Riverside Fire

Erosion Threat Assessment/Reduction Team (ETART)
Extended Report

December 2020

FEMA

This page intentionally left blank.

Table of Contents

Executive Summary

This report summarizes a rapid characterization of post-fire conditions resulting from the Riverside Fire and identifies critical values potentially at risk from threats commonly associated with burned areas. In addition, the ETART assessment of drinking water threats from the Riverside and other fires are captured in the ETART Water Quality/Drinking Water Supply Resource Report. The area of interest for this report consists of non-federal lands within and downstream of the Riverside Fire perimeter. Critical values include human life and safety; improved properties/assets such as roads, bridges, buildings and water systems; important natural resources (soil productivity, water quality and municipal water sources, habitats for wildlife and fish); and cultural resources. Threats that exist or are recognized to amplify in a post-fire setting include accelerated soil erosion and hillslope water runoff that results in increased sediment transport, high stream flows, floods or debris flows; landslides and rock fall; hazard trees; mobilization of hazardous materials; and expansion of invasive or noxious plants. This report does not include an assessment of water quality and water systems that provide safe, clean drinking water. Refer to the ETART Water Quality/Drinking Water Supply Resource Report for information on post-fire threats and response actions for these values.

The essential findings of this evaluation are: 1) to identify where emergency conditions exist as defined by critical values at unacceptable risk from imminent post-fire threats; and 2) to recommend emergency response actions that reduce risk or minimize impacts to critical values. In addition to the emergency response actions, the data, analysis and conclusions supporting this report can be used to develop restoration opportunities leading to long-term recovery of the fire-damaged landscape. Multiple “Specialist Reports” encompassing soils, hydrology and water quality, engineering, fish and wildlife, botany and cultural were used to complete this assessment.

The 2020 fire season in Oregon State affected lands across all jurisdictions and ownerships: tribal, federal, state, local and private. Fires on federal and tribal lands are assessed through the U.S. Forest Service (USFS) Burned Area Emergency Response (BAER) or Department of Interior (DOI) Emergency Stabilization and Rehabilitation (ESR) programs. Given the size and severity of the fires’ impacts to state, local and private lands throughout Oregon, the State of Oregon requested the Federal Emergency Management Agency (FEMA) form a multi-jurisdiction assessment team to assess the state, local and private lands of several fires. FEMA coordinated with Oregon Emergency Management (ODF) and Department of Forestry (ODF), National Weather Service (NWS), U.S. Army Corps of Engineers (USACE) and the USFS to staff the Erosion Threat Assessment and Reduction Team (ETART) to evaluate the fire-affected state and private lands.

The team used the USFS BAER and DOI Emergency Stabilization & Rehabilitation (ESR) assessments for several fires, which established the foundation for the ETART and allowed for comprehensive evaluation of all lands burned within the fires.

2020 Oregon ETART is comprised of personnel from Clackamas County Soil and Water Conservation District (SWCD), Lane County, Linn County, Marion County SWCD, West Multnomah SWCD, OR Department of Environmental Quality (DEQ), OR Department of Fish & Wildlife (ODFW), ODF, OR Department of Geology and Mineral Industries (DOGAMI), OR Department of Transportation (ODOT), OR Water Resources Department (OWRD), Bureau of Land Management (BLM), Environmental Protection Agency (EPA), FEMA, USFS, U.S. Geological Survey (USGS), NWS and the Natural Resources Conservation Service (NRCS). These resource specialists completed the assessments while safely managing COVID-related protections, navigating interagency data sharing barriers, operating in a hazardous post-fire field environment and working across a broad geographic area. ETART members went above and beyond the demands of their normal duties to carry out critical emergency assessments in service of local communities.

1. Overview

1.1. Burned Area Characterization

- Fire Name: Riverside
- State: Oregon
- Fire Number: OR-MHF-00859
- County: Clackamas
- Date Fire Started: September 8, 2020
- Date Fire Contained: October 31, 2020 (estimate, ICS-209 dated 10/25/2020)
- Suppression Cost: $21,000,000 (estimate, ICS-209 dated 10/25/2020)

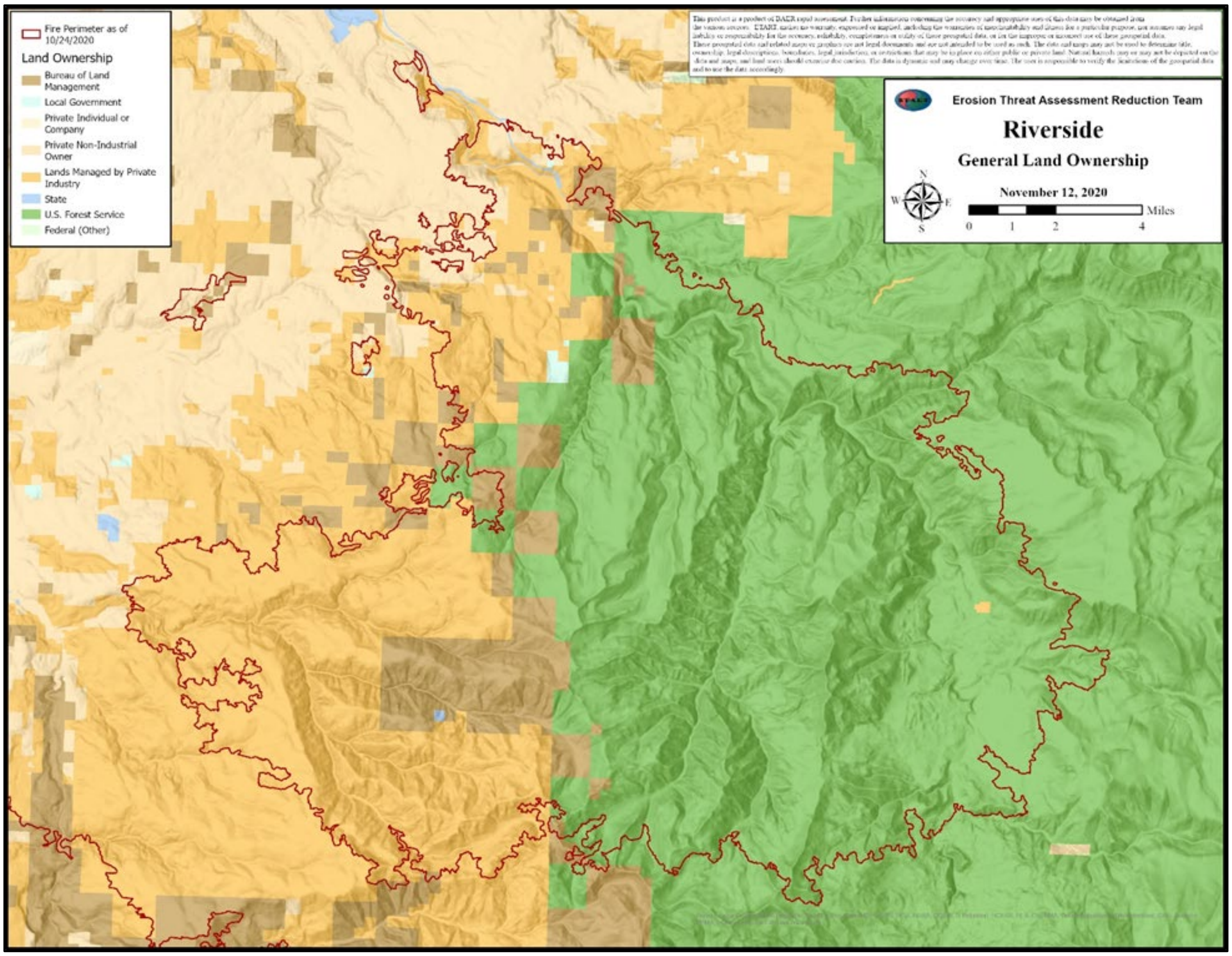


Figure 1. Land Ownership - Riverside Fire

The Riverside Fire was detected on September 8, 2020, southeast of Estacada, Oregon, in the Clackamas River drainage on the Mt. Hood National Forest. Driven by high winds the fire rapidly grew to about 40,000 acres, with fire suppression crews reporting extreme fire behavior that included running crown fire, torching and long-range spotting. By September 9th the fire had burned 112,000 acres, strong easterly winds and low humidity pushed the fire 17 miles west down the Clackamas River corridor and on to surrounding private lands. Erratic winds expanded the fire perimeter on all sides with the largest growth to the east and southeast, causing a 10,000-foot smoke column when plumes from the Riverside and Beachie Creek Fires converged. Heavy smoke conditions grounded air operations until a weather system changed conditions on September 18th. The fire burned approximately 138,151 acres, primarily within the Clackamas and Molalla River basins and destroyed an estimated 57 homes, damaged 10 other residences and 186 minor structures. Multiple land ownerships are affected by the fire, including the Mt. Hood National Forest, BLM, and commercial and private forest lands under authority of the State of Oregon Department of Forestry (ODF). (Figure 1 and Table 1.)

Table 1. Riverside Fire Total Acres Burned – 138,151 (based on post-fire analysis perimeter)

Ownership	Acres	Sq.Mi.	Percent
Local	242	<1	<1%
Private	42,059	123	30%
State	149	<1	<1%
Tribal	0	0	0%
Federal	95,701	141	69%
Total	**138,151**[a]	**216**	

a: the burned area lies entirely within Clackamas County, Oregon.

1.1.1. CLIMATE

Climate in the Clackamas and Molalla River basins is characterized by warm, dry summers, while winters are wet and mild at lower elevations. Most of the precipitation is generated by frontal storms falling between October and May in the form of light- to moderate-intensity rainfall and winter snow accumulations, and averages 72 inches annually. Higher elevation locations in the headwaters of the Clackamas River basin develop snowpack and melt out in spring. Peak flows within the Molalla River basin are largely rainfall dominated, with little storage due to minimal seasonal snowpack or groundwater contributions. Rain-on-snow events are common, typically occurring from November through January, and range in their magnitude of hydrologic responses. While flash flooding and debris flows are rare in this area, there is evidence of previous past debris flows, and these events are more likely due to the post-fire lack of effective ground cover. This may result in hazardous conditions within and downstream of the burned area in the winter and spring months.

1.1.2. GEOLOGIC TYPES

The burned area lies entirely within the Western Cascades Physiographic Province, which is characterized by older volcanic rocks, generally steep slopes, and large ancient landslide deposits. The bedrock geology is primarily comprised of Pliocene to Quaternary igneous extrusive rocks: basalt, basaltic andesite, dacite, and rhyolite. Surficial deposits consist of unconsolidated alluvium, terrace deposits, fluvial glacial, glacial till, rockslide, landslide and debris flow deposits. Landslides are a widespread and damaging natural hazards in Oregon. The general term "landslide" refers to a range of mass movements including rock falls, debris flows, earth slides, and other mass movements. In the Cascades, debris flows and related flash flooding/hyper concentrated flow events, rock fall, shallow and deep landslides are the most common types of landslides. Burned areas associated with the Riverside Fire are mostly confined to the North Fork Molalla River drainage downstream to the confluence with the Molalla River. The Molalla River exclusively drains the less permeable igneous complex of the Western Cascade Range. The layered nature of the basalt/andesite and pyroclastic igneous rock parent material can create unstable slope conditions in the Upper Molalla drainage.

1.1.3. DOMINANT SOILS

Soils in the burned area originate from the volcanic rock types that are resistant to weathering and erosion. Surface soil textures are silt loam, loam or clay loam. The upland soils commonly form from glacial deposits, colluvial materials, residuum and landslides. Soils have varying amounts of rock fragment content across the region. Typically, the skeletal soils are associated with glacial deposits and colluvial deposits. Rock outcrops and scree slopes occur on steeper areas and mountain slopes. Soils with andic soil properties are common throughout the region. The landscape in this region feature steep hillslopes having a natural tendency to slough material; this is due to the soil textures, steep slopes, geology and climate.

1.1.4. VEGETATION TYPES

Three major forest stand association groups within the fire perimeter include the following forest types: western hemlock, mountain hemlock, and silver fir. Grand fir, white fir, and other types compose a small portion of the burn area.

- Western hemlock series occurs at lower elevations in the southwest portion of the forest and the overstory is normally dominated by Douglas fir with regular disturbance such as fire. The understory is western hemlock with a variety of shrub ground cover types depending on elevational and moisture gradients as with all groups.

- Pacific silver fir series occurs in cooler and more moist conditions at a higher elevation than the Western Hemlock Series. The overstory of this series is also usually the dominant overstory species outside of disturbance with pacific silver fir and shrub types dominating the understory.

- Mountain hemlock series occurs in cool moist conditions at upper elevations on both sides of the Cascade.

1.1.5. WATERSHEDS (6TH LEVEL HYDROLOGIC UNITS)

The Riverside Fire burned within the Middle Clackamas and Upper Molalla watersheds (HUC10). The Riverside Fire also burned areas within the headwaters of the Molalla River of the Upper Molalla watershed within the Table Rock Wilderness area. The fire area was largely confined to federal lands in the Mt. Hood National Forest; however, impacts from burned areas are likely to elevate risk to critical values downstream on private and county lands.

Table 1. Affected Watersheds (6th Level Hydrologic Unit Name)

Watershed Name	Total Acres	Acres Burned	% Burned
Canyon Creek	10,713	1,710	16.0
Cedar Creek-Molalla River	8,419	58	0.7
Cot Creek-Oat Grove Fork Clackamas River	14,171	2,298	16.2
Dead Horse Canyon Creek	8,987	6,680	74.3
Dubois Creek-Clackamas River	12,636	1,383	10.9
Farm Creek-Collawash River	16,326	329	2.0
Fish Creek	29,807	24,773	83.1
Headwaters Milk Creek	10,244	301	2.9
Helion Creek-Clackamas River	11,719	10,571	90.2
Lower Eagle Creek	22,359	263	1.2
Lower Hot Springs Fork	18,272	119	0.7
Lower North Fork Molalla River	7,116	4,108	57.7
Middle Clear Creek	21,813	1,916	8.8
North Fork Clackamas River	20,638	665	3.2
Pine Creek-Molalla River	23,952	6	0.0
Pot Creek-Clackamas River	22,961	174	0.8
Roaring River	27,309	1,595	5.8
South Fork Clackamas River	17,656	14,595	82.7
Table Rock Fork	23,227	319	1.4
Three Lynx Creek-Clackamas River	31,546	22,075	70.0

Watershed Name	Total Acres	Acres Burned	% Burned
Trout Creek-Molalla River	15,678	1,450	9.3
Upper Clear Creek	12,247	7,391	60.3
Upper North Fork Molalla River	19,699	15,876	80.6
Woodcock Creek	8,200	1,029	12.5

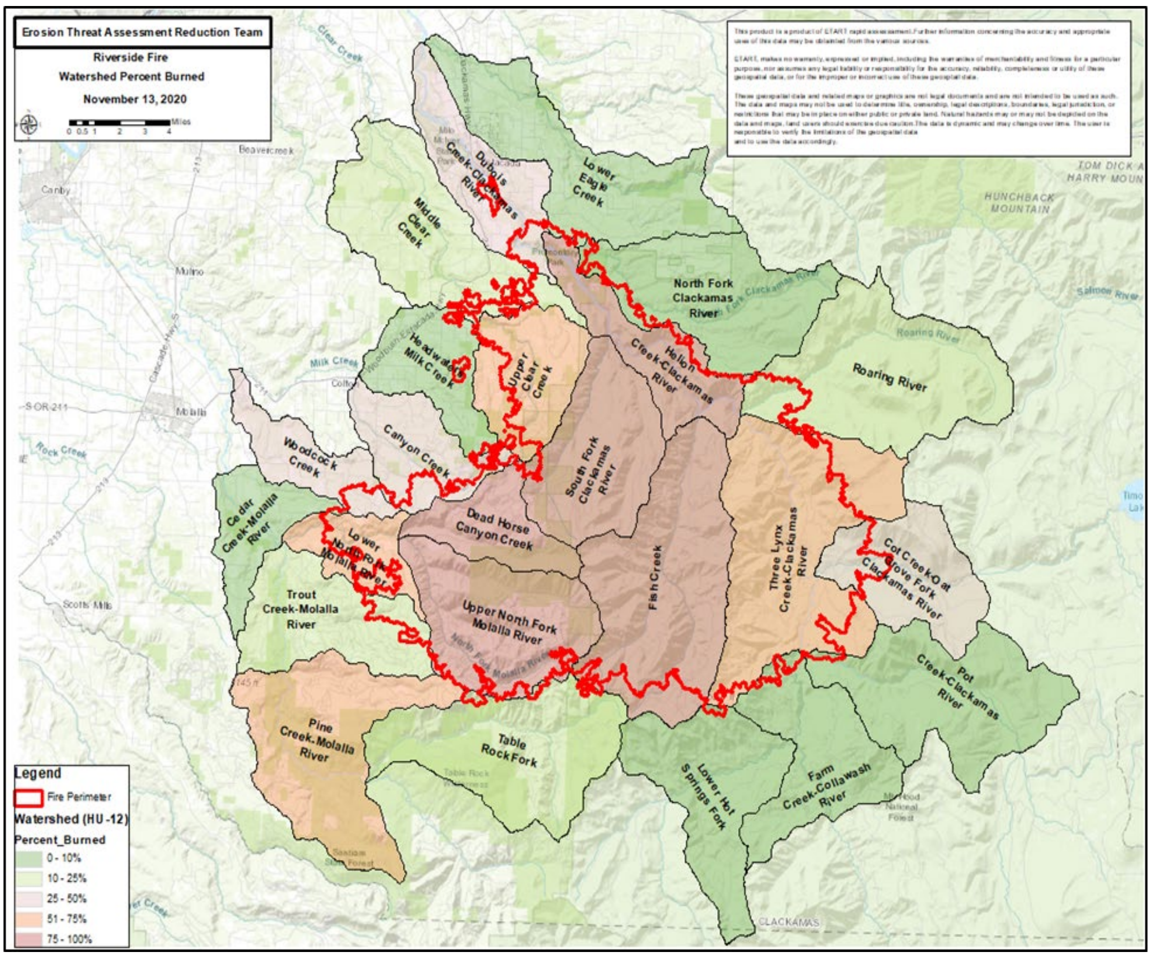


Figure 2. Watersheds Percent Area Burned - Riverside Fire

Table 4. Road Miles by Ownership Designation within Fire Perimeter

Owner Designation	Miles[a]
Bureau of Land Management	63.8
County Route	8.4
Forest Service	271.6
Other State Route (e.g., State Park)	3.2
Private Route	58.5
ODF State Forestry Route	0.3
State Highway	22.0
Unknown	320.6
Total Miles	748.4

Table 5. Miles of Stream within Fire Perimeter by Type

Stream Type	Miles by Type[b]
Perennial	302
Intermittent	621
Ephemeral	0
Other	53

a: Does not account for priority travel routes below the fire perimeter that may be a "Value" or threatened by flooding or debris flows.
b: Does not account for streams below the fire perimeter that may be a "Value" as domestic or municipal source water, or for aquatic habitat.

1.2. Post-fire Watershed Condition

1.2.1. SOIL BURN SEVERITY (SBS):

The post-fire watershed conditions are mostly driven by fire behavior, which is largely a function of pre-fire fuel conditions (vegetation types, volumes, arrangement and moisture content) as influenced by weather and topography. Soil Burn Severity (SBS) is the fundamental post-fire factor for evaluating changes in soil processes and hydrologic function, which are used to evaluate watershed response, identify post-fire threats and assess the level of risk to critical values.

Prior to the ETART effort, the Forest Service produced a Soil Burn Severity (SBS) map as part of their Riverside BAER Assessment (Figure 3). The Forest Service SBS mapping did not field-validate soil conditions on private or state lands. The ETART soils team completed soil burn severity validation on state and private lands with on-the-ground data collection and visual observations (Table 6).

Table 6. Soil Burn Severity (SBS) Acres.

Soil Burn Severity Class	All Lands		Federal Lands		Local Lands		Private Lands		State Lands	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
High	16,934	12%	14,902	88%	14	<1%	2,017	12%	0	0
Moderate	55,126	40%	37,406	68%	39	<1%	17,658	32%	23	<1%
Low	47,624	35%	31,058	65%	140	<1%	16,305	34%	122	<1%
Unburned	18,295	13%	12,274	67%	68	<1%	5,946	32%	7	<1%
Total	**137,979**		**95,640**		**261**		**41,926**		**152**	

The distribution of high burn areas, based on the soil burn severity (SBS) map, occurred on higher elevations such as ridgelines and peaks. Lower elevations were commonly unburned or had lower burned severity. Soils within the watersheds and riparian areas had heterogenous vegetation and higher moisture content which contributed to lower burn-related soil impacts in those areas. Moderate and high soil burn severity was consistently observed on south facing slopes. South facing slopes are generally drier and therefore ground fuels were less resistant to fire.

1.2.2. WATER-REPELLENT SOIL (ACRES)

Water repellent soils are present across all SBS classes. Based on field assessments and knowledge of local soil types, some degree of water-repellence is expected to exist on all upland acres. Natural repellency is common in ash-influenced soils in the Cascades. When ground cover and organic soil layers are removed by fire, runoff related to naturally occurring repellency is commonly more pronounced or more efficient. In some locations it is likely longer fire residence time has exacerbated inherent water repellency by increasing areal extent and repellency class, however it is not possible to make reliable predictions without extensive, intensive data collection.

1.2.3. SOIL EROSION INDEX

The soil erosion index (SEI) describes the sensitivity for soil loss after disturbance removes the protective vegetation and litter cover. The SEI is primarily a function of hillslope soil processes and hydrologic function, as influenced by disturbance, such as fire, and slope. The SEI is described as “low”, “moderate”, “high” or “very high”. Low SEI indicates soil erosion is unlikely. Moderate SEI indicates soil erosion is likely with a potential decrease in soil productivity. High SEI indicates soil erosion is very likely to decrease in soil productivity. Very high SEI indicates a high probability for soil loss and decreased soil productivity, where erosion control measures are impractical and cost prohibitive.

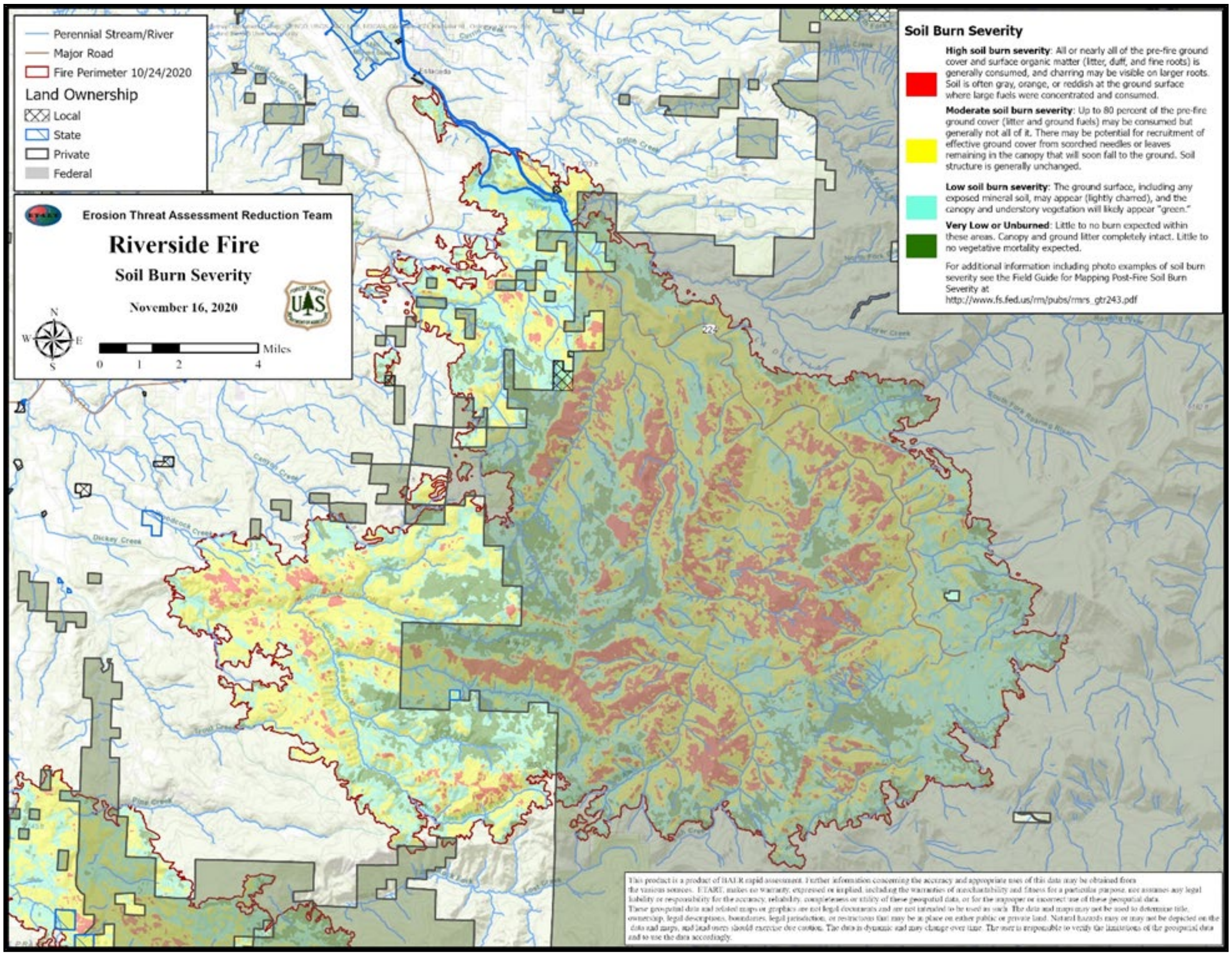
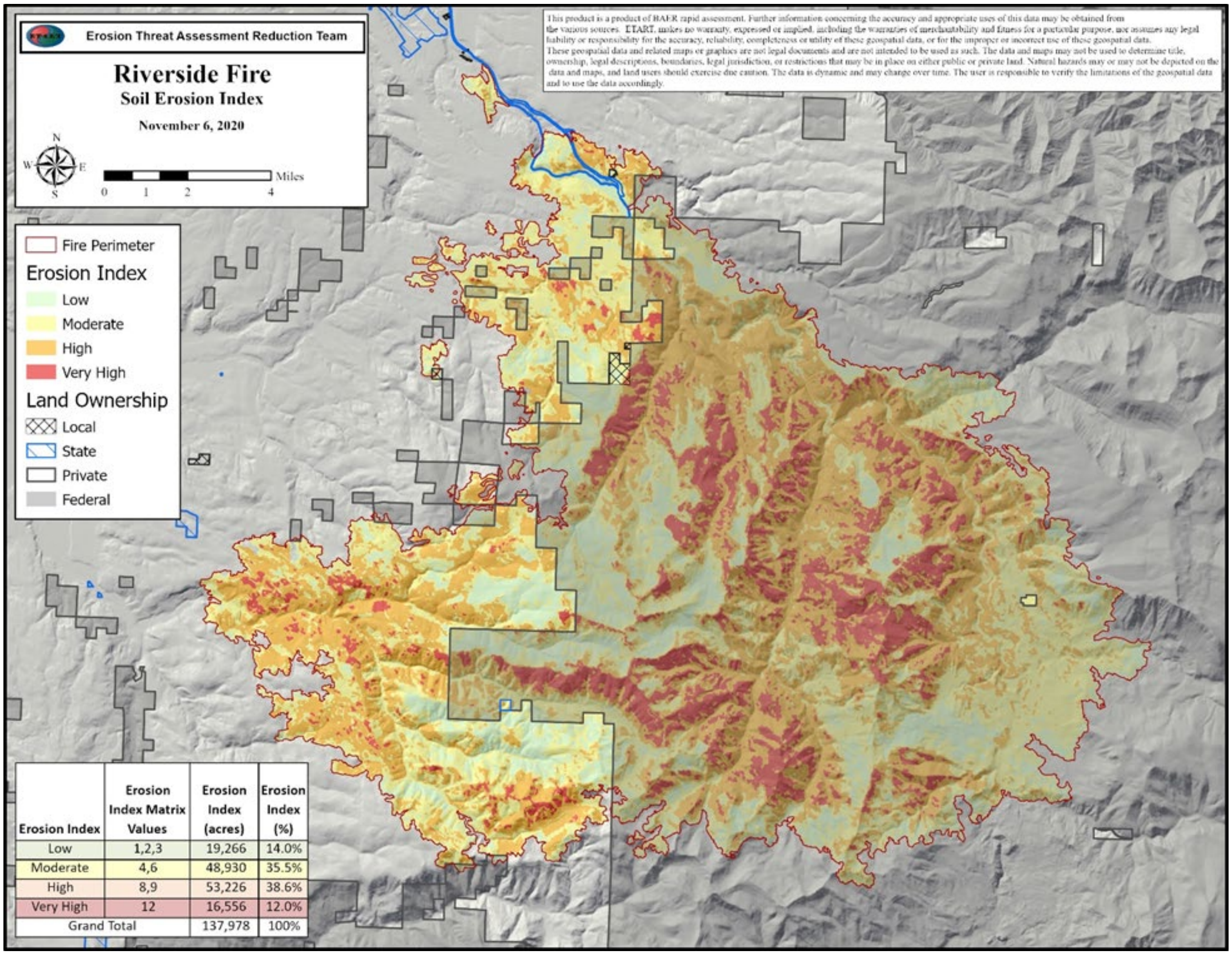


Figure 3. Soil Burn Severity – Riverside Fire

Figure 4. displays the spatial distribution and acres by SEI for the area burned by Riverside Fire. The matrix values in the map table represent combinations of inherent SEI with SBS. The analysis estimates 85% of the burned area has increased potential for accelerated soil erosion. The very high SEI is generally attributed to over-steepened slopes where SBS has minor influence to change soil erosion.



Erosion Index	Erosion Index Matrix Values	Erosion Index (acres)	Erosion Index (%)
Low	1,2,3	19,266	14.0%
Moderate	4,6	48,930	35.5%
High	8,9	53,226	38.6%
Very High	12	16,556	12.0%
Grand Total		137,978	100%

Figure 4. Soil Erosion Index – Riverside Fire

1.2.4. EROSION POTENTIAL

This analysis is used to identify hillslopes where post-fire accelerated erosion elevates the level of threat to downslope critical values. Estimates for hillslope soil loss were generated using the Water Erosion Prediction Project Cloud -Disturbed (WEPPCloud - Disturbed) Model (Robichaud and others 2019). A total of 6 drainages across 3 subwatersheds (HUC12) were evaluated. Each drainage was modeled for post-fire response using the SBS data and compared to unburned conditions. The estimated increase in soil loss per watershed unit area ranges from no change up to 0.5 tons/acre the first year after the fire, averaging about 0.3 tons/acre increase across the burned watersheds of interest. On average there is roughly a 3-times increase in potential soil erosion post-fire over undisturbed conditions.

1.2.5. ESTIMATED VEGETATIVE RECOVERY PERIOD (YEARS)

This is the estimated period of time (years) for the burned area to develop vegetation sufficient to reduce runoff and erosion potential to essentially pre-fire conditions. Vegetation recovery varies depending on plant association group, soil type, aspect, and soil burn severity. Areas burned at low severity will generally recover within two years. Areas impacted by moderate SBS may recover the understory and shrub layers in 3-5 years. For areas having high SBS and stand-replacement fire with loss of overhead canopy from conifer tree species, ecosystem recovery will take up to 2-3 decades.

1.2.6. ESTIMATED HYDROLOGIC RESPONSE

Regional regression equations were used to estimate pre- and post-fire peak flows. Relative increase in 5-year post-fire peak flows is expected to be largest in the North Fork Molalla River where approximately 43% of the watershed has burned. The North Fork Molalla River above Molalla River has a predicted increase of 1.2 times the pre-fire peak flow magnitude. The slightly elevated peak flow is due to the large portion burned acreage classified as moderate or high soil burn severity in a relatively smaller watershed. In contrast, the increase in magnitude of post-fire peak flows in the other poursheds is 1.1 times the pre-fire peak flow for the 5-year recurrence interval (Figure 5).

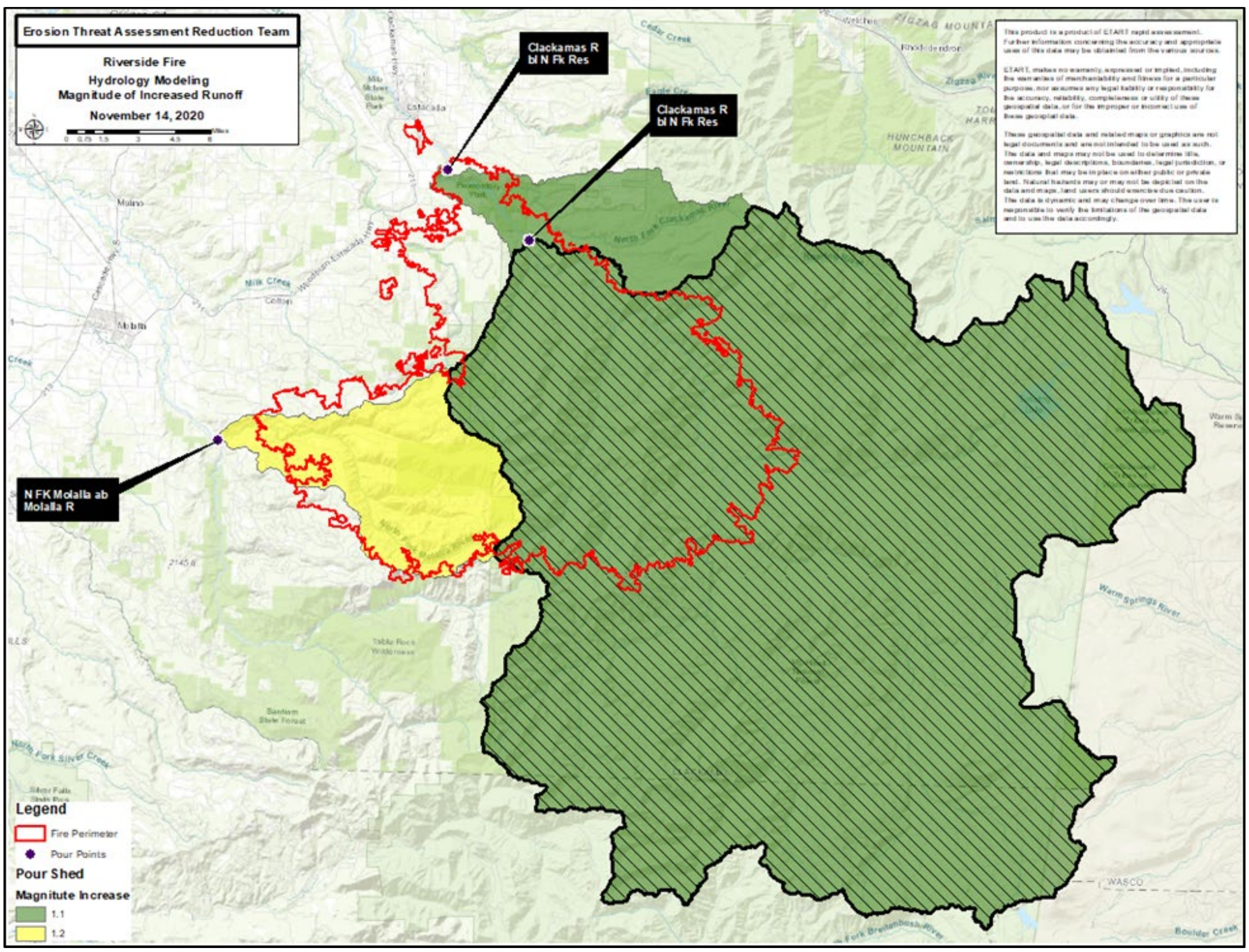


Figure 5. Watershed Response in Runoff Magnitude Increase – Riverside Fire

The analysis of post-fire peak flows should only be used as a tool to better understand relative stream response levels for various drainages throughout the fire area. Post-fire stream response in smaller watersheds tends to be much greater than those in large watersheds because of the relative volume of water it takes to show an amplified increase from pre-fire flow and the spatial scale of continuous high severity fire patches in relation to the extent of a storm event in the Cascades.

Risk Assessment and Recommendations

The ETART resource groups identified numerous values having varying degrees and types of threats, which are listed in the ETART Riverside Fire Values Table. The post-fire watershed conditions determined through field assessment and data analysis were used by the ETART to validate post-fire threats and, subsequently, using the risk assessment matrix assign each specific value a level of "Risk" defined by the probability of damage or loss coupled with the magnitude of consequences (Figure 6). A burned area emergency exists when a value has a risk rating of "very high" or "high" for all values and an "intermediate" risk for life and safety. These values are prioritized for emergency response or stabilization actions known to mitigate potential threats or minimize expected damage.

Probability of Damage or Loss	**Magnitude of Consequences**		
	Major	**Moderate**	**Minor**
Very Likely	Very High Risk	Very High Risk	Low Risk
Likely	Very High Risk	High Risk	Low Risk
Possible	High Risk	Intermediate Risk	Low Risk
Unlikely	Intermediate Risk	Low Risk	Very Low Risk

Figure 6. Risk Matrix

1. Human Life and Safety Summary

1.1. Hazard Trees

Very High risk to **motorists along roadways, people near structures, and visitors and employees at recreation areas** from falling of hazardous trees killed or damaged by fire. These locations have large numbers of dead and fire damaged trees (>75% basal area (BA) mortality). There is "Very High" risk (likely, major) in areas having 1-75% BA mortality, as well. Although there are generally lower numbers of dead and fire damaged trees, the threat will result in major consequences to human life and safety (and property). An estimated 72 road miles have moderate to high levels of basal area mortality, where fire-killed or damaged trees are within falling distance to reach a road on state and private lands. There are over 265 acres of hazard trees within the 100' buffer surrounding all structures. There are 133 structures in areas that suffered 50% or greater basal area mortality. Another 170 structures are in areas that suffered less than 50% basal area mortality. Specific areas of concern noted by the ETART the OR-224 corridor.

Recommendations: Temporary road and sites closures until hazard trees are mitigated, minimize exposure to buildings, fell danger trees within striking distance of roadways and structures. Post hazard warning signs. Inform county emergency management, stakeholders and private landowners. Complete site-specific assessments for specific treatment recommendations.

High risk to **highway users along OR-224 corridor** from getting struck or stranded/ blocked by debris. Road has little to no shoulder in some locations and poor sight distance that presents the possibility for injury. If users are struck by, or attempt to circumvent fallen debris, it may result in injury or death.

Recommendations: Road maintenance, storm patrol, debris flow and rockfall signage, hazard tree removal. Additional survey may be needed to identify appropriate treatments.

Available resources for on-the-ground assessment of danger/hazard trees

- OSU Fire Extension has recorded several post-fire webinars. Link to webinars and an extensive summary of available resources: https://extension.oregonstate.edu/fire-program.
- ODF post-fire resources, including information on locating stewardship foresters: (https://www.oregon.gov/odf/fire/Pages/afterafire.aspx).
- Field Guide for Danger Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington:
- http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd512960.pdf).
- Post-fire tree mortality assessment and marking guidelines: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd814664.pdf).

To arrange for on-the-ground training contact ODF or OSU Extension Services. USFS State and Private Forestry also has experts on staff to help with post-fire trainings at the request of ODF.

1.2. Debris flow, Rock fall, and Landslides

Low risk to **life and safety on the North Fork Reservoir, Silver Fox RV Park and the town of Dodge** from debris flows. Debris flow channels enter the reservoir and lead to the RV park and town but have limited probability for occurrence. The RV park is on a large deep landslide which has some potential to reactivate.

Recommendation: Further evaluation is needed to define site-specific threats to values and identify appropriate mitigations. Information sharing with County Emergency Management, communities, and property owners on needs for further evaluation or assessment. Facility closures, education, install hazard warning signs, use weather alert systems or monitoring.

1.3. Post-Fire Flooding, Floating Debris, and Others

Very High risk to **boaters and swimmers on North Fork Reservoir and at Silver Fox RV park** from hazard trees, floating debris and additional "stringers" (woody slightly below the water surface). Debris is already observed in the water and volumes are expected to increase.

Recommendations: Fell hazard trees that would impact human lives, implement closure of facilities until trees can be assessed and mitigated. Install hazard warning signs at boat launch locations (docks, marinas, river access) of risks from debris threats; remove debris as appropriate. Downed trees pose a significant life to human life and safety when boating or swimming, whether in rivers (North Fork Molalla and North Fork Clackamas) or on the North Fork Reservoir. Outreach and education, communication and coordination with Marine Safety Board.

2. Property Summary

High risk to **Get N Go Promontory Marina Estacada and North Fork Reservoir Dam** from woody debris build up. Large woody debris already evident in marina; expected increase in wood recruitment due to burned trees. Low velocity flow in reservoir to move floating debris.

Recommendations: Increased frequency for inspections to identify debris removal.

High risk to **landowners and property (assets)** due to shift in fire regimes and fire severity from establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties. The area impacted by the Riverside fire has had significant selection pressure to shift plant populations toward fire-adapted species. The homes, churches, and businesses destroyed in the residential areas of the Riverside fire demonstrate the potential consequences of not maintaining defensible space.

