate 1)

On the north side of Diablo Dam Road, there is a steep outcrop of weathered metamorphic bedrock (Skagit Gneiss) at angles between 35 and 85 degrees, including prominent vertical faces. While these slopes burned between Very Low and Low intensity, they are positioned immediately above the road, public parking, and a boat launch. Loss of vegetation from the burn may increase the likelihood of rockfall in the area.

Diablo Lake Fan (Sourdough 6 on Plate 1)

The unnamed basin above this fan is modeled as Moderate debris flow hazard. There are many large boulders (5 to 8 feet in diameter) present on the fan and in close proximity to Diablo Dam Road. Channel scour and levee deposition indicated that debris flow or flood activity has occurred in the past. However, large trees on the levees suggest such activity is historically infrequent. Debris flows and flooding triggered by the burn may impact Diablo Dam Road where it intersects the mapped fan. We understand that the property owner has consulted with geohazard experts to assess the stability of this area.

Sourdough Creek Fan (Sourdough 7 on Plate 1)

The Sourdough Creek Fan is positioned downslope from a basin (of Sourdough Creek) modeled as a Moderate debris flow hazard. Based on remote review and field observations, Sourdough Creek has a history of channel-clearing debris flow events. Further, a recent (post-March, 2023) landslide failure appears to have entrained and deposited considerable material in the channel of Sourdough Creek upstream from the fan. Although the arrangement and total runout distance of this upstream landslide material is unknown, we expect that this recently deposited material is now available for mobilization in future flooding and (or) debris flow events in the basin. Abandoned channels located within the central portion of the fan and east of the active channel are bounded with steep, 20–30-foot-tall levees. These levees present natural barriers that should help protect future post-fire debris flow events from impacting structures, facilities, and roads located on the south–central and southeastern portions of the fan. However, there appears to be an elevated risk of debris activity and (or) flooding impacting the portion of Diablo Dam Road and a parking lot near Sourdough Creek's active channel. From aerial imagery review, this section of road appears to have been impacted by debris flows in the currently active channel during the 1990s.

Blue Lake Fire

As USGS models were not available to assess the Blue Lake Fire, our findings and interpretations are limited to the USFS soil burn severity map, lidar and aerial imagery review, and field reconnaissance.

The burn perimeter is bisected by US Highway (SR) 20, which runs predominantly southwest to northeast in this area. There are multiple alluvial fans near the highway.

STATE ROUTE 20 CORRIDOR

Bridge Creek Parking Area (Blue Lake 1 on Plate 2)

The majority of the drainage area above the fan upslope of the parking area lies outside of the current burn perimeter, with the exception of a small portion of the northeasternmost channel. This channel is poorly confined, characterized by scoured bedrock and boulders, terminates above the parking area, and presented no apparent signs of historic debris flow activity. With the noted lack of recent debris flow evidence, Low burn severity, and poor channel confinement, the lower portion of the fan and parking area appears to contain a low potential to be impacted by debris flow activity. Notably, upslope vegetation patterns indicate that snow avalanches occur in this area. As such, the fire and loss of tree root strength may impact the risk of snow avalanches.

State Creek (Blue Lake 2 on Plate 2)

State Creek crosses State Route 20 near MP 159.8. The riparian area upstream of the highway is unburned, although there are tributary channels with fan deposits that drain from the burn and into State Creek (further discussed as Blue Lake 3). The culvert that runs under the highway and provides drainage for State Creek appears to be in good condition. Debris flow hazards due to fire activity are unlikely to damage the State Route 20 road culvert based on its topographic position relative to mapped fans. However, it is possible an increased supply of material from the burn could be mobilized during a storm event, blocking the culvert and (or) causing flooding and increased erosion along the highway.

State Creek fans (Blue Lake 3 on Plate 2)

Four fans were observed on the east side of Whistler Mountain, west of State Creek. The drainages upslope of the fans burned at low, moderate, and high intensity. The southernmost fan is approximately coincident with the outlet of a basin modeled by the USGS as a Moderate debris flow hazard. Future debris flows from this basin and the other basins associated with our mapped fans, which have modeled Low debris flow hazards, are unlikely to impact State Route 20. Such events would need to cross State Creek to impact the highway, which appears unlikely given their lower elevations and relative distances from State Route 20. However, material from debris flow or flood events could be mobilized down State Creek's channel to the culvert at Blue Lake 2, as discussed previously.

