Chapter 2 RISK ASSESSMENT

In This Chapter

The Oregon NHMP Risk Assessment chapter is divided into three sections: (a) Introduction, (b) State Risk Assessment, and (c) Regional Risk Assessment. Following is a description of each section.

1. **Introduction:**
   - Overview: States the purpose and provides an overview of the components of the risk assessment and explains risk. Presents and compares local and state vulnerability assessments.
   - 2020 Risk Assessment Methodology: Describes the pilot method used for assessing risk in a consistent way across hazards.
   - Social Vulnerability: Describes the method used for incorporating social vulnerability into the 2020 Risk Assessment Methodology.
   - Introduction to Climate Change: Describes the state of climate change knowledge and how climate change is anticipated to affect hazard occurrence.
   - State-Owned/Leased Facilities, State Critical Facilities, and Local Critical Facilities Potential Loss Assessment: Describes the potential loss assessment and how it was integrated into the 2020 Risk Assessment Methodology.
   - Seismic Transportation Lifeline Vulnerabilities: Describes and updates ODOT’s work on addressing transportation lifelines
   - Cultural Resources: Describes the value of Oregon’s cultural and historic resources, establishes a vision and suggests actions for better protecting them over time.
2. **State Risk Assessment:** Includes the following components:
   - Profiles each of Oregon’s hazards by identifying each hazard, its generalized location, and presidentially declared disasters; characterizes each hazard that impacts Oregon; lists historic events; identifies the probability of future events; and introduces how climate change is predicted to impact each hazard statewide.
   - Includes an overview and analysis of the state’s vulnerability to each hazard by identifying which communities are most vulnerable to each hazard based on local and state vulnerability assessments; providing loss estimates for state-owned/leased facilities and critical/essential facilities, local critical facilities, historic and archaeological resources located in hazard areas; identifying seismic lifeline vulnerabilities; and describing social vulnerability.
   - Includes a brief description of risk based on the probability and vulnerabilities discussed.
3. **Regional Risk Assessment:** Includes the following components for each of the eight Oregon NHMP Natural Hazard Regions:
   - Summary: Summarizes the region’s statistical profile and hazard and vulnerability analysis and generally describes projected impacts of climate change on hazards in the region.
   - Profile: Provides an overview of the region’s unique characteristics, including a natural environment profile, social/demographic profile, economic profile, infrastructure profile, and built environment profile.
   - Hazards, Vulnerability, and Risk: Further describes the hazards in each region by characterizing how each hazard presents itself in the region; listing historic hazard events; and identifying probability of future events based on local and state analysis; and introduces how climate

change is predicted to impact each hazard. Also includes an overview and analysis of the region's vulnerability to each hazard; identifies which communities are most vulnerable to each hazard based on local and state analysis; provides loss estimates for state-owned/leased facilities and critical/essential facilities, local critical facilities, historic and archaeological resources located in hazard areas; identifies the region's seismic lifeline vulnerabilities;; and describes social vulnerability.

- Includes a brief description of risk based on the probability and vulnerabilities discussed.

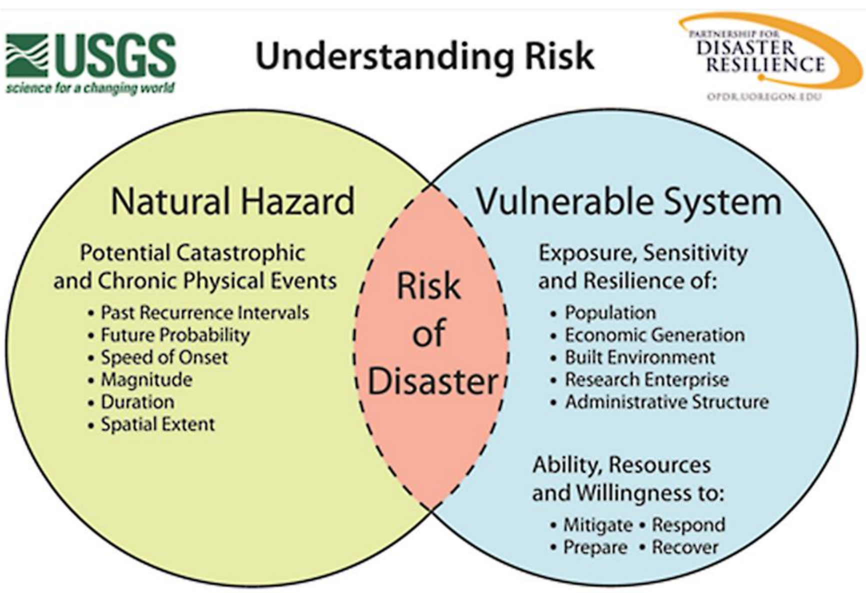
2.1 Introduction

Requirement 44 CFR §201.4(c)(2), [The plan must include] risk assessments that provide the factual basis for activities proposed in the strategy portion of the mitigation plan. Statewide risk assessments must characterize and analyze natural hazards and risks to provide a statewide overview. This overview will allow the State to compare potential losses throughout the State and to determine their priorities for implementing mitigation measures under the strategy, and to prioritize jurisdictions for receiving technical and financial support in developing more detailed local risk and vulnerability assessments.

The purpose of the Oregon NHMP Risk Assessment is to identify and characterize Oregon's natural hazards, determine which jurisdictions are most vulnerable to each hazard, and estimate potential losses to vulnerable structures and infrastructure and to state facilities from those hazards.

It is impossible to predict exactly when natural hazards will occur or the extent to which they will affect communities within the state. However, with careful planning and collaboration, it is possible to minimize losses that can result from natural hazards. The identification of actions that reduce the state's sensitivity and increase its resilience assist in reducing overall risk — the area of overlap in **Figure 2-1**. The Oregon NHMP Risk Assessment informs the State's mitigation strategy, found in **Chapter 3**.

Figure 2-1. Understanding Risk



Source: Wood (2007)

Assessing the state's level of risk involves three components: characterizing natural hazards, assessing vulnerabilities, and analyzing risk. Characterizing natural hazards involves determining hazards' causes and characteristics, documenting historic impacts, and identifying future probabilities of hazards occurring throughout the state. Section 2.2, State Risk Assessment has a chapter for each hazard (2.2.X).

Each hazard chapter has a section entitled "2.2.X.1 Analysis and Characterization" wherein the hazard is characterized. Sections "2.2.X.2 Probability" assess the probability of hazard occurrence.

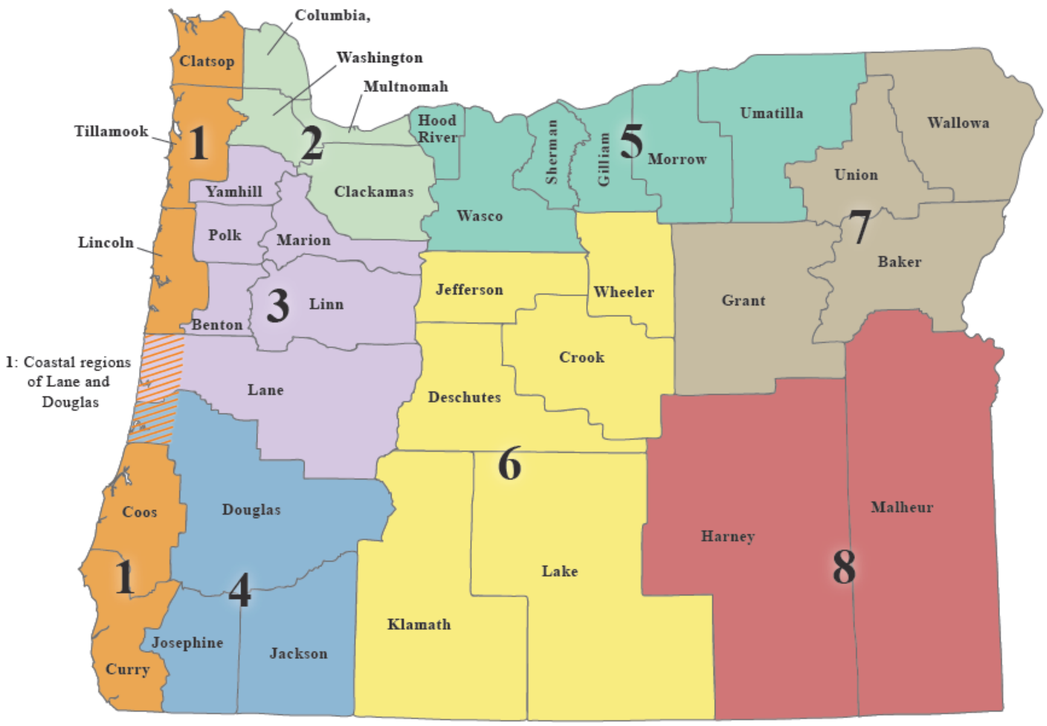
A vulnerability assessment combines information from the hazard characterization with an inventory of the existing (or planned) property and population exposed to a hazard and attempts to predict how different types of property and population groups will be affected by each hazard. Vulnerability is determined by a community's exposure, sensitivity, and resilience to natural hazards as well as by its ability to mitigate, prepare for, respond to, and recover from a disaster. Sections 2.2.X.3 Vulnerability identify assess the state's vulnerabilities to each hazard. For this update, the vulnerability assessment includes not only a summary of the potential loss estimate for state-owned and –leased facilities, critical facilities, but also local critical facilities, historic resources, archaeological resources, and social vulnerability.

A risk analysis involves estimating damages, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (a) the magnitude of the harm that may result, defined through vulnerability assessments; and (b) the likelihood or probability of the harm occurring, defined in the hazard characterization. For this update, the State developed a risk assessment methodology and applied it as a pilot to seven of the eleven hazards. These seven were chosen because data was available for the assessment. Probability and some elements of vulnerability were ranked and combined to deliver a risk score for each county for each hazard and for all seven hazards combined. Afterward, the more qualitatively assessed four remaining hazards were incorporated into the pilot and the results compared. A detailed description of the pilot is in Section 2.1.2, **2020 Risk Assessment Methodology** with a brief assessment of risk.

This Plan also analyzes risk at the regional level. Regional risk assessments begin with a description of the region's physical geography, assets, and vulnerabilities in the Regional Profile section. The Profile is followed by a characterization of each hazard and identification of the vulnerabilities and potential impacts of each hazard, and finally a brief assessment of risk. Regions are defined in the Oregon NHMP Natural Hazards Regions map (**Figure 2-2**):

- **Region 1 – Coast:** Clatsop, Tillamook, Lincoln, coastal Lane, coastal Douglas, Coos, and Curry Counties;
- **Region 2 – Northern Willamette Valley/Portland Metro:** Colombia, Clackamas, Multnomah, and Washington Counties;
- **Region 3 – Mid/Southern Willamette Valley:** Benton, Lane, Linn, Marion, Polk, and Yamhill Counties;
- **Region 4 – Southwest:** Douglas (non-coastal), Jackson, and Josephine Counties;
- **Region 5 – Mid-Columbia:** Gilliam, Hood River, Morrow, Sherman, Umatilla, and Wasco Counties;
- **Region 6 – Central:** Crook, Deschutes, Jefferson, Klamath, Lake, and Wheeler Counties;
- **Region 7 – Northeast:** Baker, Grant, Wallowa, and Union Counties; and
- **Region 8 – Southeast:** Harney and Malheur Counties.

Figure 2-2. Oregon NHMP Natural Hazards Regions



2.1.1 Overview

2.1.1.1 Hazard Characterization and Analysis

Requirement: 44 CFR §201.4(c)(2)(i): The risk assessment shall include… (i) An overview of the type and location of all natural hazards that can affect the State…

Oregon Hazards

The State of Oregon is subject to 11 primary natural hazards. **Table 2-1** lists each hazard and describes in general terms where the hazard is located. Section **2.2, State Risk Assessment** describes each hazard in greater detail in subsections 2.2.X.1. The probability of occurrence and the influence of climate change are presented in subsections 2.2.X.2. The state's vulnerability to each hazard is discussed in subsections 2.2.X.3, and a brief assessment of risk will be found in subsections 2.2.X.4. In this update, dust storms are not addressed and Extreme Heat is addressed for the first time.

Table 2-1. Oregon Hazard Overview

Hazards	Generalized Locations
Coastal Hazards	Oregon coast
Droughts	generally east of the Cascades, with localized risks statewide
Earthquakes	
Cascadia Subduction	primarily western Oregon
Other active earthquake faults	localized risks statewide
Extreme Heat	southwest, mid-Columbia, northeast and southeast Oregon
Floods	localized risks statewide
Landslides	localized risks statewide
Tsunamis	Oregon coast*
Volcanoes	central Oregon, Cascade Range and southeast Oregon, High Lava Plains
Wildfires	primarily southwest, central and northeast Oregon, with localized risks statewide
Windstorms	localized risks statewide
Winter Storms	localized risks statewide

*Maps and GIS files showing potential tsunami inundation for five levels of local Cascadia scenarios and two maximum-considered distant tsunami scenarios are available as DOGAMI Open-File Report O-13-19 (Priest, et al., 2013).

Source: Oregon NHMP lead state agency(ies) for each hazard

Requirement: 44 CFR §201.4(c)(2)(ii): The risk assessment shall include… (ii) (a)n overview and analysis of the State's vulnerability to the hazards described... based on estimates provided in … the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events…

For each of the 11 hazards addressed in this Plan, a state agency has been identified as the lead over that hazard (**Table 2-2**). All hazards have at least one lead and most have a support hazard expert who compiled and analyzed hazard data for this state risk assessment. In some instances both experts are from the same agency. For other hazards two agencies worked together to perform the analysis. Due to the wide range of data available for each hazard, the method used to assess risk varies from hazard to hazard. For example, there is a wealth of data available to assess risk to earthquakes, but data on windstorms is difficult to locate. In response, the State relies on hazard lead and support experts to determine the best method, or combination of methods, to identify probability, vulnerability and potential impacts for this Plan. In general, each hazard is assessed by using a combination of exposure, historical, and scenario analyses. Hazards for which more data exist — coastal hazards, earthquake, flood, landslide, tsunami, wildfire and, to a lesser degree, volcanic events (primarily related to Mount Hood) — have undergone a more robust analysis.

Table 2-2. Oregon NHMP Hazard Lead Agencies

Hazard	Lead Agency	Support Agency
Coastal Hazards	Department of Geology and Mineral Industries	Department of Geology and Mineral Industries
Droughts	Oregon Water Resources Department	Oregon Climate Change Research Institute
Earthquakes	Department of Geology and Mineral Industries	Oregon Office of Emergency Management
Extreme Heat	Oregon Climate Change Research Institute	Oregon Health Authority
Floods ▫ Dam Safety	Department of Geology and Mineral Industries Oregon Water Resources Department Dam Safety Program	Department of Land Conservation and Development
Landslides	Department of Geology and Mineral Industries	Department of Geology and Mineral Industries
Tsunamis	Department of Geology and Mineral Industries	Department of Geology and Mineral Industries
Volcanoes	Department of Geology and Mineral Industries	Department of Geology and Mineral Industries
Wildfires	Oregon Department of Forestry	Oregon Department of Forestry
Windstorms	Oregon Public Utility Commission	Oregon Climate Change Resource Institute
Winter Storms	Oregon Department of Land Conservation and Development	Oregon Climate Change Research Institute

Source: DLCD

Disaster Declarations

Since 1955 (the year the United States began formally tracking natural disasters), Oregon has received 34 major disaster declarations, two emergency declarations, and 49 fire management assistance declarations. **Table 2-2** lists each of the major disaster declarations, the hazard that the disaster is attributed to, and the counties impacted. Since 1955, Clackamas, Clatsop, Columbia, Coos, Curry, Douglas, Lane, Lincoln, Linn, Tillamook, and Yamhill Counties have each been impacted by 10 or more federally declared non-fire related disasters. Of the 34 major disasters to impact Oregon, the vast majority have resulted from storm events. Notably, flooding impacts from those events are reported in over two thirds of the major disaster declarations.

The reported federal disaster declarations (including fire management assistance declarations) document that storm events, floods, and wildfires have been the primary chronic hazards with major disaster impacts in Oregon over the last half century. The data also show a trend geographically of a greater number of major federal disaster declarations in the northwest corner of the state. Anecdotally, this pattern plays out for non-federally declared hazard events in the state as well. The following subsections summarize type, location, history, and probability information for each of the hazard types listed above.

Table 2-3. Presidential Major Disaster Declarations Since 1955

Disaster	Incident Period	Disaster Type	Baker	Benton	**Clackamas**	**Clatsop**	**Columbia**	**Coos**	Crook	**Curry**	Deschutes	**Douglas**	Gilliam	Grant	Harney	Hood River	Jackson	Jefferson	Josephine	Klamath	Lake	**Lane**	**Lincoln**	**Linn**	Malheur	Marion	Morrow	Multnomah	Polk	Sherman	Siletz IR*	**Tillamook**	Umatilla	Union	Wallowa	Warm Springs IR*	Wasco	Washington	Wheeler	**Yamhill**
DR-4519	Feb. 5-9, 2020	severe storms, flooding, landslides, and mudslides																															x	x	x					
DR-4452	Apr. 6-21, 2019	severe storms, flooding, landslides, and mudslides								x		x		x										x									x						x	
DR-4432	Feb. 23-26, 2019	severe winter storms, flooding, landslides, and mudslides						x		x		x						x				x																		
DR-4328	Jan. 7-10, 2017	severe winter storms, flooding, landslides, and mudslides					x				x					x			x																					
DR-4296	Dec. 14-17, 2016	severe winter storm and flooding																	x			x																		
DR-4258	Dec. 6-23, 2015	severe winter storms, straight-line winds, flooding, landslides, and mudslides			x	x	x	x		x		x										x	x	x				x	x			x						x		x
DR-4169	Feb. 6–14, 2014	severe winter storm		x																		x	x	x																
DR-4055	Jan. 17–21, 2013	severe winter storm / flooding / landslides / mudslides		x			x	x		x		x				x						x	x	x		x			x			x								
DR-1964	Mar. 11, 2011	tsunami						x		x													x																	
DR-1956	Jan. 13–21, 2011	winter storms / flooding / mudslides/ landslides / debris flows			x	x			x			x											x									x								
DR-1824	Dec. 13, 2007– Jan. 26, 2008	winter storms / flooding			x	x	x																				x		x	X		x						x		x
DR-1733	Dec. 1–17, 2007	storms / flooding / landslides / mudslides																												X		x						x		x
DR-1683	Dec. 14–15, 2006	winter storms / flooding		x		x	x																x							x	x	x					x		x	x
DR-1672	Nov. 5–8, 2006	storms / flooding / landslides / mudslides				x										x							x									x								
DR-1632	Dec. 18, 2005– Jan. 21, 2006	storms / flooding / landslides / mudslides		x	x	x	x	x	x	x		x	x				x	x	x				x	x						x	x	x				x			x	x
DR-1510	Dec. 26, 2003– Jan. 14, 2004	winter storms	x	x	x	x	x		x		x	x	x	x	x	x		x			x	x	x	x	x	x	x	x	x	x		x	x	x	x		x		x	x
DR-1405	Feb. 7-8, 2002	winter storm						x		x		x										x		x																
DR-1221	May 28–June 3, 1998	flooding							x																															
DR-1160	Dec. 25, 1996– Jan. 6, 1997	winter storm / flooding						x				x					x		x	x	x	x													x					
DR-1107	Dec. 10–12, 1995	storms / high winds		x		x	x					x										x	x	x								x						x		x
DR-1099	Feb. 4–21, 1996	storms / flooding		x	x	x	x	x			x	x	x			x		x	x			x	x	x		x	x	x	x	x		x	x	x	x		x	x		x
DR-1061	July 8–9, 1995	flash flooding																																			x			
DR-1036	May 1–Oct. 31, 1994	El Niño effects				x	x	x		x		x										x	x									x								
DR-1004	Sep. 20, 1993	earthquakes																		x																				
DR-985	Mar. 25, 1993	earthquake			x																					x												x		x
DR-853	Jan. 6-9, 1990	storms / flooding				x																										x								
DR-413	Jan. 25, 1974	storms / flooding / snow melt		x	x		x	x		x		x	x			x	x		x			x	x			x			x			x			x		x	x		x
DR-319	Jan. 21, 1972	storms / flooding			x	x		x				x										x	x	x				x				x						x		
DR-301	Feb. 13, 1971	storms / flooding				x																										x								
DR-184	Dec. 24, 1964	heavy rains / flooding	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x

Disaster	Incident Period	Disaster Type	Baker	Benton	**Clackamas**	**Clatsop**	**Columbia**	**Coos**	Crook	**Curry**	Deschutes	**Douglas**	Gilliam	Grant	Harney	Hood River	Jackson	Jefferson	Josephine	Klamath	Lake	**Lane**	**Lincoln**	**Linn**	Malheur	Marion	Morrow	Multnomah	Polk	Sherman	Siletz IR*	**Tillamook**	Umatilla	Union	Wallowa	Warm Springs IR*	Wasco	Washington	Wheeler	**Yamhill**
Total number of disasters by county / IR* post 1964			2	9	**10**	**14**	**12**	**12**	5	**10**	4	**15**	5	3	2	7	4	5	7	3	3	**14**	**15**	**11**	2	6	4	5	7	4	2	**17**	5	4	6	1	6	9	5	**11**
DR-144	Feb. 25, 1963	flooding																																						
DR-136	Oct. 16, 1962	storms																																						
DR-69	Mar. 1, 1957	flooding	**No individual county impact data available**																																					
DR-60	July 20, 1956	storm / flooding																																						
DR-49	Dec. 29, 1955	flooding																																						

*IR = Indian Reservation

Bold "x" = A county that has been impacted by 10 or more federally declared non-fire related disasters

Source: Oregon Office of Emergency Management (2013)

Vulnerability Assessments

Requirement: 44 CFR §201.4(c)(2)(ii): The risk assessment shall include… (ii) (a)n overview and analysis of the State's vulnerability to the hazards described... based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events…

The vulnerability assessment provides an overview and analysis of the state's vulnerabilities to each of Oregon's 11 hazards addressed in this Plan. Both local and state risk assessments are referenced to identify vulnerabilities, most vulnerable jurisdictions, and potential impacts from each hazard.

Requirement: 44 CFR §201.4(c)(2)(ii): The risk assessment shall include… (ii)…State owned or operated critical facilities located in the identified hazard areas shall also be addressed.

Requirement: 44 CFR §201.4(c)(2)(iii): The risk assessment shall include… (iii) An overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

State Vulnerability Assessment

The exposure analysis and estimate of potential losses to state-owned/leased facilities and critical/essential facilities and local critical facilities located within hazard zones performed by the Department of Geology and Mineral Industries (DOGAMI) for the 2015 Oregon NHMP was updated by DOGAMI in 2020. Loss data are not available in local plans. Therefore, this Plan only includes the most recent estimates provided by DOGAMI.

An overview of seismic lifeline vulnerabilities was a new addition to the 2015 Oregon NHMP and is carried forward to the 2020 Oregon NHMP because it is still being implemented. It includes a summary of the Oregon Department of Transportation's (ODOT's) 2012 Oregon Seismic Lifeline Report (OSLR) findings, including identification of system vulnerabilities, loss estimates and recommended next steps. Both the facilities and lifeline report findings are further discussed and updated in the **Regional Risk Assessments**.

For the 2020 update, DOGAMI analyzed exposure of historic resources to coastal erosion, earthquake, flood, landslide, tsunami, volcano, and wildfire hazards for each county. OPRD analyzed exposure of archaeological resources to coastal erosion, earthquake, flood, and landslide for each county. Technical issues prevented analysis with respect to tsunami, volcano, and wildfire at this time.

In addition, social vulnerability was included in the state vulnerability assessment for the first time in the 2020 update. The Centers for Disease Control and Prevention (CDC) publishes a social vulnerability index which is updated every two years. This index was used in the 2020 Risk Assessment Methodology. Details are in Section **2.1.3**.

Local Vulnerability Assessments

Requirement: 44 CFR §201.4(c)(2)(ii): The risk assessment shall include… (ii) (a)n overview and analysis of the State's vulnerability to the hazards described... based on estimates provided in local risk assessments …. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events…

The OEM Hazard Analysis Methodology was first developed by FEMA in 1983 and has been gradually refined by OEM over the years. There are two key components to this methodology: vulnerability and probability. Vulnerability examines both typical and maximum credible events, and probability reflects how physical changes in the jurisdiction and scientific research modify the historical record for each hazard.

This analysis is conducted by county or city emergency program managers, usually with the assistance of a team of local public safety officials. The assessment team initially identifies which hazards are relevant in that community. Then, the team scores each hazard in four categories: history, probability, vulnerability, and maximum threat. Following is the definition and ranking method for each category:

- History = the record of previous occurrences:
  - Low 0–1 event past 100 years,
  - Moderate 2–3 events past 100 years, and
  - High 4+ events past 100 years.
- Probability = the likelihood of future occurrence within a specified period of time:
  - Low one incident likely within 75–100 years,
  - Moderate one incident likely within 35–75 years, and
  - High one incident likely within 10–35 years.

- Vulnerability = the percentage of population and property likely to be affected under an "average" occurrence of the hazard:
  - Low < 1% affected,
  - Moderate 1–10% affected, and
  - High > 10% affected.

- Maximum Threat = the highest percentage of population and property that could be impacted under a worst-case scenario:
  - Low < 5% affected,
  - Moderate 5–25% affected, and
  - High > 25% affected.

Each county in Oregon performs its hazard analysis in conjunction with NHMP updates. As part of this analysis, each county develops risk scores for natural hazards that affect its communities. These scores range from 24 (low) to 240 (high), and reflect risk for each particular hazard, as determined by a team process facilitated by the Emergency Manager. This method provides local jurisdictions with a sense of hazard priorities, or relative risk. It does not predict the occurrence of a particular hazard in a community, but it does "quantify" the risk of one hazard compared with another. By doing this analysis, local planning can first be focused where the risk is greatest. This analysis is also intended to provide comparison of the same hazard across various local jurisdictions.

Among other things, the hazard analysis can:

- Help establish priorities for planning, capability development, and hazard mitigation;
- Serve as a tool in the identification of hazard mitigation measures;
- Be one tool in conducting a hazard-based needs analysis;
- Serve to educate the public and public officials about hazards and vulnerabilities; and
- Help communities make objective judgments about acceptable risk.

Although this methodology is consistent statewide, the reported raw scores for each county are based on partially subjective rankings for each hazard. Because the rankings are used to describe the "relative risk" of a hazard within a county, and because each county conducted the analysis with a different team of people working with slightly different assumptions, comparing scores between counties must be treated with caution.

For the purposes of the Oregon NHMP, the Local Vulnerability Assessment focuses only on county vulnerability rankings (H, M, L) taken from LNHMP Hazard Analysis scores. These rankings provide the state an understanding of local hazard concerns and priorities. **Table 2-4** presents the local vulnerability rankings for each of Oregon's 11 hazards by county. In the **Regional Risk Assessments**, county vulnerability rankings are presented alongside state vulnerability rankings.

For the 2020 update, DOGAMI analyzed exposure of historic resources to coastal erosion, earthquake, flood, landslide, tsunami, volcano, and wildfire hazards for each county. OPRD analyzed exposure of archaeological resources to coastal erosion, earthquake, flood, and landslide for each county. Technical issues prevented analysis with respect to tsunami, volcano, and wildfire at this time.

In addition, social vulnerability was included in the vulnerability assessment for the first time in the 2020 update. The Center for Disease Control and Prevention (CDC) publishes a social vulnerability index which is updated every two years. This index was used in the 2020 Risk Assessment Methodology. Details are in Section **2.1.3**.

Table 2-4. Local Vulnerability Rankings by County

County	Most Recent HVA	Coastal Erosion	Tsunami	Drought	Earthquake	Volcanic	Landslide	Wildfire	Flood	Wind Storm	Winter Storm
Baker	2020 (draft)			H	H	L	L	H	M	M	H
Benton	2015			L	H	L	L	M	M	M	M
Clackamas	2018			L	H	M	L	M	M	L	M
Clatsop	2015	—	—	N/A	H	M	M	M	M	H	—
Columbia	2020 (draft)			L	H	M	—	M	H	—	H
Coos	2016	H	M	H	M	—	H	M	H	H	L
Crook	2017				H	H	L	M	H	M	M
Curry	2015	H	M		H	H	L	H	H	H	
Deschutes	2015			L	H	H	L	H	L	M	H
Douglas - central	2017			L	H		L	H	M	M	M
Douglas - coastal	2017	—	H	L	H		M	M	H	H	L
Gilliam	2018			M	M	M		M	M	M	H
Grant	2019			H	M	H	L	H	H	L	H
Harney	2017			H	L	L	L	H	M	L	H
Hood River	2018			M	M	M	M	M	L	M	H
Jackson	2017			M	H	L	L	M	M	M	M
Jefferson	2013			H	L	H	L	H	M	L	H
Josephine	2017			H	H	L	L	H	M	M	H
Klamath	2017			H	H	M	L	H	M		M
Lake	2020			H	H	H	L	H	H	H	H
Lane - central	2015			L	M	L	M	M	M	H	H
Lane - coastal			—		—		—	—	—	—	—
Lincoln	2020		H	M	H	L	H	L	M	H	M
Linn	2017			L	H	M		M	M	M	H
Malheur	2018			H	L	L	L	M	M	M	H
Marion	2016			H	H	L	H	M	H	L	H
Morrow	2016				M	L	L	M	M	M	H
Multnomah	2016				H	M	M	H	H	M	M
Polk	2016				M	M	L	M	M	H	H
Sherman	2018			H	L	L	L	H	M	M	H
Tillamook	2016		M		H	L	M	M	H	H	H
Umatilla	2012			—	M			M	M	H	H
Union	2013			M	H	L	L	H	H	H	H
Wallowa	2013			M	L	L	L	M	M	M	M
Wasco	2019			H	M	H	L	M	M	H	H
Washington	2015			M	H	H	L	M	M	H	H
Wheeler	2018			H	H	H	M	H	H	M	H
Yamhill	2019			M	H	L	L	L	H	M	H

Note: "-" indicates that the hazard was evaluated in 2015, but not in the latest local HVA

Source: Most recent local Hazard Vulnerability Analyses, dates listed above in the table.

Local and State Vulnerability Assessment Comparison

Vulnerability rankings guide local and state mitigation goals and actions that inform mitigation priorities at the local and state scale. Prior to 2015 past iterations of the Oregon NHMP stated local and state vulnerability rankings separately. No comparison or analysis of similarities and differences among the rankings of risk assessment methods was conducted. Starting with the 2015 plan, the state placed local and state vulnerability rankings side-by-side to identify if and where similarities and differences occur.

