Chapter 3 Hazard Identification and Risk Assessment

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A natural hazards risk assessment provides the factual foundation for establishing broad mitigation goals and identifying promising places to look for specific mitigation projects that could reduce risks of natural hazards to people, property, and the natural environment. A risk assessment provides actionable information to natural hazard mitigation planners and funders to reduce risks of harm from natural hazards. A risk assessment does not, however, provide sufficient detail to evaluate potential projects at specific locations, and does not substitute for benefit-cost analysis (BCA) to determine whether specific projects are eligible for grants. One of the key assumptions of this assessment is that social and economic settings significantly contribute to the potential for harm.

This natural hazard mitigation plan uses two complementary tools to assess risk from different perspectives:

- National Risk Index
- Oregon Natural Hazards Risk Assessment

3.1 National Risk Index

The Federal Emergency Management Agency (FEMA) created the National Risk Index (NRI) in collaboration with various stakeholders and partners in academia; local, state and federal government; and private industry. It is a dataset and online tool to help illustrate the United States communities most at risk for 18 natural hazards. The Risk Index leverages available source data for natural hazard and community risk factors to develop a baseline risk measurement for each United States county and Census tract. For comprehensive details about the Risk Index, see the National Risk Index Technical Documentation.

3.1.1 Strengths

The NRI includes an estimate of expected annual loss in dollars for each census tract for each hazard. It includes social vulnerability data to recognize that the same physical event will have different impacts on people based on their characteristic and conditions. It also incorporates a community resilience index because the impact of a disaster on an individual can be reduced or magnified based on the support or lack of support from a resilient community.

3.1.2 Weaknesses

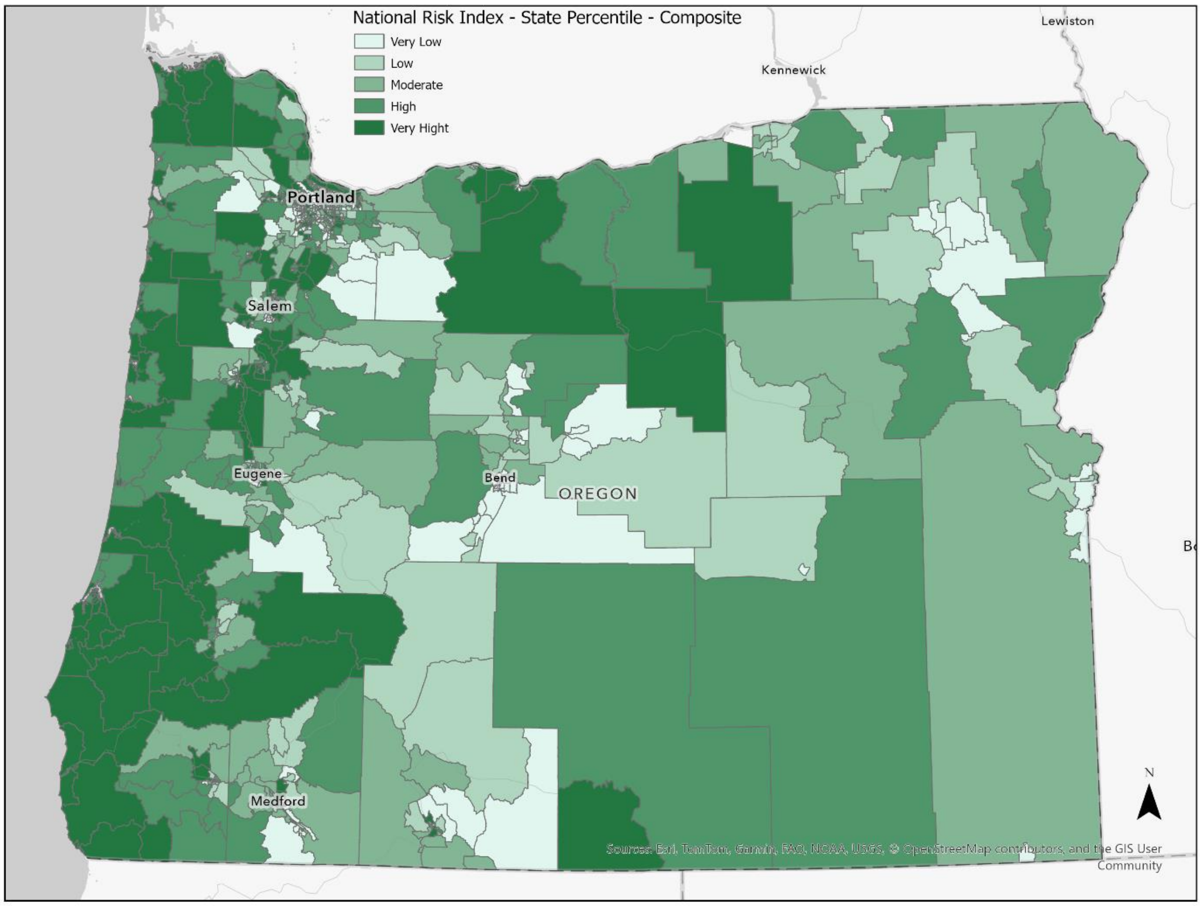
The NRI focuses on monetary values. It shows higher risk in areas with more expensive buildings and insured agricultural crops. Death and injury are counted as value-of-a-life losses to people, not disruption or monetary losses to individuals. The NRI is based on historic and current conditions. It does not account for future conditions that may be different from previous conditions. Thus, it does not meet the requirements of 44 CFR § 201.4(c)(2)(i) which require that an NHMP include, "information on previous occurrences of hazard events, as well as the probability of future hazard events."

3.1.3 Risk Maps

The Federal Emergency Management Agency, National Risk Index (NRI), maps natural hazard risk for 18 natural hazards, 11 of which occur in Oregon. DLCD downloaded the Oregon data to produce maps showing the all-hazards composite risk, and risk for each hazard. The all-hazards composite risk map is shown in Figure 3.1.3-1**Error! Reference source not found.**. Hazard specific maps are in section 3.3, following the description of each hazard.

Jenks Natural Breaks used to categorize percentiles from very low to very high. The NRI evaluates more hazards that does the Oregon Natural Hazards Risk Assessment. NRI hazards evaluated for Oregon are: avalanche, **coastal flooding**, cold wave, **drought**, **earthquake**, hail, **heat wave,** ice storm, **landslide**, lightning, **riverine flooding**, strong wind, tornado, **tsunami, volcanic activity, wildfire**, and **winter storm**. Natural hazards in bold are evaluated in the Oregon Natural Hazards Risk Assessment.

Figure 3.1.3-1: National Risk Index All-hazards by State Percentile



3.2 Oregon Natural Hazards Risk Assessment

The Oregon Department of Land Conservation and Development and the Oregon Department of Geology and Mineral Industries produced the Oregon Natural Hazards Risk Assessment (ONHRA) using data at the census tract scale. Oregon has 993 inhabited census tracts.

The ONHRA uses a statistical model to assess risk from nine natural hazards:

- Flood
- Coastal hazards
- Tsunami
- Drought
- Extreme heat
- Landslide
- Volcano
- Wildfire
- Earthquake

The ONHRA includes narrative descriptions without modeled results for three natural hazards:

- Windstorms
- Winter storms
- High hazard potential dams

Hazard mitigation risk assessments typically focus on areas and communities most at risk of harm from natural hazard events. These impacts can be viewed in a utilitarian lens— mitigating impacts to the greatest number of people and highest value properties. The ONHRA uses percentage of assets exposed to natural hazard events in a census tract rather than counts or asset values. This approach highlights where harms may be experienced more acutely. Many of the census tracts and cities highlighted by the ONHRA have low populations. These are areas that state mitigation planners often overlook even though there may be cost-effective mitigation projects in these areas (GAO 2025; Reilly et al. 2023).

This risk assessment pairs well with other assessment approaches, such as FEMA's National Risk Index (NRI). The Oregon risk assessment complements the NRI with its holistic view of hazard vulnerability. The Oregon risk assessment does not determine grant funding distribution; it merely highlights areas and people that may be good candidates for mitigation opportunities, as these communities may be missed by broader assessments focused primarily focused on dollar losses, such as the NRI. This risk assessment offers a holistic view of statewide risk to natural hazard impacts. This tool is also useful for local planning work such as outreach, creative mitigation project planning, and identifying areas for additional mitigation consideration. The ONHRA identifies mitigation focus areas in which information about state-owned or leased buildings, critical facilities, and lifelines located in these areas. The document provides brief descriptions of demographic changes in the mitigation focus areas.

3.2.1 Literature Review

Land use planning problems have multiple and often conflicting desired outcomes. Comprised of 19 statewide land use planning goals, Oregon's land use planning system is aimed at comprehensive planning for balanced land use outcomes, including hazard mitigation. The Oregon natural hazard risk assessment upgrade aims to achieve these same goals: holistic planning to mitigate risks of natural hazards to people and property. Within climate change adaptation and disaster preparedness, response, and recovery literature, integration between natural hazard mitigation and comprehensive community planning is a well-established goal (Pearce 2003).

This section provides details of the literature that the Oregon Department of Land Conservation and Development staff drew upon to inform the development of its upgraded natural hazard risk assessment tool. First, terms and definitions are provided, then a discussion of the social context of resilience. Then, an overview of multi-criteria decision method (MCDM) tools and their applications is provided. Next, a discussion of the Preference Ranking METHod for Enrichment Evaluations (PROMETHEE) method and use in risk assessment and planning, and how climate change is considered and evaluated in the natural hazard risk assessment. Finally, supporting literature and rationale for each included indicator is included. Technical application information is detailed in methods.

3.2.1.1 Defining Resilience

Hazard mitigation planning aims to enhance the capacity of a community to anticipate, respond, adapt and recover from natural hazard events. Mitigation planning helps communities adequately prepare for, and prevent or mitigate, the impacts of hazard events; such planning supports community *resilience*. A resilient community can absorb disturbances, such as hazard events, without significant structural or functional changes. Resilience is effectively synonymous with social ecological systems (SES) theory and definitions (Gunderson and Holling 2002). The resilience paradigm, as with any conceptual model, comes with attendant biases and shortfalls. Scholars have pointed out that traditional resilience thinking has several strong biases: the simplification that people's knowledge, values, and livelihoods primarily concern the environment; the homogenization of social complexities and assumption that people's experiences and expectations of what it means to be 'resilient' are the same; and the social value attached to the term 'resilience' (Fabinyi et al. 2014). As academics have succinctly asked, mitigation planners concerned with community resilience must ask, "resilience to what? Resilience for whom?" (Cote & Nightingale 2012; Cutter 2016). DLCD brings experience as planners into conversation with the resilience and mitigation literature. This iterates in a few ways. First, DLCD brings a planning-oriented approach to understandings of resilience. Resilience is not converse vulnerability, and there are multiple ways of knowing and understanding resilient systems and environments. In this assessment, resilience is a system attribute and potential outcome, if mitigation to address vulnerabilities and thus, risk, is successful. Next, this assessment methodology follows traditional conceptualizations of hazard vulnerability. Vulnerability is a function of exposure, sensitivity, and capacity to adapt to hazards (Adger 2006). Risk is a product of probability of hazard occurrence and the vulnerability of a certain area or group. Thus, risk is informed by vulnerabilities. In this way, the natural hazard risk assessment considers vulnerabilities, but is not entirely driven by vulnerability. Probability of hazard occurrence is an equally important driver in identifying particularly risky areas, and thus, strong candidate for mitigation investments.

Alarming rates of environmental and climate change have inspired policymakers and scholars to rethink the link between natural hazard mitigation and climate change adaptation actions. Mitigation typically aims to anticipate and prevent harms or losses resulting from natural hazard events, whereas adaptation responds and reorganizes to better cope with harms from natural hazards. For many communities across the state, it is not possible to mitigate every potential harm resulting from hazard events. Adaptation becomes a necessary process. This risk assessment acknowledges several nuances to the mitigation and adaptation link. Actions that may benefit one community may cause unintentional or unforeseen harms to another. Additionally, the burden of adapting or mitigating may fall on more vulnerable communities, creating or reinforcing disparate burdens on these communities. Finally, the benefits of mitigating or adapting may not be evenly spread. However, effective mitigation and adaptation practices clarify definitions, goals, and encourage the consideration of a broad range of expertise and knowledge. This assessment attempts to address these concerns by reframing potential adaptation actions towards a "whole community" framework.

