FINAL REPORT

Oregon Route 224 Corridor Study:
Phase 1 – Existing Conditions Assessment

October 2021

United States Department of Agriculture

Prepared for:
U.S. Forest Service
Mount Hood National Forest

U.S. Department of Transportation

Prepared by:
Federal Highway Administration
Western Federal Lands Highway Division

This page intentionally left blank.

Table of Contents

Executive Summary

In 2020, the Mount Hood National Forest experienced unprecedented catastrophic wildfire events that damaged recreational sites and transportation assets along the Clackamas River corridor. A 19-mile segment of OR 224, the primary route connecting travelers from the Portland metro area to the forest, has been closed to the public since the Riverside Fire due to hazardous conditions and ongoing rehabilitation work. Post-fire assessments and emergency repairs have been completed over the past year to determine the scale of damage, anticipate high-risk areas in the changed landscape, and stabilize the roadway.

To leverage the ongoing recovery efforts happening in the Mount Hood National Forest, the U.S. Forest Service (USFS) requested technical planning assistance from the Federal Highway Administration (FHWA) Office of Federal Lands Highway Western Federal Lands Highway Division (WFLHD) to complete an Existing Conditions Assessment of the OR 224 corridor to better understand the extent of post-wildfire conditions as they relate to future use and transportation system resiliency within the National Forest. The Phase 1 Existing Conditions Assessment is the first of a two-phase Corridor Study for OR 224 and its purpose is to evaluate and document current baseline conditions along the closed portion of the corridor with a focus on safety, traffic operations, unstable slopes, and hydrology features.

The findings from the Phase 1 Existing Conditions Assessment include technical recommendations, data gaps, and areas of further study for a Phase 2 OR 224 Corridor Master Plan. A high-level Phase 2 Corridor Master Plan scope and project budget was also developed to assist the USFS and ODOT in seeking additional funding resources for comprehensive planning, as they become available. While this Phase 1 baseline assessment offers valuable insights into current conditions, a Corridor Master Plan is needed to develop a long-term, coordinated vision and related goals for the impacted area, further investigate high risk areas along the corridor, develop initial site designs for priority transportation improvements, and identify a comprehensive suite of capital projects and policy recommendations that support the many uses of the Mount Hood National Forest while enhancing transportation access.

Introduction

Background

In 2020, the Mount Hood National Forest experienced unprecedented catastrophic wildfire events that damaged recreational sites, roadways, office and storage buildings, and other critical infrastructure along the Clackamas River corridor. A 19-mile segment of OR 224, the primary route connecting travelers from the Portland metro area to the forest, has been closed to the public since the Riverside Fire due to hazardous conditions and ongoing rehabilitation work. The U.S. Forest Service (USFS) has requested assistance from the Federal Highway Administration (FHWA) Office of Federal Lands Highway Western Federal Lands Division (WFL) to complete an Existing Conditions Assessment of the OR 224 corridor to better understand the extent of post-wildfire conditions as they relate to future use and transportation system resiliency within the National Forest.

This report is the first of a two phase Corridor Study for the wildfire-impacted OR 224 in the Mount Hood National Forest. The purpose of the *Phase 1 – Existing Conditions Assessment* is to evaluate and document current baseline conditions along the closed portion of OR 224, with a focus on safety, traffic operations, unstable slopes, and hydrology features. Information gathered during the post-wildfire baselining effort will be used to inform future study efforts that identify project-specific transportation improvements. WFL will document these additional areas of in-depth analysis to be completed in a *Phase 2 – Corridor Master Plan* as part of this Phase 1 effort.

Corridor Study Area

This corridor study is focused on the closed section of OR 224, located between Promontory Park and Ripplebrook (Mile Post (MP) 31.2 through MP 49.97). Figure 1 depicts the study area location within the Mount Hood National Forest.

Figure 1: OR 224 Phase 1 Study Area Corridor

The area surrounding OR 224 is characterized by a multitude of uses, including timber management, hydroelectric power transmission, regional drinking water treatment, technical career training, and outdoor recreation. The Clackamas River and OR 224 roadway, which runs parallel to the river, have both received national recognition for providing an exceptional visitor experience. These recognitions include:

- West Cascades Oregon National Scenic Byway
- Clackamas National Wild and Scenic River and State Scenic Waterway
- Cascading Rivers Scenic Bikeway

Many of the exceptional qualities that characterized the corridor were impacted by the 2020 wildfires and have altered visitation to the forest and surrounding gateway communities. While the Riverside Fire began in the Mount Hood National Forest, it spread northwest along the Clackamas Basin towards the city of Estacada and burned within a half mile of the downtown. Various river-dependent outfitters and boating groups are based in Estacada and were not able to access popular launch areas along the Clackamas River due to dangerous conditions. The closures that are currently in place have limited recreational travel to Estacada, resulting in significant impacts to the local economy.

In addition to recreation uses, the OR 224 corridor provides access to utility providers serving the Portland metro area. Portland General Electric (PGE) owns and operates the Clackamas River Hydroelectric Project, which is a series of four powerhouses, dams, reservoirs, and related facilities, including managed recreational sites. Nearly all of the Clackamas River Hydroelectric Project is located within the Mount Hood National Forest and the complex generates approximately 139 megawatts of power. While the Riverside Fire did not directly damage any of the hydroelectric generating facilities, other recreation sites and connecting transportation systems were closed due to fire impacts.

While personal property damage was minimal in the aftermath of the 2020 Riverside fire, other dangers arise in the aftermath. Many nearby communities rely on the Mount Hood National Forest for municipal water supplies. The Clackamas River is managed by various entities with agreements with the USFS, including the North Clackamas Water Commission and South Fork Water Board. Various water systems experienced interruption of service and access to water treatment plants, resulting in boil water notices.

The Riverside Fire burned through timber stands in the Mount Hood National Forest that were covered by federal logging contracts. In the Clackamas River Ranger District, two timber sale advertisements were cancelled because the hauling routes either needed to be mitigated or reassessed due to fire damages. While it is unclear how much post-fire logging will occur as the forest recovers, this issue highlights the importance of the regional transportation network in timber production.

Existing Conditions Reports and Recovery Efforts

<u>Riverside Fire BAER Report</u>

In October 2020, a Burned Area Emergency Response (BAER) team, including scientists, engineers, and recreation specialists, surveyed the Riverside Fire impacted area. The BAER team identified imminent post-wildfire threats to human life and safety, property, and critical natural or cultural resources and made emergency stabilization recommendations.

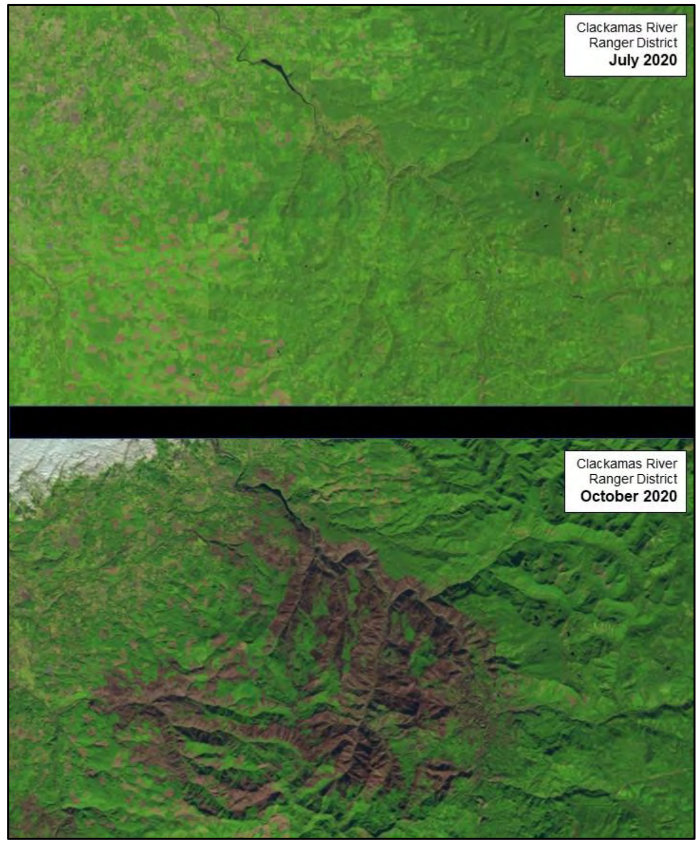


Figure 2: Comparison of pre- and post-fire imagery in the Clackamas River Ranger District (Source: USFS Riverside Fire Story Map)

<u>Fire Recovery Work Completed Since September 2020</u>

Over the past year, the USFS and ODOT have been assessing damage and repair costs for impacted infrastructure, performing environmental analysis, remedying unsafe conditions and hazmat, and implementing emergency repair projects. Many Clackamas River Ranger District employees' work has been redirected to support fire recovery.

According to the Mount Hood National Forest Clackamas River Ranger District, the following recovery work has been completed:

- Assessment of fire damage to soil, water resources, wildlife, and estimated tree mortality
- Environmental analysis required for danger tree abatement project on forest roads
- Containment of hazmat materials
- Removal & clean-up of burned vault toilets
- Debris slide catchment
- Hazard tree removal around Ripplebrook
- Installation of road and recreation site warning signs
- Installation and maintenance of closure gates for public safety
- New Remote Automated Weather Station (RAWS) to monitor storms, fire, slides, & emergency weather
- Ordered seedlings from Forest Service nursery for reforestation. Seeds were collected in the past from Mount Hood and areas with similar genetic makeup.
- Felled and cleared danger trees along FR 4220 and around Olallie Lake Resort to allow safe reopening of Olallie Lake in July.
- Noxious week surveys and treatment (~80 acres)
- Worked with PGE to clear hazards to power transmission lines
- Using local contractor, converted fire debris slash piles into biochar for future restoration projects
- Cleared Memaloose Rd to allow installation of communications equipment for local emergency services
- Cleared 18 miles of trails of downed trees and limbs

Baseline Conditions Summary: OR 224 Corridor Context

A critical first step in developing a comprehensive corridor study is to gather, organize, and analyze available sources of data about the current transportation system. The wildfire-impacted OR 224 corridor must be inventoried before decisions can be made on how to address specific problems within the constraints of future funding availability. This baselining effort allows the USFS and ODOT to understand the many needs that must be addressed in order to improve safety and access for all users. The following sections present initial findings and data gaps related to safety, traffic operations, unstable slopes, and hydrology. This transportation-specific assessment is complementary to and supports the findings of the Riverside BAER report.

Safety and Traffic Assessment

An analysis of safety and operational concerns was conducted by the WFLHD Highway Safety Team as part of the Phase 1 Corridor Study effort, focused mostly on baseline pre-wildfire conditions with additional consideration given to future forest uses and users. Recommendations, where possible, are based on available information, but may require additional resources or further study. Items reviewed and/or used for analysis as part of the safety and traffic assessment included:

- The ODOT TransGIS portal, which provides information on traffic data, lane widths, shoulder widths, mileposts (MP), signs, roadside barrier, and posted speed limits
- The ODOT Crash Data System, which provides location-specific crash history
- The ODOT guardrail damage inventory
- The Interactive Highway Safety Design Model (IHSDM), which is described below
- Aerial Imagery through a Bing Maps GIS layer
- Quadrangle maps through the United States Geologic Service (USGS)
- The Clackamas County Flood Insurance Study (FIS), which helped confirm the general grade of the river and the road (which generally follows the river throughout the corridor); the quad maps were the primary source of topographic data
- OpenRoads Designer, from which an approximated alignment was created to provide data for use by IHSDM
- The plan set for the OR DOT 224(1) Clackamas Highway Pavement Restoration Project (MP 31.73-MP 33.00 and MP 44.94-45.82)
- The ODOT Digital Video Log

This safety and traffic assessment has been mostly focused on baseline, pre-disaster conditions with some additional consideration given to future forest uses, users, and other considerations. Recommendations, where possible, are based on available information, but may sometimes require additional information or further study. A comprehensive assessment is included as *Appendix A – Safety and Traffic Assessment Final Memorandum*.

Traffic Data

The following average annual daily traffic (AADT) volumes, for both the current year and a potential design year (current year + 20 years) were retrieved from the ODOT TransGIS portal:

- MP 31.2-MP 39.1
  - Current year: 560 vehicles per day
  - Design year: 760 vehicles per day
- MP 39.1-MP 42.2
  - Current year: 550 vehicles per day
  - Design year: 760 vehicles per day
- MP 42.2-MP 48.3

    - Current year: 480 vehicles per day
    - Design year: 480 vehicles per day
- MP 48.3-MP 49.97
    - Current year: 300 vehicles per day
    - Design year: 320 vehicles per day

The percentage of the AADT that is truck traffic is 36.9% for all above segments, according to TransGIS. There is significant potential for seasonal traffic volumes to be significantly higher than the AADT volumes listed above. A potential goal for a future study would be to confirm traffic volumes within the corridor (including at some of the more prominent intersections and driveways). This confirmation may help planning or design efforts if there are ever future projects to add or upgrade parking, campground, or other forest features that would draw visitation and, potentially, congestion or user conflicts along with it. Posted speed limits are 55 MPH.

Road Users and Corridor Uses

OR 224 is an important link of the West Cascades Scenic Byway and the Cascading Rivers Scenic Bikeway. There are currently no counts available for bicycle traffic, but the USFS did note at the June 2021 site visit that on a drive-through it is possible to see six to ten cyclists using the road. Bicycle traffic may also grow in the future if the corridor's reputation as an enjoyable place to ride continues to grow. It is possible to gather bicycle counts once the corridor is reopened to the public; however, without previous baseline or pre-disaster bicycle counts, it will be more difficult to project bicycle traffic growth.

Pedestrians are an additional road user group to consider as part of future corridor uses. Currently, there are no marked or signed pedestrian crossings within the study limits. However, the USFS noted that it is common for pedestrians to cross the road to access areas on the opposite side from where they park. Campgrounds, boating access areas, and other defined recreational features are the areas where these pedestrian crossings are most likely to occur, but with vehicles parking at a large number of places throughout the corridor, the potential for pedestrian crossings is increased. Additionally, there is concern that with the loss of vegetation that may have previously served as a barrier to access, pedestrian crossings may become even more hazardous in the future as access points have increased and are even less defined or obvious to drivers.

The USFS identified some of the primary ways in which those who access this area of Mount Hood National Forest use this corridor:

- Scenic driving, including motorcycle or bicycle traffic
- Camping, including on and off designated campgrounds
- Hiking, picnicking, mushroom picking, target shooting, and other 'on foot' activities
- River activities, including boating and kayaking
- Winter sports and activities, including snowshoeing and cross country skiing
- Commercial activities, including maintenance of the hydroelectric facilities, other utilities, or logging activities (including through traffic)

The above list is not all-inclusive, and the complete list of needs for each of those uses is outside of the scope of a safety and traffic assessment. However, these needs must be considered when intersecting with corridor safety needs, parking needs, and other traffic needs. Currently, there are a large number of vehicles parking at undesirable locations throughout the entire corridor, creating safety and environmental concerns. Parking in undesirable areas is expected to be exacerbated following the loss of vegetation. Visitors who park in these undesirable areas may also be participating in other activities, such as target shooting or camping, in undesirable or unsafe areas. Another consideration is the different goals of the road users. Some of those visiting the corridor for scenic driving or other recreational activities may at times be driving at lower speeds. Those using the corridor for commercial activities may be incentivized to travel at higher speeds. These speed differentials, while difficult to model when caused by recreation, can increase the risk of crashes.

Existing Guardrail and Roadside Condition

Extensive guardrail damage was observed throughout the corridor. An accounting of the following will be needed:

1. Guardrail damaged by during the disaster or during disaster-recovery that will be replaced in-kind once the post-disaster logging activities are complete.
2. Guardrail (specifically guardrail that does not meet current crash testing criteria) that was not damaged and will not be replaced in kind.
3. Locations where there is no existing guardrail but, with post-disaster conditions, may be warranted as part of a potential future project.

An inventory of all existing guardrail in the corridor (from ODOT TransGIS, see above link) is included in Appendix A. Given the high risk of slides or fallen trees throughout the corridor, it is assumed that continued monitoring of the roadside is needed as more guardrail may become damaged until the area stabilizes. The area may not fully restabilize until the downslopes become revegetated.

The starting point for evaluating where new guardrail may be needed is an evaluation of the clear zone throughout the corridor. According to Section 3.1 of the AASHTO Roadside Design Guide, the clear zone is the unobstructed, traversable area provided beyond the edge of the traveled way for the recovery of errant vehicles. The shoulder, any turnouts, and any roadside area free of obstructions with a slope ratio that is 1 vertical to 4 horizontal (1V:4H) or flatter are considered to be part of the clear zone.

- Slopes 1V:4H are considered to be traversable and recoverable, meaning that an errant vehicle that reaches this type of slope can generally stop their vehicle or slow them enough to return to the roadway (if the slope is wide enough and free of obstructions).
- Slopes steeper than 1V:4H but flatter than 1V:3H are considered to be traversable but non-recoverable. Errant vehicles that encounter slopes in this range cannot likely navigate back to the roadway or come to a complete stop, but can likely be expected to reach the bottom of the slope without rolling over. Slopes in this range are if there are no obstructions on the slope or at the toe of the slope, and if there are slopes 1V:4H or flatter at the toe, then the clear zone resumes at the toe of the slope where vehicles have the opportunity to safely come to a stop.
- Slopes steeper than 1V:3H are considered to be non-traversable and non-recoverable, meaning that vehicles that encounter slopes in this range cannot recover to the roadway and cannot safely steer to the bottom. Slopes in this range present a rollover risk that increases proportionately to slope steepness (especially for slopes steeper than 1V:2H). No field measurements were taken on the June 16, 2021 site visit, but based on observations and the contour lines from the USGS quad maps, it seems that most slopes in the corridor fall into this range. With the loss of vegetation, many roadside slopes appeared to be undergoing soil erosion, causing the slopes to steepen in areas where the soil has migrated down-slope.

The AASHTO Guidelines for the Geometric Design for Low Volume Roads may apply to this corridor when determining the recommended clear zone width since the average daily traffic is less than 2000 vehicles per day, according to the ODOT Trans GIS site. However, until there is confirmation of seasonal highs in traffic volumes, it may be more appropriate to refer to Table 3-1 of the AASHTO Roadside Design Guide for recommended clear zone widths:

- Foreslopes (downhill):
    - 1V:6H or flatter – 12 to 14 feet

    - 1V:5H to 1V:4H – 14 to 18 feet
- Backslopes (uphill):
    - 1V:3H – 8 to 10 feet
    - 1V:5H to 1V:4H – 10 to 12 feet
    - 1V:6H or flatter – 10 to 12 feet

<u>Interactive Highway Safety Design Model (IHDSM) Description</u>

The IHDSM is a suite of software analysis tools for evaluating safety and operational effects of geometric design in the highway project development process. The IHSDM contains six modules that can be used to evaluate nominal and substantive safety performance. For this study, the Crash Prediction, Policy Review, Design Consistency, and Traffic Analysis Modules were used to evaluate the OR 224 corridor.

With no available survey, a variety of sources were used to acquire or approximate the data needed to run IHSDM. A horizontal alignment was approximated in OpenRoads Designer with the use of aerial imagery. A vertical alignment was approximated with the use of USGS quad maps, and a drive-through of the corridor on the June 2021 site visit confirmed no significant grades or grade changes that would have a major effect on IHSDM output. Data for lane widths, shoulder widths, and guardrail locations were taken from the ODOT TransGIS site. Cross slope data was approximated to be 2% for a typical tangent section. For curve sections, the cross slopes were approximated to the appropriate superelevation for each radius as listed in the AASHTO Policy on Geometric Design of Highways and Streets (8% maximum table, Table 3-10). Inputs for the roadside data were based on the USGS quad maps, Google Streetview imagery, and aerial imagery. Traffic and crash data were as listed previously in this memorandum.

Key assumptions and additional context on the use of IHSDM and these four modules for this analysis are further described in *Appendix A – Safety and Traffic Assessment Final Memorandum.*

IHSDM Output Data Analysis

The IHDSM software divides the roadway into segments based on changes in roadway geometry, such as lane width, shoulder width, cross slope, or roadside hazard rating, as well as changes in traffic data or behavior. 206 segments were identified within this corridor. To ease the analysis of the output data, the segments were combined into 12 distinct groups based on similar features such as tangent sections, reverse curves, or similar roadside conditions. A description of the 12 groups is included in Table 1 below (see Appendix A for more information).

Table 1: IHDSM Roadway Segment Groups

Group Number	Start MP*	End MP*	Description
1	31.2	32.6	Long, high radius curves; adjacent to significant recreational facility
2	32.6	34.5	Series of lower radius, shorter curves
3	34.5	35.6	Fairly straight section
4	35.6	37.8	Series of curves, including a change in horizontal alignment of approx. 180°
5	37.8	39.2	Fairly straight section
6	39.2	41.0	Series of curves, mix of medium and high radius
7	41.0	42.3	Fairly straight section
8	42.3	44.2	Series of curves, higher radius as compared to Group 8

9	44.2	46.4	Series of curves, including changes in horizontal alignment of approx. 90°
10	46.4	47.5	Fairly straight section
11	47.5	49.0	Winding section with curves of varying lengths, some lower radius
12	49.0	49.97	End of corridor, more driveways, lower speed limit

**Mileposts listed are approximate*

The Design Consistency and Traffic Analysis Modules were used to help examine expected speeds throughout the corridor. IHSDM runs a speed model through the geometry, taking into account horizontal curves and vertical grades in order to determine the effects that geometry has on speed (e.g. faster on steeper downgrades, slower on steeper upgrades). The results are sensitive to the Desired Speed input, which is estimated here in absence of formal speed data. For a design speed such as 55 mph, proposed for use on this project, an estimate of 65 mph was used since the corridor is characterized by long tangent sections with minimal significant grade changes. Anecdotally, as noted by the USFS at the June 2021 site visit, risky driving (and, at times, impaired driving) is commonplace enough during the high visitation season to be a significant concern. The speed model helps the project team with locating higher discrepancies between expected speed and design speed of individual geometric elements such as horizontal and vertical curves. This can help fine-tune countermeasures such as warning signage to better align with motorist's expectations.

Data gained through the Crash Prediction Module, the Policy Review Module, and the Design Consistency Module were used to compare groups (due to approximated data, the Driver/Vehicle Module failed to run and data from the Driver/Vehicle Module was not included in the results analysis). The comparison was completed with the following data:

1. Expected Crashes data adjusted by group length (crashes/group/mile). This data relies on an Empirical-Bayes analysis using historical crash data. This data is noted as 'Expected Crashes' for the remainder of the report.
2. Predicted Crashes data adjusted by group length (crashes/group/mile). This is the default model for crash prediction within IHSDM and relies on roadway geometry, roadside features and other program inputs. This data is noted as 'Predicted Crashes' for the remainder of the report. The predicted crash data is especially important for this analysis due to the age of the historical crash data.
3. Total expected crashes per group.
4. Total predicted crashes per group.
5. Design Consistency Module flagged data within each group (i.e. segment with an element not designed according to the AASTHO Green Book counted as one flag).
6. Policy Review Module flagged data within each group (i.e. each severe speed differential or deficient stopping sight distance within each segment counted as one flag).

These six items for each group were compared to their position with respect to the 90th percentile number and the 75th percentile number for each data set. For example, a group with predicted crashes based on Empirical-Bayes data in the 90th percentile as compared to all other groups received 1 point. A group with predicted crashes based on Empirical-Bayes data between the 75th percentile and the 90th percentile as compared to all other groups received 0.5 points. Groups with Empirical-Bayes crashes data below the 75th percentile received 0 points. Scores were totaled for the 12 groups and then ranked. Several groups were identified for further analysis. The IHSDM analysis and results allows for data-driven safety analysis to identify the sections of the project that would benefit the most from specific safety features, discussed in the Existing Data Analysis section.

Existing Data Analysis

The 12 groups are identified and described within Appendix A. These groups were scored based on criteria numbers 1-6 identified in the above IHSDM Output Data Analysis section. The ranked by risk groups are shown in Table 2 below (see Appendix A for more information on the data and scoring):

Table 2: OR 224 Groups Ranked by Risk

Rank	Group	Start MP	End MP
1	4	35.6	37.8
2	11	47.5	49.0
3	2	32.6	34.5
4	9	44.2	46.4
5	8	42.3	44.2
6	10	46.4	47.5
7	1	31.2	32.6
8	3	34.5	35.6
8	5	37.8	39.2
8	6	39.2	41.0
8	7	41.0	42.3

The Crash Prediction Module results for the corridor are in part summarized in Table 3 and Table 4:

Table 3: Comparing Crash Prediction Module Expected and Predicted (Existing Conditions - 20-Year Design Life)

Crash Prediction Module Method	Total Crashes	Fatal & Injury Crashes	Percent Fatal & Injury	Property Damage Only Crashes	Percent Property Damage Only
Predicted	108.24	34.74	32.10%	73.50	67.90%
Expected	137.12	70.84	51.67%	66.27	48.33%
% Difference	**21.06%**	**50.95%**		**10.90%**	

Table 3 shows the breakdown of expected crashes by those resulting in Fatal and Injury (FI) and those resulting in Property Damage Only (PDO). As shown, between 32% and 52% of all crashes result in a fatality or an injury, indicating the risk of roadway departures in this corridor. A roadway departure crash occurs when there is a crash that involves a vehicle crossing centerline, an edge line, or a lane line.

The expected crash data, which relies on historical crash data, shows an elevated percentage of fatal and injury crashes. This is a strong indication that the risk of severe crashes in the corridor is higher than what could be anticipated when reviewing the roadway and roadside strictly by its geometry and features. Driver behavior may be one explanation. Expected and predicted crash data cover a 20-year design life and account for the projected increase in traffic volume (exposure) over time.

Table 4: Expected Crash Type Distribution (Existing Conditions – 20-Year Design Life)

Crash Type	Fatal and Injury		Property Damage Only		Total	
	Crashes	Crashes (%)	Crashes	Crashes (%)	Crashes	Crashes (%)
Collision with Animal	2.69	2.00%	12.19	8.90%	16.59	12.10%
Collision with Bicycle	0.28	0.20%	0.07	0.00%	0.27	0.20%
Other Single-vehicle Collision	0.5	0.40%	1.92	1.40%	2.88	2.10%
Overturned	2.62	1.90%	0.99	0.70%	3.43	2.50%
Collision with Pedestrian	0.5	0.40%	0.07	0.00%	0.41	0.30%
Run Off Road	38.61	28.20%	33.47	24.40%	71.44	52.10%
Total Single Vehicle Crashes	**45.20**	**33.00%**	**48.71**	**35.50%**	**95.02**	**69.30%**
Right-Angle Collision	7.16	5.20%	4.77	3.50%	11.65	8.50%
Head-on Collision	2.41	1.80%	0.2	0.10%	2.19	1.60%
Other Multi-vehicle Collision	1.84	1.30%	1.99	1.40%	3.70	2.70%
Rear-end Collision	11.69	8.50%	8.09	5.90%	19.47	14.20%
Sideswipe	2.69	2.00%	2.52	1.80%	5.07	3.70%
Total Multiple Vehicle Crashes	**25.79**	**18.80%**	**17.56**	**12.80%**	**42.09**	**30.70%**
Total Expected Crashes	**70.98**	**51.80%**	**66.27**	**48.30%**	**137.12**	**100.00%**

Table 4 shows the expected crash type distribution. Single-vehicle crashes are highlighted in green. Multi-vehicle crashes are highlighted in yellow. Corridor totals are highlighted in orange. As shown, the largest number of crashes were single vehicle roadway departures. These three tables, in addition to all other IHDSM output especially those specific to the more at-risk groups, help to identify effective and cost-efficient crash reduction features that can be applied to the OR 224 corridor.

Traffic and Safety Assessment Recommendations

Bicycle Facilities

Widening the roadway to accommodate 4- to 5-foot shoulders throughout the entire corridor would require a significant amount of earthwork, disturbance to environmentally-sensitive areas, potential bridge widening, and cost. While widening may be the ideal solution to accommodate cyclists, the below discussion is based on the roadway template remaining the same in the future.

There is readily available online marketing and information for the West Cascades Scenic Bikeway, but signs and pavement markings for cyclists are limited south of Estacada. At a minimum, select placement of W11-1 Bicycle with supplementary W16-1P Share the Road plaques will help reinforce the presence of bicycles on the road or shoulder.

An additional option would be the use of dynamic warning signs (with either flashing LEDs or beacons) that become activated when bicycles are located within certain areas. These signs work by registering bicycle traffic counts and activating the flashing devices for a certain amount of time until cyclists have cleared an area. They are useful for areas where the shoulder is minimal and cyclists are within the roadway, and are especially useful for when cyclists can be expected within the roadway and there is limited sight distance. Potential locations along OR 224 for these types of devices would be in advance of select bridges (depending on shoulder width), areas where the road face extends adjacent to the inside of curves and limits sight distance, areas where there may be significant roadside parking and cyclists are pushed into traveling in the road, or to cover general areas where bicycle traffic volumes are anticipated to be high. These types of devices (with flashing beacons rather than LED lighting) are used elsewhere in Oregon, such as along OR 26, Cascade Lakes National Scenic Bikeway, and OR 242 near McKenzie Pass (shown in Figure 3).

Figure 3: Dynamic Warning Sign for Bicycles (OR 242, MP 78.6, ODOT Digital Video Log)

Parking, Pedestrians, and Adjustments to Vegetation Screen Loss

Any improvements installed within the corridor related to parking (either additions or discouragements), pedestrian facilities, and accommodating the loss of vegetation screens along the roadway will likely need to be complementary in order to provide the highest benefit. While parking is available along the road throughout the corridor, the areas with the highest concentration of parking will be those that feature an attraction and draw in overnight visitors. Vegetation screen loss causes the highest concern in the areas where there are campgrounds, spot camping, or environmentally-sensitive features that could be damaged by vehicles parking off-pavement. The areas with the highest number of parked vehicles will correlate directly with the highest number of pedestrians and, depending on the attraction, may correlate with the highest number of pedestrian crossings.

Other federal land management agencies are struggling with roadside parking in undesirable areas. A presentation provided to Yellowstone National Park, detailing the known methods of discouraging parking in undesirable areas, is included in Appendix A. These methods have all had mixed results, though no formal study has ever been completed on any areas in which these methods have been implemented. Based on the different uses of the OR 224 corridor, there will not likely be a 'one size fits all' solution. One example of an area where solutions to restrict parking and/or access may be needed is near MP 41.0, shown in Figure 4. Visitors either park on one side of the road to cross to the opposite (east) side or drive their vehicles into traversable areas on the east side that are not defined as access driveways. In addition to the earth disturbance, these visitors use the hillside on the east side for target shooting. There is a parking area on the west side which has space for picnicking or access to the river. The target shooting is in range of this parking area as well as the road. While target shooting is a draw to the forest, this is not the most appropriate area for it and methods of further discouraging use in this particular area are of interest.

Figure 4: Area of Concern for Parking and Access (OR 224, MP 41.0)

One method of parking discouragement discussed at the June 2021 site visit is guardrail installation. Guardrail is only recommended in areas where the crash as a result of a roadside departure is more severe than a crash caused by a vehicle striking the guardrail itself. Specific to areas of campgrounds or spot camping, a consideration for guardrail installation would be the clear zone width and location of the campers. Further discussion of guardrail and roadside design, including the clear zone, is included in the next section. Next steps include a review of the roadside slopes, a delineation of areas where parking should be discouraged, the location of the campgrounds compared to the clear zone width, and an analysis of the roadside condition.

Pedestrian facilities should be coordinated with both the future usage of campgrounds and the future context of any existing or proposed recreational facilities. Pedestrian crossings should be provided in any areas where parking is provided and there is some type of attraction on the opposite side of the road. Methods of funneling pedestrians to a defined crossing will be site-specific. The type of crossing will depend on both the number of anticipated pedestrian crossings and the stopping sight distance along the highway. Features that could be included in a pedestrian crossing may include crosswalk markings, advanced warning signage, in-street signage, or rectangular rapid flashing beacons.

The next steps include a review of roadside attractions, a review of any existing and any planned or proposed recreational facilities, and an estimation of potential pedestrian crossings based on those attractions or facilities. High visibility crosswalk markings have a 48% crash reduction factor for potential crashes involving pedestrians (which have a high probability of resulting in a fatality); Figure 5 depicts a high visibility crosswalk example at Yellowstone National Park.. Advanced Stop/Yield for Pedestrians signs and markings have a crash reduction factor of 25%. Rapid flashing beacons installed at crossings have a crash reduction factor of 47% for crashes involving pedestrians. There is benefit to using more than one of these treatments at a location; for example, high visibility markings used with advanced signs and markings will reduce the probability of crashes involving pedestrians by more than 48%. Crash reduction factors cited in this report are based on data or reports identified in the Crash

[Modification Factor Clearinghouse](#) or the AASHTO Highway Safety Manual. A crash reduction factor is applicable when an installed feature can reduce the risk (either in probability or in severity) of future crashes. Lighting and raised crosswalks may also be options.

Figure 5: High Visibility Crosswalk Markings with In-Street Signage (Yellowstone National Park; installation along OR 224 likely not in stop-controlled areas)

Guardrail and Roadside Design

The final inventory of guardrail replaced as a result of the disaster will help guide any further efforts on guardrail; the preliminary accounting of anticipated guardrail replacements will have to be compared to the actual replacements following the logging and utility work. Once it is determined how much of the existing guardrail has been replaced, the next step is to determine how much of the remaining guardrail must be replaced to meet current crash testing criteria. Additionally, a review of the existing bridge rail throughout the corridor is needed.

The final step relating to guardrail is to determine how much additional guardrail is needed, based on new conditions following the fire. New guardrail installation will likely have to be balanced between relative roadside departure risk and cost. To determine where new guardrail may be warranted, a full evaluation of the clear zone in locations where there is no existing guardrail is recommended. A special focus on the areas where there has been significant vegetation loss may be needed. Once the clear zone and roadside slopes and actual clear zone widths are documented (compared to recommended), guardrail warrants can be developed. However, it is likely that there will be budgetary restrictions on new guardrail installation. Rather than simply developing a list of locations where new guardrail is warranted, it is recommended to develop a priority list for where guardrail and other roadside design treatments are most beneficial.

Figure 6: Apparently Undamaged Guardrail and Bridge Rail (OR 224, MP 31.2 and MP 49.97)

In other WFLHD-designed roadway projects where there are similar budgetary restrictions on guardrail installation or other considerations (i.e. environmental or wildlife impacts, aesthetics, etc.), WFLHD Safety has used a benefit/cost procedure to determine where guardrail could provide the highest value.