As stated earlier in this Plan, in most cases, local governments use the OEM Hazard Analysis to assess risk. The OEM Hazard Analysis Methodology ranks vulnerability to each hazard based on the estimated percentage of population and property likely to be affected. The ranking of vulnerability is based on best data retrieved from the local level — often including objective data, studies, Hazus, etc. as well as local knowledge — and is therefore somewhat subjective. This methodology identifies which hazards are priorities at the local level.

For the State Risk Assessment, in 2015, the hazard leads determined vulnerability based on some combination of research, literature and agency knowledge forming the factual basis for each hazard risk assessment accompanied by some level of subjectivity. In 2020 the pilot risk assessment methodology was used to determine vulnerability. That determination was based on a narrow set of data – state-owned and leased buildings, state critical facilities, local critical facilities, and a social vulnerability index. **Table 2-5** shows a side-by-side comparison of local and state vulnerability rankings.

Table 2-5. Local and State Vulnerability Ranking by County

Symbols in this table are defined as:

Local
H = High Vulnerability
M = Moderate Vulnerability
L = Low Vulnerability

State
VH = Very High Vulnerability
H = High Vulnerability
M = Moderate Vulnerability
L = Low Vulnerability
VL = Very Low Vulnerability

County	Coastal Erosion/ Coastal Hazards		Tsunami		Drought		Earthquake		Volcanic		Landslide		Wildfire		Flood		Wind Storm		Winter Storm		Extreme Heat	
	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State
Baker					H	M	H	L	L	VL	L	VL	H	L	M	VL	M	H	H	H		M
Benton					L	L	H	L	L	L	L	L	M	VL	M	L	M	M	M	M		M
Clackamas					L	VL	H	VL	M	L	L	H	M	VL	M	VL	L	L	M	M		L
Clatsop	—	L	—	VH	N/A	L	H	H	M	VL	M	L	M	VL	M	L	H	H	—	H		M
Columbia					L	VL	H	VL	M	VL	—	H	M	VL	H	VL	—	H	H	H		L
Coos	H	M	M	VH	H	H	M	VH		M	H	H	M	M	H	H	H	H	L	H		H
Crook						M	H	M	H	L	L	M	M	H	H	M	M	M	M	M		M
Curry	H	VL	M	L	M	L	M	H	H	VL	H	L	H	VL	H	VL	H	H	L	—		M
Deschutes					L	H	H	VL	H	M	L	VL	H	L	L	VL	M	L	H	H		L
Douglas - central					L	H	H	H		M	L	H	H	H	M	H	M	M	M	M		H
Douglas - coastal	—	M	H	H	L	H	H	VH		M	M	H	M	M	H	H	H	M	L			
Gilliam					M	VL	M	VL	M	VL		VL	M	VL	M	VL	M	L	H	H		L
Grant					H	M	M	VL	H	VL	L	VL	H	M	H	M	L	H	H	H		L
Harney					H	H	L	L	L	L	L	L	H	M	M	H	L	L	H	M		M
Hood River					M	M	M	VH	M	VH	M	M	M	H	L	L	M	H	H	H		M
Jackson					M	H	H	H	L	M	L	H	M	M	M	VH	M	H	M	H		M
Jefferson					H	VH	L	H	H	VH	L	H	H	VH	M	VH	L	—	H	H		H
Josephine					H	H	H	H	L	M	L	M	H	M	M	H	M	H	H	H		M
Klamath					H	VH	H	VH	M	H	L	H	H	VH	M	H		—	M	M		H
Lake					H	H	H	VH	H	H	L	M	H	H	H	M	H	M	H	H		H
Lane - central					L	M	M	L	L	H	M	M	M	M	M	M	H	M	H	H		H
Lane - coastal	—	L	—	VH		M	—	VH		L	—	H	—	M	—	M	—	H	—	L		
Lincoln	L	M	H	M	M	M	H	VH	L	L	H	VH	L	L	M	L	H	H	M	—		M
Linn					L	H	H	VH	M	H		M	M	H	M	M	M	M	H	H		H
Malheur					H	VH	L	H	L	M	L	H	M	VH	M	H	M	M	H	M		M
Marion					H	VH	H	VH	L	VH	H	H	M	VH	H	H	L	H	H	H	M	H
Morrow					H	VH	M	VH	L	H	L	H	M	VH	M	VH	M	M	H	H		H
Multnomah							H	M	M	L	M	H	H	L	H	VH	M	H	M	H		M
Polk					M	M	M	M	M		L	L	M	M	M	M	H	H		—		H
Sherman					H	VL	L	VL	L	VL	L	VL	H	L	M	L	M	M	M			L
Tillamook	H	L	M	L		L	H	M	L	VL	M	H	M	VL	H	L	H	H	H	H		M
Umatilla					—	VH	M	VH		H		H	M	H	M	H	H	H	H	H		M
Union					M	L	H	M	L	VL	L	L	H	M	H	VL	H	H	H	H		M
Wallowa					M	L	L	L	L	VL	L	VL	M	L	M	L	M	M	M	M		M

County	Coastal Erosion/ Coastal Hazards		Tsunami		Drought		Earthquake		Volcanic		Landslide		Wildfire		Flood		Wind Storm		Winter Storm		Extreme Heat	
	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State	Local	State
Wasco					H	VH	M	H	H	H	L	VH	M	VH	M	H	H	H	H	H		M
Washington					M	VL	H	L	H	VL	L	H	M	VL	M	VL	H	H	H	H		L
Wheeler					H	L	H	VL	H	VL	M	L	H	H	H	VL	M	M	H	H		L
Yamhill					M	H	H	VH	L	M	L	M	L	M	H	H	M	M	H	H		H

Sources: Hazard lead agencies, local Hazard Vulnerability Analyses, dates listed in Table 2-4

This comparison indicates similarities and differences between local and state vulnerability rankings. For some counties, local and state assessments agree on the level of vulnerability to a hazard. In other instances, local and state rankings are not in sync. For example, in several instances a county did not score itself for a hazard (indicating it is not at risk to that hazard), or scored itself “L” (as having low vulnerability) to a hazard, while the state ranked that county as having “H” (high) vulnerability to that hazard.

It would be instructive to compare the hazard leads’ vulnerability scores from 2015 with the scores resulting from the 2020 risk assessment and both with the local vulnerability rankings to see which, if any, are more in sync and investigate why. The results of such a comparison could lead to more accurate assessments both by local practitioners and by improving the 2020 risk assessment methodology. All three perspectives – local practitioners, state hazard experts, and objective data – are necessary for reaching the best assessment of vulnerability.

Local vulnerability assessments are based in part on local knowledge and experience. While this perspective may be skewed by the last hazard event suffered, it also contextualizes the assessment with a depth of knowledge and experience with the community that is valuable to the assessment. Local practitioners with such understanding can identify errors in data, assumptions, or interpretation that may be made by outside experts. They know the places that the population cares about protecting, for example iconic establishments or heritage sites. The local perspective is also helpful on the human side of vulnerability assessment. People know their neighbors and the organizations in the community that serve those in need. They are invaluable in identifying the potential and actual human costs of hazard events.

While the state may provide data and analysis, the local risk assessors can use that data and analysis to derive a deeper understanding of the vulnerabilities of their community, use that knowledge to improve the local risk assessment, and then to more effectively mitigate. Local risk assessments therefore can add depth and granularity to the state risk assessment. As the state strives to incorporate local risk assessments into the state risk assessment (Section **3.6**), this deeper local understanding of local vulnerability and risk, based in part on state data and analysis and in part on local knowledge and experience, will help the state focus its limited resources in communities that need them most and in the ways those communities need them most. This partnership or linkage between state and local mitigation planning promises to be beneficial to both local and state government and most importantly, to the citizens of Oregon.

2.1.2 2020 Risk Assessment Methodology

2.1.2.1 Previous Risk Assessments

During the 2012 Oregon NHMP update process the State realized that no standardized statewide risk assessment methodology is being used across all hazards — each state hazard lead uses a different method to assess risk. This is due in part to the fact that "many state agencies do not have the tools and/or resources to conduct a full risk assessment. Likewise, most agencies do not maintain existing statewide risk assessment data" as identified in Task 5 of the Mid-Planning Alterations to the 2012 work plan. In response, the State allocated remaining federal funds from DR-1733 to support initial stages of the development of a standardized risk assessment model.

Beginning in March 2013, Oregon's Interagency Hazard Mitigation Team (IHMT) established a Risk Assessment Sub-Committee (RAS-C) that worked in partnership with faculty and staff from the University of Oregon's Department of Geography InfoGraphics Lab and Oregon Partnership for Disaster Resilience (OPDR) to develop a new risk assessment model concept. When fully developed and implemented, the model was to provide a standardized way to assess vulnerability to natural hazards in Oregon at the state level thereby allowing the State to better identify where to strategically target mitigation resources. This initiative was facilitated by the Department of Land Conservation and Development (DLCD).

The RAS-C convened a total of five times from March to August to develop a risk assessment methodology that (a) meets federal requirements, (b) draws from the strengths of existing methods, and (c) addresses Oregon's unique priorities. The committee took a four-pronged approach to developing a new risk assessment model. Phase One involved review of natural hazard risk assessment methodologies found in academic literature and in other state Natural Hazards Mitigation Plans. In Phase Two, the UO team developed a proposed risk assessment model concept drawing from the strongest elements of the literature review and other research. While this phase focused heavily on adapting Susan Cutter's Social Vulnerability Index (SoVI), a key driver was the development of a framework tailored toward Oregon that could address key shortcomings identified in the SoVI and other models. In addition, the model incorporated state priorities identified by the RAS-C. Phase Three involved testing the feasibility of the proposed model. Finally, in Phase Four, the UO team developed a timeline, work plan and budget in an effort to identify the resources needed to fully develop the risk assessment model and interface. The proposed 3-year budget was roughly $600,000, which included UO staff and resources.

2.1.2.2 2020 Risk Assessment Procedure

DLCD and partners have tried three times to procure funding for development of the risk assessment concept model; however, the project was not funded and the risk assessment model was never developed. During the 2020 Oregon NHMP update, DLCD sought to adopt a methodology that advanced the goal of employing a standardized risk assessment that could be used across all hazards statewide to inform hazard mitigation prioritization. DLCD surveyed risk assessment methodologies used in other SNHMPs, assessed its capacity to implement various techniques, and incorporated best practices into the 2020 Risk Assessment (2020 RA).

The 2020 RA methodology is driven by the understanding that risk is a function of probability and vulnerability (Wood N. , 2011). **Table 2-2** shows the different state agencies that have been identified as leads over the eleven hazards included in the Plan. Of the eleven, seven are included in the 2020 RA: coastal hazards, earthquakes, floods, landslides, tsunamis, volcanic hazards, and wildfires. Two of the seven—Tsunami and Coastal Hazards—only affect counties in Region 1. The assessment is comprised of the following probability and vulnerability components:

Probability

- Probability of a hazard event

Vulnerability

- Exposure of state-owned and –leased properties to natural hazards
- Exposure of state-owned and –leased critical facilities to natural hazards
- Exposure of local critical facilities to natural hazards
- Social vulnerability index

Relative probability is determined by subject-matter experts who assigned each county a probability score for each hazard. Scores are determined on a 1–5 scale, with 1 being the least probable and 5 being the most. The factors considered to determine probability are hazard-dependent and can be viewed in each hazard chapter of the **State Risk Assessment**.

The 1-5 scale is also used to assign vulnerability scores—both physical and social. Physical, or built-environment vulnerability, is determined using a geographic information system to analyze by hazard the exposure of State-owned and –leased facilities (critical and non-critical) and local critical facilities. Social vulnerability is derived from an index created by the U.S. Center for Disease Control and Prevention (CDC). The physical vulnerability components are combined and rescaled to calculate a 1-5 overall physical vulnerability score. This value is then combined with the social vulnerability score to determine overall vulnerability.

The probability and vulnerability scores are then summed and rescaled to calculate a cumulative 1-5 risk score. Finally, each county was assigned a descriptive ranking for each hazard and for all hazards combined using the Jenks Natural Breaks Classification method; the classification method is shown in **Table 2-6**. The remaining four hazards—drought, extreme heat, windstorms, and winter storms—are not included in the 2020 RA due to insufficient data.

Table 2-6. Risk Score Classification: Natural Breaks and Risk Scores

Natural Breaks & Risk Scores			
Low Cutoff	**High Cutoff**	**Description**	**Abbreviated Description**
0.00	2.10	Very Low	VL
2.11	2.30	Low	L
2.31	2.80	Moderate	M
2.81	3.20	High	H
3.21	5.00	Very High	VL

2.1.2.3 Risk Assessment Progress and Limitations

The 2020 RA takes certain steps toward the goal of standardizing the risk assessment. For example, the methodology enables the comparison of risk across multiple hazards and at different geographic scales—county, region, and state. Moreover, the results are easily mapped, providing useful visualizations of each jurisdiction's relative risk to 7 different natural hazards. Additionally, through incorporating the CDC's SoVI, the 2020 RA makes progress toward identifying those communities that historically have been least able to prepare, respond, and recover after a natural hazard event.

Although the new methodology represents a step forward, the 2020 RA falls short in many areas needed to capture more accurately the nuances in probability, as well as social and physical vulnerability. Moreover, an ideal risk assessment would not be a static model but a living and modifiable tool that would enable hazard mitigation planners across jurisdictions to adjust inputs to assess more accurately risk in their area. The remaining discussion illustrates the limitations of specific components of the 2020 RA and then discusses generally how the assessment could be improved to better model risk and plan for hazard mitigation in the state.

The limitations of the social vulnerability index developed by the CDC are discussed at greater length in Section **2.1.3, Social Vulnerability**; however, a few bear repeating here.

First, the SoVI relies on data from the American Community Survey (ACS). While the ACS is a tremendous resource and frequently provides the best available data on a wide variety of social and economic topics across multiple U.S. geographies, the ACS is a statistical survey and therefore subject to sampling and non-sampling error. In some instances this means that estimates cannot be relied upon—especially when considering geographies that are sparsely populated.

Data currency of the SoVI is another limitation. When the 2020 RA was developed, the most recent version of the CDC index featured data from the ACS 2012–2016 (5-year). The ACS 2014–2018 (5-year) was not released until April 2020, after much of the analysis for the 2020 RA was already been completed.

Finally, the 2020 RA fails to incorporate the total number of people exposed to each hazard, which should be considered along with each population's relative vulnerability. Moreover, although it is widely understood that socially vulnerable communities are not evenly distributed across space, the 2020 RA assumes as much by providing a single SoVI score for each county. Future iterations of the assessment should strive to more accurately model where socially vulnerable communities are concentrated; this effort should also include a spatiotemporal dimension to account for how population distribution is dependent on the time of day.

As mentioned above, the probability score in the 2020 RA is assigned by subject matter experts using different factors depending on the hazard. Although this flexibility enables subject matter experts to use their best judgement and the most appropriate data for each hazard, it also potentially skews the results toward one hazard over another. For example, some experts strictly considered the likelihood of occurrence in their assessment while others discuss aspects of vulnerability in their probability narrative — indicating that the components of the 2020 RA are not as distinct as initially intended. Future iterations of the assessment should present clearer guidelines for determining probability to further standardize the assessment and more accurately depict the relative risk of each hazard.

The methodology for the 2020 RA is straightforward, transparent, and illustrates risk at a macro level; however, the static nature the assessment implies additional limitations. For example, modeling risk at the county-level misses important geographic differences within each county. The ability to model at a more granular level would benefit both physical and social vulnerability. Additionally, the 2020 RA does not allow for weighting or easy modification of the assessment components. Ultimately, these characteristics make it challenging to consider different scenarios at different scales. For example, the current assessment cannot be used to easily model hazard events at different magnitudes; nor is it possible to consider how implementing a mitigation action might influence risk in a particular area.

Finally, the 2020 RA limits the definition of risk to people and property. Among other considerations, a more expansive definition might include how hazards impact the environment.

2.1.2.4 2020 Risk Assessment Components

As described above, the 2020 RA calculates risk using probability and vulnerability components. The following tables show by hazard how each county scored on the various components—revealing which are most influential in determining risk. Again, the components of the 2020 RA are the probability of a hazard event, the physical vulnerability of state-owned and –leased buildings and critical facilities, physical vulnerability of local critical facilities, and social vulnerability. The tables also show—in the far-right-hand columns—how the various components are combined and rescaled to arrive at a county-level risk score for each hazard. The maps following each table visually depict the results from the column labeled “Risk” under the heading “Risk (Prob. + Physical + Social).”

Table 2-7. Coastal Hazards, 2020 Risk Assessment

Coastal Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	3.50	2.00	1.00	2.00	1.67	2.00	1.83	L	2.39	M
	Coos	1.75	1.00	1.00	1.00	1.00	4.00	2.50	M	2.25	L
	Curry	2.25	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.75	VL
	Douglas Coastal	1.50	1.00	1.00	1.00	1.00	4.00	2.50	M	2.17	L
	Lane Coastal	1.75	2.00	1.00	1.00	1.33	3.00	2.17	L	2.03	VL
	Lincoln	3.00	4.00	1.00	1.00	2.00	3.00	2.50	M	2.67	M
	Tillamook	4.25	3.00	1.00	2.00	2.00	2.00	2.00	L	2.75	M

*Coastal hazard probability includes probability scores from four coastal hazards: coastal erosion, coastal flooding, coastal landslides, and coastal sand inundation.

Source: DLCD, 2020

Figure 2-3. Coastal Hazards Risk by Region

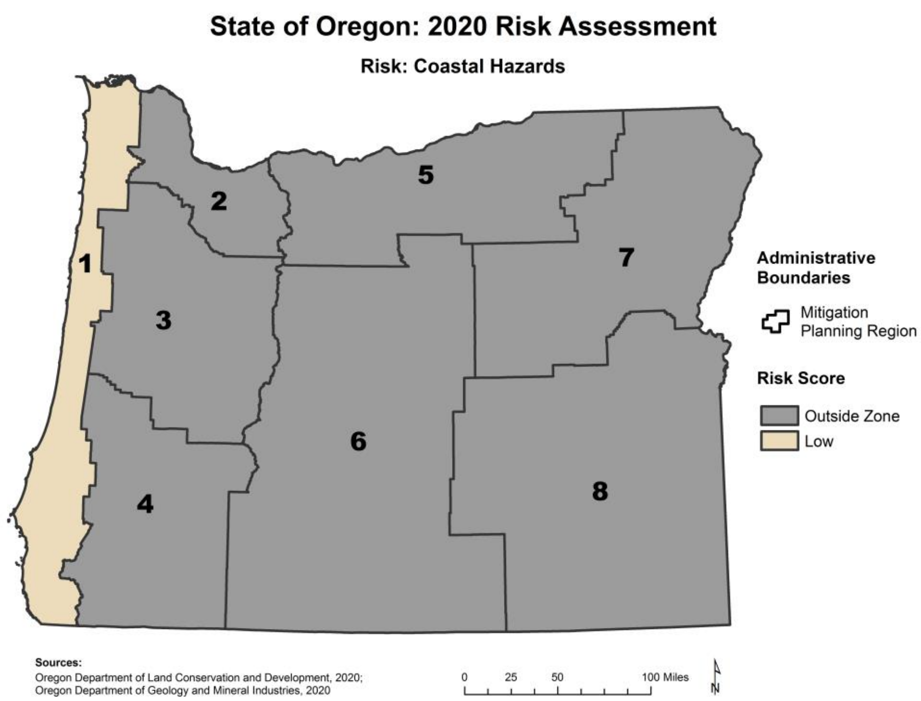


Figure 2-4. Coastal Hazards Risk by County

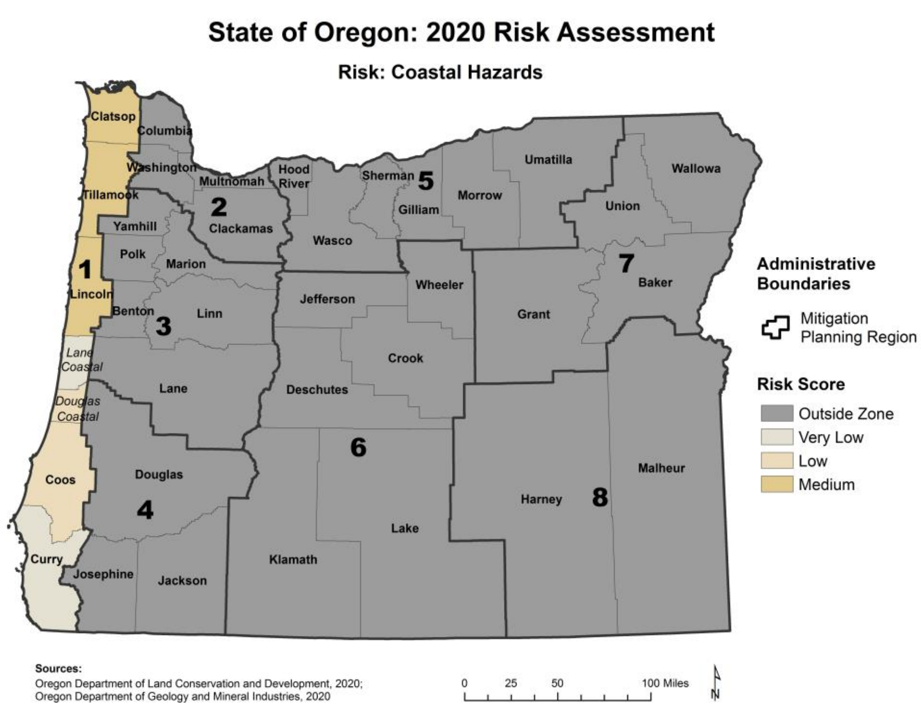


Table 2-8. Earthquake Hazard, 2020 Risk Assessment

Earthquake Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	5.00	4.00	4.00	5.00	4.33	2.00	3.17	H	3.78	VH
	Coos	5.00	5.00	5.00	5.00	5.00	4.00	4.50	VH	4.67	VH
	Curry	5.00	4.00	5.00	4.00	4.33	2.00	3.17	H	3.78	VH
	Douglas Coastal	4.00	4.00	4.00	5.00	4.33	4.00	4.17	VH	4.11	VH
	Lane Coastal	4.00	4.00	5.00	4.00	4.33	3.00	3.67	VH	3.78	VH
	Lincoln	4.00	3.00	4.00	4.00	3.67	3.00	3.33	VH	3.56	VH
	Tillamook	4.00	3.00	3.00	4.00	3.33	2.00	2.67	M	3.11	H
Region 2	Clackamas	4.00	2.00	1.00	2.00	1.67	1.00	1.33	VL	2.22	L
	Columbia	5.00	2.00	2.00	2.00	2.00	1.00	1.50	VL	2.67	M
	Multnomah	5.00	2.00	2.00	2.00	2.00	3.00	2.50	M	3.33	VH
	Washington	5.00	2.00	2.00	3.00	2.33	1.00	1.67	L	2.78	M
Region 3	Benton	4.00	2.00	2.00	2.00	2.00	2.00	2.00	L	2.67	M
	Lane	5.00	1.00	1.00	1.00	1.00	3.00	2.00	L	3.00	H
	Linn	4.00	2.00	3.00	3.00	2.67	4.00	3.33	VH	3.56	VH
	Marion	4.00	3.00	3.00	3.00	3.00	5.00	4.00	VH	4.00	VH
	Polk	4.00	1.00	1.00	3.00	1.67	3.00	2.33	M	2.89	H
	Yamhill	4.00	3.00	3.00	2.00	2.67	4.00	3.33	VH	3.56	VH
Region 4	Douglas	4.00	2.00	2.00	2.00	2.00	4.00	3.00	H	3.33	VH
	Jackson	4.00	2.00	2.00	2.00	2.00	4.00	3.00	H	3.33	VH
	Josephine	5.00	2.00	1.00	2.00	1.67	4.00	2.83	H	3.56	VH

Source: DLCD, 2020

(Table continued on next page)

Table 2 7. (*continued*) Earthquake Hazard, 2020 Risk Assessment

Earthquake Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 5	Gilliam	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Hood River	5.00	5.00	5.00	4.00	4.67	3.00	3.83	VH	4.22	VH
	Morrow	2.00	2.00	1.00	2.00	1.67	5.00	3.33	VH	2.89	H
	Sherman	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Umatilla	2.00	2.00	2.00	2.00	2.00	5.00	3.50	VH	3.00	H
	Wasco	3.00	1.00	1.00	2.00	1.33	5.00	3.17	H	3.11	H
Region 6	Crook	2.00	3.00	1.00	2.00	2.00	3.00	2.50	M	2.33	M
	Deschutes	3.00	2.00	2.00	1.00	1.67	1.00	1.33	VL	1.89	VL
	Jefferson	3.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.00	H
	Klamath	4.00	2.00	2.00	1.00	1.67	5.00	3.33	VH	3.56	VH
	Lake	3.00	3.00	4.00	3.00	3.33	4.00	3.67	VH	3.44	VH
	Wheeler	3.00	1.00	1.00	2.00	1.33	1.00	1.17	VL	1.78	VL
Region 7	Baker	3.00	2.00	3.00	2.00	2.33	2.00	2.17	L	2.44	M
	Grant	3.00	2.00	1.00	2.00	1.67	1.00	1.33	VL	1.89	VL
	Union	2.00	2.00	3.00	2.00	2.33	2.00	2.17	L	2.11	L
	Wallowa	2.00	3.00	4.00	2.00	3.00	2.00	2.50	M	2.33	M
Region 8	Harney	3.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.33	M
	Malheur	2.00	1.00	1.00	2.00	1.33	5.00	3.17	H	2.78	M

Source: DLCD, 2020

Figure 2-5. Earthquake Hazard Risk by Region

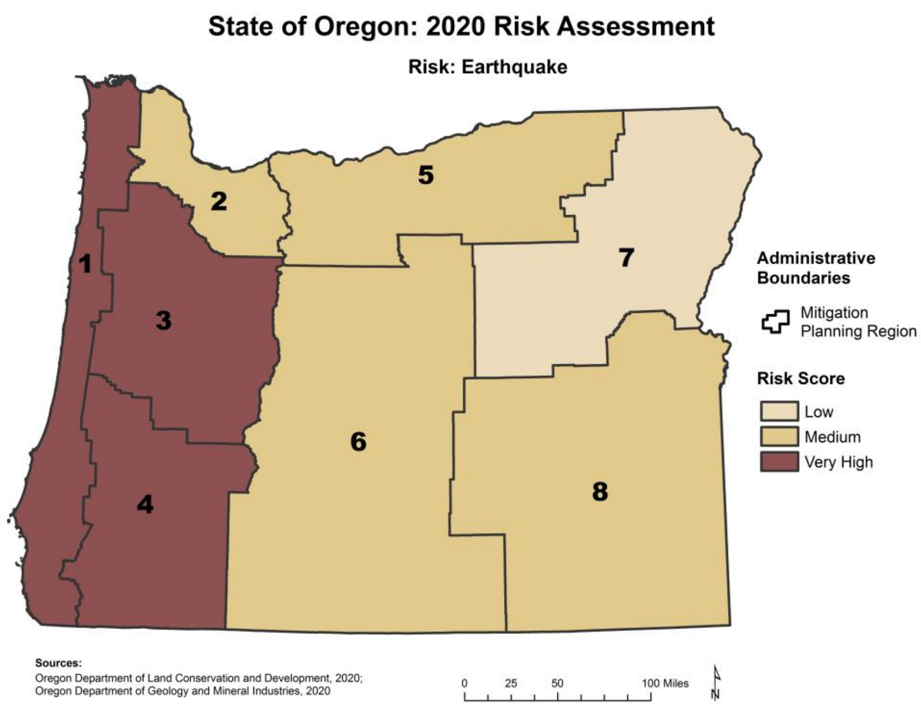


Figure 2-6. Earthquake Hazard Risk by County

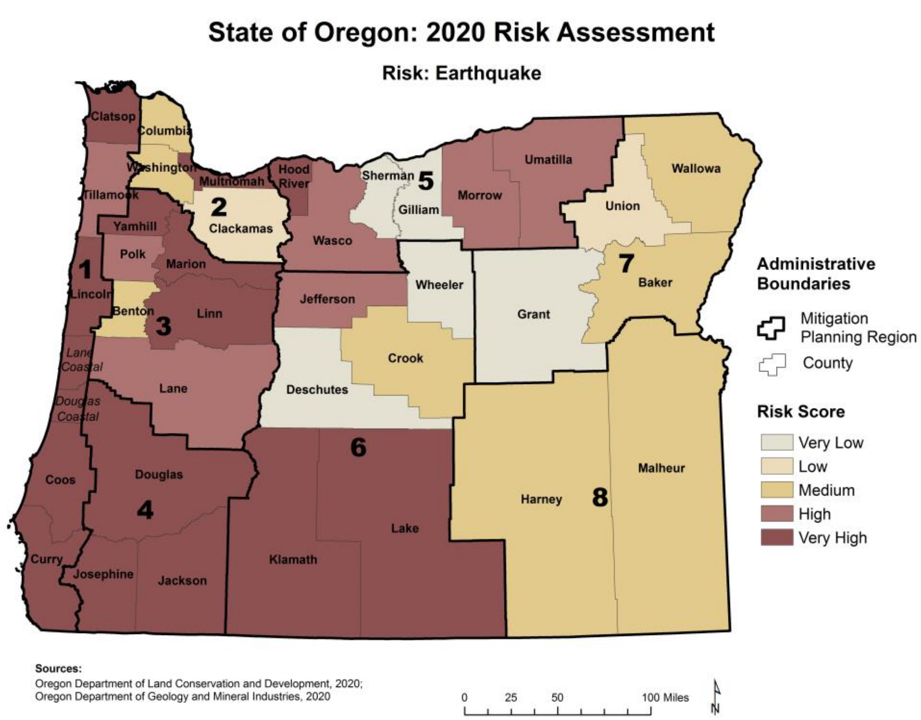


Table 2-9. Flood Hazard, 2020 Risk Assessment

Flood Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	5.00	1.00	1.00	3.00	1.67	2.00	1.83	L	2.89	H
	Coos	5.00	1.00	1.00	3.00	1.67	4.00	2.83	H	3.56	VH
	Curry	5.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	2.67	M
	Douglas Coastal	5.00	2.00	1.00	2.00	1.67	4.00	2.83	H	3.56	VH
	Lane Coastal	5.00	3.00	1.00	2.00	2.00	3.00	2.50	M	3.33	VH
	Lincoln	5.00	2.00	1.00	1.00	1.33	3.00	2.17	L	3.11	H
	Tillamook	5.00	1.00	1.00	3.00	1.67	2.00	1.83	L	2.89	H
Region 2	Clackamas	5.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	2.33	M
	Columbia	5.00	2.00	1.00	3.00	2.00	1.00	1.50	VL	2.67	M
	Multnomah	5.00	4.00	5.00	3.00	4.00	3.00	3.50	V	4.00	VH
	Washington	4.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	2.00	VL
Region 3	Benton	5.00	1.00	1.00	4.00	2.00	2.00	2.00	L	3.00	H
	Lane	5.00	2.00	2.00	3.00	2.33	3.00	2.67	M	3.44	VH
	Linn	5.00	2.00	1.00	2.00	1.67	4.00	2.83	H	3.56	VH
	Marion	4.00	3.00	3.00	3.00	3.00	5.00	4.00	VH	4.00	VH
	Polk	4.00	2.00	1.00	2.00	1.67	3.00	2.33	M	2.89	H
	Yamhill	4.00	1.00	1.00	2.00	1.33	4.00	2.67	M	3.11	H
Region 4	Douglas	5.00	1.00	2.00	3.00	2.00	4.00	3.00	H	3.67	VH
	Jackson	4.00	3.00	3.00	2.00	2.67	4.00	3.33	VH	3.56	VH
	Josephine	5.00	2.00	1.00	2.00	1.67	4.00	2.83	H	3.56	VH