3.2.1.2 Multi-Criteria Decision Analysis (MCDA) Tools

To achieve those goals, this analysis implements Multi-Criteria Decision Analysis (MCDA) to enhance risk assessment capabilities within Oregon's comprehensive land use planning system. MCDA tools have a rich history of practitioner and research applications in a variety of problem-solving settings. Multi-criteria decision analysis (MCDA) methods are widely used decision-making tools that are used to choose between multiple alternatives that have a mix of, often conflicting, criteria or desired outcomes and cannot be easily compared. There are several types of MCDA, which range from distance-based methods, pairwise comparison-based methods, utility-based methods, and outranking methods.

Distance based methods use linear algebra to identify the ideal alternative based on the shortest distance to the ideal solution and the farthest distance to the negative solution. This method uses an algorithm (Dijkstra's algorithm) to solve a shortest path problem and distance (Euclidian, city block, great circle, n-dimensional) and arrive at the most satisfactory answer for a given set of criteria. The most applied methods include Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), (Hwang & Yoon 1981). TOPSIS has frequently been used in disaster management for flooding and transportation assessments, and for seismic vulnerability assessments.

Pairwise comparison- based methods such as analytical hierarchy and analytical network processes (Saaty 2005) and Best-Worst Method (Rezaei 2015; Rudd & Fleishman 2014) prioritize options by comparing them in pairs and groups. Similarly, utility-based methods evaluate and prioritize options by assigning relative importance to different criteria. These methods rely on multi-attribute utility theory.

The best-known methods in this class are Step-wise Weight Assessment Ratio Analysis (SWARA), Weighted Aggregated Sum Product Assessment (WASPAS), and Complex Proportional Assessment (COPRAS). Agarwal et al. (2020) evaluated humanitarian supply chain management issues using a hybrid between SWARA and WASPAS. Rahman (2020) developed models to identify the optimal spatial distribution of emergency evacuation centers to improve flood emergency management in Bangladesh.

Interaction based methods interpret the effects that criteria in the decision-making hierarchy have on Laboratory (DEMATEL) (Gabus & Fontela 1972). DEMATEL has been a popular decision-making method in disaster management (Sen et al. 2021; van de Lindt et al. 2020; Yang et al. 2018).

Finally, preference-based methods consider the superiority of one alternative over the other, given a set of criteria and relative weighting. Methods at the forefront include Elimination Et Choice Translating Reality (ELECTRE) (Roy 1990), and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) (Brans & Mareschal 2005). Such outranking methods are well suited to disaster risk evaluation and hazard-mitigation planning for their relative ease of interpretation, methodological simplicity, and consideration of user inputs and preferences (Sun et al. 2020; Nassereddine et al. 2019; Caroleo et al. 2018). In sum, preference ranking is the quantification of opinion, expressed through indicator choice and variable weighting.

3.2.2 Outranking Method

The ONHRA uses an outranking method called Preference Ranking METHod for Enrichment Evaluations (PROMETHEE) (Brans and Mareschal 2005). Outranking refers to the process of determining a binary relation between a set of alternatives, given preferences of the decision-maker, evaluations of the alternatives, and the nature of the problem. This method follows a procedure that considers the superiority, or preference, of one alternative over all others given a set of criteria. Pairwise comparison matrices compute the amplitude of deviation between every possible pair of alternatives, resulting in a ranked set of alternatives based on a given set of indicator criteria. PROMETHEE is at the forefront of environmental suitability analyses (Sotiropoulou & Vavatsikos 2021), multi-hazard risk assessments (Soldati et al. 2022), and collective policy action identification (Palmisano et al. 2022). In this analysis, PROMETHEE compares risk between geographies instead of evaluating alternatives in a decision-making process. This identifies mitigation focus areas, but does not make decisions about specific mitigation actions.

The combination of geographic information systems (GIS) technology with MCDA methods is an effective tool to identify, characterize, and evaluate natural hazard risk. Many international studies have successfully combined GIS and MCDA applied to natural hazards risk rankings, including high n- criteria studies (Kappes & Papathoma-Kohle et al. 2012; Kappes & Keiler et al. 2012; Soldati et al. 2022; Zschau 2017). For example, Palmisano, Sardaro, and La Sala included 43 indicators organized into seven thematic dimensions to identify collective policy actions through PROMETHEE (Palmisano et al. 2022). Similarly, the Oregon Natural Hazard Risk Assessment (ONHRA) includes 88 total indicators, with an average of 26 indicators per hazard, to characterize multi-hazard vulnerabilities and identify potential mitigation focus areas across the state. These indicators similarly range across seven categories: people, public health, the built environment, cultural resources, economy, governance, and hazard characteristics

3.2.2.1 Best Practices

Planning for and implementing equitable hazard mitigation strategies is a well-established goal and is reflected with state-of-the-art hazard mitigation literature and research (Bradshaw 2014; Goldsmith 2022; McKittrick 2006; Woods 1998). Environmental disasters underscore and worsen existing inequities across communities, often revealing overlapping preexisting vulnerabilities (Ribot 2014). These vulnerabilities disproportionately burden marginalized and under-resourced communities. In this analysis, equity is considered across indicator themes. The Oregon Natural Hazard Risk Assessment is based on an understanding of vulnerability to natural hazards drawn from best practice literature, the DLCD strategic plan, and FEMA definitions of equitable natural hazard mitigation planning. The ONHRA identifies focus areas for mitigation actions. Specific mitigation actions may be highly local, and nuanced analysis of mitigation potential is critical to effective mitigation. For example, a mitigation action that works well in one community may not suit another. A mitigation action that is well suited to a coastal community may not be suitable for a community in the mid-Willamette Valley. Mitigation actions that benefit a part of a community may harm or create new vulnerabilities for another, resulting in what Cutter (2014) describes as 'relational vulnerability'. Thus, the ONHRA shows the drivers of vulnerability to discover mitigation actions best suited to unique communities across Oregon.

3.2.3 Hazard Scenarios

The ONHRA uses data from the Oregon Department of Geology and Mineral Industries (DOGAMI), Federal Emergency Management Agency (FEMA) National Flood Hazard Program and National Risk Index, Oregon Department of Forestry (ODF), United States Geological Survey (USGS), United States Department of Agriculture (USDA), and United States Forest Service (USFS). For example, riverine and coastal flood hazards uses data from FEMA's National Flood Hazard Program. Landslide susceptibility uses statewide landslide mapping from DOGAMI. See the Appendix in Chapter 9 for full descriptions of hazard datasets.

3.2.4 Vulnerability Indicators

The ONHRA uses vulnerability indicators in six thematic categories:

- People
- Built Environment
- Economic Environment
- Cultural Resources
- Governance
- Public Health
- Hazard Scenarios

These categories correspond to FEMA guidance describing what needs to be evaluated in natural hazard mitigation plans. The ONHRA goes beyond these minimum to better meet the needs of Oregonians.

The Oregon Natural Hazard Risk Assessment incorporates over 88 indicators in these seven categories. First, hazard scenarios were identified, and vulnerability indicators selected from each domain. The risk assessment upgrade team met with 250 interested parties, experts, and stakeholders over the course of several dozen brainstorming and selection meetings. To compile a list of potential indicators. These indicators are attributes that characterize a source of resilience or vulnerability to hazards or a combination of hazards.

To select indicators for use in the model DLCD assessed several different factors: suitable indicators focus on answering a specific question, have publicly available baseline data, and are practical, easy to measure, and interpretable (Beasley & Wright 2001). Research supporting inclusion of an indicator in the risk assessment model is peer-reviewed and well documented in its rationale, methodology, and analysis. Additionally, ideal indicator data has low variance, is available at the appropriate geographic scale, and is correlated with what the indicator measures. See the Appendix in Chapter 9 for a complete data dictionary.

3.2.4.1 People

Hazard vulnerability indicators concerning people and social demographics include race, age, housing status, disabilities, and social economic statuses. These indicators are included as a single measure in the risk assessment and are represented within the Community Resilience Estimate (CRE) from the U.S. Census. See the Appendix in Chapter 9 for a complete description of the CRE.

Housing indicators include houseless populations, people living alone, rent burden, and housing tenure. Basic shelter and housing, and the quality and affordability of such shelter and housing, plays a crucial and multifaceted role in hazard mitigation efforts (Cutter et al. 2003).

Disabilities can create a range of differential vulnerabilities to natural hazards (Morrow 1999; Hemingway & Priestley 2014). The social model of disability frames human vulnerability to natural hazards as socially reproduced, as coined by Morrow (1999). In this risk assessment, disabilities are represented within the CRE measure. These characteristics include hearing, vision, cognition, ambulatory, self-care, or independent living difficulty. This definition also includes institutionalized populations.

3.2.4.2 Built Environment

The vulnerability of the built environment and infrastructure is used in ONHRA with vulnerability indicators including buildings in the Special Flood Hazard Areas, critical facilities, building exposure to natural hazards, roads in the special flood hazard zone, roads in landslide susceptibility areas, roads in wildfire hazard zones, bridges in special flood hazard zone, bridges in landslide susceptibility areas, bridges in earthquake hazard zones, tree canopy coverage, repetitive loss and severe repetitive loss properties. In addition to this hazard-exposed infrastructure, we included two building types that are vulnerable to harm or causing harm from any hazard – mobile homes and older homes.

3.2.4.3 Cultural Resources

Cultural institutions, historic sites, and other assets can be both exposed to natural hazard impacts, and can bring communities together to increase social cohesion. The ONHRA includes the number of cultural related and historic buildings in the census tract using an inventory from the Oregon Cultural Trust. Religious institutions can also increase social cohesion and community connection. The ONHRA includes the percentage of members to a religious group. This measure is the percentage of the census tract population that belongs to any religious group. This data is maintained by the US Religion Census, a private organization that collects information about participation in religious organizations. The ONHRA uses the 2020 Religion Census for estimated adherents including members, their children, and estimated numbers of participants who are not members.

3.2.4.4 Economy

Income and poverty are significant contributing factors to vulnerability (Kasperson & Kasperson 2001). The ONHRA uses outdoor jobs, natural resource jobs, and annualized losses from the National Risk Index to people, agriculture, and buildings due to hazards as economic vulnerability indicators. Natural resource jobs and outdoor jobs are more likely to be interrupted by natural hazards, and thus areas with more of these jobs are more likely to suffer economic decline after a natural disaster.

3.2.4.5 Governance

Measuring social cohesion and community adaptive capacity is difficult, and therefore requires quantitative and qualitative measurements. Brown and Westaway (2011) note an evolution in understanding of natural hazard resilience and adaptive capacity away from solely quantifiable and objective measures towards a relational aspect of these concepts. Additionally, Agrawal (2008) argues that institutions structure vulnerability. Therefore, the ONHRA includes indicators related to government planning, government preparedness, and civic engagement. Such indicators include mitigation projects undertaken and funded by FEMA, the Community Rating System (CRS) score for the community, and the city and county tax rates obtained from the Oregon Department of Revenue.

3.2.4.6 Public Health

The ONHRA includes distances to hospitals and estimated number of hospital beds as public health vulnerability indicators.

3.2.5 Indicator Key

Some of the indicators measure vulnerability, thus a higher number indicates a **higher** vulnerability. These indicators have a gold background.
Other indicators measure resilience, thus a higher number indicates a **lower** vulnerability**.** These indicators have a blue-green background.

3.2.5.1 General

These socio-economic indicators were used for all evaluated hazards.

Indicator Name	Description	Data Source	Justification
EP_MINRTY	Percentage of non-white population		The State of Oregon and the Department of Land Conservation and Development have a "lead with race" policy. The CRE (a social vulnerability indicator) does not include race.
Housing Tenure	Percent of owned homes		Tenure definition from US Census: A unit is owner occupied if the owner or co-owner lives in the unit, even if it is mortgaged or not fully paid for. Owners have more control over mitigation projects and opportunities.
EP_MOBILE	Percentage of residential building stock that are mobile homes	2020 Census; **ACS Table(s)**: B25024, B25032	Mobile homes are more likely than site-built homes to be damaged by natural hazard events. Manufactured home parks are often located in hazard zones
Median_Yrblt	Median year built of general building stock based on HAZUS default data.	Hazus (org. 2020 Census)	Older homes likely are built with less stringent buildings codes. Maintenance status may make them more prone to damage due to natural hazard events.
HospitalDistMile	Distance from tract centroid to nearest hospital.	DOGAMI generated	Distance to the nearest hospital indicates degree of access to medical services in the face of and after a natural hazard event.
NatResrcJobs	Percentage of natural resource jobs.	2020 Census	People employed in natural resource jobs may work outdoors and also may face reductions in work hours or access to raw materials during and after a natural hazards event. Short term employment gains may be experienced from rebuilding, but these are short-lived.