Two programs available for completing this type of analysis are the AASHTO ROADSIDE procedure (outlined in previous additions of the Roadside Design Guide and used by the Alaska DOT&PF) and the Roadside Safety Analysis Program (RSAP). WFLHD Safety has used the ROADSIDE procedure previously. The benefits identified in these procedures are the reduction in crashes or the reduction in crash severities over the 20-year design life; the costs to which the benefits are compared are the initial construction costs of installation and the maintenance costs of repairs over the 20-year design life. Through the FHWA Highway Safety Improvement Program (HSIP), each state has placed a tangible, economic cost to different crash types; some of these costs include medical costs, property damage, emergency services, productivity losses, congestion impacts, insurance costs, and other legal claims. The opportunity to reduce these economic costs, or human impact costs, is considered to be a benefit. The actual costs used in these types of analysis are construction and maintenance costs, including potentially embankment material, guardrail, guardrail terminal sections, or vegetation clearing. Additionally, this analysis can identify other options that may be more cost effective than guardrail, such as providing full or partial clear zone treatments (i.e. find the optimized foreslope combinations and widths).

Other Safety Countermeasures

The IHSDM results can help guide the placement of safety countermeasures including signage, rumble strips, and delineators. From the site visit on June 2021, it appeared that much of the signage throughout the corridor was in the appropriate location. Centerline rumble strips were present throughout much of the corridor, though were somewhat worn down. Delineators may have been common in the areas where there is existing guardrail (though it was difficult to determine due to the damage to the guardrail), but appeared to be less common in areas where there is no existing guardrail.

The next step, once a decision on previously discussed recommendations has been made, would be to use the IHSDM results to determine if any additional safety countermeasures are recommended. Examples would include:

- Additional curve warning signage. Depending on the type of signage, a crash reduction factor of 25-40% is applicable for signed curves, showing a high value in areas where there is a significant crash history or where IHSDM has shown elevated risk.
- Additional delineators (especially in areas where guardrail has been shown not to be cost-effective or where there are not sufficient funds to install guardrail). A crash reduction factor of 11% is applicable for delineators placed on horizontal curves; there is additional benefit, though not yet quantified, for delineators placed on tangent sections with steep drop-offs.
- High friction surface treatment (especially in areas where the curve radius or superelevation is deficient compared to the recommended values in the AASHTO Green Book). A crash reduction factor of 24% is applicable through the length of curves where high friction surface treatment is installed, and this treatment may have a higher benefit/cost ratio than superelevation correction or curve flattening. The benefit is even higher with respect to reducing crashes in wet weather.
- Wider edge lines (discussed in the bicycle section, but the highway safety benefits are present regardless of impacts on bicycle traffic). Wider edge lines have a crash reduction factor of 18%.
- Long-term: review crashworthiness of bridge rail throughout the corridor.

Historic crash data was reviewed and used to the extent necessary to run IHSDM, but a more thorough look at individual crashes and trends is needed. For the purpose of this study, the data was gathered and included in Appendix A (no personally identifiable information included). It is recommended that any future study or project complete the review of the latest crash data. A summary by severity of the crashes along OR 224 between 2010 and 2019 is as follows:

- 7 crashes in which the most severe outcome was a fatality (K)
- 8 crashes in which the most severe outcome was a serious injury (A)
- 37 crashes in which the most severe outcome was a moderate injury (B)
- 27 crashes in which the most severe outcome was a minor injury (C)
- 16 crashes in which the most severe outcome was property damage only (PDO)

According to the ODOT 2019 State Highway Crash Rate Tables, the crash rate for non-freeway type roads is 1.40 crashes per million vehicle miles traveled. Assuming 560 vehicles per day in the corridor over 18.8 miles, the crash rate in this corridor may be as high as 2.47 crashes per day. Given that traffic decreases over the length of the corridor, this may be on the low end of the crash rate.

A final consideration is emergency management. At the June 2021 project kickoff, a desire was indicated to investigate dynamic signage to convey messaging to the public. This messaging could include road closures due to slides, wildfires, or other events. It could also indicate evacuation route information or other critical information. The type and placement of this signage will have to be coordinated with both the USFS and ODOT. It will have to be determined which agency would control the messaging, and how they will do so. A source of power would also have to be identified.

Strategies for Improving Data Collection, Analysis and Implementation of Safety Features

FLH Safety is currently conducting a geographic information systems (GIS) and systemic safety research project in order to provide FLH partner agencies with better tools to supplement a lack of traffic and safety data as well as efficiently analyze road networks for safety improvements. The pilot GIS tool is available for use and can be customized for the overall studies in the entire corridor (i.e. from Estacada to Detroit). For example, the locations of historical and current high-use and/or undesirable parking areas and pedestrian activity can be captured within the GIS application. These efforts, along with other Forest Service efforts, could be combined to help build a robust set of data while the next funding phase is identified and programmed. Contact WFLHD Safety and Planning for more information.

Other funding programs should be investigated further to identify which could be utilized to implement future improvements. These could include the ODOT-administered Highway Safety Improvement Program, the High-Risk Rural Roads Program and the All Roads Transportation Safety Program. These programs could help leverage FLAP, FLTP and other funding sources that ODOT and the Forest Service typically utilize in order to provide additional safety funding.

Performing the analysis and further study as discussed in this Phase 1 report puts ODOT and the Forest Service well on the way to completing a Local Road Safety Plan, a FHWA initiative to bring transportation users home safely. The agencies and stakeholders in this corridor should consider partnering together to create a plan and strengthen ties among engineering, enforcement, education and emergency services countermeasures to reduce fatal and serious injury crashes.

Unstable Slope Gap Analysis and On-Site Ratings Assessment

The WFLHD Geotechnical Services Team completed a review of unstable slopes along the OR 224 corridor in order to identify data gaps and determine where there may be potentially vulnerable transportation assets and areas along the corridor that require more detailed unstable slope ratings during a Phase 2 Corridor Master Plan. A comprehensive assessment is included as *Appendix B – Unstable Slope Gap Analysis and On-Site Ratings Assessment Final Memorandum.*

Corridor Geology

The OR 224 corridor study area lies entirely within the Western Cascades Physiographic Province, which is characterized by older volcanic rocks, generally steep slopes, and large pre-historic (ancient) landslide deposits (Peck, et al., 1964; see Figure 7). There are four bedrock units that underlie the corridor, and all are approximately horizontally bedded. The oldest and lowest in position are sedimentary and volcaniclastic rocks of the Little Butte Volcanic Series (approximately 23 to 33.9 million years ago (Ma)) located in the upper reaches of the Clackamas River, from Three Lynx Creek at MP 45.87 to the end of the corridor at the intersection of FSR 57. This unit is primarily composed of volcanic and volcaniclastic deposits, including volcanic tuffs, mudflows, and lava flows of basalt and andesite. Smith (1994) indicates that the unit consists of “clay-bearing volcaniclastic formations overlain by unaltered lava flows of andesite and basalt, a combination that contributed to large-scale landsliding during the late Pleistocene”, approximately 10 thousand years ago (Ka). The entire valley bottom contains large scale earthflow-type landslides that produce generally subdued topography as compared to the lower portion of the corridor.

Overlying the Little Butte Volcanic Series are the Grand Ronde and Wanapum members of the Columbia River Basalt Group (approximately 15 to 17 Ma). These lava flows form steep cliffs along the Clackamas River from the beginning of the corridor at the Mount Hood National Forest Boundary up to Three Lynx Creek. The basalt lava flows are generally resistant to erosion and form steep cliffs. However, there is a weak sedimentary interbed called the Vantage Member between the two lava flows. The Vantage Member is composed of ashy, volcanic sandstone and siltstone deposits and is a barrier to groundwater flow, resulting in increased pore-water pressure at the slope face where the unit is exposed. The resulting pore water pressure in some cases has created slope instability where large landslides occur. The Vantage Member typically forms a steep bench of loose, unconsolidated talus where the upper basalt flows have been removed by undercutting.

Immediately above the Columbia River basalts are interfingered (layered) deposits of the Rhododendron and Sardine Formations (approximately 10 to 17 Ma), which are composed of volcaniclastic deposits of mudflows, conglomerates, and ash tuffs, as well as basalt and andesite lava flows, respectively. These geologic units cap the ridges within the corridor, including Wanderer’s Peak, Soosap Peak, Fish Creek Mountain, and East Mountain. The material in the Rhododendron formation is easily eroded and is also prone to landsliding, which occasionally initiates as debris flows in the steep tributaries of the aforementioned peaks into the Clackamas River.

Overlying the Rhododendron and Sardine Formations are younger basaltic and andesitic volcanic lava flows of the High Cascades (approximately 1.2 to 3.9 Ma). These geologic units are primarily found in the headwaters of tributaries of the Clackamas River East of the corridor, and generally cap the ridge tops, including Mount Mitchell and Oak Grove Butte.

Also within the corridor is a wide plateau known as “La Dee Flat”, north of the Clackamas River at Promontory Park. La Dee Flat has a low slope angle that generally precludes the development of landslides.

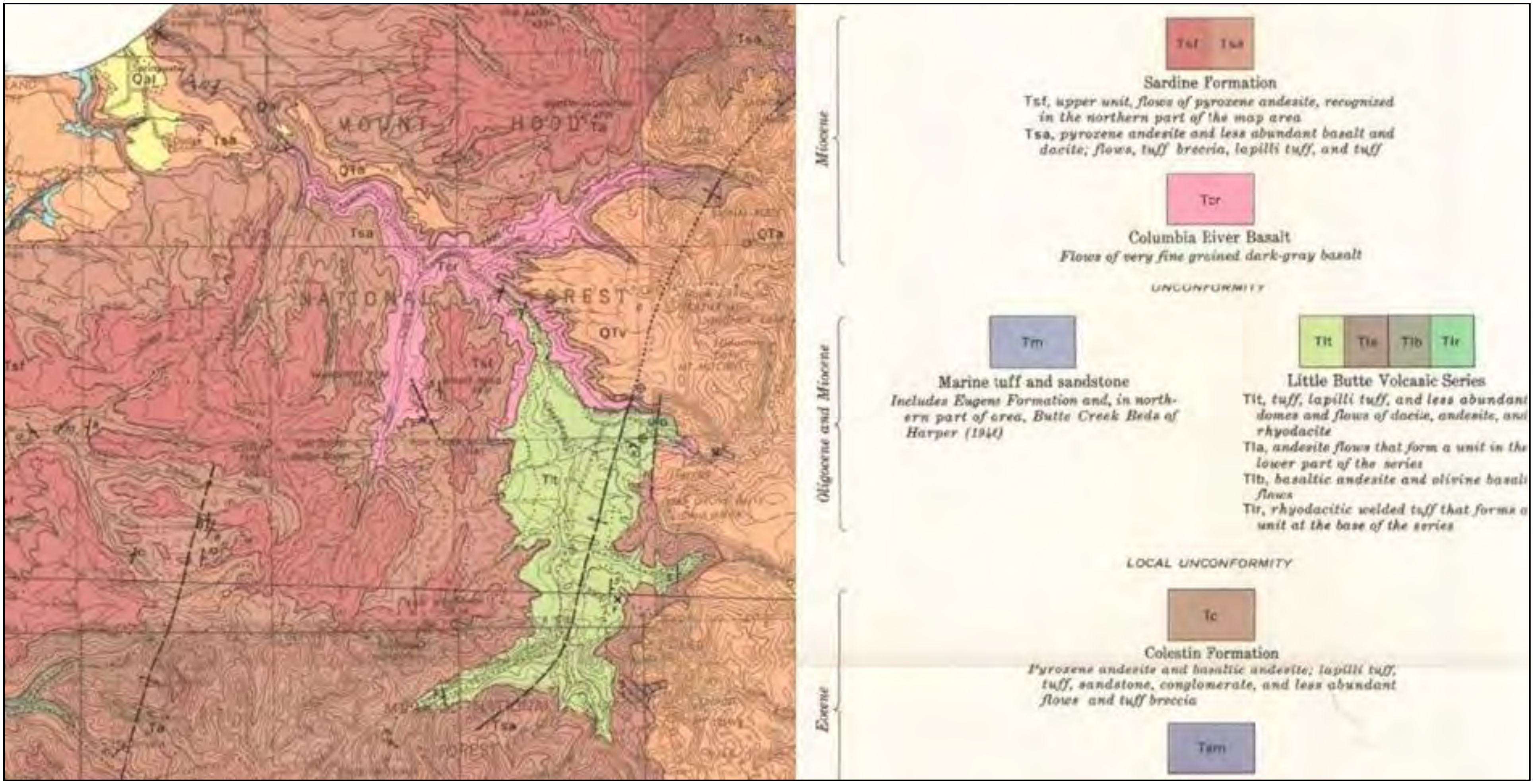


Figure 7: Geologic Map of the area of the Highway 224 corridor impacted by the Riverside Fire (modified from Peck, et al., 1964)

Site Conditions

Lower Corridor – Forest Boundary to Three Lynx Creek

Loss of vegetation from the fire has destabilized talus slopes on benches as well as on alluvial fan deposits along the base of the Columbia River basalts in the lower portion of the corridor. Increases in rockfall have occurred and should be anticipated to continue along the corridor from the Forest boundary to Three Lynx Creek. Additionally, debris flow potential exists where easily erodible deposits of Rhododendron formation overlie steep valley walls of Columbia River basalt. Modelling results provided by the U.S. Geological Survey (USGS) (Staley and Kean, 2020) indicate that streams crossing the highway in this section of the corridor are generally at moderate to high hazard for debris flows.

Upper Corridor – Three Lynx Creek to FSR 57

Increases in soil moisture related to a decrease of evapotranspiration from a loss of vegetation has the potential to reinitiate and/or accelerate earthflows in the upper portion of the corridor from Three Lynx Creek to FSR 57, although this is anticipated to be minor over the course of the next five to ten years as vegetative cover increases. This has the potential to lead to increased deformation and subsidence of the paved surface of the roadway. Additionally, increased surface runoff on the earthflows could lead to significant erosion and sedimentation, which would negatively impact transportation infrastructure (roads, ditches, culverts). Streams draining this area are generally at a low hazard for debris flows (USGS, 2020).

Analysis Method

This analysis was conducted as a desktop exercise that relied exclusively on existing data to identify two classes of unstable slopes:

1. Unstable slopes **with** ratings and/or assessments
2. Unstable slopes, or potentially unstable slopes **without** ratings and/or assessments

The intent was to identify vulnerable transportation assets and identify areas along the corridor that require more detailed unstable slope ratings or condition assessments during the Phase 2 Corridor Master Plan. The analysis relied primarily on two existing data sources:

1. Oregon Department of Transportation's (ODOT) Unstable Slope Rating System (USRS) database
2. USGS's Emergency Assessment of Post-Fire Debris-Flow Hazards debris flow modelling

ODOT's USRS analyzes slopes adjacent to state highways for potential impacts that a failure could cause. Such failures include landslides, rockfall, and fill settlement or failures. Historically, ODOT has evaluated rock fall hazards, but has expanded the program to include other (soil) types of unstable slopes (landslides and debris flows). Under the revised program, ODOT is able to include economic factors in its analysis as well as hazard and engineering considerations so that sensible repair priorities can be more easily obtained.

The USGS conducts post-fire debris-flow hazard assessments for select fires in the Western United States, utilizing geospatial data related to basin morphology, 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 event.

This analysis attempts to identify locations of debris flow prone unstable slopes or areas where debris flows could occur and are lacking unstable slope rating or site condition assessment data. These areas are clearly delineated where no unstable slope rating data exist and USGS modelling identified channels at moderate to high hazard for debris flow initiation. For this effort, we focused on stream channels that exhibited channel morphology (geology, grade, length, depth of incision, coalescing fan deposits, levies, anastomosing channels, etc.) and *observed past debris flow events* that supported potential for future debris flow events. If channels met those criteria, based on geo-practitioner judgment, a recommendation to rate the unstable slopes was made. If the channel met the above criteria, but did not include observation of past debris flow events, a recommendation to perform a site condition assessment was made.

This analysis assumes that potentially unstable slopes that have not been assessed and rated by ODOT will be assessed and rated utilizing the Unstable Slope Management Program for Federal Land Management Agencies (USMP, FLH 2019) in Phase 2. In order to combine data from the two systems, and be useful in a geotechnical asset management framework, a crosswalk between the rating systems must be established so that ranking of sites can be accomplished utilizing ratings from either system. The crosswalk would assist in an “apples to apples” comparison of ratings so that sites can be ranked and prioritized for potential risk reduction measures. Therefore, a sample of unstable slopes in the corridor, rated utilizing the USRS, should be rerated with FLH’s USMP prior to the rating of new unstable slopes utilizing the USMP. Rerating of ODOT USRS rated unstable slopes should include a range of different unstable slope types (landslide, rockfall, debris flow, etc.) from a low to high risk, and should focus on slopes that include a STIP score, which is the score used for project identification and prioritization for ODOT. This additional level of effort is strongly recommended for the Phase 2 Corridor Master Plan.

Analysis Results

ODOT’s USRS consists of 45 pre-fire unstable slope ratings conducted between 2007 and 2009, as well as 42 post-fire assessments (non-ratings) completed in 2020, which included 13 new unstable slope assessments that did not have a rating associated with them. The post-fire assessments reassessed 30 (67%) of the pre-fire unstable slopes, for a total of 58 ODOT pre and post-fire ratings and/or assessments of unstable slopes within the study corridor. Pre-fire unstable slope ratings included 30 rockfall sites, 14 road fill failures, and five landslides. The new slope assessments focused primarily on rockfall (see Attachment 2 - Unstable Slopes Existing Condition and Data Gaps Maps, and Attachment 3 - Table of Unstable Slopes with USRS Ratings).

The USGS modeled debris flow hazard for 84 streams that intersect the highway within the study corridor, which ranged from low to high (see Attachment 2 - Unstable Slopes Existing Condition and Data Gaps Maps in Appendix B). Generally, streams in the lower corridor were modelled as moderate to high hazard, while streams in the upper corridor were modelled as low to moderate hazard. This is interpreted as being controlled by the presence of differing geology and the associated basin morphology between the upper and lower corridor.

Lower Corridor – Forest Boundary to Three Lynx Creek

ODOT identified and rated 41 unstable slopes in the lower corridor. *Communication with ODOT identified four unstable slopes that were not assessed in the post-fire effort but would benefit from completing a more detailed rating.* The USGS modeled 73 stream segments for debris flows hazard in the lower corridor, and 37 (51%) were rated at high hazard, 34 (47%) moderate hazard, and 2 (3%) low hazard. *Analysis of unrated, debris flow prone channels identified two unstable slopes that should also be rated, and eight sites where condition assessments should be performed.*

Upper Corridor – Three Lynx Creek to FSR 57

ODOT identified and rated ten unstable slopes in the upper corridor. *Communication with ODOT identified four unstable slopes that were not assessed in the post-fire effort but would benefit from completing a more detailed rating.* There is a lack of slope ratings in the upper section of the corridor, which may indicate that there is minimal geologic hazard present in this area due to the generally subdued topography. The USGS modelled 13 stream segments for debris flows hazard in the upper corridor and had generally low to moderate hazard. *Analysis of unrated, debris flow prone channels identified one unstable slope that should also be rated.*

Unstable Slope Assessment Recommendations

Following the desktop analysis of existing data, the WFLHD Geotechnical Services Team identified three recommendations to address unstable slope risk along the OR 224 study area:

- Conduct a crosswalk of USRS rated unstable slopes by rerating both types of unstable slope with the USMP in order to compare ratings between the two systems so that sites can be ranked and prioritized for potential risk reduction measures.
- Utilize the USMP; (FLH, 2019) to rate identified unstable slopes where data gaps exist. This includes eight sites recommended by ODOT, three high hazard debris flow channels where past debris flow events have been observed, and the approximately five miles of the upper corridor from Three Lynx Creek to FSR 57 (see Attachment 4 - Table of Unstable Slopes Requiring USMP Ratings or Site Condition Assessments in Appendix B).
- Additionally, perform site condition assessments on eight high hazard debris flow prone channels where past debris flow events have not been observed. These data could be used to inform future study efforts that identify project-specific improvements to make OR 224 a more resilient transportation corridor.

Hydrology Gap Analysis

This section provides a hydrologic and hydraulic corridor assessment of the OR 224 study area. The assessment identifies available data, evaluates the suitability of the data, and identifies data or information gaps to be addressed in future study efforts. A desktop review of available post-fire reports, as-built information, maintenance/inspection data, basin maps, and U.S. Geological Survey (USGS) post fire debris flow hazard mapping was conducted by the WFLHD Hydraulics Team to identify drainage structures, flood and debris flow prone areas, transportation infrastructure, and facilities which may be impacted by post fire flows through and downstream of the corridor. A comprehensive analysis is included as *Appendix C – Hydraulics Data Gap Analysis Final Memorandum*.

Available Data and Suitability

The USFS Rapid Assessment Team evaluated the fire and completed a report, dated October 2020, which provided basal area mortality maps, summarized conditions, and provided action recommendations. A Burned Area Emergency Response (BAER) team began work on assessing the post-fire effects in September 2020. The team developed reports that include comprehensive information which will support the OR 224 corridor assessment.

Burned Area Reflectance Classification (BARC), aerial reconnaissance data, and on-the-ground surveys were conducted to develop a Soil Burn Severity (SBS) map which was used to estimate the soils post-fire hydrologic responses and resulting flows for the Clackamas River subwatersheds. Risk of upland erosion, sedimentation delivery rates, and increased flood flows were then estimated for 27 subwatersheds using the Water Erosion Prediction Project (WEPP) Post-Fire Erosion Predictor (PEP). This was compared to pre-fire 5-year recurrence interval flood conditions to identify levels of risks at road/stream crossings. The BAER report provides analysis results of crossing points along OR 224 listed in Table 5. Significant increase in flow are predicted for a majority of the analyzed crossings.

Table 5: 2020 BAER Report Crossing Points

Crossing Points	Pre-fire Q5 (cfs)	Post-fire Q5 (cfs)	% Increase	Times Increase	Pre-fire Q50 (cfs)	Acres
Moore Creek	380	390	3%	1.0X	530	459
Unnamed Tributary	110	240	118%	2.1X	340	171
Murphy Creek	180	250	39%	1.3X	270	257
Unnamed Creek	99	190	92%	1.9X	170	133
Three Lynx Bridge	340	590	74%	1.7X	1,300	1,675
Deer Creek	140	270	93%	1.9X	320	200
Dinner Creek	430	680	58%	1.5X	1,200	921
Roaring River	7,400	8,300	12%	1.1X	15,000	27,229

The burn area mortality, soil burn severity, subwatershed, and subwatershed peak stream flow analysis point maps developed by the BAER team have been included in Appendix C.

The USGS conducted a post-fire debris-flow hazard assessments using the post-fire data and developed mapping. They utilized geospatial data related to basin morphology, burn severity, soil properties, and rainfall characteristics to estimate the probability, volume, and combined hazard rating of debris flows at both the drainage-basin scale and in a spatially distributed manner along the drainage network within each basin. The debris flow hazard mapping can be found on the following USGS website which includes downloadable shapefiles and geodatabase information: (https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=309)

The USGS model identifies 84 streams that intersect the highway within the study corridor. This includes those crossing points listed in Table 5. Due to differences in geology and basin morphology, the 73 streams modelled in the lower corridor between the forest boundary and Three Lynx Creek rated as moderate to high hazard. The 13 streams modelled in the upper corridor from Three Lynx Creek to Forest Road 57 rated as low to moderate hazard.

Within the lower corridor there were 37 stream intersects that rated as high hazard. Although a handful of these where points modeled for flow in Table 5, additional flow modeling for the remaining crossings were not performed or unavailable.

The Oregon Department of Transportation (ODOT) was able to provide data on crossing structures for a portion of the lower corridor from the forest boundary to Mile Point (MP) 36 just south of Moore Creek. Beyond this point ODOT did not have inspection data for crossing structures, but only had culverts listed on plans. Since ODOT restricts outside access to their GIS database, the data provided was in spreadsheet format with information limited to specified queries. Additional asbuilt, inspection, and maintenance data for culverts along the corridor are available from the USFS. Per discussions with USFS staff, this data would need to be obtained from isolated databases and possibly from multiple sources. Current post-fire inspection information for crossing structures was not available.

ODOT provided asbuilt plans and inspection reports, in electronic pdf format, for all bridges within the corridor which are listed in Table 6. The table does include three large culverts (Bull Creek, NF Clackamas, and Dry Creek) that fall within the recording requirements of the National Bridge Inventory System (NBIS).

Table 6: Bridges along the OR 224 Corridor with Asbuilt Plans and Inspection Reports

Bridge No.	Mile Post	Description	Scour Critical Rating
18178	41.48	Roaring River Bridge	
18619	47.70	Bull Creek Culvert	
05269	49.96	Clackamas River (Oak Fork Ripple Brook Br)	3
05272A	30.04	North Fork Clackamas River (Steel Plate Culvert)	
08988	38.77	Clackamas River (Carter Br)	
08989	39.15	Clackamas River (Armstrong Br)	3
08990	45.83	Clackamas River (Cripple Creek Br)	3
08991	44.88	Clackamas River (Three Lynx/Whitewater Br)	3
08992	49.12	Dry Creek Culvert	

Review of the inspection reports revealed that four (4) of the bridges within the corridor have a NBIS scour critical rating of 3. This means that these structures' foundations have the potential to be undermined by stream scour or erosion. The expected post-fire changes in flow conditions, debris loads, and sediment loads have the potential to increase scour and erosion resulting in a higher risk for the bridges becoming unstable.

ODOT performed inspections of the bridges along the corridor in August of 2019. Another inspection is scheduled for this year. Inspection photos are available within the ODOT GIS database and can be provided upon request but would need to address large file transfer requirements.

In addition to the analysis and recommendations included in the USFS BAER team reports, ODOT requested that the Federal Emergency Management Agency's Erosion Threat Assessment/Reduction Team (ETART) produced a separate report to assess State, local, and private lands outside of the forest. This report re-affirms much of the recommendations made by the BAER team, but also adds recommendations for property and facilities affected downstream of the forest boundary.

Corridor Needs and Data Gaps

After review of available data and related report recommendations, the following hydrologic and hydraulic related needs and data gaps have been identified for the OR 224 corridor.

Roadway Drainage and Culverts

ODOT is currently removing debris, removing danger trees, and storm proofing (cleaning ditches, culverts, repairing drainage) along the corridor to address immediate hazard concerns. However, hazardous conditions will continue to develop over the next 5 years as the loss of vegetation will allow normal storms to more easily cause erosion and debris flows on the steep roadside slopes resulting in further plugging of ditches and culverts, and/or washouts of drainage facilities or stream crossings. The BAER and ETARTS reports recommend a number of drainage and culvert related actions to address or help reduce impacts from these expected hazards during the period in which vegetation recovers.

A prioritized mitigation action plan should be prepared that identifies the most susceptible drainage crossings impacted by increased flow and debris. Pre-fire and post-fire flow modeling has been performed on only a small number of crossings (see Table 1) within the corridor. Flow modeling of additional crossings would assist in identifying culverts that may now be undersized or less able to accommodate plugging. Modeling may involve pre-fire and post-fire flow analysis or just post-fire regression flow analysis. Crossings located at high and/or moderate debris flow potential sites should also be evaluated to determine the resulting risk and hazard that debris flows may have at each site.

Creating a complete inventory of drainage structures within the corridor (including condition assessments, documented maintenance issues, fish barrier issues, and geographic reference data) will be needed to produce a comprehensive mitigation plan and conduct flow analysis. This effort will also help identify structures needing to be replaced (specifically within the next 5-years), identify sites that may be more prone to debris/plugging, and assist crews in locating structures in the field. Conducting site specific field evaluations may also be needed to begin identifying and prioritizing mitigation actions. Mitigation actions may include, but are not limited to, the following:

- Culvert replacements or modifications to increase capacity (replacements should be sized on predicted increase in flows or fish passage requirements).
- Installation of additional culverts at high risk locations.
- Placement of upstream structures to deflect or catch debris away from the roadway.
- Installation of slotted riser pipes, debris racks, and culvert end sections where feasible to reduce sediment and debris plugging.
- Roadway embankment armoring in areas at risk for overtopping.
- Drainageway improvements at crossings to reduce or eliminate streamflow diversion potential.

Bridges

Post fire flow analysis indicates that increases in flow along the lower Clackamas River may not have a significant impact on bridges along the OR 224 corridor. Over the next 5 years, significant amounts of eroded fine sediment will be deposited in draws, stream and river channels, and floodplains. This increased loading can result in aggradation and channel migration at bridges. Large woody debris will also accompany the initial flush of fine sediments and ash that is delivered to bridges along the corridor during high-intensity rain events over the next 5-years. This will greatly increase potential for debris jams to form around bridge abutments leading to significant increases in the potential for scour to undermine piers and abutments. Debris flow potential from Fish Creek and smaller drainages adjacent to the bridges may also impact the flow patterns at bridge crossings which can lead to increases in erosion and scour.

It will be important to perform a post-fire evaluation of the four bridges rated as scour critical. Evaluation of the remaining bridges may also be warranted. The level of risk posed by increased debris jams, changes to flow patterns, aggradation, and channel migration should be re-evaluated. The evaluations will require collecting pre-fire and post-fire photos, measuring channel conditions, identifying existing scour counter measures, and documenting scour conditions near abutments and piers. This information will not only be useful in evaluating the risk but will allow inspectors to identify changing conditions more readily after significant storm events.

Identification and prioritization of additional site-specific monitoring efforts and preventative measures should consider the following:

- Increasing bridge inspection intervals.
- Additional emergency storm monitoring and response plans.
- Post-storm scour, damage, and debris inspection and assessment.
- Installing additional scour countermeasures.
- Monitoring movement of large woody debris and debris removal plans.
- Installation of real-time water surface elevation and/or scour monitoring devices to alleviate staff limitations.
- Signing and temporary emergency closure plans.

Facilities and Properties

The WFLHD review teams identified a high risk to Get-N-Go Promontory Marina and North Fork Reservoir Dam from woody debris build up. Increasing inspection frequency will be needed to identify debris removal. Staging, storage, and disposal areas will need to be identified and coordinated.

The primary access to the Portland General Electric (PGE) Oak Grove Powerhouse is also vulnerable to debris flow from Three Lynx Creek. Mitigation actions that could be considered for this location could include placement of upstream debris racks, additions culverts, or armoring of the roadway. Additionally, an emergency response and access plan should be developed in coordination with PGE.

Water Supply

The Riverside Fire burned a large part of the municipal watershed of the City of Estacada and has the potential to impact other downstream municipal water supplies that have intakes on the Clackamas River including City of Lake Oswego, Clackamas River Water, Clackamas Water District, North Clackamas County Water Commission, and South Fork Water Board municipalities.

During and after high-intensity storms, turbidity, dissolved organic carbon, nitrate, and some metals may likely increase by large magnitudes downstream of the burned area. Increases of such magnitude can pose problems for water-supply reservoirs and drinking-water treatment plants that can last many years and affect chemical treatment requirements, sludge volumes, and operating costs.

Starting coordination with the affected municipalities to assess capacity of facilities to address post-fire water quality will assist in identifying if additional water quality monitoring within Clackamas River is needed to help managers. This could provide data to better estimate affects to operations and allow them to minimize effects through temporary diversions or changes to water intakes.

Watershed

The ETARTS team recommends installation of one or more near real-time (NRT) precipitation gages in or near the burn area. A NRT 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. Further developing gaging station data with rainfall data relations can assist with future evaluations of post-fire flood magnitude and hydrologic response in ungaged.

The specific locations for possible NRT gages and funding sources will need to be evaluated and coordinated between agencies.

Hydrology Assessment Recommendations

The following summarizes recommended actions that will assist in completing data or information gaps for future study efforts in identifying project-specific improvements:

- Develop a comprehensive drainage crossing inventory that includes post-fire condition inspections, emergency maintenance history, fish barrier information, and georeferenced location mapping.
- Conduct detailed post-fire hydrologic and hydraulic analysis on identified elevated risk crossings.
- Conduct site specific field evaluations of crossings affected by significant increased flow and within high risk debris flow areas.
- At bridge crossings, collect pre-fire and post-fire photos, measure channel conditions, identify existing scour counter measures, and documenting scour conditions at abutments and piers.
- Perform post-fire site evaluations for increased scour and erosion risks at bridges within the corridor (most importantly bridges rated as scour critical)
- Identify the number of locations potential NRT gages would need to be installed to provide useful emergency response data.
- Assist municipalities in assessing water supply facility capacities to address post-fire water quality and any needs for additional water quality monitoring.

Future Study Efforts

Creating an effective and efficient mechanism to implement, monitor, evaluate, and report on recovery activities, emergency responses, updates, and progress will require establishing staff roles, responsibilities, funding sources, and contact information across agencies.

Corridor drainage structure data should be organized in a format that can be readily accessed and shared by multi-agency staff involved in the implementation. Data must also be geographically referenced, easily visualized, relevant, and up to date. Control of the data and necessary data sharing activities will need to be clearly defined.

Once all hydrologic and hydraulic drainage data has been collected and relevant analysis has been performed, preventative mitigation measures will need to be identified and prioritized at all high-risk roadway drainage crossings and bridges.

Throughout the vegetation recovery period, storm patrols will need to be conducted to monitor road drainage ditches, culverts, debris control structures, and bridges during and after significant rainfall events to ensure that structures remain safe and functioning at maximum capacity. A storm patrol plan and notification system will need to be developed and should be coordinated with other agencies accessing the corridor, including USFS, Clackamas County, Portland General Electric and ODOT.

Agencies will also need to be establish an emergency maintenance plan. They should be prepared to provide significant maintenance efforts after storm events to remove sediment and debris from ditches and entrances to culverts. Addition removal of debris flow material from the roadway and repair of the roadway may also be needed. The emergency maintenance plan should address key components such as before, during, and post-storm activities, priorities, and responsibilities. The plan should identify staging, storage, disposal areas for heavy equipment, materials, and removed debris.

Summary of Technical Recommendations and Areas of Further Study

The following sections summarize the technical recommendations and areas of further study to improve the wildfire-impacted, closed section of the OR 224 corridor.

Traffic and Safety Phase 1 Recommendations

Bicycle Facilities

- When visitation has normalized, conduct traffic counts to better understand seasonal traffic data (including bicycles), especially to understand the post-disaster differences in use throughout the corridor from the pre-disaster conditions. Many of the recommendations will be dependent on this data. The Forest should also coordinate with ODOT and WFLHD to identify traffic count needs to the south of the ODOT-maintained highway.
- Determine appropriate locations for additions of W11-1 Bicycle with supplementary W16-1P Share the Road plaques.
- Determine feasibility of dynamic warning signs (with either flashing LEDs or beacons) that become activated when bicycles are located within certain areas.
- Determine feasibility of wider edge lane markings (requires coordination with ODOT).
- Long-term: determine if shoulder widening is feasible or desired to provide 4- to 5-foot shoulders throughout the entire corridor.