Source: DLCD, 2020

(Table continued on next page)

Table 2 8. (*continued*) Flood Hazard, 2020 Risk Assessment

Flood Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 5	Gilliam	4.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	2.00	VL
	Hood River	4.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.67	M
	Morrow	4.00	2.00	1.00	3.00	2.00	5.00	3.50	VH	3.67	VH
	Sherman	4.00	4.00	1.00	4.00	3.00	1.00	2.00	L	2.67	M
	Umatilla	4.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.33	VH
	Wasco	4.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.33	VH
Region 6	Crook	2.00	1.00	1.00	5.00	2.33	3.00	2.67	M	2.44	M
	Deschutes	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Jefferson	2.00	1.00	1.00	4.00	2.00	5.00	3.50	VH	3.00	H
	Klamath	2.00	1.00	1.00	1.00	1.00	5.00	3.00	H	2.67	M
	Lake	2.00	1.00	1.00	2.00	1.33	4.00	2.67	M	2.44	M
	Wheeler	4.00	1.00	1.00	4.00	2.00	1.00	1.50	VL	2.33	M
Region 7	Baker	3.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	2.00	VL
	Grant	4.00	5.00	4.00	4.00	4.33	1.00	2.67	M	3.11	H
	Union	2.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.67	VL
	Wallowa	4.00	2.00	1.00	1.00	1.33	2.00	1.67	L	2.44	M
Region 8	Harney	3.00	3.00	3.00	4.00	3.33	3.00	3.17	H	3.11	H
	Malheur	3.00	1.00	1.00	2.00	1.33	5.00	3.17	H	3.11	H

Source: DLCD, 2020

Figure 2-7. Flood Hazard Risk by Region

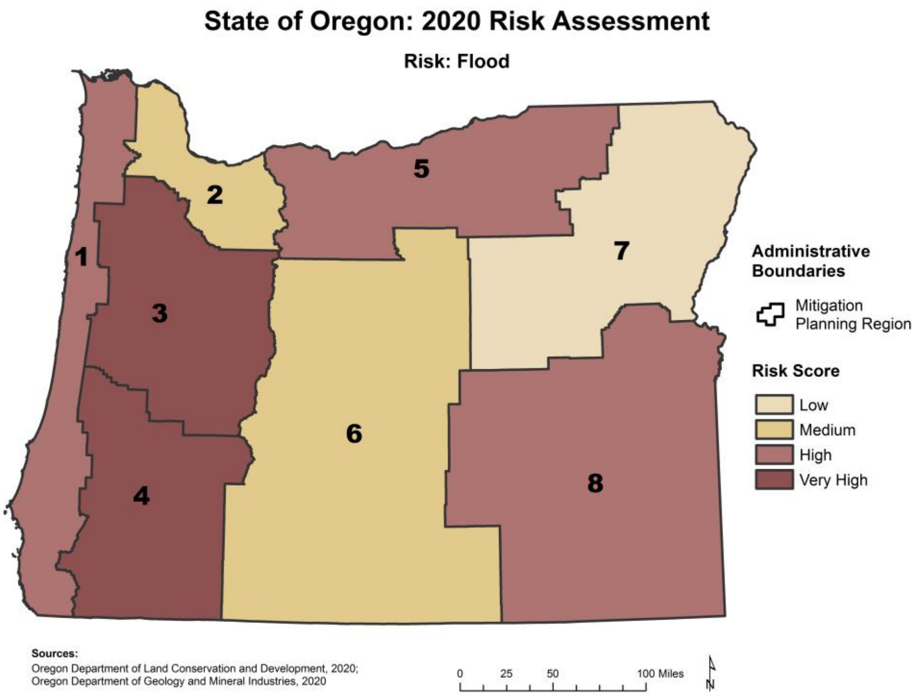


Figure 2-8. Flood Hazards Risk by County

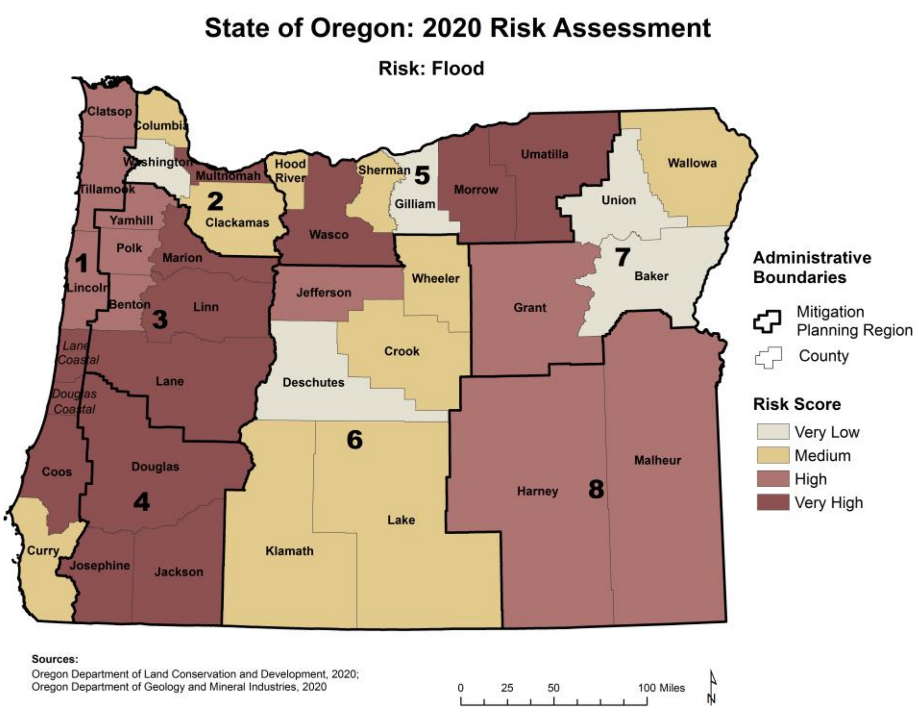


Table 2-10. Landslide Hazard, 2020 Risk Assessment

Landslide Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	5.00	2.00	1.00	4.00	2.33	2.00	2.17	L	3.11	H
	Coos	5.00	1.00	1.00	4.00	2.00	4.00	3.00	H	3.67	VH
	Curry	5.00	4.00	1.00	2.00	2.33	2.00	2.17	L	3.11	H
	Douglas Coastal	5.00	2.00	2.00	3.00	2.33	4.00	3.17	H	3.78	VH
	Lane Coastal	5.00	3.00	1.00	4.00	2.67	3.00	2.83	H	3.56	VH
	Lincoln	5.00	4.00	5.00	4.00	4.33	3.00	3.67	VH	4.11	VH
	Tillamook	5.00	3.00	4.00	4.00	3.67	2.00	2.83	H	3.56	VH
Region 2	Clackamas	4.00	1.00	1.00	2.00	1.33	1.00	1.17	VL	2.11	L
	Columbia	5.00	5.00	1.00	3.00	3.00	1.00	2.00	L	3.00	H
	Multnomah	4.00	1.00	1.00	2.00	1.33	3.00	2.17	L	2.78	M
	Washington	4.00	1.00	1.00	2.00	1.33	1.00	1.17	VL	2.11	L
Region 3	Benton	4.00	1.00	2.00	2.00	1.67	2.00	1.83	L	2.56	M
	Lane	5.00	2.00	3.00	1.00	2.00	3.00	2.50	M	3.33	VH
	Linn	4.00	2.00	1.00	1.00	1.33	4.00	2.67	M	3.11	H
	Marion	4.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.33	VH
	Polk	4.00	1.00	1.00	2.00	1.33	3.00	2.17	L	2.78	M
	Yamhill	5.00	1.00	1.00	2.00	1.33	4.00	2.67	M	3.44	VH
Region 4	Douglas	5.00	2.00	2.00	3.00	2.33	4.00	3.17	H	3.78	VH
	Jackson	5.00	1.00	2.00	3.00	2.00	4.00	3.00	H	3.67	VH
	Josephine	5.00	1.00	2.00	1.00	1.33	4.00	2.67	M	3.44	VH

Source: DLCD, 2020

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Table 2 9. (*continued*) Landslide Hazard, 2020 Risk Assessment

Landslide Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 5	Gilliam	4.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	2.00	L
	Hood River	5.00	3.00	1.00	3.00	2.33	3.00	2.67	M	3.44	VH
	Morrow	2.00	1.00	1.00	2.00	1.33	5.00	3.17	H	2.78	H
	Sherman	3.00	3.00	1.00	1.00	1.67	1.00	1.33	VL	1.89	L
	Umatilla	3.00	1.00	1.00	2.00	1.33	5.00	3.17	H	3.11	VH
	Wasco	4.00	2.00	1.00	4.00	2.33	5.00	3.67	VH	3.78	VH
Region 6	Crook	3.00	4.00	1.00	1.00	2.00	3.00	2.50	M	2.67	H
	Deschutes	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	L
	Jefferson	4.00	1.00	1.00	2.00	1.33	5.00	3.17	H	3.44	VH
	Klamath	2.00	1.00	1.00	1.00	1.00	5.00	3.00	H	2.67	H
	Lake	2.00	1.00	2.00	1.00	1.33	4.00	2.67	M	2.44	H
	Wheeler	5.00	2.00	2.00	5.00	3.00	1.00	2.00	L	3.00	VH
Region 7	Baker	4.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	2.33	H
	Grant	4.00	1.00	1.00	3.00	1.67	1.00	1.33	VL	2.22	M
	Union	4.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	2.33	H
	Wallowa	5.00	1.00	1.00	4.00	2.00	2.00	2.00	L	3.00	VH
Region 8	Harney	2.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.00	L
	Malheur	2.00	1.00	1.00	2.00	1.33	5.00	3.17	H	2.78	H

Source: DLCD, 2020

Figure 2-9. Landslide Hazard Risk by Region

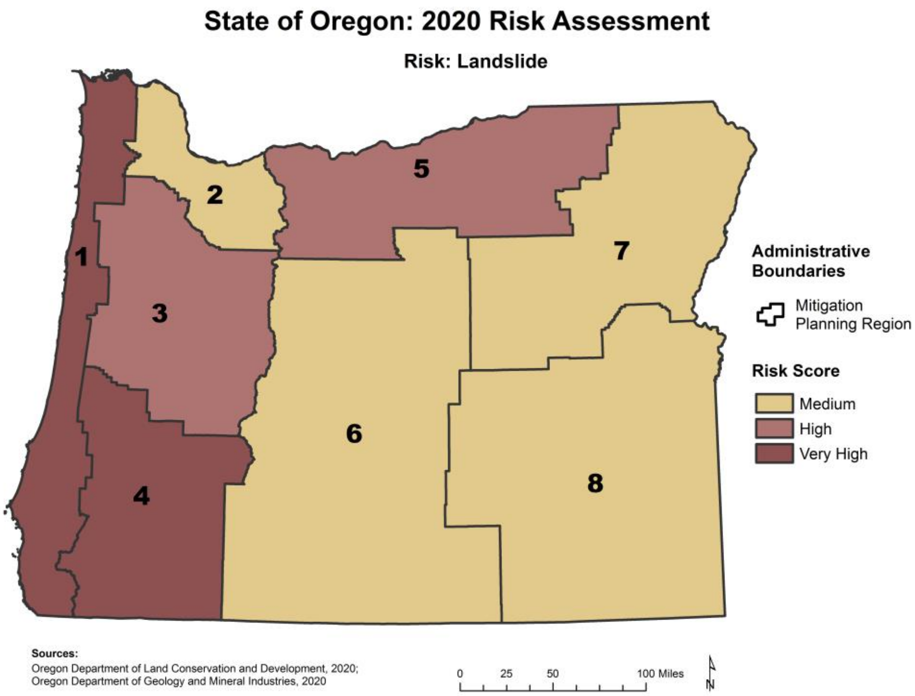

Figure 2-10. Landslide Hazards Risk by County

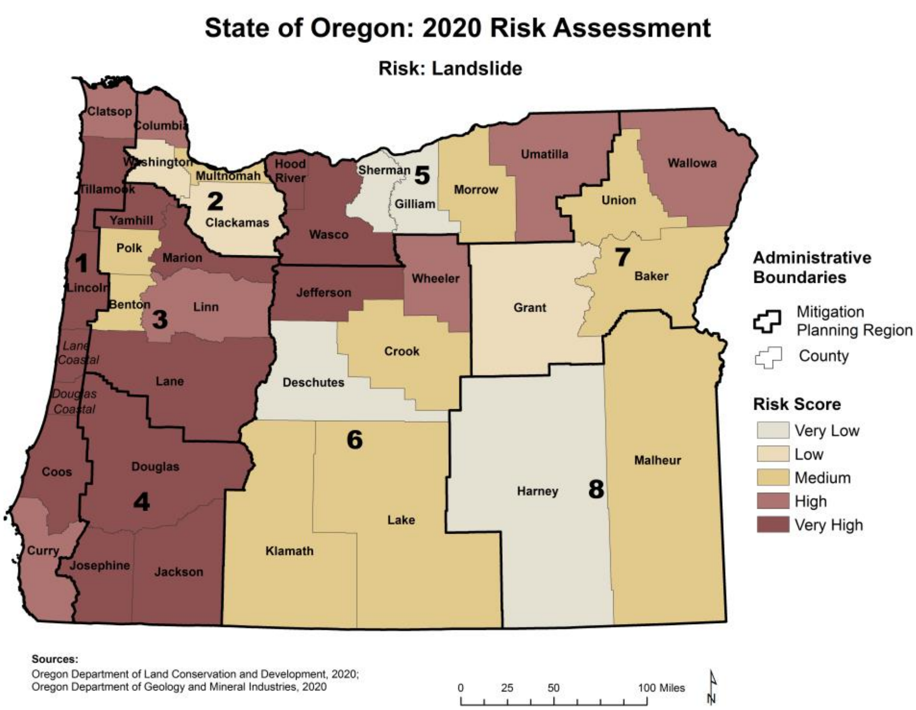

Table 2-11. Tsunami Hazard, 2020 Risk Assessment

Tsunami Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	**County**		**State Buildings**	**State Critical Facilities**	**Local Critical Facilities**	**Total Combined & Rescaled**		**Total Combined & Rescaled**	**Vulnerability**	**Total Combined & Rescaled**	**Risk**
Region 1	Clatsop	4.00	5.00	4.00	5.00	4.67	2.00	3.33	VH	3.56	VH
	Coos	5.00	4.00	5.00	3.00	4.00	4.00	4.00	VH	4.33	VH
	Curry	5.00	2.00	1.00	1.00	1.33	2.00	1.67	L	2.78	M
	Douglas Coastal	4.00	2.00	1.00	3.00	2.00	4.00	3.00	H	3.33	VH
	Lane Coastal	4.00	4.00	3.00	4.00	3.67	3.00	3.33	VH	3.56	VH
	Lincoln	4.00	3.00	2.00	2.00	2.33	3.00	2.67	M	3.11	H
	Tillamook	4.00	1.00	1.00	4.00	2.00	2.00	2.00	L	2.67	M

Source: DLCD, 2020

Figure 2-11. Tsunami Hazard Risk by Region

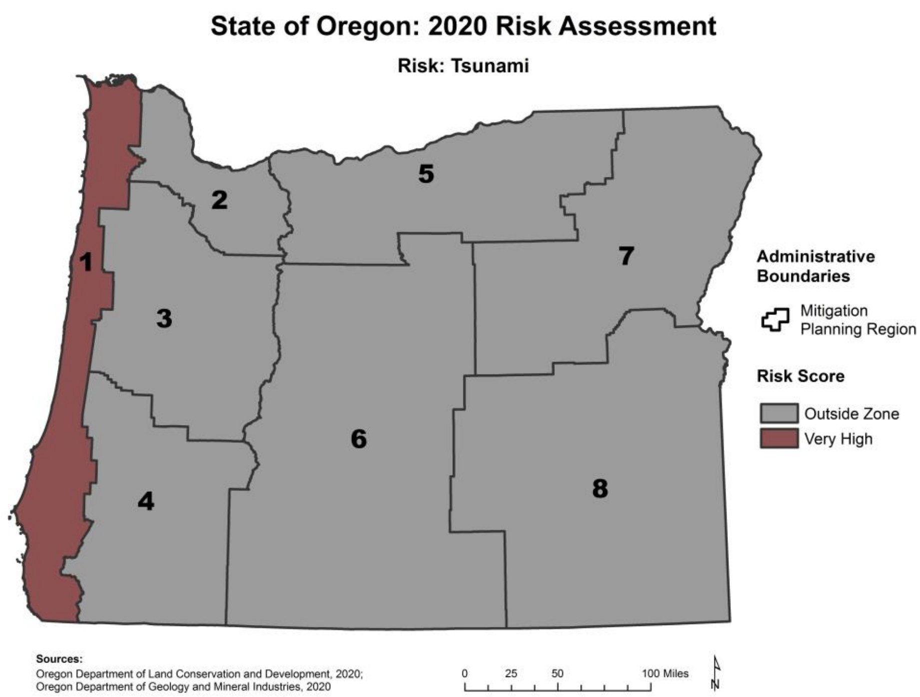

Figure 2-12. Tsunami Hazards Risk by County

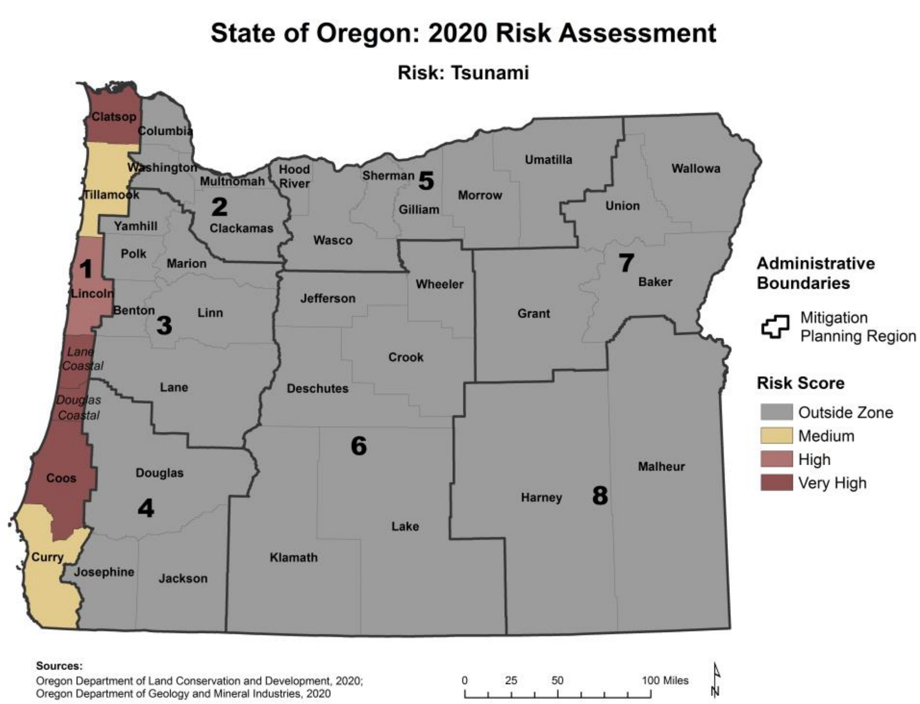

Table 2-12. Volcanic Hazard, 2020 Risk Assessment

Volcanic Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	1.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.33	VL
	Coos	1.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.00	VL
	Curry	1.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.33	VL
	Douglas Coastal	1.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.00	VL
	Lane Coastal	1.00	1.00	1.00	1.00	1.00	3.00	2.00	L	1.67	VL
	Lincoln	1.00	1.00	1.00	1.00	1.00	3.00	2.00	L	1.67	VL
	Tillamook	1.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.33	VL
Region 2	Clackamas	3.00	3.00	4.00	2.00	3.00	1.00	2.00	L	2.33	M
	Columbia	1.50	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.17	VL
	Multnomah	3.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.33	M
	Washington	1.50	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.17	VL
Region 3	Benton	1.50	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.50	VL
	Lane	3.00	5.00	3.00	2.00	3.33	3.00	3.17	H	3.11	H
	Linn	3.00	1.00	1.00	4.00	2.00	4.00	3.00	H	3.00	H
	Marion	3.00	1.00	2.00	3.00	2.00	5.00	3.50	VH	3.33	VH
	Polk	1.50	1.00	1.00	1.00	1.00	3.00	2.00	L	1.83	VL
	Yamhill	1.50	1.00	1.00	1.00	1.00	4.00	2.50	M	2.17	L
Region 4	Douglas	3.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.67	M
	Jackson	3.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.67	M
	Josephine	1.50	1.00	1.00	1.00	1.00	4.00	2.50	M	2.17	L

Source: DLCD, 2020

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Table 2 11. (*continued*) Volcanic Hazard, 2020 Risk Assessment

Volcanic Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 5	Gilliam	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Hood River	3.00	5.00	1.00	5.00	3.67	3.00	3.33	VH	3.22	VH
	Morrow	2.00	1.00	1.00	1.00	1.00	5.00	3.00	H	2.67	M
	Sherman	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Umatilla	2.00	1.00	1.00	1.00	1.00	5.00	3.00	H	2.67	M
	Wasco	3.00	2.00	1.00	1.00	1.33	5.00	3.17	H	3.11	H
Region 6	Crook	1.50	1.00	1.00	1.00	1.00	3.00	2.00	L	1.83	VL
	Deschutes	3.00	4.00	4.00	5.00	4.33	1.00	2.67	M	2.78	M
	Jefferson	3.00	2.00	1.00	3.00	2.00	5.00	3.50	VH	3.33	VH
	Klamath	3.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.00	H
	Lake	1.50	1.00	1.00	1.00	1.00	4.00	2.50	M	2.17	L
	Wheeler	1.50	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.17	VL
Region 7	Baker	1.50	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.50	VL
	Grant	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Union	1.50	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.50	VL
	Wallowa	1.50	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.50	VL
Region 8	Harney	1.50	1.00	1.00	1.00	1.00	3.00	2.00	L	1.83	VL
	Malheur	1.50	1.00	1.00	1.00	1.00	5.00	3.00	H	2.50	M

Source: DLCD, 2020

Figure 2-13. Volcanic Hazard Risk by Region

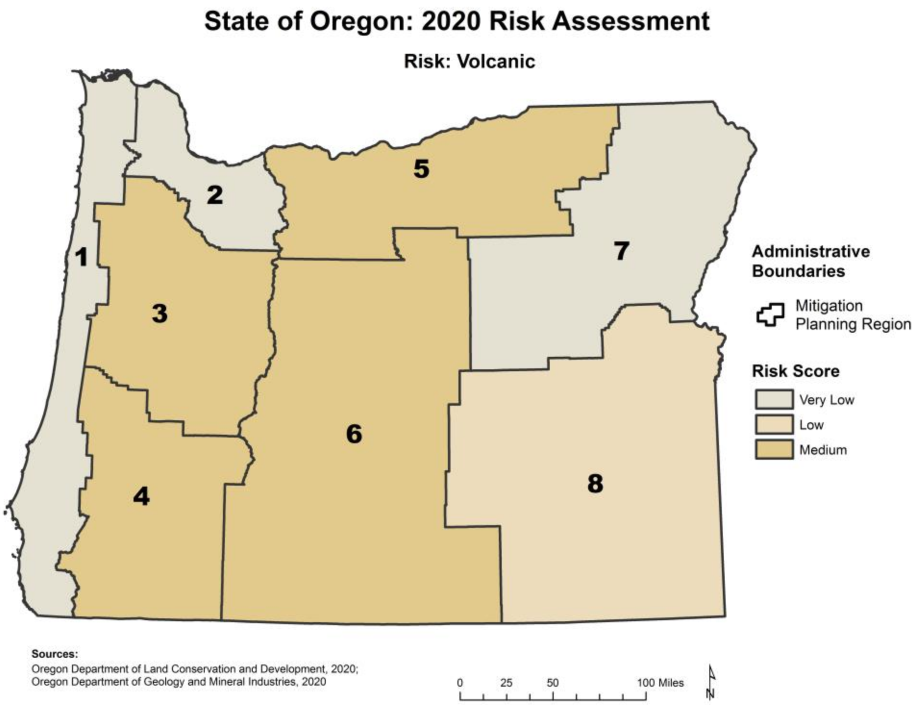


Figure 2-14. Volcanic Hazard Risk by County

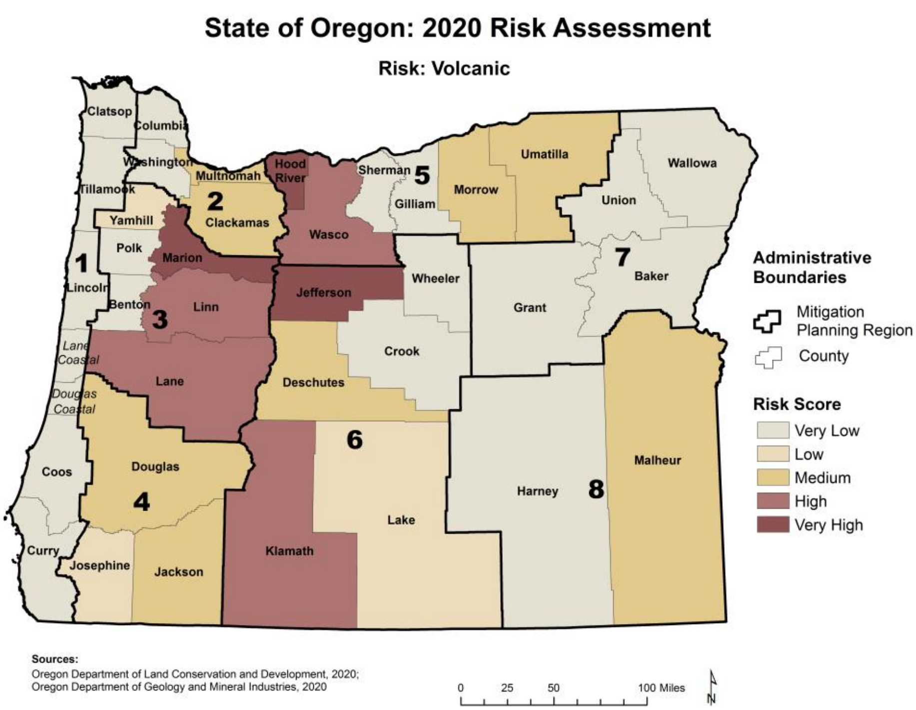


Table 2-13. Wildfire Hazard, 2020 Risk Assessment

Wildfire Risk Components											
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 1	Clatsop	2.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.67	VL
	Coos	2.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.33	M
	Curry	1.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.33	VL
	Douglas Coastal	3.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.67	M
	Lane Coastal	2.00	2.00	2.00	2.00	2.00	3.00	2.50	M	2.33	M
	Lincoln	1.00	1.00	1.00	1.00	1.00	3.00	2.00	L	1.67	VL
	Tillamook	2.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.67	VL
Region 2	Clackamas	2.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.33	VL
	Columbia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.00	VL
	Multnomah	2.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.00	VL
	Washington	1.00	1.00	1.00	1.00	1.00	1.00	1.00	VL	1.00	VL
Region 3	Benton	2.00	1.00	1.00	1.00	1.00	2.00	1.50	VL	1.67	VL
	Lane	3.00	1.00	1.00	1.00	1.00	3.00	2.00	L	2.33	M
	Linn	2.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.33	M
	Marion	2.00	1.00	1.00	1.00	1.00	5.00	3.00	H	2.67	M
	Polk	1.00	1.00	1.00	1.00	1.00	3.00	2.00	L	1.67	VL
	Yamhill	2.00	1.00	1.00	1.00	1.00	4.00	2.50	M	2.33	M
Region 4	Douglas	5.00	2.00	1.00	2.00	1.67	4.00	2.83	H	3.56	VH
	Jackson	5.00	2.00	1.00	1.00	1.33	4.00	2.67	M	3.44	VH
	Josephine	4.00	1.00	1.00	2.00	1.33	4.00	2.67	M	3.11	H

Source: DLCD, 2020

(Table continued on next page)