Recommendations: Outreach and education to impacted communities of Colton, Dodge, Dickie Prairie, Elwood, Estacada, Highland, Molalla and Springwater on Firewise planning to promote defensible space. Survey for areas with high fuel loads and regeneration potential for flammable weed species. Identify programs for noxious weed surveys, treatments and monitoring, focusing on highly flammable species such as Scotch broom, gorse and Himalayan blackberry.

High risk to **OR-224 highway corridor and associated infrastructure, including transmission lines and powerhouse (State)** from sediment and debris deposition into ditch lines and on to road surfaces. Steep slopes and decreased ground cover make sediment mobilization, in potentially substantial amounts, likely in some locations. Highway is a main access route with heavy traffic, and damage would likely be substantial and result in temporary loss of use.

Recommendations: Road maintenance, storm patrol, debris flow and rockfall signage, hazard tree removal, additional treatments may be necessary.

Intermediate risk to **boat launch infrastructure on North Fork Reservoir and at Silver Fox RV park** from hazard trees. While mostly low severity, secondary mortality could result in property damage or impact access to boat launch.

Recommendations: Fell hazard trees likely to impact infrastructure.

Intermediate risk to **private residences along the river** from sediment bulked flows impacting riverbanks with bank erosion of property boundaries along floodplain. While these properties are along the river, they are located downstream of burned area so debris and sediment may attenuate. More likely high flows will result in nuisance damage to property but not likely to impact structures.

Recommendations: Inform property owners and county emergency management of risk.

Resources for private landowners

The Natural Resources Conservation Service (NRCS) provides information about actions that can be take on your private property. Please see this list of fact sheets (click here) for details different treatment options that can be taken to combat erosion risks.

Intermediate risk to **bridge on South Dickey Prairie Rd (County)** from sediment bulked flows and debris impacting bridge footings. Bridge is high above river surface and is below burned area, but some debris may reach bridge and could damage footings or abutments. Flood source area is N. Fork Mollala, primarily federal and industrial ownership.

Recommendations: Storm Patrol with equipment, as appropriate following precipitation events, to remove debris; and monitoring.

Intermediate risk to **bridge and nearby homes at South Dickey Prairie Rd and South Megan Ave** from woody debris build-up. High volume of tree mortality will contribute to increased woody debrisin channel that could in property damage or loss. 45.083715, -122.489072

Recommendations: Increased frequency for inspections to identify debris removal. Notify ODOT.

Intermediate risk to **road infrastructure on Industrial Private Lands** from sediment and debris deposition into road ditches and travel surfaces. Steep slopes and absence of post-fire ground cover make sediment mobilization likely, with impacted road drainage which may damage running surfaces or result in road failures.

Recommendations: Coordination with landowners.

Intermediate risk to **Oak Grove Powerhouse (PGE infrastructure, private)** from erosion, sediment and falling debris damaging powerhouse. Property is located within the Riverside fire boundary, below burned hillslopes with low to moderate erosion risk and moderate to high debris flow risk. Impacts to power infrastructure may result in moderate property damage as well as service interruptions to other users, including the light railway light system.

Recommendations: Inform power companies of potential threats to infrastructure and related service concerns.

Intermediate risk to **Faraday Powerhouse (PGE infrastructure, private)** from erosion, sediment and falling debris damaging powerhouse. Property borders Riverside fire and is located adjacent to low and moderate SBS areas. Impacts to power infrastructure may result in moderate property damage as well as service interruptions to other users.

Recommendations: Inform power companies of potential threats to their infrastructure and related service concerns.

Low risk to **Clackamas County Roads (Fall Creek Road, Hillockburn Road)** from increased erosion, sediment and water flow. The roads at risk within the Riverside Fire burned areas are located primarily within or below areas of low to moderate SBS. There is a future threat to travelers along the roads within the burned area due to the increased potential for culverts plugging with sediment or debris which could washout sections of the roads. With the loss of vegetation, normal storm frequencies and magnitudes can more easily initiate erosion on the slopes, and it is likely that this runoff will cover the roads or cause washouts at drainage facilities (culverts) or stream crossings. These events make for hazardous access to forest roads and put the safety of users at risk. See Appendix A for road treatment cost estimates.

Recommendations:

- Fall Creek Road – Storm proofing and storm inspection and response.
- Hillockburn Road - Storm proofing and storm inspection and response. Replace damaged culvert.

Road Treatments

- Storm Proofing. Clean/pull ditches, clean stream crossing culvert inlets/outlets and relief culverts, run out ditches and catchment basins of sediment, debris and rock. Out slope the road prism where appropriate. Replace or repair damaged culverts pending the need of primary maintainers. Slotted riser pipes or culvert end sections could be installed where feasible and appropriate to reduce the potential for sediment and debris plugging of existing culverts.
- Storm Inspection and Response. Follow-up to storm proofing to monitor functionality post-storm event. Monitor road conditions after a storm for the first year, deploying personnel to inspect and react as appropriate. Re-storm proof may be needed after a damaging storm to keep ditches, culverts and critical dips in working order.
- Storm Patrols. Monitor road drainage structures and debris flow treatment structures after significant storm events to ensure the maximum drainage capacity is maintained until the natural revegetation of the burned area has occurred. Maintain and/or repair any damage to road surfaces. Remove sediment and debris from drainage and treatment structures and stabilize head cutting in streams and drainages to prevent further degradation of channels. Monitor the movement of large woody debris, make a determination to remove material before it contacts bridge piers, abutments or culverts.
- If feasible and cost effective, replace culverts to handle the post fire flows. Culverts being replaced should be sized on predicted increase in flows and installed with minimum fill cover and heavy armoring. If culvert is not replaced, proceed with monitoring and ditch cleaning along the roads identified in the Riverside Fire Engineering Report.

Low risk to **property on the North Fork Reservoir, Silver Fox RV Park and the town of Dodge** from debris flows. Debris flow channels enter the reservoir and lead to the RV park and town but have limited probability for occurrence. The RV park is on a large deep landslide which has some potential to reactivate.

Recommendation: Further evaluation is needed to define site-specific threats to values and identify appropriate mitigations. Information sharing with County Emergency Management, communities, and property owners on needs for further evaluation or assessment. Facility closures, education, install hazard warning signs, use weather alert systems or monitoring.

Low risk to **fish ladder at North Fork Reservoir Dam** from hazard trees. While mostly low severity, secondary mortality could result in property damage.

Recommendations: Fell hazard trees likely to impact infrastructure.

3. Natural Resources Summary

3.1. Soil and Water

High risk to **soil productivity** from accelerated erosion. High and moderate SBS on steep slopes increase potential for loss of topsoil. Ground cover in clear-cut areas may take longer than 2-5 years to establish and decrease longer term erosion.

Recommendations: Further evaluation is needed to define site-specific threats to values and identify appropriate mitigations. Apply mulch, preferably by chipping existing dead vegetation. Re-establish vegetation cover.

3.2. Fish and Wildlife Habitat

Very High risk to **T&E fisheries habitat** from water quality impairments (temperature). Loss of riparian shading leading to increased stream temperatures. A number of stream reaches experienced complete or partial loss of trees in riparian areas. This will result in increased solar radiation entering streams until vegetation regenerates. Temperature increases are likely to last multiple years (potentially 10+ years in high burn severity areas) thereby impacting several generations. In a number of locations, stream temperatures during summer were already close to the thermal tolerance limits for fish species. The actual magnitude will depend on future climatic conditions and pace of regeneration.

Recommendations: Work with partners to encourage natural regeneration and/or reforestation with mixed hardwood conifer.

High risk for contaminated **water quality that supports aquatic habitat for sensitive and T&E species** from burned debris. Runoff from burned buildings and vehicles (Job Corps/USFS facilities) containing hazardous wastes threatens aquatic habitats near wetlands, Dry Creek and the Clackamas River. A number of urban areas were subject to fire damage and are in proximity to waterways. Efforts to remove hazardous wastes are underway but in some instances surface runoff from rains has already occurred or will occur before wastes are removed. Environmentally persistent contaminants introduced to waterways may have multigenerational impacts. Other more transient chemicals will likely impact one to two generations within the area of exposure.

Recommendations: Work with partners to identify and prioritize hazardous waste removal in proximity to waterways.

Low risk to **T&E fisheries habitat** from water quality impairments (turbidity). Runoff of ash and sediment represents a near-term threat to spawning success for salmonids and lamprey. A large portion of several watersheds containing spawning habitat for salmon, trout, suckers, whitefish and lamprey was burned leaving significant ash deposits. Control measures will not be sufficient to prevent this from entering waterways during rain events. Some areas may experience increased redd failure, but likely there is sufficient alternate spawning habitat to sustain populations.

No treatment recommended.

Low risk to **T&E fisheries spawning, rearing and refugia habitat access** for ESA-listed species. Increased runoff resulting from lack of vegetative cover may result in higher peak flows leading to increased scour of redds and/or displacement of some species. A number of watersheds experienced high levels of vegetative mortality at mid- to low elevations. Winter forecasts suggest a likelihood of wetter weather. This combination of conditions creates higher likelihood of significant rainstorm/runoff events with impacts are likely to be transient (affect 1-2 generations) and spatially heterogenous.

No treatment recommended.

3.2.1. GENERAL FISH AND WILDLIFE RECOMMENDATIONS

Early Seral Habitat near Habelt Road outside of Estacada. Assist landowner (Port Blakely) with reseeding to benefit deer and elk and provide soil stability in areas of moderate to high SBS. Timberlands experienced high vegetation mortality (76-100% BA) over a large area. Reseeding is known to have major benefits to early successional species as well as help reduce erosion and decrease susceptibility for expansion of invasive plants.

Early Seral Habitat near South Fork Clackamas River/Resort Road. Assist landowner with reseeding to increase forage for deer and elk forage and improve soil quality. These lands experienced moderate to high SBS and high vegetation mortality (76-100% BA) over a large area. Reseeding is known to have major benefits to early successional species as well as reduce soil erosion and decrease potential for expansion of invasive plants.

Maintain or Retore Aquatic Habitat Connectivity. Work with partners to identify priorities and options for fish passage at stream crossings; implement aquatic organism passage options when replacing burned/washed out culverts. Given scale of fires and the number of culverts on the landscape, it is likely some culverts were or will be impacted. Restoring passage allows fish to access suitable habitat or refugia if primary habitats are impacted by post-fire events.

Riparian Habitat along Three Lynx Creek. Work with partners to revegetate and stabilize slopes to minimize erosion and runoff. from low to moderate SBS areas. High-value, sensitive amphibian species in this riparian habitat will likely benefit from erosion management and runoff prevention, which could benefit multiple sensitive species.

Intact Late Seral Habitat near Roaring River. Work with partners to encourage natural regeneration through carefully managed salvage logging practices that promotes standing dead wood and small open patches. The low to moderate SBS in this area creates favorable late seral conditions for sensitive species that retain or enhance positive habitat features.

Biodiversity Hotspot along Fish Creek. Work with partners to promote revegetation of native plant species to stabilize soil and limit invasive plant species. This is an area of high biodiversity with moderate to high SBS as well as high vegetation mortality. Reseeding would help soil stabilization and control invasive plant species, benefiting a variety of game and nongame species that use this river corridor. Consider alternative salvage logging practices to limit disturbance.

Sensitive Species Habitat in Rock Canyon. Work with partners to promote revegetation of native plant species to stabilize soil and limit invasive plant species. High quality habitat used by deer, elk, bear and sensitive species with moderate to high SBS and high debris flow probability. Revegetating and stabilizing this area to decrease erosion potential and control invasive species is expected to benefit multiple high priority and sensitive species.

Early Seral Habitat North Fork Molalla River. Work with partners to promote revegetation of native plant species to stabilize soil and limit invasive plant species. Timberlands experienced moderate to high SBS over a large area with habitat that supports black bear, Roosevelt elk and black-tailed deer. Reseeding is likely to have major benefits to early successional species as well as help with soil stability and controlling invasive plants.

Riparian Shade - Clear Creek, Mollala River, Clackamas River and Collawash River. Work with partners to identify artificial revegetation and/or natural regeneration practices that rapidly restore riparian shading. Locations are variable depending on burn severity and extent of active management. Many streams within the burn areas have summer temperatures close to thermal tolerance limits. Allowing a mix of hardwood/conifer in riparian areas promotes more rapid recovery of intermediate shading from hardwoods may be key to ensuring these streams remain suitable during summer in the near term.

Large Woody Debris (LWD). Work with partners to encourage salvage logging practices that retain LWD, to the extent practicable, for recruitment into stream channels. Locations are variable depending on extent of post-fire salvage logging within riparian zone. Many of the rivers and streams have historically low levels of LWD. Maintain standing or dead trees within riparian areas could potentially reset the system and provide substantial long-term benefits in terms of creating suitable habitat for aquatic and terrestrial species. As these trees enter streams and rivers, they create high quality habitat for salmonids.

Keystone species. Work with partners to identify alternative artificial revegetation and/or natural regeneration practices for long-term beaver habitat. Locations are variable depending on management goals. Promoting hardwood regeneration in riparian areas provides conditions for beaver to construct dams that benefit a range of aquatic species. Beaver are ecosystem engineers that create habitats for many aquatic species, including salmonids. To build dams, beavers require suitable plant materials (typically willow, alder etc).

Intact Late Seral Habitat adjacent to highly impacted LSR area at Dead Horse Canyon Creek. Work with partners to encourage natural regeneration, apply conservative salvage harvest practices and restrict motor vehicle access. Currently minimal disturbance in mostly intact late seral habitat is likely refugia for species displaced from adjacent highly impacted LSR. Standing dead wood and small open patches should benefit the sensitive species located in this area.

Sensitive Species Area - Whale Creek. Work with partners to revegetate with native plant species to stabilize soil and reduce potential for invasive species. Multiple sensitive aquatic species that occupy downstream habitats could benefit from stabilization measures. Slope stabilization activities could reduce high debris flow probability and also protect ongoing restoration projects.

Sensitive Species Areas - Worsted Creek and Fish Creek Divide. Work with partners to encourage natural regeneration and minimize additional disturbance. Low to moderate SBS area with habitat for sensitive species. Standing dead wood and small open patches from the fire create favorable late seral conditions for sensitive species.

Sensitive Species Area Wash Creek – Camelback. Work with partners to limit disturbance and promote passive restoration to decrease soil erosion and control invasive plant species. Habitat supports deer, elk and sensitive species with large areas affected by high SBS that could experience further impacts from salvage harvest and other disturbances. Consider revegetation, as needed, for soil stabilization and to control invasive species.

Sensitive Species Area - Clackamas Wilderness Area. Work with partner to encourage passive restoration of sensitive species habitat with high vegetation mortality. This area appears to be highly impacted by the fire and natural regeneration will take many years.

Late Seral Habitat in Roaring River Wilderness. Work with partners to promote retention of downed large woody debris for amphibian habitat. This is a wilderness area with habitat for sensitive species in LSR impacted by fire. Natural regeneration through passive restoration will take many years.

Biodiversity Hotspot - Lukens Creek. Work with partners to implement alternative salvage harvest practices that promote passive restoration in riparian areas. Sensitive species and habitats exist in area with low to moderate SBS located adjacent to high SBS lands. Implementing Discretionary salvage logging combined with minor riparian restoration could benefit multiple sensitive species in and adjacent to this area. Monitoring may be needed to determine impacts.

Biodiversity Hotspot - Station Creek. Work with federal partners to monitor sensitive species in this area using audio detectors and eDNA. Mostly low SBS across this area but impacts to habitat and species are unknown. Potentially opportunities to collaborate with on-going or planned monitoring activities.

3.3. Native Plant Communities Summary[1]

Very High risk to **multiple values (native plant communities, wildlife habitat, agriculture, timber production, water quality, etc.)** within and adjacent to the burned area from establishment and expansion of viable populations of local and state noxious weeds classified as priority for Early Detection and Rapid Response (EDRR). Emergent populations of Clackamas County "Priority" and "Containment" noxious weeds including Oregon "Class A" species have been documented on or near the burned area. The potential for expansion of noxious weeds are a significant ecological and economic concern. Emergent populations of local priority and containment weeds include orange hawkweed, gorse, slender false brome, Japanese knotweed, Bohemian knotweed and garlic mustard.

Recommendations: Early Detection and rapid response weed surveys and treatments using IPM based principles with the desired goal of eradication, and ongoing monitoring.

Very High risk to **multiple values (native plant communities, wildlife habitat, agriculture, timber production, water quality, etc.)** within and adjacent to the burned area from expansion of invasive plant species during fire rehabilitation, reforestation and salvage logging operations. The level of forest activities increases in numbers and intensity following the fire. There is increased potential for road systems to serve as dispersal vectors for spread of invasive plants to natural areas, nearby agricultural activities, timber salvage and reforestation operations, and residential areas. The vast amount of lands susceptible to expansion increase competition, thereby decreasing the ability for local plant communities to naturally regenerate.

Recommendations: Use equipment sanitation and prevention efforts to decrease the potential for spread of invasive and noxious weed seed. Conduct noxious weed surveys along road systems, and as needed treat noxious weeds using IPM based principles. Continue ongoing monitoring. To decrease the potential for spread of weed seed, a centrally located wash station could be installed to sanitize equipment during restoration, reforestation and salvage logging activities.

1 See appendix B for Invasive Plant Treatment Design and Cost Estimates

High risk to **native plant communities and wildlife habitat** from establishment and expansion of fire-adapted noxious weeds. Ground disturbance from fire and suppression operations resulting in bare increases susceptibility for invasive weeds, increasing competition and difficulty for local plant communities to return to pre-disturbance condition.

Recommendations: Noxious weed surveys and treatments using IPM-based principles, reseeding heavily disturbed areas and ongoing monitoring. Target survey and treatment activities in dozer lines, hand lines and drop point locations. Surveys in these areas require some expertise to include the identification of new weeds that may have been introduced during suppression activities.

High risk to **wetland habitats** from invasive plant establishment and suppression of regenerating native plants. Oregon Conservation Strategy Priority (OWEB-funded) wetland restoration projects are identified in the Riverside fire area, including the large inholding in upper area of the Mt Hood National Forest. Wetlands act as sinks on the landscape for both water-dispersed and wind-dispersed propagules. The threat of potential introduction from nearby weed populations is increased. Plants that persist within wetland areas tend to be well-adapted for wet conditions and noxious weeds that can establish in wetland systems have a tendency to proliferate. Reed canarygrass is a significant threat that has been identified in the burn zone.

Recommendations: Survey wetlands in and adjacent to areas with moderate to high SBS and treat noxious weeds adapted for wetland sites using effective IPM practices. Replant areas of high mortality and poor natural regeneration.

High risk to **grasslands and meadow habitats** from establishment of invasive plants and suppression of regenerating native species. Grasslands and meadow habitats are an Oregon Conservation Strategy Priority as intact habitats are generally rare. Local accounts of remnant prairie grasslands in the Willamette Valley is less than 1% of historic abundance, due in part to fire suppression, human development and noxious weed dispersal vectors. Forest meadows are the exception here and often contain pockets of rare plant assemblages. Due to degradation of the grasslands, they serve as noxious weed source populations to adjacent forest meadow habitats.

Recommendations: Noxious weed surveys, treatments using IPM based principles, reseeding of heavily disturbed areas and ongoing monitoring.

High risk to **rare, threatened and endangered (RTE) native plant species** from establishment and expansion of fire-adapted noxious weeds. Higher classes of SBS and vegetation mortality increase the threat and dispersal of weed seed into sensitive areas. The RTE locations are priorities for population recovery efforts and experience a greater likelihood for invasive plant introduction from vehicles and personnel. RTE species loss can often be counted by individuals; seemingly small impacts to local plant communities can be significant.

> Recommendations: Noxious weed surveys and treatments using IPM based principles with the desired goal of protecting and buffering sensitive species from the impacts and encroachment of noxious weeds. Surveys and treatments of invasive weeds should be targeted around sensitive species and undertaken in such a manner to prevent harming sensitive species. Particular focus should be on areas near dozer lines, hand lines and other suppression activity locations. Ongoing monitoring is needed.

Intermediate risk to **agricultural productivity and economic viability on designated "prime farmland" and "farmland of statewide importance"** from the establishment and expansion of agronomic noxious weeds. Disturbance from fire and suppression operations that result in bare and exposed soil increase the threat for spread of fire-adapted weeds. The presence of agronomic weeds on disturbed lands can impact local agricultural producers. Much of the existing agricultural lands are already actively managed for noxious weed. Increased pressure from weeds increases costs and reduces economic viability.

> Recommendations: Noxious weed surveys, and treatments using IPM based principles, reseeding of heavily disturbed, ongoing monitoring.

Intermediate risk to **multiple values across the burned area (native plant communities, wildlife habitat, agriculture, timber production and soil/water quality)** from the spread of invasive plant species transported from contaminated gravel and rock sources. Two county-owned rock quarries are in the fire footprint that may provide aggregate for road and repair operations. Proliferation of noxious weeds in or around the county-operated quarries can lead to unintentional distribution of weed seed across the county. Quarry operations should be maintaining a weed-free yard, but staff resources may be limited in relation to the overall operations.

> Recommendations: Prevent seed-contamination by transport of gravel and rock products through surveying and treating noxious weeds using IPM based principles in and around active quarry operations. Any weed contaminated materials should be rejected for redistribution. Equipment sanitation and prevent efforts should be taken to prevent spread of noxious weed seed. To prevent the spread of weed seed from contaminated vehicles, a centrally located wash station could be used to sanitize equipment used for distribution of gravel and rock products. Conduct ongoing monitoring.

Intermediate risk to **native plant communities in riparian areas** from establishment of invasive plants and suppression of regenerating native species. Riparian area restoration efforts are an Oregon Conservation Strategy Priority for threats from invasive weeds, including OWEB-funded projects in the public and private land matrix of Upper Molalla River, Lower Clackamas River and Middle Clackamas River. Past riparian restoration projects are limited on state and private lands. Native plants in riparian areas are generally more resilient to fire disturbance based on their proximity to water. Expected debris flows and increased sediment delivery are likely to increase disturbance and dispersal of noxious weeds.

Recommendations: Survey riparian corridors near areas with prior restoration efforts and treat noxious weeds using effective IPM practices. Replant areas with high mortality and poor natural regeneration. The OWEB-funded projects on the public and private land matrix of Upper Molalla River, Lower Clackamas River and Middle Clackamas River should be surveyed upstream and downstream for potential dispersal and transport of noxious weeds.

Intermediate risk to **oak habitats** from establishment of invasive plants and suppression of regenerating native species, threatening the success of local conservation and restoration efforts underway across the region. The Oak habitat in the Riverside fire area is already under pressure from noxious weeds and land development, but pockets of meaningful habitat persist. Oregon Conservation Strategy Priority recognizes Oak habitat as imperiled in the vicinity around the Riverside fire. Oak communities contain increasingly rare native plants assemblages in Willamette Valley and are a focus of regional and local conservation efforts. Oak habitat tends to benefit directly from fire by suppressing succession to fir-dominated stands, but oak-associated prairie forbs and grasses are detrimentally impacted by the co-occurrence of noxious weeds with fire.

Recommendations: Noxious weed surveys, treatments using IPM-based principles, reseeding of heavily disturbed with high burn severity and ongoing monitoring.

Intermediate risk to **ODF Habitat Conservation Areas** from establishment of invasive plants and suppression of regenerating native species. These conservation areas are priority for habitat improvements and experience a greater likelihood for noxious weed introduction from vehicles and personnel. Competition from noxious weeds result in the inability for local plant communities to regenerate.

Recommendations: Noxious weed surveys, treatments using IPM-based principles and ongoing monitoring. Focus survey and treatment efforts on established ODF Habitat Conservation Areas, with emphasis on riparian habitat function to protect conservation investments.

Low risk to **productivity of private forest land** from establishment and expansion of noxious weeds on economically important lands. Disturbance from fire and suppression operations resulting in bare soil increases the threat for spread of noxious weeds. The presence of noxious weeds can slow or suppress replant efforts and productivity of forestry operations. Much of the timbered lands are already under regular weed control. Increased pressure from noxious weeds can increases cost and reduces economic viability of operations.

Recommendations: Equipment sanitation and preventative efforts to prevent spread of noxious weed seed. Noxious weed surveys and treatments using IPM-based principles, reseeding of heavily disturbed areas and ongoing monitoring. The installation of a centrally located wash station could help prevent noxious weed introductions during fire rehabilitation, salvage logging and reforestation activities. Focus should be on preventing fire-adapted weeds from suppression activities on or adjacent to timber operations that may adversely impact timber production through direct competition or by altering the fire return intervals (i.e. false brome, gorse, scotch broom, blackberry, knapweeds).

Very Low risk to **old growth-late successional conifer forest** from establishment of invasive plants and suppression of regenerating native species. Old Growth and Late Successional Forest areas are an Oregon Conservation Strategy Priority. In the Riverside fire area these habitats tend to be isolated because of poor access, which decreases the threat of invasive plants being introduced. The old growth habitats on state and private lands are typically found in areas with typically high native plant cover. These areas should be resistant to invasion due to their competitive cover and lack of noxious weed propagule sources.

Recommendations: Limit access to old growth areas with high and moderate soil burn severity to minimize the potential for weed seed introduction into these areas. Survey these areas in subsequent years after vegetation has had a chance to rebound post-fire. Treat invasive weeds if new infestations are identified.

3.4. Cultural Resources Summary

Cultural resources are non-renewable and can be adversely affected by post-fire erosion and related events, such as debris flows, tree falls, exposure of sites and artifacts to looting and displacement. In addition, proposed ETART treatments can also affect cultural resources and if federal funds are involved then S.106 consultation with Tribes and the Oregon SHPO must also be addressed. Under the ETART process, attempts were made to engage state and local cultural resource specialists to assist in determining critical values, risks and treatments, however no individuals were available to perform this work due to staffing and project workload factors in several state and federal agencies. In addition, the acquisition of GIS (feature data classes) from the Oregon SHPO for state and private lands in the fire area was not timely and thus fine-grained analysis of site locations as compared to moderate to high burn severity in the fire area could not be performed.

Given the lack of cultural resource personnel and completion of a critical values analysis, we recommend that FEMA, State and local agencies seek to acquire GIS data on archaeological and historic sites directly with Oregon SHPO and then apply the ETART process to determine the cultural resource critical values, perceived risks and propose treatments where the likelihood of success is greatest. What follows are some general guidelines for addressing values, risks and treatments.

Cultural resources reflect varying social, cultural, and scientific values to society at large and to specific cultural groups, such as area tribes. Cultural resources can be categorized into four broad types: pre-contact archaeological sites, historic archaeological sites, historic structures and traditional cultural properties/sacred sites. The fire area contains cultural resources spanning at least the last 10,000 years of time. These features include task-specific activity areas and camps such as sites of spiritual and cultural value to tribes, pre-contact lithic scatters, fishing stations, rock shelters, vision quest sites, historic trails, wagon roads and highways, historic mining and logging features and artifacts, historic structures, recreation and administrative sites.

In order to determine which cultural resources should be considered as “critical values” under ETART, a triage process is used to identify critical heritage values based on their listing or eligibility to the National Register of Historic Place, and scientific or cultural values. Not all cultural resource sites should be considered under the ETART process. Ideally a small group of specialists, including representatives of interested tribes should prioritize the site inventory to reflect (in order of value) sites listed on the National Register of Historic Places (NHRP), sites determined as eligible to the (NRHP), and sites identified as having traditional cultural or spiritual values to tribes or other ethnic groups. Cultural resource sites that are designated as unevaluated are not automatically considered under ETART, unless their value is exceptional and would likely be easily determined eligible or listed on the NRHP.

Once the above critical values determination is made, a GIS analysis is used to identify their proximity to Moderate or High soil burn severity areas. The BAER risk matrix (Figure 6) is used to determine if stabilization treatments or other protection actions are warranted. Treatments range from point protection to prevent damage from erosion and/or debris flows, mulching or slash dispersal to cover exposed sites having a high likelihood of looting, directional felling of danger trees to prevent damage to archeological deposits or historic structures and treatment effectiveness monitoring. In addition, S.106 compliance is required for other recommended and federally funded ETART treatments that may affect cultural resources.

4. Monitoring and Management Recommendations

Inform stakeholders of risks and advise on threat mitigation recommendations (e.g. engineering teams to inspect culverts and other road infrastructure) and storm alert systems. For hillslope stabilization there are multiple proven treatments effective against low degrees of hillslope erosion: mulching, slash spreading, erosion barriers, wattles, silt fences, debris deflectors, and protective fences.

4.1. Watershed Response and Hydrologic Analysis - Monitoring Recommendations

Modeling suggests that some watersheds affected by the Riverside Fire will experience increased peak flows due to the extent and intensity of the fire. With this in mind, the team recommends installation of one or more near real-time (NRT) precipitation gages in or near the burn area. A NRT precipitation gage provides invaluable information about the localized intensity and amount of precipitation as it happens. Based on these data, the National Weather Service (NWS) can issue alerts to emergency managers, road crews, and other partners to warn of increased potential for flooding and debris flows that could threaten lives or damage homes, roads, and other infrastructure.

In addition to improving emergency response, expansion of the precipitation monitoring network would lead to a better understanding of how the amount and timing of runoff change due to fire in mountainous parts of the Pacific Northwest. At present, little information is available in this regard because large, intense fires have been relatively rare in this region.

Gaging stations are present in watersheds within and adjacent to the burned areas of the Beachie Creek and Riverside Fires with periods of record existing prior to fire outbreak. Such circumstances create opportunities for performing paired-watershed analyses to understand impacts of wildfires on hydrologic response. The paired-watershed method can be used to develop a runoff relationship between an experimental (i.e. burned) and control (i.e. unburned) watershed. Catchments can be instrumented to collect rainfall and runoff data to assess changes in flood flow frequency, magnitude, timing, and hydrograph shape. Further developing these relations can assist with future evaluations of post-fire flood magnitude and hydrologic response in ungaged watersheds (Moody and Martin, 2001).

4.2. Geologic Hazards - Management Recommendations

The finding in this report are from a rapid assessment of areas prone to geologic hazards. Most properties identified in this report were not fully assessed. A more complete assessment requires examining the on-the-ground characteristics of each property at risk. In some cases, this report points to high hazard areas that could benefit from “further evaluation”, therefore, additional site-specific assessments are recommended. The results of a site-specific evaluation should address protecting homes from the impacts of large debris flows, which may necessitate additional design resources and consultation with engineers that is outside the scope of this evaluation. Engineered debris flow diverting structures were not evaluated by this report. These structures need to be surveyed and designed for specific areas they would be needed.

4.3. Roads and Travel Routes - Management Recommendations

4.3.1. STORM INSPECTION AND RESPONSE

Storm inspection and response should be completed after high rainfall events on all roads open to the public. Subsequent patrols should be coordinated with all the agencies having public access roads within the fire perimeter, including USFS, Clackamas County, Portland General Electric and ODOT. Continue storm inspection and response until vegetation has reestablished in affected watersheds for at least two years.

4.3.2. ROCK FALL, CHANNEL DEBRIS AND FLOOD MITIGATION ACTIONS

For locations where rock fall may occur, install hazard warning signs and increase frequency to clear and maintain primary travel routes. During storm inspection and response, remove debris from channels upstream of road crossings that may be mobilized by flooding. Roads that become blocked from debris or damaged from road crossing failures could result in loss of access by emergency responders and residents being stranded. Inform county emergency managers of the high-risk locations and post signs to educate residents and the public.

4.4. Fish/Aquatic Habitat - Management Recommendations and Monitoring

With respect to hazard tree mitigations, the primary objective is to ensure exclusion of employees and the public from these sites and to remove the hazard trees. Treatment of large wood is somewhat more complex because it is a beneficial, natural feature in streams. Add to this that many river reaches are difficult for heavy equipment (capable of removing the wood) to access. Thus, the treatment for wood in streams is a combination of good signage and education to warn boaters of the risks posed by large wood. Large wood in an impoundment like North Fork Reservoir can more easily be treated by removing it, but signage is also important to warn boaters of the risks.

Near-term success in engaging partners can be monitored by number of projects on which engagement occurs. Over the mid- to longer-terms, success can be measured by habitat variables and populations metrics, such as LWD recruitment into stream channels and escapement of salmonids or population counts of terrestrial wildlife.

Resource Reports

1. Weeds Specialist Report

Samuel Leininger, Clackamas Soil and Water Conservation District

1.1.1. SUMMARY

Objectives

The Riverside fire extends across a plurality of land ownership. An evaluation of federally owned property has already been completed through the Riverside Fire Burned Area Emergency Response (BAER). This ETART assessment is intended to compliment the Riverside BAER, and is limited to state, local, and private lands within the perimeter of the Riverside Fire.

The proposed activities are intended to identify needs and opportunities to positively influence outcomes on lands impacted by the Riverside Fire. Special considerations have been taken to address the ecological, economic, and social resources that have or may be adversely impacted by the proliferation of noxious weeds following the Riverside Fire. The recommendations are intended to improve management of noxious weeds within the affected areas and prevent the introduction of new infestations during the vulnerable regeneration period of the native plant community. The response of vegetation post-fire necessitates a multi-year approach to allow vegetation to mature and restore some resilience across the landscape.

Critical Values

The critical values identified in the Riverside fire include both public and private interests. Critical values employed in this assessment include:

1. Human life and safety,
2. Property,
3. Natural Resources,
4. Cultural and Heritage Resources, and
5. Economic Resources

The first four values are traditionally employed on federally managed properties for post-fire analysis using the BAER process (FSM 2523.1 – Exhibit 1). While this ETART planning is similar to the BAER, the impacts to Economic Resources on private lands play an important role in defining future land use and decision-making during rehabilitation and reforestation efforts. Threats to these values can influence one or multiple critical values at any given time. These threats are identified below and are further expounded upon in the Critical Values Table[2].

Multiple Values

- Impacts to a diversity of economic, ecological, and social resources from the establishment and expansion of viable populations of local and state noxious weeds classified as targets for Early Detection and Rapid Response.
- Adverse impacts to a diversity of economic, ecological, and social resources from the spread of Invasives due to restoration, reforestation, and salvage logging operations.

Human life and safety

- Increased risk to human life from fire following the establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties.

Property

- The potential impacts to economic, ecological, and social resources due to the spread of fire adapted noxious weeds in contaminated gravel and rock products.

Natural Resources

- Impacts to native plant communities from the establishment and expansion of fire-adapted noxious weeds.
- Adverse impacts to habitat conservation efforts through the establishment and expansion of fire-adapted noxious weeds in state-designated Habitat Conservation Areas.
- A loss of habitat for threatened and endangered plants, lichens, and fungi due to fire damage and the subsequent spread of invasive weeds.
- A loss of habitat for rare, threatened, and endangered native plants due to fire damage and the establishment and expansion of fire-adapted noxious weeds.
- The impacts to riparian plant communities from invasive plant establishment and suppression of regenerating native plants.

[2] Found in Appendix B

- The impacts to old growth-late successional conifer forest from invasive plant establishment and suppression of regenerating native plants.
- Adverse impacts to wetland habitat from invasive plant establishment and suppression of regenerating native plants.
- Impacts to grasslands and meadow habitat from invasive plant establishment and suppression of regenerating native plants.
- Adverse impacts to oak habitat from invasive plant establishment and suppression of regenerating native plants.

Economic Resources

- A reduction in the productivity and economic viability on designated “prime farmland” and “farmland of statewide importance” due to the establishment and expansion of agronomic noxious weeds following fire-related disturbance.
- Adverse impacts to timber productivity from the establishment and expansion of economically important noxious weeds.

1.1.2. RESOURCE CONDITION AND SETTING

The Riverside fire in Clackamas County, Oregon was first reported on September 8, 2020 on the Mount Hood National Forest. The Riverside fire spread along the Clackamas River drainage, moving 17 miles in a single day in response to high winds and extremely low humidity. Over the course of days and weeks, the fire spread south to also include significant portions of the Molalla River drainage.

Table 2. Area of watersheds impacted by the Riverside Fire.

Watershed		Area of watershed (ac)	Area Burned (ac)	Percent of watershed burned
Clackamas River		279460	100236	35.87%
	Lower Hot Springs Fork Collawash River	18272	142	0.8%
	Farm Creek-Collawash River	16326	554	3.4%
	Pot Creek-Clackamas River	22961	203	0.9%
	Cot Creek-Oat Grove Fork Clackamas River	14171	2803	19.8%
	Three Lynx Creek-Clackamas River	31546	24891	78.9%
	Roaring River	27309	2286	8.4%

Watershed		Area of watershed (ac)	Area Burned (ac)	Percent of watershed burned
	Fish Creek	29807	26789	89.9%
	South Fork Clackamas River	17656	17407	98.6%
	North Fork Clackamas River	20638	1079	5.2%
	Helion Creek-Clackamas River	11719	11035	94.2%
	Lower Eagle Creek	22359	273	1.2%
	Upper Clear Creek	12247	9013	73.6%
	Middle Clear Creek	21813	2124	9.7%
	Dubois Creek-Clackamas River	12636	1636	12.9%
Molalla River		551933	175723	31.84%
	Table Rock Fork	23227	423	1.8%
	Pine Creek-Molalla River	23952	7	0.0%
	Trout Creek-Molalla River	15678	1528	9.7%
	Dead Horse Canyon Creek	8987	8939	99.5%
	Upper North Fork Molalla River	19699	18834	95.6%
	Lower North Fork Molalla River	7116	4297	60.4%
	Cedar Creek-Molalla River	8419	66	0.8%
	Canyon Creek	10713	2048	19.1%
	Headwaters Milk Creek	10244	497	4.9%
	Woodcock Creek	8200	1104	13.5%
Total		**415696**	**137979**	**33.2%**

The local impacts from the Riverside fire were exacerbated by several other co-occurring fires in the county including the large Beachie Creek and Lionshead fires to the south, as well as several smaller fires including the Dowty, Unger, Whilhoit, and Graves Creek fires. The co-occurrence of these fires and extreme weather conditions led to evacuation warnings to be issued throughout Clackamas County.

The Riverside burned a mosaic of mixed conifer stands totaling 137,942 acres of public and private lands. The most heavily impacted areas were on the Mt Hood National Forest which comprised 62% of the total area burned. State and Private lands were also heavily impacted with 42,337 acres burned totaling 30% of the total area impacted.

Land Use

The state and private lands within the perimeter of the Riverside Fire have a plurality of land uses. The largest and most pronounced of these is industrial timber lands. These privately managed industrial forests comprise 92% of affected non-federal lands. Privately managed non-industrial lands, including farms, small woodlots, and rural residential properties total 7% of affected lands. State and local government lands affected include both forestry and quarry operations for 1% of the affected lands.

The impacts of invasive weeds on industrial forest lands have the potential to be significant. Invasive weeds can have a significant impact on forest regeneration, especially in the first few years following reforestation. Invasive weeds like, Scotch broom (Cytisus scoparius), gorse (Ulex europaeus), slender false brome (Brachypodium sylvaticum), and Himalayan blackberry (Rubus bifrons) can also increase fuels in the understory leading to progressively more frequent and intense fires.

The privately managed non-industrial lands include a mix of rural residential, agricultural and forest, Farm and Forest, and Exclusive Farm Use. These areas are also largely deemed as “prime farmland” or as “farmland of statewide importance”. This designation connotes the importance of these lands to the economic well-being of the region and to the state in general. The proliferation of invasive weeds following fire threaten the productivity of these lands, increase operational costs, and reduce the economic viability of their future use.

A number of homes, businesses and outbuildings were also lost because of the rapidly moving Riverside Fire. The significant impact on these lands from development and fire, preclude the natural regeneration of a site. If homesites are not rebuilt, these properties will be rapidly colonized by fire-adapted noxious weeds already growing in the vicinity. Without intervention and active management, these sites will expand the prevalence of fire-adapted noxious weeds in the area. This increases the potential for future fire and poses a risk to human life and property in the vicinity.

Figure 2. A rural residential home near the community of Dodge is a complete loss following the Riverside Fire. (Photo: Samuel Leininger, Clackamas SWCD)

1.1.3. ASSESSMENT METHODOLOGY - FIELD EVALUATIONS AND MODELING

Assessing the impact of noxious weeds in response to the Riverside fire relied upon information from a variety of sources, including local land managers and organizations working in the affected areas, GIS analysis from existing spatial data sources, and field evaluations of the affected areas.

Local Consultation and Field Evaluations

This assessment relied heavily upon the knowledge of local land managers, and natural resources organizations working on and near the area impacted by the Riverside Fire. In the Clackamas River drainage, a strong noxious weed partnership already exists amongst agencies working in the Clackamas River drainage. This group known as the Clackamas River Invasive Species partnership (CRISP) is comprised of local land managers from 14 public agencies and not for profit organizations focused on invasive species issues in the Clackamas River Drainage [1]. The CRISP was organized to discuss noxious weed concerns in the affected areas.

In the Molalla River drainage, the noxious weed information was collected from feedback by Molalla RiverWatch and Clackamas SWCD that are actively working on noxious weed related issues in the watershed.

Additional consultation was also carried out with state and federal agencies including, Oregon Department of Forestry, Oregon Department of Agriculture, Bureau of Land Management US Forest Service, and the Natural Resources Conservation Service. Field evaluations were carried out in November of 2020 to further assess the response of vegetation in areas with a mosaic of burn severities.

Spatial Analysis

To prioritize noxious weed related concerns within the Riverside fire critical assets and threats were evaluated within the affected areas. Assets within the Riverside Fire were defined as Natural Vegetation Protection Areas. Threats evaluated included noxious weeds locations, Basal Area Vegetation Mortality, and disturbances from fire suppression activities.