Parking, Pedestrians, and Vegetation Screen Loss

- Determine locations where parking is undesirable and determine (from Appendix C, or from any other found sources) potential treatments to help discourage parking in those areas.
- Determine, in coordination with any potential planned recreational facility additions or upgrades and with consideration of any attractions or overnight visitation areas, where pedestrian crossings are most likely. Based on the availability of parking or the popularity of the attractions or overnight visitation areas, estimate the number of daily pedestrian crossings.
- Based on B above, determine the appropriate treatments at planned pedestrian crossings. Options include crosswalk markings, advance signage and markings, and rapid flashing beacons. If there is to be a major crossing, lighting may also be considered, but it is probable that such a major crossing does not exist in this corridor. Raised crosswalks are another option, though the impacts on maintenance and traffic must be considered.

Guardrail and Roadside Design

- Review the final inventory of replaced guardrail.
- Determine the amount of remaining existing guardrail (including terminal sections) that must be upgraded in order to meeting current crash testing criteria.
- Determine the actual clear zone throughout the corridor.
- Determine a priority list of placement of new guardrail. A benefit to cost procedure, discussed previously in this report, is likely necessary in order to determine the locations of highest value of new guardrail placement.

- Where guardrail may be warranted but cannot be installed due to lack of funding or other considerations, review other safety countermeasures (below) for alternatives.

Other Safety Countermeasures

- Once a determination has been made on recommendations for bicycles, parking, pedestrians, vegetation screen loss accommodations, guardrail, and roadside design, consider any remaining safety countermeasures that may be needed either to account for other risks or to account for any recommendations that could not be implemented due to cost or other considerations.
    - This includes but is not limited to curve warning signage, delineators, and high friction surface treatment.
- Complete review of historic crash data (see Appendix A).
- Determine feasibility of installation of dynamic signage for emergency management. The type, location, and control will have to be coordinated between USFS and ODOT.

Strategies for Improving Data Collection, Analysis, and Implementation of Safety Features

FLH Safety is currently conducting a GIS and systemic safety research project in order to provide FLH partner agencies with better tools to supplement a lack of traffic and safety data as well as efficiently analyze road networks for safety improvements. The pilot GIS tool is available for use and can be customized for the overall studies in the entire corridor (i.e. from Estacada to Detroit). For example, the locations of historical and current high-use and/or undesirable parking areas and pedestrian activity can be captured within the GIS application. These efforts, along with other Forest efforts, could be combined to help build a robust set of data while the next funding phase is identified and programmed. Contact WFLHD Safety and Planning for more information.

Other funding programs should be investigated further to identify which could be utilized to implement future improvements. These could include the ODOT-administered Highway Safety Improvement Program, the High-Risk Rural Roads program and the All Roads Transportation Safety program. These programs could help leverage FLAP, FLTP and other funding sources that ODOT and the Forest typically utilize in order to provide additional safety funding.

Performing the analysis and further study as discussed in this memorandum puts ODOT and the Forest well on the way to completing a Local Road Safety Plan, a FHWA initiative to bring transportation users home safely. The agencies and stakeholders in this corridor should consider partnering together to create a plan and strengthen ties among engineering, enforcement, education and emergency services countermeasures to reduce fatal and serious injury crashes.

Unstable Slope Phase 1 Recommendations

- Conduct a crosswalk of USRS rated unstable slopes by rerating both types of unstable slope with the USMP in order to compare ratings between the two systems so that sites can be ranked and prioritized for potential risk reduction measures.
- Utilize the USMP; (FLH, 2019) to rate identified unstable slopes where data gaps exist. This includes eight sites recommended by ODOT, three high hazard debris flow channels where past debris flow events have been observed, and the approximately five miles of the upper corridor from Three Lynx Creek to FSR 57 (see Attachment 4 - Table of Unstable Slopes Requiring USMP Ratings or Site Condition Assessments in Appendix B).
- Additionally, perform site condition assessments on eight high hazard debris flow prone channels where past debris flow events have not been observed. These data could be used to inform future study efforts that identify project-specific improvements to make OR 224 a more resilient transportation corridor.

Hydrology Phase 1 Recommendations

- Create an effective and efficient mechanism to implement, monitor, evaluate, and report on recovery activities, emergency responses, updates, and progress, which will require establishing staff roles, responsibilities, funding sources, and contact information across agencies.
- Organize corridor drainage structure data in a format that can be readily access and shared by multi-agency staff involved in implementation. Data must also be geographically referenced, easily visualized, relevant, and up to date. Control of the data and necessary data sharing activities will need to be clearly defined.
- Once all hydrologic and hydraulic drainage data has been collected and relevant analysis has been performed, preventative mitigation measures will need to be identified and prioritized at all high-risk roadway drainage crossings and bridges.
- Throughout the vegetation recovery period, storm patrols will need to be conducted to monitor road drainage ditches, culverts, debris control structures, and bridges during and after significant rainfall events to ensure that structures remain safe and functioning at maximum capacity. A storm patrol plan and notification system will need to be developed and should be coordinated with other agencies accessing the corridor, including USFS, Clackamas County, Portland General Electric and ODOT.
- Agencies will also need to be establish an emergency maintenance plan. They should be prepared to provide significant maintenance efforts after storm events to remove sediment and debris from ditches and entrances to culverts. Addition removal of debris flow material from the roadway and repair of the roadway may also be needed. The emergency maintenance plan should address key components such as before, during, and post-storm activities, priorities, and responsibilities. The plan should identify staging, storage, disposal areas for heavy equipment, materials, and removed debris.

Phase 2 - OR 224 Corridor Master Plan Scoping

The Phase 1 Existing Conditions Assessment offers a baseline understanding of the wildfire-impacted OR 224 corridor as it exists today. The report is intended to expand upon other post-fire assessments that have been completed, including the 2020 BAER report. While these baseline assessments offer valuable insights into current conditions, a comprehensive forward-thinking corridor master plan is needed to determine the future vision of the corridor, clearly articulate the complexity of transportation needs, and begin identifying alternatives and specific projects that will help achieve the corridor vision.

Proposed Work Summary

The proposed Phase 2 – OR 224 Corridor Master Plan will develop a comprehensive planning document that examines the current and future conditions and needs of the wildfire-impacted corridor. A master planning process will be especially useful in this particular context, as the future needs of the OR 224 corridor have not yet been defined and there are other related planning efforts in progress (e.g., viewshed planning, facility management, and recreational planning) that can be leveraged. The 2020 Riverside Fire completely changed the landscape within the Mount Hood National Forest Clackamas River Ranger District, impacting over 138,000 acres of land and various recreational sites. The challenges of recovering from wildfires are evident, particularly when disaster relief resources are limited, and these challenges are compounded without a clear roadmap of prioritized improvements.

The closed-portion of OR 224 from Promontory Park and Ripplebrook (MP 31.2 to MP 49.9) served a multitude of uses prior to the 2020 Riverside Fire, including timber management, hydroelectric power transmission, regional drinking water treatment, technical career training, and outdoor recreation. This planning effort will help develop a long-term, coordinated vision and related goals for the impacted area, further investigate high risk areas along the corridor, develop initial site designs for transportation improvements, and identify a comprehensive suite of capital projects and policy recommendations that support the many uses of the Mount Hood National Forest while enhancing transportation access.

High-Level Phase 2 Master Plan Scope

To assist the USFS and ODOT in pursuing additional funding resources to improve transportation access for OR 224, a high-level scoping framework and project budget have been developed.

<u>Task 1 – Project Coordination, Communication and Management Plan and Kick-Off Meeting</u>

The foundation of any successful project lies in a strong project roadmap. A productive kick-off meeting and thoughtful project work plan are essential in establishing that roadmap, which will outline the key project goals, procedures including a public involvement strategy, and a comprehensive work schedule and action tracker to maintain momentum throughout project delivery. Key activities for Task 1 may include:

- Compiling data and reports not collected in the Phase 1 Corridor Study Existing Conditions Assessment
- Developing a Public Involvement Strategy to guide the Corridor Master Plan process
    - This will serve as a framework for obtaining stakeholder input on project issues and options to inform the project decision process.
    - The strategy document shall:
        - Identify stakeholders
        - Describe approaches and techniques to involve stakeholders
        - Identify methods to gather and address stakeholder input
        - Describe methods for evaluating effectiveness of outreach efforts
        - Document the implementation of the Public Involvement Strategy
- Develop detailed project schedule

- Develop Project Coordination, Communication and Management Plan (this will describe final scope, schedule and budget for the Corridor Master Plan and serve as the project roadmap)

Task 2 – Community Visioning, Goal Setting and Public Engagement Strategy

Community visioning and goal setting offer residents, businesses, local institutions, and other stakeholders an opportunity to express their ideas about the future of their community and identify benchmarks to work towards. To effectively engage local stakeholders, a comprehensive and strategic public engagement approach must be developed. Key activities for Task 2 may include:

- Create a public-facing project website, which will be updated occasionally throughout the Corridor Master Plan with draft deliverables and information on opportunities to provide feedback.
- Establish a Project Advisory Committee (PAC) and host PAC meetings on a regular schedule.
- Develop a project contact list of interested parties.
- Develop news releases and project newsletters.
- Public meetings during the Corridor Master Plan – plan, coordinate, and attend approximately 3 public meetings. General topics for each meeting include:
    - 1st Public Open House – Identify Corridor Vision, Goals and Transportation Needs
    - 2nd Public Open House – Present Solutions and Recommendations for Stakeholder Consideration
    - 3rd Public Open House – Draft Corridor Master Plan

Task 3 – Finalize Existing Conditions Assessment, Define Desired Future Conditions, and Investigate Corridor Management Strategies

Various existing conditions data and assessments have been compiled for the closed OR 224 route, including data required to begin disaster recovery that was captured in the 2020 BAER Report and additional corridor-specific analyses included in this Phase 1 Existing Conditions Report. There are still data gaps that remain, documented in prior sections of this report, and should be included in any future planning analyses. To wrap-up the OR 224 Existing Conditions Assessments and define desired future conditions, the following Task 3 activities should include:

- Review and complete the areas of further analysis for traffic operations, safety, unstable slope ratings, and hydrology as identified in this Phase 1 report.
- Review and clarify existing right-of-way, maintenance, and operations agreements for the corridor.

Task 4 – Needs Identification and Alternatives Development

Using the stakeholder and public input received in Task 2 and the existing and desired future conditions gathered in Task 3, the USFS and ODOT can begin to identify specific corridor transportation needs along OR 224 and identify a range of system alternatives for consideration. Needs identification shall be based on both qualitative (input received during the 1st Public Open House) and quantitative data (analysis findings included in the Phase 1 report, plus additional assessments completed as part of Task 3) demonstrating deficiencies and lack of suitable conditions from a transportation user perspective.

Specific transportation improvement alternatives for OR 224 will be explored during this Task and may include, but are not limited to, parking configurations, wayfinding signage upgrades, pedestrian and wildlife crossing improvements, safety and operational improvements, context-sensitive design enhancements, bicycle facilities, etc. The final list of alternatives to be considered should include a range of options, from simple to complex, implementable by both the FS and ODOT, in coordination with other local entities.

Task 5 – Final Corridor Master Plan Report

The OR 224 Corridor Master Plan Final Report will compile the data, analysis, findings and recommendations of the previous tasks into a comprehensive roadmap that will assist the USFS and ODOT in prioritizing future transportation improvements. The report will provide contextual background and summarize the process followed from stakeholder outreach, data collection, existing and future conditions documentation, needs identification, and alternatives development. The final OR 224 Corridor Master Plan will include recommendations for implementing specific transportation solutions in response to the needs that were identified and the future vision that has been set forth by members of the local community. The final report will include an implementation plan that outlines the sequencing and phasing of capital and operational improvements and should address:

- Planning-level project cost estimates
- Prioritization of projects and initiatives
- Confirm funded and unfunded status
- Phasing of improvements
- Narrative text to clarify how actions will be advanced

Option for Planning and Environmental Linkages (PEL)

The OR 224 Phase 2 effort may benefit from a Planning and Environmental Linkages (PEL) study approach. FHWA defines PEL as a collaborative and integrated approach to transportation decision-making that considers benefits and impacts of proposed transportation system improvements to the environment, community, and economy during the transportation Planning Process. ODOT recently published a "Guide to Linking Planning and NEPA Using the ODOT PEL Questionnaire" in September 2021 that provides information to planners and environmental staff on developing a PEL strategy. While this Phase 1 report outlines a high-level Phase 2 scope, the USFS, ODOT, and FHWA should consider PEL as an option once funding has been secured and a detailed scope is needed.

Phase 2 Corridor Master Plan Cost Estimate

Table 7: OR 224 Phase 2 Corridor Master Plan Estimated Project Cost

Task	Estimated Cost
1. Project Coordination, Communication and Management Plan and Kick-Off Meeting	$50,000
2. Community Visioning, Goal Setting and Public Engagement	$75,000
3. Finalize Existing Conditions Assessment and Define Desired Future Conditions	$90,000
4. Needs Identification and Alternatives Development	$200,000
5. Draft and Final Corridor Master Plan Report	$75,000
Travel for Public Meetings and Site Visits	$10,000
TOTAL	**$500,000**

Appendix A

Safety and Traffic Assessment Technical Memorandum

U.S. Department
of Transportation
**Federal Highway
Administration**

Memorandum

Western Federal Lands Highway Division
610 E. Fifth Street
Vancouver, WA 98661

Date: September 10, 2021

From: Sean Kilmartin, P.E.
Highway Safety Engineer

To: Jamie Lemon, AICP
Transportation Planner

Subject: OR 224 Corridor Study Phase 1 – Safety and Traffic Assessment

Introduction

As part of the Phase 1 Corridor Study along Oregon State Route 224 (OR 224) within the Mount Hood National Forest, the Western Federal Lands Highway Division (WFLHD) Highway Safety Team has conducted an analysis of the corridor from Mileposts 31.2 through 49.97 with respect to safety and operational concerns. The road is owned by the U.S. Forest Service (USFS) and maintained by the Oregon Department of Transportation (ODOT). This analysis follows a June 16, 2021 site visit to the corridor.

Items reviewed and/or used for analysis as part of this assessment included:

- The ODOT TransGIS portal, which provides information on traffic data, lane widths, shoulder widths, mileposts (MP), signs, roadside barrier, and posted speed limits
- The ODOT Crash Data System, which provides location-specific crash history
- The Interactive Highway Safety Design Model (IHSDM), which is described below
- Aerial Imagery through a Bing Maps GIS layer
- Quadrangle maps through the United States Geologic Service (USGS)
- The Clackamas County Flood Insurance Study (FIS), which helped confirm the general grade of the river and the road (which generally follows the river throughout the corridor); the quad maps were the primary source of topographic data
- OpenRoads Designer, from which an approximated alignment was created to provide data for use by IHSDM
- The plan set for the OR DOT 224(1) Clackamas Highway Pavement Restoration Project (MP 31.73-MP 33.00 and MP 44.94-45.82)
- The ODOT Digital Video Log

This safety and traffic assessment has been mostly focused on baseline, pre-disaster conditions with some additional consideration given to future forest uses, users, and other considerations. Recommendations, where possible, are based on available information, but may sometimes require additional information or further study.

Traffic Data, Road Users, and Corridor Uses

The following average annual daily traffic (AADT) volumes, for both the current year and a potential design year (current year + 20 years) were retrieved from the ODOT TransGIS portal:

- MP 31.2-MP 39.1
  - Current year: 560 vehicles per day
  - Design year: 760 vehicles per day
- MP 39.1-MP 42.2
  - Current year: 550 vehicles per day
  - Design year: 760 vehicles per day
- MP 42.2-MP 48.3
  - Current year: 480 vehicles per day
  - Design year: 480 vehicles per day
- MP 48.3-MP 49.97
  - Current year: 300 vehicles per day
  - Design year: 320 vehicles per day

The percentage of the AADT that is truck traffic is 36.9% for all above segments, according to TransGIS. There is significant potential for seasonal traffic volumes to be significantly higher than the AADT volumes listed above. A potential goal for a future study would be to confirm traffic volumes within the corridor (including at some of the more prominent intersections and driveways). This confirmation may help planning or design efforts if there are ever future projects to add or upgrade parking, campground, or other forest features that would draw visitation and, potentially, congestion or user conflicts along with it. Posted speed limits are 55 MPH.

OR 224 is now part of the West Cascades Scenic Bikeway. There are currently no counts available for bicycle traffic, but the USFS did note that on a drive-through it is possible to see six to ten cyclists along the road. Bicycle traffic may also grow in the future if the corridor's reputation as an enjoyable place to ride continues to grow. It is possible to gather bicycle counts once the corridor is reopened to the public; however, without previous baseline or pre-disaster bicycle counts, it will be more difficult to project bicycle traffic growth.

Pedestrians are an additional road user group to consider as part of the future corridor. Currently, there are no marked or signed pedestrian crossings within the study limits. However, the USFS noted that it is common for pedestrians to cross the road to access areas on the opposite side from where they park. Campgrounds, boating access areas, and other defined recreational features are the areas where these pedestrian crossings are most likely to occur, but with vehicles parking at a large number of places throughout the corridor, the potential for pedestrian crossings is increased. Additionally, there is concern that with the loss of vegetation that may have previously served as a barrier to access, pedestrian crossings may become even more hazardous in the future as access points have increased and are even less defined or obvious to drivers.

The USFS identified some of the primary ways in which those who access this area of Mount Hood National Forest use this corridor:

- Scenic driving, including motorcycle or bicycle traffic
- Camping, including on and off designated campgrounds
- Hiking, picnicking, mushroom picking, target shooting, and other ‘on foot’ activities
- River activities, including boating and kayaking, as well as winter sports and activities
- Commercial activities, including maintenance of the hydroelectric facilities, other utilities, or logging activities (including through traffic)

The above list is not all-inclusive, and the complete list of needs for each of those uses is outside of the scope of a safety and traffic assessment. However, these needs must be considered when intersecting with corridor safety needs, parking needs, and other traffic needs. Currently, there are a large number of vehicles parking at undesirable locations throughout the entire corridor, creating safety and environmental concerns. The parking in undesirable areas is expected to be exacerbated following the loss of vegetation. Visitors who park in these undesirable areas may also be participating in other activities, such as target shooting or camping, in undesirable or unsafe areas. Another consideration is the different goals of the road users. Some of those visiting the corridor for scenic driving or other recreational activities may at times be driving at lower speeds. Those using the corridor for commercial activities may be incentivized to travel at higher speeds. These speed differentials, while difficult to model when caused by recreation, can increase the risk of crashes.

Existing Guardrail and Roadside Condition

Extensive guardrail damage was observed throughout the corridor. An accounting of the following will be needed:

1. Guardrail damaged by during the disaster or during disaster-recovery that will be replaced in-kind once the post-disaster logging activities are complete.
2. Guardrail (specifically guardrail that does not meet current crash testing criteria) that was not damaged and will not be replaced in kind.
3. Locations where there is no existing guardrail but, with post-disaster conditions, may be warranted as part of a potential future project.

An inventory of all existing guardrail in the corridor (from ODOT TransGIS, see above link) is included in Appendix E. Given the high risk of slides or fallen trees throughout the corridor, it is assumed that continued monitoring of the roadside is needed as more guardrail may become damaged until the area stabilizes. The area may not fully restabilize until the downslopes become revegetated.

The starting point for evaluating where new guardrail may be needed is an evaluation of the clear zone throughout the corridor. According to Section 3.1 of the AASHTO Roadside Design Guide, the clear zone is the unobstructed, traversable area provided beyond the edge of the traveled way for the recovery of errant vehicles. The shoulder, any turnouts, and any roadside area free of obstructions with slopes 1V:4H or flatter are considered to be part of the clear zone. Descriptions of recoverable, traversable, and non-traversable and non-recoverable slopes are as follows:

- Slopes 1V:4H are considered to be traversable and recoverable, meaning that an errant vehicle that reaches this type of slope can generally stop their vehicle or slow them enough to return to the roadway (if the slope is wide enough and free of obstructions).
- Slopes steeper than 1V:4H but flatter than 1V:3H are considered to be traversable but non-recoverable. Errant vehicles that encounter slopes in this range cannot likely navigate back to the roadway or come to a complete stop, but can likely be expected to reach the bottom of the slope without rolling over. Slopes in this range are if there are no obstructions on the slope or at the toe of the slope, and if there are slopes 1V:4H or flatter at the toe, then the clear zone resumes at the toe of the slope where vehicles have the opportunity to safely come to a stop.
- Slopes steeper than 1V:3H are considered to be non-traversable and non-recoverable, meaning that vehicles that encounter slopes in this range cannot recover to the roadway and cannot safely steer to the bottom. Slopes in this range present a rollover risk that increases proportionately to slope steepness (especially for slopes steeper than 1V:2H). No field measurements were taken on the June 16, 2021 site visit, but based on observations and the contour lines from the USGS quad maps, it seems that most slopes in the corridor fall into this range. With the loss of vegetation, many roadside slopes appeared to be undergoing soil erosion, causing the slopes to steepen in areas where the soil has migrated down-slope.

The AASHTO Guidelines for the Geometric Design for Low Volume Roads may apply to this corridor when determining the recommended clear zone width since the average daily traffic is less than 2000 vehicles per day, according to the ODOT Trans GIS site. However, until there is confirmation of seasonal highs in traffic volumes, it may be more appropriate to refer to Table 3-1 of the AASHTO Roadside Design Guide for recommended clear zone widths:

- Foreslopes (downhill):
    - 1V:6H or flatter – 12 to 14 feet
    - 1V:5H to 1V:4H – 14 to 18 feet
- Backslopes (uphill):
    - 1V:3H – 8 to 10 feet
    - 1V:5H to 1V:4H – 10 to 12 feet
    - 1V:6H or flatter – 10 to 12 feet

IHSDM Description

The Interactive Highway Safety Design Model (IHSDM) is a suite of software analysis tools for evaluating safety and operational effects of geometric design in the highway project development process. The IHSDM contains six modules that can be used to evaluate nominal and substantive safety performance. For this study, WFLHD Safety used the Crash Prediction, Policy Review, Design Consistency, and Traffic Analysis Modules to evaluate the OR 224 corridor.

With no available survey, a variety of sources were used to acquire or approximate the data needed to run IHSDM. A horizontal alignment was approximated in OpenRoads Designer with the use of aerial imagery. A vertical alignment was approximated with the use of USGS quad maps, and a drive-through of the corridor on the June 16, 2021 site visit confirmed no significant grades or grade changes that would have a major effect on IHSDM output. Data for lane widths, shoulder widths, and guardrail locations were taken from the ODOT TransGIS site. Cross slope data was approximated to be 2% for a typical tangent section. For curve sections, the cross slopes were approximated to the appropriate superelevation for each radius as listed in the AASHTO Policy on Geometric Design of Highways and Streets (8% maximum table, Table 3-10). Inputs for the roadside data were based on the USGS quad maps, Google Streetview imagery, and aerial imagery. Traffic and crash data were as listed previously in this memorandum.

Some key assumptions and further description of the use of IHSDM and these four modules for this analysis are listed in Appendix A. Please refer to this section to further understand the context of the model for this analysis.

IHSDM Output Data Analysis

The IHDSM software divides the roadway into segments based on changes in roadway geometry, such as lane width, shoulder width, cross slope, or roadside hazard rating, as well as changes in traffic data or behavior. 206 segments were identified within this corridor. To ease the analysis of the output data, the segments were combined into 12 distinct groups based on similar features such as tangent sections, reverse curves, or similar roadside conditions. A description of the 12 groups is as follows (see Appendix B for more information):

TABLE 1: OR 224 Groups

Group Number	Start MP*	End MP*	Description
1	31.2	32.6	Long, high radius curves; adjacent to significant recreational facility
2	32.6	34.5	Series of lower radius, shorter curves
3	34.5	35.6	Fairly straight section
4	35.6	37.8	Series of curves, including a change in horizontal alignment of approx. 180°
5	37.8	39.2	Fairly straight section
6	39.2	41.0	Series of curves, mix of medium and high radius
7	41.0	42.3	Fairly straight section
8	42.3	44.2	Series of curves, higher radius as compared to Group 8
9	44.2	46.4	Series of curves, including changes in horizontal alignment of approx. 90°
10	46.4	47.5	Fairly straight section
11	47.5	49.0	Winding section with curves of varying lengths, some lower radius
12	49.0	49.97	End of corridor, more driveways, lower speed limit

*Mileposts listed are approximate

The Design Consistency and Traffic Analysis Modules were used to help examine expected speeds throughout the corridor. IHSDM runs a speed model through the geometry, taking into account horizontal curves and vertical grades in order to determine the effects that geometry has on speed (e.g. faster on steeper downgrades, slower on steeper upgrades). The results are sensitive to the Desired Speed input, which is estimated here in absence of formal speed data. For a design speed such as 55 mph, proposed for use on this project, an estimate of 65 mph was used since the corridor is characterized by long tangent sections with minimal significant grade changes. Anecdotally, as noted by the USFS at the June 16, 2021 site visit, risky driving (and, at times, impaired driving) is commonplace enough during the high visitation season to be a significant concern. The speed model helps the project team with locating higher discrepancies between expected speed and design speed of individual geometric elements such as horizontal and vertical curves. This can help fine-tune countermeasures such as warning signage to better align with motorist's expectations.

Data gained through the Crash Prediction Module, the Policy Review Module, and the Design Consistency Module were used to compare groups (due to approximated data, the Driver/Vehicle Module failed to run and data from the Driver/Vehicle Module was not included in the results analysis). The comparison was completed with the following data:

1. Expected Crashes data adjusted by group length (crashes/group/mile). This data relies on an Empirical-Bayes analysis using historical crash data. This data is noted as 'Expected Crashes' for the remainder of the report.
2. Predicted Crashes data adjusted by group length (crashes/group/mile). This is the default model for crash prediction within IHSDM and relies on roadway geometry, roadside features and other program inputs. This data is noted as 'Predicted Crashes' for the remainder of the report. The predicted crash data is especially important for this analysis due to the age of the historical crash data.
3. Total expected crashes per group.
4. Total predicted crashes per group.
5. Design Consistency Module flagged data within each group (i.e. segment with an element not designed according to the AASTHO Green Book counted as one flag).
6. Policy Review Module flagged data within each group (i.e. each severe speed differential or deficient stopping sight distance within each segment counted as one flag).

These six items for each group were compared to their position with respect to the 90th percentile number and the 75th percentile number for each data set. For example, a group with predicted crashes based on Empirical-Bayes data in the 90th percentile as compared to all other groups received 1 point. A group with predicted crashes based on Empirical-Bayes data between the 75th percentile and the 90th percentile as compared to all other groups received 0.5 points. Groups with Empirical-Bayes crashes data below the 75th percentile received 0 points. Scores were totaled for the 12 groups and then ranked. Several groups were identified for further analysis. The IHSDM analysis and results allows for data-driven safety analysis to identify the sections of the project that would benefit the most from specific safety features, discussed in the Data Analysis section.

Existing Data Analysis

The 12 groups are identified and described within Appendix B. These groups were scored based on criteria numbers 1-6 identified in the above IHSDM Output Data Analysis section. The ranked by risk groups are shown in Table 2 below (see Appendix C for more information on the data and scoring):

Table 2: Ranked by Risk OR 224 Groups

Rank	Group	Start MP	End MP
1	4	35.6	37.8
2	11	47.5	49.0
3	2	32.6	34.5
4	9	44.2	46.4
5	8	42.3	44.2
6	10	46.4	47.5
7	1	31.2	32.6
8	3	34.5	35.6
8	5	37.8	39.2
8	6	39.2	41.0
8	7	41.0	42.3
8	12	49.0	49.97

The Crash Prediction Module results for the corridor are in part summarized through the following tables:

Table 3: Comparing Crash Prediction Module Expected and Predicted Crashes (Existing Conditions – 20-Year Design Life)

Crash Prediction Module Method	Total Crashes	Fatal & Injury Crashes	Percent Fatal & Injury	Property Damage Only Crashes	Percent Property Damage Only
Predicted	108.24	34.74	32.10%	73.50	67.90%
Expected	137.12	70.84	51.67%	66.27	48.33%
Percent Difference	*21.06%*	*50.95%*		*10.90%*	

Table 3 shows the breakdown of expected crashes by those resulting in Fatal and Injury (FI) and those resulting in Property Damage Only (PDO). As shown, between 32% and 52% of all crashes result in a fatality or an injury, indicating the risk of roadway departures in this corridor. A roadway departure crash occurs when there is a crash that involves a vehicle crossing centerline, an edge line, or a lane line.

The expected crash data, which relies on historical crash data, shows an elevated percentage of fatal and injury crashes. This is a strong indication that the risk of severe crashes in the corridor is higher than what could be anticipated when reviewing the roadway and roadside strictly by its geometry and features. Driver behavior may be one explanation. Expected and predicted crash data cover a 20-year design life and account for the projected increase in traffic volume (exposure) over time.

Table 4: Expected Crash Type Distribution (Existing Conditions – 20-Year Design Life)

Crash Type	Fatal and Injury		Property Damage Only		Total	
	Crashes	Crashes (%)	Crashes	Crashes (%)	Crashes	Crashes (%)
Collision with Animal	2.69	2.00%	12.19	8.90%	16.59	12.10%
Collision with Bicycle	0.28	0.20%	0.07	0.00%	0.27	0.20%
Other Single-vehicle Collision	0.5	0.40%	1.92	1.40%	2.88	2.10%
Overturned	2.62	1.90%	0.99	0.70%	3.43	2.50%
Collision with Pedestrian	0.5	0.40%	0.07	0.00%	0.41	0.30%
Run Off Road	38.61	28.20%	33.47	24.40%	71.44	52.10%
Total Single Vehicle Crashes	**45.20**	**33.00%**	**48.71**	**35.50%**	**95.02**	**69.30%**
Right-Angle Collision	7.16	5.20%	4.77	3.50%	11.65	8.50%
Head-on Collision	2.41	1.80%	0.2	0.10%	2.19	1.60%
Other Multi-vehicle Collision	1.84	1.30%	1.99	1.40%	3.70	2.70%
Rear-end Collision	11.69	8.50%	8.09	5.90%	19.47	14.20%
Sideswipe	2.69	2.00%	2.52	1.80%	5.07	3.70%
Total Multiple Vehicle Crashes	**25.79**	**18.80%**	**17.56**	**12.80%**	**42.09**	**30.70%**
Total Expected Crashes	**70.98**	**51.80%**	**66.27**	**48.30%**	**137.12**	**100.00%**

Table 4 shows the expected crash type distribution. Single-vehicle crashes are highlighted in green. Multi-vehicle crashes are highlighted in yellow. Corridor totals are highlighted in orange. As shown, the largest number of crashes were single vehicle roadway departures. These three tables, in addition to all other IHDSM output especially those specific to the more at-risk groups, help to identify effective and cost-efficient crash reduction features that can be applied to the OR 224 corridor.

Discussion of Recommendations and Potential Next Steps for Bicycle Facilities

A project to widen the roadway to accommodate 4- to 5-foot shoulders throughout the entire corridor would require a significant amount of earthwork, disturbance to environmentally-sensitive areas, potential bridge widening, and cost. While widening may be the ideal solution to cyclist accommodation, the below discussion is based on the roadway template remaining the same in the future.

There is readily available online marketing and information for the West Cascades Scenic Bikeway, but signs and pavement markings for cyclists are limited south of Estacada. At a minimum, select placement of W11-1 Bicycle with supplementary W16-1P Share the Road plaques will help reinforce the presence of bicycles on the road or shoulder.

An additional option would be the use of dynamic warning signs (with either flashing LEDs or beacons) that become activated when bicycles are located within certain areas. These work by registering bicycle traffic counts and activating the flashing devices for a certain amount of time until cyclists have cleared an area. These are useful for areas where the shoulder is minimal and cyclists are within the roadway, and are especially useful for when cyclists can be expected within the roadway and there is limited sight distance. Potential locations along OR 224 for these types of devices would be in advance of select bridges (depending on shoulder width), areas where the road face extends adjacent to the inside of curves and limits sight distance, areas where there may be significant roadside parking and cyclists are pushed into traveling in the road, or to cover general areas where bicycle traffic volumes are anticipated to be high. These types of devices (with flashing beacons rather than LED lighting) are used elsewhere in Oregon, such as along OR 26, Cascade Lakes National Scenic Bikeway, and OR 242 near McKenzie Pass (see Figure 1 below):

Figure 1: Dynamic Warning Signage for Bicycles (OR 242, MP 78.6, ODOT Digital Video Log)

One definite recommendation would be the use of wider edge lines throughout the corridor (compared to the current 4-inch wide lines). These lines provide improved delineation between the lane and shoulder, which may help to better separate motorists from cyclists. They also provide an 18% reduction in crashes of all types and severities. When WFLHD recommends wider edge lines, it typically recommends 6-inch wide lines. The ODOT Pavement Marking Standard Detail Blocks (TM500) show only 4-inch and 8-inch wide lines; if wider edge lines are used, coordination with ODOT would be necessary to determine the appropriate width for this road.

Discussion of Recommendations and Potential Next Steps for Parking, Pedestrians, and Adjustments to Vegetation Screen Loss

Any improvements installed within the corridor to improve parking (either additions or discouragements), to improve pedestrian facilities, and to accommodate for the loss of a vegetation screen along the roadway will likely need to be complementary in order to provide the highest benefit. While there will be parking along the road throughout the corridor, the areas with the highest concentration of parking will be the areas in which there is some type of attraction that will draw overnight visitation. The vegetation screen loss causes the highest concern in the areas where there are campgrounds, spot camping, or environmentally-sensitive features that could be damaged by vehicles parking off-pavement. The areas with the highest number of parked vehicles will correlate directly with the highest number of pedestrians and, depending on the attraction, may correlate with the highest number of pedestrian crossings.

Other US National Forests, as well as other federal agencies, are struggling with roadside parking in undesirable areas. A presentation provided to Yellowstone National Park, detailing the known methods of discouraging parking in undesirable areas, is included in Appendix F. These methods have all had mixed results, though no formal study has ever been completed on any areas in which these methods have been implemented. Based on the different uses of the OR 224 corridor, there will not likely be a ‘one size fits all’ solution. One example of an area where solutions to restrict parking and/or access may be needed is near MP 41.0. Visitors either park on one side of the road to cross to the opposite (east) side or drive their vehicles into traversable areas on the east side that are not defined as access driveways. In addition to the earth disturbance, these visitors use the hillside on the east side for target shooting. There is a parking area on the west side which has space for picnicking or access to the river. The target shooting is in range of this parking area as well as the road. While target shooting is a draw to the forest, this is not the most appropriate area for it and methods of further discouraging use in this particular area are of interest.

Figure 2: Area of Concern for Parking and Access (OR 224, MP 41.0)

One method of parking discouragement discussed at the June 16, 2021 site visit is guardrail installation. Guardrail is only recommended in areas where the crash as a result of a roadside departure is more severe than a crash caused by a vehicle striking the guardrail itself. Specific to areas of campgrounds or spot camping, a consideration for guardrail installation would be the clear zone width and location of the campers. Further discussion of guardrail and roadside design, including the clear zone, is included in the next section. The next steps include a review of the roadside slopes, a delineation of areas where parking should be discouraged, the location of the campgrounds compared to the clear zone width, and an analysis of the roadside condition.