US Highway 20 Mile Point 160.7 (Blue Lake 4 on Plate 2)

An unnamed tributary drains from Blue Lake to State Creek, flowing westward through a culvert under State Route 20. Where the channel loses confinement, material deposits onto an alluvial fan just west of mile point 160.7. A portion of the drainage to the east of the highway is within the burn perimeter and burned at either very low or low intensity. The USGS did not model this basin. No evidence of recent debris flow activity was observed on either side of the highway. Additionally, the elevation of the drainage running under the highway is approximately 30 feet lower than the elevation of the highway itself (Fig. 3). For these reasons, it is unlikely that the highway is at risk of debris flow activity in this area, although the culvert could become blocked, which may result in flooding and increased erosion along the highway.

RECOMMENDATIONS

Landowners and 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 maps provided by the USFS as a tool to find areas of high and moderate burn severity should assist in these evaluations. We can provide the data in various formats as needed.

Our assessment suggests that flash flooding and debris flows could impact the areas evaluated downstream of the burned areas. 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), and rain-on-snow events[3].

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. For more information on how to stay safe when at risk from debris flows, please consult our Floods After Fire pamphlet[4] and the USGS's fact sheet[5] with safety tips relating to post-fire debris flows.

The Stetattle Creek fan and its residential structures, roads, and bridge appear to be at an elevated risk of being impacted by flood waters and debris flow activity. We recommend that landowners consider mitigating against such risks by consulting with geohazards experts. We also recommend land stewards consider prohibiting recreational access to the Stetattle Creek watershed during the post-fire recovery period when the risk of debris flows and flooding is elevated. The Stetattle Creek area and sections of Diablo Dam Road may need signs to warn the public of flash flood and debris flow hazards that could occur post-fire.

Managers of transportation networks should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion to roads, as well as potential issues with blocked culverts. We suggest reminding transportation network managers to inspect culverts from channels draining areas impacted by the fires both before and after storm events, otherwise culverts could be blocked, causing additional flooding and damage. Elevated rockfall hazards may be present in locations where the Sourdough Fire perimeter is adjacent to steep slopes near State Route 20 and Diablo Dam Road. These areas may need signs to warn the public of rockfall that could occur post-fire.

Managers may choose to seek outside support from engineering or geologic consultants to protect and maintain critical infrastructure and should closely inspect areas where the fire perimeter drew near such infrastructure. We made an attempt to highlight locations where issues might occur but not all areas were visited during this reconnaissance survey.

ACKNOWLEDGMENTS

We'd like to thank the USFS BAER teams for their cooperation and for sharing data throughout the assessment process. Brandt March with Seattle City Light provided helpful insight, which allowed us to assess risk to the company's infrastructure within the burned area.

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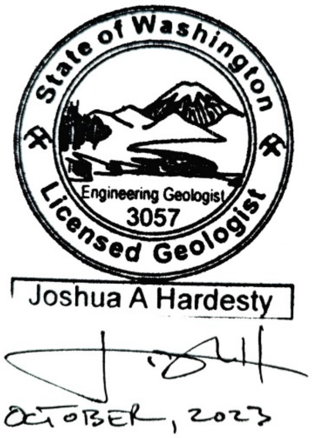
INCI Web, 2023, Sourdough Fire [webpage]: INCI Web. [accessed Sep. 26, 2023 at https://inciweb.nwcg.gov/incident-information/wancp-2023-sourdough-fire-burned-area-emergency-response-baer].

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.usda.gov/rm/pubs/rmrs_gtr243.pdf]

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 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.

[3] More information and maps for rain-on snow zones in Washington State can be found at https://data-wadnr.opendata.arcgis.com/datasets/4a8339bfe8ca46b8a0a674195827e6d3_6/about
[4] https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf
[5] https://pubs.usgs.gov/fs/2022/3078/fs20223078.pdf



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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 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

Figure 1. Inlet side of culverts at Sourdough 1, looking east.

Figure 2. Stetattle Creek bridge, looking upstream.

Figure 3. Stream channel conditions adjacent to State Route 20, looking east at culvert inlet side, for the Blue Lake Fire.