Natural Vegetation Protection Areas

Natural Vegetation Protection Areas, which included “strategy habitats” as defined in the Oregon Conservation Strategy [2] (including aspen, oak woodlands, grasslands (meadows and prairie) as defined by the Oregon Department of Fish and Wildlife (ODFW) in the Statewide Habitat map. Wetlands were defined using the ODFW Statewide Habitat Map, the National Wetlands Inventory (NWI) [3], and the National Hydrography Dataset (NHD) [4].

Riparian corridors are widespread across the burn area. These areas are also viewed as being more resilient to fire, based on their proximity to water, their topographic location on the landscape, and the composition of species within this habitat type. As a result, only riparian areas that have undergone restoration efforts documented in the Oregon Watershed Restoration Inventory [5] were included for analysis. For riparian areas excluded from this analysis, we encourage future assessment and monitoring of these sites for potential impacts because of the Riverside fire.

Similarly, old growth conifer forest was excluded from the analysis based on the scale of the habitat represented within the Riverside fire, and because best practices for rehabilitation of these areas is achieved through closure and natural recruitment. It is encouraged that these areas be surveyed and monitored in future years to assess potential noxious weed introductions that may occur during regeneration.

In addition to the habitat designation, we also included rare, threatened, and endangered plant locations from the Oregon Biodiversity Information Center (ORBIC) [6] and the Bureau of Land Management (BLM) Rare Vascular Plant Dataset, to protect sensitive species. Oregon Department of Forestry (ODF) Habitat Conservation Areas (HCA) [7] were also included in the analysis due to the prioritization of these lands for habitat improvements. Oregon Department of Fish and Wildlife (ODFW) Conservation Opportunity Areas (COA) [2] were also assessed, but no COA were present within the perimeter of the Riverside fire.

Collectively, these habitat, conservation, and restoration datasets were used to define the Natural Area Protection Areas for further analysis.

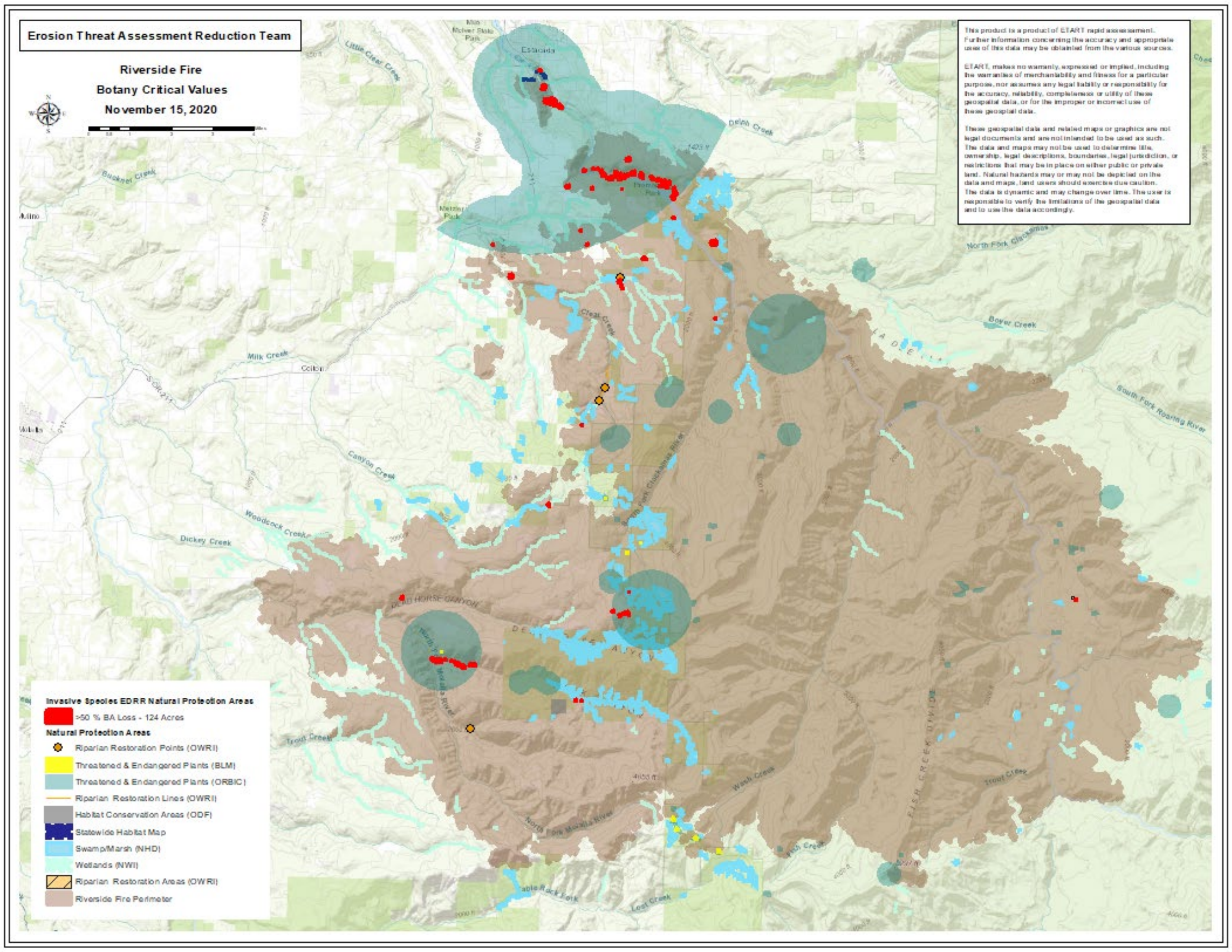


Figure 3. Botany Critical Values map depicting the Natural Vegetation Protection Areas and BA >50% Vegetation Mortality

Soil Burn Severity

The landscape-wide disturbances associated with the Riverside Fire and the post-fire response of invasive plants to these disturbances pose a significant threat to the recovery of affected lands. Areas with high and moderate burn severity and elevated vegetation mortality are especially susceptible to the unchecked proliferation of invasive weeds. The Soil Burn Severity was used primarily to inform the Vegetation Mortality data. Please see Appendix B, Section V for SBS Map.

Vegetation Mortality

The Soil Burn Severity (SBS) and Vegetation Mortality was also used for the EDRR risk modeling. These evaluations were based on remote sensing techniques and refined by ground truthing. These important inputs help to determine the vulnerability of a site to invasive noxious weeds. Heavily disturbed landscapes lack the native vegetation needed to resist encroachment by weeds. Please see Appendix B, Section IV for vegetation mortality Map.

Table 2. Soil Burn Severity by acres of ownership in the Riverside Fire.

Soil Burn Severity	Federal	Local Govt.	Private Individual or Company	Private Industrial	Private Non-Industrial Owner	State	Total Soil Burn Severity
High	14,901.60	14.5	0	1995.4	22.3	0	16,933.80
Moderate	37404.3	39.5	12.9	16749.9	896.8	22.7	55,126.10
Low	31054.9	139.4	44.6	14572.6	1683.8	122.4	47,617.70
Unburned	12244.5	68.5	0	5746.7	198.3	7.2	18,265.20
Total	95,605.30	261.90	57.50	39,064.60	2,801.20	152.30	137,942.80
Total Ownership	**69.31%**	**0.19%**	**0.04%**	**28.32%**	**2.03%**	**0.11%**	**100.00%**

Noxious Weeds

To assess noxious weed threats within the perimeter of the Riverside Fire, we used location information from several sources. These included data from Oregon iMapinvasives [8], Oregon Weedmapper [9], and the Clackamas Soil and Water Conservation District's WeedWise program noxious weed dataset. Collectively, these data sources contained 8,427 documented weed locations in the Riverside Fire perimeter. Although, these sources provide a wealth of information, it is recognized that these sources underrepresent noxious weed occurrences on private lands, and do not fully capture the extent of the threat of these noxious weeds within the Riverside Fire perimeter.

Noxious weeds classified in the Clackamas County Weed List [10] as "priority" or "containment" species are Early Detection and Rapid Response locations specifically because of their designation. These species include all Oregon Class A noxious weeds of which "infestations are subject to eradication or intensive control when and where found" [11].

EDRR Treatments Model

The model for EDRR treatments within the Riverside Fire were calculated using the Natural Vegetation Protection Areas, the BA >50% vegetation mortality, and the noxious weed occurrences. Each of these model inputs were buffered by 50 m. EDRR treatment areas were defined by the areas where these inputs co-occur on the landscape.

Suppression Activities

Many noxious weeds are well-suited to invade disturbed lands by rapidly colonizing and outcompeting native plant communities in disturbed areas. The exposed soils following fire reduces the resistance of these lands to invasive plants, allowing them to spread more rapidly. Fire suppression activities, such as handlines and bulldozer lines, can exacerbate this dynamic by potentially introducing noxious weed propagules through contaminated equipment and by exposing latent weed seed in the seedbank that was previously suppressed. Fire suppression data was also included in the data analysis to determine locations of likely soil disturbance or potential introduction of new invasive weeds during suppression activities.

1.1.4. RISK ASSESSMENT

A risk assessment of critical values was undertaken for the Riverside Fire. This assessment closely followed the BAER process, but critical values were broadened to address values meaningful to state and private lands. The risk rating used for this analysis is based on the BAER Risk Assessment criteria and relevant risk rating outline in Section 2 (page 13).

Table 3. Critical value risk assessment. Risk was evaluated based on the probability of damage or loss and the magnitude of consequences.

Critical Value	Threat to Value	Probability of Damage or Loss	Magnitude of Consequence	Risk
Multiple values across the fire perimeter	Establishment and expansion of viable populations of local and state noxious weeds classified as targets for Early Detection and Rapid Response	Likely	Major	Very High
Multiple values across the fire perimeter	Spread of Invasives during fire rehabilitation, reforestation, and salvage logging operations	Likely	Moderate	High
Human health and safety	Establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties	Possible	Major	High
Multiple values across the fire perimeter	Spread of Invasives due to contaminated gravel and rock products	Possible	Moderate	Intermediate
Native plant communities	Establishment and expansion of fire-adapted noxious weeds	Likely	Moderate	High
Habitat conservation areas	Establishment and expansion of fire-adapted noxious weeds	Possible	Moderate	Intermediate
Threatened and endangered native plants	Establishment and expansion of fire-adapted noxious weeds	Possible	Major	High

Critical Value	Threat to Value	Probability of Damage or Loss	Magnitude of Consequence	Risk
Riparian plant communities	Invasive plant establishment and suppression of regenerating native plants	Possible	Moderate	Intermediate
Old growth-late successional conifer forest	Invasive plant establishment and suppression of regenerating native plants	Unlikely	Minor	Very Low
Wetland habitat	Invasive plant establishment and suppression of regenerating native plants	Likely	Moderate	High
Grasslands and meadow habitat	Invasive plant establishment and suppression of regenerating native plants	Likely	Moderate	High
Oak habitat	Invasive plant establishment and suppression of regenerating native plants	Possible	Moderate	Intermediate
Agricultural productivity	Establishment and expansion of agronomic noxious weeds following fire-related disturbance	Possible	Moderate	Intermediate
Timber productivity	Establishment and expansion of economically important noxious weeds	Possible	Minor	Low

1.1.5. RESULTS OF FIELD WORK AND MODELING

The results of field assessments and GIS model runs have allowed us to characterize conditions within the state and private lands within the Riverside fire. This evaluation effort is based on the best information available, but it is also recognized by local authorities that this information is incomplete for much of the affected area. As a result, model predictions should be interpreted cautiously. A post-fire response to these model predictions should account for uncertainty and be adaptive in their approach. Despite these recognized limitations the model has yielded meaningful insight into conditions within the Riverside fire.

EDRR Treatment Model

The EDRR Treatment model results showed a modest co-occurrence of documented noxious weed locations, defined natural vegetation protection areas, and vegetation mortality. Across the state and private lands in the Riverside fire, these three features co-occurred across 124 acres.

The relatively low acreage predicted by the EDRR Treatment model was unexpected based on the size of the area impacted by fire, and the occurrence of weed populations observed during field assessments. One explanation for these modest totals is that the model is sensitive to the presence and absence of mapped noxious weed locations within the burn area. Unfortunately, noxious weed surveys are not systematic or uniform across the burn area. Weed observations are poorly documented outside of roadsides and riparian corridors. Many of the industrial timber lands, which total 92% of the state and private lands affected, have limited public access. As a result, weed observations in these areas are limited in comparison to similar state and county properties. It is expected that this bias underrepresents the threat from noxious weeds that will affect industrial timber lands in the Riverside fire.

Another recognized bias of the model comes from artifacts within the threatened and endangered species location information. The source data used to compile T&E location information includes observations documented through collections housed in herbaria. Unfortunately, many of these observations include vague location descriptions which predate GPS and modern features on the landscape. As a result, locations are defined by circles of varying size based on location uncertainty. This has the undue effect of increasing the natural vegetation protection areas.

Despite the two data integrity issues identified, these model inputs operate to offset each other and thereby mitigate some of the uncertainty. The other important model input is the vegetation mortality map which demonstrates the relative susceptibility of a site to the introduction and proliferation of invasive weeds. The vegetation mortality model developed by the Riverside BAER team provides meaningful context to the anticipated response of noxious weeds at a particular location and its potential threat to natural vegetation protection areas.

Suppression Activities

The disturbances from suppression activities are extensive around the western boundary of the Riverside fire. The western portion of the Riverside fire shifts rapidly from forest to rural residential properties. The suppression activities in this area were extensive to protect human life and property during the extreme weather conditions encountered during the fire.

A total of 96 miles of suppression lines were documented on state and private lands within the Riverside fire. These suppression lines consisted of completed dozer lines, completed hand lines, and roads as completed lines. In addition to the suppression lines, there were 34 locations identified where suppression-related activities could have resulted in the introduction of noxious weeds from contaminated equipment or personnel.

Area assessments for suppression lines differed depending upon the activity. Completed dozer lines were estimated at 20 ft in width, hand lines were 3 ft in width, and roads were considered to 10 ft in disturbed width. Looking at the composition of the suppression lines, this equated to 142 acres of suppression related disturbance to survey and treat. Suppression-related points varied in size but were estimated to be 10,000 ft^2 in size totaling roughly 8 acres in size. Across all suppression-related activities, these equate to roughly 150 acres for survey and treatment as needed.

Between the EDRR treatment model and the suppression related activities, survey and treatment of these areas total roughly 274 total acres in response to the Riverside fire.

Field Work

The field work carried out as part of this assessment yielded several important observations for consideration on state and private lands impacted by the Riverside fire. The most notable observation was from the communities and rural residential areas destroyed by the fire. These areas regularly featured a mosaic of burned and unburned buildings. Weedy vegetation and a lack of defensible space was an apparent feature associated with many of the damaged homes. Common weeds such as Himalayan blackberry (Rubus bifrons) and Scotch broom (Cytisus scoparius) were prevalent in much of the burn areas and are known to increase fire risk and respond well to fire [12]. Fires often create a selection pressure for fire-adapted weeds to flourish post-fire. The destruction of homes also increases the likelihood for properties to have vacant landowners and for affected properties to go unmanaged in the following years. This post-fire dynamic increases the potential for reducing fire return interval and increase the threat to human life and property.

The same mechanisms that increase risk to human life and property also threaten agricultural interests within the fire perimeter. The responses of weeds to fire-related disturbances can lead to a proliferation of weeds that adversely impact the economic viability of prime farmland. Increased costs associated with managing noxious weeds can have an impact on some producers in the area.

The other key economic interest impacted by the Riverside fire was industrial timber lands. Immediately following the Riverside fire, industrial timber producers began salvage-logging operations to try and capture some revenue before salvageable logs were lost to insect and fungal damage. Areas with extensive salvage logging are seeing significant influx of equipment, vehicles, and personnel into areas that are highly susceptible to invasion by noxious weeds. The risk of new species introduction into these burn areas is significant, which adversely impacts not only industrial timbers lands, but nearby state and federal properties.

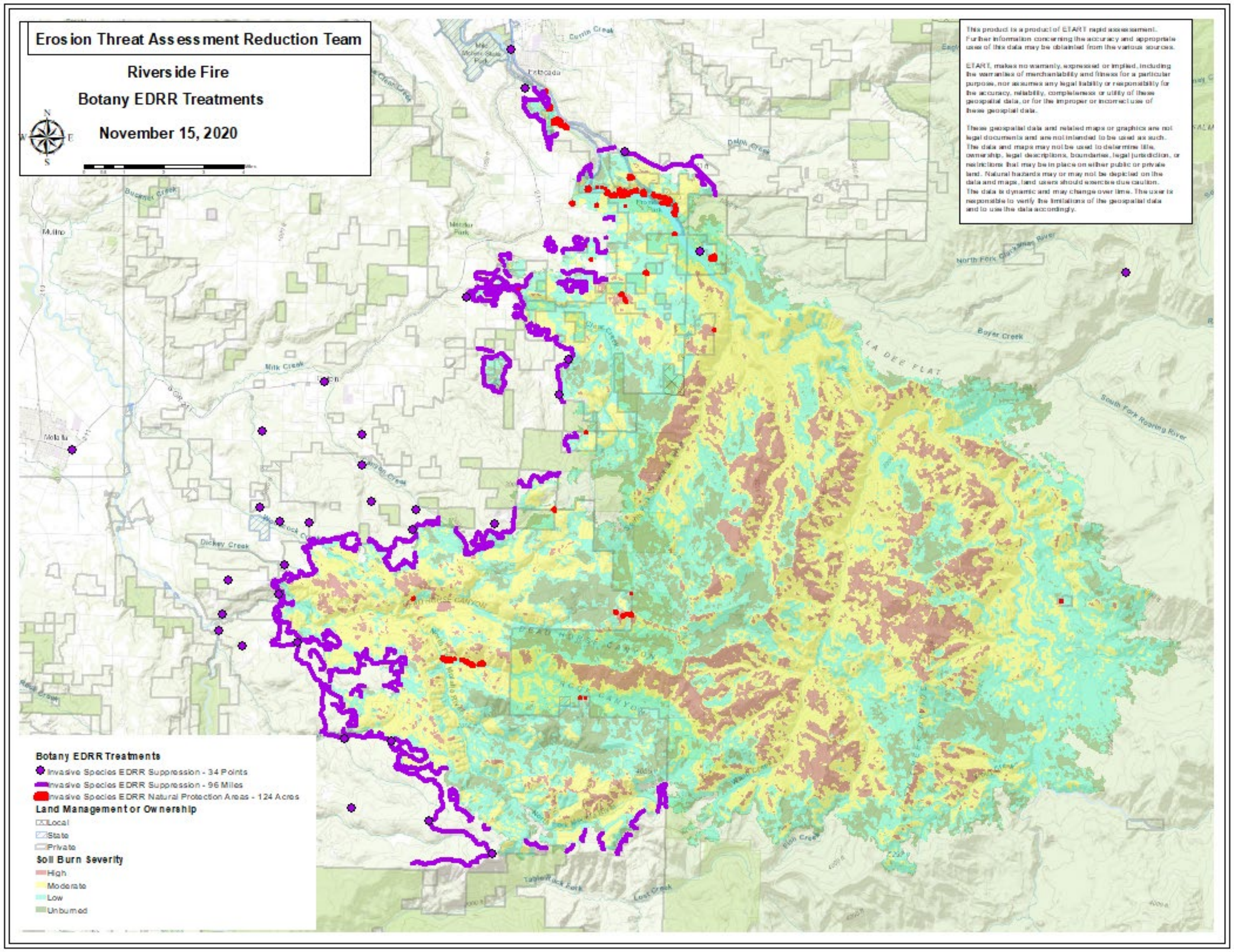


Figure 4. Botany and Invasive Plants EDRR Treatment prioritization and suppression lines within the Riverside Fire.

Figure 5. Salvage logging activities already underway on industrial timberlands affected by the Riverside fire. (Photo: Samuel Leininger, Clackamas SWCD)

Noxious Weed Assessment

To assess the potential for the rapid expansion of noxious weeds within the Riverside fire perimeter, an inventory of weed species was evaluated. This inventory was undertaken not only to assess potential, but to also help direct post-fire response efforts by helping to direct resources to species that pose a greater post-fire risk for expansion.

Weed species were evaluated using the Fire Effects Information System (FEIS) [12] to characterize the potential for post fire spread. If a species was not evaluated in the FEIS, additional peer review literature was evaluated, if no information was available about a species, closely related species were used as surrogates for a post-fire response. All available resources were then used to describe a relative post-fire priority rating based on anticipated response. Of the 32 species evaluated, 14 were ranked as “high”, 12 were ranked as “moderate”, and 6 were ranked as “low”.

Table 4. Weed species identified in the Riverside Fire boundary, with local and state weed classifications, and priority assessment based on response following fire.[3]

Scientific Name	Common Name	Clackamas Classification [10]	Oregon Classification [11]	Post-Fire Priority Rating
Alliaria petiolata	Garlic Mustard	containment	B	High
Brachypodium sylvaticum	Slender False Brome	containment	B	High [13]
Centaurea × moncktonii	Meadow Knapweed	maintenance	B	High
Centaurea diffusa	Diffuse Knapweed	maintenance	B	High
Centaurea stoebe	Spotted knapweed	maintenance	B	High
Chondrilla juncea	Rush Skeletonweed	priority	B (T)	High
Cirsium arvense	Canada Thistle	maintenance	B	Moderate
Clematis vitalba	Old Man's Beard	maintenance	B	Moderate
Crataegus monogyna	Single-seed Hawthorn	maintenance	B	Moderate
Cynoglossum officinale	Houndstongue	priority	B	High
Cytisus scoparius	Scotch Broom	maintenance	B	High
Euphorbia myrsinites	Myrtle Spurge	maintenance	B	Moderate
Fallopia × bohemica	Bohemian knotweed	containment	B	Low
Fallopia japonica	Japanese Knotweed	containment	B	Low
Fallopia sachalinensis	Giant Knotweed	containment	B	Low
Geranium lucidum	Shining Geranium	maintenance	B	High
Geranium robertianum	Herb Robert	maintenance	B	High
Hedera helix	English Ivy	maintenance	B	Low

[3] Post-fire priority rating based on Fire Effects Information System [12] supplementary literature, or expert opinion based on life history characteristics.

Scientific Name	Common Name	Clackamas Classification [10]	Oregon Classification [11]	Post-Fire Priority Rating
Hieracium aurantiacum	Orange Hawkweed	priority	A (T)	Moderate
Hieracium caespitosum	Meadow Hawkweed	priority	B (T)	Moderate
Hypericum perforatum	St. John's wort	maintenance	B	High
Ilex aquifolium	English Holly	maintenance	W	Low
Jacobaea vulgaris	Tansy Ragwort	maintenance	B	Moderate
Lathyrus latifolius	Everlasting Peavine	maintenance	B	Low
Leucanthemum vulgare	Oxeye Daisy	maintenance	not listed	Moderate
Phalaris arundinacea	Reed Canarygrass	maintenance	W	High
Potentilla recta	Sulphur Cinquefoil	priority	B	Moderate
Ranunculus ficaria	Lesser Celandine	maintenance	B	moderate
Rubus bifrons	Himalayan Blackberry	maintenance	B	Moderate
Rubus laciniatus	Cut leaf Blackberry	maintenance	not listed	Moderate
Taeniatherum caput-medusae	Medusahead rye	priority	B	High
Ulex europaeus	Gorse	priority	B,T	High

1.1.6. RECOMMENDED RESPONSE ACTIONS

The recommended actions for each critical value threat are described below. These recommendations are based on the information available at this time. Conditions in the burn area are not fully understood. As such, these recommendations should be modified as needed to address conditions in the field. These are also found in Appendix B, Section II and III, along with cost estimates.

Threat: Establishment and expansion of viable populations of local and state noxious weeds classified as targets for Early Detection and Rapid Response (EDRR)

- Implement EDRR weed surveys. If priority noxious weeds are identified, implement treatments using IPM-based principles with the desired goal of eradication. Emergent populations of local priority and containment weeds include orange hawkweed, gorse, slender false brome, Japanese knotweed, Bohemian knotweed, and garlic mustard. Ongoing monitoring is required.

Threat: Spread of noxious weeds during fire rehabilitation, reforestation, and salvage logging operations

- Equipment sanitation and prevention protocols should be implemented to prevent the spread of noxious weed with equipment and personnel. Temporary or permanent equipment wash stations should be installed in the northern and southern ends of the fire to sanitize equipment during restoration, reforestation, and salvage logging activities. A southern equipment wash station could also be used for prevention efforts in the northern portion of the Beachie Creek fire as well. Initiate noxious weed surveys along road system and treat emergent populations of noxious weeds using IPM-based principles. Ongoing monitoring is required.

Threat: Establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties

- Initiate an outreach campaign to affected communities promoting Community Wildfire Preparedness Planning, and the importance of defensible space around homes and buildings. Survey for areas with high fuel loads and regeneration of fire-adapted weed species. Focus outreach into impacted areas in the communities of Colton, Dodge, Dickie Prairie, Elwood, Estacada, Highland, Molalla, and Springwater focusing on highly flammable noxious weeds such as Scotch broom, gorse, and Himalayan blackberry. Create materials for additional messaging to other residents in the wildland interface.

Threat: Spread of Invasives due to contaminated gravel and rock products

- Prevent contamination of gravel and rock products by surveying and treating noxious weeds using IPM-based principles in and around active quarry operations. Require certified weed aggregate in all public contracting. Install a centrally located equipment wash station to sanitize vehicles and equipment used for the distribution of gravel and rock products. Any contaminated rock or gravel products should be quarantined and not redistributed. Ongoing monitoring is needed.

Threat: Establishment and expansion of fire-adapted noxious weeds in fire suppression areas

- Target survey and treatment activities in identified dozer lines, hand lines, roadsides, and suppression locations. Noxious weed surveys in these areas should include the identification of new or emergent weeds that may have been introduced during suppression activities. Emergent noxious weed populations should be treated using IPM-based principles. Reseeding heavily disturbed suppression areas and areas of high severity burn using native or non-invasive seed as needed. Ongoing monitoring is required.

Threat: Establishment and expansion of fire-adapted noxious weeds on prioritized Oregon Department of Forestry Habitat Conservation Areas

- Implement noxious weed surveys in Habitat Conservation Areas with a focus on riparian habitat function. Treat new or emergent populations of identified noxious weeds using IPM-based principles. Ongoing monitoring required.

Threat: Establishment and expansion of fire-adapted noxious weeds near populations of rare, threatened, or endangered plants

- Implement targeted noxious weed survey in areas around sensitive species. Treatments of invasive weeds in sensitive areas should be implemented using IPM-based practices only when adverse impacts to protected species can be avoided. Focus should be on areas near suppression activities dozer lines, hand lines, and other suppression activity locations. Soil burn severity and vegetation mortality will increase the threat and dispersal of weed seed into sensitive areas. Ongoing monitoring is needed.

Threat: Invasive plant establishment and suppression of regenerating native plants in riparian areas

- Initiate surveys of riparian corridors. Treat new and emergent populations of noxious weeds using IPM-based practices. Past or current riparian restoration projects should be prioritized for survey and treatment. Public and private land of Upper Molalla River, Lower Clackamas River, and Middle Clackamas River should be surveyed upstream and downstream for potential dispersal and transport of noxious weeds. Replant areas with high mortality and poor natural regeneration.

Threat: Invasive plant establishment and suppression of regenerating native plants in late successional mixed conifer forest

- Limit access to old growth areas with high and moderate soil burn severity to minimize the potential for weed seed introduction into these areas. Survey these areas in subsequent years after vegetation has rebounded post-fire. Treat noxious weeds using IPM-based practices if new or emergent noxious weed infestations are identified.

Threat: Invasive plant establishment and suppression of regenerating native plants in wetlands

- Survey wetlands in areas with moderate to high burn severity area, and treat noxious weeds adapted for wetland sites using effective IPM-based practices. Replant areas with high mortality and poor natural regeneration.

Threat: Invasive plant establishment and suppression of regenerating native plants in grassland, prairie, and meadow systems

- Initiate noxious weed surveys in conjunction with rare plant surveys, due to the rarity of this habitat compared to historical abundance. Treat new and emergent populations of noxious weeds using IPM-based principles. Avoid seeding unless native locally sourced seed can be secured. Ongoing monitoring is needed.

Threat: Invasive plant establishment and suppression of regenerating native plants in oak woodland habitats

- Initiate noxious weed surveys in conjunction with rare plant surveys, due to the rarity of this habitat compared to historical abundance. Treat new and emergent populations of noxious weeds using IPM-based principles. Avoid seeding unless native, locally sourced seed can be secured. Ongoing monitoring is needed.

Threat: Establishment and expansion of agronomic noxious weeds following fire-related disturbance

- Implement noxious weed surveys for important agronomic weeds. Treat new and emergent noxious weeds using IPM-based principles. Prevent the spread of fire-adapted weeds from suppression activities onto adjacent agricultural lands designated as" prime farmland", or "farmland of statewide importance". Reseed heavily disturbed areas if needed. Ongoing monitoring is needed.

Threat: Establishment and expansion of economically important noxious weeds in industrial timbers lands

- Equipment sanitation and prevention protocols should be implemented to prevent the spread of noxious weed with equipment and personnel. Temporary or permanent equipment wash stations should be installed in the northern and southern ends of the fire to sanitize equipment during restoration, reforestation, and salvage logging activities. A southern equipment wash station could also be used for prevention efforts in the northern portion of the Beachie Creek fire. Initiate noxious weed surveys along road system and treat emergent populations of noxious weeds using IPM-based principles. Focus should be on preventing fire-adapted weeds from suppression activities on or adjacent to timber operations that may adversely impact timber production through direct competition or by altering the fire return intervals (i.e. false brome, gorse, scotch broom, blackberry, knapweeds).Ongoing monitoring is needed.

1.1.7. BEST MANAGEMENT PRACTICES RECOMMENDATIONS

Control of targeted noxious weeds should use established Best Management Practices (BMPs) to improve control and minimize impacts to non-targets. Below is a list of recommended resources for BMP.

- 4-County CWMA Best Management Practices: https://4countycwma.org/aweeds/best-management-practices/

- Columbia Gorge CWMA Best Management Practices: https://columbiagorgecwma.org/weed-listing/best-management-practices/
- DiTomaso, J.M., G.B. Kyser, *et al.* 2013 *Weed Control in Natural Areas in the Western United States*. Weed Excerpts [online], Weed research and Information Center, Davis, CA: University of California, Davis. https://wric.ucdavis.edu/information/natural%20areas/natural_areas_scientific_A-B.htm
- Peachey, E., editor. 2020. Pacific Northwest Weed Management Handbook [online]. Corvallis, OR: Oregon State University. http://pnwhandbooks.org/weed.

1.1.8. RECOMMENDED MONITORING

Noxious weed related concerns can take several years to manifest from an introduction event or seedbank. Emergent populations of new weeds can also take several years to control. Ongoing population monitoring of treatment areas is needed for 3-5 years. Follow-up monitoring in the same season is also needed to assess treatment efficacy and to prevent late season cohorts from seeding and recharging the seedbank.

Acknowledgements

Many thanks to the following experts for contributing to this report.

Simon Apostol, Cascade Environmental
Sarah Callaghan, US Forest Service
Justin Cooley, Clackamas Soil and Water Conservation District
Michelle Delepine, West Multnomah Soil and Water Conservation District
Lindsey Karr, Clackamas Soil and Water Conservation District
Jenny Meisel, Marion Soil and Water Conservation District
Kathy Pendergrass, Natural Resource Conservation Service
Wyatt Williams, Oregon Department of Forestry
Asako Yamamuro, Molalla RiverWatch

1.1.9. REFERENCES

[1] Clackamas SWCD, "Clackamas River Invasive Species Partnership," 2020. [Online]. Available: https://weedwise.conservationdistrict.org/partnerships/crisp. [Accessed 18 November 2020].

[2] Oregon Department of Fish and Wildlife, "Oregon Conservation Strategy," 2016. [Online]. Available: https://www.oregonconservationstrategy.org/. [Accessed 18 November 2020].

[3] US Fish and Wildlife Service, "National Wetlands Inventory," 2020. [Online]. Available: https://www.fws.gov/wetlands/. [Accessed 18 November 2020].

[4] U.S. Geological Survey , "National Hydrography Dataset," US Dept of Interior, 2020. [Online]. Available: https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset. [Accessed 18 November 2020].

[5] Oregon Watershed Enhancement Board, "Oregon Watershed Restoration Inventory," 2020. [Online]. Available: https://www.oregon.gov/oweb/data-reporting/Pages/owri.aspx. [Accessed 18 November 2020].

[6] Oregon Biodiversity Information Center, "Oregon Biodiversity Information Center," 2020. [Online]. Available: https://inr.oregonstate.edu/orbic.

[7] Oregon Dept. of Forestry, "Oregon Habitat Conservation Plan Initiative," 2020. [Online]. Available: https://www.oregon.gov/odf/aboutodf/Pages/HCP-initiative.aspx. [Accessed 19 November 2020].

[8] NatureServe, "iMapInvasives: NatureServe's online data system supporting strategic invasive species management. NatureServe. Available at http://www.imapinvasives.org. (Date accessed: [dd,mm,yyyy].)," 2020. [Online]. Available: http://www.imapinvasives.org. [Accessed 18 November 2020].

[9] Oregon Dept. of Agriculture, "Oregon Weedmapper," 2020. [Online]. Available: https://www.oregon.gov/oda/programs/weeds/pages/weedmapper.aspx. [Accessed 18 November 2020].

[10] Clackamas SWCD, "Clackamas Weed List," 2020. [Online]. Available: https://weedwise.conservationdistrict.org/weeds. [Accessed 18 November 2020].

[11] Oregon Dept of Agriculture, "Noxious Weed Policy and Classification System," Oregon Department of Agriculture, Salem, OR, 2019.

[12] F. S. USDA, "Fire Effects Information System (FEIS)," 18 November 2020. [Online]. Available: https://www.feis-crs.org/feis/.

[13] L. P. Poulos and B. A. Roy, "Fire and False Brome: How do prescribed fire and invasive Brachypodium sylvaticum affect each other?," Invasive Plant Science and Management, vol. 8, no. 2, pp. 122-130, 2015.

[14] "4-County CWMA Best Management Practices," 4-County CWMA, Beavercreek, 2020.

[15] "Columbia Gorge CWMA Best Management Practices," Columbia Gorge CWMA, Beavercreek, 2020.

[16] J. M. DiTomaso and G. B. e. a. Kyser, Weed Control in Natural Areas in the Western United States, Weed research and Information Center, UC Davis, 2013.

[17] "Peachey, E., editor. 2020. Pacific Northwest Weed Management Handbook [online]. Corvallis, OR: Oregon State University. http://pnwhandbooks.org/weed.," Oregon State University, Corvallis, 2020.

2. Engineering Report

2.1. Objectives

Field investigations of existing roads within the boundaries of the Riverside Fire located on non-federal forest land occurred from October 30th-November 6th, 2020. These investigations only occurred on non-Forest Service portions of the fire.

The purpose of the engineering investigation was to assess potential negative effects on roads, culverts and other hydraulic structures attributable to the post-fire condition of the watersheds. The investigation also looked at those safety and warning structures required to provide safe passage of motorists accessing the public lands on authorized roads within the burn area. This report will provide a general summary of the values at risk, observations and findings, and recommendations resulting from the investigation.

2.2. Values at Risk

The watersheds burned within the Riverside Fire will experience increased runoff, sediment/ash laden flows, and debris flows. Increased flows may cause the capacity of drainage features to be exceeded and transported sediment and debris may cause culverts and other drainage features to fail. These impacts may cause uncontrolled flow across the road prism causing damage and potential failure. The road prism may become impassible to vehicles and in extreme cases may be completely washed out due to fill slope failure. Road prisms may also be damaged due to falling rock, tree and any other debris making the road impassible. This report identifies roads and structures that will be impacted by post-fire debris flows and flooding, evaluates their current condition and vulnerability, and considers treatments to minimize the risks to safety, infrastructure, and the potential for increased post-fire runoff. The following table describes the threats to various resources and the assigned risk value determined during this assessment.

Table 1. Values at Risk Table

Critical Value	Risk	Value Category	Threat
County road infrastructure	Low	Property	Damage to existing infrastructure from increased runoff, erosion, and debris flows
General Public including residents, recreationists, commercial traffic, and anyone wishing to access private and public land within the fire area.	Low	Human Life & Safety	Falling trees, road damage and loss of egress. Access to upper watersheds could pose a safety issue.

2.3. Observations

The Riverside Fire contains a variety of jurisdictions and private landowners that are responsible for the roads within the fire perimeter. The roads that were observed during this investigation are primarily the responsibility of Clackamas County road department with a minority of other roads under the control or ownership of private forest landowners or residents. These roads are all located on the western edge of the fire and fell within the low burn severity with a sections of moderate burn severity. None of the roads evaluated pose little to no concern for failure due to the lack of high burn severity near them.

2.4. Reconnaissance Methodology and Results

Roads were prioritized based on limited resource time. All roads driven had little investment or infrastructure and minimal drainage control.

A total of approximately 12.25 miles of roads within or adjacent to the fire perimeter were examined in detail by ETART Engineering specialists. The following roads were identified of having a risk to property or human life or safety. Other roads within the fire perimeter that were assessed did not pose any potential risks to property or human lifer and safety.

Road Name or #	Jurisdiction	Total Miles	Mileage within the burn
Fall Creek Road	Clackamas Cnty.	3.79	.42
Hillockburn Road	Clackamas Cnty.	4.3	3.02

The results of the field investigations identified risks to human life and safety due to the hazards associated with the fire adjacent to roads and property due to unmitigated hazard trees falling onto a public road and during heavy rainfall events the potential for culvert and road failures.

2.5. Findings

The roads observed on non-federal lands pose little threat due to their location within the fire and minimal damage observed. These roads will require minimal action to remain open and safe.

ROAD	DESCRIPTION & ISSUES
Fall Creek Road	▪ Paved self-maintaining county road ▪ Provides access to numerous rural residential dwellings and private forestland, small tracts of BLM and USFS land. ▪ Connects to additional county road: Michaels Road ▪ **Needs:** storm monitoring and ditch cleaning of all culverts ▪ Critical values at risk – (property)
Hillockburn Rd.	▪ Paved self-maintaining county road ▪ Provides access to numerous rural residential dwellings and private forestland, large tracts of BLM and USFS land. ▪ Connects to additional county roads: Habelt, Horner, and Pederson Road ▪ **Needs:** replacement of culverts, storm monitoring, and ditch cleaning of all culverts ▪ Critical values at risk – (property)

2.6. Recommendations

2.6.1. EMERGENCY STABILIZATION

Emergency stabilization treatments should be implemented as quickly as possible to protect human life and safety and minimize the negative impacts of other critical values.

2.6.2. STORM PATROLS

The roads at risk that were assessed within the Riverside Fire burned areas that are primarily located within or below areas of Low to Moderate burn severity. There is a future threat to travelers along the roads within the burned area due to the increased potential for culverts plugging with sediment or debris which could washout sections of the roads. With the loss of vegetation, normal storm frequencies and magnitudes can more easily initiate erosion on the slopes, and it is likely that this runoff will cover the roads or cause washouts at drainage facilities (culverts) or stream crossings. These events make for hazardous access to forest roads and put the safety of users at risk.

Recommendation: Monitor road drainage structures and debris flow treatment structures after significant storm events to ensure the maximum drainage capacity until natural re-vegetation of burned area has occurred. Maintain and repair any damage to road surfaces. Remove sediment and debris from drainage/treatment structures and repair any head cutting in streams and drainages to prevent further degradation of channels. Monitor movement of large woody debris and determine whether the material should be removed before it contacts bridge piers, abutments, or culverts.

See Burned Area Emergency Response Treatments Catalog Chapter 4, Storm Inspection and Response pg. 149 -152 and BAER Specification for Storm Patrols for more information.

2.6.3. CULVERT REPLACEMENT

Currently 1 existing culvert crossing is damaged with moderate burn drainages above on Hillockburn Road. This culvert is currently functioning but is partially damaged on the inlet and may not provide full flow potential until repaired or replaced. Other culverts in the burn area should be monitored to ensure full functionally through storm inspection and response.

Hillockburn Road is generally in good condition and is currently open and in use to public and commercial traffic. The damaged culvert is a low risk due to location and proximity to low burn severity, but high rainfall events may pose a risk of damage or closure to the road.

Recommendation (Hillockburn Rd.): Replace culvert within 1 year to ensure there is no risk to road.

Recommendation (Other culverts in burn area): If feasible and cost effective to replace the culverts to handle the post fire flows, proceed with full culvert replacement. If culvert is not replaced, proceed with monitoring and ditch cleaning along the roads identified in the report.

2.7. Management Recommendations

2.7.1. STORM PATROLS

Storm inspection and response is only funded for the initial year of implementation. Coordination should occur with all the agencies with public access roads within the fire perimeter including USFS, Clackamas County, Portland General Electric, and ODOT.

Recommendation: Continue storm inspection and response until vegetation has reestablished in affected watersheds or for at least a total of two years. This should be completed on all road that are open to the public and should be prioritized after high rainfall events.

