NATURAL RESOURCES

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

Cedar Creek and Cub Creek 2 Fires

Okanogan County, Washington

by Trevor Contreras and Kate Mickelson

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
September 8, 2021

WASHINGTON STATE DEPARTMENT OF
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Wildfire-Associated Landslide Emergency Response Team Report for the Cedar Creek and Cub Creek 2 Fires

by Trevor Contreras[1] and Kate Mickelson[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 two fires near Mazama and Winthrop, Washington. 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 soil burn severity and 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 historical evidence of debris flows using field reconnaissance, lidar interpretation, Burned Area Reflectance Classification (BARC) maps, and orthoimagery. The USFS Burned Area Emergency Response (BAER) team finalized soil burn severity maps for both fires based on satellite data, which was provided to partners and will be posted online at: http://www.centralwashingtonfirerecovery.info/. 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 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

Cedar Creek Fire

Lightning strikes on July 8 ignited several fires in the Methow Valley area of Washington. The Cedar Creek Fire merged with the Varden Fires and the combined fire retained the name Cedar Creek. As of September 6, the fire has burned 55,187 acres, primarily in brush, timber litter, and timber (INCI Web, 2021).

The majority of the land that burned is on U.S. Forest Service land (97.2% of the total burned area). See Table 1 for land ownership information.

Table 1. Ownership distribution of burned area for Cedar Creek Fire.

Land Owner/Manager	Acres	Percent of burned area
U.S. Forest Service (USFS)	53,718	97.2
WA State Dept. of Natural Resources (WADNR)	870	1.6
Private Ownership	647	1.2
Total	55,235[1]	100

[1] This value does not match the number of burned acres as reported by INCI Web. The reported burned acreage was 55,187. The acreage as reported here reflects a deviation of approximately 0.01%.

Cub Creek 2 Fire

The Cub Creek 2 Fire started on July 16, 5 miles north of Winthrop. As of September 6, the fire has burned 70,186 acres, primarily in brush, timber litter, and timber (INCI Web, 2021). The majority of the land that burned is on U.S. Forest Service land (97.6% of the total burned area). See Table 2 for land ownership information.

Table 2. Ownership distribution of burned area for Cub Creek 2 Fire.

Land Owner/Manager	Acres	Percent of burned area
US Forest Service (USFS)	68,587	97.6
Washington Dept. of Fish and Wildlife (WDFW)	763	1.1
Private Ownership	721	1
US Dept. of Fish and Wildlife	177	0.3
Total	70,248[1]	100

[1] This value does not match the number of burned acres as reported by INCI Web. The reported burned acreage was 70,186. The acreage as reported here reflects a deviation of approximately 0.01%.

OBSERVATIONS AND INTERPRETATIONS

Field assessments were performed August 30–September 1 while mop-up operations were occurring. The work focused on areas where wildfire effects on watershed hydrology could put life and property at risk along portions of State Route 20, and neighborhoods between the fire perimeter and State Route 20 for the Cedar Creek Fire. For the Cub Creek 2 Fire, we focused on areas with campgrounds and private residences along U.S. Forest Service Roads 51 and 5010.

Satellite-derived data in the form of a calibrated Soil Burn Severity map was available for the Cedar Creek and Cub Creek 2 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

The soil burn severity was assessed by the USFS BAER team using Burned Area Reflectance Classification (BARC) data provided by USFS. The BARC data was field checked using guidance from the report of Parson and others (2010), and was calibrated and will be posted online (http://www.centralwashingtonfirerecovery.info/) along with a short report. In their report the USFS BAER team outlines burn severity for each fire in acres by ownership.

According to the report, 28,750 acres or 52 percent of the area affected by the Cedar Creek fire was either unburned or had low soil burn severity. Approximately 8,165 acres (15%) were marked as high burn severity and 18,340 (33%) acres were marked as moderate burn severity.

For the Cub Creek 2 Fire, 41,830 acres or 59 percent of the area affected by the fire was either unburned or had low soil burn severity. Approximately 10,500 acres (15%) were marked as high burn severity and 18,400 (26%) acres were marked as moderate burn severity.

We encourage interested parties to consult these reports and maps. If you need assistance accessing or analyzing the data, please contact us and we can provide some support.