Pedestrian facilities should be coordinated with both the future usage of campgrounds and the future context of any existing or proposed recreational facilities. Pedestrian crossings should be provided in any areas where parking is provided and there is some type of attraction on the opposite side of the road. Methods of funneling pedestrians to a defined crossing will be site-specific. The type of crossing will depend on both the number of anticipated pedestrian crossings and the stopping sight distance along the highway. Features that could be included in a pedestrian crossing may include crosswalk markings, advanced warning signage, in-street signage, or rectangular rapid flashing beacons. The next steps include a review of roadside attractions, a review of any existing and any planned or proposed recreational facilities, and an estimation of potential pedestrian crossings based on those attractions or facilities. High visibility crosswalk markings have a 48% crash reduction factor for potential crashes involving pedestrians (which have a high probability of resulting in a fatality). Advanced Stop/Yield for Pedestrians signs and markings have a crash reduction factor of 25%. Rapid flashing beacons installed at crossings have a crash reduction factor of 47% for crashes involving pedestrians.

There is benefit to using more than one of these treatments at a location; for example, high visibility markings used with advanced signs and markings will reduce the probability of crashes involving pedestrians by more than 48%. Crash reduction factors cited in this report are based on data or reports identified in the Crash Modification Factor Clearinghouse or the AASHTO Highway Safety Manual. A crash reduction factor is applicable when an installed feature can reduce the risk (either in probability or in severity) of future crashes. Lighting and raised crosswalks may also be options.

Figure 3: High Visibility Crosswalk Markings with In-Street Signage (Yellowstone National Park; installation along OR 224 likely not in stop-controlled areas)

Discussion of Recommendations and Potential Next Steps for Guardrail and Roadside Design

The final inventory of guardrail replaced as a result of the disaster will help guide any further efforts on guardrail; the preliminary accounting of anticipated guardrail replacements will have to be compared to the actual replacements following the logging and utility work. Once it is determined how much of the existing guardrail has been replaced, the next step is to determine how much of the remaining guardrail must be replaced to meet current crash testing criteria. Additionally, a review of the existing bridge rail throughout the corridor is needed.

The final step relating to guardrail is to determine how much additional guardrail is needed, based on new conditions following the fire. New guardrail installation will likely have to be balanced between relative roadside departure risk and cost. To determine where new guardrail may be warranted, a full evaluation of the clear zone in locations where there is no existing guardrail is recommended. A special focus on the areas where there has been significant vegetation loss may be needed. Once the clear zone and roadside slopes and actual clear zone widths are documented (compared to recommended), guardrail warrants can be developed. However, it is likely that there will be budgetary restrictions on new guardrail installation. Rather than simply developing a list of locations where new guardrail is warranted, it is recommended to develop a priority list for where guardrail and other roadside design treatments are most beneficial.

Figure 4: Apparently Undamaged Guardrail and Bridge Rail (OR 224, MP 31.2)

Figure 5: Apparently Undamaged Guardrail and Bridge Rail (OR 224, MP 49.97)

In other WFLHD-designed roadway projects where there are similar budgetary restrictions on guardrail installation or other considerations (i.e. environmental or wildlife impacts, aesthetics, etc.), WFLHD Safety has used a benefit/cost procedure to determine where guardrail could provide the highest value. Two programs available for completing this type of analysis are the AASHTO ROADSIDE procedure (outlines in previous additions of the Roadside Design Guide and used by the Alaska DOT&PF) and the Roadside Safety Analysis Program (RSAP). WFLHD Safety has used the ROADSIDE procedure previously. The benefits identified in these procedures are the reduction in crashes or the reduction in crash severities over the 20-year design life; the costs to which the benefits are compared are the initial construction costs of installation and the maintenance costs of repairs over the 20-year design life. Through the FHWA Highway Safety Improvement Program (HSIP), each state has placed a tangible, economic cost to different crash types; some of these costs include medical costs, property damage, emergency services, productivity losses, congestion impacts, insurance costs, and other legal claims. The opportunity to reduce these economic costs, or human impact costs, is considered to be a benefit. The actual costs used in these types of analysis are construction and maintenance costs, including potentially embankment material, guardrail, guardrail terminal sections, or vegetation clearing. Additionally, this analysis can identify other options that may be more cost effective than guardrail, such as providing full or partial clear zone treatments (i.e. find the optimized foreslope combinations and widths).

Discussion of Recommendations and Potential Next Steps for Other Safety Countermeasures

The IHSDM results can help guide the placement of safety countermeasures including signage, rumble strips, and delineators. From the site visit on June 16, 2021, it appeared that much of the signage throughout the corridor was in the appropriate location. Centerline rumble strips were present throughout much of the corridor, though were somewhat worn down. Delineators may have been common in the areas where there is existing guardrail (though it was difficult to determine due to the damage to the guardrail), but appeared to be less common in areas where there is no existing guardrail.

The next step, once a decision on previously discussed recommendations has been made, would be to use the IHSDM results to determine if any additional safety countermeasures are recommended. Examples would include:

- Additional curve warning signage. Depending on the type of signage, a crash reduction factor of 25-40% is applicable for signed curves, showing a high value in areas where there is a significant crash history or where IHSDM has shown elevated risk.
- Additional delineators (especially in areas where guardrail has been shown not to be cost-effective or where there are not sufficient funds to install guardrail). A crash reduction factor of 11% is applicable for delineators placed on horizontal curves; there is additional benefit, though not yet quantified, for delineators placed on tangent sections with steep drop-offs.
- High friction surface treatment (especially in areas where the curve radius or superelevation is deficient compared to the recommended values in the AASHTO Green Book). A crash reduction factor of 24% is applicable through the length of curves where high friction surface treatment is installed, and this treatment may have a higher benefit/cost ratio than superelevation correction or curve flattening. The benefit is even higher with respect to reducing crashes in wet weather.
- Wider edge lines (discussed in the bicycle section, but the highway safety benefits are present regardless of impacts on bicycle traffic). Wider edge lines have a crash reduction factor of 18%.
- Long-term: review crashworthiness of bridge rail throughout the corridor.

Historic crash data was reviewed and used to the extent necessary to run IHSDM, but a more thorough look at individual crashes and trends is needed. For the purpose of this study, the data was gathered and included in Appendix D (no personally identifiable information included). It is recommended that any future study or project complete the review of the latest crash data. A summary by severity of the crashes along OR 224 between 2010 and 2019 is as follows:

- 7 crashes in which the most severe outcome was a fatality (K)
- 8 crashes in which the most severe outcome was a serious injury (A)
- 37 crashes in which the most severe outcome was a moderate injury (B)
- 27 crashes in which the most severe outcome was a minor injury (C)
- 16 crashes in which the most severe outcome was property damage only (PDO)

According to the ODOT 2019 State Highway Crash Rate Tables, the crash rate for non-freeway type roads is 1.40 crashes per million vehicle miles traveled. Assuming 560 vehicles per day in the corridor over 18.8 miles, the crash rate in this corridor may be as high as 2.47 crashes per day. Given that traffic decreases over the length of the corridor, this may be on the low end of the crash rate.

A final consideration is emergency management. At the kickoff meeting, a desire was indicated to investigate dynamic signage to convey messaging to the public. This messaging could include road closures due to slides, wildfires, or other events. It could also indicate evacuation route information or other critical information. The type and placement of this signage will have to be coordinated with both the USFS and ODOT. It will have to be determined which agency would control the messaging, and how they will do so. A source of power would also have to be identified.

Summary of Recommendations

Bicycle Facilities

I. When visitation has normalized, conduct traffic counts to better understand seasonal traffic data (including bicycles), especially to understand the post-disaster differences in use throughout the corridor from the pre-disaster conditions. Many of the recommendations will be dependent on this data. The Forest should also coordinate with ODOT and WFLHD to identify traffic count needs to the south of the ODOT-maintained highway.

II. Determine appropriate locations for additions of W11-1 Bicycle with supplementary W16-1P Share the Road plaques.

III. Determine feasibility of dynamic warning signs (with either flashing LEDs or beacons) that become activated when bicycles are located within certain areas.

IV. Determine feasibility of wider edge lane markings (requires coordination with ODOT).

V. Long-term: determine if shoulder widening is feasible or desired to provide 4- to 5-foot shoulders throughout the entire corridor.

Parking, Pedestrians, and Vegetation Screen Loss

A. Determine locations where parking is undesirable and determine (from Appendix G, or from any other found sources) potential treatments to help discourage parking in those areas.

B. Determine, in coordination with any potential planned recreational facility additions or upgrades and with consideration of any attractions or overnight visitation areas, where pedestrian crossings are most likely. Based on the availability of parking or the popularity of the attractions or overnight visitation areas, estimate the number of daily pedestrian crossings.

C. Based on B above, determine the appropriate treatments at planned pedestrian crossings. Options include crosswalk markings, advance signage and markings, and rapid flashing beacons. If there is to be a major crossing, lighting may also be considered, but it is probable that such a major crossing does not exist in this corridor. Raised crosswalks are another option, though the impacts on maintenance and traffic must be considered.

Guardrail and Roadside Design

i) Review the final inventory of replaced guardrail.
ii) Determine the amount of remaining existing guardrail (including terminal sections) that must be upgraded in order to meeting current crash testing criteria.
iii) Determine the actual clear zone throughout the corridor.
iv) Determine a priority list of placement of new guardrail. A benefit to cost procedure, discussed previously in this report, is likely necessary in order to determine the locations of highest value of new guardrail placement.
v) Where guardrail may be warranted but cannot be installed due to lack of funding or other considerations, review other safety countermeasures (below) for alternatives.

Other Safety Countermeasures

1) Once a determination has been made on recommendations for bicycles, parking, pedestrians, vegetation screen loss accommodations, guardrail, and roadside design, consider any remaining safety countermeasures that may be needed either to account for other risks or to account for any recommendations that could not be implemented due to cost or other considerations.
    1.1. This includes but is not limited to curve warning signage, delineators, and high friction surface treatment.
2) Complete review of historic crash data (see Appendix D).
3) Determine feasibility of installation of dynamic signage for emergency management. The type, location, and control will have to be coordinated between USFS and ODOT.

Strategies for Improving Data Collection, Analysis and Implementation of Safety Features

FLH Safety is currently conducting a GIS and systemic safety research project in order to provide FLH partner agencies with better tools to supplement a lack of traffic and safety data as well as efficiently analyze road networks for safety improvements. The pilot GIS tool is available for use and can be customized for the overall studies in the entire corridor (i.e. from Estacada to Detroit). For example, the locations of historical and current high-use and/or undesirable parking areas and pedestrian activity can be captured within the GIS application. These efforts, along with other Forest efforts, could be combined to help build a robust set of data while the next funding phase is identified and programmed. Contact WFLHD Safety and Planning for more information.

Other funding programs should be investigated further to identify which could be utilized to implement future improvements. These could include the ODOT-administered Highway Safety Improvement Program, the High-Risk Rural Roads program and the All Roads Transportation Safety program. These programs could help leverage FLAP, FLTP and other funding sources that ODOT and the Forest typically utilize in order to provide additional safety funding.

Performing the analysis and further study as discussed in this memorandum puts ODOT and the Forest well on the way to completing a Local Road Safety Plan, a FHWA initiative to bring transportation users home safely. The agencies and stakeholders in this corridor should consider partnering together to create a plan and strengthen ties among engineering, enforcement, education and emergency services countermeasures to reduce fatal and serious injury crashes.

If there are any questions on the content of this memorandum, please contact Sean Kilmartin at 360-619-7686 or sean.kilmartin@dot.gov.

Safety and Traffic Appendix A

IHSDM Discussion

Crash Prediction Module

The IHSDM Crash Prediction Module estimates the frequency of crashes on a highway using geometry design and traffic characteristics. It is an implementation of the crash prediction methods documented in part C of the American Association of State Highway and Transportation Officials' (AASHTO) First Edition Highway Safety Manual (HSM)—includes capabilities to evaluate rural two-lane highways, rural multilane highways, urban/suburban arterials, freeway segments, and freeway ramps/interchanges (including ramps, collector-distributor (C-D) roads, and ramp terminals). The algorithms for estimating crash frequency combine statistical Safety Performance Functions (SPFs)—i.e., base models—and crash modification factors (CMFs). SPFs are available for roadway segments, many types of intersections, freeway ramps, C-D roads, and ramp terminals. The Crash Prediction Module was run for this project for the years of 2021 through 2041. Site-specific historical crash data was available for this analysis, but was not as current as desired. 2% normal cross slopes for the length of each alignment alternative were used. Superelevation data was estimated based on the AASHTO Greenbook as an assumption, but will need to be confirmed as part of the design process. Recommendations may need to be altered where superelevation design criteria cannot be met. Roadway widths were assumed to be 24 feet (12 feet, 0 inch lanes) with four-foot shoulders on both sides of the road (with some narrowed sections). Existing guardrail locations and are known and were used for this analysis, but will need to be reviewed through further phases of a study.

Design Consistency Module

The IHSDM Design Consistency Module helps diagnose safety concerns at horizontal curves. Crashes on two-lane rural highways are over-represented at horizontal curves, and speed inconsistencies are a common contributing factor to crashes on curves. This module provides estimates of the magnitude of potential speed inconsistencies. The DCM uses a speed-profile model that estimates 85th percentile, free-flow, passenger vehicle speeds at each point along a roadway. The speed-profile model combines estimated 85th percentile speeds on curves (horizontal, vertical, and horizontal-vertical combinations), desired speeds on long tangents, acceleration and deceleration rates exiting and entering curves, and an algorithm for estimating speeds on vertical grades. Speeds entering or exiting the corridor at the northern and southern ends of the project were estimated to be 55 MPH at either end.

Policy Review Module

The Policy Review Module checks roadway-segment design elements for compliance with relevant highway geometric design policies. The module provides electronic files replicating quantitative policy values specified by the American Association of State Highway and Transportation Officials (AASHTO) in the 1990, 1994, 2001, 2004, and 2011 editions of "*A Policy on Geometric Design of Highways and Streets*" and automates checks of design values against those policy values. The Interactive Highway Safety Design Model (IHSDM) also provides a tool for inputting policy tables from other agencies' design policies. The module,

IHSDM Discussion Reference:
https://cms7.fhwa.dot.gov/research/interactive-highway-safety-design-model/modules/modules

which is applicable to rural two-lane and rural multilane highways, organizes checks into four categories: cross section, horizontal alignment, vertical alignment, and sight distance. Cross-section checks include through-traveled way width, auxiliary lane width, shoulder width and type, cross slope rollover on curves, bridge width, bike lane width, and (on rural multilane highways only) median width. Horizontal alignment checks include radius of curvature, superelevation rate, length of horizontal curve, and compound curve ratio. Vertical alignment checks include tangent grade and vertical curve length. The Policy Review Module can also check stopping, passing (on rural two-lane highways), and decision sight distance.

Traffic Analysis Module

The Traffic Analysis Module uses the TWOPAS traffic simulation model to estimate traffic quality-of-service measures for an existing or proposed design under current or projected future traffic flows. The traffic analysis module facilitates use of TWOPAS by feeding it the roadway geometry data stored by IHSDM. TWOPAS is the microscopic traffic simulation model that was previously used to develop the two-lane highway chapter of the Transportation Research Board's (TRB) "*Highway Capacity Manual*." TWOPAS produces measures including average speed and percentage of time spent following other vehicles. TWOPAS has the capability to simulate any combination of grades, curves, sight restrictions, no passing zones, and passing and climbing lanes. It is particularly useful for understanding variable traffic speeds throughout the corridor. 'Steep Grade' was selected to describe the alignment for both increasing and decreasing stations. The vehicle flow rate used was the Design Hourly Volume (Design Year ADT*0.15 – K Value selected for rural roadway).

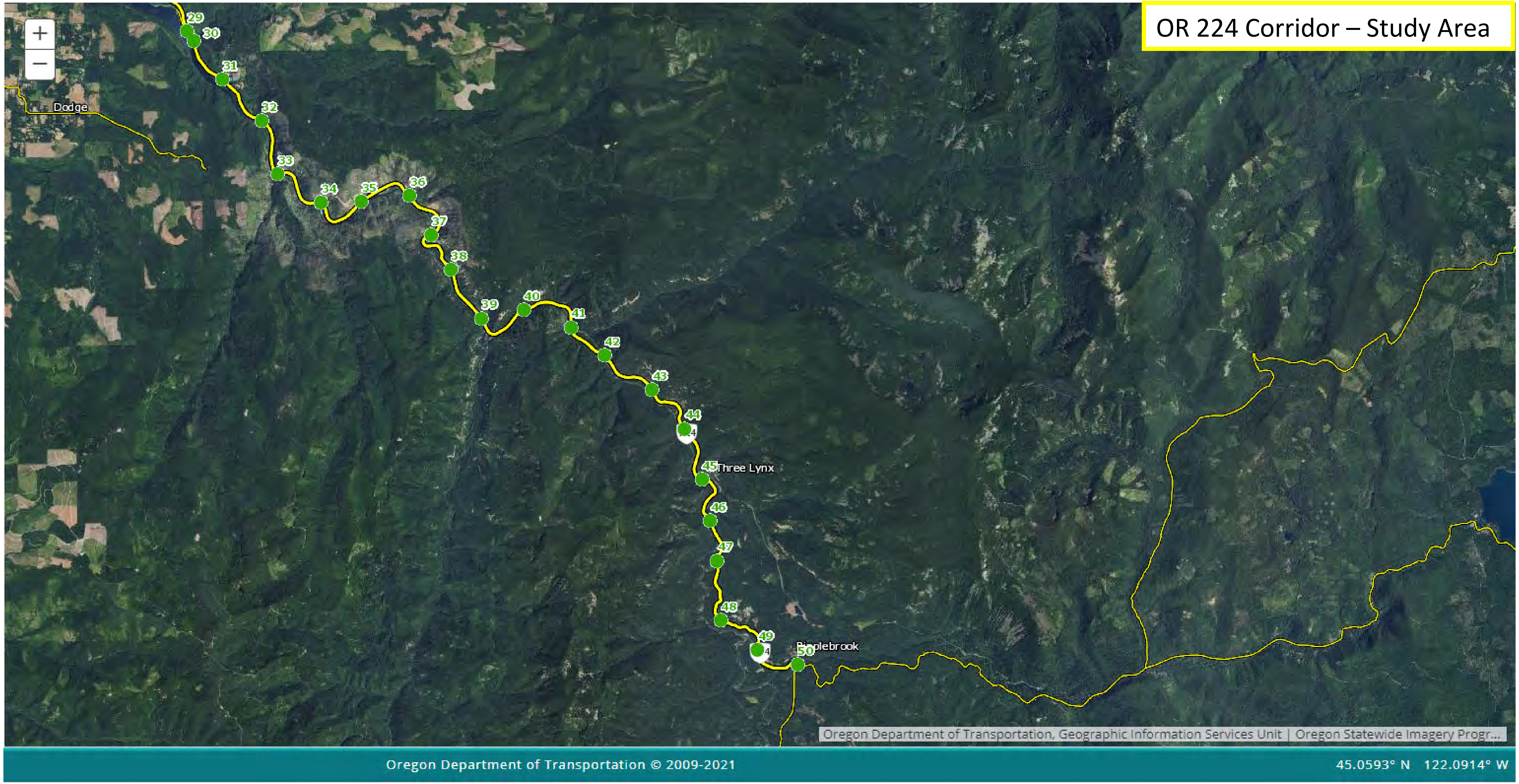
Driver/Vehicle Module

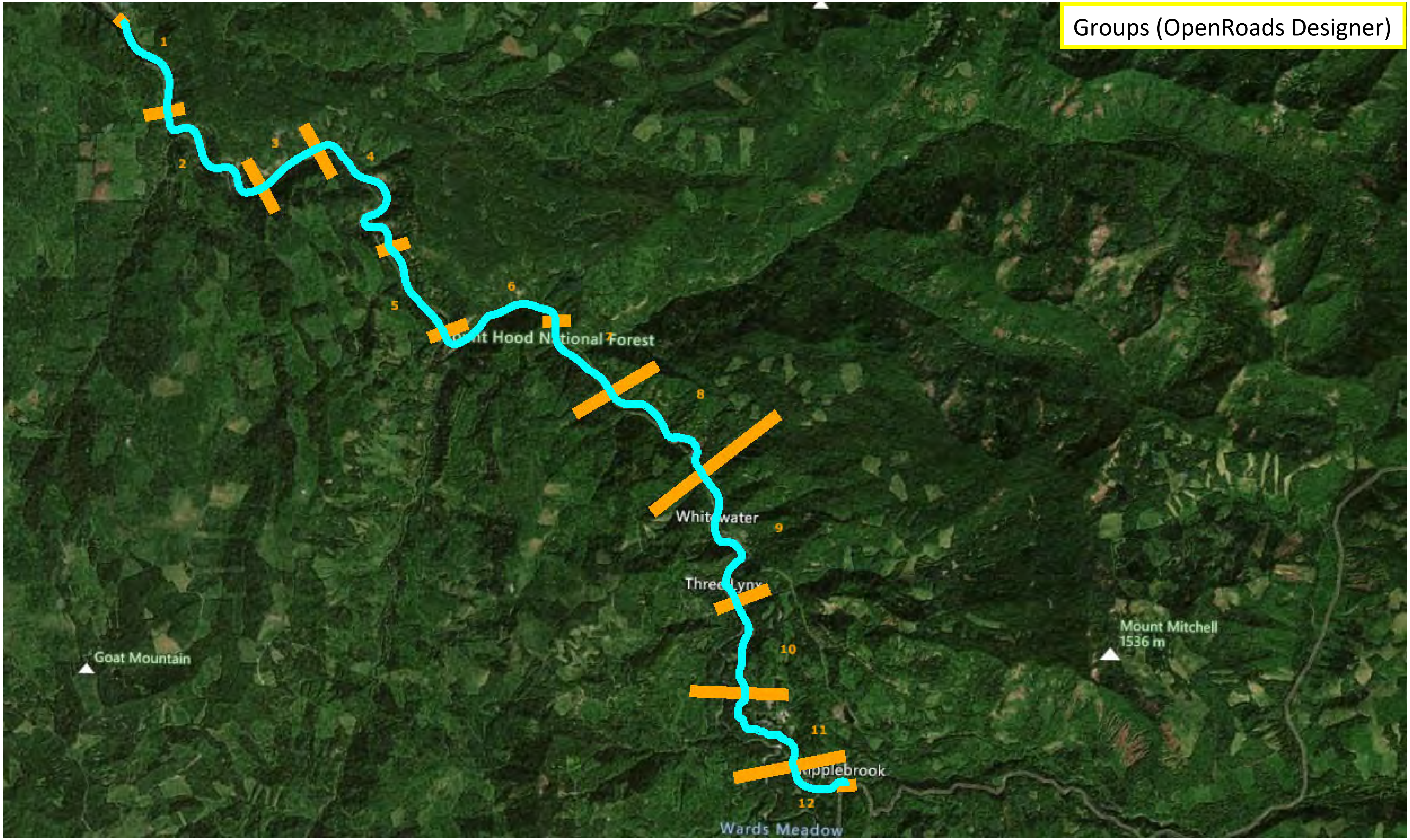
The objective of the Driver/Vehicle Module is to permit the user to evaluate how a driver would operate a vehicle (e.g., passenger car or tractor-trailer) within the context of a roadway design and to identify whether conditions exist in a given design that could result in loss of vehicle control (e.g., skidding or rollover). The Driver/Vehicle Module consists of a Driver Performance Model linked to a Vehicle Dynamics Model. Driver performance is influenced by cues from the roadway/vehicle system (i.e., drivers modify their behavior based on feedback from the vehicle and the roadway). Vehicle performance is, in turn, affected by driver behavior/performance. The Driver Performance Model estimates a driver's speed and path along a two-lane rural highway in the absence of other traffic. The resulting estimates serve as input to the Vehicle Dynamics Model, which estimates measures including lateral acceleration, friction demand, and rolling moment. The driver type selected was 'Nominal'. The path decision selected was 'Center'. The vehicle type selected was 'Passenger Car' (the module could not be completed for any alignment alternatives when using 'Truck'). The road familiarity selected was 'Curve Segment'.

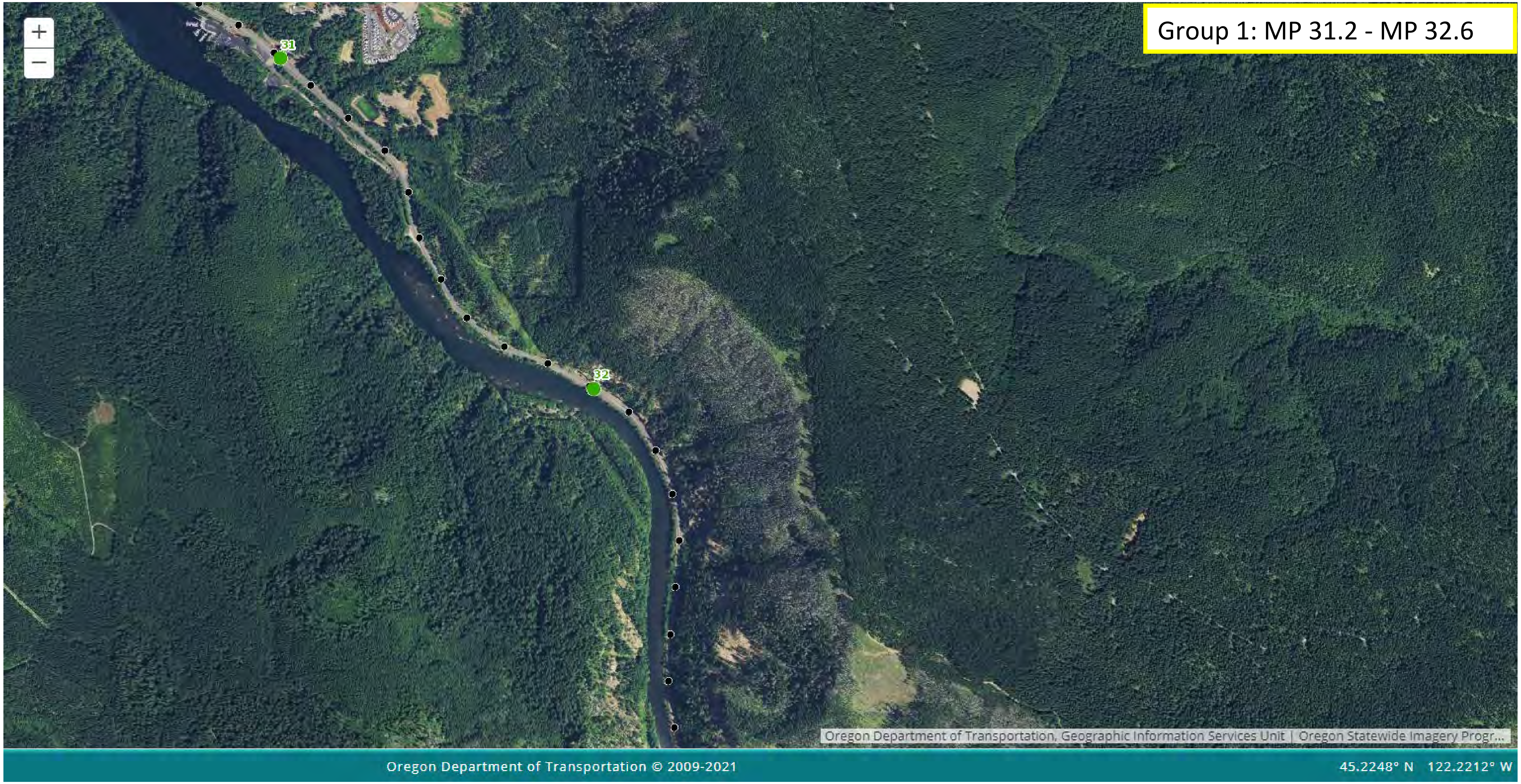
IHSDM Discussion Reference:
https://cms7.fhwa.dot.gov/research/interactive-highway-safety-design-model/modules/modules

Safety and Traffic Appendix B

IHSDM Group Map and Group Locations

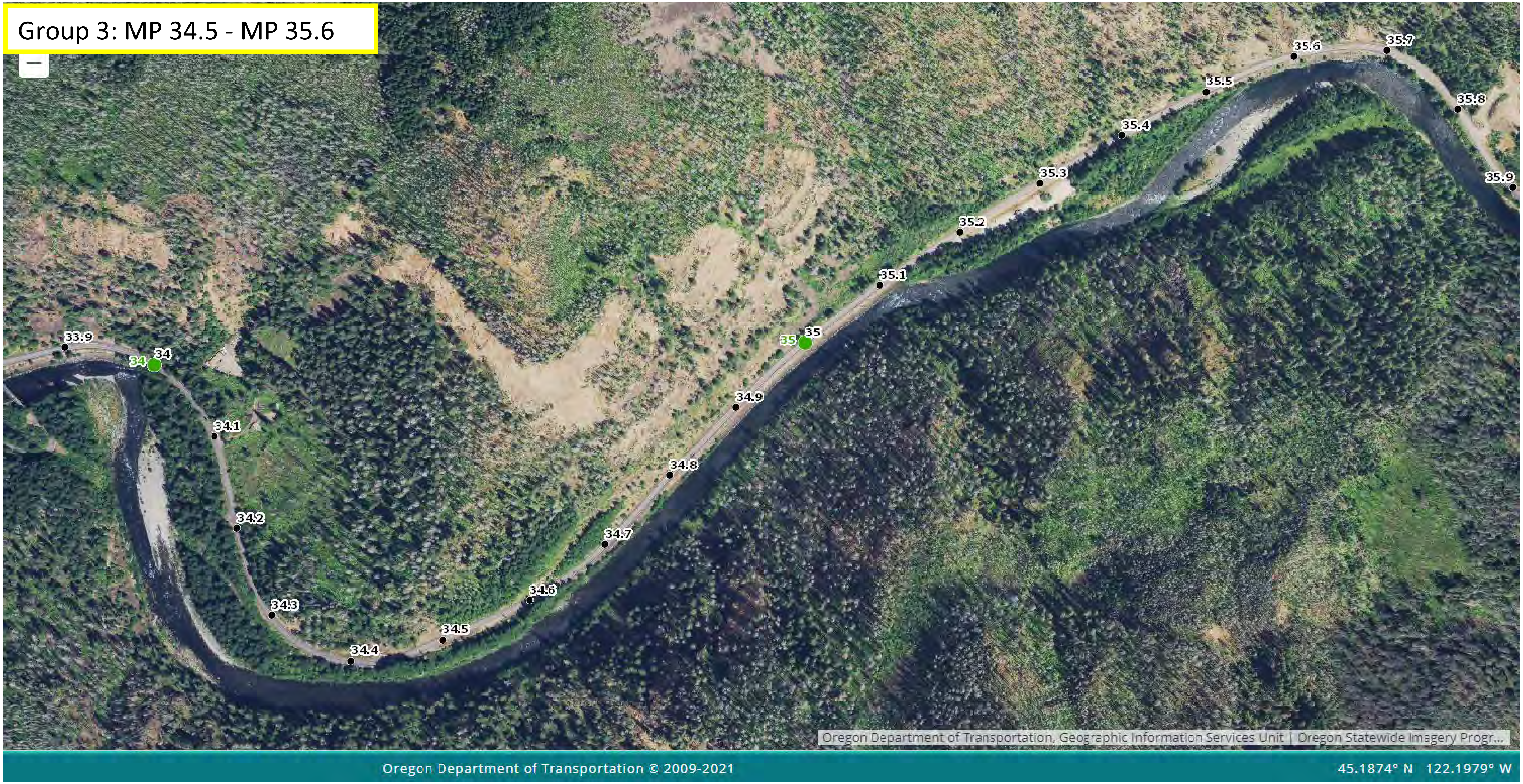

OR 224 Corridor – Study Area
+
−
Dodge
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Three Lynx
46
47
48
49
50
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.0593° N 122.0914° W


Groups (OpenRoads Designer)
1
2
3
4
5
6
7
8
9
10
11
12
Mount Hood National Forest
Whitewater
Three Lynx
Ripplebrook
Wards Meadow
Goat Mountain
Mount Mitchell
1536 m

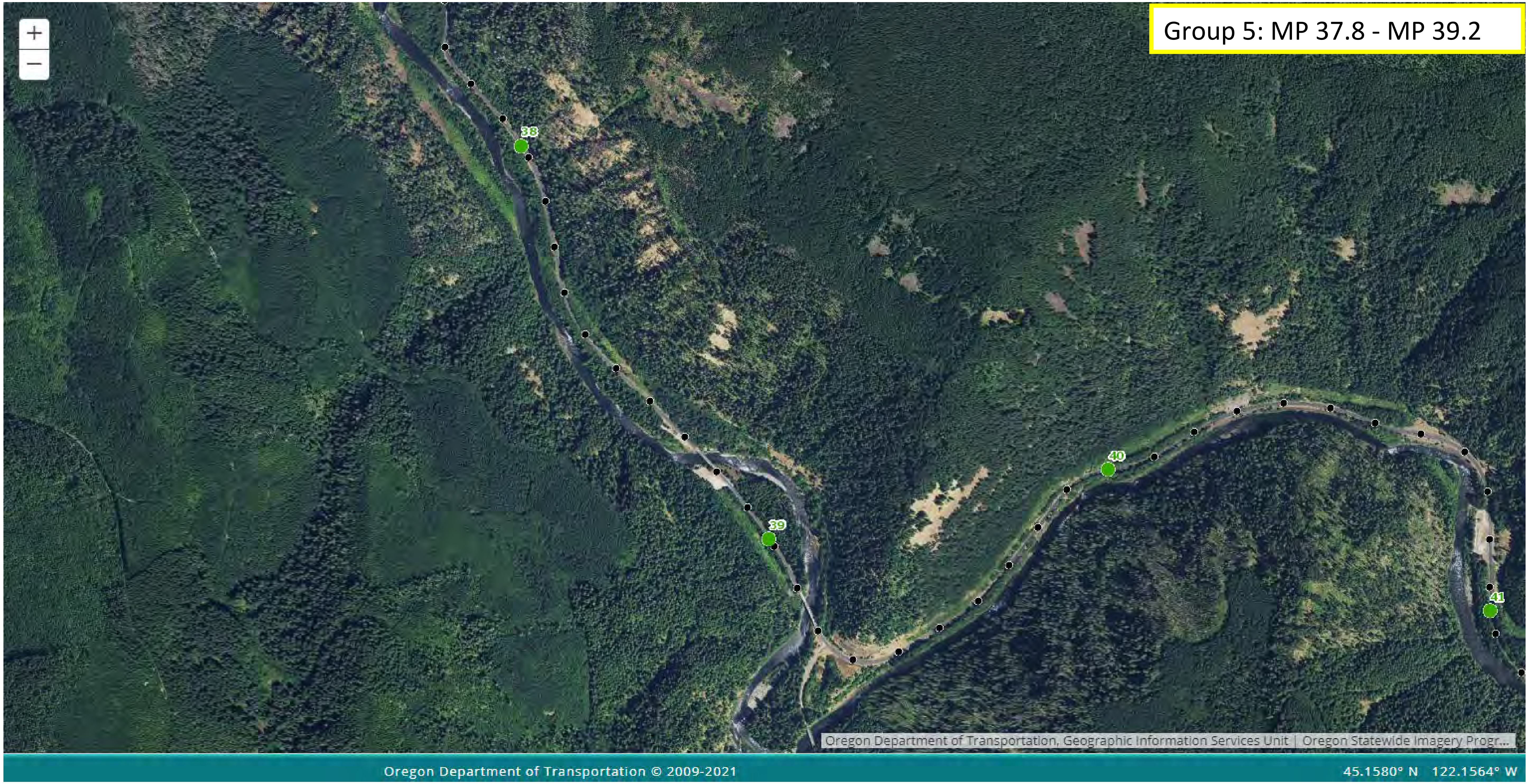

Group 1: MP 31.2 - MP 32.6
31
32
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.2248° N 122.2212° W