2.8. References

Burned Area Emergency Response Treatments Catalog December 2006 National Technology & Development Program Watershed, Soil, Air Management 0625 1801-SDTDC

Cost Estimating Guide for Road Construction March 2012 USDA Forest Service Intermountain, Southwestern, Rocky Mountain Regions

3. Heritage and Cultural Resources

Claeyssens, Paul G.
Heritage BAER Assessment Lead, Archaeologist, AD-COIDC (Deschutes & Ochoco National Forests)

ETART (Erosion Threat Assessment and Reduction Team) is a process used by FEMA in partnership with other federal lands management agencies to assist state, local governments and private land owners in preventing post-fire threats to human life and safety as well as protecting critical natural and cultural resources on state and private lands. The Forest Service and the BLM have similar procedures to address post-fire effects for national forest and public lands which are known as BAER (Burned Area Emergency Response) and ES (Emergency Stabilization) respectively. ETART is deployed following devasting wildfires once the Governor has declared a state of emergency and FEMA is deployed to assist by the Department of Homeland Security.

The goal of the ETART process for the four large fires in Oregon during the devasting 2020 wildfire season was to form a team of BAER/ES and other resources specialists who would train and supervise state and local specialists to conduct the critical value analysis. The ETART assessment for cultural resources is a high-level look at the potential for post-fire erosion, debris flows and exposure of critical cultural resources in the non-federal portions of the Riverside fire. It is not meant to be an assessment of each cultural resource site, but an overall look at the vegetation burn severity on or adjacent to cultural resources and sites of tribal significance.

Unfortunately for the Riverside Fire in western Oregon, no state or local cultural resource specialists volunteered or were otherwise made available for this effort. In addition, the acquisition of sensitive cultural resource GIS (feature data classes) from the Oregon SHPO for state and private lands in the fire area was not possible. This was due to the team's inability to secure a data sharing agreement in the timeframe allotted. Thus, a fine-grained analysis of site locations as compared to moderate to high burn severity in the fire area could not be performed.

Given the lack of cultural resource personnel and completion of a critical values analysis, we recommend that FEMA, State and local agencies seek to acquire GIS data on archaeological and historic sites directly with Oregon SHPO and then apply the ETART process to determine the cultural resource critical values, perceived risks and propose treatments where the likelihood of success is greatest. What follows are some general guidelines for addressing values, risks and treatments.

3.1. Setting

The Riverside fire in Clackamas County, Oregon originated on September 8, 2020 and burned approximately 138,182 acres. The soil burn severity on state and private lands was Moderate on 17,713 acres and High On 2,032 acres. This soil burn severity GIS data set will be critical for any future assessment of critical values, risks and determinations for treatments.

Table 1: Soil Burn Severity by Ownership

Soil Burn Severity	NFS	Other Federal (BLM)	State	Private	Total	% within the Fire Perimeter
Unburned	9,361.77	2,848.47	6.98	5,906.75	18,123.97	13.17
Low	26,069.76	4,968.31	122.24	16,248.43	47,408.74	34.46
Moderate	34,013.46	3,390.64	22.79	17,690.66	55,117.55	40.06
High	13,536.98	1,365.09	0.00	2,031.68	16,933.75	12.31
Total	**82,981.97**	**12,572.51**	**152.01**	**41,787.52**	**137,584.01**	**100**

Burn classifications are as follows:

Unburned – Little to no burn expected within these areas. Canopy and ground litter completely intact. Little to no vegetative mortality expected.

Low - The ground surface, including any exposed mineral soil, may appear lightly charred, and the canopy and understory vegetation will likely appear green.

Moderate - Up to 80 percent of the pre-fire ground cover may be consumed but generally not all of it. There may be potential for recruitment of effective ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground. Soil structure is generally unchanged.

High – All or near all pre-fire ground cover and surface organic matter is generally consumed, and charring may be visible on larger roots. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

3.2. Background

Wildfires have the potential to damage or destroy non-renewable cultural resource sites through a variety of processes, including effects from burning and smoke damage, fire suppression actions, soil movement caused by subsequent storm precipitation, such as gullying and rilling, and the implementation of suppression rehabilitation and ETART treatments. Cultural resources with fire sensitive or combustible components are most susceptible to direct fire effects. Additional direct fire effects include suppression activities such as the construction of dozer and hand lines, safety zones, helispots, contingency lines and drop points on or immediately adjacent to surface or subsurface cultural resource deposits. Indirect fire effects have the potential to impact a greater number of cultural resources over a longer period of time. Indirect effects may include erosional threats, visibility and accessibility threats that could invite unauthorized removal (looting), and hazardous fuel loading/fire-killed tree falling threats.

The objectives of the assessment are to: (1) identify critical cultural resource values, and (2) propose treatments and measures to prohibit any predicted immediate post-fire effects from fire-related erosion, debris flows, and rehabilitation treatments. Critical cultural resource values typically include historic properties, archaeological sites and sites or areas of Traditional Cultural Values or Sacred Sites as identified by resident traditional communities or groups, such as Federally recognized and non-recognized Indian Tribes.

Not all cultural resource sites should be considered under the ETART process, rather a triage process is deployed to fine-tune which sites are critical, have risks and warrant treatment. Ideally a small group of specialists, including representatives of interested tribes should prioritize the site inventory to reflect (in order of value) sites listed on the National Register of Historic Places (NHRP), sites determined as eligible to the (NRHP), and sites identified as having traditional cultural or spiritual values to tribes or other ethnic groups. Cultural resource sites that are designated as unevaluated are generally not considered under ETART, unless their value is exceptional and would likely be easily determined eligible or listed on the NRHP. Cultural resource sites are categorized into 4 broad types: precontact ("prehistoric") sites, historic sites, traditional cultural properties and Indian Sacred Sites. These are further distinguished by whether they are "above ground" structures (historic properties) or surface and buried archeological sites. A precontact site is one that was established, used and occupied prior the advent of a continuous written record. A historic site postdates this time.

A traditional cultural property is a defined locality that is associated with the cultural practices or beliefs of a living traditional community, is rooted in that community's history, and is important in maintaining the continuing cultural identity of the community. Indian Sacred Sites represent areas which hold special and sacred attachments by a Native American religion or religious practitioners.

Prehistoric and historic sites and traditional cultural areas that are eligible for listing to the National Register of Historic Places (NRHP) are considered historic properties under the National Historic Preservation Act (NHPA) and are managed and protected under that law. Cultural resource sites for which NRHP eligibility has not yet been determined are managed as historic properties until that determination is completed. The most significant and/or endangered historic properties are identified as priority heritage assets (PHAs) and are proactively monitored and managed.

The goal in performing a post-fire ETART assessment allows for the site-specific identification of threatened critical value cultural resources and provides an opportunity to recommend stabilizing treatments that may mitigate short term post-fire effects to critical value cultural resources. GIS data on soil burn severity, debris flows, other potential hazards are necessary from which to assess risks. Objectives of this assessment are as follows:

1. Identify previously documented cultural resources located on state and private lands within the fire that may be at risk.
2. Determine which cultural resource sites contain critical values that may be subjected to immediate threats from post-fire effects.

3. Assess effects of soil burn severity to critical value cultural resources, as well as the potential for indirect, post-fire effects on cultural resources.
4. Apply the BAER Risk Matrix to Critical Value cultural resources to determine which sites should be considered for treatment options.
5. Propose specific BAER treatments for critical value cultural resource sites in jeopardy, in order to prevent and mitigate future damage to cultural resources determined “eligible” or “potentially eligible” for listing on the National Register of Historic Places (NRHP), per criteria in 36 Code of Federal Regulations (CFR) 60.4.

3.3. Critical Values and Proposed Treatments

The Forest Service lands within the Riverside Fire were also subjected to a post-fire assessment process. The USDA FS BAER team archaeologist identified a total of four cultural resource sites with critical values. They proposed treatments are administrative closure of access roads and mulching to cover exposed deposits to prevent looting and vandalism. They further recommended monitoring of the four remaining sites to track changed condition and potential damage from looting or vandalism.

3.4. Assessment Methodology

It is recommended that the following process be used to identify critical values, assess risks and recommend treatments. Ideally, this effort is performed by a small group of cultural resource specialists and tribal representatives knowledgeable about the fire area. The analysis process should begin with a review of the Oregon State Historic Preservation Office (SHPO) geodatabase of archaeological sites and historic structures (feature data classes). Once the “triage” process as described above for determining which cultural resources should be considered as critical values then the focus can shift to geospatial analysis. Using geo-spatial software (ArcGIS), archaeological and historic sites are overlaid with the fire’s Soil Burn Severity map. Site locations that fall within high and moderate burn severity should be prioritized for field assessment if possible, as well as sites at risk from falling snags, flooding, or other post-fire conditions likely to adversely affect cultural resources. Since field assessments may not be feasible the initial findings of this analysis should be reviewed by a select group of cultural resource and tribal specialists for review. Based on their input a decision can be made to concentrate on sites of greater significance (critical values), such as those listed or eligible for the NRHP, sites with tribal values and those that are likely candidates for future eligibility or listing.

Once a select set of cultural resource sites of critical value are determined then the group shifts their focus to determining the level of risk and the magnitude of consequences using the table below for guidance.

Probability of Damage or Loss	Magnitude of Consequences		
	Major	**Moderate**	**Minor**
Very Likely	Very High Risk	Very High Risk	Low Risk
Likely	Very High Risk	High Risk	Low Risk
Possible	High Risk	Intermediate Risk	Low Risk
Unlikely	Intermediate Risk	Low Risk	Very Low Risk

Figure 6. Risk Matrix

Probability of Damage or Loss: The following descriptions provide a framework to estimate the relative probability that damage or loss would occur within one to three years (depending on the resource):

- Very likely - nearly certain occurrence (>90%)
- Likely - likely occurrence (>50% to < 90%)
- Possible - possible occurrence (>10% to <50%)
- Unlikely - unlikely occurrence (<10%)

Magnitude of Consequences:

- Major - Loss of life or injury to humans; substantial property damage; irreversible damage to critical natural or cultural resources.
- Moderate - Injury or illness to humans; moderate property damage; damage to critical natural or cultural resources resulting in considerable or long-term effects.
- Minor - Property damage is limited in economic value and/or to few investments; damage to natural or cultural resources resulting in minimal, recoverable or localized effects.

In determining the magnitude of consequences, it is important to consult with other natural resource specialists and engineers to help determine if the probability of damage or loss of significant cultural resource properties or their cultural and data/informational values.

Once the magnitude of consequences is determined to fall under the pink shaded cells in the matrix above then treatment options should be considered, developed, costed out in consultation with land managers, engineers and other resource specialists with knowledge and skills in point protection from flooding and debris flows, windfall or exposure. For critical value cultural resource sites newly exposed and vulnerable to unauthorized artifact removal consider temporary access closures, and mulching or slash dispersal to deter theft.

To summarize, the ETART assessment process should:

- Determine if any critical values exist; e.g. Sites listed on the National Register or that have been determined to be eligible for the NRHP, sites important to local Tribes (based on consultation with the Tribes) within the fire perimeter
- Determine if critical value sites are located within areas of high/moderate burn intensity
- Apply the Risk Matrix to determine if any sites area at risk to post-fire effects
- Propose treatments to reduce risks, treatments should have a high likelihood of success
- Monitor the effectiveness of treatment for this and future fires on state or private lands

4. Soil Resources

Megan McGinnis, Bureau of Land Management Siuslaw Field Office
Mary Young, Wallowa Whitman National Forest
Anthony Collora, Natural Resources Conservation Service

4.1. Summary

4.1.1. OBJECTIVES

This soil resource condition assessment has been conducted by an Erosion Threat Assessment Response Team (ETART), in which the primary objective was to create a landscape level post-fire risk assessment for private and state lands within the Riverside Fire. This assessment will support the prioritization of emergency funding for state and locally administered recovery programs and strategize responses. Assessments and modeling efforts have been completed for sub watersheds and drainages in which critical values were identified. Risks were assigned based on potential threats to human life, property, and critical natural and cultural resources.

This assessment is meant to serve as a broad landscape-level evaluation of post fire risk. It is not intended to serve as a site-specific evaluation of post-fire erosion threat, nor is it intended to identify site-specific long-term rehabilitation or restoration treatments. This is due to the scale at which the hazards were assessed and selected subcatchments were modeled. This assessment's target audience is state and private landowners; it is meant to help assess risk to determine the level of threat to any values within or downstream of the fire and make appropriate management decisions at the landscape level.

4.1.2. CRITICAL VALUES

The critical values that have been considered during ETART assessments include human life and safety, property, infrastructure, natural resources, and cultural and heritage resources. Generally, these critical values are located along the main road corridors and along major drainageways. Natural resource values across the entire fire area include habitat for Chinook Salmon, Coho Salmon, Steelhead Salmon, Bull Trout, and Northern Spotted Owl.

The following critical values have been outlined by HUC12 watershed. Critical values will be related to how WEPP modeling was conducted at the subwatershed level.

4.2. Resource Condition and Setting

4.2.1. BACKGROUND

The Riverside Fire occurred in the Clackamas River drainage on the Mt. Hood National Forest approximately one-half mile southeast of Estacada, Oregon. The fire initiated on September 8, 2020 near Ripplebrook, Oregon. A sustained high wind event drove fire growth to over 100,000 acres over the course of a few days and had burned approximately 138,000 acres at the time of assessment. Steep slopes and inherent geomorphic processes are expected to interact with post-fire conditions to strongly impact soil recovery and hydrologic response.

4.2.2. CLIMATE

The climate within the Riverside Fire varies by elevation but is regarded as a Mediterranean climate with warm, dry summers and wet winters and springs, with roughly 80% of the precipitation occurring from November through April, and 45% occurring between November and January. Precipitation comes primarily in the form of light- to moderate-intensity rainfall in and winter snow accumulations, and averages 72 inches annually. Runoff events are predominantly rain-on-snow and occur when soils are fully saturated. While flash flooding and debris flows are rare in this area, there is evidence of previous past debris flows, and these events are more likely due to the post-fire lack of effective ground cover. This may result in hazardous conditions within and downstream of the burned area in the winter and spring months.

4.2.3. GEOLOGY AND SOILS

Soils within this fire commonly have surface textures of silt loam, loam, or clay loam. The upland soils commonly form from glacial deposits, colluvial materials, residuum, and landslides. Soils range in rock fragment content across the region. Typically, the skeletal soils are associated with glacial deposits and colluvial deposits. Rock outcrops and screes occur on steeper areas and mountain slopes. Soils with andic soil properties are common throughout the region. The landscape of this region features active landslides, and soils with the natural tendency to slough material, this is due to the soil textures, steep slopes, geology, and climate. Bedrock geology within the Riverside fire perimeter consists of mostly Late Oligocene and Miocene volcanic and volcanic-sedimentary rocks. Volcanic rock types are resistant to weathering and erosion and contributes to the slope steepness and topography within the fire perimeter. A table of soil characteristics on state and private lands within the Riverside fire perimeter is contained in Appendix C.

4.2.4. SOIL BURN SEVERITY

The distribution of high burn areas, based on the soil burn severity (SBS) map, occurred on higher elevations such as ridgelines and peaks. Lower elevations were commonly unburned or had lower burned severity. Soils within the watersheds and riparian areas had heterogenous vegetation and higher moisture content which contributed to lower burn-related soil impacts in those areas. Moderate and high soil burn severity was consistently observed on south facing slopes. South facing slopes are generally drier and therefore ground fuels were less resistant to fire. The distribution of burn severity on state and private lands, as well as within the whole Riverside fire area are contained in Table 2 in the Assessment Results section.

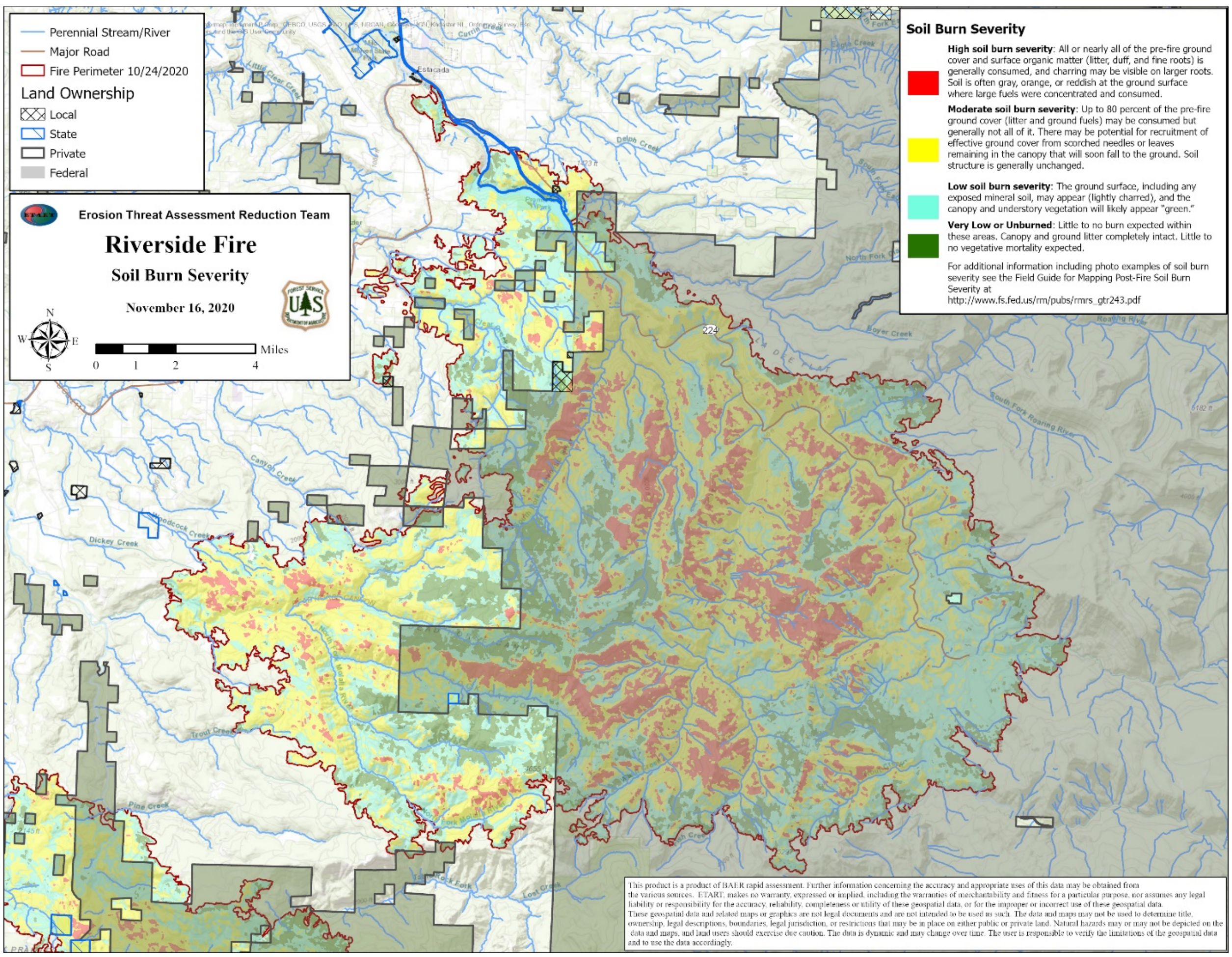


Figure 1. ETART Soil Burn Severity Map – Riverside Fire

4.3. Assessment Methodology

Burned Area Reflectance Classification (BARC) satellite imagery and aerial reconnaissance data, and field soil burn validation surveys were combined by the Forest Service to create a Soil Burn Severity (SBS) map as a part of the federal Burned Area Emergency Response assessment. While the SBS covers all lands within the fire perimeter, previous assessment only validated on-the-ground conditions on federal lands.

ETART Field assessments verified the accuracy of the SBS map on state and private lands and assessed critical values at risk. Field assessments were completed using the criteria outlined in Field Guide of Mapping Post-Fire Soil Burn Severity (RMRS-GTR-243). Partners from the NRCS and FS assessed various soil conditions in the field. Soil site assessments included ground cover amount and condition, ash color and depth, soil structure, soil texture, condition of roots, and soil water repellency. Additional site characteristics were assessed, including surface vegetation conditions, canopy vegetation char, and presence of leaf litter or duff and the degree of char or loss. A summary of soil burn severity indicators used in this assessment can be found in Appendix C. Pre-fire land management conditions and vegetation was an important part of judging the soil burn severity as well as potential risks. Since much of this fire affected private industrial forestry land under clear-felling rotations, erosion potential for selective sub watersheds and drainages were taken into close consideration. In some cases, small acreage private homesites were located downstream and downhill of private industrial forest land.

It is important to note that fire intensity and SBS are often incorrectly interchanged. Fire intensity relates to the above ground fire effects generally identified through visual observations of the over-story vegetation and ground fuels. SBS is the effect of fire at and below the ground surface; specifically, how the fire changes the physical and chemical composition of the soils. While fire intensity can help identify heat concentrations, areas of reduced ground cover, and predict hydrologic response, a high burn intensity may not result in high SBS. Fire severity that detrimentally impacts soil conditions leads to further degradation of soil productivity and soil-hydrologic function. Impacts to the natural erosion processes can lead to increased flooding, sedimentation, and loss of soil productivity – which can cause chronic and perpetual hillslope instability because of decadal or longer time periods needed for soil development and recovery if severely impaired.

With information from the final SBS map and local soil information, the change in erosion potential and sediment yield from pre- to post-fire conditions was estimated using erosion modeling tool WEPP (watershed erosion prediction project), which is hosted by the University of Idaho. WEPPCloud-Disturbed is the specific model that was used to assess erosion risk. It uses Soil Survey Geographic Database (SSURGO) data produced by the NRCS as well as data from National Land Cover Database (NLCD) to parameterize land use for unburned conditions. The Soil Burn Severity map is then fed into the WEPP Disturbed model, resulting in outputs that provide meaningful comparisons between unburned and burned conditions. The two output parameters that were used to judge the erosion potential were: Total Hillslope Soil Loss from Outlet (ton/yr) and Total Hillslope Soil Loss per unit area of watershed (lb/acr/yr). The soil loss results varied greatly depending on the size and characteristics of each modeled subcatchment, and its associated SBS. The ETART soils sub-team determined that the output values of hillslope soil loss per year that WEPP model produced a general magnitude of watershed response under average conditions, rather than an precise reflection of total possible erosion; however the comparison between the pre-fire and post-fire values were determined to be a meaningful and significant judgement of risk based on typical storm event and soil erosion behavior for the area.

4.4. Findings

Most of the Riverside Fire occurred on federal lands, which was evaluated under federal BAER assessments (see Table 1). On state and private lands, high and moderate burn severity was concentrated in upper drainages on private industrial timber lands, where primary values were soil productivity and logging road infrastructure. Private residences, country roads, and a bridge were located downstream and outside of the fire area, downslope of unburned or low severity hillslopes.

Table 1. Summary of soil burn severity acreage by land ownership - Riverside Fire

Severity	Acres on State and Private Lands	Acres across All Land Ownerships	Percent of Total Burned Area
High	2,031	16,933	12%
Moderate	17,713	55,118	40%
Low	16,497	47,535	35%
Unburned	5,982	18,207	13%
Total	**42,223**	**137,793**	

To predict potential impacts to these values, six drainages across three subwatersheds (HUC12) were modeled for hillslope soil loss. These drainages were areas with affected private lands or concentrations of downstream private values. Each drainage was modeled twice, first for unburned conditions, and the second utilizing the Soil Burn Severity map as an input. The magnitude of hillslope soil loss was determined by calculating the difference in hillslope soil loss from the unburned to the burned state. The report generated the soil loss calculated at outlets (tons/yr) as well as soil loss per unit area of watershed (lb/acr/yr). The 'Average Increase in Post-Fire Hillslope Soil Loss' is the average between those two hillslope loss equations (soil loss from outlet and soil loss per unit area of watershed). The 'Average Increase in Post-Fire Hillslope Soil Loss per Subwatershed' is an average of the values calculated at the drainage level; it does not statistically account for the area of each of the drainage, nor any drainages in that subwatershed that were not modeled, it is meant as a quick means of identifying which watersheds are at the highest risk. Modeled drainages and their predicted hillslope soil loss are displayed in Table 2. Hillslope erosion is predicted to range from 1.9 times the unburned soil loss in the North Fork Molalla drainage above Cougar Creek, up to almost six times the unburned amount the Upper Clear Creek tributary drainage. In general, models predicted drainages affected by the burn would produce 2- to 3-times the amount of soil erosion compared to the unburned condition.

Table 2. Summary of Modeled Hillslope Erosion for Target Drainages within Riverside Creek Fire

Drainage Name	Subwatershed	Total Unburned Hillslope Soil Loss from Outlet (ton/yr)	Total Unburned Hillslope Soil Loss per unit area of watershed (lb/acr/yr)	Total Burned Hillslope Soil Loss from Outlet (ton/yr)	Total Burned Hillslope Soil Loss per unit area of Watershed (lb/acr/yr)	Magnitude of Increase
Upper Clear Creek Trib.	Upper Clear Creek	57	28	320	160	5.7
Upper Clear Creek	Upper Clear Creek	220	89	670	270	3.0
Dead Horse Canyon Trib.	Dead Horse Canyon	120	79	500	340	4.2
Dead Horse Canyon Creek	Dead Horse Canyon	860	200	2200	500	2.5
Lukens Creek	Upper North Fork Molalla	700	190	2200	610	3.2
Cougar Creek	Upper North Fork Molalla	260	140	710	370	2.7
NF Molalla above Cougar Creek	Upper North Fork Molalla	1100	410	2200	770	1.9

4.5. Recommendations

The ETART assessment determined risk to critical values located on state and private lands affected by the Riverside fire. The risk assessment was conducted using the same determination framework as used by federal Burned Area Emergency Response (BAER) teams and is outlined in the Risk Matrix on Pg. 13. Values within and adjacent to the Riverside fire are listed along with the determined risk and recommended treatments in Table 3, at the end of this section.

Due to the scope and scale of the ETART fire assessment, all recommended response actions are based on the modeled hillslope soil loss potentials for individual subwatersheds. Recommendations are not meant to serve as site or parcel specific post-fire response plans. For a full list of post-fire treatments refer to USFS Burned Area Emergency Response Treatments Catalog (0625 1801-SDTDC). When selecting the appropriate treatment for individual sites, the following considerations should be taken into effect:

- Nature of downstream values at risk
- Effectiveness of treatment
- Treatment combinations (land, channel, road/trail, protection/safety) to reduce risks
- Timeframe for implementation
- Personnel and resources available for implementation and monitoring
- Hazards associated with treatment implementation
- Ease of treatment implementation
- Cost effectiveness of treatments
- Coordination with other Federal, State, and local agencies

The following response actions adheres to guidance for BAER risk assessments and treatments set forth by the USFS. Treatments are focused primarily on mitigating potential risks to human life and safety, property, infrastructure, and natural or cultural resources. The following treatments are merely recommendations made during a rapid assessment and modeling effort. Damage or loss to critical values can occur regardless of the predicted risk. Assessed values, hazards, and response actions are detailed in Table 3 below.

Table 3. Summary of critical values within the Riverside Fire, along with hazard and treatment recommendations

Value	Probability of Damage or Loss from Hillslope Erosion	Magnitude of Consequence	Hazard to Value	Treatment Recommendation	Treatment Justification
Soil Productivity on Industrial Private Lands	Likely	Minor	Low	Natural Recovery	Hillslope treatments not effective at mitigating erosion on steep slopes common within impacted areas
Road infrastructure on Industrial Private Lands	Likely	Moderate	High	Storm Patrol and Road Maintenance	Mosaic of high and moderate soil burn severity may result in increased sediment and debris
Bridge on S. Dickey Prairie Rd.	Possible	Moderate	Intermediate	Storm Patrol	Structure is well below the burned area; while it may experience increased sediment and flows, it is not at risk of direct hillslope erosion impacts
Private Residences	Possible	Moderate	Intermediate	Inform of Risk	Structures are well below the burned area; while they may experience increased sediment and flows along the floodplain, they are not at risk of direct hillslope erosion impacts

In upper drainages on private industrial lands, moderate and high burn severity interacted with steep slopes and logging practices resulting loss of ground cover, leaving many areas at elevated risk of hillslope erosion. The potential for accelerated soil loss makes it likely that soil productivity will be reduced until vegetative cover is reestablished. Because these areas are likely to be revegetated quickly, these soil productivity impacts are anticipated to be temporary. Mulching treatments to ameliorate soil erosion were considered but have not found to be effective at mitigating erosion on steep slopes, which are the dominant landform in the area. For this reason, natural recovery is the recommended response to address soil loss and reduced productivity.

However, upslope soil erosion may impact industrial logging road infrastructure though increased sediment and rolling debris impacting ditch lines, cross drains, and running surfaces, potentially resulting in moderate damage if sediment damages road drainage. Roads were not directly assessed, but impacts are likely due to modeled erosion and burn severity. Storm patrol and road maintenance are recommended to alleviate potential road impacts from upslope erosion and rolling debris.

Primary values lower in the drainage were private residences and a bridge on the S. Dicky Prairie road, near the North Fork of the Molalla river. Because these values are outside the burn perimeter and not directly below burned hillslopes, there is little risk of direct impact from hillslope erosion. However, there is potential for sediment from upper hillslopes to be conveyed outside of the burned area along the North Fork of the Molalla. This additional sediment may possibly result in bulked flows, debris conveyance, and sediment deposition near the bridge and property boundaries, with the potential to result in low to moderate damage to private property. While sediment barriers may protect private residences, they are not recommended due to the low probability of damaging flow events and distance from the burned area. Therefore, the recommended response is to conduct storm patrol of critical infrastructure and inform landowners of potential for increased sediment in winter and spring rain events.

4.5.1. RECOMMENDED MONITORING

Continued monitoring will be necessary for the roads and highways that access private property. It was determined there is a likely probability of sediment and debris sloughing onto roadways and highways due to the severity of the fire in some areas, as well as the steepness of some slopes along roadways. Soil erosion and debris sloughing will likely occur during and after significant rainfall events. For this reason, storm patrolling may be necessary to ensure public safety.

For the majority of the areas affected by this fire, long term monitoring will not be necessary, especially in areas that have no infrastructure, private residences, nor significant investments. Natural recovery is typically the best course of action in these remote areas because of the limited active treatment options that are both economically viable and effective for slowing erosion and mitigating mass movement.

5. Hydrology Resources

Ryan Andrews, Oregon Water Resources Department
W. Terry Frueh, Oregon Department of Forestry
Spencer Higginson, National Weather Service
Kyle Wright, United States Forest Service

5.1. Objectives

- Assess impacts of watershed changes caused by the fires, on values on non-federal lands, particularly those that pose substantial threats to human life and property, and critical natural and cultural resources. This assessment addresses changes to hydrologic function and watershed response to precipitation events
- Identify hazards due to potential flooding and areas for deposition of debris and sediment.
- Identify potential threats to life, property, and critical natural and cultural resources from flooding and/or deposition of sediment and debris
- Develop treatment recommendations
- Identify the need for future monitoring

5.2. Critical Values

Critical values with elevated risk of damage from post-fire erosion, flooding, and debris flows within and downstream of the Riverside fires exist on private, state and local government, and National Forest Service (NFS) land. We also assessed hazard trees impact to terrestrial recreation sites. The Erosion Threat Assessment/Reduction Team (ETART) program assesses and treats critical values on nonfederal land that has not been captured in other assessments (ex. USFS BAER assessments or BLM ESR). Due to the large geographic extent of these fires, this report will summarize values at risk (VAR) while an extensive list of VARs related to hydrologic response can be found in Appendix G. Note that because of challenges both in obtaining landowner permissions and the logistics of covering such a large area, this effort did not extensively analyze with site visits values on private property that covers much of the non-federal portions of the fire.

5.2.1. WATER QUALITY

Water quality is a major concern post-fire as elevated erosion rates and stream flows can impact drinking water supplies and associated filtration systems. Several cities (e.g., Molalla) get their drinking water supplies from watersheds downstream of burned areas. Continued communication and coordination with partners and downstream users related to water quality is considered essential for relaying the ETART assessment findings, particularly with municipal water supply providers and the Army Corps of Engineers.

The Riverside fire impacted source water drainages for numerous municipal and private domestic drinking water supplies. Downstream municipal users dependent on rivers originating in the fire area include: Molalla and Estacada. City of Molalla water intake is below the burned areas in both

Riverside and Beachie Creek Fires. Other systems are at threat of degraded water quality or at risk of intakes and systems becoming clogged or damaged by high flows. Drinking water supplies are discussed in more depth in other reports.

Landscape scale treatments to reduce erosion, debris hazards, and mitigate post-fire impacts to water quality were considered but not proposed. Areas for potential treatment were assessed by first identifying treatable hillsides based on slopes, narrowing in on contiguous patches of treatable slopes above values at risk, assessing feasibility of implementation, and analyzing potential effectiveness to reduce water quality impacts to values at risk. Areas that were theoretically treatable were found to be not practical to treat due to lack of access for equipment, timing of treatments in relation to upcoming wet season, and location of hillslopes in proximity to access for stockpiles and helicopter turnaround times. It was determined that application of these treatments, where feasible, would not be at a scale large enough in relation to the proportion of untreatable areas to reduce associated water quality risks. Additional information related to landscape scale treatments can be found in the Erosion Threat Assessment/Reduction Team (ETART) Soils Report.

5.2.2. LIFE AND SAFETY CONCERNS FROM FLOODING AND DEBRIS

ETART assessments focus on locations where people may be at risk from more rapid increases in flood flows and debris-laden flood waters on nonfederal lands. On the Riverside Fire this includes recreational use locations in the North Fork Molalla and North Fork Clackamas drainages, and the North Fork Reservoir where boaters could crash into pieces of large wood. Due to likely increased debris transport into North Fork Reservoir, coordination with Portland General electric (PGE) and Oregon State Marine Board is recommended to reduce risk to boater safety and dam operations. Additionally, hazard trees at recreation sites (e.g., parks, campgrounds, boat ramps) threaten lives and safety if not properly mitigated. Permitting and support for an Early Warning System to alert downstream users of potential flooding during large storm events is recommended to mitigate flood risks to private landowners.

5.2.3. PROPERTY RELATED CONCERNS FROM FLOODING AND DEBRIS

The biggest threats to property were due to sediment and debris clogging water intakes. Additional information related to debris and flooding hazards can be found in the ETART Geology and Engineering Reports.

5.3. Resource Condition and Setting

The Riverside Fire encompassed areas on federal, county, and private lands within the Middle Clackamas and Upper Molalla watersheds (HUC10). The Riverside Fire also burned areas within the headwaters of the Molalla River of the Upper Molalla watershed within the Table Rock Wilderness area. The fire area was largely confined to federal lands in the Mt. Hood National Forest; however, impacts from burned areas are likely to elevate risk to critical values downstream on private and county lands.

5.3.1. GEOLOGY

The Middle Clackamas Watershed is located within the Lowlands and Valleys of the Western Cascade Range. The Clackamas River basin consists of volcanic and alluvial deposits, which have been geomorphically modified by glaciation, stream erosion and mass wasting (McBain et al, 2001). The Western Cascade Range consists of a predominantly igneous complex assemblage of andesite and basalts which are less permeable than the Oregon High Cascades (Carpenter et al, 2012). Upstream portions of the Clackamas Basin in the High Cascades are underlain by porous, permeable volcanic layers, as opposed to the lower portion of the watershed within the Western Cascades which consist of impermeable soils and a well-defined drainage network (Graves & Chang, 2007).

Burned areas associated with the Riverside Fire are mostly confined to the North Fork Molalla River drainage downstream to the confluence with the Molalla River. The Molalla River exclusively drains the less permeable igneous complex of the Western Cascade Range. The layered nature of the basalt/andesite and pyroclastic igneous rock parent material can create unstable slope conditions in the Upper Molalla drainage (BLM, 1999).

5.3.2. CLIMATE

Climate in the Clackamas and Molalla River basins is characterized by warm, dry summers, while winters are wet and mild at lower elevations. Most of the precipitation is generated by frontal storms originating over the Pacific Ocean and arrive between October and May. Higher elevation locations in the headwaters of the Clackamas River basin develop snowpack and meltout in spring. Peak flows within the Molalla River basin are largely rainfall dominated, with little storage due to minimal seasonal snowpack or groundwater contributions. Snowfall accumulation begins in higher elevations from mid to late November continuing through April. Rain-on-snow events are common, typically occurring from November through January, and range in their magnitude of hydrologic responses. The basin receives heavy winter rainfall originating from atmospheric moisture in the tropics which can combine with antecedent snowfall to create elevated peak flows (Carpenter et al, 2012).

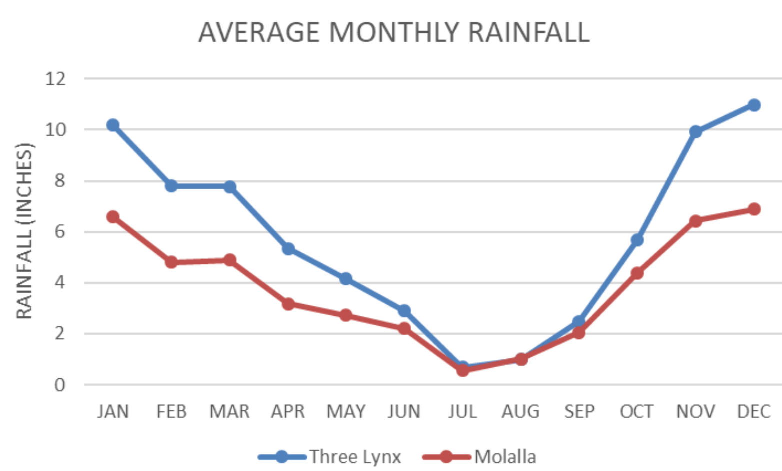


Figure 1: Average monthly rainfall at select locations among burned areas of Riverside Fire (Source: Western Regional Climate Center – www.wrcc.dri.edu)

5.3.3. HYDROLOGY

Peak streamflows are predominately generated by rain-on-snow events in the transient snow zone, which occurs between 1,200 and 4,900 feet elevation (Harr, 1981; Jones and Grant, 1996). Rain-on-snow events are considered the primary effect on peak flows and will vary along elevation bands. The relationship between peak discharge and elevation changes abruptly at around 3,000 feet, due to the fact that snow generally does not accumulate at elevations below 3,000 feet in western Oregon (Cooper, 2005).

Peak discharges on the western slopes of the Cascade Range are typically due to the result of heavy rain from frontal storms falling on snow, frozen ground, or both. Precipitation intensity from frontal storms tends to be low, but storms may last for several days. Where precipitation falls as snow, streamflow is unaffected; however, where precipitation falls as rain, streamflow usually increases rapidly leading to short-duration (i.e. hours) maximum streamflows, then gradually decreasing over several days after the storm front has passed. Generally, maximum streamflows associated with snowmelt runoff are sustained for longer periods of time (i.e. weeks) as weather warms in spring, causing gradual and sustained increases in streamflow due to snowmelt. Furthermore, it is important to note that periods of higher temperatures or rainfall on snow can cause short-duration peaks superimposed over the general trend of long-duration snowmelt peaks. These superimposed peaks will typically lead to the overall peak discharge for the period. Streamflows associated with convective storms rise and decrease rapidly, but maximum flows are not sustained.

There are several periods of elevated flood risk following wildfire, all related to the ability of the soil profile to absorb water. The first high-risk period is the fall immediately post-fire when the lack of vegetation, ground cover, and potentially hydrophobic conditions make the affected area highly susceptible to rapid runoff and erosion from heavy frontal storms.

A second high-risk period occurs in the first spring/summer following the fire when the ground cover and vegetation are just beginning to recover. During this period, soil moisture storage is recharging at a relatively rapid rate since the vegetative water use is significantly reduced, leading to saturated soils. A combination of saturated soils, high rainfall, and rapid snowmelt lead to the floods of December 1964 and February 1996, for example. Finally, the second spring/summer following the wildfire has the potential as a high-risk period for flooding and potential mass erosion. Although the ground and vegetative cover has been re-established, soil moisture storage is at unusually high levels. During periods of reduced soil infiltration capacity of saturated soils in combination with typical weather and climate patterns in these areas, increased surface runoff may lead to elevated peak discharges.

Middle Clackamas Watershed (HUC10: 1709001104)

Dominant peak flow processes within the Clackamas River basin consist of rainfall and rain-on-snow events below and above 2,300 feet elevation, respectively. The Middle Clackamas watershed has a mean elevation of approximately 1,770 feet. The hydrology is driven by the low mountain ridges, underlying andesite and basalts, and medium gradient rivers. The topography consists of forested slopes, some steep and nearly vertical, contributing to a moderate erosion rate in combination with abundant precipitation. The frequency of occasional landslides in steep headwater channels indicates the potential for increased risk due to impacts from burned areas (WPN, 2005).

Upper Molalla Watershed (HUC10: 1709000904)

The headwaters of the Upper Molalla begin in the forested lower west slopes of the Cascade Range at elevations near 4,800 feet. The stream gradient is mild with an average of 1.2 percent in the upper portion of the watershed with a varying width, flowing over boulders in narrow gorges and wider riffles. Geologic hazards associated with slope failures exist in the steep, mountainous terrain of the headwaters and can deliver large quantities of unconsolidated materials to drainage ways, and increase sediment loads and cause higher turbidities (BLM, 1999). The Riverside Fire burned areas of the North Fork Molalla River subwatershed.