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

MODELING RESULTS

The USGS provided a debris flow assessment for the Cedar Creek and Cub Creek 2 Fires based on the field-validated soil burn severity data provided by the USFS. The data will be posted directly at their website (https://landslides.usgs.gov/hazards/postfire_debrisflow).

There are various outputs and ways to view the data using the website. 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. We will focus on locations where public safety and irrigation infrastructure could be impacted.

INTERPRETATIONS

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

Cedar Creek Fire

STATE ROUTE 20 CORRIDOR

Silver Star Sno-Park Mile Point 170.7 (Cedar 1 on Plate 1)

Modeling for the basin above the Silver Star Sno-Park indicates Moderate debris flow hazard, with approximately 20 percent probability of a debris flow occurring given the modeled storm event. The creek channels suggest previous flooding, with debris coming down the channel. This area does not have lidar topographic data available so the mapped alluvial fan is approximate.

Varden Creek Mile Point 173.1 (Cedar 2 on Plate 1)

The basin above Varden Creek was modeled with various hazard ratings, including Low, Moderate, and High. The highest probabilities were between 80 and 90 percent and are within 1 mile of State Route 20. These debris flows would be capable of impacting the highway. Varden Creek shows signs of previous debris in the channel, specifically piles of large boulders against trees and additional distributary channels including Old Varden Creek.

Early Winters Irrigation Diversion Mile Point 177.7 (Cedar 3 on Plate 1)

The Early Winters irrigation intake appears to be along Early Winters Creek at Cedar 3. Directly above the intake is a basin with Moderate debris flow hazard with a 22 percent probability of a debris flow occurring. Upstream of the intake are basins along Early Winters Creek with various debris flow hazard ratings. It’s unlikely that debris flows would migrate down Early Winters Creek with the same destructive forces as might be found near the debris flow source. However, the irrigation system could be subjected to flooding and debris as material from the burned area migrates downstream and impacts the diversion, requiring more maintenance to clear it.

FANS BETWEEN MAZAMA AND WINTHROP

Overall, the steep mountain front between Mazama and Winthrop that burned in the Cedar Creek Fire has many alluvial fans that appear active. The steep cliffs also pose a rock fall hazard in the coming years, especially as the tree roots that hold the rocks decompose. We mapped alluvial fans that show the possible debris flow hazards but did not do an exhaustive assessment of all the post-fire hazards in the area. We encourage residents to evaluate these hazards on their own property. See Plate 1 for locations mentioned in the text and alluvial fan mapping. We can provide additional alluvial fan maps at appropriate scale for emergency managers and communities planning for post-fire flooding and debris flows.

Freestone Lake Fan (Cedar 4 on Plate 1)

The basin above the Freestone lake fan is modeled as Moderate debris flow hazard and has a 38 percent probability of debris flows occurring given the modeled storm event. We did not observe evidence of recent debris flow or flooding activity on the Freestone lake fan. Nearby homes exist along the outer edges of the alluvial fan. These locations are far enough away from where the channel exits the mountain front that flooding is more likely than debris flows during heavy precipitation events.

Looney Creek Fan (Cedar 5 on Plate 1)

The basin above the Looney Creek fan is modeled as High debris flow hazard and has a 68 percent probability of debris flows occurring given the modeled storm event. We observed evidence of flooding activity in the form of distributary channels across the north and central portions of the fan. Homes and an irrigation ditch exist along the outer edges of the alluvial fan, far enough away from where the channel exits the mountain front that flooding would likely be the impact during heavy precipitation events, not debris flows.

Davelaar Drive Fan (Cedar 6 on Plate 1)

The unnamed basin above the Davelaar Drive fan is modeled as Moderate debris flow hazard and has a 37 percent probability of debris flows occuring given the modeled storm event. The stream channel on the fan appears to exit toward a home and the irrigation ditch on the southeast edge of the fan. Debris flows and flooding could impact this area during the modeled storm event.

Timberline Lane Fan (Cedar 7 on Plate 1)

The unnamed basin above the Timberline Lane fan is modeled as High debris flow hazard and has a 65 percent probability of debris flows occurring given the modeled storm event. The stream channel on the fan appears to exit on the northwest edge of the fan near homes and the irrigation ditch. Debris flows and flooding could impact this area during the modeled storm event.