PRED3_PE	Percentage of individuals with three plus components of social vulnerability from the Community Resilience Estimate (CRE)	2023 CRE Estimate	Metric for how socially vulnerable people are to the impacts of disasters.
Hosp_Beds	Estimated number of hospital beds based on square footage of hospital building (1500ft^2 per bed)	DOGAMI generated	Indicates the ability of local medical system to address emergencies during and after an event.
Pct_Adherents	Percentage of members to a religious group	2020 US Religion Census	Indicates community cohesion or access to local assistance.
Mitigation	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)	FEMA: Hazard Mitigation Assistance Projects - v4 | FEMA.gov	Measures degree of mitigation attention that has been paid to the area.
Watch	Average rating from survey of neighborliness: Will watch neighbor's house	OHA	Indicates propensity to assist neighbors during and after an event.
CountyTax	County tax rate	Oregon Dept. of Revenue	Indicates capacity of local government to plan, respond to, and mitigate.
CityTax	City tax rate	Oregon Dept. of Revenue	Indicates capacity of local government to plan, respond to, and mitigate.
Cultural	Number of cultural-related institutions	Oregon Cultural Trust	Indicates community cohesion by participation in cultural activities
Favors	Average rating from survey of neighborliness: Willing to do favors for neighbor	OHA	Indicates propensity to assist neighbors during and after an event.
Advice	Average rating from survey of neighborliness: Seeks advice from neighbor	OHA	Indicates propensity to assist neighbors during and after an event.
Parties	Average rating from survey of neighborliness: Attended parties that occur in neighborhood	OHA	Indicates propensity to assist neighbors during and after an event.
Visits	Average rating from survey of neighborliness: Has visited neighbor's house	OHA	Indicates propensity to assist neighbors during and after an event.

3.2.5.2 Hazard Specific Indicators

Indicator Name	Description	Data Source	Justification
Coastal Hazards			
CFL_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to coastal flooding based on NFIP flood zones.	DOGAMI generated	Indicates the degree of disruption to critical facilities during a flood event and its aftermath.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
Port	Presence of marine port infrastructure	DOGAMI generated	Damage to ports disrupts commerce, jobs, and local economy. May be costly to repair
Bridge_Scour_pct	Percentage of bridges that are scoured from a 100 year flood.	ODOT	A high proportion of damaged bridges in an area indicates reduced ability to find detours.
CRS_Rate	Community Rating System (NFIP program for reduced insurance premiums) score for communities within census tracts (1 – 10 scores with 1 being the best score).	FEMA	Communities that participate in the Community Rating System tend to be better prepared for flood events and to adopt policies to avoid building in flood hazard zones.
ImpervSurf_Pct	Percentage of impervious surface.	Justice40	Areas with a high percentage of impervious surface tend to have flood and drainage problems, leading to the potential for damage.
FIRM_Diff	Number of years difference between median year built and first Flood Insurance Rate Map date.	FEMA/2020 Census	Older flood maps tend to misrepresent areas subject to flood; newer maps are more reliable indicators of flood hazard.
FL_Haz_Area	Area of tract in 100-year flood hazard.	FEMA	Census tracts with large flood hazard zones are more likely to suffer harm.
RepeatLoss	Number of Repetitive loss structures	FEMA	Indicates historic repetitive losses and opportunity for mitigation.
Drought			

Indicator Name	Description	Data Source	Justification
Drght_NRI_rate	Expected annual loss (EAL) rate for drought from the FEMA NATIONAL RISK INDEX.	National Risk Index	EAL rates are designed to reflect the average expected annual percentage loss for the building value, population, and agriculture value within a community
Drght_Events	Number of drought events from the FEMA NATIONAL RISK INDEX.	National Risk Index	
Drght_AL_AG	Expected annual loss (EAL) rate for agriculture from FEMA NATIONAL RISK INDEX.	National Risk Index	EAL rates are designed to reflect the average expected annual percentage loss for the building value, population, and agriculture value within a community
Over90th	Mean number of days that are above the historic 90th percentile temp	OCCRI	
Over90F	Mean number of days above 90 degrees Fahrenheit	OCCRI	
Over90th	Mean number of days that are above the historic 90th percentile temp	OCCRI	
Over90F	Mean number of days above 90 degrees Fahrenheit	OCCRI	
Earthquake			
LQ_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to Moderate to Very High liquefaction zones based on data compiled in the Oregon Seismic Hazard Dataset (OSHD).	DOGAMI generated	Indicates the degree of disruption within the census tract because of liquefaction and its aftermath.
LQ_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to Moderate to Very High liquefaction zones based on data compiled in the Oregon Seismic Hazard Dataset (OSHD).	DOGAMI generated	Indicates the degree of disruption to critical facilities as a result liquefaction.

Indicator Name	Description	Data Source	Justification
EQCSZ_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings that are red or yellow-tagged buildings based on CSZ Deterministic Hazus scenario analysis.	DOGAMI generated	Indicates the degree of disruption to critical facilities because of earthquake.
EQ25_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings that are red or yellow-tagged buildings based on 2500 Probabilistic Hazus scenario analysis.	DOGAMI generated	Indicates the degree of disruption to critical facilities because of earthquake.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
Hwy_LQ_pct	Miles of major roadway exposed to Moderate to Very High liquefaction zones based on data compiled in the Oregon Seismic Hazard Dataset (OSHD).are	ODOT/DOGAMI generated	Damaged roads disrupt transportation and access to services.
Erqk_NRI_rate	Expected annual loss (EAL) rate for earthquake from FEMA NATIONAL RISK INDEX.	National Risk Index	FEMA designed EAL rates to reflect the average expected annual percentage loss for the building value, population, and agriculture value within a community.
LQ_Haz_Area	Area of tract in high or very high liquefaction hazard.	DOGAMI generated	Indicates a potential disruption.
Bridges_LIQ	Number of bridges that are within high or very high liquefaction hazard.	ODOT/DOGAMI generated	Bridges provide critical transportation links and can take time to repair leading to disruptions.
PGA_2500	Average shaking in tract from 2500-year probabilistic earthquake.	DOGAMI generated	
Extreme Heat			
Heat_Events	Number of heat events.	National Risk Index	
Heat_ALAG	Expected annual loss (EAL) rates to agriculture from heat.	National Risk Index	FEMA designed EAL rates to reflect the average expected annual percentage loss for the

Indicator Name	Description	Data Source	Justification
			building value, population, and agriculture value within a community
Heat_ALPOP	Expected annual loss rate to population from heat.	National Risk Index	FEMA designed EAL rates to reflect the average expected annual percentage loss for the building value, population, and agriculture value within a community
OutdoorJobs	Percentage of jobs that occur outside.	ACS 2021	People who work outdoors are exposed to natural hazards and their consequences.
TreeCan_avg	Tree canopy density	USDAg	Indicates potential for shade or cooling.
Flood			
Bridge_Scour	Number of bridges that are at risk from scour during a 100-year flood.	Oregon Dept. of Transportation	Bridges provide key transportation links that can be difficult to go around if damaged during a flood. Often require extended repair times.
CRS_Rate	Community Rating System (NFIP program for reduced insurance premiums) score for communities within census tracts (1 – 10 scores with 1 being the best score).	FEMA	Communities that participate in the Community Rating System tend to be better prepared for flood events and to adopt policies to avoid building in flood hazard zones.
FL_pct_bld	Percentage of Statewide Building Footprint for Oregon buildings exposed to flooding based on NFIP flood zones.	DOGAMI generated	Indicates the degree of disruption within the census tract because of flood and its aftermath.
FL_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to flooding based on NFIP flood zones.	DOGAMI generated	Indicates the degree of disruption to critical facilities during a flood event and its aftermath.
ImpervSurf_Pct	Percentage of impervious surface.	Justice40	Areas with a high percentage of impervious surface tend to have flood and drainage problems, leading to the potential for damage.

Indicator Name	Description	Data Source	Justification
Hwy_FL_pct	Miles of major roadways miles based on ODOT data that are exposed to flood hazard from NFIP data.	ODOT/DOGAMI generated	Flooded roads disrupt transportation and access to services.
Bridge_Scour_pct	Percentage of bridges that are scoured from a 100 year flood.	ODOT	A high proportion of damaged bridges in an area indicates reduced ability to find detours.
FIRM_Diff	Number of years difference between median year built and first Flood Insurance Rate Map date.	FEMA/2020 Census	Older flood maps tend to misrepresent areas subject to flood; newer maps are more reliable indicators of flood hazard.
FL_Haz_Area	Area of tract in 100-year flood hazard.	FEMA	Census tracts with large flood hazard zones are more likely to suffer harm.
RepeatLoss	Number of Repetitive loss structures	FEMA	Indicates historic repetitive losses and opportunity for mitigation.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
CFL_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to coastal flooding based on NFIP flood zones.	DOGAMI generated	Indicates the degree of disruption within the census tract because of flood and its aftermath.
Hwy_FL_pct	Miles of major roadways that are exposed to flood hazard from NFIP data based on ODOT data.	ODOT/DOGAMI generated	Flooded roads disrupt transportation and access to services.
Landslide			
LSS_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to existing landslide deposit SLIDO.	DOGAMI generated	Indicates the degree of disruption within the census tract as a result of landslide.
LSS_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to existing landslide deposit SLIDO.	DOGAMI generated	Indicates the degree of disruption to critical facilities during a landslide event and its aftermath.

Indicator Name	Description	Data Source	Justification
Hwy_LSS_pct	Miles of major roadways based on ODOT data that are exposed to existing landslide deposits based on SLIDO.	ODOT/DOGAMI generated	Damaged roads disrupt transportation and access to services.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
LSS_Haz_Area	Area of tract in high or very high landslide hazard.	DOGAMI generated	Indicates the degree of potential disruption and harm to people or property.
Tsunami			
TSU_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to any sized (Sm-XXL) CSZ tsunami.	DOGAMI generated	Indicates the degree of disruption within the census tract as a result of fsunami.
TSU_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to any sized (Sm-XXL) CSZ tsunami.	DOGAMI generated	Indicates the degree of disruption to critical facilities because of tsunami.
Port	Presence of marine port infrastructure	DOGAMI generated	Damage to ports disrupts commerce, jobs, and local economy. May be costly to repair
Bridges_TSU	Number of bridges that are within a tsunami inundation zone.	ODOT/DOGAMI generated	Bridges provide critical transportation links, particularly on the coast where detour routes are few and far between.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
Volcano			
LAH_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to volcanic lahar hazard of any size based on USGS and DOGAMI lahar zones for Cascade volcanoes.	DOGAMI generated	Indicates the degree of disruption within the census tract, including harm to people and property.

Indicator Name	Description	Data Source	Justification
LAH_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to volcanic lahar hazard of any size based on USGS and DOGAMI lahar zones for Cascade volcanoes.	DOGAMI generated	Indicates the degree of disruption to critical facilities during a volcanic event and its aftermath.
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
Wildfire			
WF_pct_bld	Percentage of STATEWIDE BUILDING FOOOTPRINTS FOR OREGON buildings exposed to Medium and High Burn Probability based on PNW Quantitative database.	Oregon Dept. of Forestry/DOGAMI	Indicates the degree of disruption within the census tract, including harm to people and property.
WF_pct_CF	Percentage of critical facilities (2020 State NHMP data) buildings exposed to Medium and High Burn Probability based on PNW Quantitative database .	Oregon Dept. of Forestry/DOGAMI	Indicates the degree of disruption to critical facilities during a flood event and its aftermath.
BurnProb	Burn probability from the QPNW		
Hwy_WF_pct	Percentage of highway miles within High Burn Probability Zones		
Hist_count	Number of historic buildings.	OR agency for Historic bld source?)	Indicates cultural significance in the area
Over 90th	Mean number of days that are above the historic 90th percentile temp	OCCRI	
Over90F	Mean number of days above 90 degrees Fahrenheit	OCCRI	

3.2.6 Methods

This section describes the method that the Oregon Department of Land Conservation and Development used to create the Oregon Natural Hazards Risk Assessment (ONHRA). This upgraded tool can be used for future state, tribal, and local plans.

The description starts with an overview of the previous risk assessment method, the quantitative methods used for the ONHRA, and community engagement. Next is a detailed method for how the models were used in 2025 in hazard risk analysis work at DLCD. The final section describes limitations of the approach and planned future improvements to the risk assessment.