Table 2 12. (*continued*) Wildfire Hazard, 2020 Risk Assessment

Wildfire Risk Components												
		Probability*	Physical Vulnerability				Social Vulnerability	Vulnerability (Social + Physical)		Risk (Prob. + Physical + Social)	
Region	County		State Buildings	State Critical Facilities	Local Critical Facilities	Total Combined & Rescaled		Total Combined & Rescaled	Vulnerability	Total Combined & Rescaled	Risk
Region 5	Gilliam	3.00	1.00	1.00	2.00	1.33	1.00	1.17	VL	1.78	VL
	Hood River	3.00	2.00	3.00	3.00	2.67	3.00	2.83	H	2.89	H
	Morrow	4.00	2.00	3.00	3.00	2.67	5.00	3.83	VH	3.89	VH
	Sherman	3.00	3.00	2.00	4.00	3.00	1.00	2.00	L	2.33	M
	Umatilla	4.00	1.00	1.00	1.00	1.00	5.00	3.00	H	3.33	VH
	Wasco	5.00	3.00	2.00	2.00	2.33	5.00	3.67	VH	4.11	VH
Region 6	Crook	4.00	4.00	4.00	2.00	3.33	3.00	3.17	H	3.44	VH
	Deschutes	4.00	3.00	3.00	3.00	3.00	1.00	2.00	L	2.67	M
	Jefferson	5.00	5.00	5.00	1.00	3.67	5.00	4.33	VH	4.56	VH
	Klamath	3.00	2.00	1.00	2.00	1.67	5.00	3.33	VH	3.22	VH
	Lake	3.00	2.00	1.00	3.00	2.00	4.00	3.00	H	3.00	H
	Wheeler	4.00	5.00	5.00	5.00	5.00	1.00	3.00	H	3.33	VH
Region 7	Baker	5.00	2.00	1.00	2.00	1.67	2.00	1.83	L	2.89	H
	Grant	5.00	4.00	4.00	3.00	3.67	1.00	2.33	M	3.22	VH
	Union	5.00	2.00	2.00	1.00	1.67	2.00	1.83	L	2.89	H
	Wallowa	3.00	4.00	2.00	2.00	2.67	2.00	2.33	M	2.56	M
Region 8	Harney	4.00	2.00	2.00	3.00	2.33	3.00	2.67	M	3.11	H
	Malheur	4.00	4.00	4.00	2.00	3.33	5.00	4.17	VH	4.11	VH

Source: DLCD, 2020

Figure 2-15. Wildfire Hazard Risk by Region

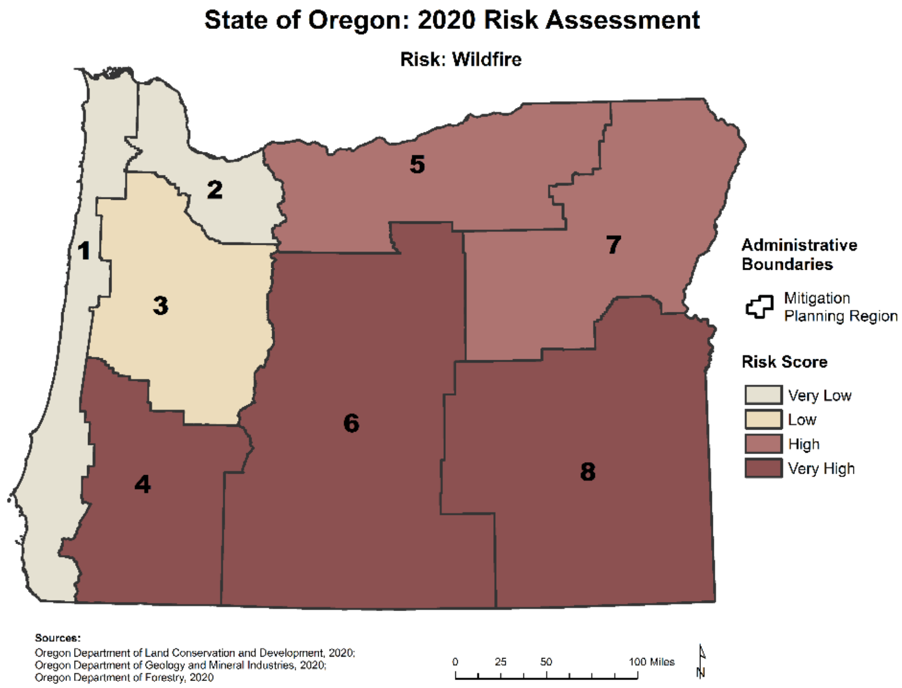
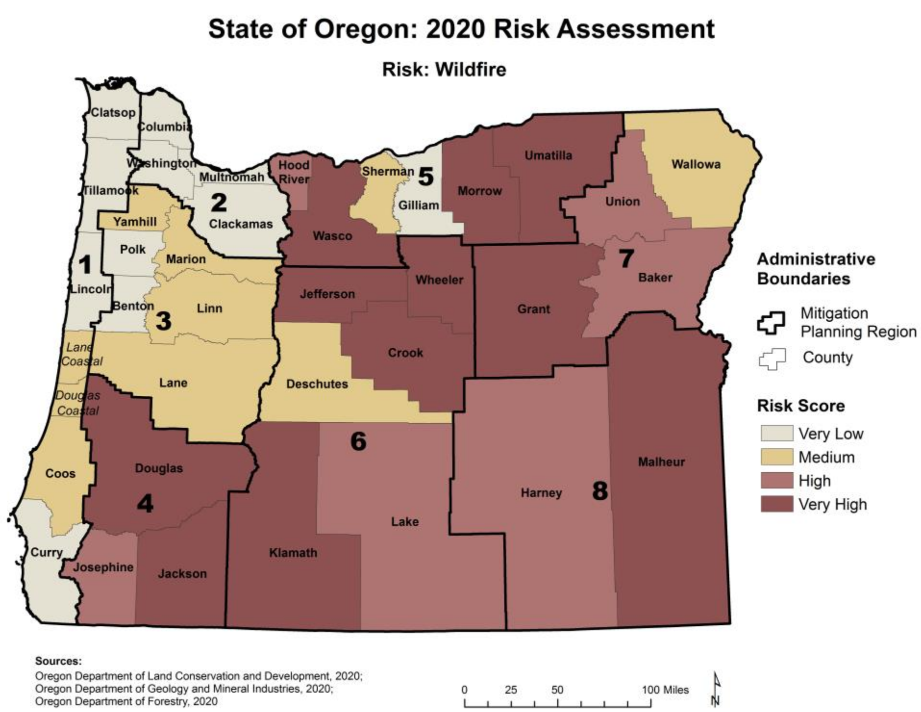


Figure 2-16. Wildfire Hazard Risk by County



2.1.2.5 2020 Risk Assessment Findings

While the component tables offer a detailed look at what is driving risk to individual hazards, **Table 2-14**, **Seven Hazards Combined, 2020 Risk Assessment** shows which counties are most at risk when all seven hazards are considered together.

According to the 2020 RA, seven counties are at very high risk when all seven hazards are considered together: Coos County, Marion County, Douglas County, Jackson County, Hood River County, Wasco County, and Jefferson County. These results are presented in the column labeled "Risk" under the heading "All Hazards (7)," and are mapped in **Figure 2-18**, **Seven Hazards Combined Risk by County**. In addition to each Oregon County, a combined risk score is also calculated for each hazard planning region. Of the eight, Region 4 is the only region that is at very high risk when the seven hazards are considered collectively. This result is mapped in **Figure 2-17**, **Seven Hazards Combined Risk by Region**.

Between the seven hazards, earthquakes pose a very high risk to the greatest number of counties—sixteen in total. Landslides pose a very high risk to fourteen counties, and flooding possess a very high risk to thirteen counties.

Ten counties, or county-equivalents, are at very high risk to three or more hazards. Seven overlap with the counties that are at very high risk when all seven hazards are considered together. Lane Coastal, Douglas Coastal, and Josephine County are the three additional counties.

Table 2-14. Seven Hazards Combined, 2020 Risk Assessment

	Coastal Hazards		Earthquake		Flood		Landslide		Tsunami		Volcanic		Wildfire		All Hazards (7)	
	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk
Oregon	2.29	L	2.99	H	2.92	H	2.94	H	3.33	VH	2.09	VL	2.62	M		
Region 1	2.29	L	3.83	VH	3.14	H	3.56	VH	3.33	VH	1.62	VL	1.95	VL	2.82	H
Clatsop	2.39	M	3.78	VH	2.89	H	3.11	H	3.56	VH	1.33	VL	1.67	VL	2.67	M
Coos	2.25	L	4.67	VH	3.56	VH	3.67	VH	4.33	VH	2.00	VL	2.33	M	3.26	VH
Curry	1.75	VL	3.78	VH	2.67	M	3.11	H	2.78	M	1.33	VL	1.33	VL	2.39	M
Douglas Coastal	2.17	L	4.11	VH	3.56	VH	3.78	VH	3.33	VH	2.00	VL	2.67	M	3.09	H
Lane Coastal	2.03	VL	3.78	VH	3.33	VH	3.56	VH	3.56	VH	1.67	VL	2.33	M	2.89	H
Lincoln	2.67	M	3.56	VH	3.11	H	4.11	VH	3.11	H	1.67	VL	1.67	VL	2.84	H
Tillamook	2.75	M	3.11	H	2.89	H	3.56	VH	2.67	M	1.33	VL	1.67	VL	2.57	M
Region 2	—	—	2.75	M	2.75	M	2.50	M	—	—	1.75	VL	1.33	VL	2.22	L
Clackamas	—	—	2.22	L	2.33	M	2.11	L	—	—	2.33	M	1.33	VL	2.07	VL
Columbia	—	—	2.67	M	2.67	M	3.00	H	—	—	1.17	VL	1.00	VL	2.10	VL
Multnomah	—	—	3.33	VH	4.00	VH	2.78	M	—	—	2.33	M	2.00	VL	2.89	H
Washington	—	—	2.78	M	2.00	VL	2.11	L	—	—	1.17	VL	1.00	VL	1.81	VL
Region 3	—	—	3.28	VH	3.33	VH	3.09	H	—	—	2.49	M	2.17	L	2.87	H
Benton	—	—	2.67	M	3.00	H	2.56	M	—	—	1.50	VL	1.67	VL	2.28	L
Lane	—	—	3.00	H	3.44	VH	3.33	VH	—	—	3.11	H	2.33	M	3.04	H
Linn	—	—	3.56	VH	3.56	VH	3.11	H	—	—	3.00	H	2.33	M	3.11	H
Marion	—	—	4.00	VH	4.00	VH	3.33	VH	—	—	3.33	VH	2.67	M	3.47	VH
Polk	—	—	2.89	H	2.89	H	2.78	M	—	—	1.83	VL	1.67	VL	2.41	M
Yamhill	—	—	3.56	VH	3.11	H	3.44	VH	—	—	2.17	L	2.33	M	2.92	H
Region 4	—	—	3.41	VH	3.59	VH	3.63	VH	—	—	2.50	M	3.37	VH	3.30	VH
Douglas	—	—	3.33	VH	3.67	VH	3.78	VH	—	—	2.67	M	3.56	VH	3.40	VH
Jackson	—	—	3.33	VH	3.56	VH	3.67	VH	—	—	2.67	M	3.44	VH	3.33	VH
Josephine	—	—	3.56	VH	3.56	VH	3.44	VH	—	—	2.17	L	3.11	H	3.17	H

Source: DLCD, 2020

(Table continued on next page)

Table 2 13. (*continued*) Seven Hazards Combined, 2020 Risk Assessment

	Coastal Hazards		Earthquake		Flood		Landslide		Tsunami		Volcanic		Wildfire		All Hazards (7)	
	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk
Oregon	2.29	L	2.99	H	2.92	H	2.94	H	3.33	VH	2.09	VL	2.62	M		
Region 5	—	—	2.65	M	2.94	H	2.83	H	—	—	2.39	M	3.06	H	2.77	M
Gilliam	—	—	1.33	VL	2.00	VL	2.00	VL	—	—	1.33	VL	1.78	VL	1.69	VL
Hood River	—	—	4.22	VH	2.67	M	3.44	VH	—	—	3.22	VH	2.89	H	3.29	VH
Morrow	—	—	2.89	H	3.67	VH	2.78	M	—	—	2.67	M	3.89	VH	3.18	H
Sherman	—	—	1.33	VL	2.67	M	1.89	VL	—	—	1.33	VL	2.33	M	1.91	VL
Umatilla	—	—	3.00	H	3.33	VH	3.11	H	—	—	2.67	M	3.33	VH	3.09	H
Wasco	—	—	3.11	H	3.33	VH	3.78	VH	—	—	3.11	H	4.11	VH	3.49	VH
Region 6	—	—	2.67	M	2.37	M	2.59	M	—	—	2.38	M	3.37	VH	2.68	M
Crook	—	—	2.33	M	2.44	M	2.67	M	—	—	1.83	VL	3.44	VH	2.54	M
Deschutes	—	—	1.89	VL	1.33	VL	1.33	VL	—	—	2.78	M	2.67	M	2.00	VL
Jefferson	—	—	3.00	H	3.00	H	3.44	VH	—	—	3.33	VH	4.56	VH	3.47	VH
Klamath	—	—	3.56	VH	2.67	M	2.67	M	—	—	3.00	H	3.22	VH	3.02	H
Lake	—	—	3.44	VH	2.44	M	2.44	M	—	—	2.17	L	3.00	H	2.70	M
Wheeler	—	—	1.78	VL	2.33	M	3.00	H	—	—	1.17	VL	3.33	VH	2.32	M
Region 7	—	—	2.19	L	2.31	L	2.47	M	—	—	1.46	VL	2.89	H	2.26	L
Baker	—	—	2.44	M	2.00	VL	2.33	M	—	—	1.50	VL	2.89	H	2.23	L
Grant	—	—	1.89	VL	3.11	H	2.22	L	—	—	1.33	VL	3.22	VH	2.36	M
Union	—	—	2.11	L	1.67	VL	2.33	M	—	—	1.50	VL	2.89	H	2.10	VL
Wallowa	—	—	2.33	M	2.44	M	3.00	H	—	—	1.50	VL	2.56	M	2.37	M
Region 8	—	—	2.56	M	3.11	H	2.39	M	—	—	2.17	L	3.61	VH	2.77	M
Harney	—	—	2.33	M	3.11	H	2.00	VL	—	—	1.83	VL	3.11	H	2.48	M
Malheur	—	—	2.78	M	3.11	H	2.78	M	—	—	2.50	M	4.11	VH	3.06	H

Figure 2-17. Seven Hazards Combined Risk by Region

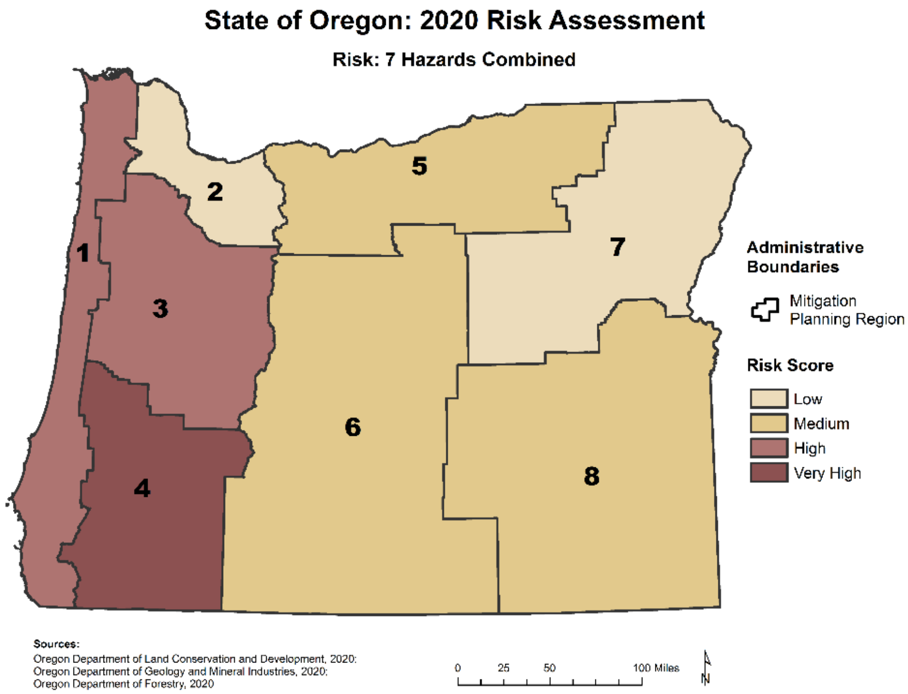
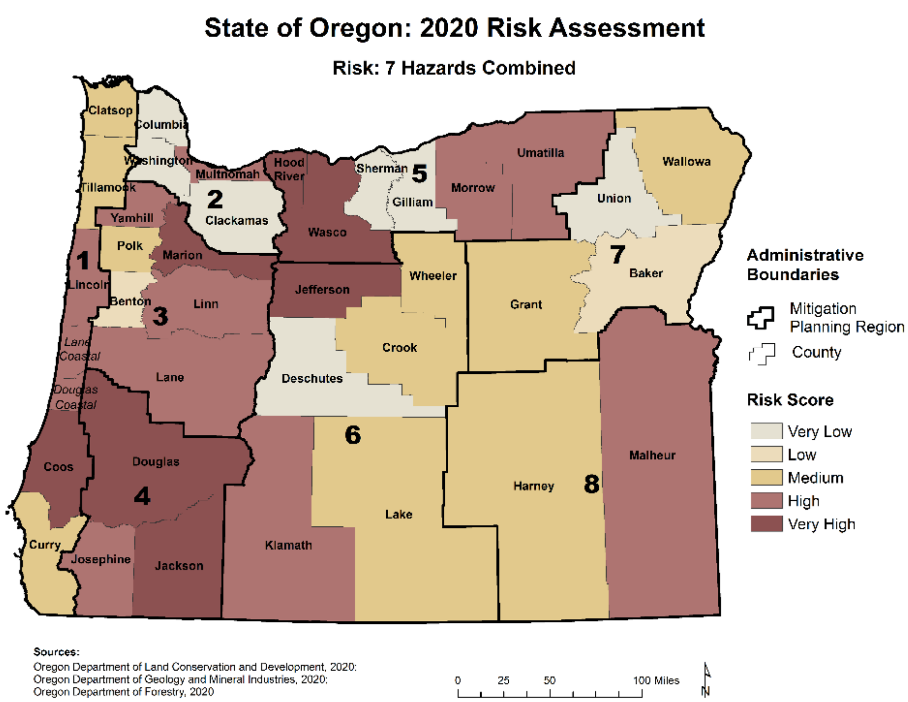


Figure 2-18. Seven Hazards Combined Risk by County



2.1.2.6 Considering All Eleven Hazards

As mentioned previously, not all of the hazards covered in the Plan are included in the 2020 Risk Assessment. Four hazards - drought, extreme heat, windstorms, and winter storms - are excluded due to insufficient data. Although not included in the official assessment, relying on available data and their expertise, subject-matter experts assigned each hazard a qualitative risk score on the Very Low to Very High (1-5) scale. DLCD used that score to calculate a combined risk score for all eleven hazards using the same methodology employed in the 2020 RA. Based on its combined score, each region and county was assigned a descriptive ranking using the Jenks Natural Breaks Classification method. The results are presented in **Table 2-15**, **Eleven Hazards Combined, 2020 Risk Assessment** in the "Risk Score" and "Risk" columns under the "All Hazards (11)" banner.

Incorporating the four additional hazards does not drastically change the results of the 2020 RA. Seven counties are at very high risk when all eleven hazards are considered together—two are different from the seven-hazard assessment and five remain the same. Hood River and Coos Counties are replaced by Morrow and Linn Counties.

Between the eleven hazards, earthquakes, landslides, and flooding continue to pose a very high risk to the greatest number of counties. Of the four additional hazards examined, winter storms possess a very high risk to the greatest number of counties—four in total.

Thirteen counties, or county-equivalents, are at very high risk to three or more hazards: Coos County, Douglas Costal, Lane Coastal, Marion County, Douglas County, Jackson County, Josephine County, Hood River County, Morrow County, Umatilla County, Wasco County, Jefferson County, and Klamath County.

Table 2-15. Eleven Hazards Combined, 2020 Risk Assessment

	Coastal Hazards		Earthquake		Flood		Landslide		Tsunami		Volcanic		Wildfire		All Hazards (7)		Drought	Extreme Heat	Wind-storm	Winter Storm	All Hazards (11)	
	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk	Risk	Risk	Risk	Risk Score	Risk
Oregon	2.29	L	2.99	H	2.92	H	2.94	H	3.33	VH	2.09	VL	2.62	M			M	M	M	M	3.18	M
Region 1	2.29	L	3.83	VH	3.14	H	3.56	VH	3.33	VH	1.62	VL	1.95	VL	2.82	H	M	L	H	M	3.18	M
Clatsop	2.39	M	3.78	VH	2.89	H	3.11	H	3.56	VH	1.33	VL	1.67	VL	2.67	M	L	L	H	H	3.18	M
Coos	2.25	L	4.67	VH	3.56	VH	3.67	VH	4.33	VH	2.00	VL	2.33	M	3.26	VH	M	M	VH	M	3.64	H
Curry	1.75	VL	3.78	VH	2.67	M	3.11	H	2.78	M	1.33	VL	1.33	VL	2.39	M	M	L	H	M	2.73	L
Douglas Coastal	2.17	L	4.11	VH	3.56	VH	3.78	VH	3.33	VH	2.00	VL	2.67	M	3.09	H	H	—	H	M	3.36	M
Lane Coastal	2.03	VL	3.78	VH	3.33	VH	3.56	VH	3.56	VH	1.67	VL	2.33	M	2.89	H	M	—	H	M	3.18	M
Lincoln	2.67	M	3.56	VH	3.11	H	4.11	VH	3.11	H	1.67	VL	1.67	VL	2.84	H	M	L	H	H	3.27	M
Tillamook	2.75	M	3.11	H	2.89	H	3.56	VH	2.67	M	1.33	VL	1.67	VL	2.57	M	L	L	H	H	3.00	M
Region 2	—	—	2.75	M	2.75	M	2.50	M	—	—	1.75	VL	1.33	VL	2.22	L	VL	L	L	L	2.00	VL
Clackamas	—	—	2.22	L	2.33	M	2.11	L	—	—	2.33	M	1.33	VL	2.07	VL	VL	L	L	L	2.00	VL
Columbia	—	—	2.67	M	2.67	M	3.00	H	—	—	1.17	VL	1.00	VL	2.10	VL	VL	L	L	L	2.11	VL
Multnomah	—	—	3.33	VH	4.00	VH	2.78	M	—	—	2.33	M	2.00	VL	2.89	H	L	M	M	M	3.11	M
Washington	—	—	2.78	M	2.00	VL	2.11	L	—	—	1.17	VL	1.00	VL	1.81	VL	VL	L	L	L	1.67	VL
Region 3	—	—	3.28	VH	3.33	VH	3.09	H	—	—	2.49	M	2.17	L	2.87	H	M	H	H	H	3.78	H
Benton	—	—	2.67	M	3.00	H	2.56	M	—	—	1.50	VL	1.67	VL	2.28	L	L	M	M	M	2.56	L
Lane	—	—	3.00	H	3.44	VH	3.33	VH	—	—	3.11	H	2.33	M	3.04	H	M	M	M	M	3.67	H
Linn	—	—	3.56	VH	3.56	VH	3.11	H	—	—	3.00	H	2.33	M	3.11	H	H	H	H	H	4.11	VH
Marion	—	—	4.00	VH	4.00	VH	3.33	VH	—	—	3.33	VH	2.67	M	3.47	VH	H	M	H	VH	4.33	VH
Polk	—	—	2.89	H	2.89	H	2.78	M	—	—	1.83	VL	1.67	VL	2.41	M	M	M	M	M	2.78	L
Yamhill	—	—	3.56	VH	3.11	H	3.44	VH	—	—	2.17	L	2.33	M	2.92	H	M	H	H	H	3.78	H
Region 4	—	—	3.41	VH	3.59	VH	3.63	VH	—	—	2.50	M	3.37	VH	3.30	VH	H	H	M	M	4.11	VH
Douglas	—	—	3.33	VH	3.67	VH	3.78	VH	—	—	2.67	M	3.56	VH	3.40	VH	H	H	M	M	4.11	VH
Jackson	—	—	3.33	VH	3.56	VH	3.67	VH	—	—	2.67	M	3.44	VH	3.33	VH	H	H	M	M	4.11	VH
Josephine	—	—	3.56	VH	3.56	VH	3.44	VH	—	—	2.17	L	3.11	H	3.17	H	H	H	M	H	4.00	H

Source: DLCD, 2020

(Table continued on next page)

Table 2 14. (*continued*) Eleven Hazards Combined, 2020 Risk Assessment

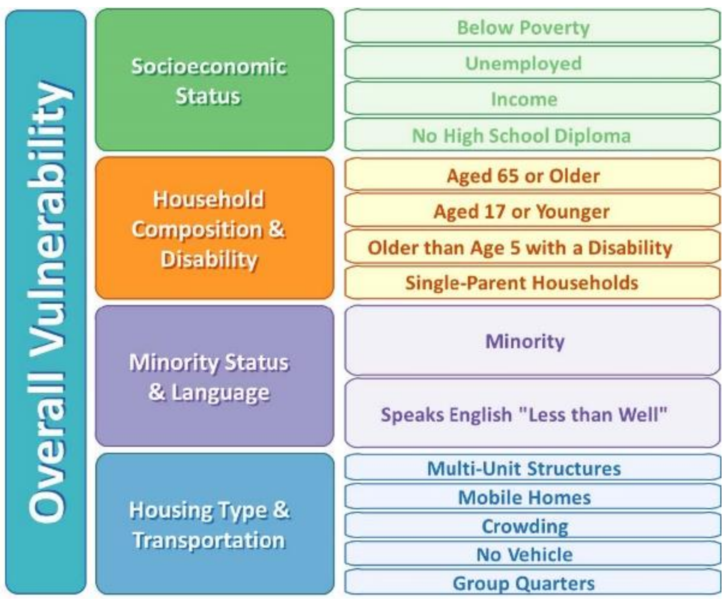
	Coastal Hazards		Earthquake		Flood		Landslide		Tsunami		Volcanic		Wildfire		All Hazards (7)		Drought	Extreme Heat	Wind-storm	Winter Storm	All Hazards (11)	
	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk Score	Risk	Risk	Risk	Risk	Risk	Risk Score	Risk
Oregon	2.29	L	2.99	H	2.92	H	2.94	H	3.33	VH	2.09	VL	2.62	M			M	M	M	M	3.18	M
Region 5	—	—	2.65	M	2.94	H	2.83	H	—	—	2.39	M	3.06	H	2.77	M	M	M	M	VH	3.56	H
Gilliam	—	—	1.33	VL	2.00	VL	2.00	VL	—	—	1.33	VL	1.78	VL	1.69	VL	L	L	M	H	1.78	VL
Hood River	—	—	4.22	VH	2.67	M	3.44	VH	—	—	3.22	VH	2.89	H	3.29	VH	M	M	M	H	3.89	H
Morrow	—	—	2.89	H	3.67	VH	2.78	M	—	—	2.67	M	3.89	VH	3.18	H	VH	H	VH	VH	4.33	VH
Sherman	—	—	1.33	VL	2.67	M	1.89	VL	—	—	1.33	VL	2.33	M	1.91	VL	L	L	M	H	2.22	VL
Umatilla	—	—	3.00	H	3.33	VH	3.11	H	—	—	2.67	M	3.33	VH	3.09	H	H	M	L	VH	3.89	H
Wasco	—	—	3.11	H	3.33	VH	3.78	VH	—	—	3.11	H	4.11	VH	3.49	VH	H	M	H	VH	4.33	VH
Region 6	—	—	2.67	M	2.37	M	2.59	M	—	—	2.38	M	3.37	VH	2.68	M	H	M	L	M	3.22	M
Crook	—	—	2.33	M	2.44	M	2.67	M	—	—	1.83	VL	3.44	VH	2.54	M	H	M	VL	L	2.78	L
Deschutes	—	—	1.89	VL	1.33	VL	1.33	VL	—	—	2.78	M	2.67	M	2.00	VL	H	L	VL	L	2.00	VL
Jefferson	—	—	3.00	H	3.00	H	3.44	VH	—	—	3.33	VH	4.56	VH	3.47	VH	H	H	M	H	4.22	VH
Klamath	—	—	3.56	VH	2.67	M	2.67	M	—	—	3.00	H	3.22	VH	3.02	H	VH	H	M	H	4.00	H
Lake	—	—	3.44	VH	2.44	M	2.44	M	—	—	2.17	L	3.00	H	2.70	M	H	H	L	H	3.44	M
Wheeler	—	—	1.78	VL	2.33	M	3.00	H	—	—	1.17	VL	3.33	VH	2.32	M	M	L	M	H	2.89	L
Region 7	—	—	2.19	L	2.31	L	2.47	M	—	—	1.46	VL	2.89	H	2.26	L	H	M	M	M	2.78	L
Baker	—	—	2.44	M	2.00	VL	2.33	M	—	—	1.50	VL	2.89	H	2.23	L	H	M	L	M	2.67	L
Grant	—	—	1.89	VL	3.11	H	2.22	L	—	—	1.33	VL	3.22	VH	2.36	M	H	L	L	M	2.67	L
Union	—	—	2.11	L	1.67	VL	2.33	M	—	—	1.50	VL	2.89	H	2.10	VL	M	M	M	M	2.56	L
Wallowa	—	—	2.33	M	2.44	M	3.00	H	—	—	1.50	VL	2.56	M	2.37	M	M	M	M	M	2.89	L
Region 8	—	—	2.56	M	3.11	H	2.39	M	—	—	2.17	L	3.61	VH	2.77	M	VH	H	L	L	3.33	M
Harney	—	—	2.33	M	3.11	H	2.00	VL	—	—	1.83	VL	3.11	H	2.48	M	H	H	VL	VL	2.56	L
Malheur	—	—	2.78	M	3.11	H	2.78	M	—	—	2.50	M	4.11	VH	3.06	H	VH	H	L	L	3.44	M

2.1.3 Social Vulnerability

Social vulnerability describes the socioeconomic factors that affect individual and community resilience (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011). While there is no single set of vulnerability criteria, researchers have identified a core set of traits commonly associated with higher vulnerability. The 2020 Risk Assessment leverages a social vulnerability index created by the U.S. Center for Disease Control and Prevention (CDC) and expands on select vulnerability variables in each regional profile.

In collaboration with public health experts in the public and private sectors, the Geospatial Research, Analysis & Services Program (GRASP) at the CDC developed a Social Vulnerability Index (**Figure 2-19**). The index is comprised of fifteen social factors, with the underlying data derived from the U.S. Census Bureau's American Community Survey (ACS). The 2020 Risk Assessment uses data aggregated at the county level but the index is also available for census tracts.

Figure 2-19. CDC Social Vulnerability Themes and Components



Source Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry / Geospatial Research, Analysis, and Services Program (2016)

The fifteen variables are grouped into four broad "themes" and then combined to create an overall vulnerability score which is then used to calculate a percentile rank, with a higher value indicating greater vulnerability (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011). For the 2020 Risk Assessment, counties were further divided into quintiles based on their percentile rank using the equal interval classification method. These vulnerability categories were then factored into the risk assessment along with physical exposure—to state-owned and -leased buildings and state and local critical facilities—and the probability of hazard occurrence.