Little Boulder Creek Fan (Cedar 8 on Plate 1)

The basin above the Little Boulder Creek fan has subbasins that are modeled as Low, Moderate, and High debris flow hazard. Approximately 2,050 acres, or 40 percent of this basin, are modeled as High debris flow hazard, and the highest probability of a debris flow occurring is 83 percent.

We observed evidence of flooding activity in the form of multiple distributary channels across the fan with the current channel flowing north to a culvert under State Route 20 approximately one half-mile from where the stream exists the canyon. Previous flooding of Little Boulder Creek was noted in 1948 and 1974 (USBR, 2008). Homes and an irrigation canal exist along the outer edges of the alluvial fan, far enough away from where the channel exits the mountain front that flooding would likely be the impact during heavy precipitation events, not debris flows.

Fawn Meadow Lane Fan (Cedar 9 on Plate 1)

The basin above Fawn Meadow Lane is modeled as Low debris flow hazard. The fan appears to have multiple channels where it exits a steep drainage. While debris flow hazards may be low, reports of rock fall suggest that this area should anticipate additional rock fall as the burned tree roots lose strength in the coming years

Mountain Valley Road and Holloway Lane Fan (Cedar 10 on Plate 1)

The basin above Mountain Valley Road and Holloway Lane is modeled as Moderate debris flow hazard, with a 19 percent probability of a debris flow occurring for the modeled storm event. The fan appears to have multiple channels where it exits a steep drainage. The network of distributary channels on the fan suggests that it can become active, although residents that have lived in the area for 25 years have not reported flooding. While debris flow hazards may be Moderate, reports of nearby rock fall suggest that this area should anticipate additional rock fall as tree roots lose strength in the coming years.

Unnamed fan at the 600 Block of Wolf Creek Road (Cedar 11 on Plate 1)

The basin above the 600 Block of Wolf Creek Road is modeled as High debris flow hazard, with a 63 percent probability of a debris flow occurring for the modeled storm event. The network of distributary channels on the fan suggests that it can become active, and abundant boulders at the surface of the fan suggest debris flows have impacted the area in the past. From across the valley we observed what appeared to be a slide scar in the burned area at an elevation of about 3,600 feet. This suggests that material may already be transporting downslope due to the fire.

Cabins exist on the distal edge of the fan and thus may be subjected to flooding, and not debris flows. However, the access road could be impacted and impassible if a debris flow event occurs.

Wolf Creek Reclamation District Infrastructure (Cedar 12, 13, and 14 on Plate 1)

The Wolf Creek Reclamation District (WCRD) provides water to over 800 acres downstream of Wolf Creek. The irrigation intake is in the channel of Wolf Creek at point Cedar 12 on the map. There are basins above the intake that are modeled as Low, Moderate, and High hazard for debris flows that could impact this critical infrastructure. Additionally, the ditch that conveys the water has two drainages modeled as High and two modeled as Moderate that cross it before going into a siphon at Little Wolf Creek (point Cedar 13).

An additional intake exists along Little Wolf Creek (point Cedar 14) and above it there are basins modeled with Low, Moderate, and High hazard for debris flows. Approximately 1,600 feet upstream of point Cedar 14 is a basin with High hazard for debris flows that has an 86 percent probability of a debris flow occurring for the modeled storm event. Both the intake and siphon could be impacted should a debris flow occur.

The remainder of the conveyance canals and pipes, depicted on Plate 1 as blue lines, cross drainages with Low and Moderate debris flow hazards before going into Patterson Lake.

Wolf Creek Fan (Cedar 15 on Plate 1)

The basin above the Wolf Creek fan was modeled with various hazard ratings, including Low, Moderate, and High. Previous flooding of Wolf Creek was noted in 1948 and 1974 (USBR, 2008; Inter-Fluve, 2020) and distributary channels are visible in lidar and aerial photos. We wouldn't typically expect debris flows to travel far from the apex of an alluvial fan that drains such a large basin, however, we observed very large boulders and dry channels over 2,000 feet from the apex of the alluvial fan. This suggests that debris flows have occurred on the fan in the past (Fig. 1). The Inter-Fluve (2020) report outlines the channel shifting several thousand feet to the south between 1895 and 1947.