3.2.6.1 Quantitative Natural Hazard Vulnerability Analysis Using Multi-Criteria Decision Analysis

The natural hazard risk assessment used in the 2020 Oregon NHMPO relied on subject matter experts' opinions to develop risk and vulnerability scores for each hazard. This assessment approach had several shortcomings. The results were subjective, making it impossible to compare hazards. This approach did not adequately account for social vulnerabilities. Finally, the previous approach focused primarily on assets and people that were directly exposed to hazards. The upgraded natural hazard risk assessment identifies places particularly at risk to the effects of natural hazards by balancing a set of indicators against all census tract geographies in Oregon. Broad groups of experts met to choose vulnerability indicators in six thematic categories. Each indicator is supported by best practice literature. Finally, the upgraded assessment method can handle indicator complexity.

Multi-Criteria Decision Analysis (MCDA) methods are decision aids well suited to identify focus areas for hazard mitigation. The ONHRA uses Preference Ranking Organization Method for Enrichment Evaluation II (PROMETHEE II), which is used for complete ranking and selection of a finite set of the best compromise alternatives (Behzadian et al. 2010; Brans & Mareschel 2005).

The PROMETHEE II method uses preference functions to calculate at least one indicator value within each domain for each hazard. Results were then mapped and analyzed to identify risk drivers for the census tracts with the highest hazard ranking. See Appendix in Chapter 9 for more information.

PROMETHEE II is intended to provide a complete ranking of a finite set of feasible alternatives and is preferred by a majority of researchers and practitioners (Behzadian et al. 2010). This outranking method is based on pair-wise comparison of alternatives along each recognized criterion. Alternatives are evaluated according to selected criteria. Thus, the decision maker, or end-user, must weigh the criteria appropriately (Macharis et al. 2004).

3.2.6.2 Weighting

The PROMETHEE model allows weighting of indicators by assigning fractional weighs to each indicator such that the total of all weights equals 1. Weighting is used to emphasize one criterion over another in the ranking.

The ONHRA uses two types of indicators: hazard specific and vulnerability. The vulnerability indicators are labeled "General" on the hazard maps and tables because they apply to all hazards. Together they have 65 percent of the total indicator weight. The hazard-specific indicators varied by hazard and have 35 percent of the total indicator weight.

Within the General category, the indicators are equally weighed, except for a group of indicators that are highly correlated and were therefore treated as a combined indicator. This group included Watch, Favors, Advice, Parties, and Visits. Those five indicators are highly correlated. As a result, they were considered one indicator for weighting purposes and then equally weighted among themselves. When the five indicators are combined into one, there are 14 General indicators. Sixty-five percent divided by 14 equals 0.046. Then dividing 0.046 by 5 equals 0.009. So, the General indicators are all assigned weights of 0.046, except for Watch, Favors, Advice, Parties, and Visits, which are assigned weights of 0.009.

The collection of indicators specific to each hazard were weighted equally among themselves. For example, the Flood hazard has eleven hazard-specific indicators. Thirty-five percent divided by 11 equals 0.0318, rounded to 0.032 as shown on the flood hazard map.

The table to the right of each map shows the weights used for that hazard Weights for the General category are the same across hazards.

3.2.6.3 Process

DOGAMI programmed the multi-criteria process using Python. The multi-criteria component is relatively simple, but processing the data can be complicated, including ingesting, checking, de-coupling, and re-building.

The process is three individual Python functions:

1. Perform the multi-criteria process and write results at the census tract, county, and city levels.
2. Create maps based on the results.
3. Create tables summarizing the results.

There are two pieces of input data needed to run this analysis. First, a spreadsheet that specifies which indicators are used for each hazard. This sheet defines the weight and type for each indicator. Second, a geographic information system (GIS) with a polygon feature class containing the outline all census tracts within Oregon. This feature class contains the following attributes: Census tract ID, county name, and values for each indicator.

The multi-criteria method used by DOGAMI in this analysis is **PROMETHEE_II**, from the *pymcdm* Python package version 1.2.1: https://pypi.org/project/pymcdm/. The preference function used in this case by **PROMETHEE_II** is "usual."

The multi-criteria method uses three inputs:

1. An un-labeled array of indicator columns and value for each census tract in rows.
2. A list of weight values for each indicator. The list must correspond correctly to the indicator array.
3. A list of types for each indicator showing whether high values are good (1) or bad (-1). The list must correspond correctly to the indicator array.

The output of the method is an un-labeled array (in-memory) with each indicator in columns and the preference rank for each census tract in rows.

This assessment performs three Python functions.

Python Function 1: Run a Multi-Criteria Analysis.

First, identify applicable indicators for the hazard using the spreadsheet . Convert the information in the census tracts to an un-labeled array representing each indicator associated with the hazard for each census tract. Construct a list of weights and types associated with the hazard (from the spreadsheet). Run the multi-criteria analyses based on the inputs listed above. For each hazard, write the analysis result to a new census tracts polygon feature class, containing: PROMETHEE score for each census tract, PROMETHEE rank for each census tract, and the indicators used for the hazard (all others are removed).

The census tract results are used to summarize by county. For each hazard:

1. Using the existing County column in the census tract results, calculate the average PROMETHEE preference score for each county based on the associated census tracts.
2. Calculate the rank based on the newly calculated county level scores.
3. Save the county result to a new feature class containing the PROMETHEE score and rank for each county.

The census tract results are also used to summarize by city. For each hazard:

1. Create a geospatial intersection of city boundaries and the census tract PROMETHEE results.
2. For each city, calculate the mean PROMETHEE preference score for each county based on the associated census tracts.
3. Calculate the rank based on the newly calculated city level scores.
4. Convert the polygon result to a point feature class to better represent the cities cartographically.

Python function 2: Create Result Maps.

This tool generates maps based on the multi-criteria results produced in Function 1.

Python function 3: Create Result Tables.

This tool generates spreadsheets of the multi-criteria results produced in Function 1.

3.2.6.4 Limitations and Planned Future Improvements

The upgraded risk assessment has several limitations that could be addressed in future iterations of the tool. First, while the risk assessment is conceptually rooted in resilience scholarship and best practice, not all of the expert advisors agreed on all of the indicators to use in the first run of the model. Verifying the validity of indicators, and model results, is a crucial aspect of maintaining a relevant risk assessment tool and this work will be pursued in the future. Additionally, indicators included in the assessment may not be comprehensive. Indicators were selected based on peer reviewed evidence and stakeholder support, and their data availability. Additionally, as this method is a quantification of expert opinion, weighting choices have a subjective influence on the results. As further research continues, new indicators or representative data may be applicable and incorporated into the risk assessment. The ONHRA does not address compounding and cascading hazards.

Finally, this risk assessment is limited in its purpose: identifying communities and geographic areas that are most in need of further investigation for mitigation investment. It is not a diagnostic tool. It cannot evaluate the benefits and costs of a for a specific proposed project to mitigate natural hazards.

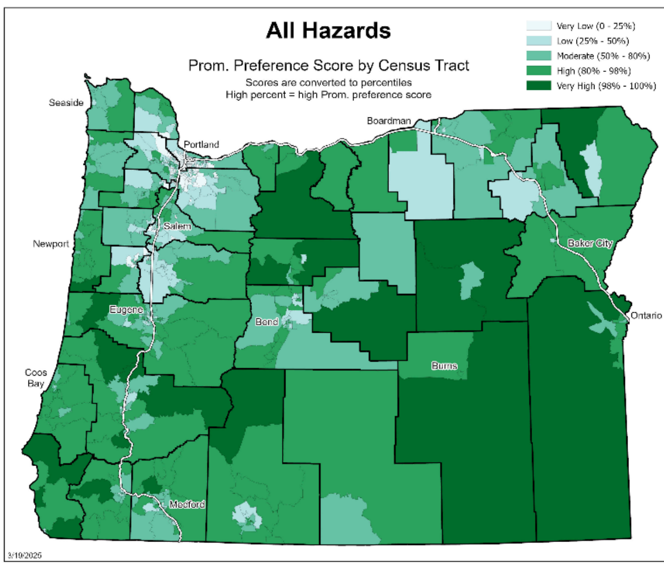
A second iterative phase will continue development of the risk assessment model. In this next phase, a public facing tool will be developed and available as an option for tribes, counties, cities, and other local governments to use in their own risk assessments.

3.2.7 Risk Maps

The ONHRA maps show the risk ranking for each census tract across Oregon. One map shows ranking using both hazard-specific indicators and socio-economic vulnerability indicators. The second map shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. This section includes maps using all-hazards composite risk rankings. The hazard specific maps are in section 3.3, following the description of each hazard. Chapter 9 includes a key to all indicators used in the model and has examples of the information available from the risk assessment model.

Figure 3.2.7- shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.2.7- shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city.

Figure 3.2.7-1 All Hazards Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators included

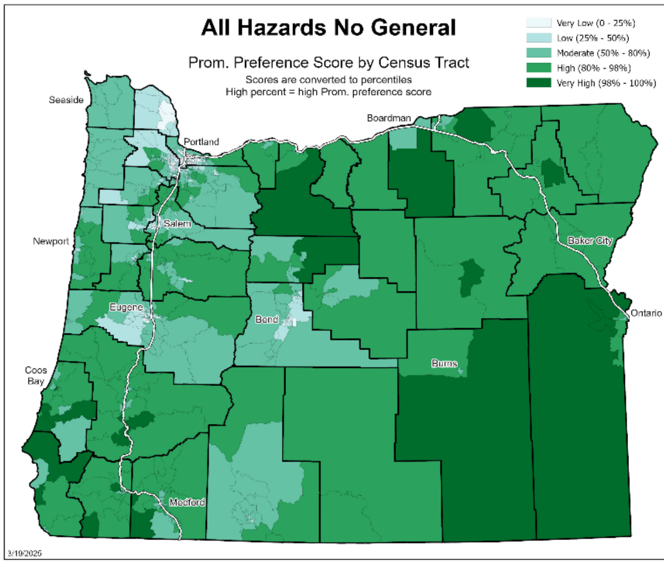


Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
All Hazards	General	1	0.65	The General preference score is it's indicator value.
All Hazards	Coastal hazards	1	0.039	The Coastal hazards preference score is it's indicator value.
All Hazards	Drought	1	0.039	The Drought preference score is it's indicator value.
All Hazards	Earthquake	1	0.039	The Earthquake preference score is it's indicator value.
All Hazards	Flood	1	0.039	The Flood preference score is it's indicator value.
All Hazards	Heat	1	0.039	The Heat preference score is it's indicator value.
All Hazards	Landslide	1	0.039	The Landslide preference score is it's indicator value.
All Hazards	Tsunami	1	0.039	The Tsunami preference score is it's indicator value.
All Hazards	Volcano	1	0.039	The Volcano preference score is it's indicator value.
All Hazards	Wildfire	1	0.039	The Wildfire preference score is it's indicator value.

Map combines the rankings for all hazards into a composite ranking.

Figure 3.2.7-2 All Hazards Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
All Hazards	Coastal hazards	1	0.111	The Coastal hazards preference score is it's indicator value.
All Hazards	Drought	1	0.111	The Drought preference score is it's indicator value.
All Hazards	Earthquake	1	0.111	The Earthquake preference score is it's indicator value.
All Hazards	Flood	1	0.111	The Flood preference score is it's indicator value.
All Hazards	Heat	1	0.111	The Heat preference score is it's indicator value.
All Hazards	Landslide	1	0.111	The Landslide preference score is it's indicator value.
All Hazards	Tsunami	1	0.111	The Tsunami preference score is it's indicator value.
All Hazards	Volcano	1	0.111	The Volcano preference score is it's indicator value.
All Hazards	Wildfire	1	0.111	The Wildfire preference score is it's indicator value.

Map combines the rankings for all hazards into a composite ranking

DLCD contracted with the Oregon Climate Research Institute to produce data by census tract for future meteorological conditions that influence natural hazards. DLCD used the future conditions data to produce maps. For some hazards, the data relate directly to the natural hazard, for example drought. For other hazards, the map shows a condition that indirectly influences the natural hazard. For example, heavy precipitation influences floods and landslides, but a 10 percent increase in heavy precipitation would not automatically result in a 10 percent increase in flooding or landslides. Days over 90°F can indicate the possibility of extreme heat events. An increase in days with temperatures above the local 90th percentile can contribute to local heat stress. The wind section includes a map showing change from present conditions, but the ONHRA is not yet able to produce risk rankings for windstorms.

3.3 Hazard Identification

3.3.1 Coastal Hazards

Figure 3.3.1-1: Erosion at the Capes Condominiums, Oceanside, Oregon

Source: DOGAMI Notes: The Capes, a multi-million dollar condominium complex constructed on an old Holocene dune field adjacent to Oceanside. Due to erosion of the sand at the toe of the bluff during the 1997-98 El Nino winter, the bluff face began to fail threatening several of the homes built nearest the bluff edge.