While the CDC tool aggregates various socioeconomic characteristics to create a composite measure of vulnerability, each regional community profile examines select risk factors to identify trends and dynamics between and within natural hazard mitigation planning regions. Some of the variables examined in the profiles are the same as or similar to those included in the CDC tool. However, it should be noted that although the CDC index and regional profiles both use estimates from the five-year ACS, the periods are different (2012-2016 versus 2013-2017, respectively). Other characteristics presented in the regional community profiles have been included in previous iterations of this Plan and remain relevant drivers of vulnerability. **Table 2-16** illustrates which variables are included in the CDC index that are also presented in the regional community profiles and those that are covered in one but not the other.

Table 2-16. Comparing Social Vulnerability Variables: CDC Index and Oregon NHMP Regional Community Profiles

CDC Social Vulnerability Index Variable ACS 2012-2016		2020 NHMP Regional Community Profile Variable ACS 2013-2017	
Variable	**Table/Source**	**Variable**	**Table/Source**
Persons below poverty estimate	B17001	Persons below poverty estimate	S1701
Civilian (age 16+) unemployed estimate	DP03	Civilian (age 16+) unemployment rates	Oregon Employment Department, 2019
Per capita income estimate	B19301		
Persons (age 25+) with no high school diploma estimate	B06009	Persons (age 25+) with no high school diploma estimate and other educational attainment estimates	DP02
Persons aged 65 and older estimate	S1501	Persons aged 65 and older estimate	DP05
Persons aged 17 and younger estimate	B09001	Persons aged 17 and younger estimate	DP05
Civilian noninstitutionalized population with a disability estimate	DP02	Civilian noninstitutionalized population with a disability and disability by vulnerable age groups estimates	DP02
Single-parent household with children under 18 estimate	DP02	Single-parent household with children under 18 estimate	DP02
Minority (all persons except white non-Hispanic) estimate	B01001H		
Persons (age 5+) who speak English "less than well" estimate	B16005	Persons (age 5+) who speak English "less than very well" estimate	DP02
Housing in Structure with 10 or more units estimate	DP04		
Mobile homes estimate	DP04	Units in Structure estimates (includes multi-family, single-family, and mobile homes)	B25024
At household level (occupied housing units), more people than rooms estimate	DP04		
Household with no vehicle estimate	DP04		
Persons in institutionalized group quarters estimate	B26001		
		Annual tourism estimates	(Dean Runyan Associates, 2019)
		Homeless population estimate	Point-in-Time Count, 2019
		Sex Ratio estimate	S0101

CDC Social Vulnerability Index Variable ACS 2012-2016	2020 NHMP Regional Community Profile Variable ACS 2013-2017	
	Median household income and median household income distribution estimates	DP03
	Housing tenure estimates (owner-occupied housing units, renter-occupied housing units)	DP04
	Persons under 18 years below poverty line estimate	S1701
	Household type estimates (family, non-family, householder living alone)	DP02
	Family household with children estimate	DP02

Source: Source Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry / Geospatial Research, Analysis, and Services Program (2016); DLCD, 2020

2.1.4 Introduction to Climate Change

The climate is an important factor influencing certain natural hazards. Industrialization has given rise to increasing amounts of greenhouse gas emissions worldwide, which is causing the Earth's climate to warm (IPCC, 2013). Climate change is already affecting Oregon communities and resources (Dalton, Dello, Hawkins, Mote, & Rupp, 2017); (May, et al., 2018); (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019). In itself, climate change is not a distinct natural hazard, but it is expected to amplify the risk of certain natural hazards. Climate change is anticipated to increase the frequency and/or magnitude of some natural hazards in Oregon, such as extreme heat events, droughts, wildfires, floods, landslides, and coastal erosion and flooding. This section presents an overview of climate change in Oregon as it pertains to climate-related natural hazards.

Oregon's climate is broadly characterized by mild, wet winters and warm, dry summers. East of the Cascade Range, winters tend to be colder, summers hotter, and annual precipitation less than west of the Cascades due to farther proximity to the moderating effects of the Pacific Ocean and the rain shadow created by the Cascade Range. Oregon's climate is also characterized by large variability from year to year, and that variability is largely dominated by the interaction between the atmosphere and ocean in the tropical Pacific Ocean that is responsible for El Niño and La Niña events. Human activities are changing the climate, particularly temperature, beyond natural variability.

Already, Oregon's average temperature has increased by nearly 2°F since the beginning of the 20th century. Not only that, but hot days are getting hotter and more frequent and cold days less frequent. In the same timeframe, Cascade Mountain snowpacks have declined due to warmer winters causing precipitation to fall more as rain and less as snow, and higher temperatures have caused earlier spring snowmelt and spring peak stream flows resulting in lower summer stream flows in many rivers. In Oregon's forested areas, large areas have been impacted by disturbances that include wildfire in recent years, and climate change is a major factor contributing to forest dryness that facilitates fire. On the coast, sea level rise and increasing deep-water wave heights in recent decades are likely to have increased the frequency of coastal flooding and erosion. Closer to home for some Oregonians, a three-fold increase in heat-related illness has been documented in Oregon with each 10°F rise in daily maximum temperature (Dello & Mote (2010); Dalton, et al. (2013), (2017); May, et al. (2018); Mote, et al. (2019).

2.1.4.1 Oregon Responses to Climate Change

The human influence on the climate is clear (IPCC, 2013). Global greenhouse gas emissions will determine the amount of warming both globally and here in Oregon. On that basis, Oregon and other states and local communities have undertaken measures to reduce greenhouse gas emissions as a way to slow the warming trend. Even if greenhouse gas emissions were drastically reduced globally, we cannot avoid some additional warming over the coming century due to the climate system's considerable inertia. Climate changes happening today are largely a result of emissions that occurred up to several decades to almost a century ago. As such, states and local communities are planning and beginning to implement measures to adapt to future climate conditions that cannot be avoided. In many cases, planning for climate change — or adaptation planning — quickly comes down to improved planning for natural hazards, since many of the anticipated effects of climate change will be experienced in the form of natural hazard events. That said, planning to adapt to climate change and planning to mitigate natural hazards are not entirely the same thing, although there is considerable overlap.

In 2010, the State of Oregon produced the Oregon Climate Adaptation Framework, which identifies 11 climate-related risks for which the state must plan. The Framework is in the process of being updated as of this writing (2020). Six of those 11 climate risks — drought, extreme heat, coastal erosion, fire, flood, and landslides — are directly identified in the 2020 Oregon NHMP. Extreme heat is a new hazard considered in the 2020 Oregon NHMP that was not included in the 2015 Oregon NHMP. In addition, two other hazards in the 2020 Oregon NHMP — windstorms and winter storms — have an underlying climate component.

Oregon and the Pacific Northwest have a wealth of climate impacts research from the last several decades. In 2007 the Oregon Legislature created the Oregon Climate Change Research Institute (OCCRI) under HB 3543. Much of the material in this "Introduction to Climate Change" is drawn from OCCRI's Oregon Climate Assessment Reports (OCAR) from 2010–2019, with emphasis on the two most recent assessments: OCAR3 (Dalton, Dello, Hawkins, Mote, & Rupp, 2017) and OCAR4 (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019), which includes the Northwest chapter of the Fourth National Climate Assessment (May, et al., 2018). This section also relies on a summary report from the "Oregon Climate Change Effects, Likelihood, and Consequences Workshop" held in August 2019 that brought together subject matter experts from the State's regional public universities along with Oregon state agency staff to discuss the likelihood, confidence, and consequences of a range of climate change effects in Oregon. All of OCCRI's reports can be found at http://www.occri.net/publications-and-reports/.

This section is not meant to be a comprehensive assessment of climate change and impacts in Oregon or an all-encompassing overview of each hazard. Rather, it presents future projections of temperature and precipitation, and describes some of the effects of such future conditions based on the frequency and magnitude of natural hazards in Oregon.

2.1.4.2 Past and Future Climate in Oregon

Historical

The impacts of climate change in Oregon are largely driven by changes in temperature and precipitation. Temperatures in Oregon increased nearly 2°F since the beginning of the 20th century. Nearly every year in the 21st century (2000–2019) has been warmer than the 20th century average, excepting 2011. Looking at it another way, only 9 years during 20th century have been above the 21st century average (NOAA, 2020). Over the last 30 years (1990–2019), temperatures in Oregon have been above the 1970–1999 average in all but three years (1993, 2008, 2011) (**Figure 2-20**). Annual precipitation amounts since the beginning of the 20th century have varied considerably from year to year without a significant trend beyond the normal range of natural variability (**Figure 2-20**). However, warmer temperatures have caused precipitation to fall more often as rain instead of snow contributing to a 37% reduction in the amount of water stored in the Oregon's mountain snowpack during 1955–2016 (Mote, Lettenmaier, Xiao, & Engel, 2018).

Future Climate

Projections of future climate changes come from simulations using global climate models (GCMs), which are sophisticated computer models of the Earth's atmosphere, water, and land and how these components interact over time and space on a gridded sphere according to the fundamental laws of physics. GCMs are some of the most sophisticated tools scientists use for understanding the climate system. Research centers around the world run computerized GCMs as part of the Coupled Model Intercomparison Project (CMIP), providing scientists and decision makers with many simulations of future global climate to use to assess the range of future climate projections for the globe. For the fifth and latest available phase of CMIP, called CMIP5, simulations of the 21st century climate are driven by what are called "representative concentration pathways" (RCPs). RCPs represent the total amount of extra energy (in watts per square meter) entering the climate system due primarily to increasing greenhouse gas emissions throughout the 21st century and beyond. There are several RCPs, each with a different set of assumptions regarding global greenhouse gas emissions. The higher global emissions are, the greater the expected increase in global temperature.

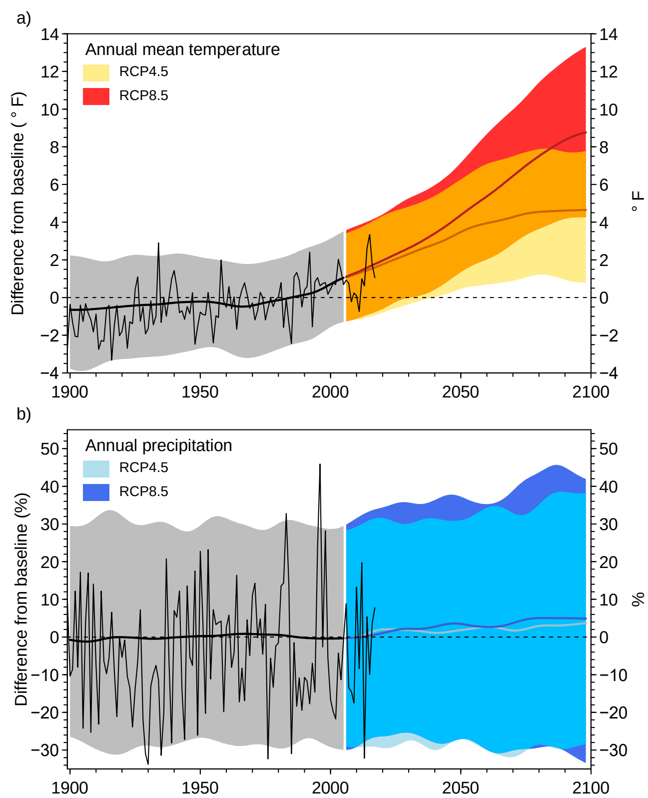
The temperature and precipitation projections summarized for Oregon in this section use data from the grid cells covering Oregon in multiple GCMs driven by two RCPs. The lower emissions scenario, RCP 4.5, represents a moderate effort to reduce global greenhouse gas emissions which peak near mid-21st century then decline. The higher emissions scenario, RCP 8.5, represents a business-as-usual continuation of emissions throughout the 21st century.

Annual

Figure 2-20 shows Oregon's observed mean annual temperatures and total annual precipitation from 1900 to 2017, simulated historical mean annual temperatures and precipitation for 1900 to 2005, and simulated future mean annual temperatures and precipitation for 2006 to 2099 under the two different RCPs. Note that the observed temperatures and precipitation generally fall within the range of simulated historical values which gives confidence in the future simulations. Note also that the projected temperature trends under different RCPs generally track closely until about 2030 or so, and then dramatically diverge after 2050. There are not substantial differences between the RCPs for projected precipitation changes.

Every climate model shows an increase in temperature for Oregon, with the magnitude of the increase depending on the rate or magnitude of global greenhouse gas emissions. Larger temperature increases are projected under the higher emissions scenario (RCP 8.5) than under the lower emissions scenario (RCP 4.5). There is no plausible scenario in which Oregon cools in the 21st century. CMIP5 global climate models project an increase by mid-21st century (2040–2069) in annual temperatures in Oregon of 1.8°F to 6.9°F over the recent past (1970–1999) (**Table 2-17**). The lower projection is possible only if greenhouse gas emissions are significantly reduced (**Figure 2-20**, RCP 4.5 scenario). Both scenarios show a similar amount of warming through about 2040, meaning that temperatures beyond 2040 depend on global greenhouse emissions occurring now (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Climate models are split on whether annual precipitation in Oregon will increase or decrease.

Figure 2-20. Observed, Simulated, and Projected Changes in Oregon's Mean Annual (a) Temperature and (b) Precipitation from the Baseline (1970–1999) for RCP 4.5 and RCP 8.5 Scenarios



Note: Thin black lines are observed values (1900-2017) from the National Centers for Environmental Information. The thicker solid lines depict the mean values of simulations from 35 climate models for the 1900-2005 period based on observed climate forcings (black line) and the 2006-2099 period for the two future scenarios (orange and red lines in the top panel, blue and grey in the bottom panel). The shading depicts the range in annual temperatures from all models. The mean and range have been smoothed to emphasize long-term (greater than year-to-year) variability.

Source: Mote, et al. (2019)

Seasonal

Projections of annual temperature and precipitation provide a foundation of general expectations of climate change, but some of the most relevant climate projections for planning purposes, and the most crucial to some of the hazards addressed in this Plan, are projected changes in seasonal temperature and precipitation and projected changes in extreme temperature and precipitation events. **Table 2-17** and **Table 2-18** summarize projections in Oregon's annual and seasonal temperature and precipitation, respectively, based on analyses of CMIP5 data.

Table 2-17 contains the mean and range of projected changes in Oregon's mean annual temperatures from historical (1970–1999) to mid-21st century (2040–2069), using both RCP 4.5 and RCP 8.5 scenarios. Projected changes are shown annually and for each season. Of particular note in **Table 2-17** is that both scenarios (for RCP 4.5 and RCP 8.5) show projected increases in average temperature for the year and for every season. All models are in agreement that each season will be warmer in the future, and that the largest amount of warming will occur in the summer. Increased summer temperatures will increase the risk of wildfires, drought, and heat waves as well as increase health-threats from poor air quality conditions. Increased average winter temperatures will result in less snowpack in Oregon, which also contributes to increase risk of "snow droughts"—years with normal precipitation, but lack of sufficient accumulated snowpack due to warm temperatures.

Table 2-17. Projected Future Changes in Oregon's Mean Annual and Seasonal Temperatures from Late 20th Century (1970–1999) to Mid-21st Century (2040–2069) under RCP 4.5 and RCP 8.5 Scenarios

Time Period	Annual		Winter (Dec, Jan, Feb)		Spring (Mar, Apr, May)		Summer (Jun, Jul, Aug)		Fall (Sep, Oct, Nov)	
Representative concentration pathway scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Mean change	3.6°F	5.0°F	3.3°F	4.5°F	3.1°F	4.1°F	4.5°F	6.3°F	3.7°F	5.2°F
Range	1.8–5.4°F	2.9–6.9°F	1.6–5.1°F	2.4–6.5°F	1.4–5.0°F	2.0–5.9°F	2.2–6.8°F	3.6–8.9°F	1.5–5.4°F	2.6–7.0°F

Note: The mean change is averaged across 35 global climate models and the range is the 5th to 95th percentile range representing model responses across the 35 global climate models excluding the smallest 5% and largest 5% of changes.
Source: Dalton, et al. (2017)

Table 2-18 contains a summary of projected mean percent change and range of changes for total precipitation in Oregon from historical (1970–1999) to mid-21st century (2040–2069), under both RCP 4.5 and RCP 8.5 scenarios. Projected changes are shown annually and for each season. Note in the "Annual" column in Table 2-4 that precipitation amounts are projected to remain within the range of current natural variability. However, Table 2-4 also shows that there is some indication from climate models that summers will be drier in the future. Such warmer and drier summers projected for Oregon would increase the risk of wildfire and drought hazards.

Table 2-18. Projected Future Relative Changes in Oregon's Total Annual and Seasonal Precipitation from Late 20th Century (1970–1999) to Mid-21st Century (2040–2069) under RCP 4.5 and RCP 8.5 Scenarios

	Annual		Winter (Dec, Jan, Feb)		Spring (Mar, Apr, May)		Summer (Jun, Jul, Aug)		Fall (Sep, Oct, Nov)	
Representative concentration pathway scenario	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Mean change	1.9%	2.7%	4.9%	7.9%	1.9%	2.7%	-6.3%	-8.7%	0.5%	-0.8%
Range	-4.9–9.0%	-6.0–11.4%	-6.4–16.5%	-4.7–24.3%	-8.9–12.1%	-7.2–17.4%	-28.5–16.1%	-33.1–22.5%	-17.0–14.4%	-17.1–14.9%

Note: The mean change is averaged across 35 global climate models and the range is the 5th to 95th percentile range representing model responses across the 35 global climate models excluding the smallest 5% and largest 5% of changes.

Source: Dalton, et al. (2017)

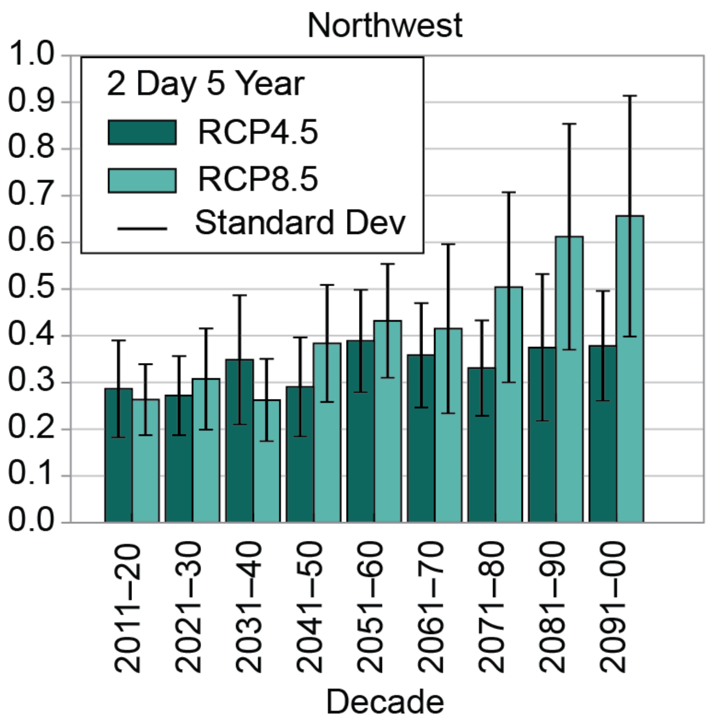
Extremes

Natural hazards are often an expression of extreme conditions — windstorms, rain storms, floods, droughts, heat waves, and so on. Extreme precipitation is perhaps the most common and widespread natural hazard in Oregon. Many people may associate extreme rainfall events almost exclusively with western Oregon, but in fact extreme precipitation events occur across the entire state. Extreme precipitation events west of the Cascades are generally associated with atmospheric rivers—long, narrow swaths of warm, moist air that carry large amounts of water vapor from the tropics to mid-latitudes—whereas closed low pressure systems often lead to isolated precipitation extremes east of the Cascade Range (Parker & Abatzoglou, 2016).

Observed trends in the frequency of extreme precipitation events across Oregon have depended on the location, time frame, and metric considered, but overall the frequency has not changed substantially. As the atmosphere warms, it is able to hold more water vapor that is available for precipitation. As a result, the frequency and intensity of extreme precipitation events are expected to increase in the future (Dalton, Dello, Hawkins, Mote, & Rupp, 2017), including atmospheric river events (Kossin, et al., 2017). In addition, regional climate modeling results suggest a weakened rain shadow effect in winter projecting relatively larger increases in precipitation east of the Cascades and smaller increases west of the Cascades in terms of both seasonal precipitation totals and precipitation extremes (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019).

There are multiple ways to define extreme precipitation events. One way is the 2-day, 5-year return interval event—that is, the magnitude of cumulative precipitation over two days with a 20% probability of occurring in any given year. The frequency of such events is projected to increase over the 21st century (**Figure 2-21**). For example, by the 2050s under RCP 8.5, the frequency is expected to double, becoming a 2.5-year return interval event. This translates to a couple more events of the type per year by mid-21st century. The frequency of extreme precipitation events increases more under RCP 8.5 than RCP 4.5 because warming is greater for RCP 8.5 allowing the atmosphere to hold more water vapor available for precipitation.

Figure 2-21. Projected Extreme Precipitation Event Frequency for the 2-day duration and 5-year return interval event for the Northwest under RCP 4.5 and RCP 8.5 Scenarios



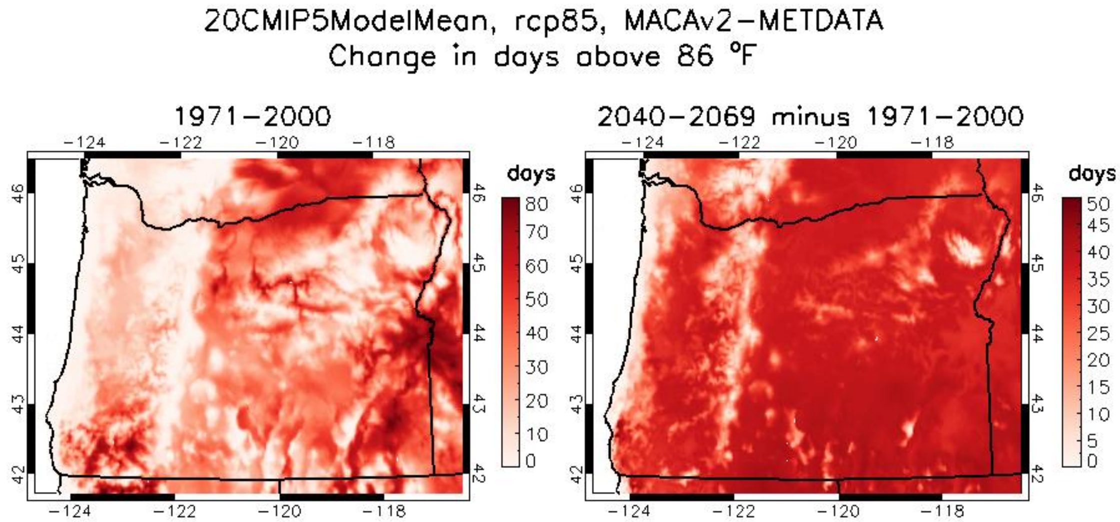
Calculated for 2006–2100 but decadal anomalies begin in 2011. Error bars are ±1 standard deviation; standard deviation is calculated from the 14 or 16 model values that represent the aggregated average over the regions, over the decades, and over the ensemble members of each model. The average frequency for the historical reference period is 0.2 by definition and the values in this graph should be interpreted with respect to a comparison with this historical average value.

Source: Easterling, et al. (2017)

For the first time, extreme heat is included as a hazard in the 2020 Oregon NHMP. This is due to the recognition that as the climate continues to warm, extreme heat events will be an emerging hazard with implications for public health as well as infrastructure. Extreme heat events are expected to increase in frequency, duration, and intensity in Oregon due to continued warming temperatures. In fact, the hottest days in summer are projected to warm more than the change in mean temperature over the Pacific Northwest (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Extreme heat events occur from time to time as a result of natural variability, but human-caused climate change is already contributing to the severity of such events (Vose, Easterling, Kunkel, LeGrande, & Wehner, 2017).

There are several ways to measure extreme heat. One is to measure the change in magnitude of the warmest day of the year; another is to count the number of days with temperatures above a certain threshold. By the middle of the 21st century (2036–2065), the temperature of the warmest day of the year is projected to increase by about 6°F averaged over the Northwest relative to the period 1976–2005 (Vose, Easterling, Kunkel, LeGrande, & Wehner, 2017). The number of days with temperatures greater than 86°F—"hot days"—are expected to increase across Oregon (**Figure 2-22**). In the baseline period (1970–1999), the hottest parts of the state—lower elevation portions of eastern Oregon, as well as the Rogue River valley—experience at least 30 hot days per year. By mid-21st century under the higher scenario (RCP 8.5), most locations in Oregon except the mountains and the coast will experience at least an additional 30 hot days per year, in many places doubling the frequency of such days (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019).

Figure 2-22. Average Number of Hot Days Per Year for 1971–2000 (left) and Projected Change by 2040–2069 under RCP 8.5 (right).



Note: Hot days are defined as days with daily high temperature >86°F (30°C). Results were averaged over 20 climate models (right). Data comes from the Northwest Climate Toolbox, climatetoolbox.org.

Source: Mote, et al. (2019)

Effect of Oregon's Future Climate Conditions on Natural Hazards

In 2010, Oregon achieved a significant milestone in the release of two reports for two important initiatives that developed in parallel; both reports addressed climate change across the state. OCCRI released the Oregon Climate Assessment Report (Dello & Mote, 2010), the first ever comprehensive scientific assessment of climate change in Oregon. At the same time, the state released the Oregon Climate Change Adaptation Framework, representing the efforts of over a dozen state agencies and institutes, including OCCRI, to begin to establish a rigorous framework for addressing the effects of climate change across the state.

Since the 2010 Oregon Climate Assessment Report, OCCRI has produced three updated assessment reports in 2013, 2017, and 2019 (http://www.occri.net/publications-and-reports/). The latter two—the Third Oregon Climate Assessment Report (Dalton, Dello, Hawkins, Mote, & Rupp, 2017) and the Fourth Oregon Climate Assessment Report (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019), which includes the Northwest chapter of the Fourth National Climate Assessment (May, et al., 2018) —are relied upon to update the climate change information in the 2015 Oregon NHMP.

The Framework is concurrently being updated (2020) along with the 2020 Oregon NHMP. Development of Oregon's 2010 Climate Change Adaptation Framework was significant in that the state began to address the need to plan for the effects of future climate conditions. Furthermore, Oregon's 2010 Framework was the first state-level adaptation strategy based on climate risks as opposed to affected sectors. Oregon's 2010 Framework lays out 11 climate risks that are of concern to the state. The risks provide a consistent basis for agencies and communities to review plans and decisions to identify measures to reduce those risks. Many of the risks in the 2010 Oregon Framework are natural hazards.

Following is a summary of the principal effects of changing climate conditions on the natural hazards addressed in the 2020 Oregon NHMP. Hazards are discussed together where the climate changes and drivers are essentially the same. How each hazard (or group of hazards) affects each of the eight Oregon NHMP Natural Hazard Regions is then summarized.

Relationship Between Adaptation Framework Risks and Hazards in the Oregon NHMP

Table 2-19. Relationship Between Adaptation Framework Risks and Hazards in the Oregon NHMP

	Oregon NHMP Hazards							
Adaptation Framework climate risks	Coastal Erosion	Droughts	Heat Wave*	Wildfire	Floods/ CMZ	Landslides	Wind-storms	Winter Storms
Increased temperatures	x	X	X	X				
Changes in hydrology		X			X	X		
Increased wildfires		x		X	x	x		
Increase in ocean temperatures and changes in ocean chemistry	X				x			X
Increased drought		X		X				
Increased coastal erosion	X					x		
Changes in habitat								
Increase in invasive species and pests		x		X				
Loss of wetland ecosystems and services		X			X			
Increased frequency of extreme precipitation events and flooding					X	X		x
Increased landslides						X		

*Heat waves or extreme heat is now identified as a natural hazard for the first time in the 2020 Oregon natural hazards mitigation plan.

What is contained in Table 2-6: The leftmost column contains the climate risks in the 2010 Oregon Climate Change Adaptation Framework. Column headings show natural hazards identified in the 2020 Oregon Natural Hazards Mitigation Plan (NHMP).

How to read this table: Cells with an x or X show which climate risks will affect the frequency, intensity, magnitude, or duration of which natural hazards. A big X shows a primary relationship between the risk and the hazard. A small x shows a secondary relationship. The green cells in the body of the table show where a 2010 Adaptation Framework risk and a natural hazard in the 2020 Oregon NHMP are essentially the same thing.

Note that the first two risks — increased temperatures and changes in hydrology — are the primary climate drivers for natural hazards. The other climate risks represent known environmental or ecosystem responses to one or both of the primary drivers. Note also that a clear link has not been established between climate change and the frequency or intensity of windstorms.

Coastal Erosion and Coastal Flooding

Regions affected: 1

Oregon's ocean shoreline is constantly subject to the dynamic and powerful forces of the Pacific Ocean, and it changes at timescales that vary from days to decades. Variable and changing ocean conditions continuously reshape the ocean shoreline, particularly where the shore is composed primarily of sand. Sand levels on Oregon's beaches generally experience an annual cycle of erosion through winters and rebuilding in summer months. Over any extended time period, sandy beaches and shores will build out and retreat several times, due in part to the effects of winds, storms, tides, currents, and waves. These cycles can occur over decades. In the annual cycle, beach profiles do not always recover to the heights and extent of previous years. In recent years, sand levels have remained fairly low at many locations on the Oregon coast.

The shape of Oregon's ocean shoreline is a function in part of ocean water levels and wave heights. Ocean water levels are also a primary factor in the frequency of flooding around the fringes of Oregon's estuaries. In other words, erosion of the ocean shore is directly affected by sea levels and wave heights. Flooding on the estuarine fringe is affected by ocean water levels — including tides and storm surges — in addition to freshwater inflow from the estuarine watershed. Other factors influence coastal erosion, but sea levels and wave heights are the primary climate-related drivers that influence rates of coastal erosion.