At least three homes near the current channel of Wolf Creek and a small bridge at Perrow Drive could be impacted by flooding and debris flows. There is a small irrigation intake at the apex of the fan that provides water to the north that could also be impacted.

Cub Creek 2 Fire

INTERPRETATIONS

The USGS modeling suggests that there is Low, Moderate, and High debris flow hazard in drainages throughout the burned area. This 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. See Plate 2 showing locations mentioned in the text and alluvial fan mapping for the Cub Creek 2 Fire.

Two main USFS Roads, 5010 and 51, follow the east and west sides of the Chewuch River. These roads cross multiple alluvial fans. The modeled debris flow hazard along these roads is predominantly Moderate, with some basins modeled as Low and High. On FS 5010 High debris flow hazard exists on Butte Creek (81% probability), Spring Creek (78% probability), Leroy Creek (62% probability), and Junior Creek (82% probability). Alluvial fans exist at the mouths of each of these drainages and we observed boulders on all of the fans, indicating past debris flow activity. During heavy precipitation events these drainages could be impacted by flooding, erosion and sedimentation, and (or) debris flows. This would most likely occur as a result of thunderstorms in the spring or summer within the next few years following the fire, or until vegetation is reestablished.

Two irrigation canals exist along the Chewuch River, one on the east side of the river and one on the west. A small portion of the eastern canal is within the fire perimeter. One basin above the eastern canal is modeled as Low debris flow hazard with a 12 percent probability of a debris flow occurring for the modeled storm event. While it's unlikely that debris flows would impact the eastern irrigation canal, the area above the canal is steep and additional rock fall may occur as tree roots lose strength in the coming years.

The irrigation canal on the western side of the Chewuch River has Moderate and Low debris flow hazard with the Moderate probabilities ranging from 32–59 percent of a debris flow occurring for the modeled storm event. The canal also crosses five alluvial fans and areas with rock fall potential. Flooding, debris accumulation, and rock fall could be ongoing problems as material from the burned area migrates downslope, possibly impacting the canal and requiring more maintenance to clear it.

Boulder Creek Drainage Basin (Cub 1 on Plate 2)

Most of the Boulder Creek drainage basin was modeled as Moderate and Low debris flow hazard. Where the channel starts to become confined, there are a few areas modeled as High and Moderate. Where the channel becomes unconfined, Boulder Creek emerges onto an alluvial fan. Large boulders (up to 8 ft in diameter) are present on the fan (Fig. 2). Dispersed campsites from the Boulder Creek Campground are intermixed between these boulders. Toward the southern portion of the fan, activity appears older and less active. With the noted past debris flow activity and the Low, Moderate, and High debris flow hazard modeled in basins along the creek, the fan may experience debris flows and flash flooding in the future.

Brevicomis Creek Drainage Basin (Cub 2 on Plate 2)

Several cabins exist on the Brevicomis Creek alluvial fan. We observed large boulders across the fan and smaller boulders down past the cabins (approximately 1,900 feet away from the apex of the fan), suggesting previous debris flow activity (Fig. 3). Two steep drainages (Brevicomis Creek and an unnamed drainage) remain confined until they merge and exit onto the fan. Both drainages were modeled as having Moderate hazard for debris flows, with 34 percent probability of a debris flow occurring for Brevicomis Creek and 14 percent for the unnamed drainage for the modeled storm event. Based on evidence of past debris flows and the Moderate debris flow hazard, cabin residents should be made aware of post-fire flooding and the possibility of debris flows to the fan.

Doe Creek Drainage Basin (Cub 3 on Plate 2)

The upper reach of Doe Creek drainage basin was modeled as High and Moderate debris flow hazard with the High debris flow probabilities ranging from 87–93 percent for the modeled storm event. The drainage is short, steep, and confined until it exits onto an alluvial fan. Many of the campsites at Chewuch Campground are situated on this alluvial fan. There are large boulders west of USFS road 51, toward the apex of the fan. Within the campground, smaller boulders and cobbles were observed reaching the distal edge of the fan at the Chewuch River, suggesting past debris flow activity. With observed past debris flow activity and with the High and Moderate modeled debris flow hazard, there is potential for future flash flooding and debris flows to the fan.