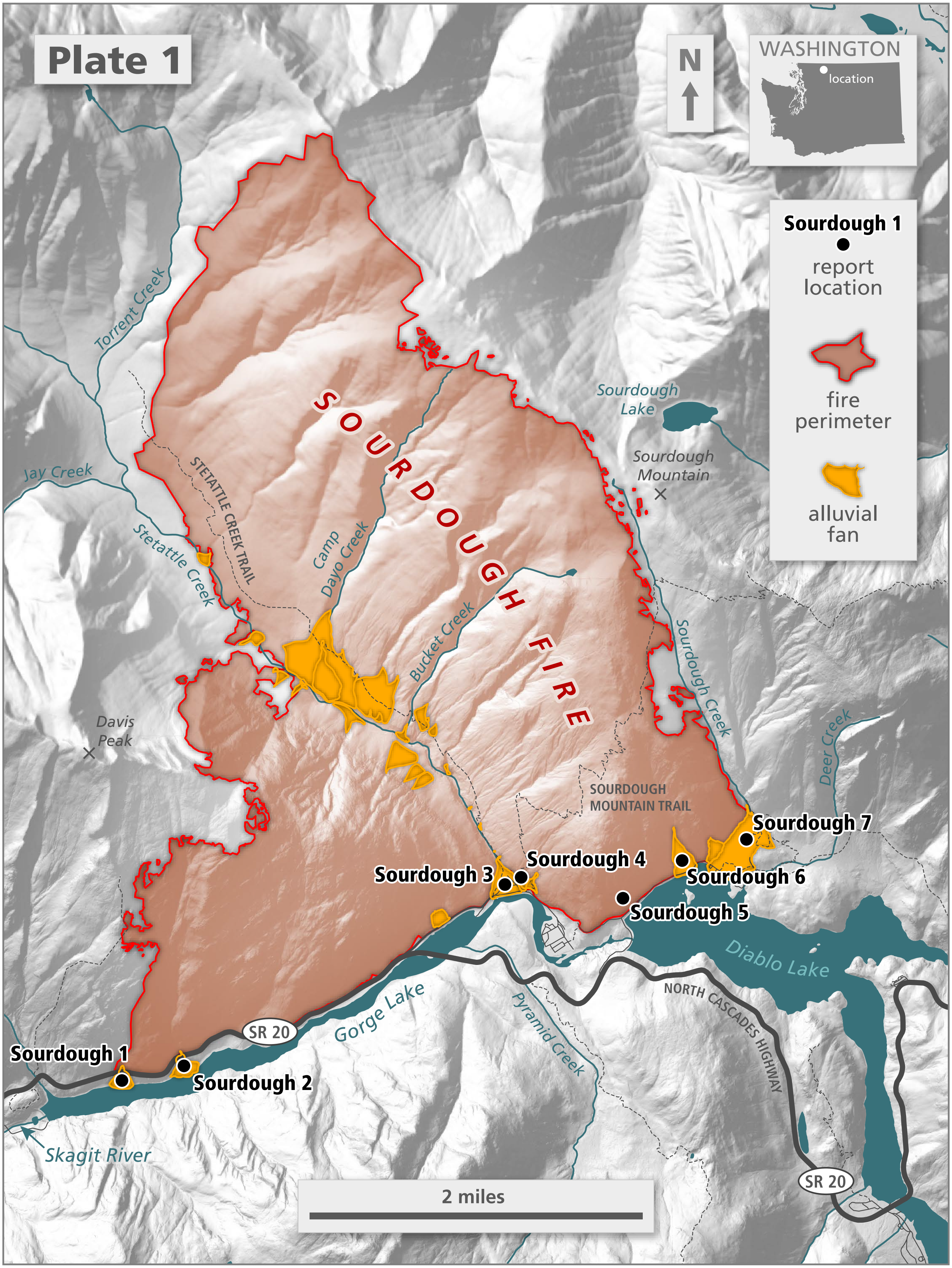
Plate 1
N
WASHINGTON
location
Sourdough 1
report location
fire perimeter
alluvial fan
SOURDOUGH FIRE
Torrent Creek
Jay Creek
Stetattle Creek
STETATTLE CREEK TRAIL
Camp Dayo Creek
Bucket Creek
Sourdough Lake
Sourdough Mountain
Sourdough Creek
Deer Creek
Davis Peak
SOURDOUGH MOUNTAIN TRAIL
Sourdough 7
Sourdough 4
Sourdough 3
Sourdough 6
Sourdough 5
Diablo Lake
NORTH CASCADES HIGHWAY
SR 20
Gorge Lake
Pyramid Creek
Sourdough 1
Sourdough 2
Skagit River
SR 20
2 miles