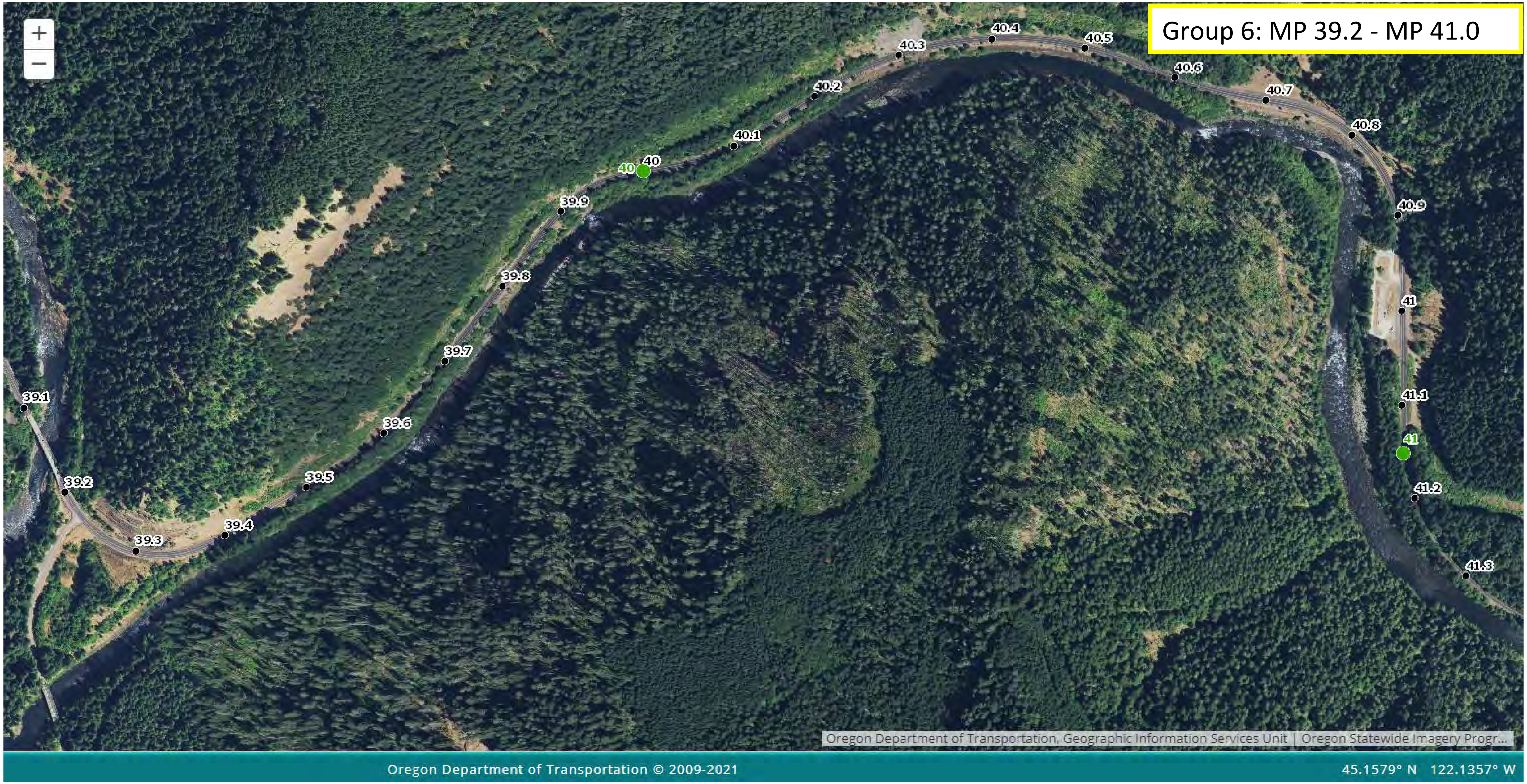

Group 2: MP 32.6 - MP 34.5
33
34
35
36
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1898° N 122.2070° W

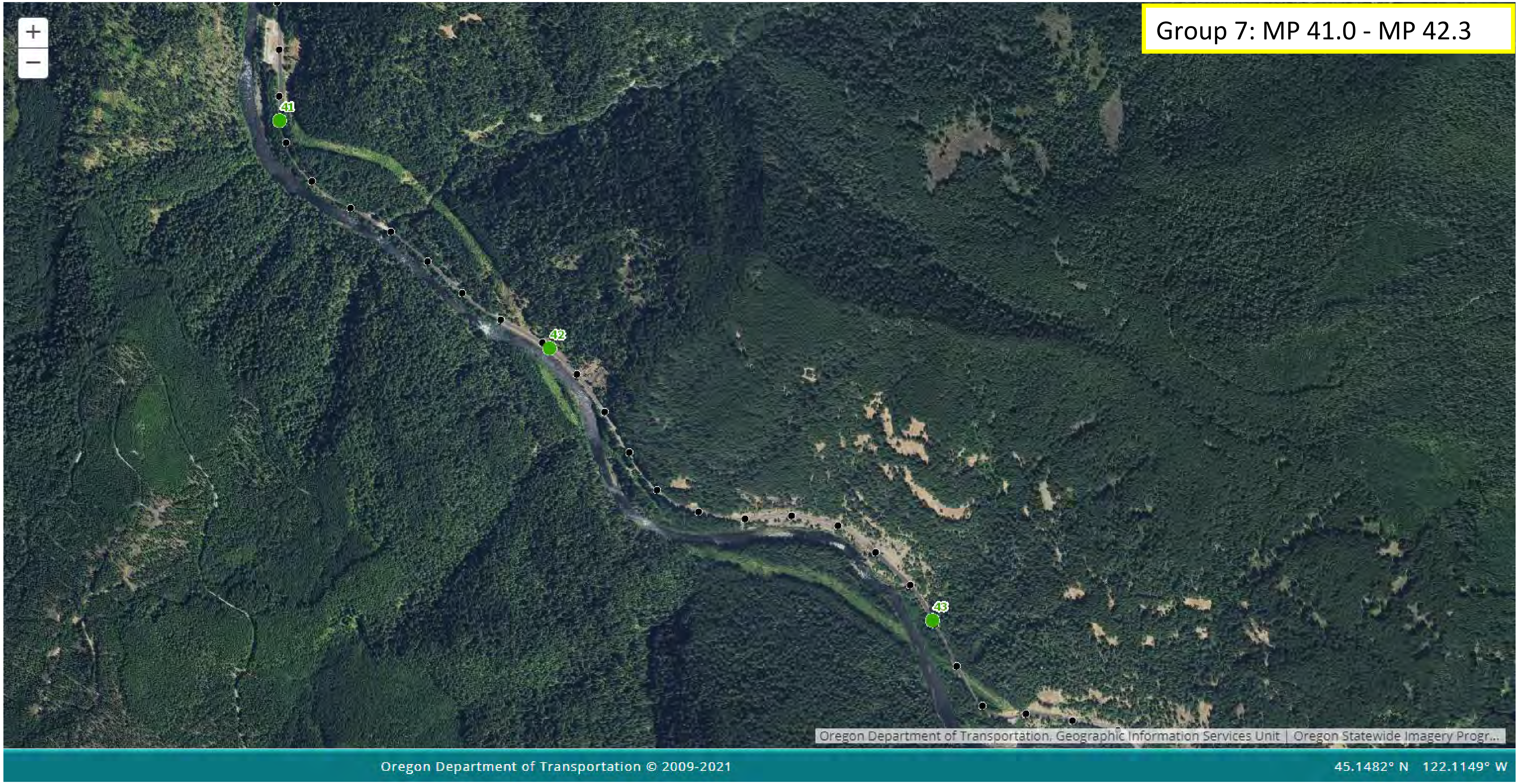
Group 3: MP 34.5 - MP 35.6



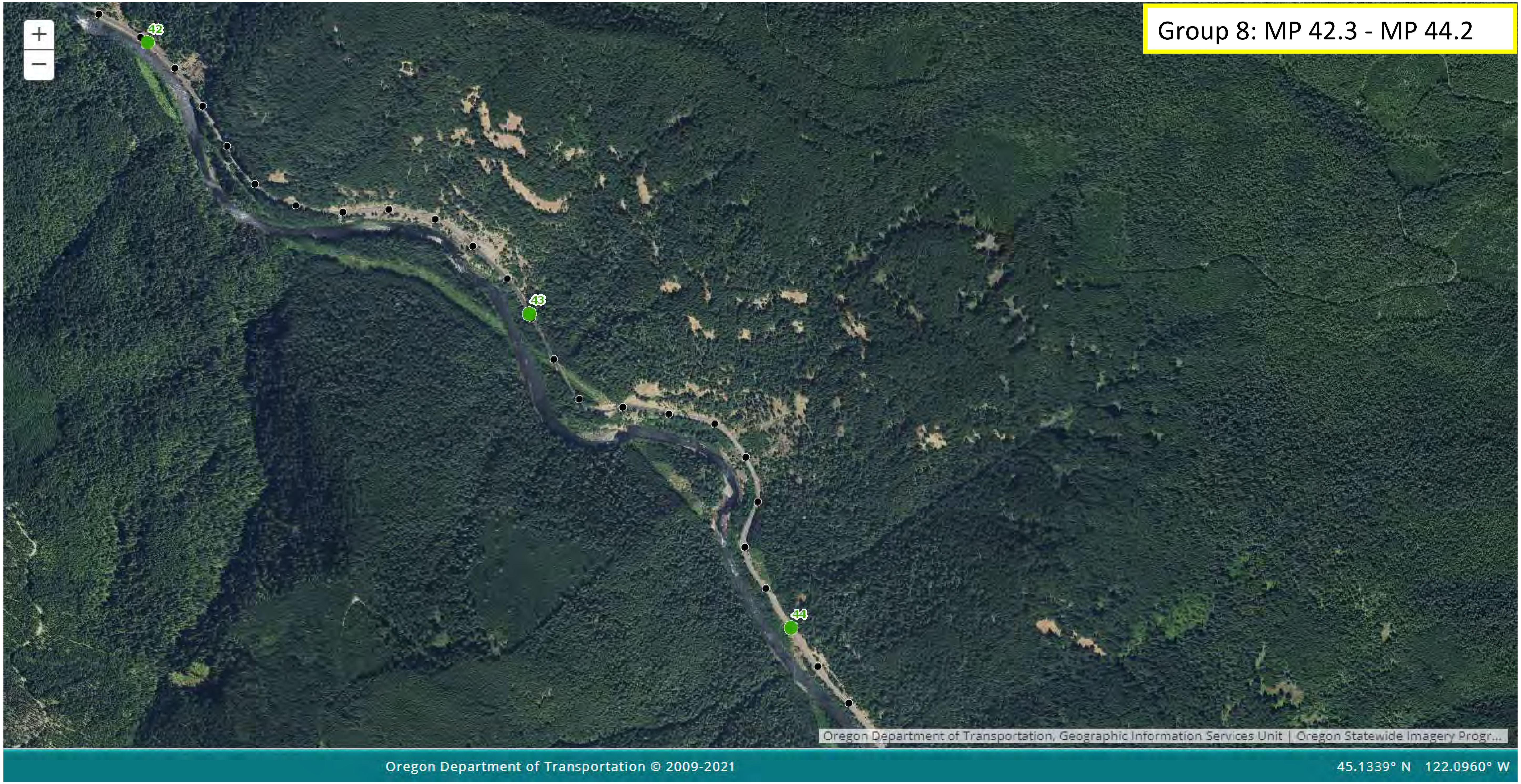

Group 4: MP 35.6 - MP 37.8
35
36
37
38
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1769° N 122.1449° W

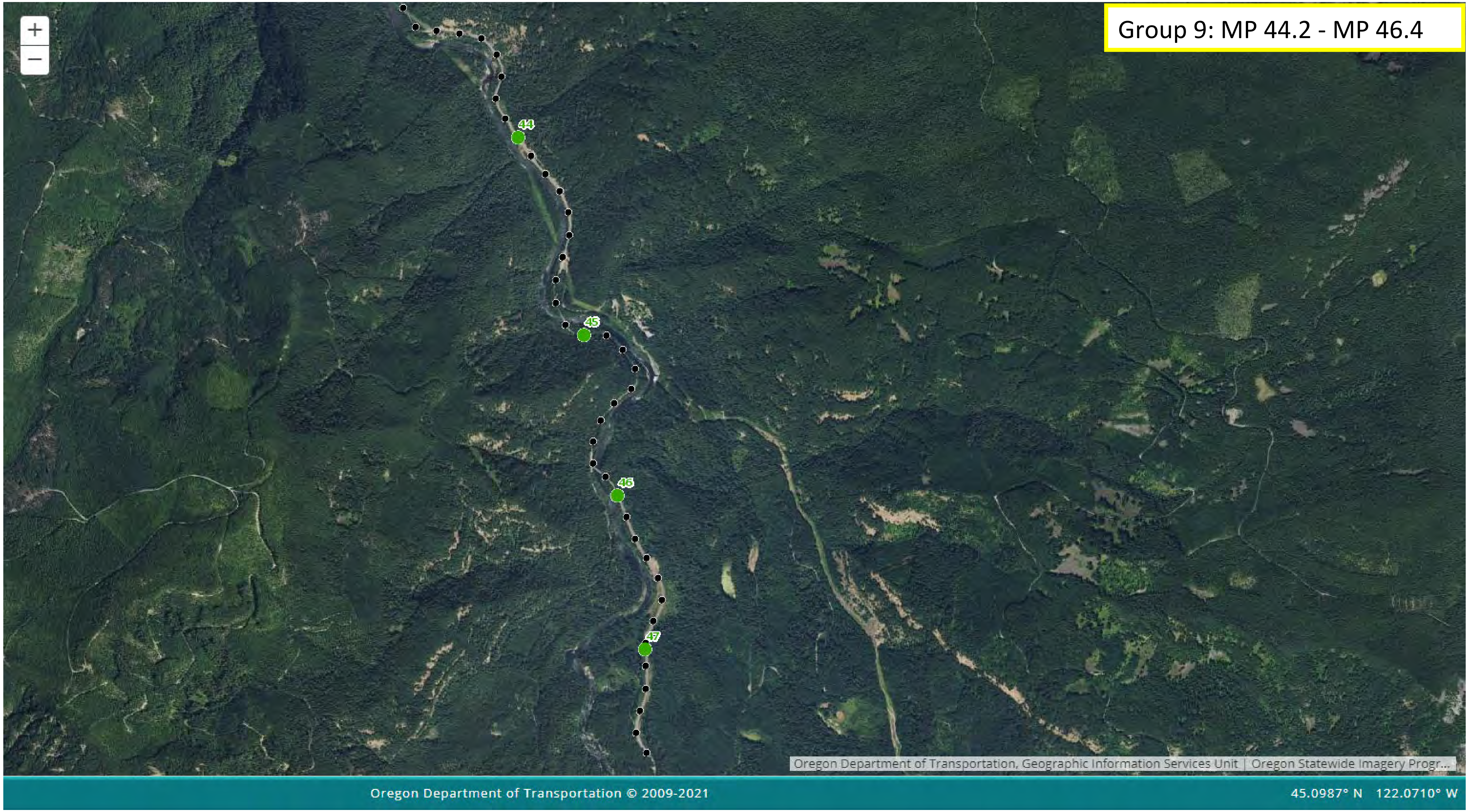

Group 5: MP 37.8 - MP 39.2
38
39
40
41
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1580° N 122.1564° W

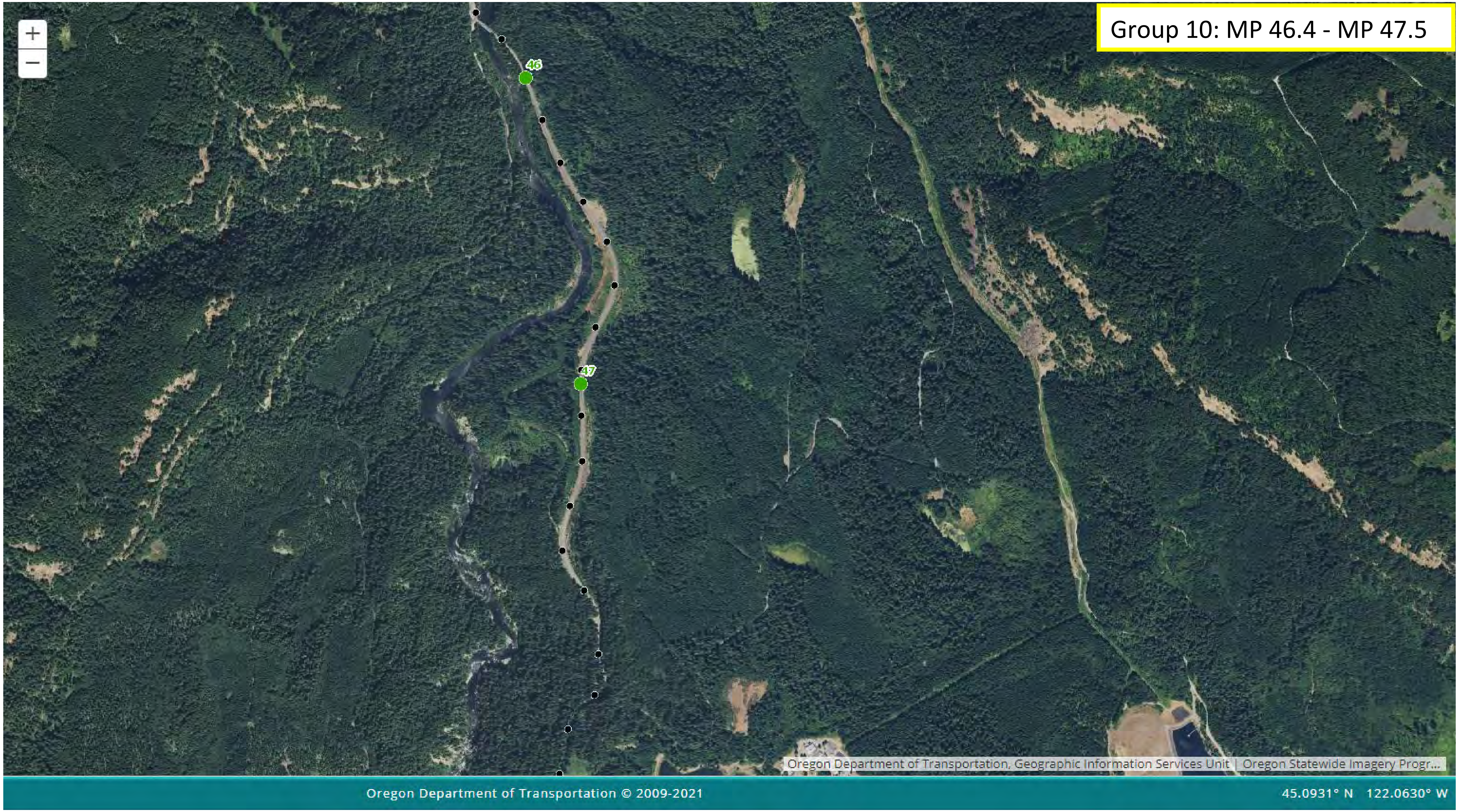

Group 6: MP 39.2 - MP 41.0
39.1
39.2
39.3
39.4
39.5
39.6
39.7
39.8
39.9
40
40
40.1
40.2
40.3
40.4
40.5
40.6
40.7
40.8
40.9
41
41.1
41
41.2
41.3
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1579° N 122.1357° W



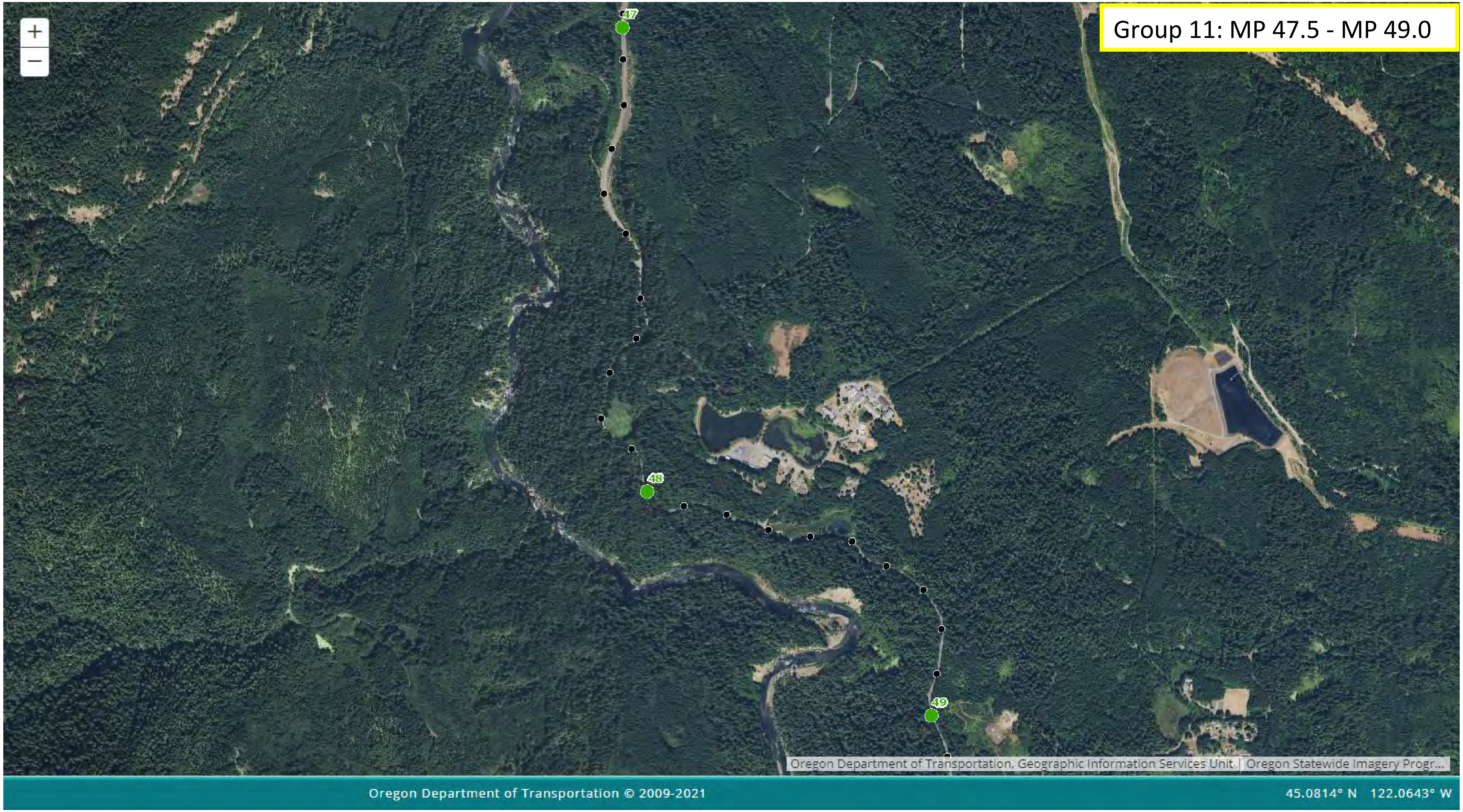
Group 7: MP 41.0 - MP 42.3
41
42
43
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1482° N 122.1149° W


Group 8: MP 42.3 - MP 44.2
42
43
44
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.1339° N 122.0960° W


Group 9: MP 44.2 - MP 46.4
+
−
44
45
46
47
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.0987° N 122.0710° W



Group 10: MP 46.4 - MP 47.5
46
47
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.0931° N 122.0630° W


Group 11: MP 47.5 - MP 49.0
47
48
49
+
−
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.0814° N 122.0643° W


Group 12: MP 49.0 - MP 49.97
49
49
49.1
49.2
49.3
49.4
49.5
49.6
49.7
49.8
49.9
50
Oregon Department of Transportation, Geographic Information Services Unit | Oregon Statewide Imagery Progr...
Oregon Department of Transportation © 2009-2021
45.0790° N 122.0450° W

Safety and Traffic Appendix C

IHSDM Output Data Summary and Scoring for Existing Conditions

OR 224 - Existing Conditions

90th Percentile	**90th Percentile**	**90th Percentile**	**90th Percentile**	**90th Percentile**	**90th Percentile**	**90th Percentile**	**90th Percentile**
12.42	**19.94**	**6.90**	**10.28**	**6.00**	**3.00**	**0.00**	**0.00**
75th Percentile	**75th Percentile**	**75th Percentile**	**75th Percentile**	**75th Percentile**	**75th Percentile**	**75th Percentile**	**75th Percentile**
11.64	**14.34**	**6.25**	**7.63**	**5.25**	**2.25**	**0.00**	**0.00**

IHSDM Crash Module Results by Group

Group	Start MP	End MP	Predicted Crashes by Group Evaluation Period	Expected Crashes by Group Evaluation Period	Predicted Crash Rate by Group Evaluation Period (Crash/mi)	Expected Crash Rate by Group Evaluation Period (Crash/mi)	Design Consistency Flags by Group	Policy Review Flags by Group	DV Module Ave Lateral Offset Increasing (ft)	DV Module Ave Lateral Offset Decreasing (ft)
1	31.2	32.6	9.19	10.15	6.27	6.93	3	1	0	0
2	32.6	34.5	11.40	20.32	6.24	11.11	6	2	0	0
3	34.5	35.6	5.16	7.27	4.71	6.63	1	1	0	0
4	35.6	37.8	15.29	20.05	6.97	9.14	3	2	0	0
5	37.8	39.2	6.27	9.34	4.78	7.12	1	0	0	0
6	39.2	41.0	10.54	10.97	5.83	6.07	5	2	0	0
7	41.0	42.3	6.78	6.01	5.14	4.56	2	2	0	0
8	42.3	44.2	10.03	18.93	5.52	10.41	3	3	0	0
9	44.2	46.4	12.43	12.81	5.75	5.92	6	2	0	0
10	46.4	47.5	4.85	5.66	4.40	5.14	2	3	0	0
11	47.5	49.0	12.34	10.47	8.12	6.88	9	3	0	0
12	49.0	49.97	3.95	5.14	4.29	5.58	5	2	0	0

Safety and Traffic Appendix D

Historical Crash Data

CRASH LOCATION LIST

Highway 171 ALL ROAD TYPES, MP 31.0 to 49.97 01/01/2010 to 12/31/2019, Both Add and Non-Add mileage

1 - 28 of 95 Crash records shown.

SERIAL NO	DATE	TIME	DAY	*COUNTY OR CITY NAME	RDWY #	CMPNT	MLGTYP	CRASH LOCATION	COLL TYPE	EVENT	CAUSE	ERROR	SURF	TOT VEH	VEHICLE TYP/OWN #1	#2	KILL	INJ	ALCOHOL	SPEED
04464	10/20/2012	8A	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 31.49	FIX	067	12		WET	1	011		0	1	N	N
02761	07/12/2014	8P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 31.55	FIX	060,079	10	079	DRY	1	091		0	1	Y	N
04673	10/10/2016	10A	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 31.62	OTH	081	12		WET	1	010		0	0	N	N
02678	06/22/2015	1P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.00	OTH		01	079,047	DRY	1	091		0	1	N	Y
02550	07/14/2012	2P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.50	FIX	079,010	16,32	080,052	DRY	1	011		0	1	N	N
02613	07/18/2012	9P	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.85	FIX	035,079,010	12	083	DRY	1	011		0	2	N	N
02469	06/29/2011	3P	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.91	FIX	124,079,086	01,32	047,052,080	DRY	1	091		0	1	Y	Y
02387	07/04/2013	11A	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.91	SS-O		10	080	DRY	3	091	011	0	1	N	N
00801	02/19/2016	1P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 32.92	FIX	043,079	30	050,079	WET	1	011		0	1	N	Y
02877	08/13/2010	1P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.00	FIX	043	10	080	DRY	1	091		0	1	N	N
02211	06/06/2017	4P	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.00	FIX	079,010	01,05	047,079	DRY	1	011		0	1	N	Y
03384	08/20/2015	8P	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.17	FIX	079	10	079	DRY	1	011		0	0	N	N
03932	07/16/2016	8P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.25	HEAD		01	047,079,083	DRY	2	011	011	1	5	Y	Y
03532	08/27/2017	3P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.75	OTH		01	047,079	DRY	1	011		0	1	N	Y
01636	04/28/2017	10A	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 33.93	FIX	072	01	047,079	WET	1	011		0	1	Y	Y
03253	09/03/2011	6A	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.00	FIX	079	32,16	052,080,081	DRY	1	011		0	1	N	N
04654	12/03/2011	5P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.00	FIX	124,079,010	01	047,080	ICE	1	011		0	0	N	Y
03268	09/05/2011	4P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.20	TURN		02,01	047	DRY	2	011	011	0	6	N	Y
01567	03/23/2018	3P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.20	FIX	062,010	17,01	047,081	DRY	1	011		1	2	N	Y
03142	08/24/2012	9P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.82	FIX	035,079	10	083	DRY	1	011		0	0	N	N
03493	09/30/2018	5P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 34.82	FIX	043	10	083,080	DRY	1	011		0	3	N	N
00094	01/10/2010	4P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 35.17	HEAD		16,27	016,080	DRY	2	011	011	0	3	N	N
03482	08/24/2017	12P	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 35.19	REAR		30,07	050,042	DRY	2	011	011	0	4	N	Y
04117	10/02/2017	2P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 35.67	FIX	079,001	01	047,079	DRY	1	091		0	1	N	Y
03289	07/11/2012	9P	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 35.70	FIX	079	01	047,080	WET	1	011		0	0	N	Y
01389	04/23/2011	12P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 36.00	FIX	072	01	047,080,081	DRY	1	091		0	1	N	Y
01566	04/29/2012	2P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.00	FIX	079,001	01	047,080	DRY	1	091		0	1	N	Y
02587	06/27/2015	9A	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.00	FIX	043	10	079	DRY	1	091		0	1	N	N

CRASH LOCATION LIST

Highway 171 ALL ROAD TYPES, MP 31.0 to 49.97 01/01/2010 to 12/31/2019, Both Add and Non-Add mileage

29 - 56 of 95 Crash records shown.

SERIAL NO	DATE	TIME	DAY	*COUNTY OR CITY NAME	RDWY #	COMPNT	MLGTYP	CRASH LOCATION	COLL TYPE	EVENT	CAUSE	ERROR	SURF	TOT VEH	VEHICLE TYP/OWN #1	#2	PEOPLE KILL	PEOPLE INJ	ALCOHOL	SPEED
03468	09/28/2018	12P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.00	TURN		02,08		DRY	2	011	011	0	1	N	N
01445	04/20/2015	11A	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.11	FIX	034,043	30	050,079	DRY	1	091		0	1	N	Y
03744	10/08/2019	10A	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.19	FIX	034,062	10	083	WET	1	011		0	1	N	N
02535	07/20/2018	8P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.33	PED		10	079	DRY	1	091		0	1	N	N
01785	06/02/2019	2P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.42	FIX	126,001,128	10	079	DRY	1	091		1	0	N	N
01748	05/05/2017	1A	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.45	FIX	003,079	10	079	WET	1	011		0	1	N	N
02057	06/20/2019	6P	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.47	SS-M		05	083,079	DRY	2	011	011	0	5	N	N
03249	08/10/2015	5P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 37.49	FIX	043	30,05	050,079	DRY	1	011		0	1	N	Y
03953	10/29/2018	6P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 38.00	FIX	068	12		WET	1	010		0	0	N	N
01581	04/07/2016	6P	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 38.34	FIX	043	30,05		DRY	1	010		0	0	N	Y
00192	01/12/2016	5A	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 38.36	FIX	079,010	33	079,051	WET	1	011		0	1	Y	N
03728	08/14/2016	5P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 38.70	TURN	001	06,30	032,050	DRY	2	091	011	1	1	Y	Y
00231	01/15/2017	12P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 39.00	FIX	124,079,010	10	080	ICE	1	011		0	2	N	N
00521	02/08/2012	7P	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 39.14	FIX	124,046	01	047	ICE	1	011		0	0	N	Y
00771	02/29/2012	7A	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 39.22	FIX	124,079,010	01	047,080	ICE	1	011		0	1	N	Y
02540	07/26/2019	4P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 39.23	FIX	057,072	30	050,079	DRY	1	011		0	3	N	Y
00806	03/04/2018	1P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 39.97	FIX	062	01		DRY	1	010		0	0	Y	Y
01958	05/22/2015	9P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 40.00	FIX	068	12		DRY	1	011		0	2	N	N
03065	04/15/2017	3P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 40.24	FIX	079,010,001	01	047,079,080	DRY	1	091		1	0	N	Y
01424	04/26/2011	12P	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 40.74	FIX	079	27	016,081	WET	1	011		0	2	N	N
01381	03/26/2018	3P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 41.28	FIX	079,062	05,01	047,079	WET	1	011		0	1	Y	Y
02706	07/26/2013	6P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 41.61	TURN		06,01	032,047	DRY	2	091	011	0	1	N	Y
03311	08/13/2017	5P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 42.17	FIX	062,087	16,32	080,052	DRY	1	011		0	2	N	N
01806	05/27/2018	4P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 42.48	FIX	069,079,072	10	083	DRY	1	011		0	1	Y	N
01711	05/22/2010	1A	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 42.50	FIX	035,079	12	080	WET	1	011		0	1	N	N
04517	10/28/2017	4P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 42.70	FIX	079	10	079	DRY	1	091		0	1	N	N
01768	05/10/2015	4P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.17	FIX	043,001	01,05	047,079	DRY	1	091		0	1	N	Y
03074	09/02/2018	2P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.19	FIX	079	01	047,079	DRY	1	091		0	1	N	Y

CRASH LOCATION LIST

Highway 171 ALL ROAD TYPES, MP 31.0 to 49.97 01/01/2010 to 12/31/2019, Both Add and Non-Add mileage

57 - 84 of 95 Crash records shown.