Falls Creek Drainage Basin (Cub 4 on Plate 2)

The top of the Falls Creek drainage basin was modeled as Moderate and Low debris flow hazard. Where the channel starts to become confined, most of the area was modeled as having High and Moderate hazard, with the High debris flow probabilities ranging from 78–93 percent for the modeled storm event. As Falls Creek loses confinement, material deposits onto an alluvial fan. The majority of campsites at Falls Creek Campground are situated on this alluvial fan. Large boulders ranging in size from 3–10 ft across are present west of USFS road 51 and toward the apex of the fan (Fig. 4). One foot diameter boulders could be seen in the campsites on the distal edge of the fan by the Chewuch River, suggesting previous debris flow activity. Based on past debris flows activity and the High and Moderate debris flow hazard, future debris flows and flash flooding may impact the fan.

Eightmile Creek Drainage Basin (Cub 5 on Plate 2)

The upper and middle reaches of Eightmile Creek are broad and unconfined. As Eightmile approaches the Chewuch River, the channel becomes confined until it exits onto the Chewuch River floodplain. Eightmile Creek is modeled predominantly as Moderate debris flow hazard with patches of Low and High hazard. A section of High hazard exists before the channel becomes confined. At the mouth of the drainage there is an alluvial fan with one home built upon it. The home is situated 15 ft above the active channel and may not be impacted by debris flows or flooding. Residents at this home should be alerted to the flooding and debris flow potential during intense rainstorms in the basin above.

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 map provided by the USFS as a tool to find areas of high and moderate burn severity should assist in this evaluation. 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 area. 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). 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.

The parking lots and camping areas at Falls Creek, Chewuch, and Boulder Creek Campgrounds may need signs to warn the public of flash flood and debris flow hazards during heavy rainstorms. Some campsites may need to be temporarily closed due to the hazard.

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.

Irrigation district managers may need additional support to protect and maintain this critical infrastructure and should closely inspect areas where drainages cross the canals. These crossings could be vulnerable to additional sedimentation, and if the irrigation water is running, additional damage to the system could occur. We made an attempt to highlight locations where issues might occur but not all areas were visited during this reconnaissance survey.

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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 for sharing data throughout the assessment process. Curt Bovee with the Wolf Creek Reclamation District was very helpful in helping us assess their infrastructure within the burned area.

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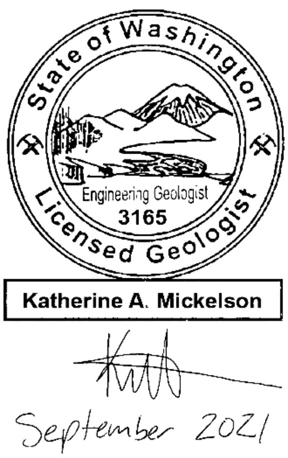

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APPENDIX A: GEOLOGICAL BACKGROUND

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.