The Pacific Northwest (PNW) coast of Oregon is, without a doubt, one of the most dynamic coastal landscapes in North America, evident by its long sandy beaches, extensive dune systems, sheer coastal cliffs, dramatic headlands and vistas, and ultimately the power of the Pacific Ocean that serves to erode and change the shape of the coast. It is these qualities along with its various natural resources that have drawn people to live along its narrow shores. However, coastal communities are increasingly under threat from a variety of natural hazards that all come together along the coastal strip. These include wave-induced coastal erosion (both short and long term), wave runup and overtopping (wave-induced flood hazards), inundation of homes by wind-blown sand, coastal landslides, earthquakes, and potentially catastrophic tsunamis generated by the Cascadia Subduction Zone (CSZ). Over time, these hazards are gradually being compounded, in part due to the degree of development that has evolved along the Oregon coast in recent decades. A particular concern is that the local geology and geomorphology of the region have restricted development to low-lying areas, chiefly along dunes, barrier spits, or along coastal bluffs present along the open coast that are subject to varying rates of erosion, and to low-lying areas adjacent to the numerous estuaries that make up the coast. All of these sites are highly susceptible to increased impacts as erosion processes and flood hazards intensify, driven by rising sea level and increased storminess, especially when combined with shoreline armoring such as riprap.

Figure 3.3.1-2: A) Emergency riprap being placed in front of a home at Gleneden Beach following a bluff failure (February 2013). B) Homes being inundated with excess sand during strong wind event in November 2021

Source: DOGAMI

There are many dangers inherent in living on the coast. Beaches and coastal bluffs are some of the most dynamic landforms, responding to a myriad of variables. Both landforms are constantly changing (at varying time scales) as they respond to changes in the ocean processes (waves, nearshore currents, and tides) that affect the beach and toe of the bluff as well as those sub-aerial processes (rainfall, sun, wind) that directly affect coastal bluffs. While coastal bluffs gradually erode over the long-term, they can also respond very rapidly, at times sliding away (in a matter of minutes to a few hours) so that homes and sections of highways are damaged or destroyed (Figure 3.3.1-2A). Beaches are especially dynamic features, as wave action constantly shifts sand around This is especially noticeable in major storms, with the shoreline retreating rapidly, periodically destroying homes built too close to the sea. At other times, large quantities of sand migrate back onto beaches, burying homes built atop coastal dunes (Figure 3.3.1-2B). There is no location on the Oregon coast that is immune to coastal hazards. Without question, the most important natural variables that influence changes to the shape and width of the beach and ultimately its stability are the beach sand budget (balance of sand entering and leaving the system) and the processes (waves, currents, tides, and wind) that drive these changes. Human influences associated with jetty construction, dredging practices, coastal engineering, and the introduction of non-native dune grasses during settlement have all affected the shape and configuration of the beach, including the volume of sand on a number of Oregon's beaches, ultimately influencing the stability or instability of these beaches. These developments restrict the natural movement of sand and the ability of estuaries to migrate inland, causing the phenomenon known as 'coastal squeeze.' Coastal squeeze occurs when coastal habitats, like beaches and wetlands, are confined between human-made structures and rising sea levels, preventing them from naturally shifting or adapting to environmental changes. This not only undermines the natural resilience of coastal ecosystems but also increases the vulnerability of coastal communities to flooding, erosion, and storm surges.

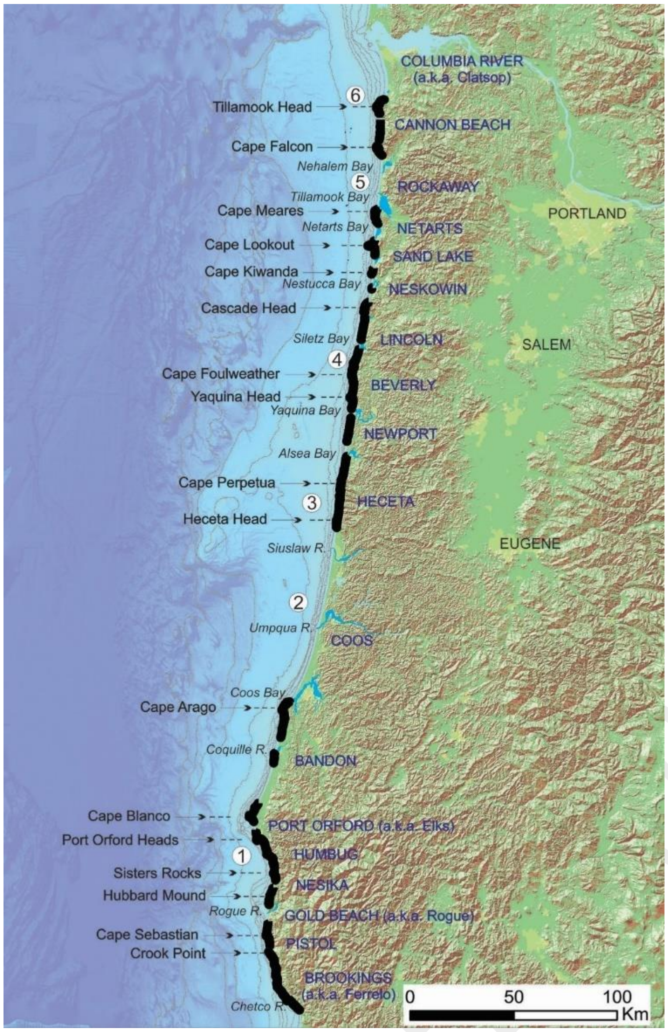
3.3.1.1 Analysis and Characterization

Geology and Geomorphology

The Oregon coast is 366 miles long from the Columbia River to the California border. The present coastline is the result of geologic processes that include a rise in sea level as Ice Age glaciers melted. The coastal geomorphology of this landscape reflects a myriad of geomorphic features (Figure 3.3.1-3.) that range from plunging cliffs (in Regions 1, 4, and 5), rocky shorelines and shore platforms (Regions 1, 3, 5, and 6), wide and narrow sandy beaches backed by both dunes (Regions 2, 5, and 6) and cliffs (Regions 3 and 4), gravel and cobble beaches backed by cliffs (Regions 1, 5, and 6), barrier spits (Regions 2, 4, and 5), and estuaries (Regions 1–6). Cliff or bluff-backed shorelines make up the bulk of the coast accounting for 58 percent of the coastline, the remainder being dune-backed beaches. Geomorphically, the coast can be broken up into a series of “pocket beach” littoral cells (Figure 3.3.1-3) that reflect resistant headlands (chiefly basalt) interspersed with short to long stretches of beaches backed by both less resistant cliffs or dunes (e.g., Lincoln and Tillamook Counties [Regions 3 and 5 in Figure 3.3.1-3; also see Figure 3.3.1-4.]). The headlands effectively prevent the exchange of sand between adjacent littoral cells. Some beaches form barrier spits, creating estuaries or bays behind them (e.g., Netarts, Nestucca, and Siletz spits). About 75.6 percent of the coastline consists of beaches composed of sand or gravel backed by either dunes or bluffs, while the remaining 24.4 percent of the coast is composed of a mixture of rocky cliffs (including headlands) and shores. The Coos Cell is the largest of the 18 littoral cells on the Oregon coast, which extends from Cape Arago in the south to Heceta Head in the north, some 62.6 miles long.

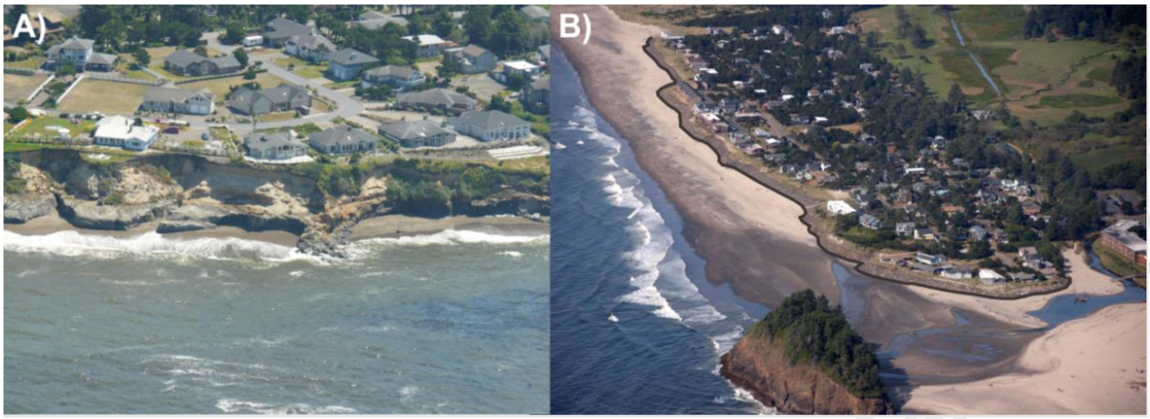
Bold black lines denote the locations of cliffs and rocky shores. Faint grey lines denote faulting. Blue text denotes littoral cells. Numbers indicate regional coastal geomorphic features: plunging cliffs (1, 4, and 5); rocky shorelines and shore platforms (1, 3, 5, and 6); wide and narrow sandy beaches backed by dunes (2, 5, and 6) and cliffs (3 and 4); gravel and cobble beaches backed by cliffs (1, 5, and 6); barrier spits (2 and 5); and estuaries (1–6).

Figure 3.3.1-3: Oregon's coastal geomorphology and littoral cells



Source: DOGAMI

Figure 3.3.1-4 (A) Houses Line the Cliff at Fogarty Creek in Lincoln County. (B) Extensive Erosion along the Dune-Backed Beaches in Neskowin Have Resulted in the Construction of Massive Riprap



Note the proximity of the eroding cliff edge to homes.
Source: L. Stimely, DOGAMI

Interspersed among the littoral cells are 21 estuaries that range in size from small, such as the Winchuck estuary (0.5 km2) adjacent to the Oregon/California border, to large, such as the Columbia River (380 km2), which separates the states of Oregon and Washington. The estuaries are all ecologically important to many fish and wildlife species and in many cases are the sites of important recreational and commercial enterprise. Additionally, estuaries play a crucial role in carbon sequestration, acting as natural carbon sinks that help mitigate climate change. When unaltered, undeveloped estuaries also provide valuable localized protection against storms and flooding, buffering coastal communities from extreme weather events and rising sea levels. In general, Oregon estuaries can be divided into two broad groups based on physiographic differences between estuaries located on the north and south coast. On the northern Oregon coast, the prevalence of pocket beach littoral cells and weaker rock formations in the coast range has resulted in more rapid erosion of the region's rock formations. This produces ample material at the coast, and coupled with alongshore sediment transport, has aided the formation of barrier spits across drowned river valleys and hence the formation of estuaries landward of the spits. In contrast, sediment loads on the southern Oregon coast are comparatively lower due to the presence of more resistant rock formations. Furthermore, the region is generally much steeper, which essentially limits the landward extent of the tide in drowned rivers and, hence, ultimately the size of the estuaries.

Unlike much of the U.S. coast, population pressure on the Oregon coast is relatively low and is largely confined to small coastal towns separated by large tracts of coast with little to no development. The bulk of these developments are concentrated on the central to northern Oregon coast in Lincoln, Tillamook, and Clatsop Counties. On the cliffed shores of the central Oregon coast, between Newport and Lincoln City, homes are perched precariously close to the edge of the cliffs (Figure 3.3.1-4A). In some areas, the erosion has become acute, requiring various forms of coastal engineering (commonly riprap) as an attempt to mitigate the problem (Figure 3.3.1-4B), and in a few cases the landward relocation of the homes. In other areas, critical infrastructure such as US Highway101 tracks close to the coast, and in a few areas, erosion of the cliffs has resulted in expensive remediation (e.g., adjacent to Nesika Beach in Curry County). Although the processes driving coastal erosion on bluff-backed shores are entirely a function of the delicate balance between the assailing forces (waves, tides, and currents) and properties of the rock (rock type, bedding, strength, etc.), increasing development pressure, weak land-use regulations, a lack of quantitative information, and ignorance of the physical processes have contributed to the need for remediation in many coastal areas.

Elsewhere, significant development is typically located along the most seaward dune (foredune) system (Figure 3.3.1-4B), as developers seek to capitalize on ocean views and proximity to the beach. However, major storms, especially those associated with El Niño events in the late 1990s, have resulted in extensive erosion, with many communities (e.g., Neskowin and Rockaway Beach in Tillamook County) having to resort to major coastal engineering in order to safeguard individual properties. The magnitude and extent of these erosion events have now left entire communities entirely dependent on the integrity of these structures.