SERIAL NO	DATE	TIME	DAY	*COUNTY OR CITY NAME	RDWY #	COMPNT	MLG TYP	CRASH LOCATION	COLL TYPE	EVENT	CAUSE	ERROR	SURF	TOT VEH	VEHICLE TYP/OWN #1	#2	KILL	INJ	ALCOHOL	SPEED
03619	09/30/2012	2P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.25	NCOL	124	01	047,080	DRY	1	091		0	1	N	Y
01740	05/22/2018	2A	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.25	FIX	068,079,010	10	079	DRY	1	011		0	2	N	N
02240	06/27/2018	12A	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.25	OTH	035,079,072	30	050,079	DRY	1	011		0	2	Y	Y
02095	06/23/2019	10A	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.26	FIX	034,079,010	05	083	DRY	1	011		0	2	N	N
03524	09/13/2013	12P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.27	OTH	124	10	083	DRY	1	091		0	1	N	N
02588	08/05/2018	2P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.51	FIX	079,010,001	01	047,081	DRY	1	091		1	0	N	Y
01036	03/30/2019	6P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.57	FIX	079,010	10		WET	1	010		0	0	N	N
02683	08/02/2010	4P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.80	NCOL	001,079	01	047,080	DRY	1	091		0	1	N	Y
03182	08/07/2015	10P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.81	OTH		33	079	DRY	1	011		0	1	Y	N
03482	01/14/2018	6P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.81	FIX	072,010	33	079,051	DRY	1	011		0	1	N	N
00044	01/05/2014	8A	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 43.84	FIX	124,079,072	01	047,080	ICE	1	011		0	2	N	Y
03493	09/23/2011	3P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 44.95	FIX	062	02	083,081	DRY	1	011		0	1	N	N
00129	01/10/2016	12P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.32	FIX	124,062	10	079	ICE	1	011		0	1	N	N
03522	06/08/2013	6P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.50	OTH	124,001	10	083	DRY	1	091		0	1	N	N
03722	09/27/2013	1P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.50	FIX	079,010	01,32	047,080,052	WET	1	011		0	1	N	Y
01171	03/29/2012	9P	TH	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.78	FIX	043	01	047,081	WET	1	011		0	4	N	Y
01868	06/05/2010	4P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.79	FIX	043	27	016,080,081	DRY	1	011		0	2	N	N
01221	03/28/2014	1P	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.80	FIX	078,043	25	083	WET	1	011		0	3	N	N
04733	11/09/2015	11A	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 45.82	FIX	035,043,079	10	081	WET	1	011		0	0	N	N
03461	08/19/2012	4P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 46.03	FIX	079,010	16	081	DRY	1	011		0	3	N	N
02320	06/13/2015	6P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 47.56	FIX	043	10	080	DRY	1	011		0	1	N	N
00149	01/13/2013	6P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 47.57	FIX	124,079,010	01	047,080	ICE	1	011		0	0	N	Y
02001	05/23/2017	11P	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 47.59	FIX	079,010	01,05	073,047,079	DRY	1	011		0	2	Y	Y
90806	03/04/2018	1P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 47.78	FIX	079	01,05		WET	1	010		0	0	Y	Y
03020	07/25/2017	2P	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 48.06	FIX	079	01	047,079	DRY	1	091		0	1	N	Y
04551	10/30/2017	2P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 48.07	FIX	079,001,128	10	079	DRY	1	091		0	1	N	N
01916	06/04/2018	10A	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 48.07	OTH	021,022	24,01	047,085,079	DRY	1	011		0	1	N	Y
01795	03/31/2014	2P	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 48.55	FIX	079	01	079,047	DRY	1	091		0	1	N	Y

CRASH LOCATION LIST

Highway 171 ALL ROAD TYPES, MP 31.0 to 49.97 01/01/2010 to 12/31/2019, Both Add and Non-Add mileage

85 - 95 of 95 Crash records shown.

SERIAL NO	DATE	TIME	DAY	*COUNTY OR CITY NAME	RDWY #	COMPNT	MLGTYP	CRASH LOCATION	COLL TYPE	EVENT	CAUSE	ERROR	SURF	TOTVEH	VEHICLE TYP/OWN #1	#2	KILL	INJ	ALCOHOL	SPEED
02954	08/15/2011	12A	MO	*Clackamas	1	MN	R	Clackamas Highway AT MP 48.97	FIX	062	10	081	DRY	1	011		0	1	N	N
03354	09/11/2011	8A	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.10	FIX	124,079,010	01	047,080	DRY	1	011		0	2	N	Y
00803	03/04/2018	7A	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.80	FIX	124,062	01	047,079	ICE	1	011		0	1	N	Y
04296	12/01/2019	10A	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.82	HEAD	124	01,05	047,079	ICE	2	011	011	0	2	N	Y
02716	07/25/2012	4P	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.86	FIX	079,010	01,33	047,081,051	DRY	1	011		0	4	Y	Y
03394	08/30/2014	1P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.87	SS-M		05,01	080,047	WET	2	011	011	0	4	N	Y
02428	07/06/2012	11A	FR	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.88	SS-M		01,05,32	047,080,052	DRY	2	011	011	0	0	N	Y
01941	05/21/2014	12A	WE	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.88	FIX	043,046	01	047,080	DRY	1	011		0	0	N	Y
02687	07/05/2014	8P	SA	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.88	FIX	047,043	01,05	047,079	DRY	1	011		0	4	N	Y
01793	05/06/2014	5P	TU	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.89	FIX	043	30,05	050,080	DRY	1	011		0	1	N	Y
03871	06/17/2012	1P	SU	*Clackamas	1	MN	R	Clackamas Highway AT MP 49.96	HEAD	001	30,05	050,080	DRY	3	091	011	1	0	N	Y

Safety and Traffic Appendix E

Existing Guardrail Locations

Barrier			
Start MP	End MP	Side	Offset
31.15	31.72	Right	6
31.74	32.87	Right	6
32.93	33.31	Right	6
33.4	33.42	Right	6
33.51	33.52	Right	6
33.76	33.82	Right	6
33.83	34.09	Right	6
34.23	34.49	Right	6
34.56	35.18	Right	6
35.42	35.72	Right	6
35.77	36.2	Right	6
36.27	36.94	Right	6
36.98	37.19	Right	6
37.23	37.45	Right	6
37.46	38.65	Right	6
38.66	38.69	Right	6
38.8	38.83	Left	6
39.07	39.12	Left	6
39.19	39.23	Left	6
39.19	39.23	Right	6
39.58	39.71	Right	6
39.75	40.01	Right	6
40.08	40.92	Right	6
41.44	41.47	Right	6
41.51	41.52	Right	6
41.78	42.14	Right	6
42.44	43.27	Right	6
43.29	44.04	Right	6
44.13	44.57	Right	6
44.58	44.59	Right	6
45.8	45.81	Left	6
45.8	45.81	Right	6
45.86	45.87	Left	6
45.86	45.87	Right	6
46.04	46.64	Right	6
49.89	49.9	Left	6
49.89	49.9	Right	6

Safety and Traffic Appendix F

Presentation to Yellowstone National Park on Roadside Parking Discouragement

Shoulder Parking Solutions

Yellowstone NP is looking for permanent solutions to prevent parking along roadway shoulders. Larger physical obstacles such as logs and boulders have been used but can be considered hazards and create maintenance issues. The ideas look at signing, striping and physical obstacles that could be used to deter parking along the shoulder and other locations.

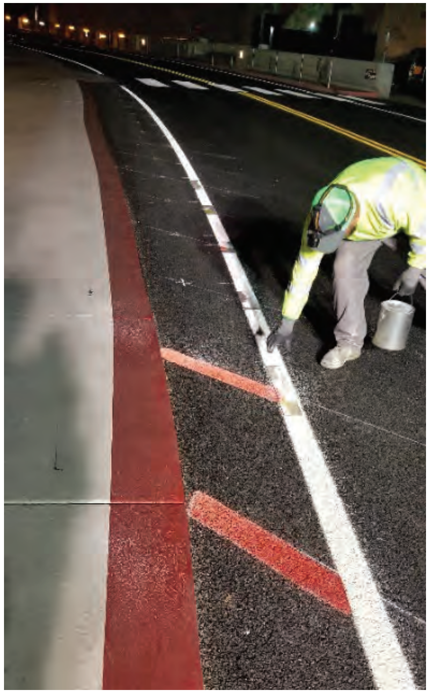
Striping & Rumble Strips

Options:

- Cross-hatch markings on shoulder
- "No Parking" pavement markings
- Wide or double edge line
- Colored Pavement
- Longitudinal Rumble Strips

Considerations:

1. Maintenance needs
2. Striping may not have high compliance or impact
3. Rumble strips have noise restrictions



Red transverse pavement markings at Hoover Dam

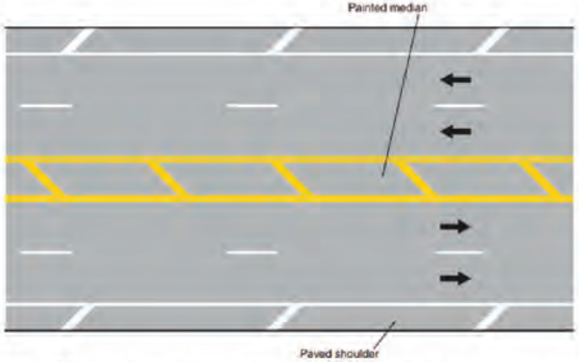


FIGURE 9 Examples of diagonal lines in painted medians and on paved shoulders.

FIGURE 2. Edge Line Rumble Strips

Signing

Options:

No Parking signs (R7/R8 series)

- Signing could be standalone or a more comprehensive park signing plan
- Establish a park rule/law about where parking is or isn't legal, that could be enforced. Install signing in several places throughout the park to notify drivers of rule.

Considerations:

1. Signs may not have high compliance
2. Initial cost and maintenance of signs
3. Aesthetics of signage
4. Need enforcement effort for compliance

MUTCD Chapter 2B.46

Physical Deterrents: Rocks & Boulders

Options:

Innovative idea: to create breakaway boulders that look real but are still crashworthy.

Available products:

- https://www.amazon.com/Outdoor-Essentials-Faux-Rock-X-Large/dp/B00NOP1PAM (large plastic boulders that can be moved around)
- http://dinorentosstudios.com/fake-foam-rock-10-x-10-x-12/ (foam boulders that weigh only 8 lbs!)

Considerations:

1. up to 12” are considered less hazardous in the Roadside Design Guide
2. Use smaller rocks within clear zone, blend to bigger rocks outside of clear zone

Yosemite – they are using little rocks closer to the travel way, and bigger rocks further away

Near Grand Teton NP

Physical Deterrents: Delineators

Options:

- Shoulder delineators near Jenny Lake area in Grand Teton NP.
- No Parking signs are 1’x1’

Considerations:

1. Maintenance
2. Aesthetics

Delineator with ‘No Parking’ symbol, seen in forest units

Grand Teton NP- delineators with No Parking symbol signs along shoulder

Physical Deterrents: Curb & Fence

Considerations:

1. Curbs affect drainage
2. Fence should still be crashworthy
3. Curbs not practical in most rural areas

Low-profile curbs being used to separate traffic modes

Golden Gate NRA near the Point Bonita Lighthouse parking area

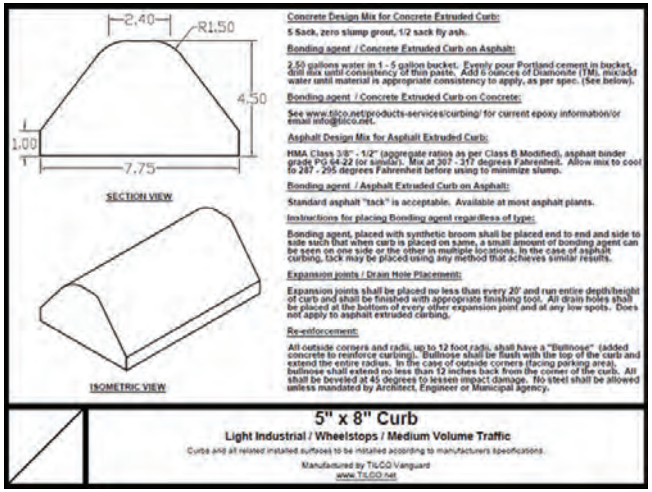
Physical Deterrents: Bollards & Wheel stops

Considerations:

1. Bollard considered hazard unless breakaway design (costly)
2. Wheel stops could be considered hazard
3. Poor aesthetics

Death Valley NP – No Parking signs and bollards near the visitor center parking area

Death Valley – wheelstops along a campground access road



Physical Deterrents: Vegetation

Considerations:

1. Maintenance may be required
2. Height of vegetation to not restrict sight distance

1:3 Foreslope Design

Options:

- A Project Manager from the Denver Service Center has been recommending 1:3 foreslopes on some projects just to deter parking along the shoulder.

Considerations:

1. Creates a roadside safety hazard
2. Unknown if it has been effective

Appendix B

Unstable Slope Gap Analysis and On-Site Ratings Assessment Technical Memorandum

U.S. Department
of Transportation
**Federal Highway
Administration**

M E M O R A N D U M

Western Federal Lands Highway Division
610 E. Fifth Street
Vancouver, WA 98661

DATE: August 06, 2021

TO: Jamie Lemon
Transportation Planner

FROM: Ryan Cole
Engineering Geologist

SUBJECT: **Geotechnical Memo 30-21**
Unstable Slope Data Gap Analysis
OR FLPP FS PLAN 2021(8)
OR 224 Corridor Study -Phase 1
Clackamas County, Oregon

INTRODUCTION

The Mount Hood National Forest in Clackamas County, Oregon (OR) experienced catastrophic wildfire events in September 2020. These events caused significant impacts to recreational use and multimodal travel within the region, particularly along OR State Highway 224. The OR 224 corridor between Promontory Park and Ripplebrook has been closed since September 2020 due to fire damages, but is expected to reopen in late-summer 2021. The U.S. Forest Service (USFS) has requested assistance from the Western Federal Lands Highway Division (WFL) of the Federal Highway Administration (FHWA) to complete an Existing Conditions Assessment of USFS lands within the OR 224 corridor to better understand the extent of post-wildfire conditions as they relate to future use and to assess transportation system resiliency and access within the National Forest. The Existing Conditions Assessment will be the first of a two phase Corridor Study for OR 224. The purpose of the Phase 1 – Existing Conditions Assessment is to evaluate and document current baseline conditions along the closed portion of OR 224. Information gathered during the post-wildfire baseline conditions assessment will be used to inform future study efforts that identify project-specific improvements. WFL will document these additional areas of in-depth study to be completed in Phase 2 – Planning and Environmental Linkages (PEL) Initial Scoping as part of the Phase 1 effort.

PROJECT DESCRIPTION

The purpose of this memorandum is to review Existing Conditions of unstable slopes in the OR 224 corridor from the Mt. Hood National Forest Boundary at MP 31.56 to the intersection of Forest Service Road (FSR) 57 at approximately MP 50 to identify data gaps and determine where there may be potentially vulnerable transportation assets and areas along the corridor that require more detailed unstable slope ratings or condition assessments during Phase 2.

GEOLOGY

The corridor lies entirely within the Western Cascades Physiographic Province, which is characterized by older volcanic rocks, generally steep slopes, and large pre-historic (ancient) landslide deposits (Peck, et al., 1964; see Attachment 1 - Geologic Map of the Highway 224 Corridor). There are four bedrock units that underlie the corridor, and all are approximately horizontally bedded. The oldest and lowest in position are sedimentary and volcaniclastic rocks of the Little Butte Volcanic Series (approximately 23 to 33.9 million years ago (Ma)) located in the upper reaches of the Clackamas River, from Three Lynx Creek at MP 45.87 to the end of the corridor at the intersection of FSR 57. This unit is primarily composed of volcanic and volcaniclastic deposits, including volcanic tuffs, mudflows, and lava flows of basalt and andesite. Smith (1994) indicates that the unit consists of “clay-bearing volcaniclastic formations overlain by unaltered lava flows of andesite and basalt, a combination that contributed to large-scale landsliding during the late Pleistocene”, approximately 10 thousand years ago (Ka). The entire valley bottom contains large scale earthflow-type landslides that produce generally subdued topography as compared to the lower portion of the corridor.

Overlying the Little Butte Volcanic Series are the Grand Ronde and Wanapum members of the Columbia River Basalt Group (approximately 15 to 17 Ma). These lava flows form steep cliffs along the Clackamas River from the beginning of the corridor at the Mt. Hood National Forest Boundary up to Three Lynx Creek. The basalt lava flows are generally resistant to erosion and form steep cliffs. However, there is a weak sedimentary interbed called the Vantage Member between the two lava flows. The Vantage Member is composed of ashy, volcanic sandstone and siltstone deposits and is a barrier to groundwater flow, resulting in increased pore-water pressure at the slope face where the unit is exposed. The resulting pore water pressure in some cases has created slope instability where large landslides occur. The Vantage Member typically forms a steep bench of loose, unconsolidated talus where the upper basalt flows have been removed by undercutting.

Immediately above the Columbia River basalts are interfingered (layered) deposits of the Rhododendron and Sardine Formations (approximately 10 to 17 Ma), which are composed of volcaniclastic deposits of mudflows, conglomerates, and ash tuffs, as well as basalt and andesite lava flows, respectively. These geologic units cap the ridges within the corridor, including Wanderer’s Peak, Soosap Peak, Fish Creek Mountain, and East Mountain. The material in the Rhododendron formation is easily eroded and is also prone to landsliding, which occasionally initiates as debris flows in the steep tributaries of the aforementioned peaks into the Clackamas River.

Overlying the Rhododendron and Sardine Formations are younger basaltic and andesitic volcanic lava flows of the High Cascades (approximately 1.2 to3.9 Ma). These geologic units are primarily found in the headwaters of tributaries of the Clackamas River East of the corridor, and generally cap the ridge tops, including Mount Mitchell and Oak Grove Butte.

Also within the corridor is a wide plateau known as “La Dee Flat”, north of the Clackamas River at Promontory Park. La Dee Flat has a low slope angle that generally precludes the development of landslides.

SITE CONDITIONS

Lower Corridor – Forest Boundary to Three Lynx Creek

Loss of vegetation from the fire has destabilized talus slopes on benches as well as on alluvial fan deposits along the base of the Columbia River basalts in the lower portion of the corridor. Increases in rockfall have occurred and should be anticipated to continue along the corridor from the Forest boundary to Three Lynx Creek. Additionally, debris flow potential exists where easily erodible deposits of Rhododendron formation overlie steep valley walls of Columbia River basalt. Modelling results provided by the U.S. Geological Survey (USGS) (Staley and Kean, 2020) indicate that streams crossing the highway in this section of the corridor are generally at moderate to high hazard for debris flows.

Upper Corridor – Three Lynx Creek to FSR 57

Increases in soil moisture related to a decrease of evapotranspiration from a loss of vegetation has the potential to reinitiate and/or accelerate earthflows in the upper portion of the corridor from Three Lynx Creek to FSR 57, although this is anticipated to be minor over the course of the next five to ten years as vegetative cover increases. This has the potential to lead to increased deformation and subsidence of the paved surface of the roadway. Additionally, increased surface runoff on the earthflows could lead to significant erosion and sedimentation, which would negatively impact transportation infrastructure (roads, ditches, culverts). Streams draining this area are generally at a low hazard for debris flows (USGS, 2020).

ANALYSIS METHODOLOGY

This analysis was conducted as a desktop exercise that relied exclusively on existing data to identify two classes of unstable slopes:

1. Unstable slopes **with** ratings and/or assessments
2. Unstable slopes, or potentially unstable slopes **without** ratings and/or assessments

The intent was to identify vulnerable transportation assets and identify areas along the corridor that require more detailed unstable slope ratings or condition assessments during Phase 2. The analysis relied primarily on two existing data sources:

1. Oregon Department of Transportation's (ODOT) Unstable Slope Rating System (USRS) database
2. USGS's Emergency Assessment of Post-Fire Debris-Flow Hazards debris flow modelling

ODOT's USRS analyzes slopes adjacent to state highways for potential impacts that a failure could cause. Such failures include landslides, rockfall, and fill settlement or failures. Historically, ODOT has evaluated rock fall hazards, but has expanded the program to include other (soil) types of unstable slopes (landslides and debris flows). Under the revised program, ODOT is able to include economic factors in its analysis as well as hazard and engineering considerations so that sensible repair priorities can be more easily obtained.

The USGS conducts post-fire debris-flow hazard assessments for select fires in the Western United States, utilizing geospatial data related to basin morphology, 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 event.

This analysis attempts to identify locations of debris flow prone unstable slopes or areas where debris flows could occur and are lacking unstable slope rating or site condition assessment data. These areas are clearly delineated where no unstable slope rating data exist and USGS modelling identified channels at moderate to high hazard for debris flow initiation. For this effort, we focused on stream channels that exhibited channel morphology (geology, grade, length, depth of incision, coalescing fan deposits, levies, anastomosing channels, etc.) and *observed past debris flow events* that supported potential for future debris flow events. If channels met those criteria, based on geo-practitioner judgment, a recommendation to rate the unstable slopes was made. If the channel met the above criteria, but did *not* include observation of past debris flow events, a recommendation to perform a site condition assessment was made.

This analysis assumes that potentially unstable slopes that have not been assessed and rated by ODOT will be assessed and rated utilizing the Unstable Slope Management Program for Federal Land Management Agencies (USMP, FLH 2019) in Phase 2. In order to combine data from the two systems, and be useful in a geotechnical asset management framework, a crosswalk between the rating systems must be established so that ranking of sites can be accomplished utilizing ratings from either system. The crosswalk would assist in an "apples to apples" comparison of ratings so that sites can be ranked and prioritized for potential risk reduction measures. Therefore, a sample of unstable slopes in the corridor, rated utilizing the USRS, should be *rerated* with FLH's USMP prior to the rating of new unstable slopes utilizing the USMP. Rerating of ODOT USRS rated unstable slopes should include a range of different unstable slope types (landslide, rockfall, debris flow, etc.) from a low to high risk, and should focus on slopes that include a STIP score, which is the score used for project identification and prioritization for ODOT. This additional level of effort is strongly recommended for Phase 2.

Results

ODOT's USRS consists of 45 pre-fire unstable slope ratings conducted between 2007 and 2009, as well as 42 post-fire assessments (non-ratings) completed in 2020, which included 13 new unstable slope assessments that did not have a rating associated with them. The post-fire assessments reassessed 30 (67%) of the pre-fire unstable slopes, for a total of 58 ODOT pre *and* post-fire ratings and/or assessments of unstable slopes within the study corridor. Pre-fire unstable slope ratings included 30 rockfall sites, 14 road fill failures, and five landslides. The new slope assessments focused primarily on rockfall (see Attachment 2 - Unstable Slopes Existing Condition and Data Gaps Maps, and Attachment 3 - Table of Unstable Slopes with USRS Ratings).

The USGS modeled debris flow hazard for 84 streams that intersect the highway within the study corridor, which ranged from low to high (see Attachment 2 - Unstable Slopes Existing Condition and Data Gaps Maps). Generally, streams in the lower corridor were modelled as moderate to high hazard, while streams in the upper corridor were modelled as low to moderate hazard. This is interpreted as being controlled by the presence of differing geology and the associated basin morphology between the upper and lower corridor.

Lower Corridor – Forest Boundary to Three Lynx Creek

ODOT identified and rated 41 unstable slopes in the lower corridor. *Communication with ODOT identified four unstable slopes that were not assessed in the post-fire effort but would benefit from completing a more detailed rating*. The USGS modeled 73 stream segments for debris flows hazard in the lower corridor, and 37 (51%) were rated at high hazard, 34 (47%) moderate hazard, and 2 (3%) low hazard. *Analysis of unrated, debris flow prone channels identified two unstable slopes that should also be rated, and eight sites where condition assessments should be performed*.

Upper Corridor – Three Lynx Creek to FSR 57

ODOT identified and rated ten unstable slopes in the upper corridor. *Communication with ODOT identified four unstable slopes that were not assessed in the post-fire effort but would benefit from completing a more detailed rating*. There is a lack of slope ratings in the upper section of the corridor, which may indicate that there is minimal geologic hazard present in this area due to the generally subdued topography. The USGS modelled 13 stream segments for debris flows hazard in the upper corridor and had generally low to moderate hazard. *Analysis of unrated, debris flow prone channels identified one unstable slope that should also be rated*.

RECOMMENDATIONS

Conduct a crosswalk of USRS rated unstable slopes by rerating both types of unstable slope with the USMP in order to compare ratings between the two systems so that sites can be ranked and prioritized for potential risk reduction measures. Utilize the USMP; (FLH, 2019) to rate identified unstable slopes where data gaps exist. This includes eight sites recommended by ODOT, three high hazard debris flow channels where past debris flow events *have* been observed, and the approximately five miles of the upper corridor from Three Lynx Creek to FSR 57 (see Attachment 4 - Table of Unstable Slopes Requiring USMP Ratings or Site Condition Assessments). Additionally, perform site condition assessments on eight high hazard debris flow prone channels where past debris flow events *have not* been observed. These data could be used to inform future study efforts that identify project-specific improvements to make OR 224 a more resilient transportation corridor.

REFERENCES

Federal Lands Highway, 2019, Unstable Slope Management Program for Federal Land Management Agencies, FHWA-FLH-19-002.

Oregon Department of Transportation, 2020, Unstable Slopes Rating System Database, data provided by ODOT on April 29, 2021 and July 19, 2021, respectively.

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.

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.

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/.

Walker, G.W., and MacLoed, N.S., 1991, Geologic Map of Oregon: U.S. Geological Survey, 1:500,000 scale.

U.S. Department of Agriculture Forest Service, 2020, Riverside and White River Fires Burned Area Emergency Response Geologic Hazards Assessment.

CLOSING

Please contact Ryan Cole at (360) 619-7571 or ryan.cole@dot.gov with any questions regarding this memorandum.

INITIALS

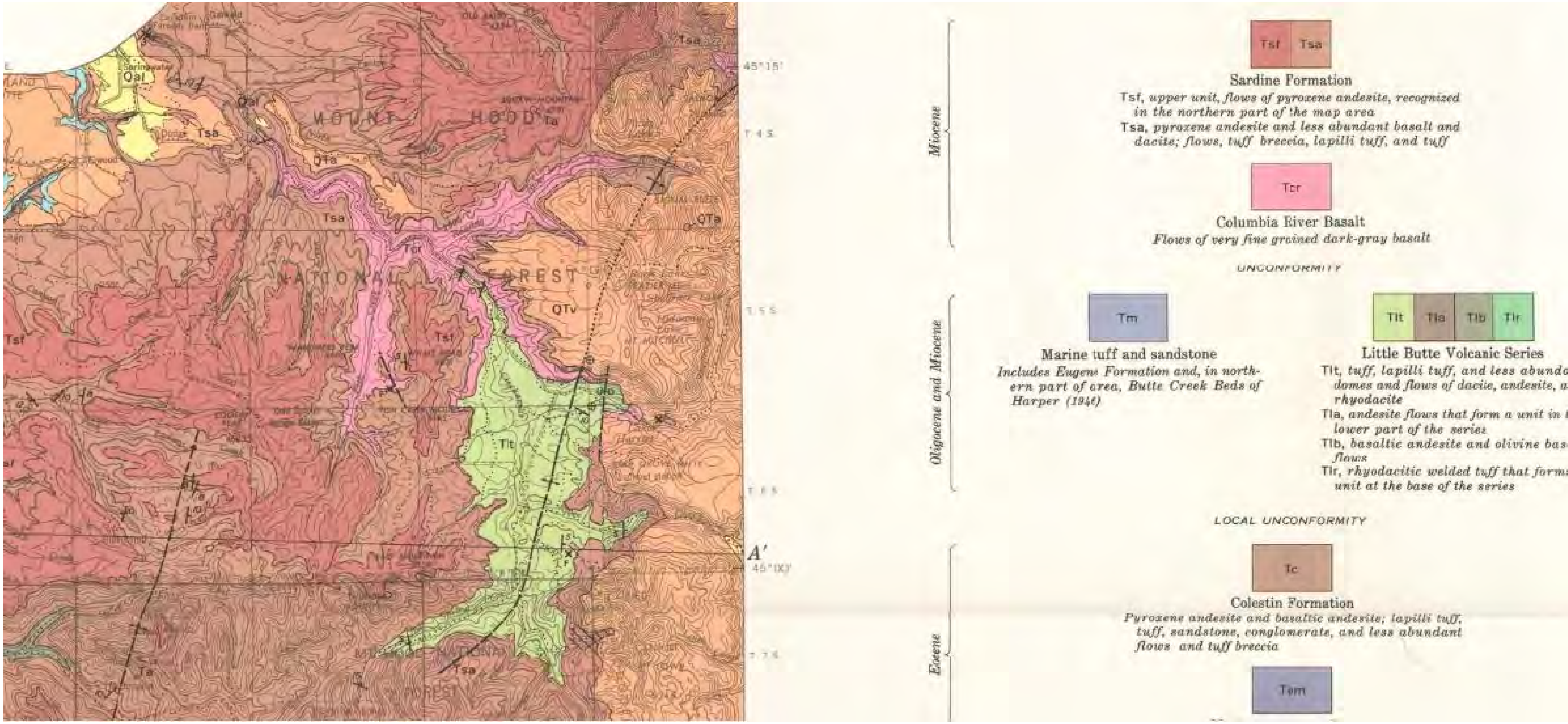
CC: Douglas A. Anderson, WFL Geotechnical Functional Manager
Geotechnical File

Attachments:

1. Geologic Map of the Highway 224 Corridor
2. Unstable Slopes Existing Condition and Data Gaps Maps (9 figures)

3. Table of Unstable Slopes with USRS Ratings
4. Table of Unstable Slopes Requiring USMP Ratings or Site Condition Assessments

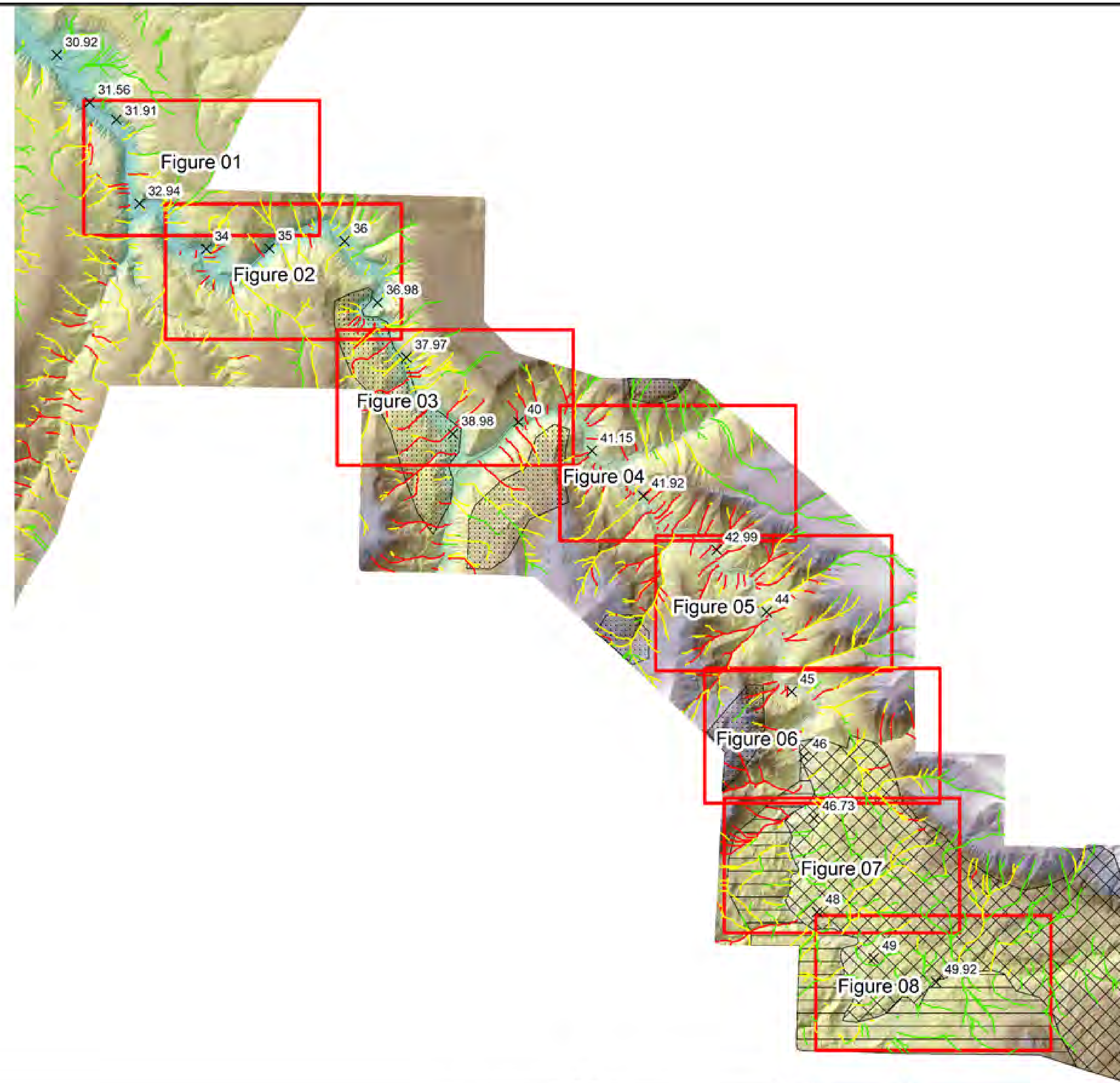
ATTACHMENT 1 - GEOLOGIC MAP OF THE HIGHWAY 224 CORRIDOR



Geologic Map of the area of the Highway 224 corridor impacted by the Riverside Fire (modified from Peck, et al., 1964).