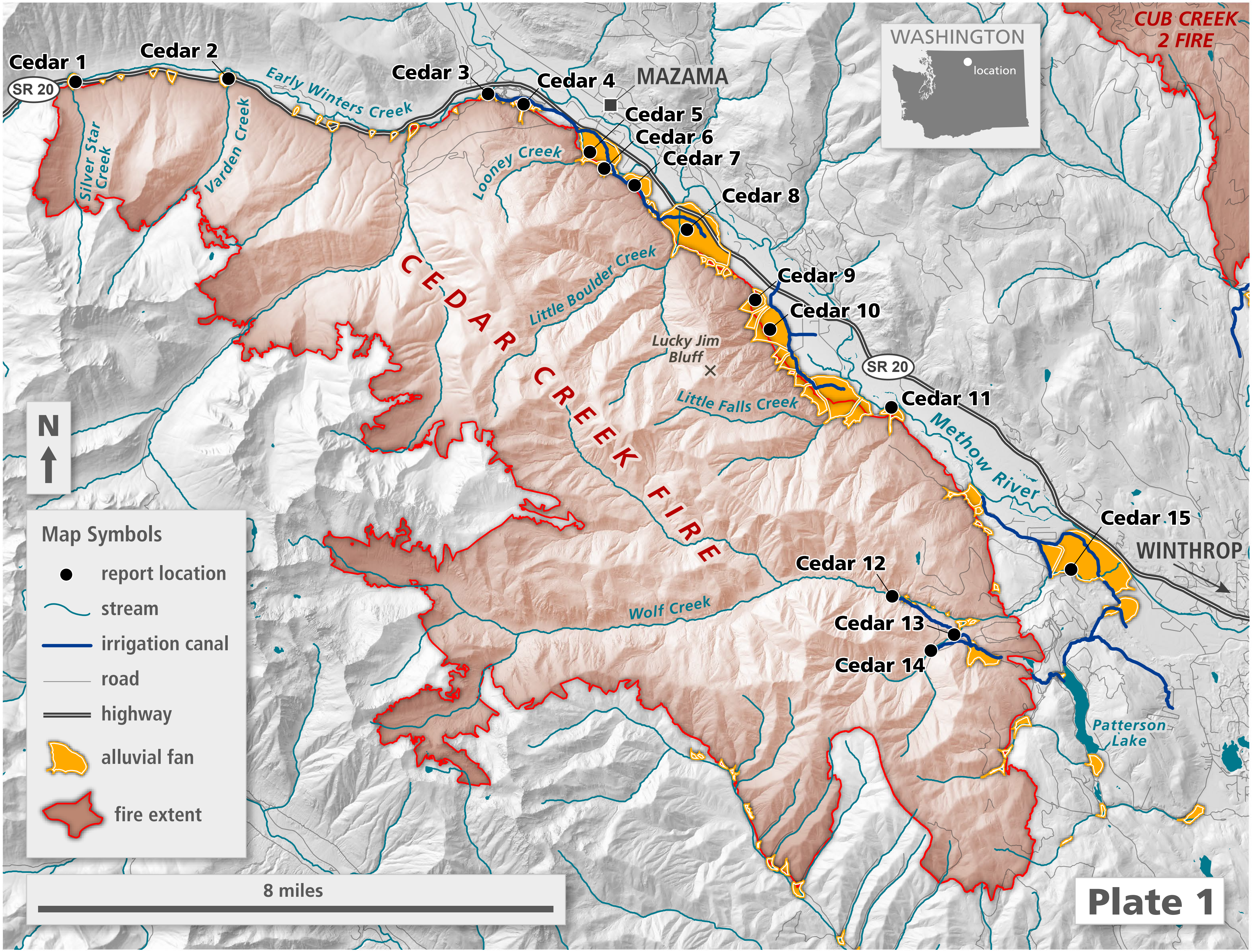
An information flyer about alluvial fan hazards is available on our website in both English (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf) and Spanish (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans_esp.pdf).

Figure 1. Boulders on Wolf Creek fan approximately 2,000 feet downstream of the apex of the alluvial fan. The boulders suggest previous debris flow activity in the area.

Figure 2. Large boulders from previous debris flow activity at Boulder Creek. Campsites are dispersed amongst the boulders at Boulder Creek Campground.

Figure 3. Boulders near the cabins on the Brevicomis Creek alluvial fan, suggesting previous debris flow activity.

Figure 4. Large boulders from past debris flows on the west side of USFS Road 51 at the Falls Creek alluvial fan.



CUB CREEK 2 FIRE
WASHINGTON
location
Cedar 1
Cedar 2
SR 20
Early Winters Creek
Cedar 3
Cedar 4
MAZAMA
Cedar 5
Cedar 6
Cedar 7
Cedar 8
Silver Star Creek
Varden Creek
Looney Creek
Little Boulder Creek
CEDAR CREEK FIRE
Lucky Jim Bluff
Cedar 9
Cedar 10
SR 20
Little Falls Creek
Cedar 11
Methow River
Cedar 15
WINTHROP
Cedar 12
Wolf Creek
Cedar 13
Cedar 14
Patterson Lake
N
Map Symbols
report location
stream
irrigation canal
road
highway
alluvial fan
fire extent
8 miles