Sand Budget

The beach sand budget is the rate at which sand is brought into the coastal system versus the rate at which sand leaves the system. A negative balance means that more sand is leaving than is arriving and results in erosion of that segment of shoreline. A positive balance means that more sand is arriving than is leaving, enabling that segment of shoreline to gain sand and accrete and potentially advance seaward. Along the Oregon coast, potential sources of sand include rivers, bluffs, dunes, and the inner shelf. Potential sand sinks include bays (estuaries), dunes, dredging around the mouths of estuaries, and mining of sand.

Attention is often focused on the effects of beach and dune erosion. Yet, there are segments of Oregon's coast where periodically the concern is excess sand build-up, as has occurred in places like Pacific City, Manzanita, Bayshore Spit, Nedonna, and Cannon Beach. This excess accumulation of sand can impact the structural integrity of and access to ocean-fronting homes, requiring the sand to be removed through remedial sand grading.

Classifying Coastal Hazards

Natural hazards that affect coastal regions can be divided into two general classes, *chronic* and *catastrophic*.

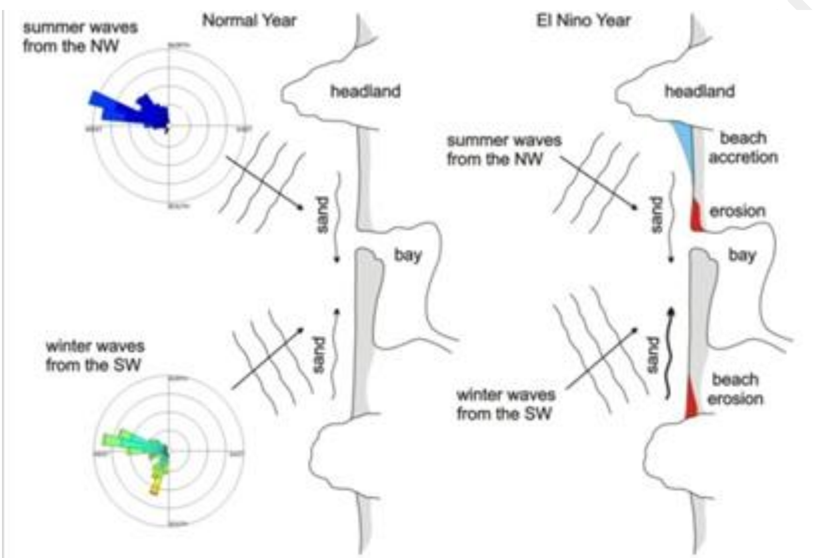
Chronic hazards such as beach, dune, and bluff erosion; landslides; slumps; and flooding of low-lying lands during major storms usually cause gradual and cumulative damage. However, storms that produce large winter waves, heavy rainfall, and/or high winds may result in very rapid, episodic erosion or other damage that can affect properties and infrastructure over a matter of hours. The regional, oceanic, and climatic environments that result in intense winter storms determine the severity of chronic hazards along the Oregon coast. Chronic hazards are typically local in nature, and threats to human life and property that arise from them are generally less severe than those associated with catastrophic hazards. However, the wide distribution and frequent occurrence of chronic hazards makes them a more immediate concern.

Catastrophic hazards are regional in scale and scope. Cascadia Subduction Zone earthquakes, and the ground shaking, subsidence, landsliding, liquefaction, and tsunamis that accompany them are catastrophic hazards. Tsunamis generated from distant earthquakes can also cause substantial damage in some coastal areas. The processes associated with earthquakes, tsunamis, floods, and landslides are discussed later in this chapter.

Causes of Coastal Hazards

Chronic coastal hazards include periodic high rates of beach and dune erosion;, sand inundation; “Hotspot erosion” due to the occurrence of El Niño's and from rip current embayments; intermittent coastal flooding as a result of El Niño's, storm surges and high ocean waves;, and the enduring recession of coastal bluffs due to long-term changes in mean sea level, variations in the magnitude and frequency of storm systems, and climate change. Other important hazards include mass wasting of sea cliffs such as slumping and landslides, which may be due to wave attack and geologic instability.

Figure 3.3.1-5:Patterns of Sediment Transport During “Normal” and El Nino Years



Source: Komar (1986)

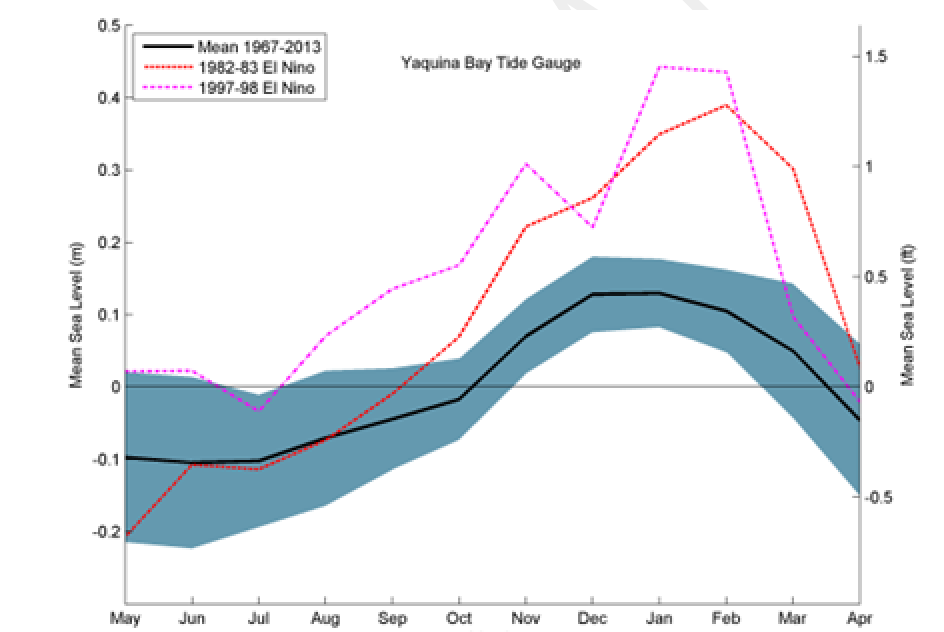
Most of these hazards are the product of the annual barrage of rain, wind, and waves that batter the Oregon coast, causing ever-increasing property damage and losses. A number of these hazards may be further exacerbated by climate cycles such as the El Niño Southern Oscillation, or longer-term climate cycles associated with the Pacific Decadal Oscillation. Other hazards, such as subduction zone earthquakes and resulting tsunamis, can have catastrophic impacts on coastal communities’ residents and infrastructure, and in many areas these impacts will persist for many decades following the event due to adjustments in the coastal morphodynamics following subsidence or uplift of the coast. All of these processes can interact in complex ways, increasing the risk from natural hazards in coastal areas.

Waves

Along dune- and bluff-backed shorelines, waves are the major factor affecting the shape and composition of beaches. Waves transport sand onshore (toward the beach), offshore (seaward to form nearshore bars etc.), and along the beach (longshore transport). Short-term beach and shoreline variability (i.e., storm related changes) is directly dependent on the size of the waves that break along the coast, along with high ocean water levels, and cell circulation patterns associated with rip currents. In contrast, long-term shoreline change is dependent on the balance of the beach sediment budget, changes in sea level over time, and storm and wave climate patterns.

The Oregon coast is exposed to one of the most extreme ocean wave climates in the world, due to its long fetches (area over which the wind can blow to create waves) and the strength of the extratropical storms that develop and track across the North Pacific. These storms exhibit a pronounced seasonal cycle producing the highest waves (mean = 12.8 ft) in the winter, with winter storms commonly generating deep-water wave heights greater than 33 ft, with the largest storms in the region having generated waves in the range of 45 to 50 ft. In contrast, summer months are dominated by considerably smaller waves (mean = 5.3 ft), enabling beaches to rebuild and gain sand eroded during the preceding winter. When large waves are superimposed on high tides, they can reach much higher elevations at the back of the beach, contributing to significantly higher rates of coastal erosion and flood hazards. It is the combined effect of these processes that leads to the erosion of coastal dunes and bluffs, causing them to retreat landward.

Figure 3.3.1-6:Average Monthly Tides for the Yaquina Bay Tide Gage. Expressed as an Average for the Period 1967–2013, and as Monthly Averages for the 1982-83 and 1997-98 El Niños



Source: Jonathan Allan, DOGAMI
Shaded region= ±1 standard deviation providing a measure of normal ranges.

Winds and waves tend to arrive from the southwest during the winter and from the northwest during the summer. Net sand transport tends to be offshore and to the north in winter and onshore and to the south during the summer (Figure 3.3.1-5). El Niño events can exaggerate the characteristic seasonal pattern of erosion and accretion and may result in an additional 60–80 feet of “hotspot” dune erosion along the southern ends of Oregon’s littoral cells, particularly those beaches that are backed by dunes, and on the north side of estuary inlets, rivers and creeks.

Ocean Water Levels

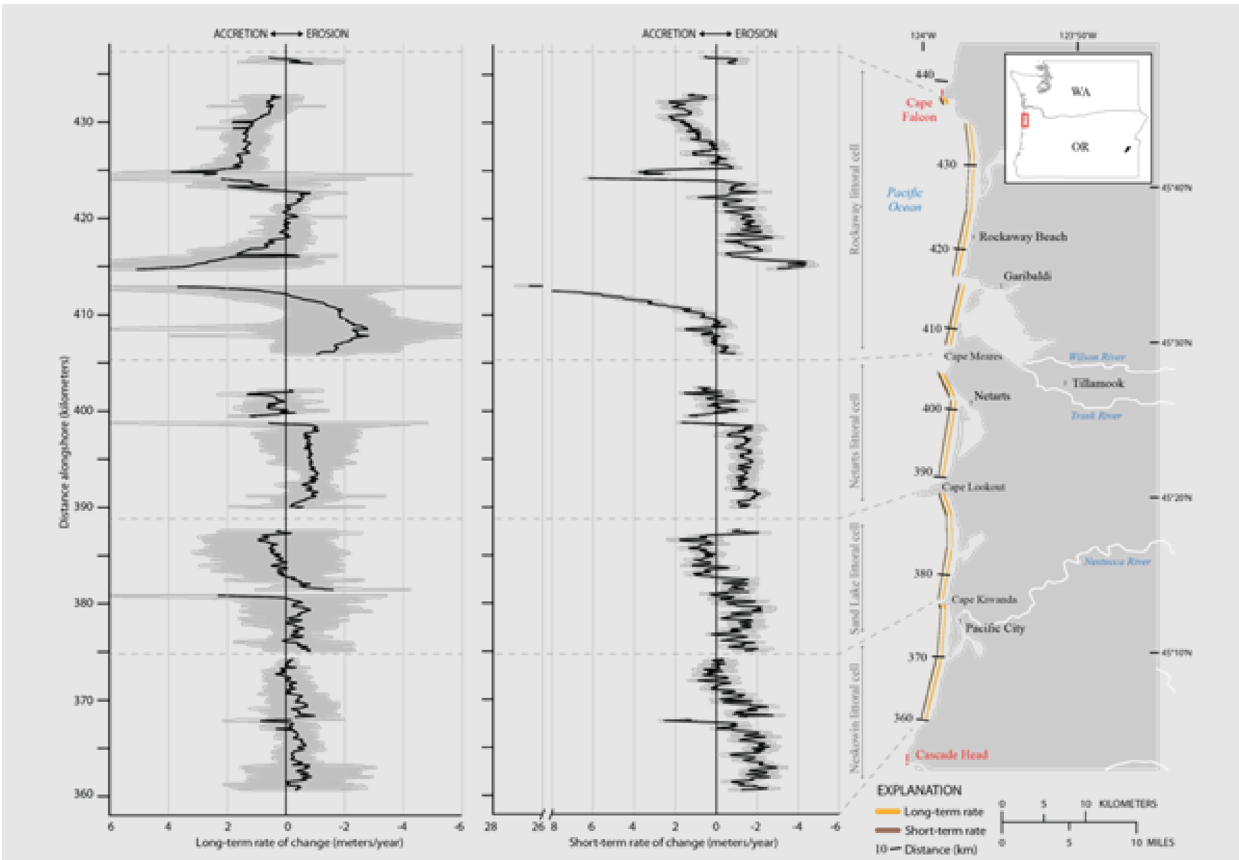
The elevation of the sea is controlled in part by the astronomical tide. High ocean water levels at the shoreline may be the product of combinations of high tides, storm surges, strong onshore-directed winds, El Niños, and wave runup. As can be seen in Figure 3.3.1-6, the Oregon coast experiences a seasonal cycle in its measured tides, with the tides tending to be highest in the winter and lowest in the summer. This seasonal variation is entirely a function of ocean upwelling during the summer months, which brings cold dense water to the surface; due to the Coriolis effect and ocean currents, this water is directed landward where it piles up along the coast depressing sea level. In the winter, this process breaks down resulting in a warming of the ocean, which raises the mean sea level. The typical seasonal variability in water levels is about 0.8 ft, increasing to as much as 2 ft during an El Niño (Figure 3.3.1-6), essentially raising the mean shoreline elevation, enabling waves to break closer to dunes or along the base of coastal bluffs.