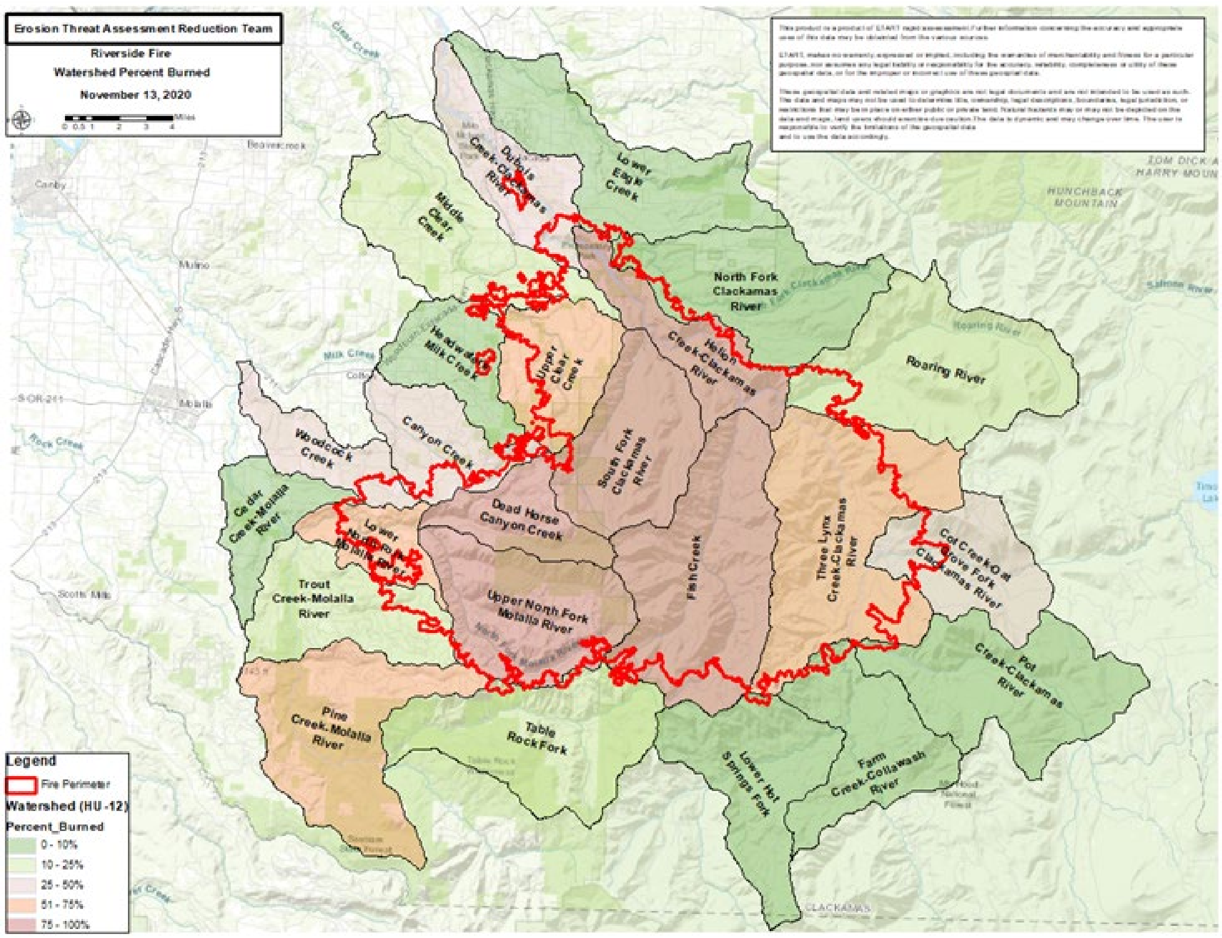


Figure 2: Map of Riverside subwatersheds and percent burned

Table 1: Burn statistics of watersheds (HUC10) – Riverside Fire

Watershed Name	Acres	Acres Burned	% of Watershed Burned
Canyon Creek	10,713	1,710	16.0
Cedar Creek-Molalla River	8,419	58	0.7
Cot Creek-Oat Grove Fork Clackamas River	14,171	2,298	16.2
Dead Horse Canyon Creek	8,987	6,680	74.3
Dubois Creek-Clackamas River	12,636	1,383	10.9
Farm Creek-Collawash River	16,326	329	2.0
Fish Creek	29,807	24,773	83.1
Headwaters Milk Creek	10,244	301	2.9
Helion Creek-Clackamas River	11,719	10,571	90.2
Lower Eagle Creek	22,359	263	1.2
Lower Hot Springs Fork	18,272	119	0.7
Lower North Fork Molalla River	7,116	4,108	57.7
Middle Clear Creek	21,813	1,916	8.8
North Fork Clackamas River	20,638	665	3.2
Pine Creek-Molalla River	23,952	6	0.0
Pot Creek-Clackamas River	22,961	174	0.8
Roaring River	27,309	1,595	5.8
South Fork Clackamas River	17,656	14,595	82.7
Table Rock Fork	23,227	319	1.4
Three Lynx Creek-Clackamas River	31,546	22,075	70.0
Trout Creek-Molalla River	15,678	1,450	9.3
Upper Clear Creek	12,247	7,391	60.3
Upper North Fork Molalla River	19,699	15,876	80.6
Woodcock Creek	8,200	1,029	12.5

5.4. Assessment Methodology and Modeling

Team members drove public roads near rivers and stopped to assess conditions predominantly at publicly-owned facilities, including sites for which we had advance notice to assess risk (e.g., City of Molalla water intake). We used a combination of indicators we could see and best professional judgment to assess these risks. These indicators included:

- Level of moss on rocks and vegetation type and elevation to indicate flood return intervals of e.g., less than 5 years
- Channel form (e.g., incised canyons) to assess potential flood heights
- Portion of upslope area with different percentages of burn severity
- Existence of hazard trees onsite and along upstream channels

Post-fire watershed response for the Riverside Fire was conducted in order to determine the impact of soil burn severity on the response of modeled peak flows in drainages with values identified as at elevated risk. The findings contribute towards understanding post-fire impacts on flooding and subsequent increases in sediment yield and debris flows to evaluate risk to downstream values on state- and county-owned properties and values. Pourpoint watersheds were created to estimate watershed characteristics, analyze drainages, and assess the need for treatment actions.

5.5. Findings

The team found numerous values that had varying degrees and types of threats, which are detailed in the Values at Risk table in Appendix G. There are some imminent threats due to existence of numerous hazard trees and large wood that will be entering stream systems. However, flooding at most of these sites is not too likely since they are mostly situated either well above flood stage or downstream of a flood-regulating dam.

Regional regression equations were used to estimate pre- and post-fire peak flows (see Appendix G for further details). Relative increase in 5-year post-fire peak flows is expected to be largest in the North Fork Molalla River where approximately 43% of the watershed has burned. The North Fork Molalla River above Molalla River has a predicted increase in peak flow from 5,553 cfs to 6,917 cfs at the 5-year recurrence interval, an increase of 1.2 times the pre-fire peak flow magnitude. The slightly elevated peak flow response is due to the large portion burned acreage classified as moderate or high soil burn severity in a relatively smaller watershed. In contrast, the increase in magnitude of post-fire peak flows in the other poursheds is 1.1 times the pre-fire peak flow for the 5-year recurrence interval.

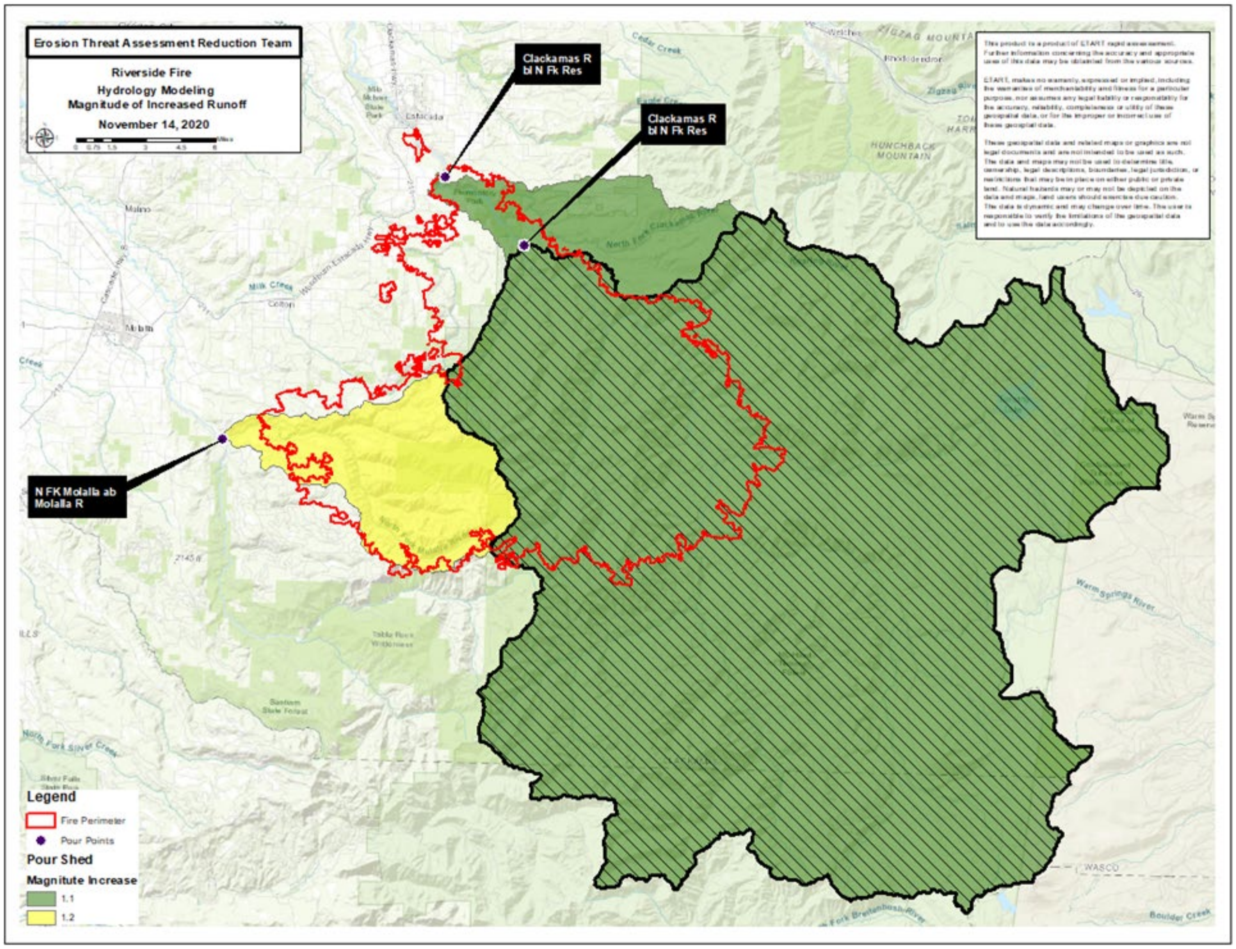


Figure 3: Map of Riverside fire areas and streamflow response for select poursheds for 5-year return interval storms.

Figure 4: Pre- and post-fire peak discharge at select poursheds.

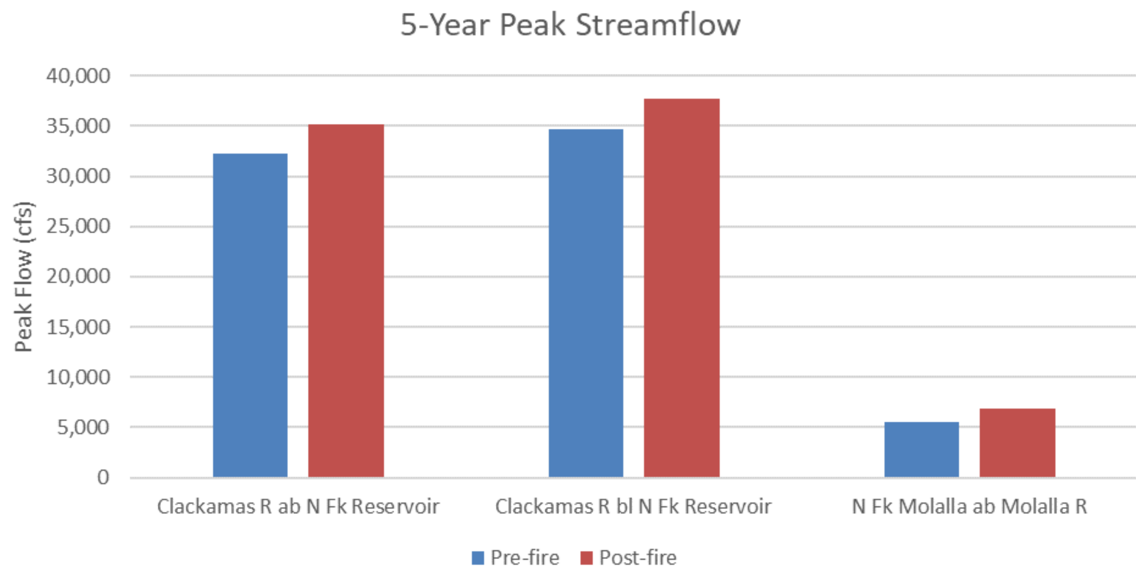


Table 2: Modeling results for post-fire increase in watershed peak flows.

			Peak Streamflows (cfs)					Magnitude Increase	
PourShed	Drainage Area (sq mi)	% Mod + High Burn Severity	Pre-fire 2-year	Pre-fire 5-year	Pre-fire 10-year	Post-fire 2-year	Post-fire 5-year	2-year	5-year
Clackamas R ab N Fk Reservoir	629	12.0	20,900	32,300	40,500	23,699	35,142	1.1	1.1
Clackamas R bl N Fk Reservoir	668	11.7	22,500	34,700	43,600	25,470	37,698	1.1	1.1
N Fk Molalla ab Molalla R	56	43.3	3,964	5,553	6,686	5,434	6,917	1.4	1.2

5.5.1. RISK ASSESSMENT

The predominant high risk at assessed sites (including but not limited to boat launches on North Fork Reservoir, and Silver Fox RV park) were from hazard trees potentially falling, and thereby destroying property, or killing or grotesquely maiming people. Similarly, downed trees pose a significant life to human safety and life when boating, whether in rivers (North Fork Molalla and North Fork Clackamas) or on the North Fork Reservoir. The final major risk is clogging of water intakes from increased loading of sediment and large wood (e.g., for City of Molalla). For more information on these risks, see the Values at Risk table in Appendix G.

5.6. Recommendations

Regarding hazard trees, the main recommendations are to ensure exclusion of the public from these sites until the hazard trees have been removed. Treatment of large wood is somewhat more complex because it is a beneficial, natural feature in streams. Add to this that many river reaches are difficult for heavy equipment (capable of removing the wood) to access. Thus, the treatment for wood in streams is a combination of good signage and education warning boaters of the risks posed by large wood. Large wood in reservoirs can more easily be treated by removing it, but signage is also important to warn boaters of the risks. For protection of water intakes, the primary treatment is to increase frequency of inspection and debris removal, and outreach to the public on water usage should the increased loading of sediment and debris require a temporary shutdown.

5.6.1. RECOMMENDED MONITORING

Modeling suggests that some watersheds affected by the Riverside Fire will experience increased peak flows due to the extent and intensity of the fire. With this in mind, the team recommends installation of one or more near real-time (NRT) precipitation gages in or near the burn area. A NRT precipitation gage provides invaluable information about the localized intensity and amount of precipitation as it happens. Based on these data, the National Weather Service (NWS) can issue alerts to emergency managers, road crews, and other partners to warn of increased potential for flooding and debris flows that could threaten lives or damage homes, roads, and other infrastructure.

In addition to improving emergency response, expansion of the precipitation monitoring network would lead to a better understanding of how the amount and timing of runoff change due to fire in mountainous parts of the Pacific Northwest. At present, little information is available in this regard because large, intense fires have been relatively rare in this region.

Gaging stations are present in watersheds within and adjacent to the burned areas of the Beachie Creek and Riverside Fires with periods of record existing prior to fire outbreak. Such circumstances create opportunities for performing paired-watershed analyses to understand impacts of wildfires on hydrologic response. The paired-watershed method can be used to develop a runoff relationship between an experimental (i.e. burned) and control (i.e. unburned) watershed. Catchments can be instrumented to collect rainfall and runoff data to assess changes in flood flow frequency, magnitude, timing, and hydrograph shape. Further developing these relations can assist with future evaluations of post-fire flood magnitude and hydrologic response in ungaged watersheds (Moody and Martin, 2001).

5.7. References

Bureau of Land Management. 1999. Molalla Watershed Analysis.

Burned Area Emergency Response (BAER) Plan, Beachie Creek and Riverside Fires: Watershed Resources Assessment. October 2020.

Carpenter, K.D., Czuba, C.R., Magirl, C.S., Marineau, M.D., Sobieszcyk, S., Czuba, J.A., and Keith, M.K. 2012. Geomorphic Setting, Aquatic Habitat, and Water-Quality Conditions of the Molalla River, Oregon, 2009-2010. U.S. Geological Survey Scientific Investigations Report 2012-5017, 78 p.

Cooper, R.M. 2005. Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon. U.S. Geological Survey Scientific Investigations Report 2005-5116, 134 p.

Graves, D., and Chang, H. 2007. Hydrologic Impacts of Climate Change in the Upper Clackamas River Basin, Oregon, USA. Climate Research, 33, 143-157.

Harr, R. D. 1981. Some Characteristics and Consequences of Snowmelt During Rainfall in Western Oregon. Journal of Hydrology, 53(3-4), 277-304.

Hydrology Resource Report, Beachie and Lionshead Fire BAER Assessment: Willamette, Mt. Hood, and Deschutes National Forests. October 2020.

Jones, J.A., and Grant, G.E. 1996. Peak Flow Responses to Clear-Cutting and Roads in Small and Large Basins, Western Cascades, Oregon. Water Resources Research, 32(4), 959-974.

McBain, S., Trush, W., Hales, G., Wampler, P., and Grant, G. 2001. Geomorphic Setting Summary Report for the Mainstem Clackamas River and Oak Grove Fork of the Clackamas River. McBain and Trush, 52 p.

Moody, J.A., and Martin, D.A. 2001. Post-Fire, Rainfall Intensity – Peak Discharge Relations for Three Mountainous Watersheds in the Western USA. Hydrological Processes, 15, 2981-2993.

Tague, C., and Grant, G.E. 2004. A Geological Framework for Interpreting the Low-Flow Regimes of Cascade Streams, Willamette River Basin, Oregon. Water Resources Research, 40, W04303.

USDA Forest Service. 2009. USGS Regression methods, https://forest.moscowfsl.wsu.edu/BAERTOOLS/ROADTRT/Peakflow/USGS

Watershed Professionals Network. 2005. Clackamas Basin Summary Watershed Overview. Clackamas River Basin Council, Clackamas, Oregon.

6. Geologic Hazards

Barton Wills – Geologist, U.S. Forest Service
Bill Burns – Engineering Geologist, Oregon Department of Geology and Mineral Industries
Brandon Overstreet – Geomorphologist, U.S. Geological Survey

6.1. Introduction

This report is a rapid post-wildfire geologic hazards assessment of the non-federal land portions of the Riverside Fire area. Hazards assessed include debris flows, rockfall, shallow and deep landslides and related flash flooding/hyper-concentrated flow that may adversely impact public safety and (or) infrastructure.

Wildfire can significantly change the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash flooding and (or) debris flows. Areas downstream of slopes burned by wildfire were assessed for historical evidence of debris flow impacts through limited field reconnaissance and GIS interpretation. This is a qualitative assessment based on our professional judgement and experience and was performed in cooperation with U.S. Forest Service (USFS), U.S. Geological Survey (USGS), and the State of Oregon Department of Geology and Mineral Industries (DOGAMI). Summarized in the report are geologic observations, interpretations, and recommendations.

The Riverside fire was human caused on September 8. Firefighters responded immediately in the early morning hours when the fire was first reported. Driven by high winds, crews reported extreme fire growth including torching, running, and spotting fire behavior as the fire moved 17 miles west along the Clackamas River drainage over the course of the day. High east winds and low humidity continued to drive the fire in the Clackamas River corridor and surrounding private lands. Erratic winds continued to push growth on all sides of the fire with crews reporting the largest growth to the east and southeast causing a 10,000-foot smoke plumes from the Riverside and Beachie Creek Fires to merge. Heavy smoke prevented pilots from conducting air operations for several days until a weather system changed conditions on Sept. 18. At least 57 homes and 186 other structures were lost in the fire. As of Oct. 10, the fire was 60% contained.

The USFS assembled a Burned Area Emergency Response (BAER) team. The BAER team of experts in soils, geology, hydrology, engineering, botany, recreation, archaeology, wildlife, fisheries, and GIS began assessing the post-fire effects to assets/critical values on USFS managed lands. The team developed a Soil Burn Severity (SBS) map to document the degree to which soil properties had changed within the burned area. Fire damaged soils have low strength, high root mortality, and increased rates of water runoff and erosion. Using the SBS map, BAER team members ran models to estimate changes in stream flows (hydrology) and the USGS ran models for debris flow (soils and geology) potential. Even though the reports produced by this team cover the USFS land only, the reports are likely generally applicable for communities just outside the forest boundary and we recommend these reports are acquired and consulted.

On October 26, 2020, the Oregon Erosion Threat Assessment and Reduction Team (ETART) was formed to make assessments of state, county, and private lands and property using information collected by the BAER team. The ETART team of experts from a variety of national, state, and local agencies in soils, geology, hydrology, engineering, botany, recreation, archaeology, wildlife, fisheries, and GIS began assessing the post-fire effects to assets/critical values on non-federal lands managed lands.

6.1.1. RAPID ASSESSMENT OBJECTIVES

When evaluating Geologic Hazards, the objectives of the "Geology" specialty group on an ETART Team are to identify the geologic conditions and geomorphic processes that have helped shape and alter the watersheds and landscapes, and assess the impacts from the fire on those conditions and processes that could affect downstream assets/critical values. The fire removed vegetation which keeps slopes and drainages intact, changed the structure and erosiveness of the soil, and altered the stability of the landscape. Using the understanding of rock types and characteristics, geomorphic processes, and distribution of geologic hazards helps predict how the watersheds will respond to and be affected by upcoming precipitation events. Analysis focused on areas where geologic hazards coincide with assets/critical values. In addition to the immediate threats, considerations also include geologic hazards that are more likely to occur during the coming years and up to 15 years post-fire. The following tasks were performed:

- Review mapping products to generate a risk map within the fire areas.
- Limited on the ground reconnaissance of burned area
- Development of this report that describes the risks of geologic hazards across the fire and identifies assets/critical values at high risk.
- Emergency response recommendations
- Additional analysis and advice, as requested, for the fire assessment teams for specific assets/critical values that are of high concern for post-fire effects.

6.1.2. GEOLOGIC HAZARDS DESCRIBED

The fire is located within the Cascade Mountains geologic province. The Cascade Range is almost entirely comprised of igneous extrusive volcanic rocks and are the magmatic expression of the Cascadia subduction zone where the Juan de Fuca tectonic plate is being subducted beneath the North American plate. The Cascade Range is divided into two physiographic sub provinces: Western Cascades and the High Cascades.

Landslides are one of the most widespread and damaging natural hazards in Oregon. The general term "landslide" refers to a range of mass movements including rockfall, debris flows, and earth slides. Different types of landslides have varying frequencies of movements, triggering conditions, and very diverse resulting hazards. In the Cascades, debris flows and related flash flood/hyper concentrated flow events, rockfall, shallow and deep landslides are the most common types of landslides.

Debris flows are a complicated landslide process. They commonly start or initiate on steep slopes or colluvium-filled hollows or in a drainage in the upper portions of a basin. As the landslide moves down the channel, they commonly grow in volume through erosion of the sediments and debris on the channel bed, erosion of the channel banks, rilling and surface erosion of slopes adjacent to a channel, or by coalescing with adjacent channel debris flows, and the addition of water. As they continue to transport down the channel, depending on volume and channel gradient debris flow can reach speeds of 100 miles per hour. The downslope transport distance can be relatively long depending on the morphology of the channel. For example, some have traveled over a mile down a channel before they stop. When the debris flows reach the canyon mouth, the debris spreads out over the flatter unconfined ground (generally referred to as run out), many times forming a fan shaped deposit frequently made up of many events. Life safety is the biggest concern because debris flows can start a long distance away from final depositional zones and thus residents can be unaware of the pending danger. Vegetation and soil changes after a fire increase the runoff and erosion in a watershed and can significantly increase the likelihood of debris flows and flash flooding. Flash flooding and debris flows can initiate during even moderate rainstorms over burn areas and often occur with very little warning. Post-fire flow can alternate between flood and debris flow depending on the concentration of sediment and debris in transport.

In addition to debris flows, rockfall and post-fire activation/reactivation of shallow and deep landslides can occur. Rockfall is common throughout the Cascades where steep/near vertical cliffs form. Shallow landslides are also very common throughout the Cascades especially on relatively steep soil/colluvium mantled slopes. The influence of root reinforcement on shallow landslides has been widely established. Beginning in less than five years after a fire, when roots of burned trees lose strength, heavy rains could saturate and destabilize steep slopes and cause them to slide.

6.2. Assessment Methodology

Assessment of potential post-fire impacts from geologic hazards at locations intersecting infrastructure and public safety were reliant upon limited observations in the field, LIDAR derived topography (where available), soil burn severity maps (SBS), GIS data with buildings/structures and infrastructure, USGS emergency assessments of post-fire debris-flow hazards, Statewide Landslide Information Database of Oregon (SLIDO), and orthoimagery. A detailed list of assessments is included in the Appendix D of this report.

The USGS emergency assessments of post-fire debris-flow hazards is considered ongoing research and uses geospatial data related to basin morphometry, burn severity, soil properties, and rainfall characteristics to estimate the probability and volume of debris flows that may occur in response to a design storm (Staley, 2013). They recommend using the hazard data with a 15-minute rainfall intensity of 24 millimeters (~1 inch) per hour (mm/h) and is included in the Appendix D – Figure 1 of this report.

The USGS Landslide Hazards Program, in cooperation with DOGAMI and university researchers, are actively conducting research to better calibrate the model to western Oregon. At this time the model may overestimate or underestimate the risk in some areas. Model thresholds can provide approximate information for warning systems but should be considered alongside hydrologic modeling and local knowledge.

SLIDO is a compilation of existing landslide deposits and landslides susceptibility in Oregon that have been compiled from published maps. Many landslides have not yet been located or are not on these maps and therefore are not in this database. The original studies vary widely in scale, scope, and focus, which is reflected in a wide range in the accuracy, detail, and completeness with which the landslides are mapped.

In addition to the immediate threats, considerations also include shallow-landslide-initiated debris flows that are more likely to occur roughly 3-15 years post-fire and are unlikely to be an immediate post-fire concern.

Reconnaissance of the burn area was a rapid assessment at high level. The assessment concentrated on local communities at risk, state and county property, transmission lines, dams and reservoirs, schools, non-profit education and sport camps, and fish hatcheries.

6.3. Findings

The following is a summary of the observations and interpretations. A detailed list is included Appendix D to this report. Below is a short list of the primary high-risk assets/critical values:

North Fork Dam – The North Fork Dam and facilities are located below channels identified by the USGS as low and moderate potential for debris flows. The southern side of the dam abuts up to a large deep landslide complex. Some of these existing landslides are marginally stable and therefore maybe reactivated by post-fire landscape contribution (Appendix D).

Promontory Park and Silver Fox RV Park – Both of these parks are located on a large deep landslide. Some of these existing landslides are marginally stable and therefore maybe reactivated by post-fire landscape contribution (Appendix D).

Oregon State Route 224 – The state highway was not specifically analyzed by this report. Dependent on the specific location along the highway, a variety of post-fire geologic hazards are likely including, flooding, erosion, sluffing, dry ravel, rockfall and debris flows. Communications with ODOT geologist and geotechnical engineers indicate that they are currently planning and addressing rockfall and potential debris flow hazards on the highway corridor.

During the ground survey, evidence of widespread mass wasting, rockfall, landslides, and debris flow deposits were observed throughout the burned area. People living, working, traveling or recreating through and below burned areas could be subject to loss of life or injury as a result of debris flows, rockfall, or flash flooding in and downstream of the burn area. For further site-specific areas such as State and county roads, private access roads, and water systems refer to the ETART hydrologic and engineering reports for recommendations of operation and maintenance of those facilities. For critical infrastructure, such as transmission lines and pipelines, examine the provided maps, data, and models to determine if further site-specific evaluation is needed.

Depending on the specific location of these assets/critical values, some of these might be impacted by various types of slope failures such as landslides and/or rockfall, while others might be impacted by hyper-concentrated flows and/or debris flows. In addition to the immediate threats, longer term landslide hazards are more likely to occur during the next several years to 15 years.

Based on this rapid assessment, we find there is a range of landslide risk highly dependent on location from very low to high within the fire affect area. Therefore, we make the following recommendations to reduce landslide risk. These recommendations are focused on life safety.

6.4. Recommendations

This rapid assessment was performed to alert communities in portions of Riverside Fire of the need to be prepared for post-fire landslides. We note that the portion of Oregon included in this assessment has high average annual precipitation as well as potentially high 24-hour-duration precipitation related to storm events. Both factors are extremely important in triggering landslides, especially when combined with the local geology and geomorphology. Human activities may also contribute and/or trigger landslides.

The results of this rapid assessment indicate that some assets/critical values in the Riverside Fire area are at high risk from post-fire landslide hazards. Post-fire debris flows are generally the primary concern because of their speed, debris flows threaten both lives and property. Rockfall is also a primary concern. Shallow and deep landslides cover a much broader area and can threaten property and possibly lives in the long term.

We provide the following recommendations to communities in the fire area for continued work on landslide risk reduction. These recommendations are not comprehensive, but they should provide an adequate foundation. The primary actions are awareness, warnings, and emergency mitigation/further evaluation. Additional details are provided below.

6.4.1. AWARENESS

Awareness of local hazards is crucial to understanding associated dangers and how to prepare for them. One of the main purposes of this assessment and data compilation is to help residents and landowners in the fire area become aware of the risk reduction actions they can take for preparation for hazardous events.

At many sites, we recommend signs are placed in locations to help awareness and remind everyone of the potential risk. These signs should include a clear message and a link to additional information (Appendix D).

To increase awareness, the following flyers and fact sheets can be linked and and/or distributed to help educate landowners of activities that individuals can take in order to reduce landslide risk.

Educational Flyers

Homeowners Guide to Landslides

- https://www.oregongeology.org/Landslide/ger_homeowners_guide_landslides.pdf

Landslide Hazards in Oregon

- https://www.oregongeology.org/pubs/fs/landslide-factsheet.pdf

Debris flow hazards. Includes recommendations for before and during events

- https://pubs.usgs.gov/fs/fs-176-97/fs-176-97.pdf

Post Wildfire Flash Flood and Debris Flow Guide

- https://www.wrh.noaa.gov/lox/hydrology/files/DebrisFlowSurvivalGuide.pdf

General landslide preparedness

- https://www.usgs.gov/natural-hazards/landslide-hazards/science/landslide-preparedness?qt-science_center_objects=0#qt-science_center_objects

State, city, county, and other local community leaders can implement awareness campaigns to educate neighborhoods, businesses, and individual homeowners about the locations of local hazards and how to reduce risk. For example, just knowing if one lives in a debris flow susceptible area can provide the impetus to switch to actively reducing risk through monitoring and preparing for evacuation if necessary.

6.4.2. LANDSLIDE WARNINGS

Preparing for emergency situations such as storm events can be done in several ways. Oregon has a statewide landslide alert system triggered by the National Weather Service (NWS). When the NWS issues a flood watch or flash flood watch, they include language about the potential for landslides and debris flows. Several Oregon state agencies (Oregon Emergency Management [OEM], Oregon Department of Transportation [ODOT], and DOGAMI) then disseminate the alert. The current alert system could be used by the communities in the fire area. In addition, the USGS Landslide Program has conducted emergency assessments of post-fire debris-flow hazards in the fires that occurred in Oregon during the 2020 season (https://landslides.usgs.gov/hazards/postfire_debrisflow/). The following are the 15, 30, and 60-minute rainfall amounts for post-fire debris flow potential for the five largest fires in the Cascades.

- Archie Creek
  - 15-minute: 19 mm/h, or 0.2 inches in 15 minutes
  - 30-minute: 15 mm/h, or 0.3 inches in 30 minutes
  - 60-minute: 13 mm/h, or 0.5 inches in 60 minutes
- Beachie Creek

  - 15-minute: 24 mm/h, or 0.25 inches in 15 minutes
  - 30-minute: 19 mm/h, or 0.4 inches in 30 minutes
  - 60-minute: 17 mm/h, or 0.65 inches in 60 minutes
- Holiday Farm
  - 15-minute: 22 mm/h, or 0.2 inches in 15 minutes
  - 30-minute: 17 mm/h, or 0.3 inches in 30 minutes
  - 60-minute: 15 mm/h, or 0.6 inches in 60 minutes
- Lionshead
  - 15-minute: 36 mm/h, or 0.35 inches in 15 minutes
  - 30-minute: 28 mm/h, or 0.55 inches in 30 minutes
  - 60-minute: 26 mm/h, or 1.0 inches in 60 minutes
- Riverside
  - 15-minute: 28 mm/h, or 0.3 inches in 15 minutes
  - 30-minute: 22 mm/h, or 0.45 inches in 30 minutes
  - 60-minute: 20 mm/h, or 0.8 inches in 60 minutes

Additionally, after the 1996-97 landslide events, DOGAMI created a map of 24-hour rainfall intensity that is likely to trigger debris flows for western Oregon. Although post-fire affects are not included in the DOGAMI thresholds, it is another resource that should be reviewed before future storms. Below are the lowest rainfall intensities for each fire.

- Archie Creek - 3-4 inches in 24 hours
- Beachie Creek - 4-5 inches in 24 hours
- Holiday Farm - 3-4 inches in 24 hours
- Lionshead - 2-3 inches in 24 hours
- Riverside - 3-4 inches in 24 hours

Knowing when there will be periods of increased landslide potential will help communities prepare and respond should landslides occur. Evacuation should be considered, recommended, or required under certain conditions in high risk areas.

A life-safety action plan also can be enacted. When the NWS issues a flood watch or flash flood watch with landslide and debris flow language, local emergency managers can relay that information to residents located in high debris flow hazard areas. This could entail a local emergency notification system directed by the county or city or a reverse 911 call being put out to residents when a debris flow warning is issued, alerting them to the potential danger.

6.5. Mitigation and Further Evaluation

This is a high-level report, done through a rapid assessment of areas prone to geologic hazards. Most properties identified in this report were not fully assessed. A more complete assessment requires examining the on the ground characteristics of each property at risk. Therefore, we recommend additional site-specific evaluation. The results of a site-specific evaluation should include recommendations for site-specific mitigation. Protecting homes from the impacts of large debris flows should be explored but may need additional design resources and consultation with engineers that is outside the scope of this evaluation. In some cases, from this review, the report points to high hazard areas that would need “further evaluation.” Further evaluation could lead to constructing mitigative control structures. Engineered debris flow diverting structures were not evaluated by this report. These structures need to be surveyed and designed for specific areas they would be needed. Examples of debris flow and rockfall structures may include:

Debris flow

- Debris basin
- Deflection wall or berm
- Terminal wall or berm
- Small log crib check dams located near distal end of fan
- Debris racks (straining structure)
- Debris check dams

Rockfall

- Hand/mechanical scaling
- Trim blasting
- Rock bolts
- Anchored wire mesh/draped mesh
- Shotcrete
- Barrier and fences

Other forms of mitigation to consider should include emergency management buyouts of property with very high risk. Consulting an expert to conduct a site-specific evaluation if considering reconstruction or new construction in these high-risk areas. Residents on the fans should consider flood insurance coverage if possible, consult the Post Wildfire Flash Flood and Debris Flow guide https://www.wrh.noaa.gov/lox/hydrology/files/DebrisFlowSurvivalGuide.pdf.

6.6. References

Burns, W.J., Mickelson, K.A., and Madin, I.P., 2016, Landslide Susceptibly Overview Map of Oregon, Oregon Department of Geology and Mineral Industries, Open File Report O-16-02

Cannon, S.H. and DeGraff, J (2009) The Increasing Wildfire and Post-Fire Debris-Flow Threat in Western USA, and Implications for Consequences of Climate Change: Landslides – Disaster Risk Reduction.

De Graff, J. V. and Gallegos, A. J. (2012) The Challenge of Improving Identification of Rockfall Hazard after Wildfires: Environmental and Engineering Geoscience 18(4): 389-397.

DeGraff J.V., Shelmerdine B., Gallegos, A., and Annis D. (2015) Uncertainty Associated with Evaluating Rockfall Hazard to Roads in Burned Areas. Environmental & Engineering Geoscience, Vol. XXI, No. 1: 21-33

DOGAMI, 2020, Statewide Landslide Information Database for Oregon (SLIDO), Oregon Department of Geology and Mineral Industries, updated October 2020, https://www.oregongeology.org/slido/index.htm

DeRoo, T.G., Anderson, D.A., and Smith, D.A., 1996, An assessment of landslide frequency in the Fish Creek and Roaring River watersheds, Clackamas River Subbasin: A validation of watershed analysis?, Mt. Hood National Forest.

Highland, L.M., and Bobrowsky, Peter, 2008, The landslide handbook—A guide to understanding landslides: Reston, Virginia, U.S. Geological Survey Circular 1325: 129

Kean, J.W., McCoy, S.W., Tucker, G.E., Staley, D.M., Coe, J.A., 2013, Runoff-generated debris flows: Observations and modeling of surge initiation, magnitude, and frequency, Journal of Geophysical Research Earth Surface, 118(4), p. 2190-2207

Oregon Department of Transportation (2014) Hydraulics Design Manual – Rainfall Intensity-Duration-Recurrence Interval Curves, Chapter 7, Appendix A.

Peck, D.L., Griggs, A.B., Schlicker, H.G., Wells, F.G., and Dole, H.M, 1964, Geology of the central and northern parts of the western Cascade Range in Oregon: U.S. Geological Survey PP-449, scale 1:250,000.

Roering, JJ, et al, 2003, Shallow landsliding, root reinforcement, and the special distribution of trees in the Oregon Coast Range, Canadian Geotechnical Journal

Sherrod, D.R., and Scott, W.E., 1995, Preliminary geologic map of the Mount Hood 30- by 60-minute quadrangle, northern Cascade Range, Oregon: U.S. Geological Survey, Open-File Report OF-95-219, scale 1:100,000.

Smith, D.A., 1994, Soil Properties and Behavior of Earthflows in the Mt. Hood National Forest, Oregon. Portland State University: Dissertations and Theses. Paper 4779.

Smith, R.L., and Roe, W.P., 2015, Oregon Geologic Data Compilation, release 6: Oregon Department of Geology and Mineral Industries, various scales.

Staley, D.M, and Kean, J.W., 2020, Emergency assessment of post fire debris flow hazards, Riverside an White River Fires (Mt. Hood National Forest): U.S. Geological Survey https://landslides.usgs.gov/hazards/postfire_debrisflow/.

Staley DM, Kean JW, Cannon SH, Schmidt KM, Laber JL, 2013, Objective definition of Rain-fall intensity–duration thresholds for the initiation of post-fire debris flows in Southern California. Landslides 10:547–562

Staley, D.M., Negri, J.A., Kean, J.W., Tillery, A.C., Youberg, A.M., 2016, Updated logistic regression equations for the calculation of post-fire debris-flow likelihood in the western

Staley, D.M., Negri, J.A., Kean, J.W., Tillery, A.C., Youberg, A.M., 2016, Updated logistic regression equations for the calculation of post-fire debris-flow likelihood in the western United States: U.S. Geological Survey Open-File Report 2016-1106, 20 p., available at https://pubs.er.usgs.gov/publication/ofr20161106

Staley, D.M., Negri, J.A., Kean, J.W., Tillery, A.C., Youberg, A.M., 2016, Updated logistic regression equations for the calculation of post-fire debris-flow likelihood in the western United States: U.S. Geological Survey Open-File Report 2016-XXXX, 20 p., available at http:// pubs.usgs.gov/of/2016/XXXX/

Staley DM, Negri JA, Kean JW, Laber JL, Tillery AC, Youberg AM (2017) Prediction of spatially explicit rainfall intensity–duration thresholds for post-fire debris-flow generation in the Western United States. Geomorphology 278:149–162

Wiley, T.J., 2000, Relationship between rainfall and debris flows in western Oregon, Oregon Geology, Volume 62, Number 20, Department of Geology and Mineral Industries

7. Hazard Trees

I. Blakey Lockman- Regional Pathologist, USDA Forest Service, PNW Region, State and Private Forestry

This report is a rapid post-wildfire danger/hazard tree assessment of the non-federal land portions of the Riverside Fire.

7.1. Objectives

This assessment provides a high-level look at the potential for danger/hazard trees along roads and around structures in the non-federal portions of the Riverside Fire. It is not meant to be an assessment of each mile of road, nor of each structure, but an overall look at the vegetation burn severity along the roads and around structures that lead to a risk of danger trees. Overall objectives of this assessment are:

- Assess the miles of roads traveling across non-federal lands that are most likely to have danger trees
- Assess the number of structures, and the acres surrounding these structures, that will need detail assessments for danger/hazard trees
- Provide general details on criteria used to assess danger/hazard trees
- Provide information on training available for assessing danger/hazard trees

7.2. Danger/Hazard Trees Described

A danger/hazard tree is defined as a tree that is located near a structure, roadway, or infrastructure that has an imminent or immediate risk of failing. Danger/hazard trees pose safety hazards to the public and must be identified for prompt mitigation of the risk.