Plate 1

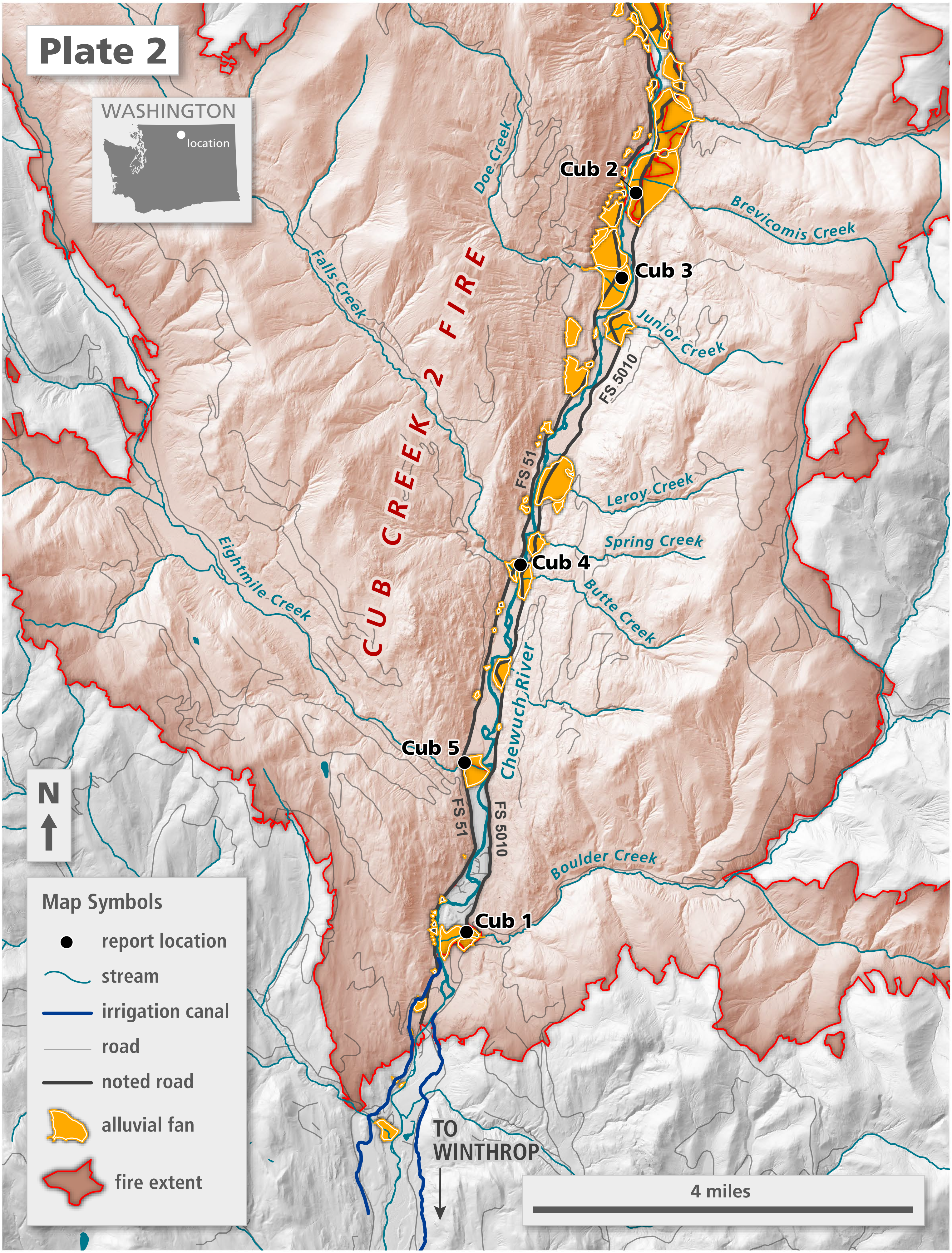


Plate 2
WASHINGTON
location
Doe Creek
Cub 2
Brevicomis Creek
Falls Creek
CUB CREEK 2 FIRE
Cub 3
Junior Creek
FS 5010
FS 51
Leroy Creek
Spring Creek
Cub 4
Butte Creek
Eightmile Creek
Chewuch River
Cub 5
FS 51
FS 5010
Boulder Creek
Cub 1
N
Map Symbols
report location
stream
irrigation canal
road
noted road
alluvial fan
fire extent
TO WINTHROP
4 miles