Recent studies make it clear that global ocean water levels are rising. Global mean sea levels are very likely to rise 0.3–0.6 feet (9–18 cm) by 2030, 0.5–1.2 feet (15–38 cm) by 2050, and 1.0–4.3 feet (30–130 cm) by 2100. However, faster-than-expected Antarctic ice sheet melt under higher emissions scenarios could result in a global mean sea level rise exceeding 8 feet (2.4 m) by 2100. Regardless of pathway, oceans will continue rising even after 2100 (Sweet, Horton, Kopp, LeGrande, & Romanou, 2017a). In Oregon (as elsewhere) the rates of relative sea level rise—those experienced along Oregon's coastlines—are not the same as rates of change in global mean sea levels, because of a number of factors related to ocean conditions and vertical movement of the land. Oregon's western edge is uplifting, so the rates of relative sea level rise in Oregon are not as high as rates seen in other West Coast locations. But even after factoring in local conditions, sea levels along most of Oregon's coast are rising. For locations in which sea level is not currently rising, the projected rate of future sea level rise is expected to outpace the current rate of vertical land movement in the 21st century. For more information on coastal erosion and sea level rise, see the **Coastal Hazards** section.

Recent research also indicates that significant wave heights off Oregon's shorelines are increasing. Increasing significant wave heights may be a factor in the observed increase of coastal flooding events in Oregon. During El Niño events, sea levels can rise up to about 1.5 feet (0.5 meters) higher over extended periods (seasons). Attributing increasing wave heights to climate change may not be possible until the second half of the 21st century because natural variability is quite large and future projections of average and extreme wave heights along the West Coast are mixed (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

It is *very likely* (>90%) that the Oregon coast will experience an increase in coastal erosion and flooding hazards due to climate change induced sea level rise (*high confidence*) and possible changes to wave dynamics (*medium confidence*).

The executive summary of the 2010 Oregon Climate Adaptation Framework provides a summary of various challenges associated with "increased coastal erosion and risk of inundation from increasing wave heights and storm surges":

Increased wave heights, storm surges, and sea levels can lead to loss of natural buffering functions of beaches, tidal wetlands, and dunes. Accelerating shoreline erosion has been documented and is resulting in increased applications for shore protective structures. Shoreline alterations typically reduce the ability of beaches, tidal wetlands, and dunes to adjust to new conditions.

Increasing sea levels, wave heights, and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion and the common response to reduce shoreland erosion can lead to long-term loss of natural buffering functions of beaches and dunes. Applications for shoreline alteration permits to protect property and infrastructure are increasing, but in the long term they reduce the ability of shore systems to adjust to new conditions.

Extreme Heat

Regions affected: 1-8

All eight regions in the 2020 Oregon NHMP are projected to experience an increase in the frequency and severity of very warm temperatures, relative to the local climate. Inland areas at lower elevations, which climatologically see the greatest number of very hot temperature days, will see an even greater number of very hot days in the coming decades. Very hot days, measured in an absolute sense, will continue to be rare in coastal and high elevation regions.

Extreme heat events occur from time to time as a result of natural variability, but human-caused climate change is already contributing to the severity of such events (Vose, Easterling, Kunkel, LeGrande, & Wehner, 2017). Recent extremely hot summers (2015, 2017, 2018) in highly populated parts of western Oregon have been unprecedented and have brought increased interest in the effect of global warming on local summer temperatures. In Oregon's biggest city, Portland, summer extreme heat in terms of annual total days over 90°F has steadily increased in frequency and severity despite large year-to-year variability. The record number of days over 90°F in Portland was set in 2018. Today, Portland sees about nine more days above 90°F than in 1940. This trend will continue, though the rate of change may increase, along with continued year-to-year variability. The hot summers of 2015, 2017, and 2018 serve as wake-up calls for what is to come, as they are good examples of what is projected to be relatively common by the mid-21st century.

Extreme heat events will to continue to increase in frequency and severity under continued climate warming. The number of days with temperatures greater than 86°F (30°C)—"hot days"—are expected to increase across Oregon (**Figure 2-22**). In the baseline period (1970–

1999), the hottest parts of the state—lower elevation portions of eastern Oregon, as well as the Rogue River valley—experience at least 30 hot days per year. By mid-21st century under the higher scenario (RCP 8.5), most locations in Oregon except the mountains and the coast will experience at least an additional 30 hot days per year, in many places doubling the frequency of such days (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019). Closer to home for some Oregonians, a three-fold increase in heat-related illness has been documented in Oregon with each 10°F rise in daily maximum temperature.

Extreme heat events can bring a wide array of impacts from increased morbidity and mortality from heat-related illness to disrupted transportation and infrastructure damaged by extreme heat. Heat waves will result in increased deaths and illness among vulnerable human populations. The elderly, infants, chronically ill, low-income communities, and outdoor workers are the main groups threatened by heat waves (Ebi, et al., 2018). Extreme heat events can disrupt transportation by delaying rail and air transportation when safe operating guidelines are exceeded, damaging rail tracks that may bend or roadway joints that may buckle under extreme heat (Jacobs, et al., 2018). In addition, heat waves can increase the demands on electric power for cooling, increasing the risk of cascading failures within the electric power network (Clarke, et al., 2018).

Droughts and Wildfires

Regions affected: 1-8

All eight regions in the 2020 Oregon NHMP are potentially affected by increasingly common droughts and wildfires. Moreover, areas that have historically been both hotter and drier than the statewide average — southwest Oregon counties and central and eastern Oregon — are at somewhat higher risk of increased drought and wildfire than the state overall. Droughts and wildfires are addressed as separate hazards in this Plan. However, the underlying climate mechanism is similar for both. These hazards all occur in conjunction with warmer and drier conditions.

Virtually all climate models project warmer, drier summers for Oregon, with mean projected increases in summer temperatures of 4.5 to 6.3°F and a decline in mean summer precipitation amounts of 6.3 to 8.7% by mid-21st century relative to late-20th century depending on emissions scenario (**Table 2-17**, **Table 2-18**). These summer conditions will be coupled with projected decreases in mountain snowpack due to warmer winter temperatures. Models project a mean increase in winter temperatures of 3.3 to 4.5°F by mid-21st century relative to late-20th century depending on emissions scenario (**Table 2-17**). This combination of factors exacerbates the likelihood of drought, which in turn can dry out vegetation often leading to an increase in the incidence and likelihood of wildfires. Vegetation dryness is expected to increase across most of Oregon—with the most pronounced increases in southern Oregon, the eastern Cascade Range, and parts of the Blue Mountains—resulting in increased wildfire frequency and area burned across the state, even in areas west of the Cascade Range where wildfire has historically been infrequent (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

It is likely (>66%) to *very likely* (>90%) that Oregon will experience an increase in the frequency of one or more types of drought. An increase in drought frequency caused by increasing temperature is more likely than an increase in drought frequency caused by an increase in periods of low precipitation, and the confidence of this assessment is higher for temperature driven drought (*high confidence*) than for precipitation driven drought (*medium confidence*).

It is likely (>66%) that Oregon will experience an increase in wildfire frequency and intensity (*high confidence*). The greatest increased risk will be in the western and southern portions of the region, and more so at lower elevation wildlands than higher elevation wildlands.

The executive summary of Oregon's 2010 Climate Change Adaptation Framework provides a summary of challenges associated with "increased incidence of drought" and "increase in wildfire frequency and intensity," as follows.

Wildfire

Increased temperatures, the potential for reduced precipitation in summer months, and accumulation of fuels in forests due to insect and disease damage present high risk for catastrophic fires, particularly in forests east of the crest of the Cascade Range. An increase in frequency and intensity of wildfire will damage larger areas, and likely cause greater ecosystem and habitat damage. Larger and more frequent wildfires will increase human health risks due to exposure to smoke.

Increased risk of wildfire will result in increased potential for economic damage at the urban-wildland interface. Wildfires destroy property, infrastructure, commercial timber, recreational opportunities, and ecosystem services. Some buildings and infrastructure subject to increased fire risk may not be adequately insured against losses due to fire. Increased fire danger will increase the cost to prevent, prepare for, and respond to wildfires.

Droughts

Longer and drier growing seasons and droughts will result in increased demand on ground water resources and increased consumption of water for irrigation, which will have potential consequences for natural systems. Droughts affect wetlands, stream systems, and aquatic habitats. Droughts will result in drier forests and increase likelihood of wildfire.

Droughts will cause significant economic damage to the agriculture industry through reduced yields and quality of some crops. Droughts can increase irrigation-related water consumption, and thus increase irrigation costs. Drought conditions can also have a significant effect on the supply of drinking water.

Winter Storms, Floods, and Landslides

Regions affected: 1–4

Flooding and landslides are projected to occur more frequently throughout western Oregon, in Oregon NHMP Regions 1 through 4. While winter storms affect all areas of the state, there is no current research available indicating any change in the incidence of winter storms due to changing climate conditions.

The projected increases in extreme precipitation is expected to result in a greater risk of flooding in certain basins. Changes in flood risk are strongly associated with the dominant form of precipitation in a basin, with mixed rain-snow basins in Washington and Oregon already seeing increases in flood risk. Generally, western Oregon basins are projected to experience increased flood risk in future decades. Increased flood risk involves both an increased incidence of flooding of a certain magnitude and an increase in the magnitude of floods of a certain return interval. In other areas of the state, flood risk may decrease in some basins and increase in others. Some of Oregon's largest floods occur when warm heavy rain from atmospheric rivers falls on snowpack leading to rapid snowmelt, resulting in rain-on-snow flooding events (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). The frequency and intensity—amount of transported moisture—of atmospheric river events is projected to increase along the West Coast in response to rising atmospheric temperatures (Kossin, et al., 2017). This larger moisture transport of atmospheric rivers would lead to greater likelihoods of flooding along the West Coast (Konrad & Dettinger, 2017).

It is *very likely* (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events (*high confidence*). It is *very likely* that Oregon will experience an increase in the frequency of extreme river flows (*high confidence*). It is *more likely than not* (>50%) that these extreme river flows will lead to an increase in the incidence and magnitude of damaging floods (*low confidence*), although this depends on local conditions (site-dependent river channel and floodplain hydraulics).

In Oregon, landslides are strongly correlated with rainfall when the soil becomes saturated, so increased rainfall — particularly in extreme events — will likely trigger increased incidence of landslides. Landslide risk can also be amplified in areas with recent wildfire, particularly if followed by heavy rain. With climate change expected to increase the frequency of both wildfires and heavy rains, it follows that landslide risk also increases with climate change (Kopp, et al., 2017). However, landslide risk depends on a variety of site-specific factors unrelated to climate.

The executive summary of Oregon's 2010 Climate Change Adaptation Framework provides a summary of challenges associated with both flooding and landslides:

Floods

Extreme precipitation events have the potential to cause localized flooding due partly to inadequate capacity of storm drain systems. Extreme events can damage or cause failure of dam spillways. Increased incidence and magnitude of flood events will increase damage to property and infrastructure and will increase the vulnerability of areas that already experience repeated flooding. Areas thought to be outside the floodplain may begin to experience flooding. Many of these areas have improvements that are not built to floodplain management standards and are not insured against flood damage, therefore being more vulnerable to flood events. Finally, increased flooding will increase flood-related transportation system disruptions, thereby affecting the distribution of water, food, and essential services.

Landslides

Increased landslides will cause increased damage to property and infrastructure and will disrupt transportation and the distribution of water, food, and essential services. Widespread damaging landslides that accompany intense rainstorms (such as "Pineapple Express" winter storms) and related floods occur during most winters. Particularly high consequence events occur about every decade; recent examples include those in February 1996, November 2006, and December 2007.

Windstorms

Regions affected: Unknown

There is little research on changing wind in the Pacific Northwest as a result of climate change.

2.1.4.3 Evolving Climate Science and the Oregon NHMP

Oregon is committed to planning and understanding how climate change will impact its citizens and natural resources. Climate change will exacerbate certain natural hazards such as drought, wildfire, and extreme heat in the State of Oregon. Climate change planning is not only for the future; it is occurring and affecting Oregon now.

Oregon sits at the forefront of climate change research in the United States. In 2007, the Oregon State Legislature established the Oregon Climate Change Research Institute (OCCRI) at Oregon State University. Since its establishment, OCCRI has provided extensive support to Oregon State agencies, conducted novel climate change research, delivered numerous community outreach and education activities, produced multiple regional, state, and local climate assessment reports, and led two large federal climate change centers: the Pacific Northwest Climate Impacts Research Consortium (2010–2021), funded through the National Oceanic and Atmospheric Administration, and the Northwest Climate Science Center (2010–2017), funded through the Department of Interior. Both centers specifically focus on how climate change impacts the Pacific Northwest, with an interest in natural hazards. The NHMP will once again draw from the latest research at OCCRI and region partners for the 2025 plan.

The 2020 NHMP relied on climate change information based on the current state-of-the-art global climate model outputs from the Coupled Model Intercomparison Project phase 5 (CMIP5). CMIP5 outputs supported the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which was released in 2013, as well as the Fourth National Climate Assessment, which was released in 2017–2018. The legislation that created OCCRI requires an assessment of the state of the science as it impacts Oregon. The 2020 NHMP drew heavily from the two most recent reports: the Third and Fourth Oregon Climate Assessment Reports (Dalton, Dello, Hawkins, Mote, & Rupp, 2017) (Mote, Abatzoglou, Dello, Hegewisch, & Rupp, 2019).

From 2013 to 2020, a new round of global climate model outputs—CMIP phase 6—was developed from which new climate information and knowledge will continue to be developed in the coming years. The sixth assessment report of the IPCC is planned to be released in 2021. The Fifth National Climate Assessment is scheduled to be released in 2022. The climate change information for the 2025 update will be based on these reports and future OCCRI Oregon climate assessment reports.

Climate science is rapidly evolving, and it is impossible to predict where the state of the science will be in 5 years. Many of the foundational findings have remained the same throughout generations of climate assessments, yet new understanding of certain aspects of the climate is evolving, such as attribution of extreme climate events to human-caused climate change, compounding climate extremes, and regional or local climate impacts.

Oregon commits to addressing climate change in each climate-related hazard, statewide and by OEM hazard mitigation region, in the 2025 plan to the extent that the science can support inclusion into each section. We addressed the uncertainty of the state of the science, and maintain that we will only draw from peer-reviewed literature to support the plan. The U.S. National Climate Assessment is now undergoing a sustained assessment, or continued examination of climate change impacts as they affect the United States. OCCRI is involved in the sustained assessment, and we will draw from this work in the 2025 plan. With some confidence, OCCRI will be able to improve information about climate change impacts to extreme heat, drought, flood, wildfire, and coastal hazards in the 2025 report.

2.1.5 State-Owned/Leased Facilities, State Critical Facilities, and Local Critical Facilities Potential Loss Assessment

Requirement: 44 CFR §201.4(c)(2)(ii): The risk assessment shall include… (ii) State owned or operated critical facilities located in the identified hazard areas shall also be addressed.

Requirement: 44 CFR §201.4(c)(2)(iii): The risk assessment shall include… (iii) An overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

According to the Oregon Department of Administrative Services (DAS), the State of Oregon owns or leases buildings having a total value of nearly $7.3 billion in 2019. Because of this investment it is important the State assess the vulnerability of these structures to Oregon's natural hazards. Data to support this analysis were available for the following hazards: coastal erosion, earthquake, flood, landslide, tsunami, volcano, and wildfire. The Oregon Department of Geology and Mineral Industries (DOGAMI) assembled the best-available statewide natural hazard data and assessed which state-owned/leased buildings are exposed to each hazard. While this study primarily focused on state assets, DOGAMI also assessed the vulnerability of local critical facilities to natural hazards throughout the state.

The data for this analysis was furnished by DAS. As a part of the quality control review, DOGAMI removed nearly 400 building points from the original 2019 DAS dataset to build the dataset used in the vulnerability assessment. Many of the buildings were removed based on attributes in the GIS data that indicated that the points represented non-structures (e.g., property grounds). The final data set contained 5,350 state facilities.

Notably, the DAS building data does not identify "critical/essential" facilities. Within the state facilities dataset DOGAMI created a subcategory of critical facilities. DOGAMI and the Department of Land Conservation and Development (DLCD) defined critical facilities as buildings that function as airports, communications, emergency operations, fire stations, hospitals or health clinics, military facilities, police stations, schools, detention centers, or miscellaneous facilities (e.g., ODOT Maintenance Facility) that would be needed during or immediately after a natural disaster. DOGAMI identified 1,674 state critical facilities. **Figure 2-23** shows the distribution and dollar value (potential loss) of these 5,350 state-owned/leased facilities, including critical facilities, within Oregon NHMP Natural Hazard Regions.

Local critical facilities are a building, or a group of buildings, that either are publicly or privately owned airports, communications, emergency operations, fire stations, hospitals or clinics, military facilities, police stations, schools, detention centers, or miscellaneous facilities, as defined by DOGAMI and DLCD. The dataset that DOGAMI developed and used in the vulnerability assessment had 8,757 buildings with a total value of $26 billion. Local critical facilities are shown in **Figure 2-24** and are included in regional maps.

These facilities were carried forward from the database developed for the 2015 State NHMP. The 2015 data of local critical facilities were verified or modified, and additions or deletions were completed as necessary.

2.1.5.1 Assessment Methods

DOGAMI used two primary methods for assessing vulnerability to hazards: Hazus damage estimates for earthquakes and exposure analysis for floods, coastal erosion, volcanic hazards, tsunamis, wildfires, and landslides.

Hazus is a software package developed by FEMA that “provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis… The multi-hazard Hazus is intended for use by local, state, and regional officials and consultants to assist mitigation planning and emergency response and recovery preparedness. For some hazards, Hazus can also be used to prepare real-time estimates of damages during or following a disaster” (FEMA, 2012, pp. 1-1). The results of the Hazus damage analysis are provided as a *loss estimation* (i.e., the building damage in dollars) and as a *loss ratio* (loss estimation divided by the total value of the building, represented as a percentage). DOGAMI aggregated and reported losses at a county level.

Exposure analysis was used to characterize risk for floods, coastal erosion, volcanic hazards, tsunamis, wildfires, and landslides. This is a simple method to determine which facilities lie within a natural hazard area and which do not. It is an alternative for natural hazards for which Hazus damage functions or high-quality, statewide hazard mapping is not available, and therefore, loss estimation is not possible or recommended. DOGAMI categorized most hazards with simple classification schemes (most commonly “High,” “Moderate,” “Low,” or “Other”). For each hazard, the attribute “Other” was used to describe very low hazard areas, unmapped and/or unstudied areas, or zero hazard zones (further defined for individual hazards). Exposure analysis results are communicated in terms of the number of facilities exposed, the value exposed (i.e., total facility value in dollars), and a county-level percentage of value exposed (i.e., the total value exposed value divided by the total value of all facilities in the county).

For the 2020 Risk Assessment, DOGAMI used the percentage of building value exposed or a loss ratio to a given hazard to calculate a vulnerability score for each county in each category of potential loss for each hazard faced by a county. Scores for coastal hazards and tsunamis were only calculated for counties in Region 1. The percentage of exposure or loss for each county for each hazard was statistically distributed into five categories (Very Low, Low, Moderate, High, or Very High) using the Jenks Natural Breaks method. DOGAMI applied this method to the results for all state facilities, state critical facilities, and local critical facilities. The vulnerability scores derived from this method were used along with other parameters (e.g., social vulnerability index) to calculate an overall vulnerability score for each county for each hazard and an overall risk score for each county for all hazards combined.

2.1.5.2 Hazard Data Limitations

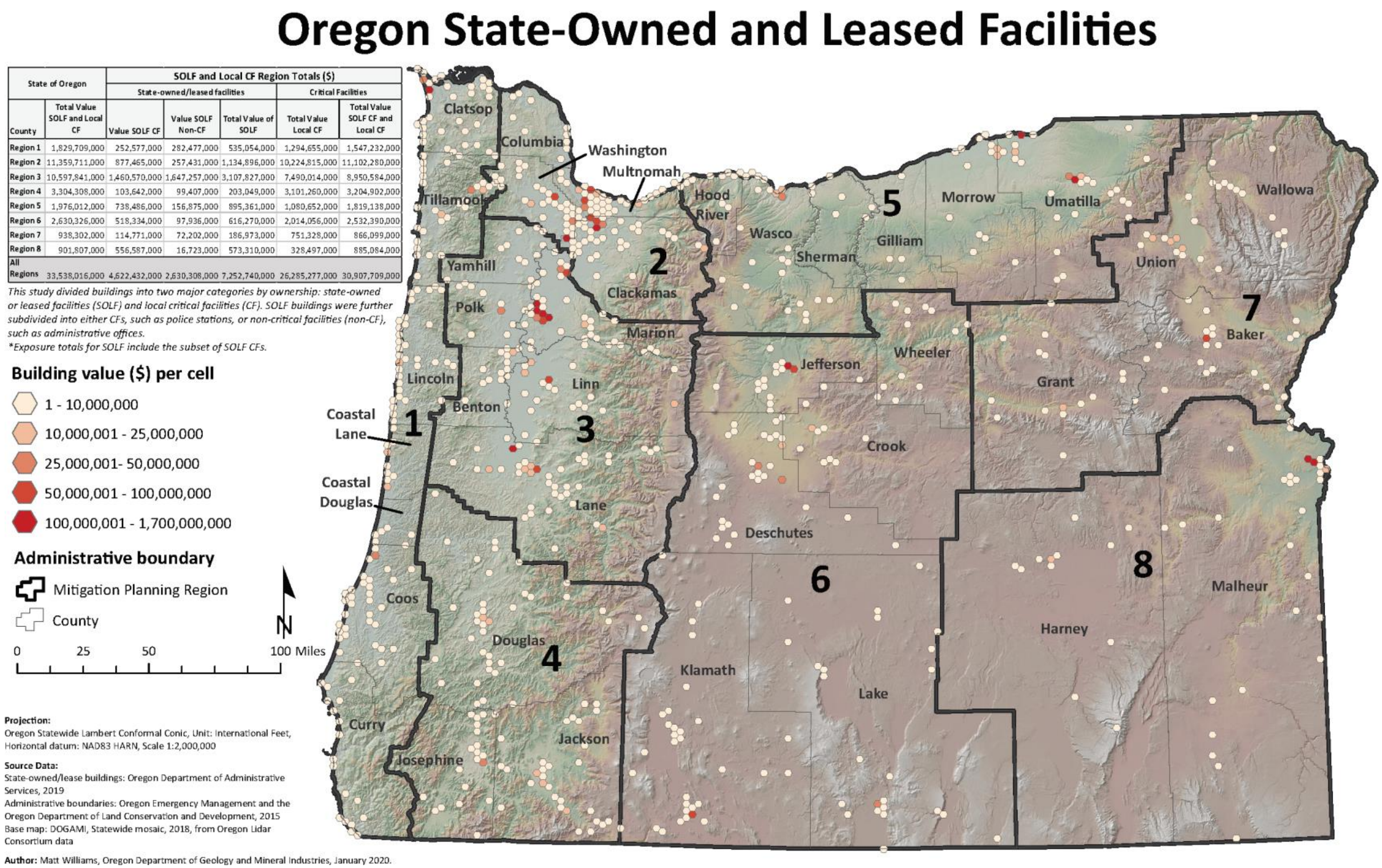
This assessment evaluates each hazard individually; there are no comprehensive or multi-hazard assessments. In order to prioritize facilities most vulnerable facilities to natural hazards, DOGAMI categorized most hazards with simple classification schemes (most commonly “High,” “Moderate,” “Low,” or “Other”). For each hazard “Other” is used to describe very low hazard areas, unmapped and/or unstudied areas, or zero hazard zones (further defined for individual hazards).

Statewide natural hazard data are generalized in several ways and provide a gross view of their distribution and magnitude across the state. They are often combined or derived from other data sources that themselves can have widely different quality, accuracy, attribution, or currency. Future investigations or actual hazard events may substantially modify our understanding of where and when natural hazards might occur.

It is worth noting that building-specific information can make an enormous difference when evaluating the actual damaging effects of natural hazards. For example, a modern seismically reinforced building may receive far less or no earthquake damage relative to older un-reinforced buildings next door. The Hazus damage assessment is highly dependent on the quality of the facility attributes and as some assumptions had to be made due to lack of specificity in the data, some error is inevitable. In addition, Hazus is a model, not reality, which is an important factor when considering the loss ratio of an individual building. The results of the Hazus model are only useful when aggregated across large numbers of facilities and it does not provide a site-specific analysis. Because of this model limitation, we chose to aggregate at a county level and the loss estimates for individual buildings are likely inaccurate. Exposure analysis does not attempt to account for building- or site-specific characteristics.

The limitations of the vulnerability scoring were related to the sample of size of the results for some hazards. This issue was most prevalent with the coastal hazards because there were only seven counties (i.e., sample size of seven) to statistically distribute into five categories. Therefore, the reliability of the vulnerability scores for tsunami and coastal erosion is greatly reduced. The vulnerability scoring for state critical facilities exposed to volcanic hazards was limited to four counties, so data were distributed into four categories instead of five. In this case, the Very High category was dropped from the possible vulnerability scores.

Figure 2-23. Statewide Distribution of State-Owned/Leased Facilities and State Critical Facilities

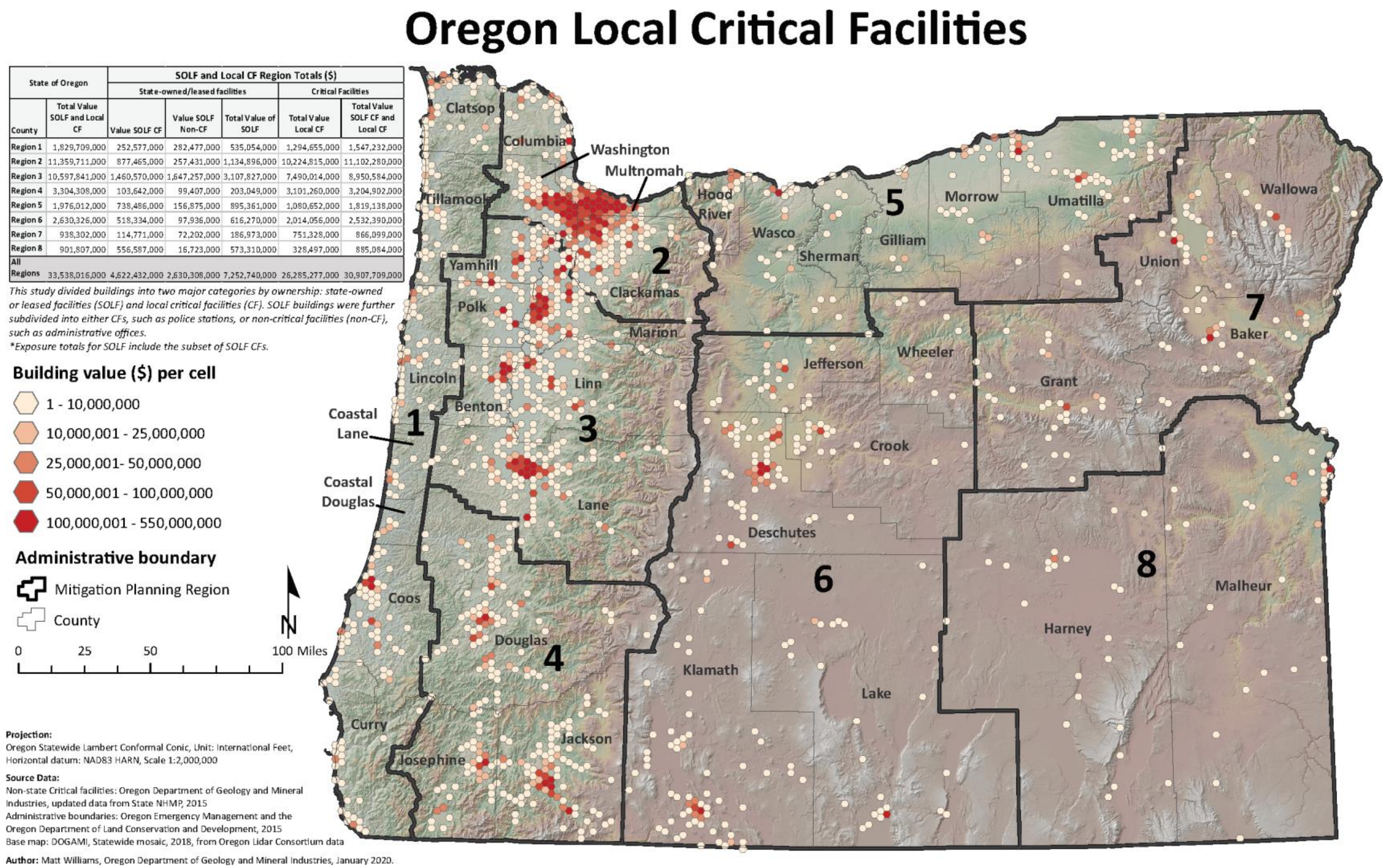


State of Oregon		SOLF and Local CF Region Totals ($)				
		State-owned/leased facilities			Critical Facilities	
County	Total Value SOLF and Local CF	Value SOLF CF	Value SOLF Non-CF	Total Value of SOLF	Total Value Local CF	Total Value SOLF CF and Local CF
Region 1	1,829,709,000	252,577,000	282,477,000	535,054,000	1,294,655,000	1,547,232,000
Region 2	11,359,711,000	877,465,000	257,431,000	1,134,896,000	10,224,815,000	11,102,280,000
Region 3	10,597,841,000	1,460,570,000	1,647,257,000	3,107,827,000	7,490,014,000	8,950,584,000
Region 4	3,304,308,000	103,642,000	99,407,000	203,049,000	3,101,260,000	3,204,902,000
Region 5	1,976,012,000	738,486,000	156,875,000	895,361,000	1,080,652,000	1,819,138,000
Region 6	2,630,326,000	518,334,000	97,936,000	616,270,000	2,014,056,000	2,532,390,000
Region 7	938,302,000	114,771,000	72,202,000	186,973,000	751,328,000	866,099,000
Region 8	901,807,000	556,587,000	16,723,000	573,310,000	328,497,000	885,084,000
All Regions	33,538,016,000	4,622,432,000	2,630,308,000	7,252,740,000	26,285,277,000	30,907,709,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Source: DOGAMI

Figure 2-24. Statewide Distribution of Local Critical Facilities



State of Oregon		SOLF and Local CF Region Totals ($)				
		State-owned/leased facilities			Critical Facilities	
County	Total Value SOLF and Local CF	Value SOLF CF	Value SOLF Non-CF	Total Value of SOLF	Total Value Local CF	Total Value SOLF CF and Local CF
Region 1	1,829,709,000	252,577,000	282,477,000	535,054,000	1,294,655,000	1,547,232,000
Region 2	11,359,711,000	877,465,000	257,431,000	1,134,896,000	10,224,815,000	11,102,280,000
Region 3	10,597,841,000	1,460,570,000	1,647,257,000	3,107,827,000	7,490,014,000	8,950,584,000
Region 4	3,304,308,000	103,642,000	99,407,000	203,049,000	3,101,260,000	3,204,902,000
Region 5	1,976,012,000	738,486,000	156,875,000	895,361,000	1,080,652,000	1,819,138,000
Region 6	2,630,326,000	518,334,000	97,936,000	616,270,000	2,014,056,000	2,532,390,000
Region 7	938,302,000	114,771,000	72,202,000	186,973,000	751,328,000	866,099,000
Region 8	901,807,000	556,587,000	16,723,000	573,310,000	328,497,000	885,084,000
All Regions	33,538,016,000	4,622,432,000	2,630,308,000	7,252,740,000	26,285,277,000	30,907,709,000

Source: DOGAMI

2.1.5.3 Facilities within Hazard Areas

The spatial distribution of the facilities within hazard zones is not easily viewed on a statewide map. Therefore, maps depicting hazard zones and facilities within those zones have only been created at the regional scale. Those maps can be found in the **Regional Risk Assessments**.