ATTACHMENT 2 - UNSTABLE SLOPES EXISTING CONDITION

AND DATA GAPS MAPS (9 FIGURES)



Legend

× Milepost

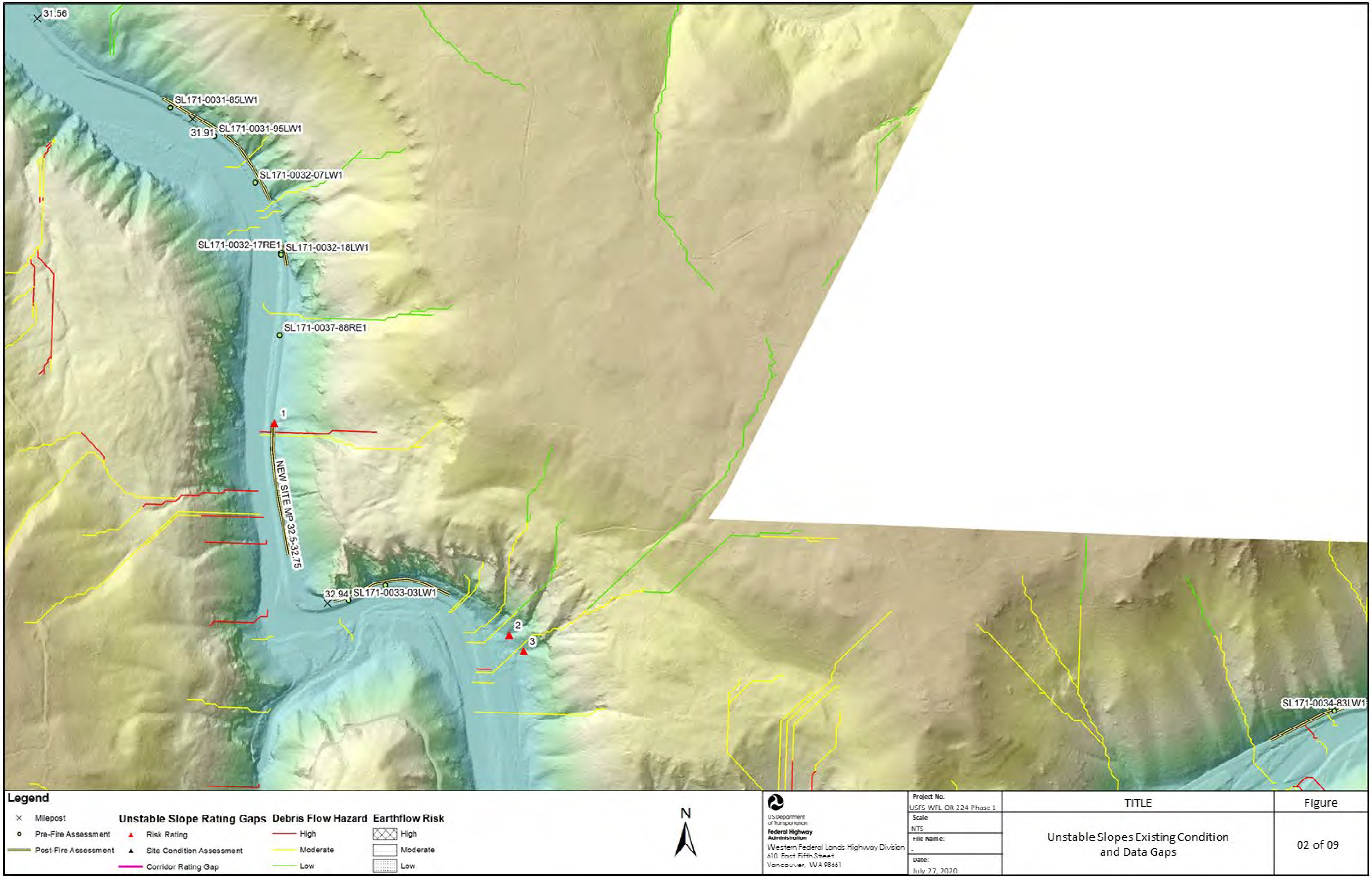
Figures

Debris Flow Hazard	Earthflow Risk
High	High
Moderate	Moderate
Low	Low

N

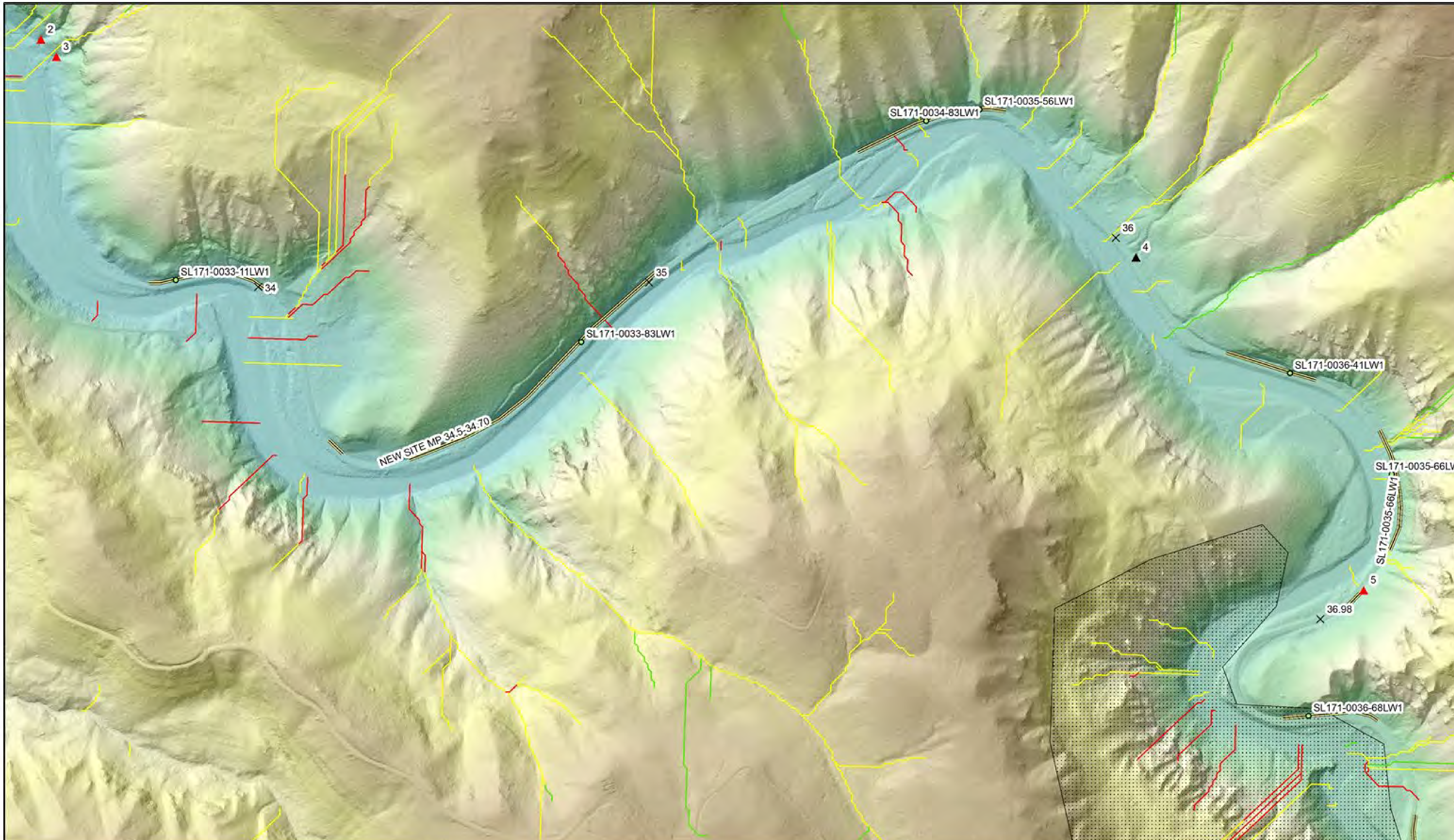
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	TITLE	Figure
USFS WFL OR 224 Phase 1	Unstable Slopes Existing Condition and Data Gaps	01 of 09
Scale: NTS		
File Name: -		
Date: July 27, 2020		



US Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	TITLE	Figure
USFS WFL OR 224 Phase 1	Unstable Slopes Existing Condition and Data Gaps	02 of 09
Scale: NTS		
File Name: -		
Date: July 27, 2020		



Legend

× Milepost
∘ Pre-Fire Assessment
Post-Fire Assessment

Unstable Slope Rating Gaps
▲ Risk Rating
▲ Site Condition Assessment
Corridor Rating Gap

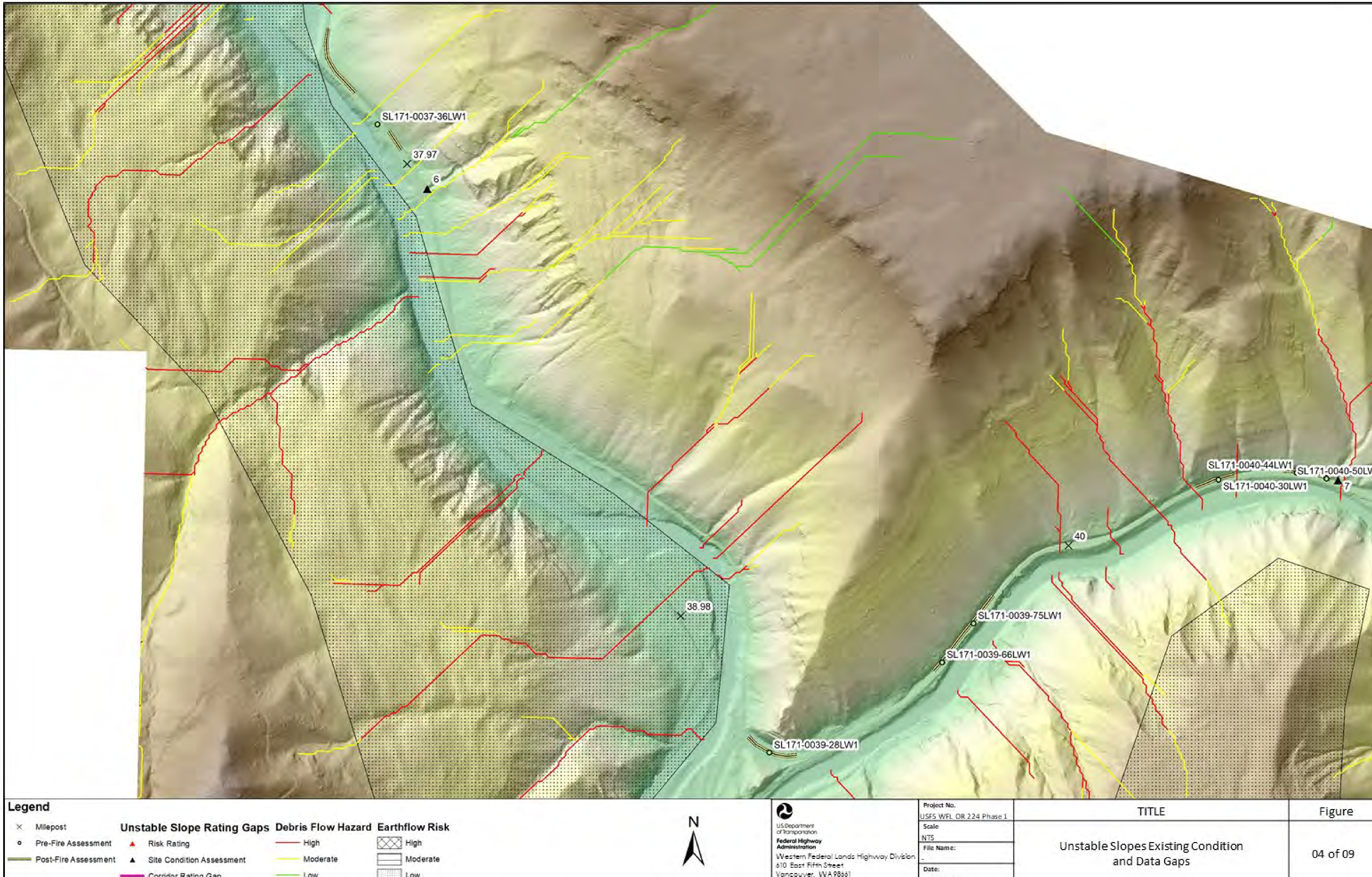
Debris Flow Hazard
High
Moderate
Low

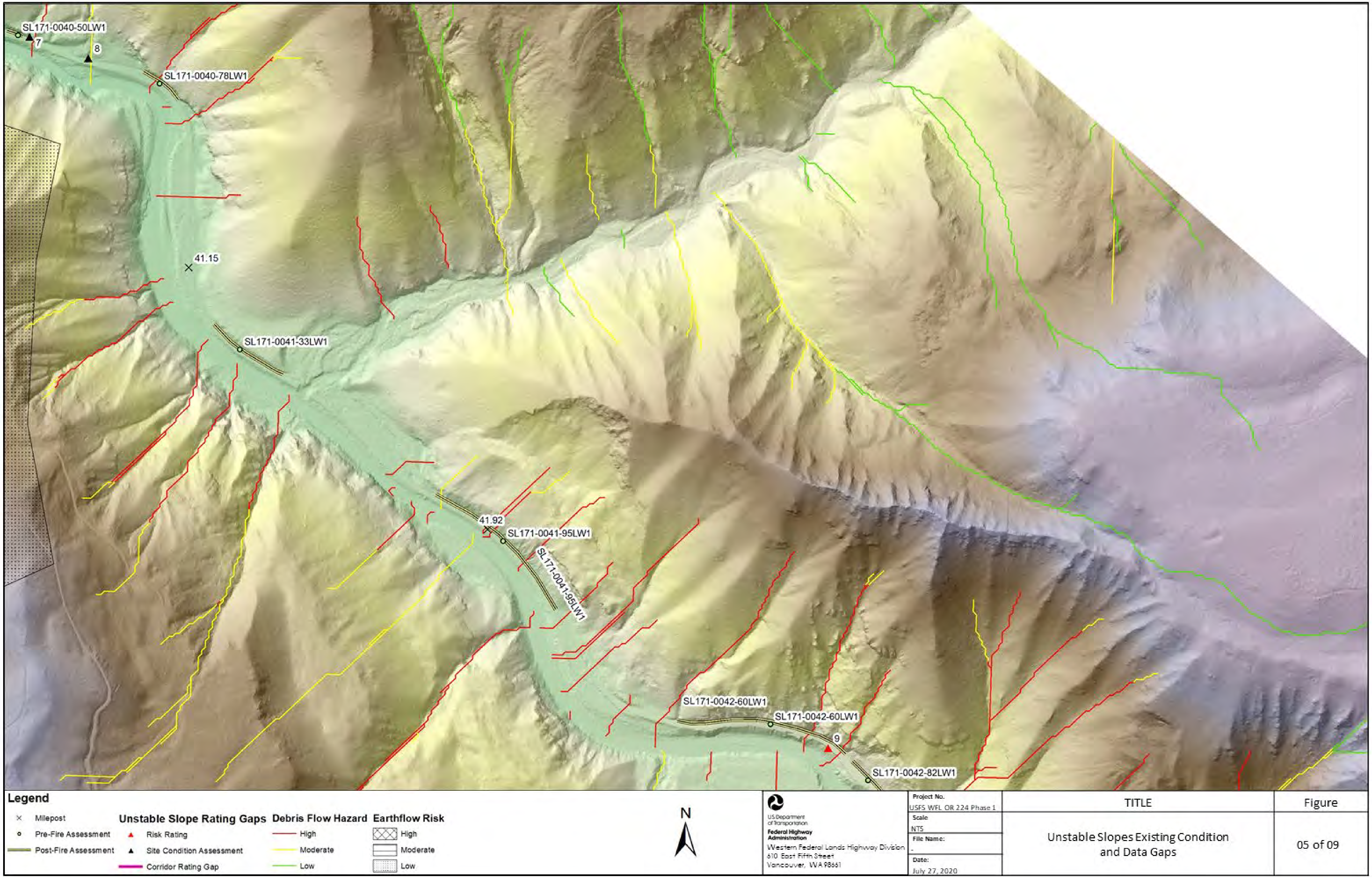
Earthflow Risk
High
Moderate
Low

N

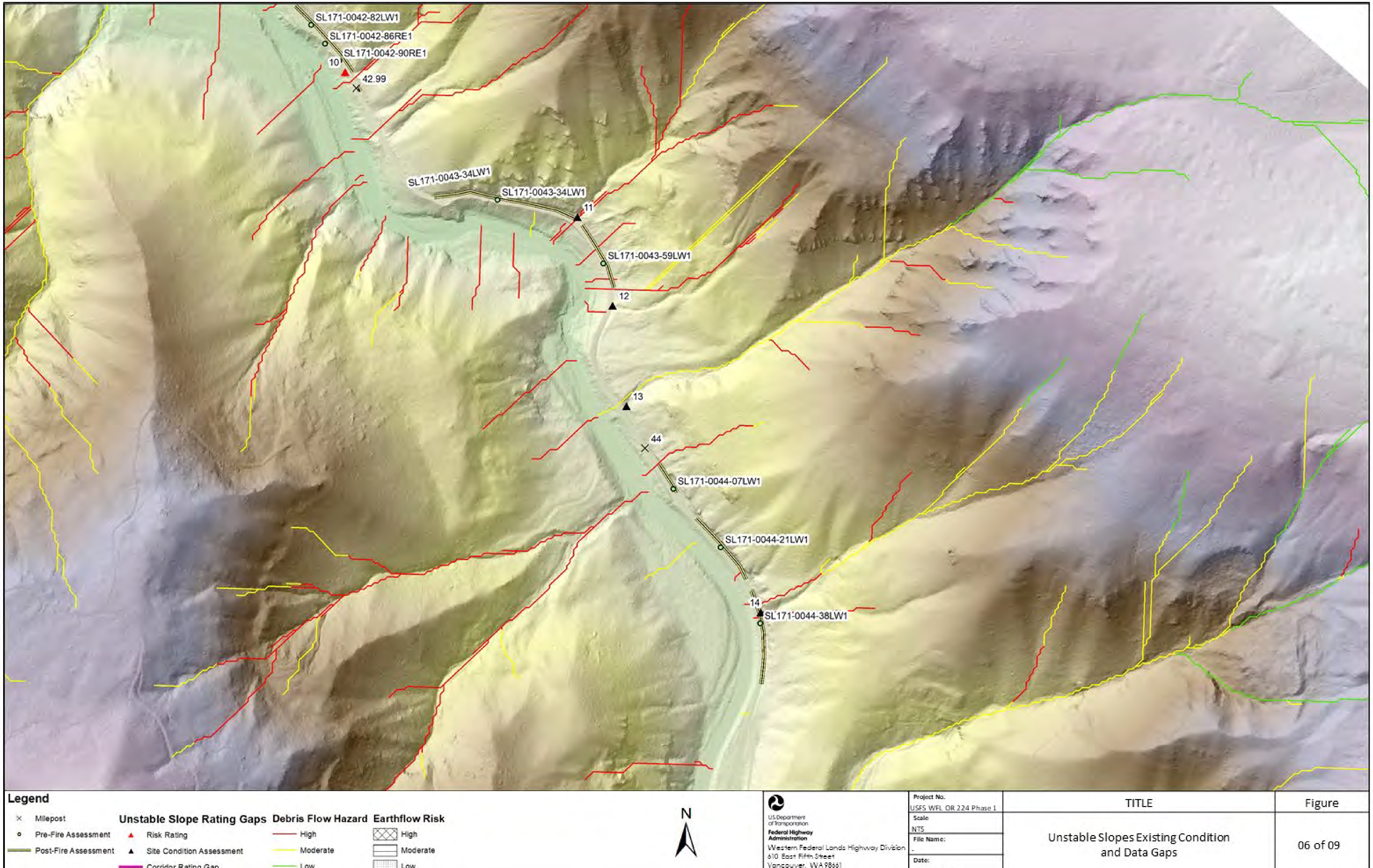
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	TITLE	Figure
USFS WFL OR 224 Phase 1	Unstable Slopes Existing Condition and Data Gaps	03 of 09
Scale: NTS		
File Name: -		
Date: July 27, 2020		

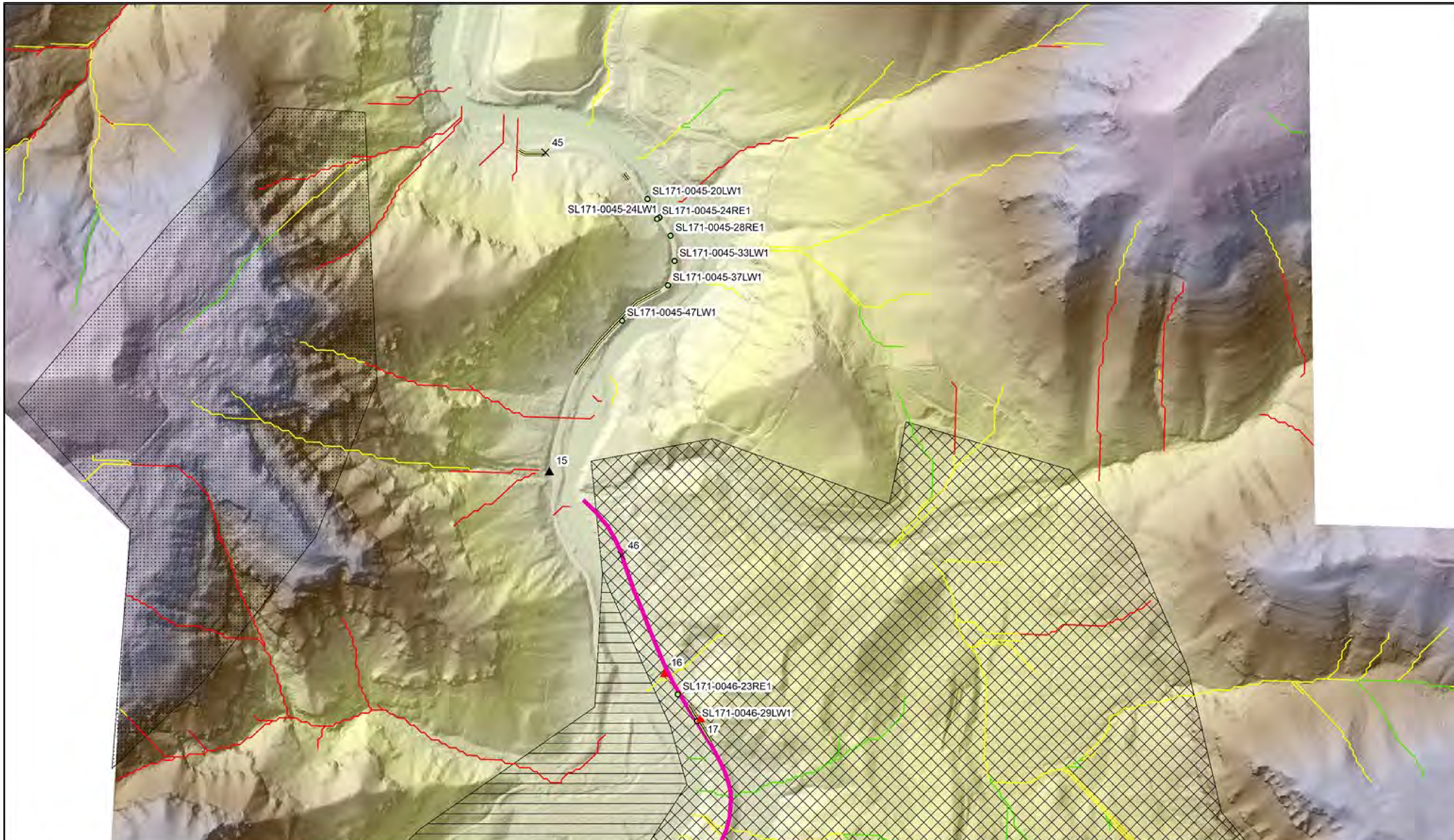

SL171-0037-36LW1
37.97
6
SL171-0040-44LW1
SL171-0040-50LW1
SL171-0040-30LW1
7
40
38.98
SL171-0039-75LW1
SL171-0039-66LW1
SL171-0039-28LW1
Legend
Milepost
Pre-Fire Assessment
Post-Fire Assessment
Unstable Slope Rating Gaps
Risk Rating
Site Condition Assessment
Corridor Rating Gap
Debris Flow Hazard
High
Moderate
Low
Earthflow Risk
High
Moderate
Low
N
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661
Project No.
USFS WFL OR 224 Phase 1
Scale
NTS
File Name:
-
Date:
July 27, 2020
TITLE
Unstable Slopes Existing Condition and Data Gaps
Figure
04 of 09



SL171-0040-50LW1
7
8
SL171-0040-78LW1
41.15
SL171-0041-33LW1
41.92
SL171-0041-95LW1
SL171-0041-95LW1
SL171-0042-60LW1
SL171-0042-60LW1
9
SL171-0042-82LW1
Legend
Milepost
Pre-Fire Assessment
Post-Fire Assessment
Unstable Slope Rating Gaps
Risk Rating
Site Condition Assessment
Corridor Rating Gap
Debris Flow Hazard
High
Moderate
Low
Earthflow Risk
High
Moderate
Low
N
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661
Project No.
USFS WFL OR 224 Phase 1
Scale
NTS
File Name:
Date:
July 27, 2020
TITLE
Unstable Slopes Existing Condition and Data Gaps
Figure
05 of 09



SL171-0042-82LW1
SL171-0042-86RE1
SL171-0042-90RE1
10
42.99
SL171-0043-34LW1
SL171-0043-34LW1
11
SL171-0043-59LW1
12
13
44
SL171-0044-07LW1
SL171-0044-21LW1
14
SL171-0044-38LW1
Legend
Milepost
Pre-Fire Assessment
Post-Fire Assessment
Unstable Slope Rating Gaps
Risk Rating
Site Condition Assessment
Corridor Rating Gap
Debris Flow Hazard
High
Moderate
Low
Earthflow Risk
High
Moderate
Low
N
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661
Project No.
USFS WFL OR 224 Phase 1
Scale
NTS
File Name:
-
Date:
July 27, 2020
TITLE
Unstable Slopes Existing Condition and Data Gaps
Figure
06 of 09



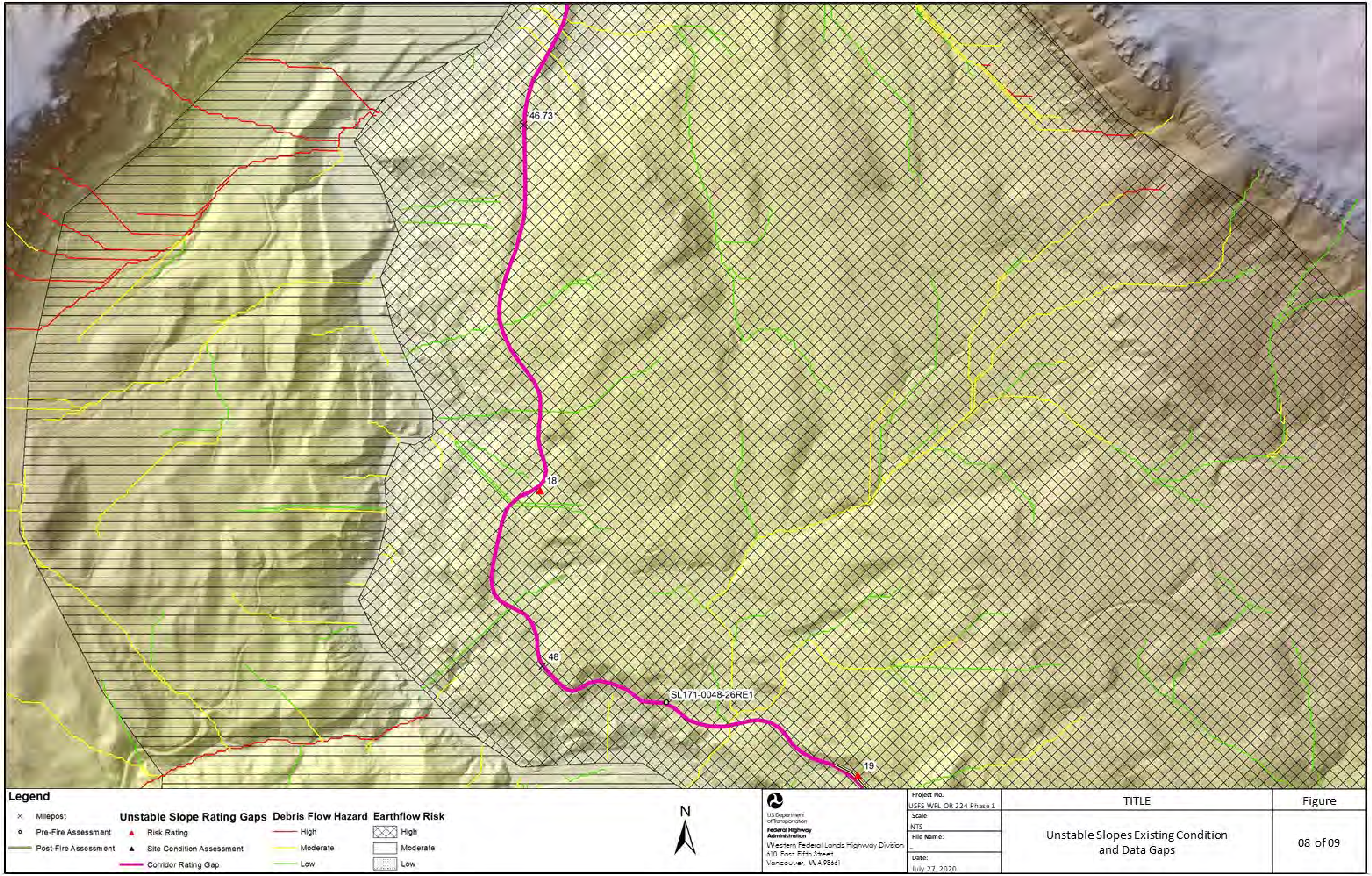
Legend

	Unstable Slope Rating Gaps	Debris Flow Hazard	Earthflow Risk
Milepost	Risk Rating	High	High
Pre-Fire Assessment	Site Condition Assessment	Moderate	Moderate
Post-Fire Assessment	Corridor Rating Gap	Low	Low

N

U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	TITLE	Figure
USFS WFL OR 224 Phase 1	Unstable Slopes Existing Condition and Data Gaps	07 of 09
Scale: NTS		
File Name: -		
Date: July 27, 2020		


46.73
18
48
SL171-0048-26RE1
19
Legend
Milepost
Pre-Fire Assessment
Post-Fire Assessment
Unstable Slope Rating Gaps
Risk Rating
Site Condition Assessment
Corridor Rating Gap
Debris Flow Hazard
High
Moderate
Low
Earthflow Risk
High
Moderate
Low
N
U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661
Project No.
USFS WFL OR 224 Phase 1
Scale
NTS
File Name:
Date:
July 27, 2020
TITLE
Unstable Slopes Existing Condition and Data Gaps
Figure
08 of 09

Legend

× Milepost
○ Pre-Fire Assessment
Post-Fire Assessment

Unstable Slope Rating Gaps
▲ Risk Rating
▲ Site Condition Assessment
Corridor Rating Gap

Debris Flow Hazard
High
Moderate
Low

Earthflow Risk
High
Moderate
Low

N

U.S. Department of Transportation
Federal Highway Administration
Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	TITLE	Figure
USFS WFL OR 224 Phase 1	Unstable Slopes Existing Condition and Data Gaps	09 of 09
Scale: NTS		
File Name: -		
Date: July 27, 2020		

ATTACHMENT 3 - TABLE OF UNSTABLE SLOPES WITH USRS RATINGS

Table 1. Rated and/or assessed unstable slopes; italicized rows indicate that unstable slope was reassessed after the 2020 Riverside Fire.

Record ID	M	Begin MP	End MP	Unstable Slope Type
SL171-0031-85LW1	*31.85*	*31.82*	*31.88*	*Rockfall*
SL171-0031-95LW1	*31.95*	*31.88*	*32.02*	*Rockfall*
SL171-0032-07LW1	*32.07*	*32.03*	*32.11*	*Rockfall*
SL171-0032-17RE1	*32.17*	*32.16*	*32.18*	*Fill Failure*
SL171-0032-18LW1	*32.18*	*32.15*	*32.21*	*Rockfall*
SL171-0032-37RE1	32.37	32.36	32.38	Fill Failure
NEW SITE	-	32.50	32.75	Soil Raveling
SL171-0032-96LW1	*32.96*	*32.92*	*33.00*	*Rockfall*
SL171-0033-03LW1	*33.03*	*33.01*	*33.05*	*Rockfall*
SL171-0033-11LW1	*33.11*	*33.05*	*33.17*	*Rockfall*
SL171-0033-83LW1	*33.83*	*33.79*	*33.87*	*Rockfall*
NEW SITE	-	33.91	34.03	Rockfall
NEW SITE	-	34.32	34.35	Rockfall
NEW SITE	-	34.50	34.70	Soil Raveling
SL171-0034-83LW1	*34.83*	*34.71*	*34.95*	*Rockfall*
SL171-0035-56LW1	*35.56*	*35.50*	*35.62*	*Rockfall*
SL171-0035-66LW1	*35.66*	*35.65*	*65.67*	*Rockfall*
SL171-0036-41LW1	*36.41*	*36.33*	*36.49*	*Rockfall*
SL171-0036-68LW1	*36.68*	*36.62*	*36.74*	*Rockfall*
NEW SITE	-	36.90	36.94	Debris Flow
SL171-0037-36LW1	*37.36*	*37.29*	*37.43*	*Rockfall*
NEW SITE	-	37.45	37.48	Rockfall
NEW SITE	-	37.65	37.80	Rockfall
SL171-0037-88RE1	37.88	37.87	37.89	Fill Failure
SL171-0039-28LW1	*39.28*	*39.23*	*39.33*	*Rockfall*
SL171-0039-66LW1	*39.66*	*39.65*	*39.67*	*Rockfall*
SL171-0039-75LW1	*39.75*	*39.67*	*39.83*	*Rockfall*
SL171-0040-30LW1	*40.30*	*40.27*	*40.33*	*Rockfall*
SL171-0040-44LW1	*40.44*	*40.42*	*40.45*	*Rockfall*
SL171-0040-50LW1	*40.50*	*40.48*	*40.51*	*Rockfall*
SL171-0040-78LW1	*40.78*	*40.74*	*40.82*	*Rockfall*
SL171-0041-33LW1	*41.33*	*41.25*	*41.41*	*Rockfall*
SL171-0041-95LW1	*41.95*	*41.80*	*42.10*	*Rockfall*
SL171-0042-60LW1	*42.60*	*42.45*	*42.75*	*Rockfall*
SL171-0042-82LW1	*42.82*	*42.76*	*42.88*	*Rockfall*
SL171-0042-86RE1	42.86	42.85	42.87	Fill Failure
SL171-0042-90RE1	42.90	42.89	42.91	Fill Failure
NEW SITE	43.00	-	-	Rockfall
SL171-0043-34LW1	*43.34*	*43.21*	*43.47*	*Rockfall*
SL171-0043-59LW1	*43.59*	*43.51*	*43.67*	*Rockfall*
SL171-0044-07LW1	*44.07*	*44.04*	*44.10*	*Rockfall*

Record ID	M	Begin MP	End MP	Unstable Slope Type
SL171-0044-21LW1	*44.21*	*44.14*	*44.27*	*Rockfall*
SL171-0044-38LW1	*44.38*	*44.29*	*44.47*	*Rockfall*
NEW SITE	-	44.95	45.00	Rockfall
NEW SITE	-	45.15	45.16	Rockfall
SL171-0045-20LW1	45.20	45.20	45.21	Fill Failure
SL171-0045-24LW1	45.24	45.24	45.25	Fill Failure
SL171-0045-24RE1	45.24	45.24	45.25	Landslide
SL171-0045-28RE1	45.28	45.28	45.29	Fill Failure
SL171-0045-33LW1	45.33	45.32	45.34	Fill Failure
SL171-0045-37LW1	45.37	45.36	45.38	Fill Failure
NEW SITE	-	45.40	45.60	Rockfall
SL171-0045-47LW1	45.47	45.41	45.53	Fill Failure
SL171-0046-23RE1	46.23	46.20	46.26	Fill Failure
SL171-0046-29LW1	46.29	46.26	46.33	Fill Failure
NEW SITE	-	46.30	46.37	Rockfall
SL171-0048-26RE1	48.26	48.24	48.28	Fill Failure
NEW SITE	-	48.69	48.69	Rockfall

ATTACHMENT 4 - TABLE OF UNSTABLE SLOPES REQUIRING USMP RATINGS OR SITE CONDITION ASSESSMENTS

Table 2. Unstable slopes identified as requiring USMP ratings or site condition assessments.