Trees along open roads and surrounding structures in areas of low to high vegetation burn severity are susceptible to falling and pose an imminent hazard to people and property within striking distance if they fall. Trees that are determined to be a danger and could cause damage to life and property along roads and around private structures should be mitigated by closing roads, preventing access to structures, or felling the trees.

For the purpose of this document the terms danger and hazard trees are synonymous. The USDA-FS PNW region has guiding documents that reference both danger and hazard trees. The Field Guide for Danger Tree Identification and Response along forest Roads and Work Sites in Oregon and Washington (Filip et al. 2016) uses the term danger trees for identifying trees surrounding roads or work sites. The Field Guide for Hazard Tree Identification and Mitigation on Developed Sites in Oregon and Washington Forests (Filip et al. 2014) is a similar guide for developed recreation sites and uses the term hazard trees for identifying trees surrounding sites with permanent infrastructure.

7.2.1. ROADS ANALYSIS

- Roads within the Riverside Fire were stratified by underlying ownership and percent basal area mortality. Miles per basal area burn severity class were then calculated (Table 1).
- Roads within the fire perimeter were then symbolized by basal area burn severity class and mapped on top of the soil burn severity layer (Figure 1).

Table 1. Miles of road by basal area mortality on Riverside Fire. This provides a coarse estimate of miles of roads where roadside danger tree treatments will be needed. Underlying land ownership is the land under and around the road. Orange shading indicates state, county and non-industrial private land ownership, including unspecified private lands.

Miles of Road by basal area mortality (BA Mort)							
Fire Name	Underlying Land Ownership	0.0	Low BA Mort (1-50%)	Mod BA Mort (51-75%)	High BA Mort (>75%)	Total Miles	Total BA Mort Miles
Riverside	BLM	25	13	5	8	52	27
	County	2	2	1	0.9	6	4
	Local Government	0.8	0.3	0.2	0.1	1	0.6
	ODF	0.0	0.1	0.0	0.0	0.1	0.1
	Other	2	1	0.2	0.0	3	2
	Port Blakely	19	14	10	16	59	40
	Private (Unspecified)	0.3	1	0.4	0.1	2	2
	Private Industrial	4	4	5	7	20	15
	Private Non-industrial	3	5	3	3	14	11
	State	0.3	1	0.3	0.1	2	2
	USFS	7	1	0.8	3	12	5
	Weyco	88	52	47	119	306	218
Riverside Total		**151**	**95**	**73**	**158**	**476**	**326**

There are nearly 48 miles of roads with moderate to high levels of basal area mortality on state and private land (including unspecified private), with another 24 miles with low basal area mortality (less than 50%; Fig. 1). Cost to mitigate danger trees along these roads will vary with the mortality that occurred due to fire, post-fire mortality that will occur within the next 3 to 5 years, as well as the size of the trees which determines the failure zone. Additional details on determining if a tree is a danger or will become a danger are discussed below in "Damage indicators likely to contribute to failure of fire-injured trees".

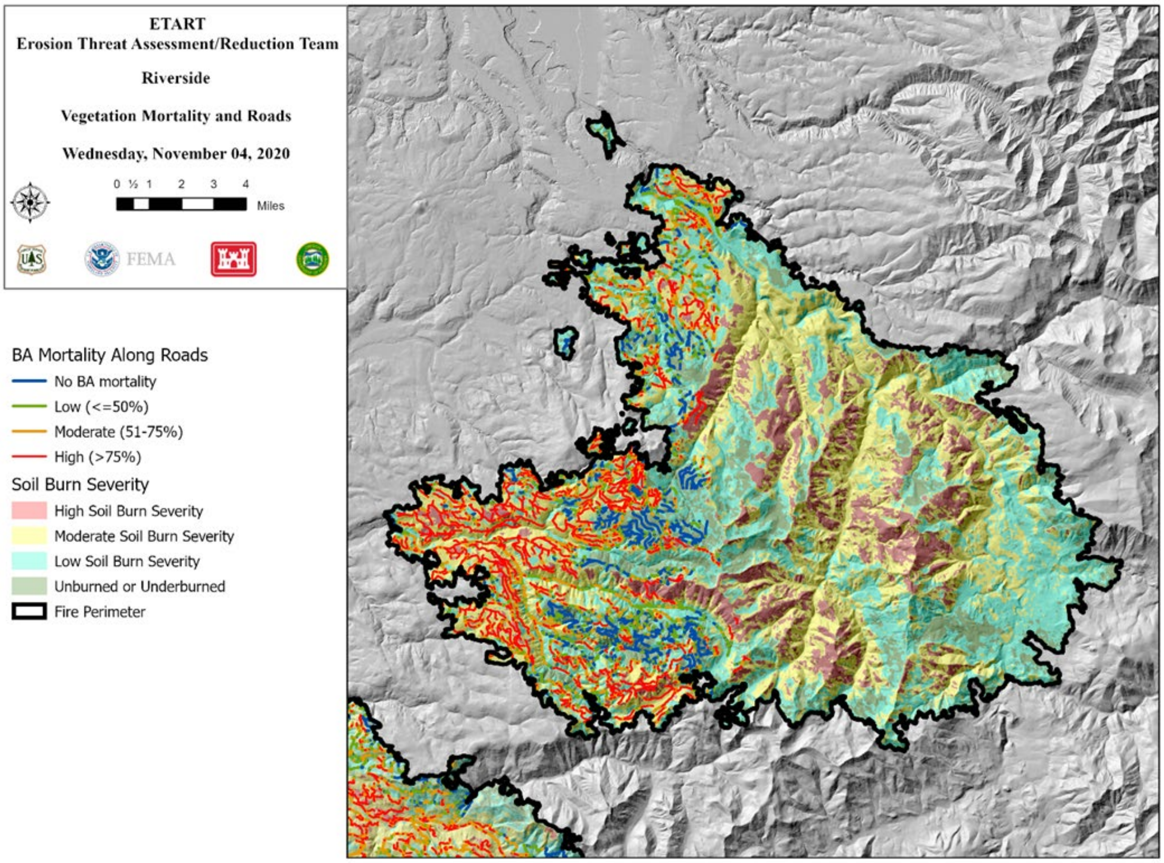


Figure 1. Roads mapped by percent basal area mortality within the Riverside Fire perimeter.

7.2.2. STRUCTURES ANALYSIS

- Acres within a 100' buffer surrounding all structures within the Riverside Fire perimeter were calculated and then stratified by percent basal area mortality class (none, low (1-50%), moderate (51-75%), high (>75%)). One hundred feet was used as a surrogate for the average height of trees assessed for hazard and within striking distance of structures. The numbers of structures were also counted by percent basal area mortality class (Table 2).
- Structures were then symbolized and mapped on top of the basal area burn severity map to provide a visual and to assist with general location of structures (Figure 2).

Table 2. Numbers of structures and acres by percent basal area mortality within 100-foot buffer surrounding structures in fire perimeter.

	None (No BA Mortality)		Low BA Mort (1-50% BA Mortality)		Mod BA Mort (51-75% BA Mortality)		High BA Mort (>75% BA mortality)		Total BA Mort (>1% BA Mortality)	
Fire Name	Acres within 100' foot buffer	Number of structures	Acres within 100' foot buffer	Number of structures	Acres within 100' foot buffer	Number of structures	Acres within 100' foot buffer	Number of structures	Acres within 100' foot buffer	Number of structures
Riverside Creek	113	134	13	170	85	89	41	44	263	303

There are 133 structures located in areas that suffered 50% or greater basal area mortality (Fig. 2). Another 170 structures are located in areas that suffered less than 50% basal area mortality. A 100-foot buffer was drawn around these structures and the acres calculated by basal area burn severity class to provide some guidance on the level of hazard trees that need to be mitigated. There are nearly 265 acres of hazard trees within the 100' buffer surrounding all structures. The radius of 100 feet was used as a surrogate for tree height, which determines the failure zone. The actual failure zone around structures may be less with shorter trees and greater with taller trees. Additional details on determining if a tree is a hazard or will become a hazard are discussed below in "Damage indicators likely to contribute to failure of fire-injured trees".

Work sites around recovery efforts

Many activities involving people and machinery will occur within the fire perimeter during the recovery efforts. Danger trees should be evaluated around these work sites for their likelihood of failure.

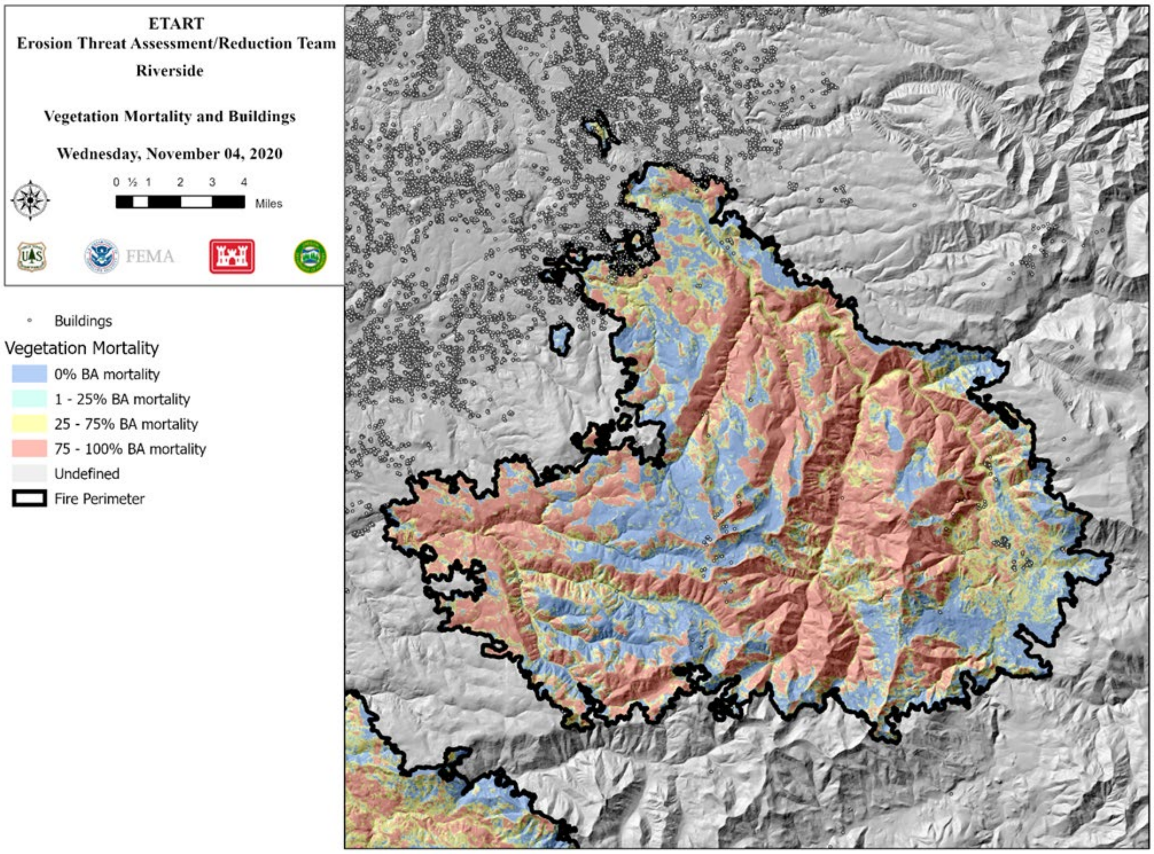


Figure 2. Location of structures within the Riverside Fire perimeter and their locations relative to vegetation mortality.

7.3. Recommendations

- Fell all trees assessed to be a danger and within the potential failure zone of road systems, work sites, and around structures.
- If resources are limited for accomplishing the felling of all danger trees, then:
  - Roads and structures should be prioritized for evaluation and treatment;
  - Close roads until danger trees can be assessed and felled;
  - Prevent access to structures until danger trees can be assessed and felled.

Recommendation is to use the USFS publication, Field Guide for Danger Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington (Filip et al. 2016) along with Post-fire Assessment of Tree Status and Marking Guidelines for Conifers in Oregon and Washington (Hood et al. 2020) to assess and mark danger trees for removal.

7.3.1. MONITORING

It would be prudent to monitor roads and areas surrounding structures for continued mortality and failure for 3-5 years after initial mitigation. Although the provided guidelines and criteria are meant to identify danger/hazard trees, not all trees will be accurately assessed, and further mortality or degradation may occur after initial assessment and mitigation.

Resources available for assessing danger/hazard trees on the ground

- OSU Fire Extension has recorded a number of post-fire webinars. Links to these webinars, as well as an extensive summary of resources available, can be found by following this link: https://extension.oregonstate.edu/fire-program.
- ODF post-fire resources, including information on locating stewardship foresters, can be found here: (https://www.oregon.gov/odf/fire/Pages/afterafire.aspx)
- *Field Guide for Danger Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington.* Link in references and here: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd512960.pdf
- Post-fire tree mortality assessment and marking guidelines. Link in references and here: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd814664.pdf
- If on the ground training is needed, this can be arranged by contacting ODF and/or OSU Extension. USFS State and Private Forestry also has experts on staff to help with trainings for assessing trees post-fire at the request of ODF.

7.3.2. FURTHER EVALUATION OF DANGER/HAZARD TREES

Authors: I. Blakey Lockman- Regional Forest Pathologist, USDA Forest Service, PNW Region, State and Private Forestry; Kristen Chadwick- Forest Pathologist, USDA Forest Service, PNW Region, State and Private Forestry; Sharon Hood- Research Ecologist, USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Lab; and Iral Ragenovich- Regional Entomologist, USDA Forest Service, PNW Region, State and Private Forestry.

Damage indicators likely to contribute to failure of fire-injured trees

The following are damage indicators from the USDA-FS Danger Tree criteria (Filip et al. 2016) that should be considered in the post-fire period. Damage thresholds for determining structural stability of a tree are outlined later in this document.

- Trees with **bole cross-section partially consumed**, may be at base or higher on the bole (Filip et al. 2016). This is one of the most common causes of failure post fire.
- Trees with **undermined or severed roots, or roots consumed** by fire (Filip et al. 2016)
- Trees with **cracks or splits** (due to fire and wind) (Filip et al. (2016) refers to this as a bole crack)
- **Detached or broken tops, branches, or bark** (Filip et al. 2016)
- **Recent leaning and/or root sprung trees.** Filip et al. (2016) uses degree of lean greater than 15 degrees.

- Trees with **multiple indicators that are synergistic** where one condition worsens the other. This is very common post-fire where pre-existing conditions are often exacerbated by fire, leading to a tree being a danger. Examples of multiple indicators include: a bole wound with a crack; trees with undermined or severed roots and a lean; stem decay and cracks.
- Additional criteria for determining likelihood of post-fire tree mortality are below.

Additional Criteria for Determining Danger / Hazard Trees After Wildfire

The determination of danger trees after wildfire is based on two documents:

1. Danger Tree Guidelines document: Field Guide for Danger Tree Identification and Response along forest Roads and Work Sites in Oregon and Washington (Filip et. al. 2016)
2. Post-fire Tree Mortality Guidelines document: Post-fire Assessment of Tree Status and Marking Guidelines for Conifers in Oregon and Washington (Hood et al. 2020)

The two documents work together, as shown in Figure 3, to determine if a tree qualifies as a danger tree. First, dead trees are evaluated for their failure potential using Filip et al. (2016). If the tree is damaged, but alive, then it should be evaluated for structural damage using Filip et al. (2016), and subsequently evaluated using Hood et al. (2020) to determine if the tree will likely die within five years of the wildfire. If the tree is likely to die from the fire, then the Danger Tree Guidelines document (Filip et al. 2016) for recently dead trees is used (even if the tree still has green foliage) to determine if the tree is likely to fail within 5 years.

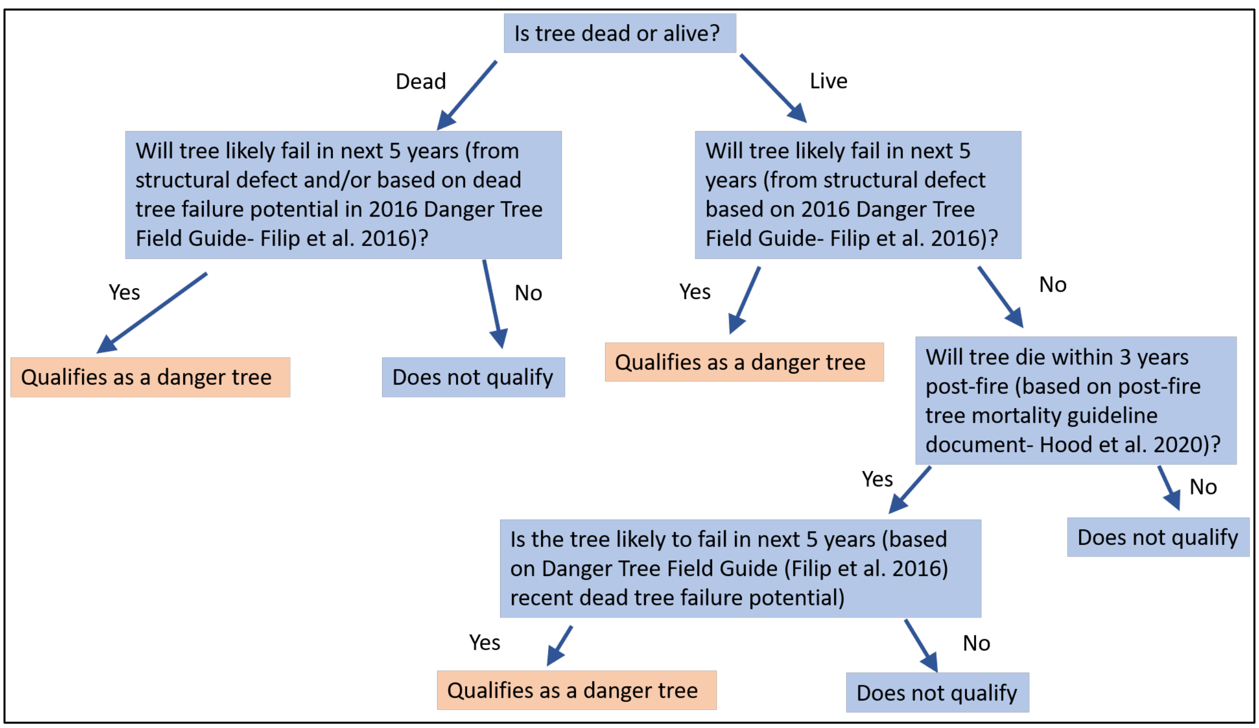


Figure 3. Decision tree for determination of danger trees after wildfire

7.4. Danger Tree Guidelines

The Pacific Northwest Region of the USDA Forest Service uses the Field Guide for Danger Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington (Filip et al. 2016) to identify danger trees on Federal lands. Filip et al. (2016) was authored by forest pathologists, logging specialists, and the Regional road engineer. The Field Guide outlines three levels of failure potential (low, likely, and imminent) and describes structural thresholds that lead to failure based on common failure indicators, including fire damage, on tree species in Oregon and Washington. This publication was first developed in 2005 (Toupin and Barger 2005) to assist field going personnel in the workplace and along roads. It was updated in 2008 (Toupin et al. 2008) and again in 2016 (Filip et al. 2016). The first rendition was based on Harvey and Hessburg (1992), which was designed for developed campgrounds. It was then recognized that a more simplistic process was needed to identify danger trees for field going personnel in a variety of work sites.

The Field Guide for Danger trees outlines three failure potentials:

- ***Low Failure Potential:*** Trees or their parts are defective or decayed, but it would take considerable effort to make them fail. These trees or parts have a low probability of failure within 10 years.
- ***Likely Failure Potential:*** Trees or their parts are defective or decayed, but it would take moderate effort to make them fail. These trees or parts have a high probability of failure within 3 to 5 years.
- ***Imminent Failure Potential:*** Trees or their parts are so defective or decayed that it would take little effort to make them fail. These trees or parts have a high probability of failure within one year.

The “likely” and “imminent” failure potential timelines in Filip et al. (2016) appear to be in line with FEMA’s guidance to consider imminent hazards within 5 years of the incident.

Table 1 in the Field Guide (Filip et al. 2016, pp. 27-31) lists the failure indicators and their associated failure potentials along with descriptions of low, likely, and imminent. Failure indicators that are relevant to fire damaged trees are outlined below (Table 3), which is an excerpt from Filip et al. (2016; p. 27). Other indicators that may be relevant to fire damaged trees (as listed above) can be found in Appendix E (Table 1 from Filip et al. 2016).

Table 3. Failure indicators that are relevant to living and dead or dying fire-damaged trees.

Failure indicator	Failure potential		
	Imminent	**Likely**	**Low**
Old Dead trees (>5 years) No foliage or fine branches; bark is absent or falling off	All tree species except cedar, juniper, and large (>20 in. dbh[1]) Douglas-fir	Cedar, juniper, larch or large Douglas-fir with no other visible indicators	none
Recent Dead Trees (<5 years) All or some foliage; fine branches; bark mostly intact	All trees< 10 in dbh	All trees> 10 in. dbh except cedar, juniper, larch, or large Douglas-fir	Cedar, juniper, larch, or large Douglas-fir
Living, fire-damaged trees with recent (<5 year) fire damage	True fir, hemlock, spruce or hardwood with >50% of bole cross-section burned & consumed. DF, pine, cedar, juniper or larch with >75% of bole cross-section burned & consumed. Any species with >1 quadrant burned & consumed structural roots.	True fir, hemlock, spruce or hardwood with 25-50% of bole cross-section burned & consumed. DF, pine, cedar, juniper or larch with 50-75% of bole cross-section burned & consumed, Any species with 1 quadrant burned & consumed structural roots.	True fir, hemlock, spruce or hardwood with <25% of bole cross-section burned & consumed. DF, pine, cedar, juniper or larch with <50% of bole cross-section burned & consumed, AND no burned & consumed structural roots.

1. diameter breast height

Potential Failure Zone

The potential failure zone is the area on the ground that could be reached by any part of a failed tree. The potential failure zone of a total tree failure is based on several factors, including tree height; ground slope angle- the steeper the slope, the larger the failure zone downhill; and direction of lean if tree is leaning 15 degrees or more. In the USFS Pacific Northwest Region, Engineering Policy FSM R6 supplement 7730-2007-2, the potential failure zone is generally defined as a circle with a radius of 1 ½ times the height of the tree or tree segment, plus additional distance for ground slope and tree lean.

Failure of dead trees

The potential for failure of recent and older dead trees from Table 3 has guidelines based on tree species and size. These recommendations were developed from an analysis of two separate long-term permanent plot data sets on federal and non-federal lands. These analyses were completed and then incorporated into DecAID. “DecAID” is an advisory system developed from a synthesis of data and research results pertaining to forests in Oregon and Washington. These analyses and documentation and data can be found in the summary information on the DecAID application (https://apps.fs.usda.gov/r6_decaid/views/snag_dynamics.html). Over time, more data has become available and the region plans to re-analyze this data in the near future.

Post-fire Tree Mortality Research

The Post-fire Tree Mortality Guidelines (Hood et al. 2020) provides injury thresholds for predicting which trees will likely die (see Table 4 below, which is Appendix A in Hood et al. 2020). Trees are considered dead if they have a > 50% likelihood of dying within 3 years post-fire to capture delayed tree mortality. Trees exceeding the listed thresholds are considered dead, even if they have green needles, because they will likely die within 3 years.

The Post-fire Tree Mortality Guidelines are a compilation of the latest research on predicting post-fire mortality and were developed from data collected from Oregon and Washington (Ryan and Reinhardt 1988, Thies et al. 2006, Grayson et al. 2017) and other research on post-fire mortality model predictions and accuracy evaluation (Fowler et al. 2010, Hood et al. 2010, Davis et al. 2012, Thies and Westlind 2012, Hood and Lutes 2017). The majority of data used to develop and assess accuracy of post-fire tree mortality models that are reported in the above-referenced peer-reviewed publications are described in Cansler et al. (2020a) and are publicly available in the Forest Service Research Data Archive (Cansler et al. 2020b). Model performance is described in (Cansler et al. 2020c); see appendices for full descriptions by species. The 3-year estimate was used because that is what the data support – trees were followed for 3 years after fire and logistic regression was used to develop predicted probability of mortality models. Therefore, any estimate FEMA makes of hazard trees following these guidelines will be conservative in that additional mortality could occur between three and five years.

The Post-fire Tree Mortality Guidelines are based, in part, on Forest Service guidelines for the US Department of Agriculture, Forest Service, Pacific Southwest Region (Smith and Cluck 2011) and

Northern Region (USDA Forest Service Region One 2017). The document describes how to determine the levels of fire injury and insect damage that have been shown to be the best indicators of tree mortality. The guidelines use the crown injury indicator of crown scorch, DBH, bark char or cambium injury, and/or the presence or absence of beetle activity indicators to predict mortality.

The likelihood of a tree dying after fire can be assessed by the following indicators:

1. Crown Condition: the percentage of the live crown volume or length that is remaining,
2. Cambium Injury: the cambium mortality at the root collar,
3. Beetle Activity: mass attack or simple presence of bark beetles and wood boring beetles.

The probability that a tree will die after fire depends upon the magnitude of severity of all three factors. More detailed reviews of fire-caused tree mortality are described in (Filip et al. 2007) and (Hood et al. 2018).

Assessing Fire-caused Injury and Bark Beetle Attacks

Percent crown volume scorch (PCVS) is the percentage of the pre-fire crown volume that is scorched from fire. Crown scorch is generally the most important predictor of tree mortality after fire (Sieg et al. 2006, Woolley et al. 2012). It is determined by first estimating the pre-fire live crown volume, based on remaining live crown, residual scorched foliage, residual burned foliage, and residual branches that have burned but likely had live needles prior to the fire. After estimating what the pre-fire live crown looked like, the percentage of the crown by volume that is scorched is estimated (Hood et al. 2007a).

Bark char is an indicator of the condition of the cambium and determines whether a tree will be able to continue to transport nutrients to roots. Trees with high amounts of dead cambium, but with little crown injury, may take several years to die because the trees can still photosynthesize and transport water up through the xylem, but the connection between the crown and roots is severed. Over time, fine roots die without photosynthates, causing a decline in the tree's ability to transport water to the crown and photosynthesize and eventually the tree dies (Hood et al. 2018). Root injury is not included as a mortality risk factor in the guidelines in the mortality document because it is very difficult to assess. However, if a fire consumed deep duff (>5 inches) that had accumulated around the bases of trees, and root injury is a concern, we direct readers to Hood (2010). Cambium death, caused by high or sustained heating of the tree bole or root collar, is an influential factor in tree mortality following fire. Ryan (1982) states that, in the absence of significant crown injury, most trees survive up to 25% basal girdling, but few trees survive more than 75% girdling. The severity and extent of bark char at the root collar can be used as a surrogate for direct cambium sampling. Estimating bark char to determine if a tree is fire-killed is much faster; however, the accuracy varies by species and not all species have been evaluated (Hood et al. 2008). Table 4 (Hood et al. 2020) provides a crosswalk for bark char codes and probable cambium status by species.

Trees heavily infested by bark and/or wood boring beetles are predicted to die (Goheen and Willhite 2006). Beetle mass-attacks that indicate tree mortality are designated by presence of pitch tubes and/or boring dust around > 50% of the circumference of the lower bole of a tree (Hagle et al. 2003). This is either due directly to the impact of bark beetle infestation and/or indirectly due to trees being so significantly injured that they have become infested by wood boring or ambrosia beetles that only feed in dying and recently dead hosts. The amount of bark beetle and wood boring beetle infestation will determine the potential for mortality even if the tree is not predicted to die based on other injury variables. Some types of beetle attack can indicate a tree may, in fact, already be dead or dying while still appearing alive. Beetle infestation is typically indicated by the presence of pitch tubes or boring dust on the bole or around the base of a tree.

Determining Immediate and Imminent Mortality

The rubric shown in Table 4 (which is Appendix A of the Post-fire Tree Mortality Guidelines) provides criteria for determining when there is a high likelihood of tree mortality after fire based on the crown condition as estimated by crown scorch, cambium injury based on bark char severity and magnitude, and bark beetle attack severity. The species included in the rubric are ones in Washington and Oregon for which accurate post-fire mortality models exist. If a species is not listed, either no post-fire tree mortality data exist, or the existing evaluated models performed very poorly. The rubric draws on published research of post-fire tree mortality (Ryan and Reinhardt 1988, Thies et al. 2006, Hood and Bentz 2007, Hood et al. 2007b, Hood et al. 2008, Fowler et al. 2010, Smith and Cluck 2011, Grayson et al. 2017, Hood and Lutes 2017). All trees should be evaluated before the beginning of the second post-fire winter, preferably within the first post-fire year. These criteria are a simplification of statistical model predictions.

Once a tree is evaluated if it will likely live or die, the Danger Tree Guidelines (“Recent Dead Trees” in Table 3 above; Filip et al. 2016) can then be used to determine if it is likely to fail within five years of the wildfire.

Table 4. The rubric shows mortality thresholds using percent crown scorched (either as a percentage of volume or length), circumference and severity of bark char at the root collar, and the bole circumference infested by bark beetles or wood boring beetles. For the rubric, bark char severity is used instead of cambium kill. A tree is considered dead if any criterion is met. (Table from Appendix A in Hood et al. 2020).

Species	Criteria	Diameter Class		
		5 – 11.9”	12 – 20.9”	21”+
ABAM: Pacific silver fir	Crown scorch	> 30% volume		> 40% volume
	Bark char	≥ 50% any char		
ABCO: white fir or hybrids	Crown scorch	≥ 70% volume		
	Bark char	≥ 75% deep char		

ABGR: grand fir	Crown scorch	≥ 60% volume	
	Bark char	≥ 50% any char	≥ 75% moderate or deep char
ABLA: subalpine fir	Crown scorch	> 30% volume	> 40% volume
	Bark char	> 50% any char	
ABMA: red fir	Crown scorch	≥ 70% volume	
	Bark char	> 75% deep char	
CADE: Incense cedar	Crown scorch	≥ 85% volume	
	Bark char	> 75% deep char	
LAOC: Western larch	Crown scorch	If needles on: ≥ 80% crown length If needles off: average char height over entire tree length > 70%	
	Bark char	> 75% deep char	Bole char not a predictive injury indicator
PIEN: Engelmann spruce	Crown scorch	≥ 75% volume	
	Bark char	> 75% any char	
PISI: Sitka spruce	Crown scorch	≥ 75% volume	
	Bark char	> 75% any char	
PICO: Lodgepole pine	Crown scorch	≥ 40% volume	
	Bark char	≥ 75% any char	
PIAL: Whitebark pine	Crown scorch	≥ 40% volume	
	Bark char	≥ 75% any char	
PILA: Sugar pine	Crown scorch	≥ 70% volume	
	Bark char	> 90% moderate or deep char	
	Crown scorch	> 30% volume	

PIMO: Western white pine	Bark char	≥ 90% any char		
PIPO: Ponderosa pine	Crown scorch	Pre-bud break (volume): • > 85% needles scorched OR • > 40% needles consumed/blackened OR • > 5% and ≤ 40% needles consumed/blackened combined with >50% needles scorched Post-bud break (volume): > 70% crown volume killed (no new growth)		
	Bark char	> 90% deep char		
PSME: Douglas-fir	Crown scorch	> 65% crown volume		
	Bark char	> 50% deep char	> 75% deep char	
THPL: Western red cedar	Crown scorch	> 20% crown volume	> 40% crown volume	> 60% crown volume
	Bark char	> 50% any char		> 75% any char
TSHE: Western hemlock	Crown scorch	≥ 20% crown volume		
	Bark char	≥ 90% any char		
TSME: Mountain hemlock	Crown scorch	≥ 20% crown volume		
	Bark char	≥ 90% any char		

Note: If a species is host to bark beetles or wood borers and there is boring dust and attack signs that are not RTB around > 50% of the bole circumference, the tree will die regardless of fire injury.

7.5. References

Cansler, C. A., S. M. Hood, J. M. Varner, P. J. van Mantgem, M. C. Agne, R. A. Andrus, M. P. Ayres, B. D. Ayres, J. D. Bakker, M. A. Battaglia, B. J. Bentz, C. R. Breece, J. K. Brown, D. R. Cluck, T. W. Coleman, R. G. Corace, W. W. Covington, D. S. Cram, J. B. Cronan, J. E. Crouse, A. J. Das, R. S. Davis, D. M. Dickinson, S. A. Fitzgerald, P. Z. Fulé, L. M. Ganio, L. M. Grayson, C. B. Halpern, J. L. Hanula, B. J. Harvey, J. Kevin Hiers, D. W. Huffman, M. Keifer, T. L. Keyser, L. N. Kobziar, T. E. Kolb, C. A. Kolden, K. E. Kopper, J. R. Kreitler, J. K. Kreye, A. M. Latimer, A. P. Lerch, M. J. Lombardero, V. L. McDaniel, C. W. McHugh, J. D. McMillin, J. J. Moghaddas, J. J. O'Brien, D. D. B. Perrakis, D. W. Peterson, S. J. Prichard, R. A. Progar, K. F. Raffa, E. D. Reinhardt, J. C. Restaino, J. P. Roccaforte, B. M. Rogers, K. C. Ryan, H. D. Safford, A. E. Santoro, T. M. Shearman, A. M. Shumate, C. H. Sieg, S. L. Smith, R. J. Smith, N. L. Stephenson, M. Stuever, J. T. Stevens, M. T. Stoddard, W. G. Thies, N. M. Vaillant, S. A. Weiss, D. J. Westlind, T. J. Woolley, and M. C. Wright. 2020a. The Fire and Tree Mortality Database, for empirical modeling of individual tree mortality after fire. Scientific Data **7**:194.

Cansler, C. A., S. M. Hood, J. M. Varner, P. J. van Mantgem, M. C. Agne, R. A. Andrus, M. P. Ayres, B. D. Ayres, J. D. Bakker, M. A. Battaglia, B. J. Bentz, C. R. Breece, J. K. Brown, D. R. Cluck, T. W. Coleman, R. G. Corace, W. W. Covington, D. S. Cram, J. B. Cronan, J. E. Crouse, A. J. Das, R. S. Davis, D. M. Dickinson, S. A. Fitzgerald, P. Z. Fulé, L. M. Ganio, L. M. Grayson, C. B. Halpern, J. L. Hanula, B. J. Harvey, J. K. Hiers, D. W. Huffman, M. Keifer, T. L. Keyser, L. N. Kobziar, T. E. Kolb, C. A. Kolden, K. E. Kopper, J. R. Kreitler, J. K. Kreye, A. M. Latimer, A. P. Lerch, M. J. Lombardero, V. L. McDaniel, C. W. McHugh, J. D. McMillin, J. J. Moghaddas, J. J. O'Brien, D. D. B. Perrakis, D. W. Peterson, S. J. Prichard, R. A. Progar, K. F. Raffa, E. D. Reinhardt, J. C. Restaino, J. P. Roccaforte, B. M. Rogers, K. C. Ryan, H. D. Safford, A. E. Santoro, T. M. Shearman, A. M. Shumate, C. H. Sieg, S. L. Smith, R. J. Smith, N. L. Stephenson, M. Steuver, J. T. Stevens, M. T. Stoddard, W. G. Thies, N. M. Vaillant, S. A. Weiss, D. J. Westlind, T. J. Woolley, and M. Wright. 2020b. Fire and tree mortality database (FTM). Fort Collins, CO: Forest Service Research Data Archive. Updated 24 July 2020. https://doi.org/10.2737/RDS-2020-000.

Cansler, C. A., S. M. Hood, P. J. van Mantgem, and J. M. Varner. 2020c. A large database supports the use of simple models of post-fire tree mortality for thick-barked conifers, with less support for other species. Fire Ecology **16**:25.

Davis, R. S., S. Hood, and B. J. Bentz. 2012. Fire-injured ponderosa pine provide a pulsed resource for bark beetles. Canadian Journal of Forest Research **42**:2022-2036.

Filip, G., M. Barger, J. Bronson, K. Chadwick, R. Collins, B. Goodrich, H. Kearns, M. McWilliams, B. Oblinger, D. Omdal, A. Ramsey, and A. Saaverdra. 2016. Danger-Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington. R6-NR-TP-021-2016. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd512960.pdf.

Filip, G., J. Biro, K. Chadwick, D. Goheen, E. Goheen, J. Hadfield, A. Kanaskie, H. Kearns, H. Maffei, K. Mallams, D. Omdal, A. Saavedra, and C. Schmitt. 2014. Field Guide for Hazard-Tree Identification and Mitigation on Developed Sites in Oregon and Washington Forests. R6-NR-TP-021-2013. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3799993.pdf .

Filip, G. M., C. L. Schmitt, D. W. Scott, and S. A. Fitzgerald. 2007. Understanding and defining mortality in western conifer forests. Western Journal of Applied Forestry **22**:105-115.

Fowler, J. F., C. H. Sieg, J. McMillin, K. K. Allen, J. F. Negron, L. L. Wadleigh, J. A. Anhold, and K. E. Gibson. 2010. Development of post-fire crown damage mortality thresholds in ponderosa pine. International Journal of Wildland Fire **19**:583-588.

Goheen, E. M., and E. A. Willhite. 2006. Field guide to the common diseases and insect pests of Oregon and Washington Conifers. R6-NR-FID-PR-01-06. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR. 325p.

Grayson, L. M., R. A. Progar, and S. M. Hood. 2017. Predicting post-fire tree mortality for 14 conifers in the Pacific Northwest, USA: Model evaluation, development, and thresholds. Forest Ecology and Management **399**:213-226.

Hagle, S. K., K. Gibson, and S. Tunnock. 2003. Field guide to diseases and insect pests of Northern and Central Rocky Mountain conifers. Report Number R1-03-08. U.S. Department of Agriculture, Forest Service, State and Private Forestry, Northern Region and Intermountain Region, Missoula, MT.

Harvey, R. D., and P. F. Hessburg. 1992. Long-Range Planning for Developed Sites in the Pacific Northwest: The context of Hazard Tree Management. FPM-TP039-92. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_026108.pdf.

Hood, S., and D. Lutes. 2017. Predicting post-fire tree mortality for 12 western US conifers using the First-Order Fire Effects Model (FOFEM). Fire Ecology **13**:66-84.

Hood, S., I. Ragenovich, and B. Schaupp. 2020. Post-fire Assessment of Tree Status and Marking Guidelines for Conifers in Oregon and Washington. Report Number R6-FHP-RO-2020-02. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd814664.pdf

Hood, S., M. Varner, P. van Mantgem, and C. A. Cansler. 2018. Fire and Tree Death: Understanding and Improving Modeling of Fire-induced Tree Mortality Environmental Research Letters **13**:113004.

Hood, S. M. 2010. Mitigating old tree mortality in long-unburned, fire-dependent forests: a synthesis. RMRS-GTR-238. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hood, S. M., and B. Bentz. 2007. Predicting post-fire Douglas-fir beetle attacks and tree mortality in the Northern Rocky Mountains. Canadian Journal of Forest Research **37**:1058-1069.

Hood, S. M., B. Bentz, K. Gibson, K. C. Ryan, and G. DeNitto. 2007a. Assessing post-fire Douglas-fir mortality and Douglas-fir beetle attacks in the northern Rocky Mountains. RMRS-GTR-199. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Hood, S. M., D. R. Cluck, S. L. Smith, and K. C. Ryan. 2008. Using bark char codes to predict post-fire cambium mortality. Fire Ecology **4**:57-73.

Hood, S. M., C. McHugh, K. C. Ryan, E. Reinhardt, and S. L. Smith. 2007b. Evaluation of a post-fire tree mortality model for western US conifers. International Journal of Wildland Fire **16**:679-689.

Hood, S. M., S. Smith, and D. Cluck. 2010. Predicting tree mortality for five California conifers following wildfire. Forest Ecology and Management **260**:750-762.

Ryan, K. C. 1982. Techniques for assessing fire damage to trees. Pages 1-11 *in* J. Lotan, editor. Proceedings of the symposium: Fire, its field effects, 19-21 October 1982, Jackson, Wyoming. Intermountain Fire Council, Missoula, MT.

Ryan, K. C., and E. D. Reinhardt. 1988. Predicting postfire mortality of seven western conifers. Canadian Journal of Forest Research **18**:1291-1297.

Sieg, C. H., J. D. McMillin, J. F. Fowler, K. K. Allen, J. F. Negrón, L. L. Wadleigh, J. A. Anhold, and K. E. Gibson. 2006. Best predictors for postfire mortality of ponderosa pine trees in the Intermountain West. Forest Science **52**:718-728.

Smith, S. L., and D. R. Cluck. 2011. Marking Guidelines for Fire-Injured Trees in California. Report RO-11-01. RO-11-01, USDA Forest Service, Forest Health Protection, Region 5, Susanville, CA.

Thies, W. G., and D. J. Westlind. 2012. Validating the Malheur model for predicting ponderosa pine post-fire mortality using 24 fires in the Pacific Northwest, USA. International Journal of Wildland Fire **21**:572-582.

Thies, W. G., D. J. Westlind, M. Loewen, and G. Brenner. 2006. Prediction of delayed mortality of fire-damaged ponderosa pine following prescribed fires in eastern Oregon, USA. International Journal of Wildland Fire **15**:19-29.