Coastal Erosion

DOGAMI used the results from several of their coastal erosion studies to develop a coastal erosion hazard zone for this analysis. However, these data do not cover the entire Oregon coastline: coastal erosion hazard zones have not been created for Lane, Douglas, and Coos Counties, and only partial data coverage exists for Curry County. To address these data gaps, DOGAMI excluded those portions of the coast from the analysis, using a 0.5-km buffer of the coastline to delineate an “other” value. In areas where mapping exists, the hazard is mapped as Active, High, Moderate, or Low Hazard Zones which, for the purposes of this analysis, were simplified to “High” (encompassing Active and High), “Moderate,” and “Other” (encompassing Low hazards and unmapped areas). The “Low” hazard zones incorporate hypothetical landslide block failures assumed to fail in the event of a M9 Cascadia earthquake and were placed under “Other” due to their very low probability. All other areas of the state received a “None” attribute.

Coastal Erosion Hazard Facility Summary

Of the 5,350 state facilities evaluated, 34 were located within a High or Moderate coastal erosion zone and represented a value of approximately $11.5 million. No critical state facilities were identified to be within a coastal erosion hazard zone. An analysis of local critical facilities shows that 22 buildings with a total value of $7.5 million are vulnerable to coastal erosion.

Earthquake

The state facilities and local critical facilities vulnerability assessment used a combination of datasets that represent key geologic factors that contribute to earthquake hazard damage. This assessment utilized the FEMA developed software of Hazus-MH to estimate the amount of damage that may occur during a CSZ event and a 2,500-year probabilistic scenario. The damage estimates from the CSZ were very low east of the Cascade Mountains, so the loss estimates we reported from this event were limited to the western regions (1–4) (Madin & Burns, 2013). DOGAMI assessed the four eastern regions (5–8) with the USGS 2500-year probabilistic scenario (Petersen, et al., 2014).

Results from both earthquake analyses were reported in terms of loss estimation (i.e., the building damage in dollars) and loss ratio which is the loss estimation divided by the total value of the building, represented as a percent. The results were also summarized by extensive or complete damage probabilities, which is synonymous with yellow-tagged or red-tagged buildings.

Earthquake Hazard Facility Summary

Of 5,350 state facilities evaluated, 838 building were flagged as completely or extensively damaged following a CSZ event (Regions 1–4) or a 2,500-year probabilistic scenario (Regions 5–8) totaling over $1.3 billion of damages to property. Among the 1,647 critical state facilities, 360 were flagged as completely or extensively damaged. DOGAMI determined that out of the 8,757 local critical facilities, 1,880 buildings were flagged as completely or extensively damaged following a CSZ event (Regions 1–4) or a 2,500-year probabilistic scenario (Regions 5–8) totaling over $4.3 billion of damages to property.

Flood

DOGAMI used a combination of Federal Emergency Management Agency (FEMA) effective and preliminary flood zone data, state digitized flood zone data, and FEMA Q3 data to develop a statewide flood hazard zone for this analysis. DOGAMI indicated a flood hazard if a building fell within floodways, 100-year floodplains, or 500-year floodplains. The flood hazard was not divided in to High, Moderate, or Low categories due to the wide variety of flood data, its variable absolute and relative accuracy, and its variable geographic coverage and completeness. In particular, rural or sparsely populated areas tend to have poorly mapped or nonexistent flood hazard data. For these reasons, buildings were simply classified as “Hazard Zone” or “Other.” “Hazard Zone” indicates a building falls within one of the floodway, 100-year, or 500-year flood hazard zones. “Other” indicates there is insufficient information to determine whether a flood hazard exists for a given site. Buildings with “Other” designations could conceivably face relatively high flood hazards or no flood hazard at all.

Flood Hazard Facility Summary

Of the 5,350 state facilities evaluated, 632 were located within a flood hazard zone and had an estimated total value of over $900 million. Of these, 165 were identified as critical state facilities. DOGAMI also found that 683 local critical facilities were exposed to flood hazard, with a total value of $1.6 billion.

Landslides and Debris Flow

The state facilities and local critical facilities vulnerability assessment used the statewide landslide susceptibility map (Burns, Mickelson, & Madin, 2016) in this report to identify the general level of susceptibility to landslide hazards, primarily shallow and deep landslides. Burns and others (2016) used SLIDO inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns, Mickelson, & Madin, 2016). This susceptibility map was used to determine which state facilities are vulnerable to the landslide hazard. The statewide landslide susceptibility model was originally published with susceptibility values of 1 through 4. Since landslide susceptibility is also an input into Hazus-MH, it was necessary to translate the results into a Hazus compliant scale of 1–10. The landslide susceptibility categories were changed in this way: Low (1 = 1), Moderate (2 = 4), High (3 = 7) and Very High (4 = 10).

Landslide Hazard Facility Summary

Of the 5,350 state facilities evaluated, 1,379 (amounting to nearly $835 million) were located within Very High and High landslide hazard areas; this included 277 critical state facilities. DOGAMI determined that out of the 8,757 local critical facilities, 472 were in Very High or High hazard zones with a total value over $640 million.

Tsunami

DOGAMI used published tsunami inundation model results (Priest, et al., 2013) for the entire coast to determine the tsunami hazard zone for this analysis. The coast-wide inundation models divide tsunami scenarios by whether an earthquake source is local or distant. The distant source tsunami scenarios were not used in this report. The local tsunami scenarios used in this report for exposure analysis were CSZ "t-shirt" sizes of Small (Sm), Medium (M), Large (L), Extra Large (XL), and Extra-Extra Large (XXL).

The recurrence interval associated with each local source tsunami scenario is as follows (Priest, et al., 2013):

- XXL 1,200 years
- XL 1,050–1,200 years
- L 650–800 years
- M 425–525 years
- SM 300 years

For the purposes of the NHMP building exposure analysis, all these zones are described as "High," with the remainder of the state receiving an "Other" designation to encompass very-low probability events or no tsunami hazard

Tsunami Hazard Facility Summary

Of the 5,350 state facilities evaluated, 523 were located within the tsunami hazard zone and had an estimated total value of $248 million. Of the 523 state facilities exposed to tsunami hazard, 131 were identified as critical state facilities. DOGAMI determined that out of the 8,757 local critical facilities, 281 were in High hazard zones with a total value over $350 million.

Volcanic Hazards

DOGAMI used data from the U.S. Geological Survey (USGS) and DOGAMI's Mount Hood lahar mapping to develop the statewide volcanic hazard layer for this analysis. USGS maintains hazard zone data for five volcanic areas in the Cascade Mountains of Oregon: Mount Hood, Crater Lake, Newberry Crater, Mount Jefferson, and the Three Sisters. This assessment scores each facility based on whether it is located within a proximal hazard zone (translating to "High") or distal hazard zone (translating to "Moderate" or "Low"). The maximum credible lahar scenario for each volcano was classified as "Low" because it has a very low probability of occurring, while the others were placed into a "Moderate" category. DOGAMI added its own lahar data for Mount Hood which resulted in a slight expansion of "Low" hazard areas for the maximum credible lahar scenario. Any facility located within these hazard zones is considered vulnerable to volcanic hazards. Outside these hazard zones, the volcanic hazard is undetermined and categorized as "Other" rather than "None" due to the possibility of widespread volcanic effects, such as ash fall or acid rain.

Volcanic Hazard Facility Summary

Of the 5,350 state facilities evaluated, 125 were located within a volcanic hazard area and represented an approximate value of $355 million. Of those, 100 were located in the Moderate or High hazard zones. 19 critical facilities fall in a High or Moderate hazard zone, while the remaining 3 critical facilities fall into Low volcanic hazard zone. DOGAMI determined that out of the 8,757 local critical facilities, 110 were in Moderate or High hazard zones with a total value of $244 million.

Wildfire

The Oregon Department of Forestry (ODF) participated in a statewide fire hazard and risk assessment in 2018 as part of the Pacific Northwest Quantitative Wildfire Risk Assessment for Oregon and Washington (Pyrologix LLC, 2018). Following ODF guidance, DOGAMI evaluated building exposure to wildfire using the Burn Probability dataset which was classified by ODF in “High,” “Moderate,” and “Low” categories. Urban areas, lake surfaces, and areas bare of vegetation do not have fire risk classifications in the data and are also represented here as “Low.” For more detailed information regarding this dataset, refer to the Pacific Northwest Quantitative Wildfire Risk Assessment or contact an ODF representative.

Wildfire Hazard Facility Summary

Of the 5,530 state facilities evaluated, 1,111 were within the High or Moderate wildfire hazard zone and total about $950 million in value. Among critical state facilities, 365 were within the High or Moderate wildfire hazard zone. DOGAMI determined that out of the 8,757 local critical facilities, 955 were in High or Moderate hazard zones with a total value over $775 million.

2.1.6 Seismic Transportation Lifeline Vulnerabilities

Requirement: 44 CFR §201.4(c)(2)(iii): The risk assessment shall include… (iii) …The State shall estimate the potential dollar losses to … infrastructure…located in the identified hazard areas.

The Oregon Department of Transportation has been engaged for several decades in data collection on highway and bridge conditions (Oregon Seismic Lifelines Identification Project, May 2012; https://www.oregon.gov/ODOT/Planning/Documents/Seismic-Lifelines-Evaluation-Vulnerability-Synthese-Identification.pdf), development of options for mitigation against damage to roadways and bridges that may be caused by seismic events (Oregon Seismic Options Report, May 2013; ftp://ftp.odot.state.or.us/bridge/bridge_website_chittirat/Oregon_Highways_Seismic_Options_Report_3_2013.pdf) and in 2014 completed a prioritization of these options in the Oregon Highways Seismic Plus Report (https://www.oregon.gov/ODOT/Bridge/Docs_Seismic/Seismic-Plus-Report_2014.pdf) published in October 2014.

The Governor's Task Force on Resilience Plan Implementation (ORTF) recommendations on implementation of the Oregon Resilience Plan (ORP) issued in September 2014 brought forward the most critical recommendations of the ORP to be implemented in the 2015-17 biennium. With respect to transportation infrastructure resilience, the ORTF recommended that additional revenue be identified to complete the most critical backbone routes identified in ODOT's Seismic Options Report within a decade, and the complete program by 2060. The funding source should be ongoing and "pay-as-you-go," rather than financed through bonding, to provide resources for all phases over the course of several decades (Governor's Task Force on Resilience Plan Implementation, 2014).

The 2013 Oregon Seismic Options Report presented the seismic bridge retrofit as a standalone program. The program cost and implementation approach were simplified in 2014 by focusing only on seismic retrofit work on bridges and mitigation of unstable slopes along proposed lifeline routes. The ODOT Bridge Section evaluated a variety of options for blending the seismic mitigation effort with other bridge structural needs. ODOT looked for opportunities for cost effective approaches. The following classifications formed the framework for this prioritization process.

- Many bridges along Oregon state highways are in relatively good condition, with many years of remaining service life absent a major seismic event, and could benefit from a standalone retrofit project.
- Some bridges are not good candidates for seismic retrofit due to structural and other condition issues. Most of these bridges were built in the 1950s and 1960s, and many were built over poor soils which can amplify the seismic forces the bridge must endure during a seismic event.
- Other bridges will need to be replaced within the next several decades, and it makes no sense to retrofit a bridge only to replace it within a decade; for these structures, replacement will be more cost-effective in the long term than retrofit.
- Still other bridges will need significant rehabilitation work, and there would be significant cost benefits to combining retrofit and repair projects.

The 2014 Seismic Plus Report provides ODOT's last statewide seismic vulnerability assessment for state bridges and unstable slopes along the state's seismic lifeline routes. It also provides a mitigation plan for strengthening Oregon's lifeline corridors and making them seismically resilient in case of a major Cascadia seismic event. Since the publication of this report, a few state bridges have either been replaced or seismically retrofitted. Updates to the program are reflected in the annual Bridge Condition Report (ODOT Bridge Condition Report).

Phase I of the Oregon Highways Seismic Plus Report received funding through HB 2017 passed in 2017 during the 79th Oregon Legislative Assembly that has allowed scoping for seismic work on I-5 near Eugene for the 2021-2024 State Transportation Improvement Program (STIP). The initial amount is $10 million/year with increases expected over time as the gas tax revenue increases. Phase I also includes portions of I-84 that are planned for to be retrofitted moving from east to west. **Figure 2-25** below illustrates the Phases 1–5 of the Seismic Plus Report.

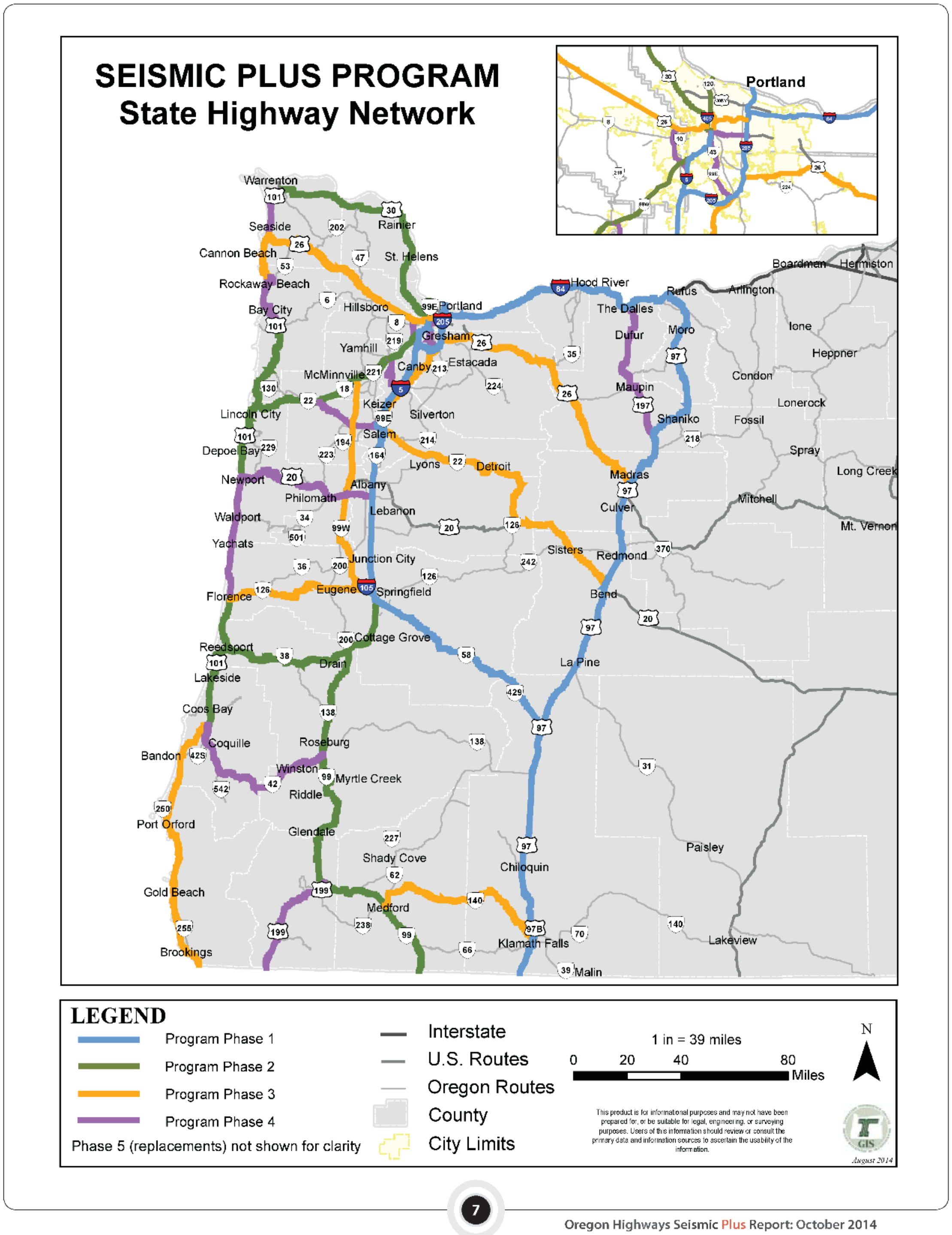
The 2021-2024 STIP funding includes $31M to address ODOT bridge seismic needs.

Since the allocation of funding in 2017, four bridges along the Phase I route have been replaced mainly due to their age and condition. ODOT's first priority for seismic retrofitting are state bridges carrying the Phase 1 highway segments. Construction is underway on the northern half of US-97 (I-84 to OR-58), while the southern half of US-97 and OR-58 is under design. Also, several bridges carrying I-205, including the Abernethy bridge, will be either replaced or widened and retrofitted as an additional benefit to a modernization project between Stafford Road and OR-213 (https://www.i205corridor.org/).

The Southern Oregon Seismic Bridge Retrofit project is currently being designed. The project includes portions of Phase 2 and Phase 3 addressing key lifeline routes to and from the Rogue Valley. The construction phase is funded.

ODOT worked in cooperation with a variety of stakeholders and decision makers over several decades to find solutions to this statewide problem. The most challenging decision is to determine when to begin these investments and how to generate the necessary revenue. As part of the statewide effort to make the Oregon highway system seismically resilient, ODOT's responsibility has become clear: retrofit all seismically vulnerable bridges and address unstable slopes on key lifeline routes in a strategic and systematic program to allow for rescue and recovery following a major earthquake.

Figure 2-25. ODOT Seismic Plus Programs State Highway Network Program Phases



The Oregon Highway Seismic Plus Program is based on the work of the Oregon Seismic Lifeline Routes identification project, which is described below.

In 2012 the Oregon Department of Transportation (ODOT) conducted the Oregon Seismic Lifeline Routes (OSLR) identification project. The purpose of the OSLR project was twofold:

- Support emergency response and recovery efforts by identifying the best connecting highways between service providers, incident areas and essential supply lines to allow emergency service providers to do their jobs with minimum disruption; and
- Support community and regional economic recovery after a disaster event.

The focus of the OSLR project is on state highway right of way, with the assumption that other transportation modes and facilities are part of an integrated lifelines system. The Oregon Seismic Resilience Plan furthers the discussion of the roles of the different modes and facilities in the aftermath of a CSZ event.

The OSLR project study recommended a specific list of highways and bridges that comprise the seismic lifeline network; and established a three-tiered system of seismic lifelines to help prioritize investment in seismic retrofits on state-owned highways and bridges.

A Cascadia Subduction Zone event has the potential to simultaneously affect all of western Oregon, potentially crippling the statewide transportation network.

This project was conducted by the ODOT Transportation Development Division (TDD) from September 2011 through April 2012, in coordination and consultation with Bridge, Maintenance, Geotechnical, and other impacted divisions within the agency, as well as with other state agencies including the Oregon Department of Geological and Mineral Industries (DOGAMI) and the Public Utility Commission (PUC) through a Project Management Team (PMT) and Steering Committee (SC). The full report (https://www.oregon.gov/ODOT/Planning/Documents/Seismic-Lifelines-Evaluation-Vulnerability-Synthese-Identification.pdf) is located in **9.1.16**, Statewide Loss Estimates: Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification.

2.1.6.1 Methodology

The OSLR project management team used the following five-step process to conduct the OSLR analysis.

Step 1: Identify Study Corridors

State highways west of US-97 were selected as study corridors that met one or more of the following characteristics (**Table 2-20**):

- Likely ability to promote safety and survival through connections to major population centers with survival resources;
- Current use as a strategic freight and commerce route; and
- Connection to one or more of the following key destinations of statewide significance:
  - I-84 east of Biggs Junction,
  - US-20 east of Bend,
  - The California border on I-5,
  - The California border on US-97,
  - A crossing of the Columbia River into southwest Washington,
  - A port on the Columbia or Willamette River,
  - A port on the coast,
  - Portland International Airport, and
  - Redmond Municipal Airport.

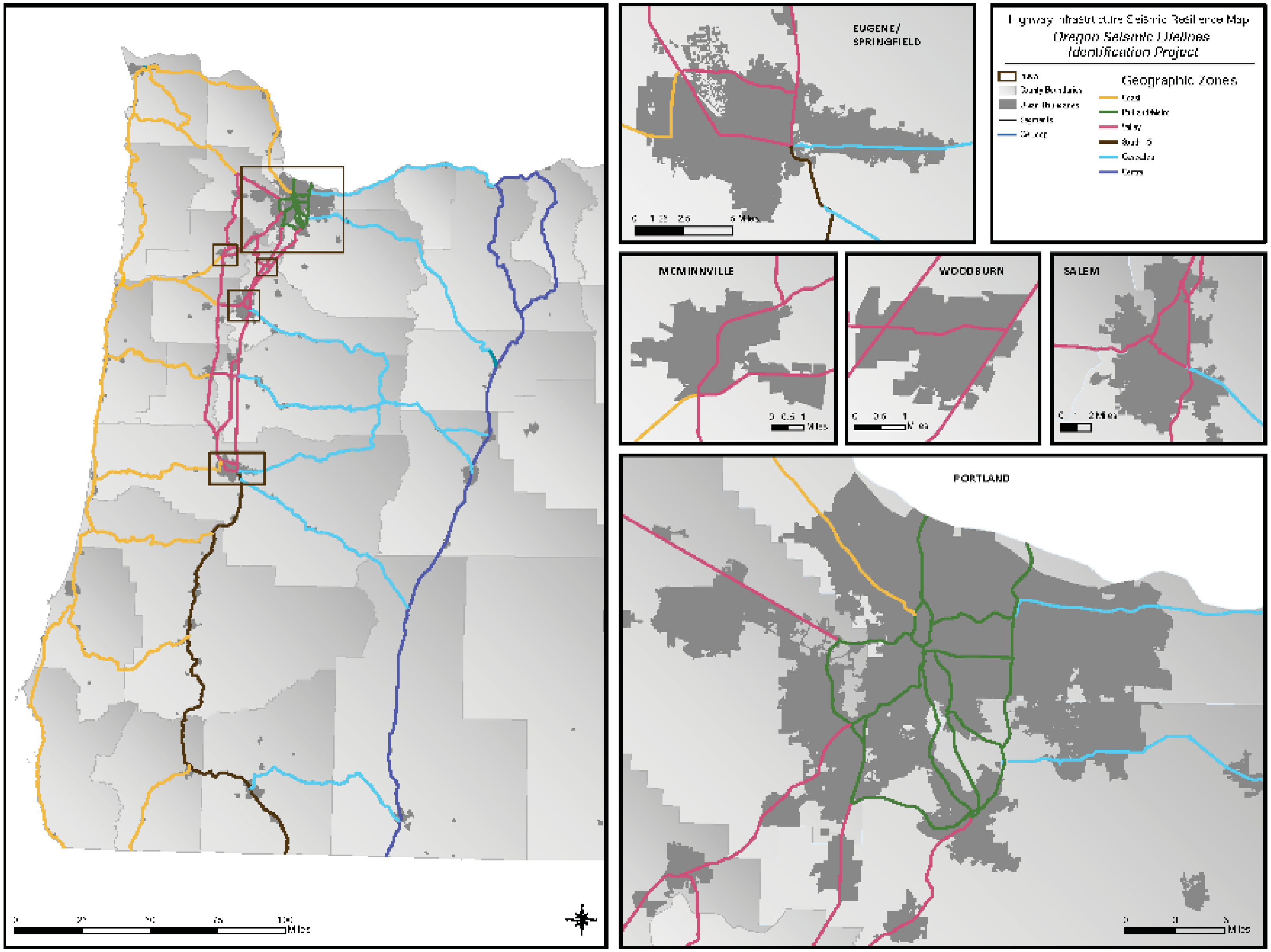
The study corridors were grouped geographically into the following six distinct zones within the western half of the state (**Figure 2-26**):

- Coast (US-101 and connections to US-101 from the I-5 corridor),
- Portland Metro (highways within the Portland Metro region),
- Valley (circulation between the Portland metro area and other major population centers in the Willamette Valley),
- South I-5 (the section of I-5 south of Eugene-Springfield),
- Cascades (highways crossing the Cascades Mountains),
- Central (the US-97/US-197 corridor from Washington to California), and
- Central (the US-97/US-197 corridor from Washington to California).

Step 2: Develop Evaluation Framework

The PMT established an evaluation framework that consists of the following four main elements: goals, objectives, criteria, and parameters (**Table 2-20**).

Figure 2-26. Oregon Seismic Lifeline Routes (OSLR) Geographic Zones



Source: ODOT

Table 2-20. Oregon Seismic Lifeline Routes (OSLR) Evaluation Framework

Goals	Objectives	Criteria
Support survivability and emergency response efforts immediately following the event *(immediate and short-term needs)*	1A. Retain routes necessary to bring emergency responders to emergency locations	bridge seismic resilience roadway seismic resilience dam safety roadway width route provides critical non-redundant access to major area access to fire stations access to hospitals access to ports and airports access to population centers access to ODOT maintenance facilities ability to control use of the highway
	1B. Retain routes necessary to (a) transport injured people from the damaged area to hospitals and other critical care facilities and (b) transport emergency response personnel (police, firefighters, and medical responders), equipment and materials to damaged areas	route provides critical non-redundant access to a major area bridge seismic resilience dam safety roadway seismic resilience access to hospitals access to emergency response staging areas
Provide transportation facilities critical to life support for an interim period following the event *(midterm needs)*	2A. Retain the routes critical to bring life support resources (food, water, sanitation, communications, energy, and personnel) to the emergency location	access to ports and airports bridge seismic resilience after short term repair dam safety roadway seismic resilience access to critical utility components access to ODOT maintenance facilities Freight access
	2B. Retain regional routes to hospitals	access to hospitals
	2C. Retain evacuation routes out of the affected region	access to Central Oregon access to ports and airports Importance of route to freight movement
Support statewide economic recovery *(long-term needs)*	3A. Retain designated critical freight corridors	Freight access bridge seismic resilience after short-term repair roadway seismic resilience after short-term repair route provides critical non-redundant access to a major area access to ports and airports access to railroads
	3B. Support statewide mobility for connections outside the affected region	access to Central Oregon access to ports and airports access to railroads
	3C. Retain transportation facilities that allow travel between large metro areas	route provides critical non-redundant access to a major area connection to centers of commerce

Source: ODOT

The criteria in the evaluation framework fell into three categories:

1. **Connections:** criteria relating to proximity to key resources and geographic areas likely to be essential after a seismic event,
2. **Capacity:** measure the characteristics of the roadway itself, and
3. **Resilience:** assess the likely capability that a corridor will function in the aftermath of a major seismic event, with or without a short term repair.

Criteria within each category are listed in **Table 2-21**.

Table 2-21. Oregon Seismic Lifeline Routes (OSLR) Criteria by Group

Connections	Capacity	Resilience
Access to fire stations	width of roadway	bridge seismic resilience
Access to hospitals	ability to control use of highway	roadway seismic resilience
Access to ports and airports	freight access	bridge seismic resilience after short-term repair
Access to railroads		roadway seismic resilience after short-term repair
Access to ODOT maintenance facilities		
Access to population centers		
Access to emergency response staging areas		
Access to critical utilities		
Access to central Oregon		

Source: ODOT

Step 3: Analyze Selected Highways

Each of the criteria were weighted and ranked (high, moderate, low performance) for each study segment.

Step 4: Solicit Feedback from Steering Committee

The OSLR project team used the results of the evaluation to identify a three-tiered seismic lifeline system — Tier 1 being the highest priority roadway segment, Tier 2 being the next highest, and Tier 3 being the third highest priority grouping to functions as follows:

- Tier 1: A system that provides access to and through the study area from Central Oregon, Washington, and California, and provides access to each region within the study area;
- Tier 2: Additional roadway segments that extend the reach of the Tier 1 system throughout seismically vulnerable areas of the state and that provide lifeline route redundancy in the Portland Metro Area and Willamette Valley; and
- Tier 3: Roadway segments that, together with Tier 1 and Tier 2, provide an interconnected network (with redundant paths) to serve all of the study area.