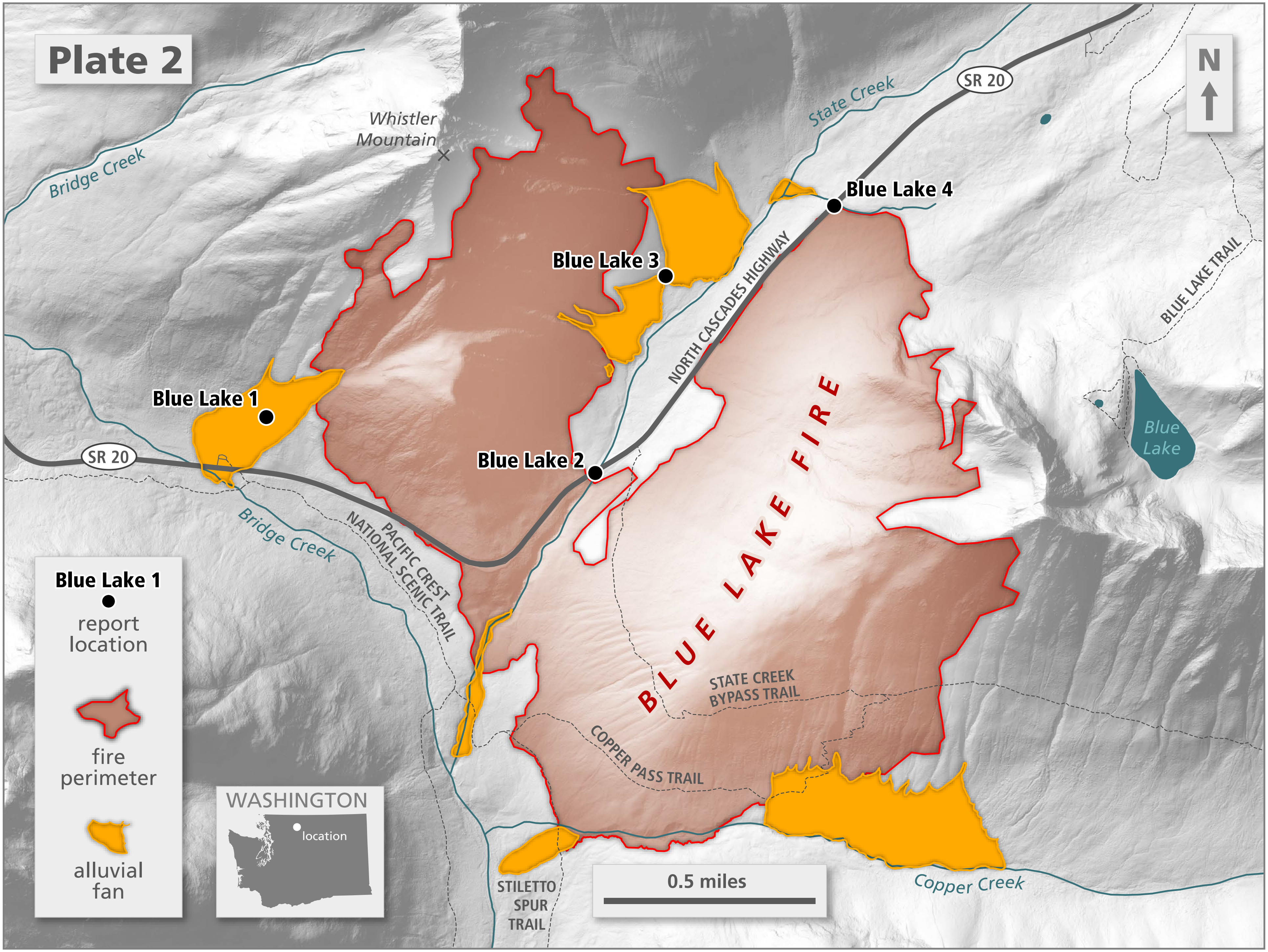

Plate 2
N
Whistler Mountain
Bridge Creek
State Creek
SR 20
Blue Lake 4
Blue Lake 3
Blue Lake 1
Blue Lake 2
NORTH CASCADES HIGHWAY
BLUE LAKE TRAIL
Blue Lake
BLUE LAKE FIRE
Bridge Creek
PACIFIC CREST NATIONAL SCENIC TRAIL
STATE CREEK BYPASS TRAIL
COPPER PASS TRAIL
STILETTO SPUR TRAIL
Copper Creek
0.5 miles
WASHINGTON
location
Blue Lake 1
report location
fire perimeter
alluvial fan