Record ID	MP	Begin MP	End MP	Unstable Slope Type	Source	Recommendation; Notes
1	32.56	-	-	Landslide, debris flow	ODOT/USGS	RISK RATING; ODOT identified soil raveling at MP 32.50-32.75, H DF haz., channel geometry
2	33.26	-	-	Landslide, debris flow	USGS	RISK RATING; observed DF
3	33.32	-	-	Landslide, debris flow	USGS	RISK RATING; observed DF
4	-	36.00	36.05	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; M DF haz., channel geometry
5	36.89			Landslide, debris flow	ODOT	RISK RATING; post-fire debris flows 01/2021 and 05/2021, includes rockfall in a 100-yard long zone
6	38.03	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; M DF haz., channel geometry
7	40.53	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; H DF haz., channel geometry
8	40.65	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; M DF haz., channel geometry
9	-	42.72	42.78	Landslide, translational	ODOT	RISK RATING; cracks/offsets in pavement - bin wall rotation
10	42.95	-	-	Landslide, erosional	ODOT	RISK RATING; slope erosion has crept close to the road prism
11	43.52	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; H DF haz., channel geometry
12	43.70	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; H DF haz., channel geometry
13	43.91	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; M DF haz., channel geometry
14	44.38	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; H DF haz., channel geometry
15	45.81	-	-	Landslide, debris flow	USGS	SITE CONDITION ASSESSMENT; H DF hazard, channel geometry
16	-	46.23	46.30	Landslide, rotational	ODOT	RISK RATING; showing continued gradual movement from slope instability, west of tieback wall
17	-	46.30	46.40	Rockfall?	ODOT	RISK RATING; cutslope not in inventory
18	47.6	-	-	Rockfall/landslide?	ODOT	RISK RATING; no evidence of issues, but could become unstable
19	-	48.60	48.78	Rockfall?	ODOT	RISK RATING; scaled chute at MP48.69 after fire and the crest of that slope from the chute eastward to about MP 48.71
20	-	45.87	49.92	CORRIDOR	WFLHD	RISK RATING; 5 miles of the corridor may lack ratings

Appendix C

Hydrology Gap Analysis Technical Memorandum

U.S. Department
of Transportation
Federal Highway
Administration

Memorandum

Western Federal Lands Highway Division
610 E. Fifth Street
Vancouver, WA 98661-3801

TO: Jamie Lemon, WFLHD Transportation Planner

FROM: James Neighorn, WFLHD Hydraulic Engineer

DATE: September 7, 2021

SUBJECT: OR FLPP FS PLAN 2021(8) – OR 224 Corridor Study Phase 1
Draft Hydraulics Data Gap Analysis

INTRODUCTION

The Riverside fire was one of several catastrophic wildfire events which occurred across the Mount Hood National Forest, Oregon in 2020. The fire occurred within the Clackamas River basin and caused significant impacts along the Oregon State Route 224 corridor between Promontory Park and Ripplebrook. The U.S. Forest Service (USFS) is assessing the post-wildfire conditions along this corridor and has requested assistance from Western Federal Lands Highway Division (WFL) of the Federal Highway Administration (FHWA). As part of the initial two-phased effort, an existing conditions assessment is being conducted to identify and document available information along the OR 224 corridor which can then be used to inform future study efforts for identifying project-specific improvements.

BACKGROUND

The purpose of this memorandum is to provide a hydrologic and hydraulic corridor assessment that identifies available data, evaluates the suitability of the data, and identifies data or information gaps.

A desktop review of available post-fire reports, as-built information, maintenance/inspection data, basin maps, and U.S. Geological Survey (USGS) post fire debris flow hazard mapping was conducted to identify drainage structures, flood and debris flow prone areas, transportation infrastructure, and facilities which may be impacted by post fire flows through and downstream of the corridor.

AVAILABLE DATA AND SUITABILITY

The USFS Rapid Assessment Team evaluated the fire and completed a report, dated October 2020, which provided basal area mortality maps, summarized conditions, and provided action recommendations. A Burned Area Emergency Response (BAER) team began work on assessing the post-fire effects in September 2020. The team developed reports that include comprehensive information which will support the OR 224 corridor assessment.

Burned Area Reflectance Classification (BARC), aerial reconnaissance data, and on-the-ground surveys were conducted to develop a Soil Burn Severity (SBS) map which was used to estimate the soils post-fire hydrologic responses and resulting flows for the Clackamas River subwatersheds. Risk of upland erosion, sedimentation delivery rates, and increased flood flows were then estimated for 27 subwatersheds using the Water Erosion Prediction Project (WEPP) Post-Fire Erosion Predictor (PEP). This was compared to pre-fire 5-year recurrence interval flood conditions to identify levels of risks at road/stream crossings. The BAER report provides analysis results of crossing points along OR 224 listed in Table 1. Significant increase in flow are predicted for a majority of the analyzed crossings.

Table 1.

Crossing Points	Pre-fire Q5 (cfs)	Post-fire Q5 (cfs)	% Increase	Times Increase	Pre-fire Q50 (cfs)	Acres
Moore Creek	380	390	3%	1.0X	530	459
Unnamed Tributary	110	240	118%	2.1X	340	171
Murphy Creek	180	250	39%	1.3X	270	257
Unnamed Creek	99	190	92%	1.9 X	170	133
Three Lynx Bridge	340	590	74%	1.7X	1300	1,675
Deer Creek	140	270	93%	1.9X	320	200
Dinner Creek	430	680	58%	1.5X	1200	921
Roaring River	7400	8300	12%	1.1X	15000	27,229

The burn area mortality, soil burn severity, subwatershed, and subwatershed peak stream flow analysis point maps developed by the BAER team have been included in Appendix A.

The USGS conducted a post-fire debris-flow hazard assessments using the post-fire data and developed mapping. They utilized geospatial data related to basin morphology, burn severity, soil properties, and rainfall characteristics to estimate the probability, volume, and combined hazard rating of debris flows at both the drainage-basin scale and in a spatially distributed manner along the drainage network within each basin. The debris flow hazard mapping can be found on the following USGS website which includes downloadable shapefiles and geodatabase information: (https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=309)

The USGS model identifies 84 streams that intersect the highway within the study corridor. This includes those crossing points listed in Table 1. Due to differences in geology and basin morphology, the 73 streams modelled in the lower corridor between the forest boundary and Three Lynx Creek rated as moderate to high hazard. The 13 streams modelled in the upper corridor from Three Lynx Creek to Forest Road 57 rated as low to moderate hazard.

Within the lower corridor there were 37 stream intersects that rated as high hazard. Although a handful of these where points modeled for flow in Table 1, additional flow modeling for the remaining crossings were not performed or unavailable.

The Oregon Department of Transportation (ODOT) was able to provide data on crossing structures for a portion of the lower corridor from the forest boundary to Mile Point (MP) 36 just south of Moore Creek. Beyond this point ODOT did not have inspection data for crossing structures, but only had culverts listed on plans. Since ODOT restricts outside access to their GIS database, the data provided was in spreadsheet format with information limited to specified queries. Additional asbuilt, inspection, and maintenance data for culverts along the corridor are available from the USFS. Per discussions with USFS staff, this data would need to be obtained from isolated databases and possibly from multiple sources. Current post-fire inspection information for crossing structures was not available.

ODOT provided asbuilt plans and inspection reports, in electronic pdf format, for all bridges within the corridor which are listed in Table 2. The table does include three large culverts (Bull Creek, NF Clackamas, and Dry Creek) that fall within the recording requirements of the National Bridge Inventory System (NBIS).

Table 2.

Bridge No.	Mile Post	Description	Scour Critical Rating
18178	41.48	Roaring River Bridge	
18619	47.70	Bull Creek Culvert	
05269	49.96	Clackamas River (Oak Fork Ripple Brook Br)	3
05272A	30.04	North Fork Clackamas River (Steel Plate Culvert)	
08988	38.77	Clackamas River (Carter Br)	
08989	39.15	Clackamas River (Armstrong Br)	3
08990	45.83	Clackamas River (Cripple Creek Br)	3
08991	44.88	Clackamas River (Three Lynx/Whitewater Br)	3
08992	49.12	Dry Creek Culvert	

Review of the inspection reports revealed that four (4) of the bridges within the corridor have a National Bridge Inventory System (NBIS) scour critical rating of 3. This means that these structure's foundations have the potential to be undermined by stream scour or erosion. The expected post-fire changes in flow conditions, debris loads, and sediment loads has the potential to increase scour and erosion resulting in a higher risk for the bridges becoming unstable.

ODOT performed inspections of the bridges along the corridor in August of 2019. Another inspection is scheduled for this year. Inspection photos are available within the ODOT GIS database and can be provided upon request but would need to address large file transfer requirements.

In addition to the analysis and recommendations included in the USFS BAER team reports, ODOT requested that the Federal Emergency Management Agency's Erosion Threat Assessment/Reduction Team (ETART) produced a separate report to assess State, local, and private lands outside of the forest. This report re-affirms much of the recommendations made by the BAER team, but also adds recommendations for property and facilities affected downstream of the forest boundary.

CORRIDOR NEEDS AND DATA GAPS

After review of available data and related report recommendations, the following hydrologic and hydraulic related needs and data gaps have been identified for the OR 224 corridor.

Roadway Drainage and Culverts

ODOT is currently removing debris, removing danger trees, and storm proofing (cleaning ditches, culverts, repairing drainage) along the corridor to address immediate hazard concerns. However, hazardous conditions will continue to develop over the next 5 years as the loss of vegetation will allow normal storms to more easily cause erosion and debris flows on the steep roadside slopes resulting in further plugging of ditches and culverts, and/or washouts of drainage facilities or stream crossings. The BAER and ETARTS reports recommend a number of drainage and culvert related actions to address or help reduce impacts from these expected hazards during the period in which vegetation recovers.

A prioritized mitigation action plan should be prepared that identifies the most susceptible drainage crossings impacted by increased flow and debris. Pre-fire and post-fire flow modeling has been performed on only a small number of crossings (see Table 1) within the corridor. Flow modeling of additional crossings would assist in identifying culverts that may now be undersized or less able to accommodate plugging. Modeling may involve pre-fire and post-fire flow analysis or just post-fire regression flow analysis. Crossings located at high and/or moderate debris flow potential sites should also be evaluated to determine the resulting risk and hazard that debris flows may have at each site.

Creating a complete inventory of drainage structures within the corridor (including condition assessments, documented maintenance issues, fish barrier issues, and geographic reference data) will be needed to produce a comprehensive mitigation plan and conduct flow analysis. This effort will also help identify structures needing to be replaced (specifically within the next 5-years), identify sites that may be more prone to debris/plugging, and assist crews in locating structures in the field. Conducting site specific field evaluations may also be needed to begin identifying and prioritizing mitigation actions. Mitigation actions may include, but are not limited to, the following:

- Culvert replacements or modifications to increase capacity (replacements should be sized on predicted increase in flows or fish passage requirements).
- Installation of additional culverts at high risk locations.
- Placement of upstream structures to deflect or catch debris away from the roadway.
- Installation of slotted riser pipes, debris racks, and culvert end sections where feasible to reduce sediment and debris plugging.
- Roadway embankment armoring in areas at risk for overtopping.
- Drainageway improvements at crossings to reduce or eliminate streamflow diversion potential.

Bridges

Post fire flow analysis indicates that increases in flow along the lower Clackamas River may not have a significant impact on bridges along the OR 224 corridor. Over the next 5 years, significant amounts of eroded fine sediment will be deposited in draws, stream and river channels, and floodplains. This increased loading can result in aggradation and channel migration at bridges. Large woody debris will also accompany the initial flush of fine sediments and ash that is delivered to bridges along the corridor during high-intensity rain events over the next 5-years. This will greatly increase potential for debris jams to form around bridge abutments leading to significant increases in the potential for scour to undermine piers and abutments. Debris flow potential from Fish Creek and smaller drainages adjacent to the bridges may also impact the flow patterns at bridge crossings which can lead to increases in erosion and scour.

It will be important to perform a post-fire evaluation of the four bridges rated as scour critical. Evaluation of the remaining bridges may also be warranted. The level of risk posed by increased debris jams, changes to flow patterns, aggradation, and channel migration should be re-evaluated. The evaluations will require collecting pre-fire and post-fire photos, measuring channel conditions, identifying existing scour counter measures, and documenting scour conditions near abutments and piers. This information will not only be useful in evaluating the risk but will allow inspectors to identify changing conditions more readily after significant storm events.

Identification and prioritization of additional site-specific monitoring efforts and preventative measures should consider the following:

- Increasing bridge inspection intervals.
- Additional emergency storm monitoring and response plans.
- Post-storm scour, damage, and debris inspection and assessment.
- Installing additional scour countermeasures.
- Monitoring movement of large woody debris and debris removal plans.
- Installation of real-time water surface elevation and/or scour monitoring devices to alleviate staff limitations.
- Signing and temporary emergency closure plans.

Facilities and Properties

The review teams identified a high risk to Get-N-Go Promontory Marina and North Fork Reservoir Dam from woody debris build up. Increasing inspection frequency will be needed to identify debris removal. Staging, storage, and disposal areas will need to be identified and coordinated.

The primary access to the Portland General Electric (PGE) Oak Grove Powerhouse is also vulnerable to debris flow from Three Lynx Creek. Mitigation actions that could be considered for this location could include placement of upstream debris racks, additions culverts, or armoring of the roadway. Additionally, an emergency response and access plan should be developed in coordination with PGE.

Water Supply

The Riverside Fire burned a large part of the municipal watershed of the City of Estacada and has the potential to impact other downstream municipal water supplies that have intakes on the

Clackamas river including City of Lake Oswego, Clackamas River Water, Clackamas Water District, North Clackamas County Water Commission, and South Fork Water Board municipalities.

During and after high-intensity storms, turbidity, dissolved organic carbon, nitrate, and some metals may likely increase by large magnitudes downstream of the burned area. Increases of such magnitude can pose problems for water-supply reservoirs and drinking-water treatment plants that can last many years and affect chemical treatment requirements, sludge volumes, and operating costs.

Starting coordination with the affected municipalities to assess capacity of facilities to address post-fire water quality will assist in identifying if additional water quality monitoring within Clackamas River is needed to help managers. This could provide data to better estimate affects to operations and allow them to minimize effects through temporary diversions or changes to water intakes.

Watershed

The ETARTS team recommends installation of one or more near real-time (NRT) precipitation gages in or near the burn area. A NRT 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. Further developing gaging station data with rainfall data relations can assist with future evaluations of post-fire flood magnitude and hydrologic response in ungaged.

The specific locations for possible NRT gages and funding sources will need to be evaluated and coordinated between agencies.

RECOMMENDATIONS

The following summarizes recommended actions that will assist in completing data or information gaps for future study efforts in identifying project-specific improvements:

- Develop a comprehensive drainage crossing inventory that includes post-fire condition inspections, emergency maintenance history, fish barrier information, and georeferenced location mapping.
- Conduct detailed post-fire hydrologic and hydraulic analysis on identified elevated risk crossings.
- Conduct site specific field evaluations of crossings affected by significant increased flow and within high risk debris flow areas.
- At bridge crossings, collect pre-fire and post-fire photos, measure channel conditions, identify existing scour counter measures, and documenting scour conditions at abutments and piers.
- Perform post-fire site evaluations for increased scour and erosion risks at bridges within the corridor (most importantly bridges rated as scour critical)

- Identify the number of locations potential NRT gages would need to be installed to provide useful emergency response data.
- Assist municipalities in assessing water supply facility capacities to address post-fire water quality and any needs for additional water quality monitoring.

Future Study Efforts
Creating an effective and efficient mechanism to implement, monitor, evaluate, and report on recovery activities, emergency responses, updates, and progress will require establishing staff roles, responsibilities, funding sources, and contact information across agencies.

Corridor drainage structure data should be organized in a format that can be readily accessed and shared by multi-agency staff involved in the implementation. Data must also be geographically referenced, easily visualized, relevant, and up to date. Control of the data and necessary data sharing activities will need to be clearly defined.

Once all hydrologic and hydraulic drainage data has been collected and relevant analysis has been performed, preventative mitigation measures will need to be identified and prioritized at all high-risk roadway drainage crossings and bridges.

Throughout the vegetation recovery period, storm patrols will need to be conducted to monitor road drainage ditches, culverts, debris control structures, and bridges during and after significant rainfall events to ensure that structures remain safe and functioning at maximum capacity. A storm patrol plan and notification system will need to be developed and should be coordinated with other agencies accessing the corridor, including USFS, Clackamas County, Portland General Electric and ODOT.

Agencies will also need to be establish an emergency maintenance plan. They should be prepared to provide significant maintenance efforts after storm events to remove sediment and debris from ditches and entrances to culverts. Addition removal of debris flow material from the roadway and repair of the roadway may also be needed. The emergency maintenance plan should address key components such as before, during, and post-storm activities, priorities, and responsibilities. The plan should identify staging, storage, disposal areas for heavy equipment, materials, and removed debris.

cc: Sven Leon, WFLHD Senior Hydraulics Engineer

Attachments: Appendix A - Maps

REFERENCES

Cerise, Luke, Mary Young. 2020. Soil Resource Report; Riverside Fire. Clackamas Ranger District, Mt. Hood National Forest

Cole, Ryan. 2021. Geotechnical Memo 30-21; Unstable Slope Data Gap Analysis. U.S. Department of Transportation; Western Federal Lands Highway Division.

Clackamas River and Barlow Ranger Districts. 2020. Riverside and White River Fires Rapid Assessment Team Report. Mount Hood National Forest.

Daggett, Anna, Kelsey Madsen, et al. 2020. Riverside Fire; Erosion Threat Assessment/Reduction Team (ETART) Summary Report. DR-4562-OR. Federal Emergency Management Agency

Huppi, Pete, Kevin Duchow. 2020. Mt Hood National Forest Burned Area Emergency Stabilization Plan; Riverside Fire; Engineering Resource Assessment – Transportation System. Mt. Hood National Forest.

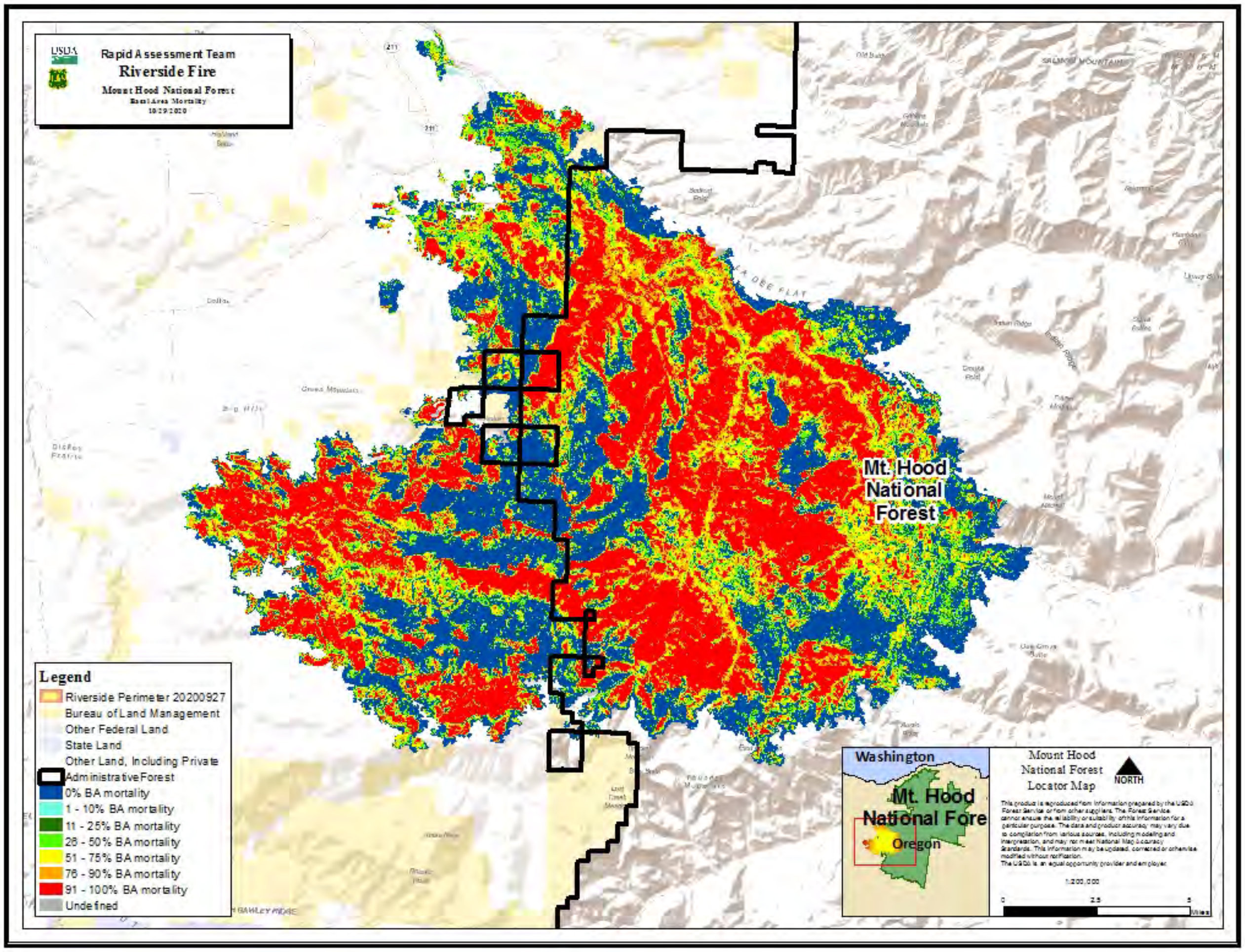
Parker, Todd, Hazel Wood. 2020. Hydrology Report, Riverside Fire Burned Area Emergency Response. Mt. Hood National Forest.

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

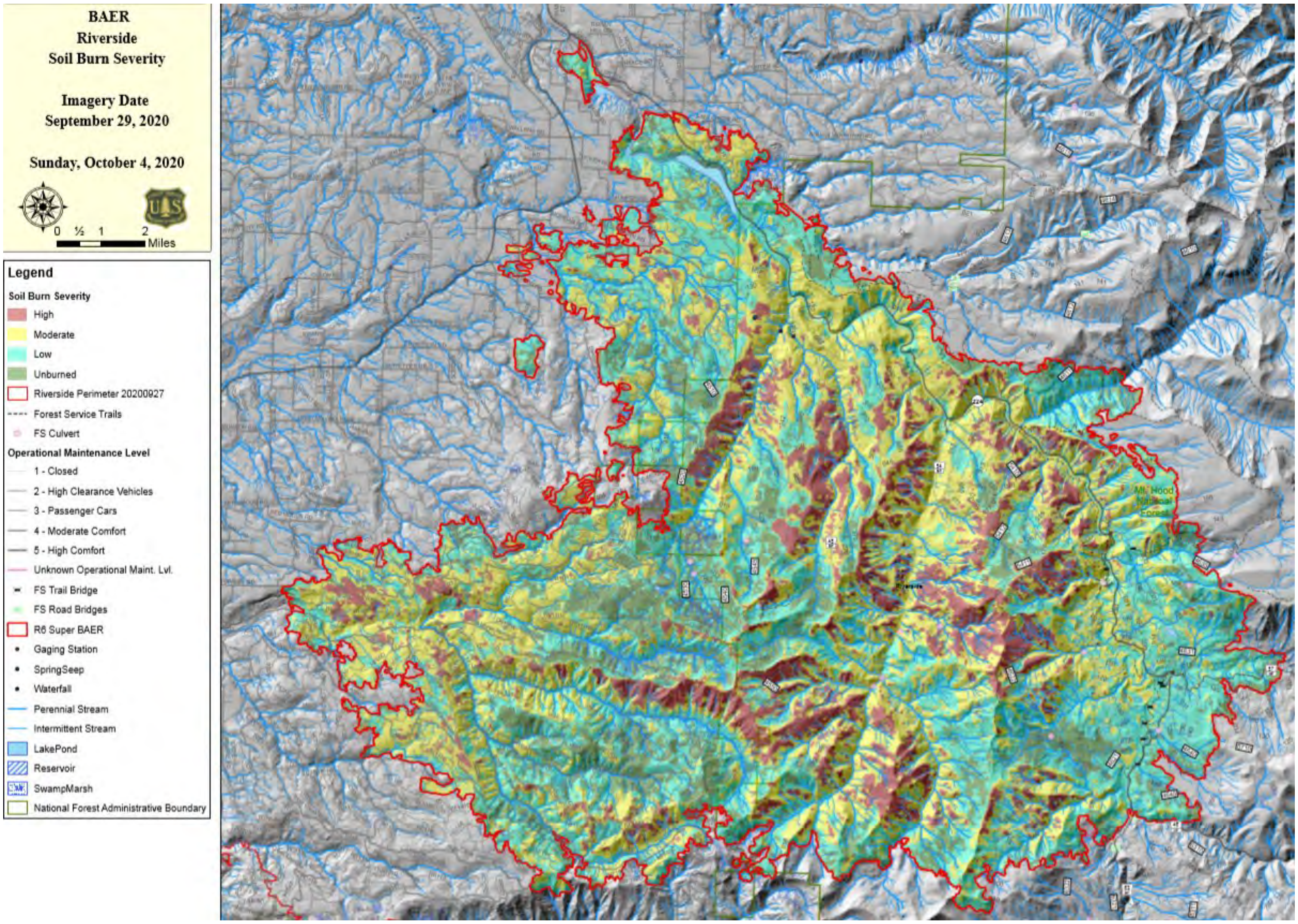
U.S. Geological Survey. 2020. Clackamas River Basin Water-Quality Assessment. https://www.usgs.gov/centers/or-water/science/clackamas-river-basin-water-quality-assessment?qt-science_center_objects=0#qt-science_center_objects

U.S. Department of Agriculture Forest Service. 2020. Riverside and White River Fires Burned Area Emergency Response Geologic Hazards Assessment.

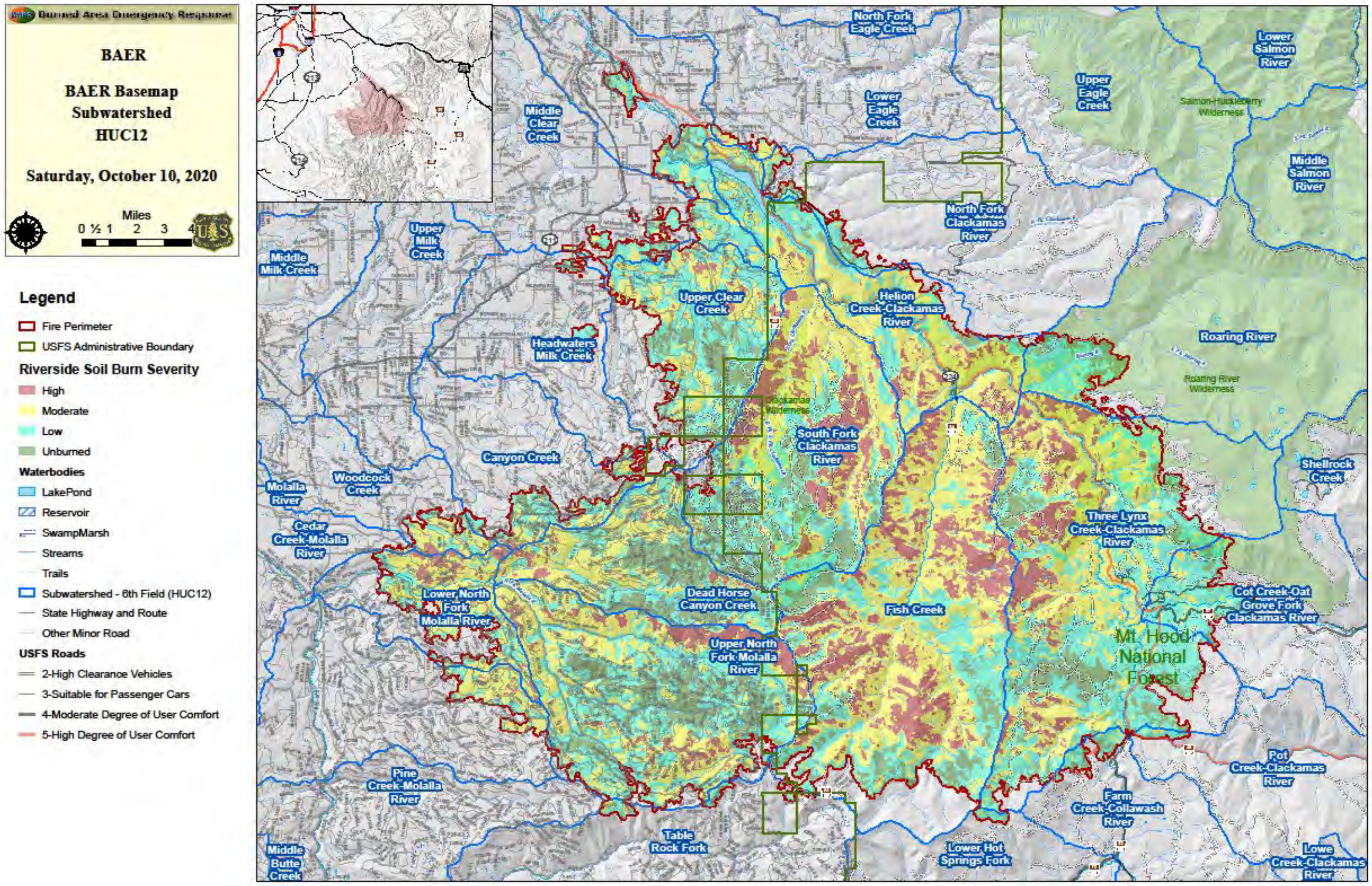
APPENDIX A – MAPS



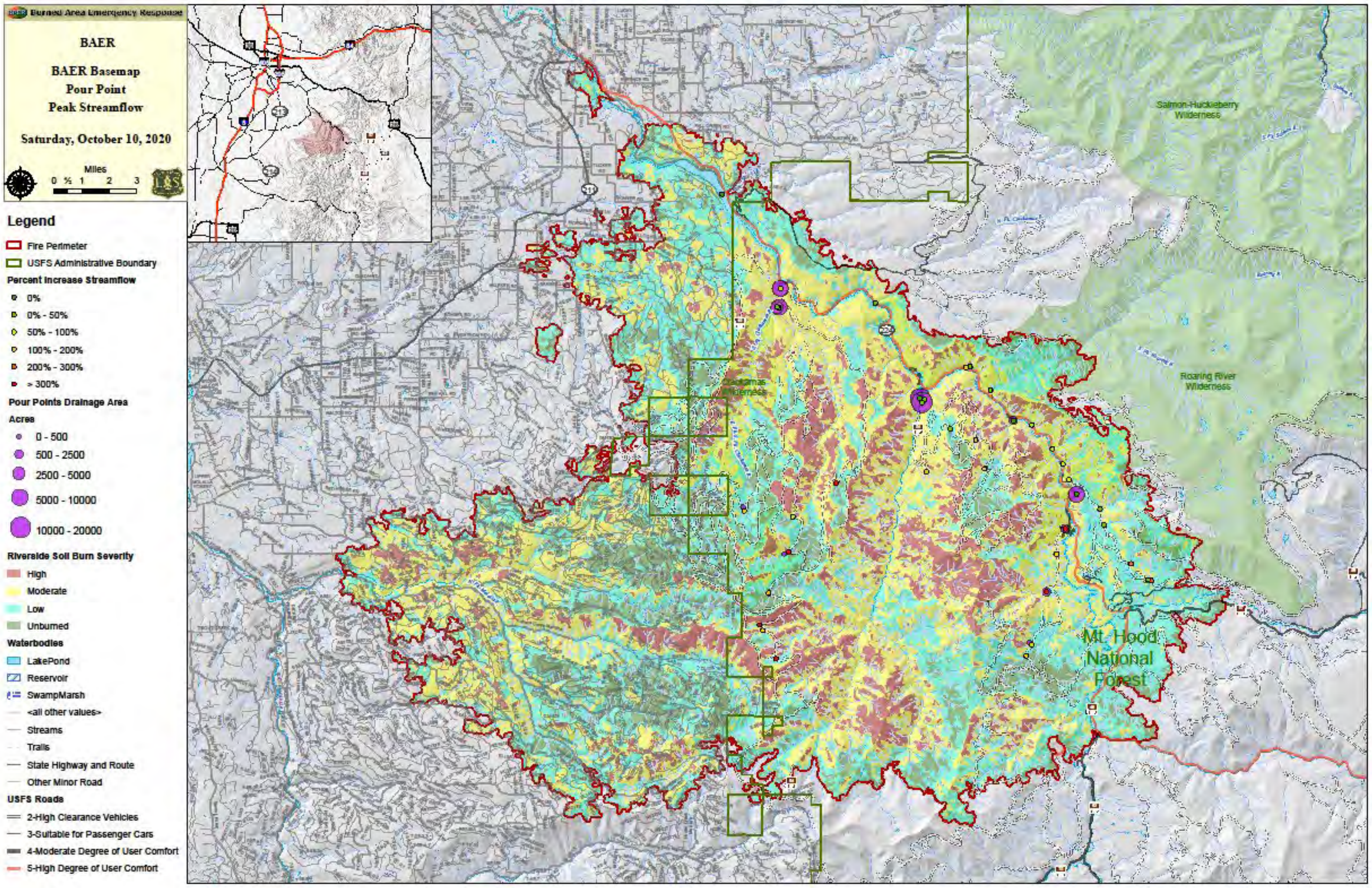
Riverside Fire - Basal Area Mortality Map



Riverside Fire – Soil Burn Severity Map



Riverside Fire – Subwatershed Map



Riverside Fire – Subwatershed Peak Stream Flow Analysis Points