Shoreline Changes

Dune-backed beaches respond very quickly to storm wave erosion, sometimes receding tens of feet during a single storm and hundreds of feet in a single winter season. Beach monitoring studies undertaken by DOGAMI staff (http://nvs.nanoos.org/BeachMapping) have documented storm induced erosion of 30–60 ft from single storm events, while seasonal changes may reach as much as 90–130 ft on the dissipative, flat, sandy beaches of Oregon, and as much as 190 ft on the more reflective, steeper beaches of the south coast (e.g., adjacent to Garrison Lake, Port Orford). Furthermore, during the past 15 years a number of sites on the northern Oregon coast (e.g., Neskowin, Netarts Spit, and Rockaway Beach) have experienced considerable erosion and shoreline retreat. For example, erosion of the beach in Neskowin has resulted in the foredune having receded landward by as much as 150 ft since 1997. South of Twin Rocks near Rockaway Beach, the dune has eroded about 140 ft over the same time period. Continued monitoring of these study sites is now beginning to yield enough data from which trends (erosion or accretion rates) may be extrapolated. These latter datasets are accessible via the web (http://nvs.nanoos.org/BeachMapping).

Recently, studies undertaken by the USGS provide additional insights into the spatial extent of erosion patterns on the Oregon coast. Figure 3.3.1-7 provides analyses of both long-term (about 1900s to 2002) and short-term (about 1960s/80s to 2002) shoreline change patterns along the Tillamook County coast, confirming measured data reported by DOGAMI. As can be seen from the figure, long-term erosion rates (albeit low rates) dominate the bulk of Tillamook County (i.e., Bayocean Spit, Netarts, Sand Lake, and Neskowin littoral cells), while accretion prevailed in the north along Rockaway Beach and on Nehalem Spit. The significant rates of accretion identified adjacent to the mouth of Tillamook Bay are entirely due to construction of the Tillamook jetties, with the north jetty completed in 1917 and the south jetty in 1974. Short-term shoreline change patterns indicate that erosion has continued to dominate the bulk of the shoreline responses observed along the Tillamook County coast. Erosion is especially acute in the Neskowin, Sand Lake and Netarts littoral cells, and especially along Rockaway Beach. In many of these areas, the degree of erosion remains so significant, that were communities to experience a major storm(s) in the ensuing winters, the risk of considerable damage to property and infrastructure in these areas would likely be high.

Figure 3.3.1-7: Long- and Short-Term Shoreline Change Rates for the Tillamook County Region



Source: Ruggiero, et al. (2013)

The processes of wave attack significantly affect shorelines characterized by indentations, known as inlets, that lead to estuaries or other enclosed bodies of water. Waves interact with ocean tides and river forces to control patterns of inlet migration. This is especially the case during El Niño. During an El Niño, large storm waves tend to arrive out of the south, which causes the mouth of the estuary to migrate to the north, where it may abut against the shoreline, allowing large winter waves to break much closer to the shore. This can result in significant “hotspot” erosion north of the estuary mouth. Recent examples of the importance of inlet dynamics during an El Niño are Alsea Spit near Waldport (Figure 3.3.1-8), Netarts Spit near Oceanside, and at Hunter Creek on the southern Oregon coast at Gold Beach.

Figure 3.3.1-8: Alsea Bay Spit Erosion as a Result of the 1982-83 El Niño (left), and State of the Beach in 2009 (right)

Source: DOGAMI
Notes: Yellow/black line delineates a riprap structure constructed to protect the properties from further erosion. Orange line defines the maximum extent of dune erosion due to wave attack as a result of the 1982-83 event. Note the northward migration of the estuary mouth compared to its position in 2009.

Floods

Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FISs) are also often used in characterizing and identifying flood-prone areas. FEMA conducted many FISs in the late 1970s and early 1980s. Included were “VE” zones, areas subject to wave action and ocean flooding during a “100-year” event that encompass the area extending from the surf zone to the inland limit of wave runup, and/or wave overtopping and inundation, and/or the location of the primary frontal dune or any other area subject to high-velocity wave action from coastal storms. Areas identified as VE zones are subject to more development standards than other flood zones. Between 2009 and 2014, DOGAMI worked with FEMA to remap FEMA coastal flood zones established for Oregon’s coastal communities, utilizing improved topographic information, revised information on extreme storm waves and ocean water levels, and a revised methodology for calculating erosion, wave runup and overtopping. Tidal flooding, especially during perigean spring tides and El Niño events, already impacts low-lying coastal areas, including a stretch of Highway 101 just south of Seaside.

Landslides

Simple surface sloughing is the dominant process along bluff-backed shorelines. Other shorelines are backed by steep slopes, where deep-seated landslides and slumping are the dominant processes (Figure 3.3.1-9). The geologic composition of the bluff is a primary control on slope stability.

Headlands, generally composed of basalt, are more resistant to erosion and do not readily give way. In contrast, soft bluff-forming sandstone and mudstone are highly susceptible to slope movement. Prolonged winter rains saturate these porous bluff materials, increasing the likelihood of landslides.

The geometry and structure of bluff materials also affect slope stability by defining lines of weakness and controlling surface and subsurface drainage. As waves remove sediment from the toe of the bluff, the bluffs become increasingly vulnerable to slope failure due to increased exposure to wave attack. The extent to which the beach fronting the bluff acts as a buffer is thus important in this regard. Thus a reduction in the sand beach volume in front of a bluff increases its susceptibility to wave erosion along its toe, which can eventually contribute to the failure of the bluff by undercutting of the base of the bluff, creating instability of the overhanging slope face.

A recent example of such a process occurred at Gleneden Beach in Lincoln County in November 2006 (Figure 3.3.1-9), when a large rip current embayment (an area of the beach that exhibits more erosion and beach narrowing due to removal of sand by rip currents) formed in front of a portion of the bluff, allowing waves to directly attack the base of the bluff. In a matter of two days, the bluff eroded back by up to 30 ft, undermining the foundations of two homes, and almost resulting in their destruction.

Figure 3.3.1-9: Bluff Failure Due to Toe Erosion by Ocean Waves

Source: OPDR
Note: The top of the bluff eroded landward by about 30 ft over a 48-hour period in November 2006.

Similar processes occurred nearby during the 1972-73 winter, which led to one home having to be pulled off its foundation. Both examples provide a stark reminder of the danger of building too close to the beach and that episodic erosion events can happen without warning and can cause significant damages and hazards. It is important to note as well that under Oregon's Statewide Planning Goal 18, only oceanfront properties that were developed on or prior to January 1st 1977 are eligible for shoreline armoring, which is subjected to the permitting regulations of the Oregon Parks and Recreation Ocean Shores Division. Therefore, not all properties that face erosional issues are eligible to armor their property to prevent further erosion from occurring.

Landslide risk is especially high on the southern Oregon coast in Curry County, where multiple slide failures are presently affecting Highway 101. One of the largest recent events occurred on March 3, 2019 at Hooskanaden Creek, affecting travel on Highway 101 (Figure 3.3.1-10). Movement in the central part of the landslide near Highway 101 varied from 45 to 130 ft. Significant active landsliding is also evident on the central Oregon coast in the Beverly Beach littoral cell, located immediately north of Yaquina Head. Within this eight-mile stretch of highway, there are four active landslide blocks that require frequent remediation of the highway.

Figure 3.3.1-10: Landslide Movement Affecting U.S. Highway 101 at Hooskanaden Creek on March 3, 2019

Source: Michael Olsen, 2020.
Note: Inset Photo Shows the Overall Scale of the Landslide and Its Proximity to the Coast.

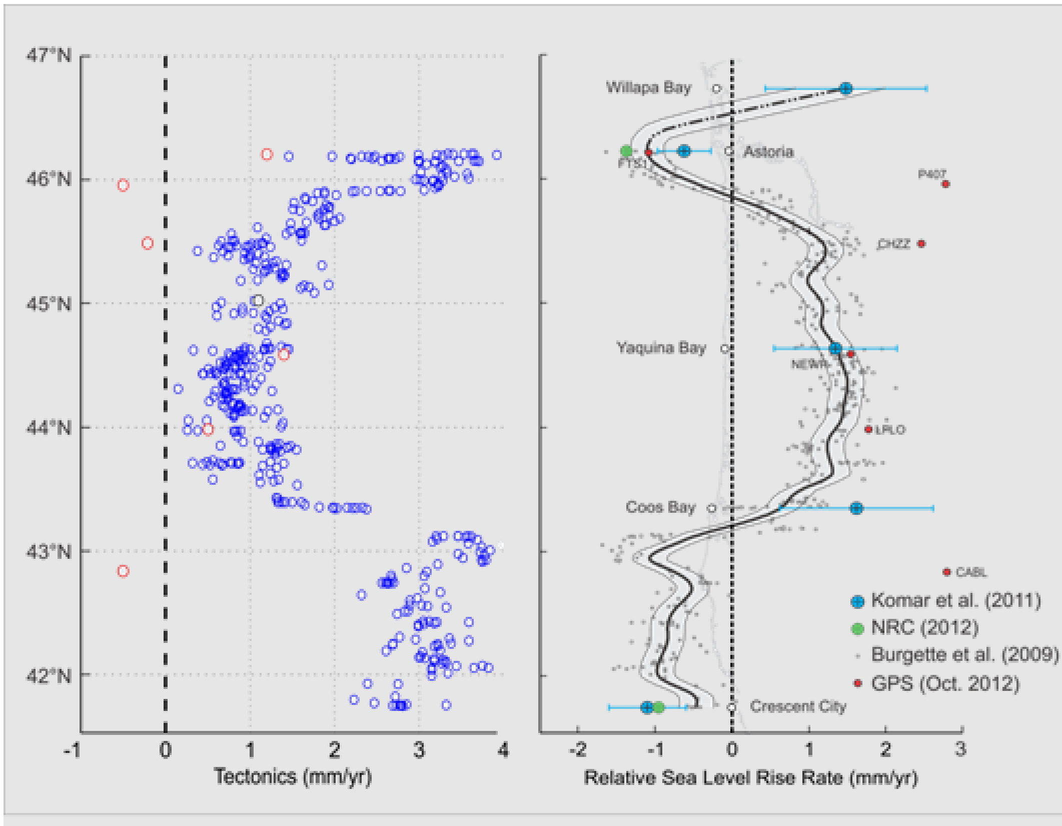
Climate Change and Sea Level Rise

An understanding of the trends and variations in sea level on the Oregon coast provides important insights as to the spatial patterns of erosion and flood hazards. In general, tectonic uplift is occurring at a much faster rate (about 2–4 mm/year) on the south coast (south of about Coos Bay), while the uplift rates on the central to northern Oregon coast are much lower, averaging about 1 mm/year (Figure -11, left). When combined with regional patterns of sea level change (Figure -11, right), it is apparent that the southern Oregon coast is essentially an emergent coast, with the coast rising at a much faster rate when compared with sea level. In contrast, the central to northern Oregon coast is a submergent coast due to the fact that sea level is rising faster than the land. Not surprisingly, it is the north coast that exhibits the most pervasive erosion and flood hazards when compared with the south coast.

In 2012, the National Research Council (2012) completed a major synthesis of the relative risks of sea level rise on the U.S. West Coast. The consensus from that report is that sea level has risen globally by on average 1.7 mm/year, while rates derived from satellite altimetry indicate an increase in the rate of sea level rise to 3.2 mm/year since 1993 (National Research Council, 2012). Combining data on glacial isostatic rebound (the rate at which the earth responds to the removal of ice from the last glaciations), regional tectonics, and future temperature patterns, the committee concluded that sea level on the Oregon coast would increase by approximately 2.1 ft by 2100.