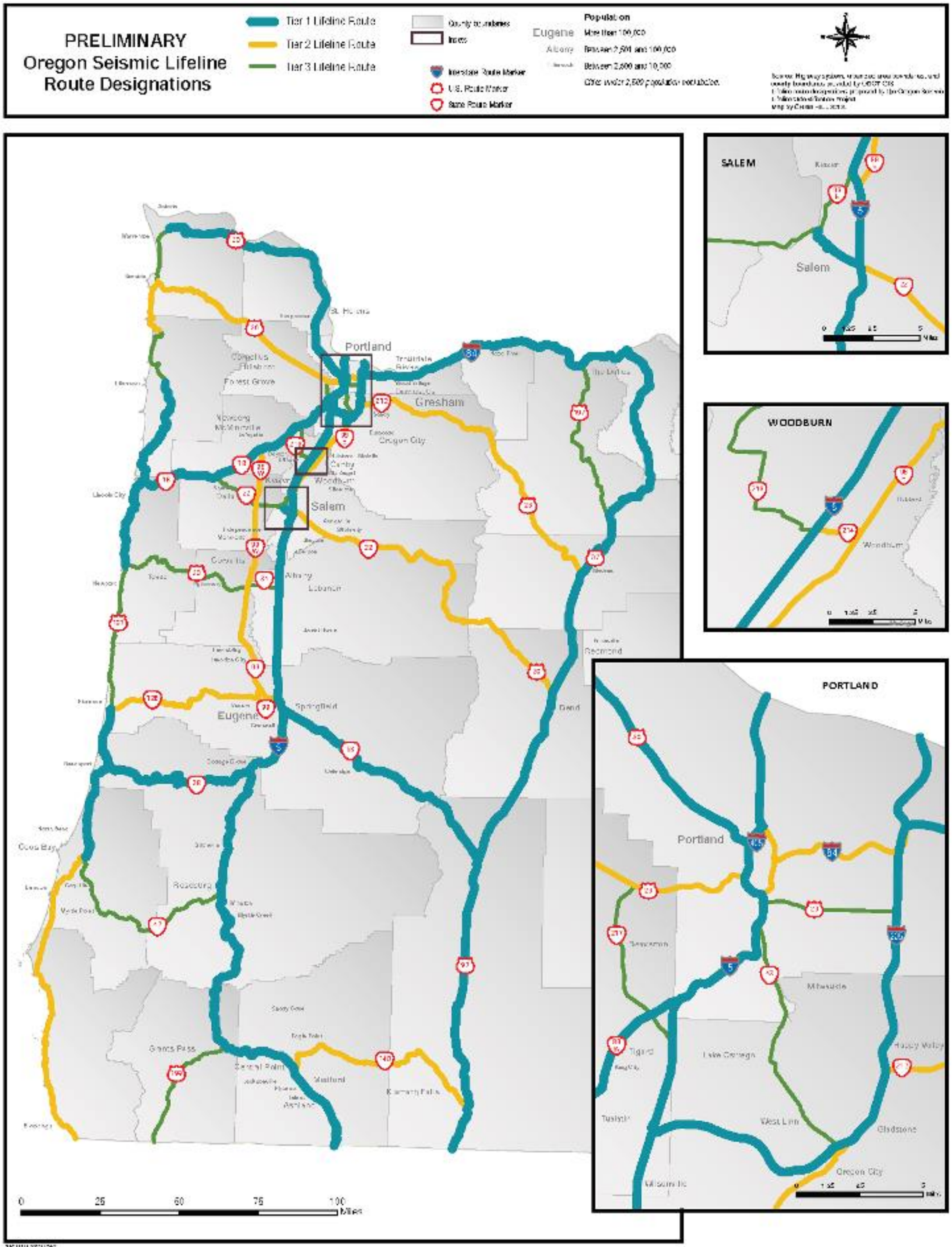
Step 5: Propose a System of Lifeline Routes

The proposed Tier 1 lifeline network shown provides roadway access to within about 50 miles of all locations in western Oregon. Total roadway miles for each tier are as follows:

- Tier 1: 1,146 miles,
- Tier 2: 705 miles, and
- Tier 3: 422 miles.

This provides a total of 2,273 miles of designated lifeline route. Study routes not identified as seismic lifelines total 298 miles. **Figure 2-27** shows the proposed seismic lifeline routes with tier designations.

Figure 2-27. Preliminary Oregon Seismic Lifeline Routes (OSLR), by Tier



Source: ODOT

2.1.6.2 Seismic Hazards Affecting Lifeline Routes

The following seismic hazards have the potential to affect the seismic vulnerability of structures (such as bridges, retaining walls, culverts, and tunnels) and roadway grades along the lifeline routes during a CSZ event:

Ground shaking. Ground shaking is a function of the distance to the earthquake epicenter, the magnitude of the earthquake, regional bedrock properties, and the stiffness of the site-specific soils. It includes the potential for ground amplification because of soft soil deposits. The effects of ground shaking, including the intensity, frequency content, and duration of the shaking, can physically damage structures (such as bridges, culverts, retaining walls, and tunnels), as well as trigger other seismic hazards (such as liquefaction and landslides).

Coseismic deformation. During a subduction zone earthquake, the tectonic plates undergo elastic deformation on a regional scale, resulting in the potential for several meters of permanent uplift or subsidence that could occur along the entire rupture zone, as expected along the entire Oregon Coast for the CSZ magnitude 9.0 event. Coseismic subsidence can affect tsunami wave heights and runup. If the ground subsides during the seismic event, the effective tsunami wave and associated runup are increased by the amount of subsidence. In addition, coseismic deformation can reduce ground elevations along low-elevation roadway grades to the extent that the elevations end up below design sea level following coseismic subsidence.

Liquefaction. Soil liquefaction is a phenomenon by which loose, saturated, and sandy/silty soils undergo almost a complete loss of strength and stiffness because of seismic shaking. Its occurrence along highway corridors is likely most significant at bridge sites (which are often near bodies of water) or along roadways that are adjacent to bodies of water (such as estuaries, rivers, and lakes). Liquefaction may cause failure of retaining walls from excessive earth pressure, movement of abutments and slopes caused by lateral spreading (liquefaction-induced slope instability), and loss of bearing or pile capacity for bridge abutments and pile caps.

Landslides. Landslide hazards are most likely to occur at locations of steeply sloping ground within the Coast Range and Cascade Mountains, or near alluvial channels. Landslides located above a roadway may lead to the blockage of a road from debris buildup. Landslides located below a roadway may cause undermining and loss of road grade. Landslides can occur at locations with recognized slope instabilities, but they can also occur in areas without a historic record of landslide activity.

However, the thoroughness of current mapping of faults for the State of Oregon is uncertain and very few of the observed earthquakes in Oregon are associated with mapped crustal faults. It is anticipated that, given the heavy vegetative cover for a lot of Oregon and the short period of time for which records have been kept, not all active faults have been identified.

Tsunamis. Tsunamis may affect lifeline routes near and adjacent to the coastline. The resulting water forces can damage structures within the tsunami run-up zone and can also cause debris buildup or inundation and the washing away of roadway grades.

2.1.6.3 State Vulnerability

Given the current conditions of the state highway system, the western half of Oregon will be profoundly impacted by a CSZ that will fragment major highways by damaging and destroying bridges, triggering landslides that obstruct and/or undermine roadways, other geological hazards such as soil liquefaction and the potential for tsunami that could overwhelm low-lying transportation facilities.

Significant loss of life is likely in tsunami prone areas. Additional loss of life from untreated injuries and disease due to a fragmented response network could also be significant. Loss of life due to structural collapse could be widespread, exacerbating by the duration of ground shaking and the size of the event at the coast, in the Coast Range, along the Lower Columbia, in the Metro area and in the central valleys.

The long-term economic impacts would be profound. Many residential, commercial, and industrial buildings would collapse or suffer significant damage. Supply lines for reconstruction materials would be disrupted and the transportation system capacity to move goods is likely to be usurped for a period of weeks for response/survival supplies and materials and personnel needed to re-establish essential services. The ability of employees and customers to get to businesses could be disrupted for weeks if not longer. Smaller and locally based businesses cannot typically survive long periods of closure.

A program to immediately (within the next few years) retrofit all seismic lifeline routes in western Oregon to current design standards is not possible with current budget limitations. Even if the State were able to embark on a program of rapid seismic strengthening of the entire highway system, let alone other regional and private transportation assets, it would be prudent to begin where the most benefit is accomplished in the least time for the least cost. That is a key premise of the development of the OSLR project and the Seismic Options Report that was, in part, based upon it.

2.1.6.4 Statewide Loss Estimates

The OSLR project included consideration of the costs of retrofitting bridges and other highway facilities to support the tiering decisions and a preliminary work for revenue requests for implementation. Cost estimates were made for construction projects to mitigate or correct vulnerabilities on the recommended Seismic Lifelines system. Details can be found in Appendix A of the Seismic Plus Report (Appendix **9.1.13**).

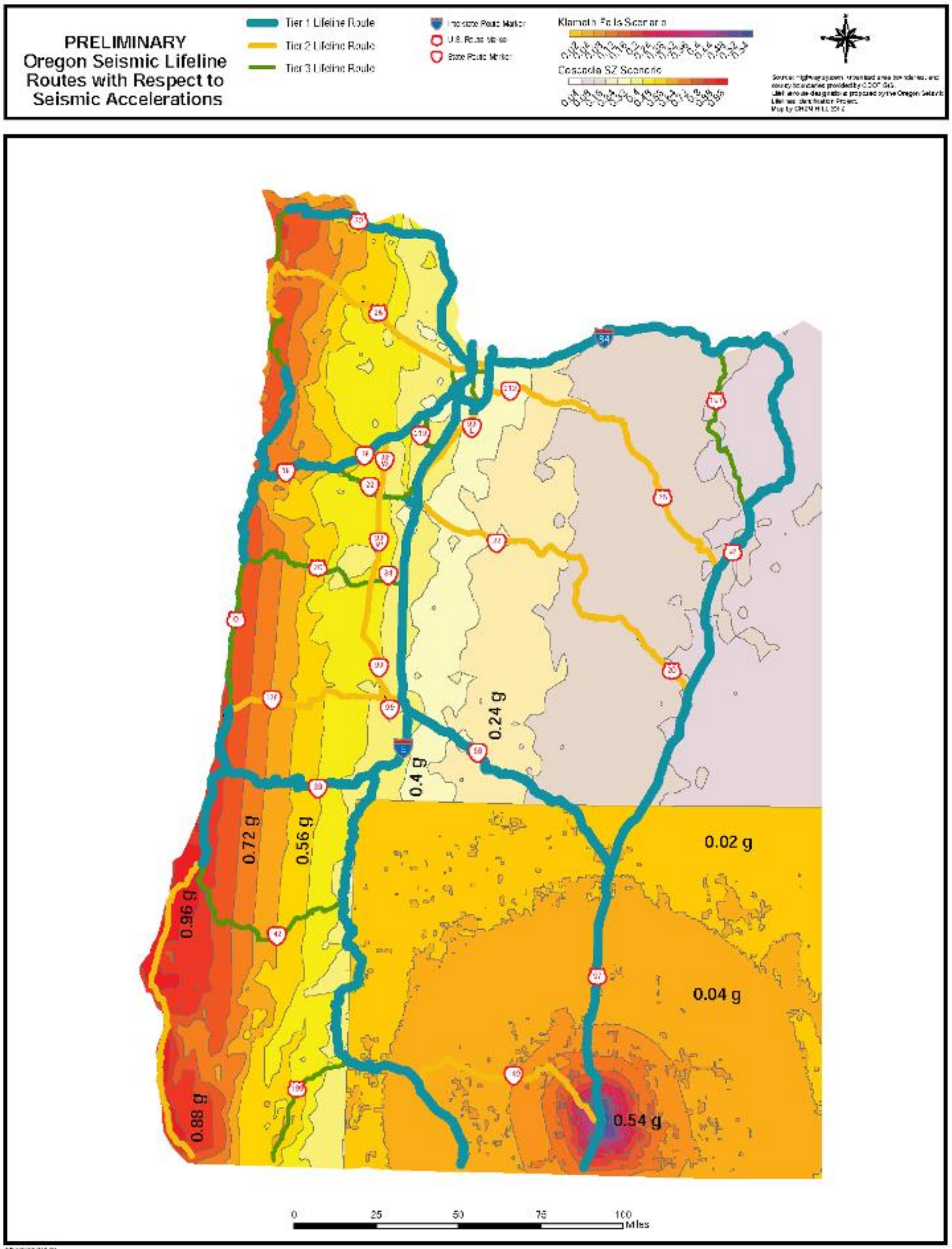
Appendices G and H of that report (Appendix **9.1.13**) address both a scenario wherein a major earthquake occurs and a scenario wherein a major earthquake does not occur**.** This analysis was done to answer a slightly different question: what is the value of making the recommended improvements to the identified lifeline routes?

> *"Significant economic losses in production activity can be avoided by preparing for a major earthquake ahead of time. With no preparation ahead of time, Oregon could lose up to $355 billion in gross state product in the 8 to 10 year period after the event. Proactive investment in bridge strengthening and landslide mitigation reduces this loss between 10% and 24% over the course of the eight years simulated for this analysis."*
>
> *By keeping bridges that would otherwise decay and restrict the movement of freight open to heavy trucks, the proposed program will have significant benefits to Oregon's economy even if we avoid a major earthquake. ODOT's analysis (see Appendix H) indicates the investments in bridge replacements and rehabilitation made over the initial two decades of the Seismic Plus Program will avoid the loss of 70,000 jobs by 2035, compared to the significant deterioration in bridge conditions that will occur with the current levels of investment in bridges. This benefit occurs regardless of whether Oregon suffers a major earthquake and is on top of the significant economic losses avoided by the Seismic Plus Program in the event of an earthquake."*

It is important to note that the losses considered in the economic analysis only considered impacts directly related to transportation system failures. It did not account for impacts outside of the transportation economic impacts such as the collapse of industrial or commercial buildings or basic service failures. Even so, the benefit to cost ratio of making needed improvements to the Seismic Lifelines system is 46:1.

Figure 2-28 shows seismic vulnerability of proposed lifeline routes relative to projected ground shaking from a CSZ event. These lifelines, including bridges on these roadways, are the most significant vulnerabilities of the state highway system.

Figure 2-28. Preliminary Seismic Lifeline Routes and Seismic Acceleration



Source: OSLR, ODOT

Bridges: Bridges are the most significant vulnerabilities of the state highway system. They are primarily vulnerable to the following seismic hazards:

- Ground shaking, which can result in structural damage of the bridge elements;
- Liquefaction, which can result in movement or failure of the abutments and/or the bridge piers;
- Tsunamis that can scour or result in large loads on bridge piers and abutments and, if high enough, can damage the bridge superstructure; and
- Landslides that can undermine a bridge.

Road grade vulnerabilities: Roadway grades are vulnerable to the following seismic hazards:

- Ground shaking, which can result in structural damage of roadway elements, including culverts, retaining walls, and abutments;
- Liquefaction, which can result in movement or failure of the slopes and ground under and adjacent to the roadway;
- Landslides, which can result in failure of the slope above the roadway (which may lead to the blockage of a road from debris buildup) and/or failure of the slope below the roadway (which may result in loss or complete failure of road grade). Landslides may be known, new, or ancient slides reactivated by ground shaking. Landslide potential is most prominent in the Coast Range and Cascade Mountains.
- Tsunamis, which can scour or deposit debris on the roadways making them inaccessible; and
- Coseismic deformation, which can result in the roadway grade being below design sea level.

Tunnels: Tunnels generally perform well in seismic events; however, some amount of rock fall and structural damage is likely, particularly at portals. The length of tunnels along each segment was tabulated.

Dams: Dams can pose significant risk to roadways because of releases of large volumes of water that can wash out roadway grades and scour out bridge foundations. This sudden release of water could be due to a dam failure, intentional rapid drawdown in response to structural damage, or overtopping due to a landslide into the upstream pool. Furthermore, rapid drawdown of water levels can also cause slope failures upstream of the dam along the edge of the reservoir. The dams identified in this study are those that have a potential to pose a risk to a state highway. Only one segment was noted to be at risk per dam, in spite of the fact that a dam failure may cause damage on multiple downstream segments. In general, segments farther downstream are at lower risk due to attenuation of the flood wave and the fact that further downstream waterways and crossings generally have a larger capacity.

2.1.6.5 Data

The main sources of data used to analyze the seismic vulnerability of each highway segment include:

- ODOT GIS database;
- DOGAMI references;
- U.S. Geological Survey (USGS) seismic hazard references;
- Risks from Earthquake Damage to Roadway Systems (REDARS2) data;
- DOGAMI and the Federal Emergency Management Agency evaluations of the potential impacts of a major seismic event in Oregon;
- Local knowledge of CH2M HILL staff who have lived and worked in these regions;
- Interviews with key maintenance and technical staff at ODOT;
- Interviews of technical and field staff at DOGAMI; and
- Public mapping databases, including aerial photographs, digital terrain models (DTMs), and transportation GIS databases.

During the last 15 years ODOT Bridge Section has compiled statewide hazard and vulnerability data including data on bridge seismic vulnerabilities and existing landslides, while other state and federal agencies have compiled geographic and other data defining seismic risks including predicted tsunami inundation zones. That work was the foundation of the OSLR study. Most of the earlier studies have been either comprehensive (statewide) but imprecise, or precise but not comprehensive.

Some statewide information used in the OSLR analysis (for example, the landslide data) was compiled from various sources and is based on varied data-gathering technologies and data-evaluation methods. Therefore, the data are highly variable and are not precise or consistent as a whole. Some older statewide or region-wide data were used in this project in place of more recent site-specific information to provide a platform to make relative comparisons (rather than absolute measures) of seismic risks along various candidate lifeline routes.

2.1.6.6 Anticipated Next Steps

Funds provided by the HB 2017 are mainly allocated for the seismic work on Phase 1 highway segments. With the current budget for bridge seismic retrofitting, it may take even more than the originally planned (20–30 years) to strengthening all the roadway in Phase 1. The 2014 Seismic Plus Report shows similar mitigation costs for other phases, but those figures will look much different 20-30 years from now. It is not clear how long the HB 2017 will authorize funds to support ODOT's seismic program, but even if it were to be indefinite, inflation 20–30 years from now will diminish the buying power of these funds (Albert Nako, Elizabeth Hunt, and Bret Hartman, personal communications, May 2020).

During the 2021–2024 STIP cycle is the first time any of the seismic program work has been field scoped providing updated costs. The scoping results were much higher than the planning level estimates previously calculated due to:

- More detailed level estimates that capture site specific costs associated with staging and foundation work; and
- A recent trend of increasing construction costs noted for all work types across the Agency (Oregon Department of Transportation, 2019).

Based on the estimated costs, it would take decades to complete Phase 1 of the Seismic Plus Program at which time many of the bridges that were initially retrofitted would be reaching the end of their service life. Without additional funds it is unlikely that all five phases could be completed as planned. Most of the bridges would be replaced because of their age and conditions before they would be considered for seismic retrofit. Also, to address seismic resiliency bridges still in relatively good condition would need to be replaced (Oregon Department of Transportation, 2019).

Discussions are continuing around options to maximize the value of the HB 2107 seismic funding. The first priority will be on retrofitting major river crossings. The major I-5 river crossings between Eugene and Portland include the Boone Bridge, which will be evaluated as directed by the 2019 Legislature, and the Santiam River Bridge. To address the seismic resiliency of the Southbound Santiam River Bridge, the plan is to include retrofit work as part of the 2021–2024 STIP (Oregon Department of Transportation, 2019).

The second priority will be around evaluating alternate lifeline routes by addressing the portion of I-5 north of Eugene similar to the Southern Oregon Triage project. The process of identifying a route south of Eugene, involved a triage strategy that included the use of local roads and bridges to provide a lifeline following a Cascadia seismic event (Oregon Department of Transportation, 2019).

HB 2017 seismic funding available after the Southbound Santiam River Bridge retrofit is funded will be used to address bridges identified for work as part of an updated strategy (Oregon Department of Transportation, 2019).

During the 2021-2024 STIP scoping process, ODOT realized this need to re-evaluate the current approach. Since publication of the 2019 Bridge Condition Report, ODOT has developed a Seismic Implementation Plan that currently is in draft form and anticipated for Oregon Transportation Commission approval sometime in the later part of 2020. The Implementation Plan will provide guidance for maximizing seismic resiliency with the current budget by considering detour routes for the most expensive state bridges and/or adopting triage approaches for certain highway segments (Albert Nako, Elizabeth Hunt, and Bret Hartman, personal communications, May 2020).

HB 2017 provided funding for an additional seismic project entitled the Southern Oregon Triage strategy. The strategy focuses on mitigating seismic impacts along Interstate 5 south of Eugene, and OR 140, which are key lifeline routes to and from the Rogue Valley. Most of the seismic impacts on the routes are expected to be addressed through quick repairs or temporary detours. The funding will be used to address those bridges and potentially unstable slopes that are more problematic or where a feasible detour does not exist (Oregon Department of Transportation, 2019).

Right of way funding is available for Coastal Maintenance Stations at central coast and Coos Bay; an additional facility at Astoria is being considered but is not currently funded. Each station will be supplied with seismic response kits. The purpose of the kits is to stockpile key materials and supplies that can be used to assist local communities in the early days following a seismic event. The kits will include culvert pipes of various sizes; construction materials; solar power generators and trailer mounted solar light panels; diesel and unleaded fuel storage tanks; survival supplies (water, field rations, first aid supplies); power tools; batteries; portable boats; flat railroad cars; and satellite phones and Ham radios (Oregon Department of Transportation, 2019) (personal communications with ODOT staff, May 2020).

The Bridge Seismic Standards Engineer and other ODOT leadership, is working collaboratively with Oregon counties to develop planning reports documenting county routes and priorities for seismic resiliency. ODOT provides bridge data and technical support and the counties provide information about their network. While the information is useful for county planning, a comparison can be made to the state seismic bridge priorities to determine possible state highway detour routes that may be more cost effective to seismically retrofit or replace. Eventually the planning reports may provide an opportunity for seismic resiliency funding from either state or federal funds (Oregon Department of Transportation, 2019).

2.1.7 Cultural Resources

2.1.7.1 Overview

Every day, in countless ways, Oregonians experience their cultural heritage. They drive roads following routes first created by pioneers or Native Americans. They buy food from century-old farms. They shop at businesses in historic commercial areas. They visit parks created years ago by Oregonians with visions of healthy communities.

Oregonians attend schools and work in buildings built by and named for historic people, whose fortitude and dreams created the businesses and communities they live in. An Oregonian's engineering or medical discovery decades ago may have been the breakthrough that enabled today's medical treatment.

An Oregonian's dress, food, language, material goods and music are the tangible remnants of heritages transmitted to them from previous generations of Oregonians and from those new to Oregon. This means heritage is found in the closet, the workplace, the auditorium, the historic barn and elsewhere. In short, Oregon heritage is everywhere.

Our diverse Oregon cultural heritage attracts visitors to Oregon, who in turn help our economy. Eighty-three percent of the leisure tourists responding to a Mandala Research study in 2012 said they are cultural and heritage tourists for whom heritage activities and places were important to their decision to vacation in Oregon. Cultural and heritage activities are especially popular with "well-rounded, active" tourists. These active tourists are the most common variety of tourist in Oregon and they spend on average 39% more on their visits than the average tourist.

Oregon recognizes the importance of protecting and preserving the natural, cultural, and historic resources found throughout the state. Additionally, the economic impact that these resources have on local, regional, and statewide tourism is documented and significant. The important connection to our history and our future economic growth is tied to the deliberate efforts to preserve these resources. Oregon's recognized experts — Oregon Parks and Recreation Department, the State Historic Preservation Office, and the Oregon Heritage Commission — are essential partners in the identification, protection, and preservation of Natural, Cultural, and Historical Resources (NCHR) on mitigation projects. Through agency partnership, and at all levels of government, we share responsibility to develop plans of action that ensure these important resources are preserved for future generations to connect with, experience, and enjoy.

2.1.7.2 Existing Efforts

The State's success in preserving Oregon's resources through intentional planning and mitigation efforts through collaborative partnerships and creative approaches is an ongoing process. This work is accomplished by working with local, tribal, state, and national partners to increase the awareness of Natural, Cultural, and Historical Resources (NCHRs) and identifying opportunities to protect them through existing site specific plans and actions. OEM is committed to requiring local jurisdictions to follow all applicable laws, rules, and regulations related to resource protection in mitigation projects administered by the State Hazard Mitigation Officer.

An example of this commitment through action is the availability of NCHR-related information on OPRD's website and encouragement of consideration of NCHRs in disaster planning. This information is designed to assist emergency managers, organizations, and agencies charged with protecting and preserving collections, sites, and artifacts in making informed decisions related to NCHR. OPRD intends to promote awareness, Best Management Practices, and dialog within the emergency management community and the professionals that maintain these important resources.

OEM curates and manages a GIS system called RAPTOR (Real-Time Assessment and Planning Tool for Oregon). This used by emergency managers before, during, and after disasters in staying informed of developing situations and maintaining an awareness of issues or resources at risk. NCHR information in RAPTOR ensures an awareness of resources at risk and allows for consideration in the development of mitigation, response, and recovery actions that can help protect them. NCHRs are included in the RAPTOR training being delivered to emergency managers to ensure they are aware of existing data sets that can assist them in their decision making process.

For the 2020 Risk Assessment, OPRD provided a spreadsheet of historic structures and their attributes that DOGAMI developed into a GIS layer and analyzed against the seven hazards included in the 2020 Risk Assessment pilot. The resulting report indicated the number of historic resources in each hazard area in each county and statewide. This information was used to inform the vulnerability analyses in the state and regional risk assessments. The next steps would be to rank the resources according to type and significance, map them, and develop strategies for better protecting them from the hazards to which they are vulnerable.

In addition, for the 2020 Risk Assessment, OPRD conducted just such a GIS analysis for archaeological resources against four of the seven hazards: coastal erosion, earthquakes, floods, and landslides. Technical difficulties prevented analysis at this time against tsunamis, volcanic hazards, and wildfires. The resulting report indicated the number of archaeological resources:

- In each county;
- Listed on the National Register of Historic Places;
- Eligible for listing;
- Ineligible for listing; and
- Eligibility not yet evaluated.

This information was used to inform the vulnerability analyses in the state and regional risk assessments. Next steps would be to overcome the current technical difficulties and produce the same results for the remaining three hazards; map the resources; and develop strategies for protecting them from the hazards to which they are vulnerable. These steps will have to be carefully planned and executed to comply with laws and rules about access to sensitive archaeological data.

2.1.7.3 Future Strategic Opportunities

There is a recognized need for additional staff at OEM and some of that need is for attention to natural, cultural, and historic resources in mitigation and recovery projects. Additional staff could provide assistance in the development of onsite, tailored project proposals that include consideration of NCHRs. Specific guidance on project application development considering NCHR presence, known risk potential, and mitigation opportunities throughout the development of any local project proposal would result in more consistent compliance with FEMA's Environmental Planning and Historic Preservation Program (EHP) requirements as well as in elevating the importance of the consideration and inclusion of NCHRs in the mitigation and recovery program at all levels of government. This would enable OEM to develop an implementation strategy including formal planning processes, mitigation project standard operating procedures, and mechanisms that ensure NCHRs are considered in comprehensive mitigation planning efforts.

As part of a future risk assessment process, methods to determine potential collection losses in monetary value as well as methods to assess potential tourism loss as a result of collection damage or destruction could be identified and implemented. This would be followed by possible mitigation strategies to protect cultural and historical resources. Additionally, some strategies are offered as ways to provide technical assistance to local governments and nonprofit organizations to ensure cultural and historic resources of local significance are included in risk assessment and mitigation strategies.

1. Possible actions to assess risk to cultural and historic resources of statewide significance in a future <u>risk assessment:</u>
    a. Actions related to assessing exposure of cultural and historic resources of statewide significance to potential damage from natural disaster events —
        - Continue to update historical resource surveys to maintain an accurate inventory of resources at both the state and local levels.
        - Survey and re-survey historic repositories and ensure resource catalog information is current.
        - Continue to develop a GIS inventory of resources that has current, verified information which can then be used in concert with hazard specific GIS information to identify resources at risk and the level of hazard potential exposure to which they are subject.
        - Prioritize combining resource data layers and known hazard data layers to identify resources at risk and prioritize mitigation efforts to protect and preserve them.
        - Continue to provide emergency preparedness training to museums, libraries, and archivists to assist them in understanding the risks to their collections and steps they can take to minimize damage.
        - Work toward compatibility of historic site databases so they can be integrated into a single mapping system.
        - Create and promote local incentives to inventory, designate, and rehabilitate historic properties.
    b. Actions related to assessing potential damage to cultural and historic resources of statewide significance and resulting dollar losses from natural disaster events —
        - Survey existing federal, state, and local jurisdictions' potential damage assessment tools for natural, historical, and cultural resources. Identify models or modify models that are feasible for use in Oregon.
        - Survey existing federal, state, and local methodologies currently in use for valuation of resources. Identify multiple methods that are peer group or nationally accepted forms of valuation.

- Develop and deliver training to emergency managers and resource curators on valuation methods. Encourage emergency managers and resource curators to estimate potential losses in both collection damage/loss as well as economic impacts due to a loss of tourism and visitors.
- Encourage emergency managers to include these estimated potential losses in their planning and prioritization of mitigation projects to ensure resource protection and preservation.
- Identify existing data sets and develop assessment tools to estimate the economic loss potential to the state economy from impacts to historic buildings, organizations, and businesses located in historic buildings, and tourism.

2. Possible actions to include cultural and historic resources of statewide significance in a future <u>mitigation strategy</u> —
    a. Actions related to identifying how to protect cultural and historic resources of statewide significance from potential damage from natural disaster events —
        - As natural, cultural, and historic resource data sets are updated and become available in GIS data layers, this information can continue to be combined with existing natural hazard information to assess existing risk potential and possible mitigation opportunities.
        - Provide training to state and local decision makers on the availability of these data sets and how the information can be used to identify resources at risk.
        - Provide guidance on methods of assessment for the potential economic impacts as a result of resource damage or loss.
        - Continue to add resource inventories into GIS layers for access to the information in RAPTOR by emergency managers for planning, response, recovery, and mitigation activities.
    b. Actions related to providing funding or technical assistance to local governments for including cultural and historic resources of local significance in local NHMP risk assessments and mitigation strategies —
        - Provide technical assistance to local governments related to the identification, risk assessment, valuation, and mitigation options and opportunities to ensure resource protection and preservation.
        - Update resource inventory databases and work toward the consolidation of this information into a single location that can be used by emergency managers for awareness and consideration in local NHMPs.
        - Work toward developing and providing resource identification and preservation training opportunities targeting emergency managers, historic site owners, and collection curators to promote collaborative planning efforts.
        - Assess national, state, and local programs to identify best management practices related to emergency management and resource protection efforts. Include the results of this work in training courses delivered to emergency managers, historic site owners, and collection curators.

- Identify opportunities to include volunteers and collection curators in the mitigation, notification, response, and recovery phases of disaster management to ensure resource protection.
- Continue to assist local representatives in resource identification and recordation.
- Compile "Connecting to Collections" disaster plans and engage organizations in sharing them with emergency managers for inclusion in local NHMPs. Use the collection to promote the development of additional plans through awareness and technical assistance.

2.1.7.4 Summary

OEM will continue to incorporate natural, cultural, and historical resource consideration and compliance in all mitigation and recovery projects. As additional information related to these resources becomes more accessible through the use of current and new technology, decision makers at all levels will have the opportunity to make more informed decisions that ensure protection and preservation. These resources are important for the historical significance as well as the economic impacts to the community of Oregon. With additional staff, OEM and OPRD could increase the level of consideration and prioritization of NCHRs in mitigation work and pre-disaster planning, fostering more consistent consideration of NCHRs in mitigation and recovery projects and planning while protecting and promoting Oregon's historical treasures.