Toupin, R., and M. Barger. 2005. Field Guide for Danger Tree Identification and Response. R6-NR-FP-PR-03-05.

Toupin, R., G. Filip, T. Erkert, and M. Barger. 2008. Field Guide for Danger Tree Identification and Response. R6-NR-FP-PR-01-08.

USDA Forest Service Region One. 2017. Post-fire assessment of Tree Status. Vegetation Classification, Mapping, Inventory and Analysis Report. Report 17-17 v2.0.

Woolley, T., D. C. Shaw, L. M. Ganio, and S. A. Fitzgerald. 2012. A review of logistic regression models used to predict post-fire tree mortality of western North American conifers. International Journal of Wildland Fire **21**:1-35.

8. Fish and Wildlife Resources

Shaun Clements and Jennifer Ringo, Oregon Department of Fish and Wildlife
Scott Barndt, USDA Forest Service

8.1. Objectives

Document post-fire concerns and management opportunities for fish and wildlife critical values within the Archie Creek, Beachie Creek, Holiday Farm and Riverside Fires.

8.2. Assessment Methodology - Field and Modeling

Oregon Department of Fish and Wildlife (ODFW) fish and wildlife biologists combined pre-fire knowledge of fish and wildlife distribution, habitat, and limiting factors with post-fire information such as soil burn severity, vegetation mortality, hazardous materials, and other data to develop maps depicting both threats to critical values and areas where post-fire management could benefit critical values. These maps were compared to recent field data collected by the ETARTs effort to determine any additional threats or opportunities. Additionally, ODFW identified potential negative impacts to Oregon Conservation Strategy (OCS) wildlife priorities from the fires.

8.3. Resource Setting

High value natural resources are found in and around the Riverside Fire: populations of spring Chinook, winter steelhead, coho, and bull trout (all federally threatened); cutthroat trout; Roosevelt elk and black-tailed deer, and multiple wildlife strategy species including Oregon slender salamander (state sensitive), Cascade torrent salamander (state sensitive), Cascades frog (state sensitive), coastal tailed frog (state sensitive), northern red-legged frog (state sensitive), Townsend's big-eared bat (state sensitive-critical), northern spotted owl (federal threatened), olive-sided flycatcher (state sensitive), and harlequin duck (state sensitive); and key strategy habitats including late successional forest and riparian habitats that support these species. Prior to the fire, some of the riparian and stream habitats supporting these values were depauperate of large woody debris (LWD) and/or vegetation suitable to support beavers. The Riverside Fire burned these habitats with a moderate percentage of moderate to high burn severity.

8.4. Critical Values, Results, Risk Assessment, and Recommendations

Two categories of fish and wildlife Critical Values (CVs) were identified: those determined to be at risk of post-fire threats, and those deemed restoration/natural recovery opportunities. In some cases, ODFW can directly implement actions to address direct threats (e.g. to hatchery water supplies or fish ladders); in all other cases, ODFW will work with partners to address both risks and opportunities.

Four Critical Values (CVs) were determined to be at risk of post-fire threats (1 at high risk), and restoration/natural recovery opportunities were identified for 9 additional CVs (8 with high reward; Table 4). For all CVs, ODFW will work with partners to address both risks and opportunities. There are no COAs within the fire perimeter.

8.5. Recommended Monitoring

Near-term success in engaging partners can be monitored by number of projects on which engagement occurs. Over the mid- to longer-terms, success can be measured by habitat variables and populations metrics, such as LWD recruitment into stream channels and escapement of salmonids or population counts of terrestrial wildlife. In addition, partners should prioritize monitoring to increase understanding of species response to fire and post-fire habitat treatments. Likewise, habitats should be assessed over time to determine effectiveness of and responses to treatments, changes in species composition, and presence of invasive species.

See Appendix F for detailed table of Fish and Wildlife Critical Values, Opportunities and Threats, Risks and Rewards, and Recommendations.

Riverside ETART Members

Riverside ETART

Team Member	Resource	Agency
Samuel Leininger	Botany (Weeds)	Clackamas Soil and Water Conservation District
Thomas Whittington	Engineering	Oregon Department of Forestry
Travis Wootan	Engineering	Clackamas County Road Department
Shaun Clements	Fisheries	Oregon Department of Fish and Wildlife
Jennifer Ringo	Fisheries	Oregon Department of Fish and Wildlife
Bill Burns	Geologic Hazards	Oregon Department of Geology and Mineral Industries
Brandon Overstreet	Geologic Hazards	USDI Geological Survey
Ryan Andrews	Hydrology	Oregon Water Resources Department
W. Terry Frueh	Hydrology	Oregon Department of Forestry
Anthony Collora	Soils	USDA Natural Resource Conservation Service

ETART Resource Leads

Team Member	Resource	Agency
Sarah Callaghan	Botany (Weeds)	USDA Forest Service
Megan McGinnis	Soils	Bureau of Land Management
Mary Young	Soils	USDA Forest Service
Scott Barndt	Fisheries	USDA Forest Service
Spencer Higginson	Hydrology	National Weather Service
Kyle Wright	Hydrology	USDA Forest Service
Barton Wills	Geologic Hazards	USDA Forest Service
Kipp Klein	Engineering	USDA Forest Service
Paul Claeyssens	Cultural Resources	USDA Forest Service
I. Blakey Lockman	Danger/Hazard Trees	USDA Forest Service

ETART Coordination Team

Team Member	Agency
Anna Daggett	FEMA
Kelsey Madsen	FEMA
Katherine Rowden	National Weather Service
Daryl Downing	US Army Corps of Engineers
Ryan Gordon	Oregon Department of Forestry
Cara Farr	USDA Forest Service
Dave Callery	USDA Forest Service
Terry Hardy	USDA Forest Service

ETART GIS Team

Team Member	Agency
Dorothy Thomas	USDA Forest Service
David Askov	FEMA
Yaw Acheampong	FEMA
Sharon Williams	FEMA
Joshua Keller	FEMA
Sean Carroll	US Army Corps of Engineers

Appendix A – Road Treatment Cost Estimates

Approximately 12.25 miles of roads within or adjacent to the fire perimeter were examined by ETART Engineering specialists. These roads are primarily the responsibility of Clackamas County road department, with a minority of other roads under the control or ownership of private forest landowners or residents. All roads are located on the western edge of the fire and within low SBS with a few segments bordered by moderate SBS. The roads evaluated pose little to no concern for failure due to the lack of high burn severity near them.

The identified risks to human life and safety and potential property damage are associated with threats from unmitigated hazard trees. The hazard trees falling onto a public road during heavy rainfall events increase the potential for culvert and road failures. These roads will require minimal action to maintain open and safe to all traffic.

Road Name	Description and Issues
Fall Creek Road Total Miles: 3.79 Miles in Burn: 0.42	▪ Paved, self-maintaining county road ▪ Provides access to numerous rural residential dwellings and private forestland, small tracts of BLM and USFS lands. ▪ Connections to additional county road: Michaels Road ▪ Needs: ditch cleaning, culvert inlet/outlet cleaning and storm monitoring. ▪ Values at Risk: property
Hillockburn Road Total Miles: 4.30 Miles in Burn: 3.02	▪ Paved, self-maintaining county road ▪ Provides access to numerous rural residential dwellings and private forestland, large tracts of BLM and USFS land. ▪ Connects to additional county roads: Habelt, Horner and Pederson Road ▪ Needs: culvert replacements, ditch cleaning, culvert inlet/outlet cleaning and storm monitoring. ▪ Values at Risk: property

Storm Inspection and Response

Monitor road drainage structures and debris flow treatment structures after significant storm events to ensure the maximum drainage capacity is maintained until the natural revegetation of the burned area has occurred. Maintain and/or repair any damage to road surfaces.

The roads at risk within the Riverside Fire burned areas are located primarily within or below areas of low to moderate SBS. There is a future threat to travelers along the roads within the burned area due to the increased potential for culverts plugging with sediment or debris which could washout sections of the roads. With the loss of vegetation, normal storm frequencies and magnitudes can more easily initiate erosion on the slopes, and it is likely that this runoff will cover the roads or cause washouts at drainage facilities (culverts) or stream crossings. These events make for hazardous access to forest roads and put the safety of users at risk.

Culvert Replacement

One existing culvert crossing on Hillockburn Road is damaged with moderate SBS drainages upslope. This culvert is currently functioning but is partially damaged on the inlet and may not provide full flow potential until repaired or replaced. If feasible and cost effective, replace the culvert to accommodate the expected post-fire flows. If culvert is not replaced, proceed with monitoring and ditch cleaning along the roads identified in the report. Other culverts in the burned area should be monitored to ensure full functionally through storm inspection and response.

Road Treatment Cost Estimates – Riverside Fire

Mobilization	Qty	Rate	Method	Unit	Total
Mobilization (total for all treatments)	1	$2,500	LSQ	lump sum	$3,500
Mobilization Total					**$3,500**

Culvert Replacement	Qty	Rate	Method	Unit	Total
Culvert Installation	1	$5,500	AQ	each	$2,500
Treatment Total					**$2,500**

Storm Inspection and Response	Qty	Rate	Method	Unit	Total
Monitoring crew (2 personnel)	3	$900	NA	day	$2,700
Vehicles, Equipment and Misc.	3	$300	NA	day	$900
Treatment Total					**$3,600**
Hillockburn Road Treatment Total					**$9,600**

Appendix B – Supporting Botany Information

I. Summarized Values at Risk Table[4]

Critical value risk assessment. Risk was evaluated based on the probability of damage or loss and the magnitude of consequences.

Critical Value	Threat to Value	Probability of Damage or Loss	Magnitude of Consequence	Risk
Multiple values across the fire perimeter	Establishment and expansion of viable populations of local and state noxious weeds classified as targets for Early Detection and Rapid Response	Likely	Major	Very High
Multiple values across the fire perimeter	Spread of Invasives during fire rehabilitation, reforestation, and salvage logging operations	Likely	Moderate	High
Human health and safety	Establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties	Possible	Major	High
Multiple values across the fire perimeter	Spread of Invasives due to contaminated gravel and rock products	Possible	Moderate	Intermediate
Native plant communities	Establishment and expansion of fire-adapted noxious weeds	Likely	Moderate	High

[4] Full Values at Risk Table can be found in *Supplementary Document – Riverside VAR Table.pdf / Supplementary Document – Riverside VAR Table.xlsx*

Critical Value	Threat to Value	Probability of Damage or Loss	Magnitude of Consequence	Risk
Habitat conservation areas	Establishment and expansion of fire-adapted noxious weeds	Possible	Moderate	Intermediate
Threatened and endangered native plants	Establishment and expansion of fire-adapted noxious weeds	Possible	Major	High
Riparian plant communities	Invasive plant establishment and suppression of regenerating native plants	Possible	Moderate	Intermediate
Old growth-late successional conifer forest	Invasive plant establishment and suppression of regenerating native plants	Unlikely	Minor	Very Low
Wetland habitat	Invasive plant establishment and suppression of regenerating native plants	Likely	Moderate	High
Grasslands and meadow habitat	Invasive plant establishment and suppression of regenerating native plants	Likely	Moderate	High
Oak habitat	Invasive plant establishment and suppression of regenerating native plants	Possible	Moderate	Intermediate
Agricultural productivity	Establishment and expansion of agronomic noxious weeds following fire-related disturbance	Possible	Moderate	Intermediate
Timber productivity	Establishment and expansion of economically important noxious weeds	Possible	Minor	Low

II. Recommended Treatments

The recommended treatments for each critical value and threat are described in below table. These recommendations are based on the information available at this time. Conditions in the burn area are not fully understood. As such, these recommendations should be modified as needed to address conditions in the field. Cost estimates for recommended treatments described here can be found in Table 8.

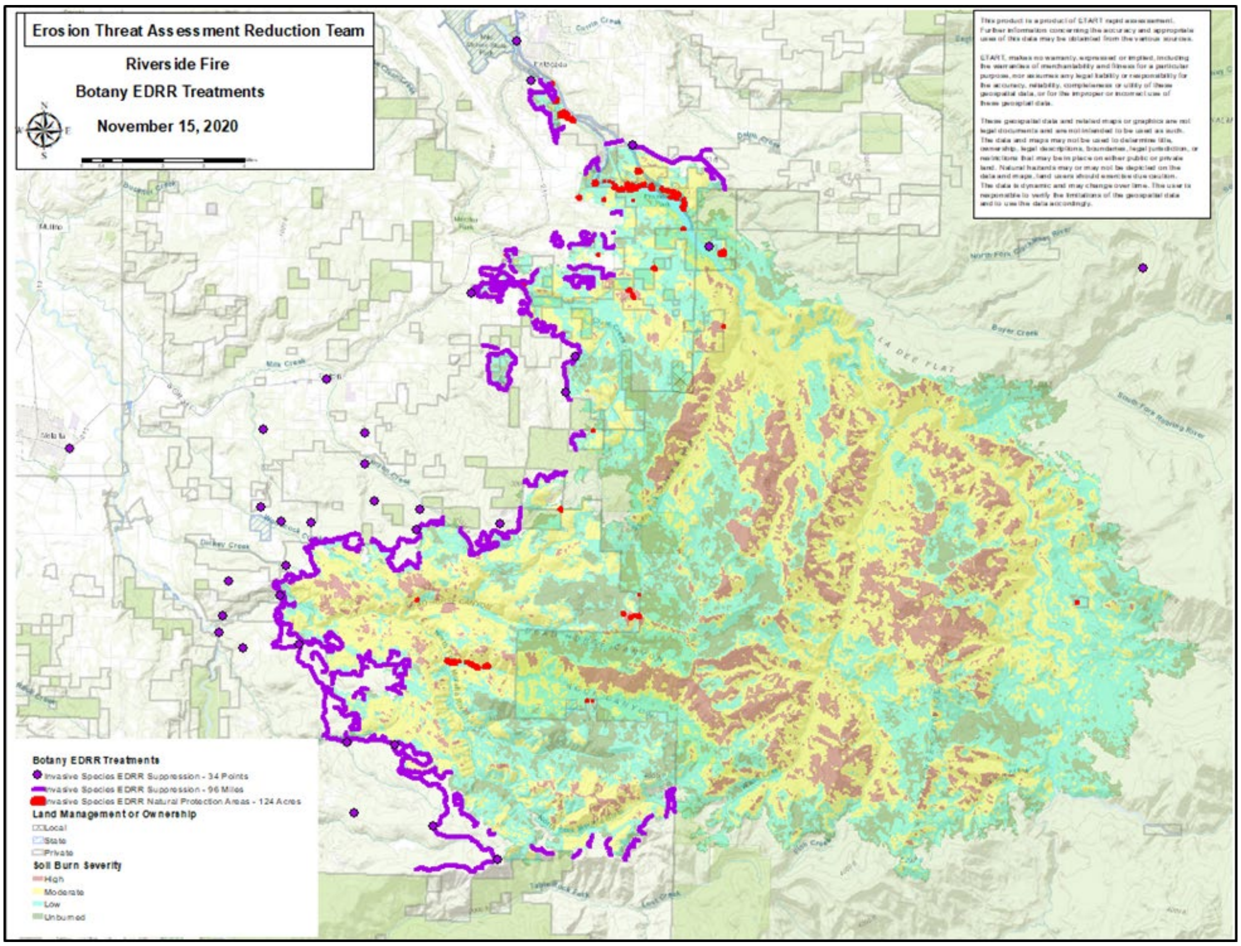


Figure 7. ETART EDRR Survey and Treatments – Riverside Fire

The cost estimates in Table 2 were prepared based on the recommended treatments. Estimates for noxious weed surveys, noxious weed treatments and T&E surveys were adapted from per acre rates for contracted restoration work in Clackamas County, 2020. Weed wash station estimates are based on published rates from the Lemhi CWMA Weed Wash Station installation and operational costs. Community planning and outreach estimates are based on localized mailing and outreach events. Seeding prices are very diverse and depend greatly on sourcing of seed species and broadcast rate.

Table 1. Critical Values and Recommended Treatments

Threat to Critical Value	Recommended Treatment
Establishment and expansion of viable populations of local and state noxious weeds classified as targets for Early Detection and Rapid Response (EDRR).	Implement EDRR weed surveys and if priority noxious weeds are identified, implement treatment using IPM-based principles with the desired goal of eradication. Emergent populations of local priority and containment weeds include orange hawkweed, gorse, slender false brome, Japanese knotweed, Bohemian knotweed, and garlic mustard. Ongoing monitoring is required.
Spread of noxious weeds during fire rehabilitation, reforestation, and salvage logging operations.	Implement sanitation and prevention protocols to prevent the spread of noxious weed with equipment and personnel. Use temporary or permanent equipment wash stations in the northern and southern ends of the fire to sanitize equipment during restoration, reforestation and salvage logging activities. A southern equipment wash station could also be used for prevention efforts in the northern portion of the Beachie Creek fire as well. Initiate noxious weed surveys along road systems and treat emergent populations of noxious weeds using IPM-based principles. Ongoing monitoring is required.
Establishment and expansion of fire-adapted noxious weeds on or near rural and residential properties	Initiate an outreach campaign to affected communities promoting Community Wildfire Preparedness Planning, and the importance of defensible space around homes and buildings. Survey for areas with high fuel loads and regeneration of fire-adapted weed species. Focus outreach into impacted areas in the communities of Colton, Dodge, Dickie Prairie, Elwood, Estacada, Highland, Molalla and Springwater, focusing on highly flammable noxious weeds such as Scotch broom, gorse, and Himalayan blackberry. Materials developed could be used for additional messaging to other residents in the wildland interface.
Spread of invasives due to contaminated gravel and rock products.	Prevent contamination of gravel and rock products by surveying and treating noxious weeds using IPM-based principles in and around active quarry operations. Require certified weed-free aggregate in all public contracting. Install a centrally located equipment wash station to sanitize vehicles and equipment used for the distribution of gravel and rock products. Any contaminated rock or gravel products should be quarantined and not redistributed. Ongoing monitoring is needed.

Threat to Critical Value	Recommended Treatment
Establishment and expansion of fire-adapted noxious weeds in fire suppression areas.	Target survey and treatments on dozer lines, hand lines, roadsides and suppression locations. Noxious weed surveys in these areas should include the identification of new or emergent weeds that may have been introduced during suppression activities. Emergent noxious weed populations should be treated using IPM-based principles. Reseeding heavily disturbed suppression areas and areas of high SBS using native or non-invasive seed as needed. Ongoing monitoring is required.
Establishment and expansion of fire-adapted noxious weeds on prioritized Oregon Department of Forestry Habitat Conservation Areas.	Implement noxious weed surveys in Habitat Conservation Areas with a focus on riparian habitat function. Treat new or emergent populations of identified noxious weeds using IPM-based principles. Ongoing monitoring required.
Establishment and expansion of fire-adapted noxious weeds near populations of rare, threatened, or endangered plants.	Implement targeted noxious weed survey in areas around sensitive species. Treatments of invasive weeds in sensitive areas should be implemented using IPM-based practices only when adverse impacts to protected species can be avoided. Focus should be on areas near suppression activities dozer lines, hand lines, and other suppression activity locations. Soil burn severity and vegetation mortality will increase the threat and dispersal of weed seed into sensitive areas. Ongoing monitoring is needed.
Invasive plant establishment and suppression of regenerating native plants in riparian areas.	Initiate surveys of riparian corridors. Treat new and emergent populations of noxious weeds using IPM-based practices. Past or current riparian restoration projects should be prioritized for survey and treatment. OWEB-funded projects occurring in the public and private land matrix of Upper Molalla River, Lower Clackamas River, and Middle Clackamas River should be surveyed upstream and downstream for potential dispersal and transport of noxious weeds. Replant areas with high mortality and poor natural regeneration.
Invasive plant establishment and suppression of regenerating native plants in late successional mixed conifer forest.	Limit access to old growth areas with high and moderate soil burn severity to minimize the potential for weed seed introduction into these areas. Survey these areas in subsequent years after vegetation has rebounded post-fire. Treat noxious weeds using IPM-based practices if new or emergent noxious weed infestations are identified.
Invasive plant establishment and suppression of regenerating native plants in wetlands.	Survey wetlands in areas with moderate to high SBS, and treat noxious weeds adapted for wetland sites using effective IPM-based practices. Replant areas with high mortality and poor natural regeneration.

Threat to Critical Value	Recommended Treatment
Invasive plant establishment and suppression of regenerating native plants in grassland, prairie, and meadow systems.	Initiate noxious weed surveys in conjunction with rare plant surveys, due to the rarity of this habitat compared to historical abundance. Treat new and emergent populations of noxious weeds using IPM-based principles. Avoid seeding unless native locally sourced seed can be secured. Ongoing monitoring is needed.
Invasive plant establishment and suppression of regenerating native plants in oak woodland habitats.	Initiate noxious weed surveys in conjunction with rare plant surveys, due to the rarity of this habitat compared to historical abundance. Treat new and emergent populations of noxious weeds using IPM-based principles. Avoid seeding unless native, locally sourced seed can be secured. Ongoing monitoring is needed.
Establishment and expansion of agronomic noxious weeds following fire-related disturbance.	Implement noxious weed surveys for important agronomic weeds. Treat new and emergent noxious weeds using IPM-based principles. Prevent the spread of fire-adapted weeds from suppression activities onto adjacent agricultural lands designated as" prime farmland", or "farmland of statewide importance". Reseed heavily disturbed areas if needed. Ongoing monitoring is needed.
Establishment and expansion of economically important noxious weeds in industrial timbers lands.	Implement sanitation and prevention protocols to prevent the spread of noxious weeds with equipment and personnel. Use temporary or permanent equipment wash stations in the northern and southern ends of the fire to sanitize equipment during restoration, reforestation and salvage logging activities. A southern equipment wash station could also be used for prevention efforts in the northern portion of the Beachie Creek fire. Initiate noxious weed surveys along road system and treat emergent populations of noxious weeds using IPM-based principles. Focus should be on eradicating fire-adapted weeds from suppression activities on or adjacent to timber operations that may adversely impact timber production through direct competition, or by altering the fire return intervals (i.e. false brome, gorse, scotch broom, blackberry, knapweeds). Ongoing monitoring is needed.

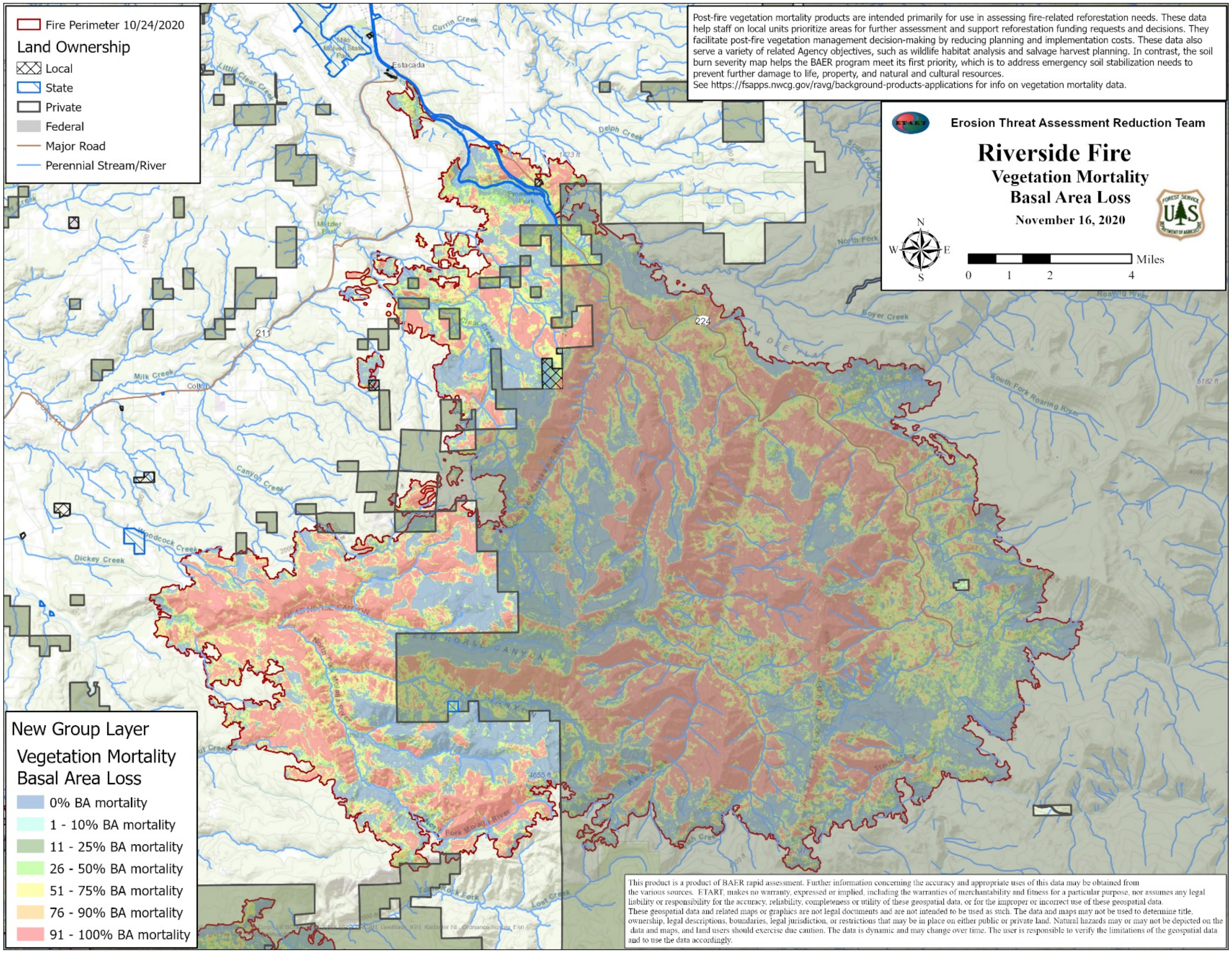
III. Cost Estimates

This preliminary budget was prepared based on plan recommendations. Pricing for noxious weed surveys, noxious weed treatments, and T & E surveys were adapted from mean price of per acre rates for restoration contract work in Clackamas County, 2020. Weed Wash station pricing was estimated based on published rates from the Lemhi CWMA Weed Wash Station installation and operational costs. Community planning and outreach efforts are estimated based on localized mailing and outreach events. Seeding prices are very diverse and depend greatly on the sourcing of seed, species applied, and broadcast rate.

Table 2. Cost Estimates for Invasive Plant and Noxious Weed Treatments – Riverside Fire

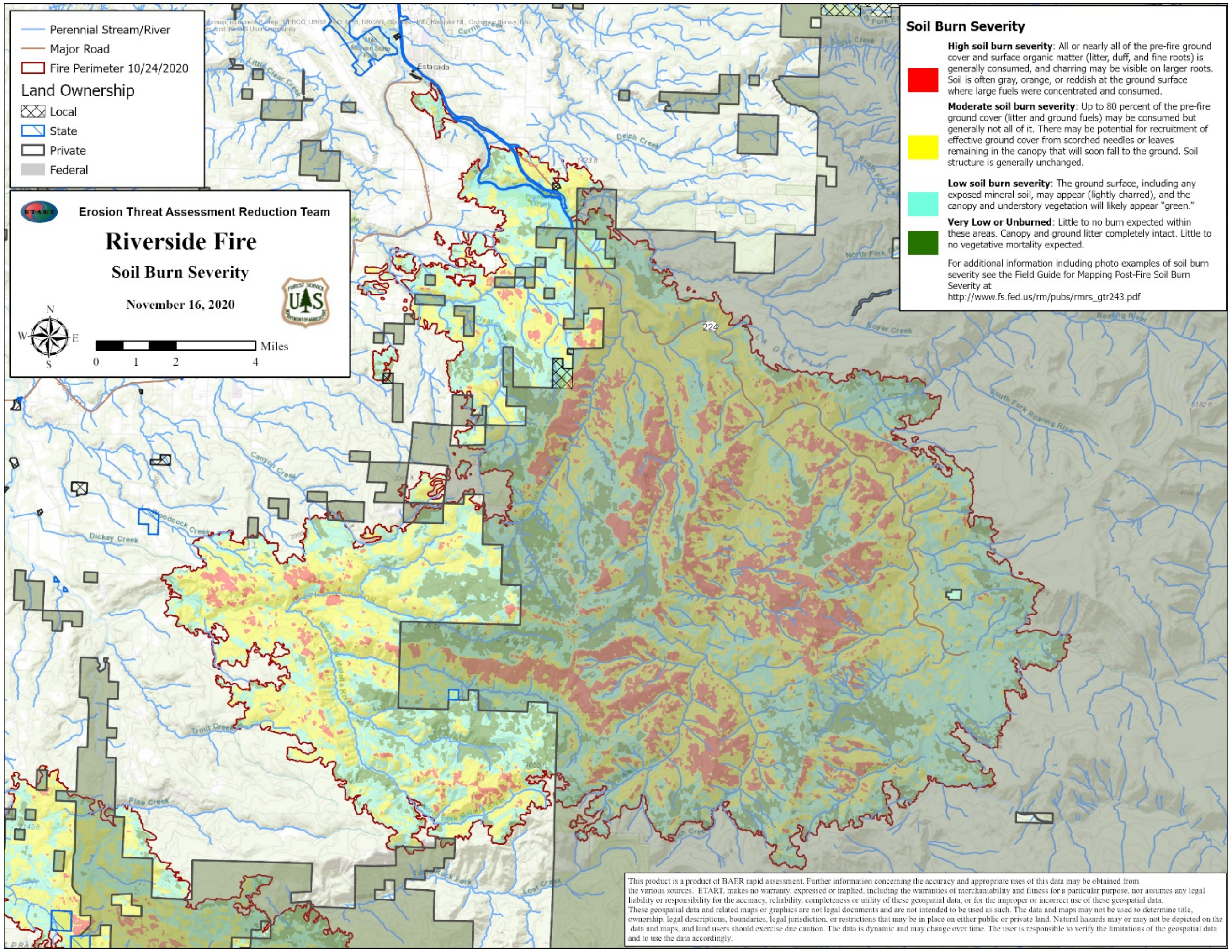
Recommended Treatment	Unit	Number of Units	Estimated Unit Cost	Total
EDRR Surveys and Treatments – Natural Vegetation Protection Areas (includes follow-up treatments on 124 acres)	acre	248	$326	$80,848
EDRR Survey and Treatments – Fire Suppression Operation Disturbances (includes follow-up treatments on 142 acres)	acre	284	$326	$92,584
Weed Wash Stations (purchase and operational expenses)	each	2	$150,000	$300,000
Community Wildfire Planning Outreach	lump sum	1	$25,000	$25,000
Threatened and Endangered Surveys	acres	248	$82	$20,336
Native Seed and Revegetation	acres	120	$1,500	$180,000
Total				**$698,768**

IV. Vegetation Mortality Map



Map 1. Vegetation Mortality - Riverside Fire

V. Soil Burn Severity Map



Map 2. Soil Burn Severity - Riverside Fire

Appendix C – Supporting Soil Information

I. Soil Types and Erosion Hazard

II. Field Indicators of Soil Burn Severity

I. Soil Types and Erosion Hazard

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
101 D	Wilhoit-Zygore gravelly loams, 5 to 30 percent slopes	Fine-loamy, mixed, frigid Andic Haplumbrepts	Slight	36.5
103 E	Zygore-Wilhoit gravelly loams, 30 to 60 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Severe	125.3
10E	Bensley stony loam, 2 to 30 percent slopes	Loamy-skeletal, mixed Dystric Cryochrepts	Slight	357.5
11F	Bensley-Valsetz stony loams, 30 to 50 percent slopes	Loamy-skeletal, mixed Dystric Cryochrepts	Moderate	719.5
11G	Bensley-Valsetz stony loams, 50 to 75 percent slopes	Loamy-skeletal, mixed Dystric Cryochrepts	Severe	791.7
17	Clackamas silt loam	Fine-loamy, mixed, mesic Typic Argiaquolls	Slight	1.5
17C	Bull Run silt loam, 3 to 15 percent slopes	Medial, mesic Umbric Vitrandepts	Moderate	624.5
17E	Bull Run silt loam, 15 to 30 percent slopes	Medial, mesic Umbric Vitrandepts	Severe	404.4
18	Camas gravelly sandy loam	Sandy-skeletal, mixed, mesic Fluventic Haploxerolls	Slight	162.5
19	Chapman loam	Fine-loamy, mixed, mesic Cumulic Ultic Haploxerolls	Slight	7.7
20	Coburg silty clay loam	Fine, mixed, mesic Pachic Ultic Argixerolls	Slight	40.5
20C	Chehalem silt loam, 3 to 12 percent slopes	Fine, mixed, mesic Cumulic Haplaquolls	Moderate	0

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
21	Chehalis silty clay loam	Fine-silty, mixed, mesic Cumulic Ultic Haploxerolls	Slight	0.5
23	Clackamas gravelly silt loam	Fine-loamy, mixed, mesic Typic Argiaquolls	Slight	5.2
24B	Cottrell silty clay loam, 2 to 8 percent slopes	Clayey, mixed, mesic Aquic Haplohumults	Slight	37.2
24C	Cottrell silty clay loam, 8 to 15 percent slopes	Clayey, mixed, mesic Aquic Haplohumults	Moderate	0.3
2C	Alspaugh clay loam, 8 to 15 percent slopes	Clayey, mixed, mesic Humic Hapludults	Moderate	158.6
2D	Alspaugh clay loam, 15 to 30 percent slopes	Clayey, mixed, mesic Humic Hapludults	Moderate	337.8
2E	Alspaugh clay loam, 30 to 50 percent slopes	Clayey, mixed, mesic Humic Hapludults	Severe	528
30D	Crabtree stony loam, 2 to 25 percent slopes	Loamy-skeletal, mixed Aquic Cryochrepts	Slight	241.8
30F	Crabtree stony loam, 25 to 45 percent slopes	Loamy-skeletal, mixed Aquic Cryochrepts	Moderate	5.6
32D	Fernwood very gravelly loam, 5 to 30 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Slight	10.6
32E	Fernwood very gravelly loam, 30 to 60 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Moderate	97.6
33F	Fernwood-Rock outcrop complex, 50 to 90 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Severe	858.1
34D	Fernwood-Wilhoit complex, 5 to 30 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Slight	1316.3
36C	Hardscrabble silt loam, 7 to 20 percent slopes	Fine, mixed, mesic Aquic Palexeralfs	Severe	1650.2
36D	Dupee silt loam, 3 to 20 percent slopes	Fine, mixed, mesic Aquultic Haploxeralfs	Severe	346.5
37D	Flane gravelly loam, 3 to 25 percent slopes	Clayey-skeletal, mixed, frigid Umbric Dystrochrepts	Slight	160.1

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
37F	Flane gravelly loam, 25 to 50 percent slopes	Clayey-skeletal, mixed, frigid Umbric Dystrochrepts	Moderate	89.1
37G	Flane gravelly loam, 50 to 75 percent slopes	Clayey-skeletal, mixed, frigid Umbric Dystrochrepts	Severe	190
38E	Highcamp very gravelly loam, 30 to 60 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Severe	12.4
38F	Flane-Moe gravelly loams, 25 to 50 percent slopes	Clayey-skeletal, mixed, frigid Umbric Dystrochrepts	Moderate	938.8
38G	Flane-Moe gravelly loam, 50 to 75 percent slopes	Clayey-skeletal, mixed, frigid Umbric Dystrochrepts	Severe	22.6
39	Fluvents-Fluvaquents complex, nearly level	Mesic Fluvents	Not rated	32.7
39F	Highcamp-Rock outcrop complex, 50 to 90 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Severe	156.1
40D	Highcamp-Soosap complex, 5 to 30 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Moderate	1900.1
40G	Harrington-Klickitat complex, 50 to 75 percent north slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Severe	319.4
42H	Harrington-Rock outcrop complex, 50 to 90 percent slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Severe	187.1
43D	Humaquepts, 2 to 20 percent slopes	Mesic Humaquepts	Moderate	181
44E	Henline very stony sandy loam, 6 to 30 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Slight	9.6
44F	Henline very stony sandy loam, 30 to 55 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Moderate	13.9
44G	Henline very stony sandy loam, 55 to 80 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Moderate	328.6
45F	Henline-Yellowstone-Rock outcrop complex, 25 to 50 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Slight	455.3
45H	Henline-Yellowstone-Rock outcrop complex, 50 to 90 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Moderate	161.1

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
47C	Kinney cobbly loam, 3 to 20 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Moderate	1269.5
47E	Kinney cobbly loam, 20 to 50 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Severe	304
49D	Kinzel-Divers complex, 5 to 30 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Slight	23.3
49E	Kinzel-Divers complex, 30 to 60 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Moderate	222.5
4E	Andic Cryaquepts, moderately steep	Aquandic Cryaquepts	Slight	1054.5
4F	Andic Cryaquepts, steep	Aquandic Cryaquepts	Moderate	83.3
50D	Hummington very gravelly loam, 5 to 25 percent slopes	Medial-skeletal Dystric Cryandepts	Moderate	45.5
50F	Hummington very gravelly loam, 25 to 50 percent slopes	Medial-skeletal Dystric Cryandepts	Severe	47.5
50G	Hummington very gravelly loam, 50 to 75 percent slopes	Medial-skeletal Dystric Cryandepts	Severe	51.9
51E	Klickitat stony loam, 30 to 60 percent slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Moderate	23.8
52D	Klickitat-Kinney complex, 5 to 30 percent slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Slight	1837.9
52F	Keel gravelly silt loam, 25 to 45 percent slopes	Medial Dystric Cryandepts	Severe	1481.2
52G	Keel gravelly silt loam, 45 to 75 percent slopes	Medial Dystric Cryandepts	Severe	9.8
54D	Kinney cobbly loam, 3 to 20 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Slight	48.3
55F	Kinney cobbly loam, 20 to 50 percent north slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Moderate	144.9
55G	Kinney cobbly loam, 50 to 70 percent north slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Severe	260.5
56	McBee silty clay loam	Fine-silty, mixed, mesic Cumulic Ultic Haploxerolls	Slight	96.4

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
58C	McCully gravelly loam, 2 to 15 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Slight	11.7
58D	McCully gravelly loam, 15 to 30 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Moderate	310.5
58E	McCully gravelly loam, 30 to 50 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Severe	245.2
58F	Kinney-Klickitat complex, 20 to 50 percent north slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Moderate	114
58G	Kinney-Klickitat complex, 50 to 70 percent north slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Severe	193.6
59F	Kinney-Klickitat complex, 20 to 50 percent south slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Moderate	61.4
59G	Kinney-Klickitat complex, 50 to 70 percent south slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Severe	202.2
5D	Aschoff cobbly loam, 5 to 30 percent slopes	Loamy-skeletal, mixed, mesic Andic Haplumbrepts	Moderate	41.6
5E	Aschoff cobbly loam, 30 to 60 percent slopes	Loamy-skeletal, mixed, mesic Andic Haplumbrepts	Severe	21.1
60E	Klickitat-Harrington complex, 3 to 30 percent slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Slight	365.1
61F	Klickitat-Harrington complex, 30 to 50 percent north slopes	Loamy-skeletal, mixed, mesic Typic Haplumbrepts	Moderate	58.1
63	Malabon silty clay loam	Fine, mixed, mesic Pachic Ultic Argixerolls	Slight	81.1
64	Malabon variant loam	Medial, mesic Typic Dystrandepts	Slight	1.1
65F	Newanna-Rock outcrop complex, 60 to 90 percent slopes	Medial-skeletal, frigid Alic Haplocryands	Severe	368.9
67	McBee silty clay loam	Fine-silty, mixed, mesic Cumulic Ultic Haploxerolls	Slight	179.1
69	Pits	0	Not rated	3.2
69B	Minniece silty clay loam, 0 to 8 percent slopes	Fine, mixed, mesic Typic Umbraqualfs	Slight	46.2

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
6F	Aschoff-Brightwood complex, 60 to 90 percent slopes	Loamy-skeletal, mixed, mesic Andic Haplumbrepts	Severe	0.8
70D	Moe gravelly loam, 3 to 25 percent slopes	Medial, frigid Andic Haplumbrepts	Moderate	472
70F	Moe gravelly loam, 25 to 50 percent slopes	Medial, frigid Andic Haplumbrepts	Severe	238.2
72D	Ritner cobbly silty clay loam, 5 to 30 percent slopes	Clayey-skeletal, mixed, mesic Dystric Xerochrepts	Moderate	46.2
73	Newberg fine sandy loam	Coarse-loamy, mixed, mesic Fluventic Haploxerolls	Slight	9.1
74H	Ochrepts, very steep	Frigid Ochrepts	Not rated	285.5
76B	Salem silt loam, 0 to 7 percent slopes	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Pachic Ultic Argixerolls	Slight	208.2
77B	Salem gravelly silt loam, 0 to 7 percent slopes	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Pachic Ultic Argixerolls	Slight	21.1
78D	Saum silt loam, 15 to 30 percent slopes	Fine, mixed, mesic Typic Xerumbrepts	Severe	60.3
80	Pits	0	Not rated	0.9
80C	Springwater loam, 8 to 15 percent slopes	Fine-loamy, mixed, mesic Typic Xerochrepts	Moderate	4.1
80D	Springwater loam, 15 to 30 percent slopes	Fine-loamy, mixed, mesic Typic Xerochrepts	Moderate	72.3
80E	Springwater loam, 30 to 60 percent slopes	Fine-loamy, mixed, mesic Typic Xerochrepts	Severe	68.1
81D	Quartzville silt loam, 2 to 25 percent slopes	Fine, mixed, mesic Andic Haplumbrepts	Moderate	476.4
82F	Quartzville silt loam, 25 to 50 percent north slopes	Fine, mixed, mesic Andic Haplumbrepts	Severe	330.6
84	Wapato silty clay loam	Fine-silty, mixed, mesic Fluvaquentic Haplaquolls	Slight	11

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
85D	Wilhoit-Zygore gravelly loams, 5 to 30 percent slopes	Fine-loamy, mixed, frigid Andic Haplumbrepts	Slight	45.2
86G	Rock outcrop-Orthents complex, steep	0	Not rated	2240
87	Salem gravelly silt loam	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Pachic Ultic Argixerolls	Slight	567.8
90F	Witzel-Rock outcrop complex, 50 to 75 percent slopes	Loamy-skeletal, mixed, mesic Lithic Ultic Haploxerolls	Severe	0.5
91D	Alspaugh clay loam, 15 to 30 percent slopes	Clayey, mixed, mesic Humic Hapludults	Moderate	27.2
92	Sifton variant gravelly loam	Sandy-skeletal, mixed, mesic Andic Xerumbrepts	Slight	0.2
94E	Zygore gravelly loam, 30 to 60 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Severe	246.2
95E	Zygore-Wilhoit gravelly loams, 30 to 60 percent slopes	Loamy-skeletal, mixed, frigid Andic Haplumbrepts	Severe	169.8
96E	Highcamp very gravelly loam, 30 to 60 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Severe	1505.4
97F	Highcamp-Rock outcrop complex, 50 to 90 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Severe	14.2
98D	Highcamp-Soosap complex, 5 to 30 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Moderate	325
99E	Kinzel-Divers complex, 30 to 60 percent slopes	Medial-skeletal, frigid Typic Haplocryands	Moderate	14.8
Ad	Alluvial land	Mesic Xerofluvents	Not rated	696.7
Ca	Camas gravelly sandy loam	Sandy-skeletal, mixed, mesic Fluventic Haploxerolls	Slight	78.9
CLD	Cumley silty clay loam, 2 to 20 percent slopes	Clayey, mixed, mesic Typic Palehumults	Moderate	1372.8
Cm	Cloquato silt loam	Coarse-silty, mixed, mesic Cumulic Ultic Haploxerolls	Slight	994.5

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
HEE	Henline extremely stony sandy loam, 6 to 30 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Slight	62.7
HEF	Henline extremely stony sandy loam, 30 to 55 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Moderate	401.4
HEG	Henline extremely stony sandy loam, 55 to 80 percent slopes	Loamy-skeletal, mixed Entic Cryumbrepts	Moderate	1325.2
HRD	Horeb loam, 2 to 20 percent slopes	Fine-loamy, mixed, mesic Typic Haplumbrepts	Moderate	4295.8
HSC	Horeb gravelly silt loam, gravelly substratum, 0 to 15 percent slopes	Fine-loamy, mixed, mesic Typic Haplumbrepts	Slight	1605.4
HSE	Horeb gravelly silt loam, gravelly substratum, 15 to 35 percent slopes	Fine-loamy, mixed, mesic Typic Haplumbrepts	Moderate	1299.1
HTD	Hullt clay loam, 2 to 20 percent slopes	Fine-loamy, mixed, mesic Typic Xerumbrepts	Moderate	400.1
HTE	Hullt clay loam, 20 to 30 percent slopes	Fine-loamy, mixed, mesic Typic Xerumbrepts	Severe	15.2
HTF	Hullt clay loam, 30 to 60 percent slopes	Fine-loamy, mixed, mesic Typic Xerumbrepts	Severe	30.8
JoB	Jory silty clay loam, 2 to 7 percent slopes	Clayey, mixed, mesic Xeric Palehumults	Slight	10.8
KCD	Kinney cobbly loam, 2 to 20 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Slight	27.6
KCF	Kinney cobbly loam, 20 to 50 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Moderate	4078.1
KCG	Kinney cobbly loam, 50 to 70 percent slopes	Fine-loamy, mixed, mesic Andic Haplumbrepts	Severe	7129.7
MaA	McAlpin silty clay loam, 0 to 3 percent slopes	Fine, mixed, mesic Cumulic Ultic Haploxerolls	Slight	380.7
MaB	McAlpin silty clay loam, 3 to 6 percent slopes	Fine, mixed, mesic Cumulic Ultic Haploxerolls	Slight	29.8
Mb	McBee silty clay loam	Fine-silty, mixed, mesic Cumulic Ultic Haploxerolls	Slight	0.3

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
McB	McCully clay loam, 2 to 7 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Slight	34
McC	McCully clay loam, 7 to 12 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Slight	167.6
McD	McCully clay loam, 12 to 20 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Moderate	151.5
McE	McCully clay loam, 20 to 30 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Moderate	30.6
MmE	McCully very stony clay loam, 2 to 30 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Slight	2.8
MUE	McCully clay loam, 2 to 30 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Moderate	2157
MUF	McCully clay loam, 30 to 50 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Severe	3289.8
MUG	McCully clay loam, 50 to 70 percent slopes	Fine, mixed, mesic Typic Haplumbrepts	Severe	5712.8
MYB	Minniece silty clay loam, 0 to 8 percent slopes	Fine, mixed, mesic Typic Umbraqualfs	Slight	2373
NeB	Nekia silty clay loam, 2 to 7 percent slopes	Clayey, mixed, mesic Xeric Haplohumults	Slight	456.3
NeC	Nekia silty clay loam, 7 to 12 percent slopes	Clayey, mixed, mesic Xeric Haplohumults	Moderate	70.2
NeD	Nekia silty clay loam, 12 to 20 percent slopes	Clayey, mixed, mesic Xeric Haplohumults	Moderate	114.7
NsF	Nekia very stony silty clay loam, 30 to 50 percent slopes	Clayey, mixed, mesic Xeric Haplohumults	Severe	114.2
Nu	Newberg fine sandy loam	Coarse-loamy, mixed, mesic Fluventic Haploxerolls	Slight	326.4
Nw	Newberg silt loam	Coarse-loamy, mixed, mesic Fluventic Haploxerolls	Slight	6.7
PITS	Pits	0	Not rated	9.1

Map Unit	Name	Taxonomic Classification	Soil Erosion Hazard	Total Map Unit Acres
Sa	Salem gravelly silt loam	Fine-loamy over sandy or sandy-skeletal, mixed, mesic Pachic Ultic Argixerolls	Slight	2.1
St	Sifton gravelly loam	Medial over sandy or sandy-skeletal, mixed, mesic Typic Melanoxerands	Slight	98.1
Sy	Stony rock land	0	Not rated	435.3
W	Water	0	Not rated	35.6
Wa	Waldo silty clay loam	Fine, mixed, mesic Fluvaquentic Endoaquolls	Slight	530.7
Wc	Wapato silty clay loam	Fine-silty, mixed, mesic Fluvaquentic Endoaquolls	Slight	12.7
WHE	Whetstone stony loam, 3 to 25 percent slopes	Loamy-skeletal, mixed, frigid, ortstein Typic Haplocryods	Not rated	7.6
WHF	Whetstone stony loam, 25 to 55 percent slopes	Loamy-skeletal, mixed, frigid, ortstein Typic Haplocryods	Not rated	1054.3
WHG	Whetstone stony loam, 55 to 75 percent slopes	Loamy-skeletal, mixed, frigid, ortstein Typic Haplocryods	Not rated	4135.3

II. Field Indicators of Soil Burn Severity

Indicator	Importance	Low	Moderate	High
Ash depth and color	Ash, while nutrient rich, is susceptible to loss through wind and rain	May be black or gray, and ash is shallow. Natural duff remains	Dominantly gray and variable depths. All duff consumed.	Typically gray and white, with areas of deep ash. All duff is consumed, and in some places, reddish oxidized soil may be present on the surface. In some instances, ash is lost from wind erosion during the fire.
Soil Char	Indicates soil organic matter consumption in the upper portions of the soil	Nonexistent or very thin	Thin, from 0.5 to 2 cm deep	Thick or variable, with charred soil extending 2 cm and deeper
Roots	Live roots may indicate speedier vegetation recovery, while loss of live roots may signal slower recovery	Fine roots are alive, flexible, and intact	Fine roots are brittle or charred, deeper and larger roots may remain viable	Fine roots are entirely consumed. Larger roots may be brittle and charred.
Soil Structure	Soil structure provides resistance to erosion from rain drop impacts and overland flow. Loss of structure increases susceptibility to erosion	Soil retains natural structure.	Soil structure may be minimally altered at the surface, but not at depth	Soil structure is lost in the upper surface and has a powdery texture and appearance.

Indicator	Importance	Low	Moderate	High
Hydrophobicity	Hydrophobicity reduces water infiltration and increases runoff	Naturally present in volcanic ash soils and persisting at depth	Natural hydrophobic properties are minimally altered by heat. May be interrupted at surface, but alterations are patchy and inconsistent	Native hydrophobicity interrupted at soil surface with fire-induced hydrophobicity be present depths more than 4 cm below the soil surface

Appendix D – Supporting Geologic Hazards Information

I. Figures and Photos
II. Summary of Critical Values and Geohazards

I. Figures and Photos

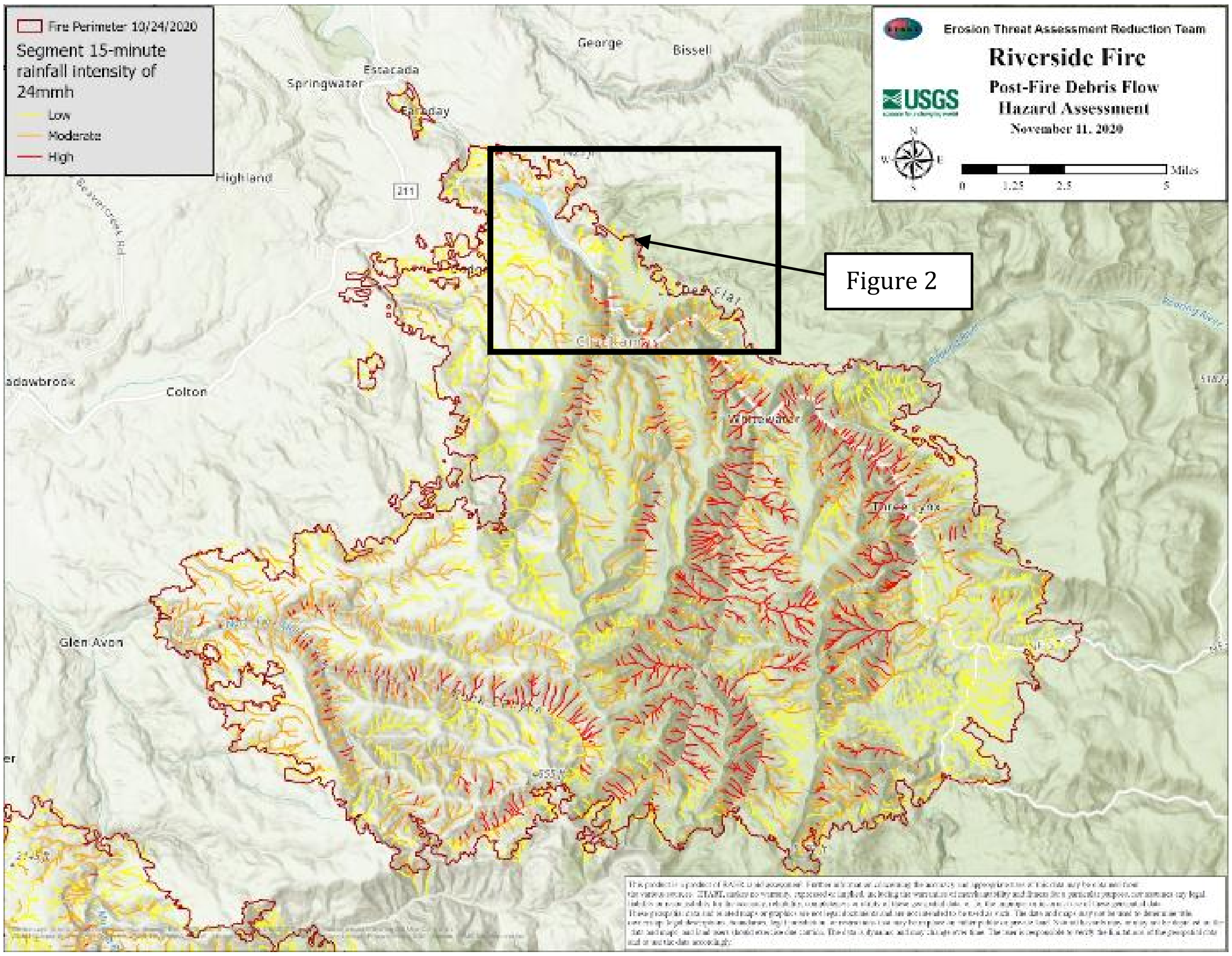


Figure 1: The map displays estimates of the combined relative debris flow hazard. These predictions are made at the scale of the drainage basin, and at the scale of the individual stream segment. Estimates of combined hazard are based upon a design storm with a peak 15-minute rainfall intensity of 24 millimeters (~1 inch) per hour (mm/h).

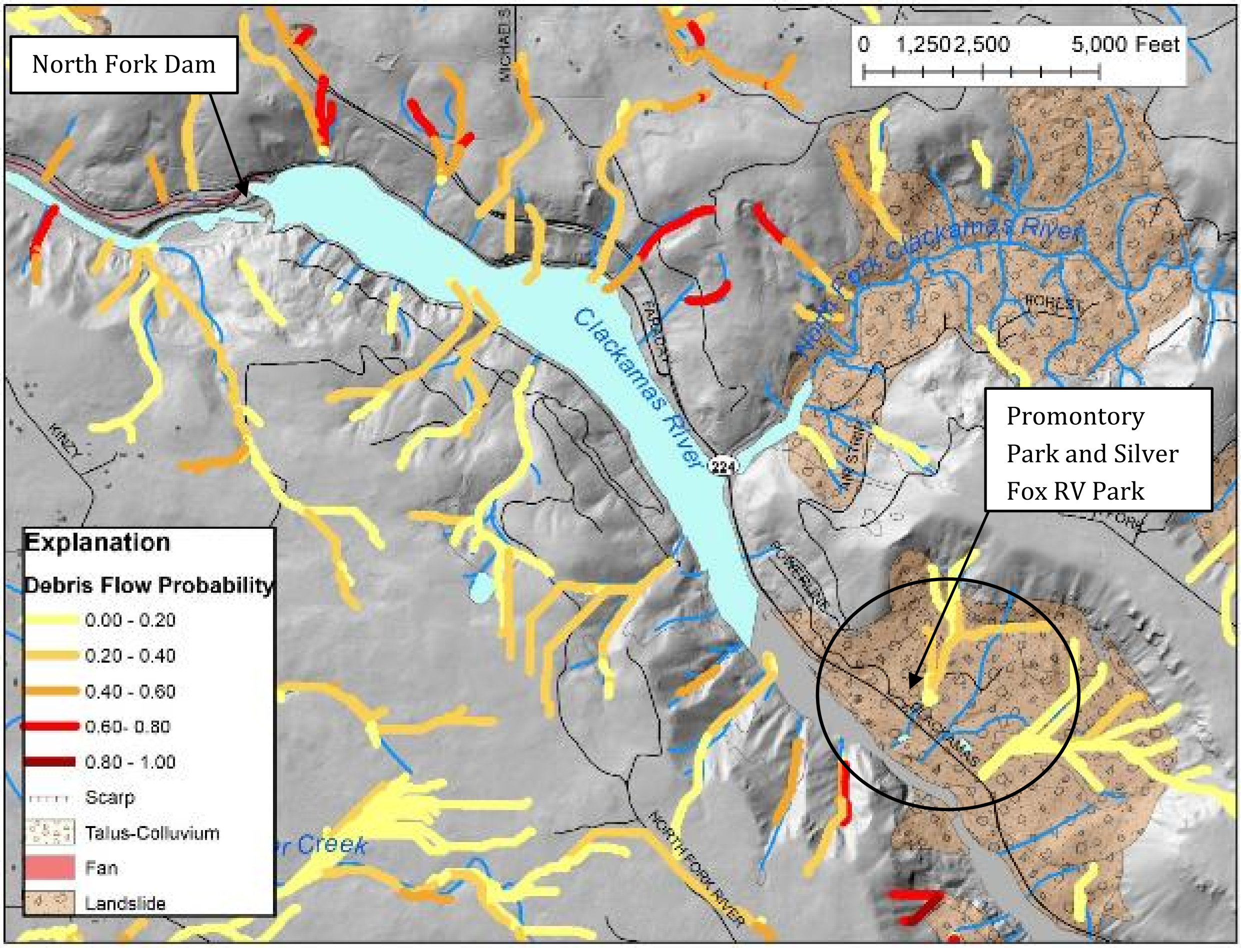


Figure 2: North Fork Reservoir will potentially receive some low to moderate hazard debris flows. Promontory Park and Silver Fox RV Park are located very close to a small channel that has low debris flow hazard and on deep landslide deposits which could reactivate in the next 0 -10 years. Map includes USGS debris flow hazard channels and DOGAMI SLIDO landslide areas.

Photo 1: Example of a debris flow hazard sign that can be placed along roads impacted by the fire. Signs must have large enough letters to be read at driving speed.

II. Summary of Critical Values and Geohazards

Value Description	Owner	Threat to Value	Debris Flow Hazard (1-inch /h of rain in 15 min)	Probability	Magnitude of Consequence	Risk	Risk Reduction Options
North Fork Reservoir Dam	USACE	Debris Flow	Low	Possible	Minor	Low	monitor
▪ Debris flow channels enter the reservoir. But most are moderate to low							
Silver Fox RV Park	Community	landslide, Debris flow	Low	Possible	Minor	Low	monitor
▪ Some debris flow channels leading down to the park. The entire park is on a large deep landslide which has the potential to move post-fire. Landslide could reactivate.							
Town of Dodge	Community	Debris flow	Low	Unlikely	Minor	Very Low	monitor
▪ Most of the channels are low df hazard, but a handful are moderate.							

Appendix E – Supporting Hazard Tree Information

Table 1. Failure indicators for imminent, likely, and low-failure potentials for trees along forest roads and work sites in Oregon and Washington.

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
Dead Trees	*Old dead trees* (≥5 years) No foliage or fine branches; bark is absent or falling off	All tree species except cedar, juniper, larch, or large (≥20 in. dbh) Douglas-fir	Cedar, juniper, larch, or large Douglas-fir with no other visible indicators	None
	Recent dead trees (<5 years) All or some foliage; fine branches; bark mostly intact	All trees <10 in. dbh	All trees ≥10 in.dbh except cedar, juniper, larch, or large Douglas-fir	Cedar, juniper, larch, or large Douglas-fir
	Recent dead trees in *root disease centers* (p. 59-66)	All tree species except cedar	Cedar	None
Roots	Live trees in laminated root rot centers (p. 64) *Phellinus sulphurascens*	Trees with signs or symptoms (ectotrophic mycelium or laminated decay; foliage thinning or yellowing)	Douglas-fir, mountain hemlock, or true firs *without* signs or symptoms and ≤25ft. from an infected tree or stump	Douglas-fir, mountain hemlock, or true firs *without* signs or symptoms and >25ft. from an infected tree or stump; All other species *without* signs or symptoms

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
	Live trees in Armillaria or Heterobasidion root disease centers *Armillaria* spp. (p. 60) *Heterobasidion* spp. (p. 62)	Trees with signs or symptoms (mycelial fans, resinosis, staining, conks, or wounds with decay; foliage thinning or yellowing) and adjacent (≤50 ft.) to windthrown trees with root disease	Trees with signs or symptoms but not adjacent to windthrown trees with root disease	Trees without signs or symptoms
	Live trees in black stain or Port-Orford-cedar root disease centers *Leptographium wageneri* (p. 62) *Phytophthora lateralis* (p. 65)	None	None	All trees
	Live trees with undermined or severed roots (p. 66)	Trees with <50% of the structural roots remaining in the ground	Trees with 50 to 75% of the structural roots remaining in the ground	Trees with >75% of the structural roots remaining in the ground

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
Butt	Butt rot (p. 66-69) *Schweinitzii* (cow- pie conk) *Tomentosus* (spruce rot conk) *Ganoderma* (artist's and varnish conks)	Trees with ≥1 conk(s) associated with open cracks or exposed decay	Trees with ≥1 conk(s) not associated with open cracks or exposed decay	Trees with butt swell but no conks
	Living, fire-damaged trees for recent (<5yr) fire damage; use bole-wounds for old fire damage (p. 70)	True fir, hemlock, spruce, or hardwoods with >50% of the bole cross-sectional area burned and consumed, or more than one quadrant of burned and consumed structural roots Douglas-fir, pine, cedar, juniper, or larch with >75% of the bole cross-sectional area burned and consumed, or more than one quadrant of burned and consumed structural roots	True fir, hemlock, spruce, or hardwoods with 25 to 50% of the bole cross-sectional area burned and consumed, or one quadrant of burned and consumed structural roots Douglas-fir, pine, cedar, juniper, or larch with 50 to 75% of the bole cross-sectional area burned and consumed, or one quadrant of burned and consumed structural roots	True fir, hemlock, spruce, or hardwoods with <25% of the bole cross-sectional area burned and consumed, and no burned and consumed structural roots Douglas-fir, pine, cedar, juniper, or larch with <50% of the bole cross-sectional area burned and consumed, and no burned and consumed structural roots

Failure Indicator		**Failure Potential**		
		Imminent	**Likely**	**Low**
Bole/Stem	Bole wounds mistletoe cankers, fungal cankers, or old fire wounds (≥5 years) (p. 71-80)	True fir, hemlock, spruce, or hardwoods with <50% cross- section of bole with sound wood Douglas-fir, pine, cedar, juniper, or larch with <25% cross-section with sound wood	True fir, hemlock, spruce, or hardwoods with 50 to 75% cross-section of bole with sound wood Douglas-fir, pine, cedar, juniper, or larch with 25 to 50% cross- section with sound wood	True fir, hemlock, spruce, or hardwoods with >75% cross- section of bole with sound wood Douglas-fir, pine, cedar, juniper, or larch with >50% cross- section with sound wood
	Frost cracks (p. 82)	None	Trees with weeping cracks	Trees without weeping cracks
	Bole cracks (p. 82)	Trees with open splits or cracks with independent movement or exposed rot	Trees with open splits or cracks without movement or exposed decay	Trees with sealed cracks
	Burls (p. 82)	None	None	All trees
	Quinine conks (p. 86) *Laricifomes officinalis*	Trees with ≥1 conk(s)	None	None
	Indian paint fungus conks (p. 92) *Echinodontium tinctorium*	Trees with multiple, large (≥6 in. wide) conks; Single, large conk or multiple, small conks associated with open cracks or exposed rot	Trees with single, large conk or multiple, small conks not associated with open cracks or exposed rot	Trees with a single, small conk

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
	Red ring rot conks, white speck (p. 90) *Porodaedalea pini*	Trees with ≥1 conk(s) associated with extensive advanced decay[1] such as open cracks or exposed rot	True fir, hemlock, spruce, or hardwoods with ≥1 conk(s) not associated with extensive advanced decay; Douglas-fir, pine, cedar, juniper, or larch with ≥3 large conks (≥6 in. wide) within a 3-ft.-long trunk cylinder	Douglas-fir, pine, cedar, juniper, or larch with ≥3 large conks not within a 3-ft.-long trunk cylinder; ≤2 large conks within a 3-ft.-long trunk cylinder; any number or location of small conks
	Other heart-rot conks (p. 84-93)	Trees with ≥1 conk(s) associated with open cracks or exposed rot	Trees with ≥1 conk(s) not associated with open cracks or exposed rot	None
	Sap-rot conks *Cryptoporus volvatus* (pouch conk) (p. 95) *Fomitopsis pinicola* (red-belt conk) (p.94)	Dead trees with ≥1 red-belt conk(s)	Live trees with ≥1 red-belt conk(s) usually associated with bole wounds	Live trees with ≥1 pouch conk(s); check for extent of dead bark and sound wood
Tops and Branches	Forked or multiple tops or stems (p. 97)	Trees with any fork associated with open cracks, decay, or conks* (tops are imminent FP, not the whole tree unless fork is at the base)	Trees with V-shaped forks with embedded bark but not associated with open cracks, decay, or conks* (tops are likely FP, not the whole tree unless fork is at the base)	Trees with U-shaped forks and no open cracks, decay, or conks*; V-shaped forks with no embedded bark, open cracks, decay, or conks* (tops are low FP, not the whole tree unless fork is at the base)

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
	Dead tops or branches (≥3 in. diameter) (p. 96)	True fir, hemlock, spruce, or hardwoods ≥5 years dead or with red-belt conks (tops and branches are imminent FP, not the whole tree)	True fir, hemlock, spruce, or hardwoods <5 years dead; Douglas-fir ≥5 years dead (tops and branches are likely FP, not the whole tree)	Cedar, larch, juniper, or pine; Douglas-fir <5 years dead (tops and branches are low FP, not the whole tree)
*Any conk except for red ring rot conks (*P. pini*) on forked Douglas-fir, pine, cedar, juniper, or larch.				
Tops and Branches	Detached tops, branches (≥3 in. diameter), or bark (≥1 ft.^{2}) (p. 96)	All detached parts (parts are imminent FP, not the whole tree)	Live and attached tops or branches but cracked or split (parts are likely FP, not the whole tree)	None
	Dwarf mistletoe brooms (p. 98)	None	Trees with large (≥10ft. in diameter) dead brooms (broom is likely FP, not the whole tree)	Trees with small, dead brooms or live brooms (broom is low FP, not the whole tree)
	Cottonwood branches (p. 97)	Trees with large (≥3 in. diam.) dead branches (branches are imminent FP, not the whole tree)	Trees with large, live branches with evidence of decay or past breakage (branches are likely FP, not the whole tree)	Trees with large, live branches with no evidence of decay or past breakage
Whole Tree	Broken or uprooted trees supported by other trees (p. 99)	All	None	None

Failure Indicator		Failure Potential		
		Imminent	**Likely**	**Low**
	Leaning and/or root-sprung trees (p. 99)	Trees with recent (<5yr) leans $\geq$15 degrees or old, uncorrected leans with freshly disturbed soil or root damage	Trees with recent leans $\geq$15 degrees or old, uncorrected leans without freshly disturbed soil or root damage	Trees with old, corrected leans
	Height to diameter ratio (p. 100)	Trees with >100 H:D ratio[2]	Trees with 80 to100 H:D ratio	Trees with <80 H:D ratio
	Multiple indicators (p. 113)	Two or more likely-FP indicators with synergistic effects: one condition (indicator) worsens the other (i.e. recently killed true fir with a large, Indian paint fungus conk)	Two or more low-FP indicators with synergistic effects (i.e. 15% severed roots and an old, corrected lean); two or more likely-FP indicators without synergistic effects (i.e. true fir with a weeping frost crack and a recently killed top)	Two or more low-FP indicators without synergistic effects (i.e. top-killed cedar with two *P. pini* conks on the live bole)

[1]Firm wood with white speck or firm wood with red discoloration is not considered advanced decay from *P. pini*. Advanced decay is very soft and crumbly.

[2]To calculate H:D ratio, divide the total tree height in feet by the diameter breast height (dbh)

Appendix F – Fish and Wildlife Values at Risk Table

Table 1. VAR table

Critical Value	Opportunity to Benefit Value	Probability and Rationale	Magnitude of Consequence and Rationale	Reward	Treatment Options Considered	Recommended Treatment
Refugia (Intact Ecosites/Ecosystems)	Intact ecosystems - low burn severity, low vegetation mortality, and low road/trail disturbance factor - are important refugia and source areas, and thus are important to post-fire maintenance and recovery of species.	Likely - Refugia/ecosites with low burn severity and low vegetation mortality are likely very important to species displaced by the fire - particularly late seral obligates - given large areas burned and the extent of moderate to high burn intensity and severity.	Major - Protection of remaining core habitat is critical to retaining source populations of some species, as loss of late successional forest will have long-term effect on species such as the Northern spotted owl.	Very High	Allow for natural regeneration, minimize disturbance, and manage access if necessary	Work with partners to encourage natural regeneration and minimize disturbance to the extent practicable

Standing Dead Wood	Retaining burned wood on the landscape supports a variety of terrestrial species.	Likely - Large areas of high severity fire will result in a high density of snags and woody debris that are used by a variety of terrestrial species.	Moderate - Use of severely burned forest by late successional species such as Northern spotted owl will depend on patch size and availability of unburned or lightly burned habitat nearby.	High	Allow for natural regeneration, limit salvage logging, limit disturbance	Work with partners to encourage natural regeneration and limit salvage to the extent practicable
Early-successional Ecosystems	Management of early seral habitat created by these burns (both forest and meadow) can ensure desireable successional pathways, and provide pollinator habitat and deer and elk forage.	Likely - The fire converted large areas of forest to early seral habitat that is vulnerable to invasive species, unregulated vehicle intrusions, other kinds of disturbance, and in some places with high soil burn severity, lack of revegetation.	Moderate - Measures that limit or control invasive species and other kinds of disturbance are critical to recovery of desireable early seral plant species, particularly in areas of moderate to high burn severity.	High	Control invasive species, reseed or revegetate where appropriate, and limit other disturbances such travel management.	Work with partners to prioritize invasive species EDRR*, limit travel vectors, and prioritize revegetation and reseeding as needed for native plants, pollinators, and high forage value.

Security Cover	Limiting motorized vehicle access to newly accessible security cover will protect vulnerable species.	Very Likely - Access to previously closed roads may have opened up due to the burn, exposing areas with reduced hiding cover and sensitive unburned areas. Additional road closures may be needed, particularly if deer and elk populations increase.	Major - Security cover is limiting post-fire, and vehicle access into these habitats compromises security. Some areas previously inaccessible pre-fire are now accessible. Protecting these areas from vehicle intrusions will thus preserve secure habitat.	Very High	Maintain road closures and limit motorized access in areas with habitat providing security cover.	Work with partners to maintain existing road closures and identify need for additional closures to protect or provide security cover.
Stable slopes/soil	Mass wasting and soil erosion can result in terrestrial habitat loss and lower water quality.	Possible - Reseeding areas or mulching areas with high soil burn severity, vegetation mortality and risk of debris flow may improve habitat and reduce erosion.	Moderate - Efforts to stabilize slopes could protect habitat from slides. Reseeding roadbeds could reduce erosion and provide valuable forage.	Intermediate	Hill slope treatments, including reseeding where appropriate.	Work with partners to stabilize slopes, reseed where appropriate.

Large Woody Debris (LWD): Various locations	Maintaining standing or dead trees within the riparian zone will be critical to post fire recovery/long term improvement of habitat. As these trees enter the river they create high quality habitat for salmonids	Possible - Variable depending on extent of post fire salvage logging within riparian zone	Major - Many of these systems have historically low levels of LWD, this could potentially reset the system and provide significant long term benefits in terms of creating suitable habitat for aquatic and terrestrial spp.	High	Alternative salvage logging practices to retain LWD in streams to the extent practicable	Work with partners to encourage salvage logging practices that retain LWD for recruitment into stream channels
Riparian Shade: Portions of Clear Creek, Molalla River, Clackamas River, Collawash RIver	Allowing a mix of hardwood/conifer in riparian areas provides more rapid recovery of intermediate shading	Possible - Will be variable depending on burn severity and extent of active management	Major - Many streams within the burn areas have summer temperatures close to thermal tolerance limits-rapid shading from hardwoods may be key to ensuring these streams remain suitable during summer in the near term	High	Reseeding practices and/or natural regeneration practices that will result in riparian shading more quickly	Work with partners to identify alternate reseeding practices and/or natural regeneration for riparian shading

Keystone species	Allowing for some proportion of the riparian area to regenerate with hardwoods provides conditions for beaver to construct dams that benefit a range of aquatic spp	Possible - Will be variable depending on management goals	Major - Beaver are ecosystem engineers that create habitat suitable for many aqautic species, including salmonids. To build dams, beavers require sutiable plant material (typically willow, alder etc)	High	Reseeding practices and/or natural regeneration practices that will result in beaver habitat long-term	Work with partners to identify alternate reseeding practices and/or natural regeneration for long-term beaver habitat
Connectivity	Replacement of burned/washed out culverts structures	Likely - Given scale of fires and the number of culverts on the landscape it is likely that some were or will be impacted.	Major - Restoration of passage allows fish to access habitat above these sites	High	Aquatic organism passage options at culvert blockages	Work with partners to identify priorities and options for fish passage at culverts

Critical Value	Threat to Value	Probability and Rationale	Magnitude of Consequence and Rationale	Risk	Treatment Options Considered	Recommended Treatment
Water quality (contaminants)	Runoff from urban areas containing hazardous wastes poses risk to aquatic species	Likely - A number of urban areas were subject to fire damage and are in proximity to waterways. Efforts to remove hazardous wastes are underway but in some instances surface runoff from rains has already occurred, or will occur before wastes are removed.	Moderate - Environmentally persistent contaminants that are introduced to waterways may have multigenerational impacts. Other more transient chemcicals will likely have impact on 1-2 generations within the area of exposure	Intermediate	Prioritize hazardous waste removal in proximity to waterways	Work with partners to identify prioritize hazardous waste removal in proximity to waterways
Water quality (turbidity)	Runoff of ash and sediment represents a near-term threat to spawning success for salmonids and lamprey	Very Likely - A large portion of several watersheds containing spawning habitat for salmon, trout, and lamprey was burned leaving significant ash deposits (source). Control measures will not be sufficient to prevent this from entering waterways during rain events	Minor - Some areas may experience increased redd failure but likely there is sufficient alternate spawning habitat to sustain populations	Low	None	None

Water quality (temperature)	Loss of riparian shading leading to increased stream temperatures	Very Likely - A number of stream reaches experienced complete or partial loss of trees in riparian areas. This will result in increased solar radiation entering streams until vegetation regenerates	Moderate - Temperature increases are likely to last multiple years (potentially 10+ years in high burn severity areas) thereby impacting several generations. In a number of locations that were burnt, stream temperatures during summer were already close to the thermal tolerance limits for fish species. The actual magnitude will depend on future climatic conditions and pace of regeneration (e.g., drought)	Very High	Natural regeneration and/or reforestation with mixed hardwood conifer	Work with partners to encourage natural regeneration and/or reforestation with mixed hardwood conifer

Water quantity (flood)	Increased runoff resulting from lack of vegetative cover may result in higher peak flows leading to increased scour of redds and/or displacement of some species	Likely - A number of watersheds experienced high levels of vegetative mortality and mid/low elevation. Winter forecasts suggest a likelihood of wetter weather. This combination of conditions creates higher likelihood of significant rainstorm/runoff events	Minor - Impacts are likely to be transient (affect 1-2 generations) and spatially heterogenous	Low	None	None
*EDRR - Early Detection Rapid Response, strategy used for invasive species management						

Appendix G - Supporting Hydrology Information

I. Values at Risk Table

Critical Value	Threat to Value	Probability of Damage or Loss and Rationale	Magnitude of Consequence and Rationale	Risk	Treatment Options Considered	Recommended Treatment
Get N Go Promontory Marina Estacada; North Fork Reservoir Dam	Woody debris build up	Likely - Large woody debris already evident in marina; high wood recruitment due to burned trees	Moderate - Low velocity flow in reservoir	High	Increased frequency of inspection for removal	Increased frequency of inspection for removal
Boater's on North Fork Reservoir	Floating woody debris	Likely - Pre-existing condition; high tree mortality will contribute to increased woody debris	Major - Could result in injury or death impacted while boating	Very High	Signage at boat dock/marina	Signage at boat dock/marina; removal of woody debris
Fish Ladder	Burnt trees impacting structure	Possible - Hazard trees - mostly low severity	Minor - Burn severity adjacent to fish ladder mostly low and some moderate	Low	Fell hazard trees that would impact structure	Fell hazard trees that would impact structure

Critical Value	Threat to Value	Probability of Damage or Loss and Rationale	Magnitude of Consequence and Rationale	Risk	Treatment Options Considered	Recommended Treatment
Boat launches on North Fork Reservoir; Silver Fox RV park	Burnt trees impacting structure	Possible - Hazard trees - mostly low severity	Moderate - Could result in property damage or loss; impact access to boat launch	Intermediate	Fell hazard trees that would impact structure	Fell hazard trees that would impact structure
Boat launches on North Fork Reservoir; Silver Fox RV park	Hazard trees	Possible - Hazard trees - mostly low severity	Major - Hazard could result in injury or death to guests/visitors to RV park and boat launches	High	Fell hazard trees that would impact human lives	Fell hazard trees that would impact human lives; propose closure of facilities until trees can be assessed; post signage for caution
Bridge on S Dickie Prairie Rd x S Megan Ave; nearby homes	Woody debris build up	Possible - High tree mortality will contribute to increased woody debris	Moderate - Could result in property damage or loss	Intermediate	Increased frequency of inspection for removal	Increased frequency of inspection for removal. Notify ODOT; 45.083715, -122.489072
Molalla City water intake	Increased deposition of gravel and fine sediment	Likely - modeled increase in peak flows, reduced ground cover	Moderate - Have ~3 days of reserve to shut down intake during high water	High		Increase frequency of inspection and debris removal, outreach to public on water usage

II. Peak Flow Modeling

Regional regression equations were used in order to estimate pre-fire peak flows for western Oregon streams. The prediction equations were developed for estimating peak discharges at ungaged sites for various return intervals by relating peak discharges to physical and climatological watershed characteristics (Cooper, 2005). The equations are valuable for estimating peak flows in rural, unregulated drainages which derive a significant portion of their streamflow from storm runoff and/or snowmelt and are a commonly accepted method for estimating peak flows in ungaged basins. Regression equations were developed specific to hydrologic regions defined by the processes which largely influence peak flows, such as rain only, snowmelt, and/or rain-on-snow. Watersheds within each hydrologic region show similar flood frequency relationships, and display similarities in watershed, geomorphological, and meteorological characteristics. It is important to note that prediction equations do not account for reservoir operations, diversions, or urbanization, and the estimates of peak flows represent a hypothetical situation of the watershed, not the actual condition. For further discussion of the assumptions, methodologies, and errors associated with the prediction equations, refer to Cooper (2005).

Basins were delineated for poursheds of interest, which typically contained critical values that required further assessment to understand elevated risk associated with increased peak flows. ArcGIS was used to delineate basins and extract watershed characteristics. The methodology developed by Cooper (2005) contains equations to estimate instantaneous peak flows with annual exceedance probabilities of 50, 20, 10, 4, and 2 percent, corresponding to recurrence intervals of 2, 5, 10, 25, and 50 years, respectively. Given the setting of the burned areas in the Middle Clackamas and Upper Molalla watersheds, equations 1 and 2 were used to estimate pre-fire peak flows for watersheds with mean elevations below and above 3000 feet:

Q2 = 100.9607Area0.9004Slope0.4695I24-20.8481 [1] – elevation < 3000 ft

Q2 = 10-2.506Area1.021Slope0.8124I24-22.050MinJanTemp3.541MaxJanTemp-1.867 [2] – elevation > 3000 ft

where Area = drainage area (sq mi), Slope = mean watershed slope (degrees), I24-2 = 2-year, 24-hour rainfall intensity (inches), MinJanTemp = mean minimum January temperature (degrees F), and MaxJanTemp = mean maximum January temperature (degrees F). Coefficients were also calibrated to develop additional equations for estimating peak flows at return intervals of 5, 10, 25, and 50 years for each region (see Cooper, 2005). In circumstances where a stream gage is located on the same stream as the ungaged watershed of interest, and the gaged watershed is between 50 and 150 percent of the ungaged watershed area, it is advised that peak discharges for ungaged watersheds, Qu(T), be determined directly from peak discharges for the gaged watershed using equation 3:

Qu(T) = Qg(T)*(Au/Ag)Ca(T) [3]

where Qa(T) = peak discharge for gaged watershed at return interval T (cfs), Au = area of ungaged watershed (sq mi), Ag = area of gaged watershed (sq mi), and Ca(T) is the coefficient for area for the specified hydrologic region and return interval T.

Post-fire peak flows were estimated by modifying pre-fire peak flow estimates based on the weighted area of low, moderate, and high soil burn severity. Q50 was applied to high burn severity, Q25 was applied to moderate burn severity, and the area of low burn severity was split evenly between Q10 and Q5 peak flows ([USDA, 2009]; note: Qn represents the discharge in cubic feet per second associated with the n-year recurrence interval). Post-fire peak flows at the 2-year and 5-year recurrence interval were estimated using equations 4 and 5:

Q2post = (%Areaunburned)(Q2) + (%Arealow)(Q5) + (%Areamod/2)(Q5) + (%Areamod/2)(Q10) + (%Areahigh)(Q10) [4]

Q5post = (%Areaunburned)(Q5) + (%Arealow/2)(Q5) + (%Arealow/2)(Q10) + (%Areamod)(Q25) + (%Areahigh)(Q50) [5]

Where %Area represents the percent of watershed area classified based on soil burn severity (i.e. unburned/outside, low, moderate, or high) and Qn represents the pre-fire peak flow at the specified return interval.