Global measurements of sea level change continue to be quantified through satellite altimetry, with the most recent (February 2020) measurements indicating a net increase of 3.39 mm/year since 1993 (Copernicus Marine and Environment Monitoring Service (CMEMS), Aviso Satellite Altimetry Data website, Mean Sea Level Rise page, https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html). Regional projections of future sea level rise scenarios have also been updated for the United States, based on revised global projections of sea level change undertaken using global climate change modeling (Sweet and others, 2017). These revised data reflect the most up-to-date scientific information, including recent observational and modeling literature that examine the potential for rapid ice melt in Greenland and Antarctica. Based on these latest analyses, a physically plausible global sea level rise in the range of 6 ft to 8.9 ft is now more likely. Sweet and others (2017) define six global sea level rise scenarios, termed: Low, Intermediate-low, Intermediate, Intermediate-high, High and Extreme, which correspond to global sea level increases of 1 ft, 1.6 ft, 3.3 ft, 4.9 ft, 6.6 ft, and 8.2 ft respectively. These data can then be used to calculate regional estimates of sea level rise, after accounting for tectonic changes, glacial isostatic rebound, and shifts in ocean circulation patterns. For the Pacific Northwest, Sweet and others (2007) indicate that the regional sea level rise is projected to be less than the global average falling mainly under the Low-to-Intermediate scenarios (e.g., 0.3–3.3 ft).

Figure -11: Coast Variations in Rates of Tectonic Uplift, and Relative Sea Level Trends for the Oregon Coast



Source: Komar & Allan (2010); http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/

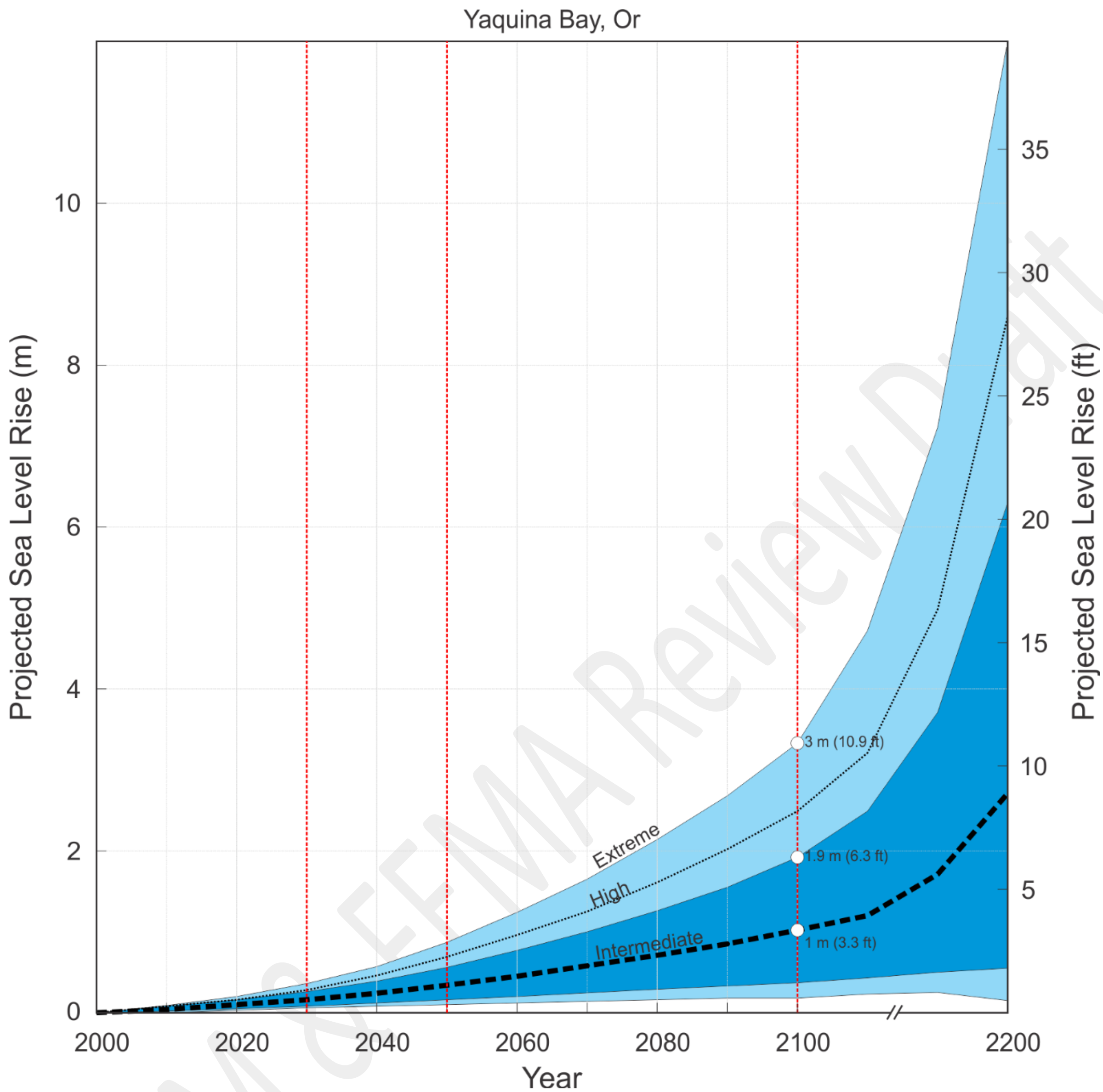
Table 3.3.1-1: Projected Sea Level Rise for the Central Oregon Coast

By Year 2030		**By Year 2050**		**By Year 2100**	
Projection	Range	Projection	Range	Projection	Range
0.5 ft	0.2–1.2 ft	1.1 ft	0.3–2.9 ft	3.4 ft	0.6–10.9 ft

Table 3.3.1-1 presents the revised Sweet and others (2017a) projected sea level rise findings for the Central Oregon coast. The largest increase in regional sea level is estimated to be 10.9 ft by 2100 (Figure 3.3.1-12) while the intermediate projection reflects an increase of about 3.4 ft by 2100. As noted previously, the extreme 10.9 ft projection reflects the now plausible scenario of a catastrophic failure of the Greenland and Antarctic ice sheets. Under this latter scenario, projected sea levels in 2200 could well exceed 30 ft along the Oregon coast.

Of importance, these projections assume that sea level is uniform year- round. However, as noted previously, sea level on the Oregon coast exhibits a pronounced seasonal cycle of about 0.8 ft between summer and winter, increasing to as much as 2 ft in response to the development of a strong El Niño. Thus, when combined with projected future increases in regional sea level, it becomes apparent that the potential increase in mean sea level could be substantially greater depending on the time of year. For example, by 2100, sea level during an El Niño winter could be as much as 13 ft under the most extreme scenario, raising the mean shoreline position by that amount, which will have shifted upward and landward as beaches respond to the change in mean water levels. Based on these projections, it can be expected that areas presently classified as emergent (e.g., the southern Oregon coast), will become submergent over time as the rate of sea level rise surpasses tectonic uplift. Furthermore, erosion and flood hazards on the northern Oregon coast will almost certainly accelerate, increasing the risk to property. As sea levels rise, beaches and cliffs will also continue to erode; with increased development and armoring along the shoreline, the landward migration of the shoreline will be limited, leading to beach narrowing and sediment loss.

Figure 3.3.1-12: Projected Future Changes in Regional Sea Levels on the Oregon Coast.



Source: Created by Jonathan Allan, DOGAMI, with integrated sea level rise projections from Sweet and others (2017).

Human Activities

Human activities affect the stability of all types of shoreline. Large-scale human activities such as jetty construction and maintenance dredging have a long-term effect on large geographic areas. This is particularly true along dune-backed and inlet-affected shorelines such as the Columbia River and Rockaway littoral cells (Figure 3.3.1-3). The planting of European beach grass (*Ammophila arenaria*) since the early 1900s and, more recently, American beach grass (*Ammophila breviligulata*) has locked up sand in the form of high dunes. Such a process can contribute to a net loss in the beach sand budget and may help drive coastal erosion.

Residential and commercial development can affect shoreline stability over shorter time periods and smaller geographic areas. Activities such as grading and excavation, surface and subsurface drainage alterations, vegetation removal, and vegetative as well as structural shoreline stabilization can all affect shoreline stability.

While site-specific coastal engineering efforts such as the construction of riprap revetments is less likely to cause direct adverse impacts to the littoral cell as a whole, the cumulative effect of constructing many of these structures along a particular shore (e.g., as has occurred along the communities of Gleneden Beach, Siletz Spit, Lincoln City, Neskowin, Pacific City, and Rockaway) will almost certainly decrease the volume of sediment being supplied to the beach system, potentially affecting the beach sediment budget and hence the stability of beaches within those littoral cells. Shoreline armoring structures can also lead to increased erosion of neighboring properties, known as flanking erosion.

Heavy recreational use in the form of pedestrian and vehicular traffic can affect shoreline stability over shorter time frames and smaller spaces. Because these activities may result in the loss of fragile vegetative cover, they are a particular concern along dune-backed shorelines. Graffiti carving along bluff-backed shorelines is another byproduct of recreational use that can damage fragile shoreline stability.

3.3.1.2 Historic Coastal Hazard Events

Table 3.3.1-2: Historic Coastal Hazard Events in Oregon

Date	Location	Description
Jan. 1914	Newport	damage (Nicolai Hotel)
1931	Rockaway	coastal damage from December storm
Oct–Dec. 1934	Waldport and Rockaway	flooding (Waldport) coastal damage (Rockaway Beach)
Dec. 1935	Cannon Beach and Rockaway Beach	coastal damage
Jan. 1939	coastwide	severe gale; damage: coastwide severe flooding (Seaside, and Ecola Creek near Cannon Beach): multiple spit breaches (southern portion of Netarts Spit) storm damage (along the shore of Lincoln City and at D River) flooding (Waldport)

Date	Location	Description
		extensive damage (Sunset Bay Park) storm surge overtopped foredune (Garrison Lake plus Elk River lowland)
Dec. 1940	Waldport	flooding
1948	Newport	wave damage (Yaquina Arts Center)
Jan. 1953	Rockaway	70-ft dune retreat; one home removed
Apr. 1958	Sunset Bay State Park Newport	flooding (Sunset Bay); wave damage (Yaquina Arts Center in Newport)
Jan.–Feb. 1960	Sunset Bay State Park	flooding
1964	Cannon Beach	storm damage
Dec. 1967	Netarts Spit Lincoln City Newport Waldport	damage: coastwide State constructed wood bulkhead to protect foredune along 600 ft section (Cape Lookout State Park campground) flooding and logs (Lincoln City) wave damage (Yaquina Arts Center, Newport) flooding (Waldport) Storm damage (Beachside State Park washed up driftwood (Bandon south jetty parking lot)
1971–73	Siletz Spit	high tide line eroded landward by 300 ft Feb. 1973; one home completely destroyed; spit almost breached logs through Sea Gypsy Motel (Nov. 1973)
1982–83	Alsea Spit	northward migration of Alsea Bay mouth; severe erosion
1997–98	Lincoln and Tillamook Counties	El Niño winter (second strongest on record); erosion: considerable
1999	coastwide	five storms between January and March; coastal erosion: extensive, including: significant erosion (Neskowin, Netarts Spit, Oceanside, Rockaway beach); overtopping and flooding (Cape Meares) significant erosion along barrier beach (Garrison Lake); overtopping 27-ft high barrier

Date	Location	Description
Dec. 2007	Tillamook and Clatsop Counties	wind storm
Dec. 7-11 2015	Tillamook and Clatsop Counties	coastal and riverine flooding in response to several days of heavy rain. large storm waves exceeding 30 ft on Dec 11th resulted in coastal erosion issues in several communities.
Feb. 2018	Curry County	major coastal landslide at Hooskanaden, located in southern Curry County
2019-2020	Siletz Spit	significant erosion over the 2019-20 winter resulted in several homes impacted and the need for emergency permits for coastal engineering.
2024	Coos, Lincoln, Tillamook Counties; CTSI	Oregon Severe Winter Storms, Straight-line Wind, Landslides, and Mudslides

Sources: Allan & Priest (2001); Allan & Komar (2002); Allan, et al. (2003), (2006); Allan & Hart (2007), (2008); Allan, et al. (2009), (2012); Allan & Stimely (2013); Komar (1986) (1987); Komar & Rea (1976); Komar & McKinney (1977), (1997); Komar & Allan (2010); Peterson, et al. (1990); Priest (1999); Revell, et al. (2002); Schlicker, et al. (1973); Stembridge (1975); and Terich and Komar (1974)

3.3.1.3 Risk Maps

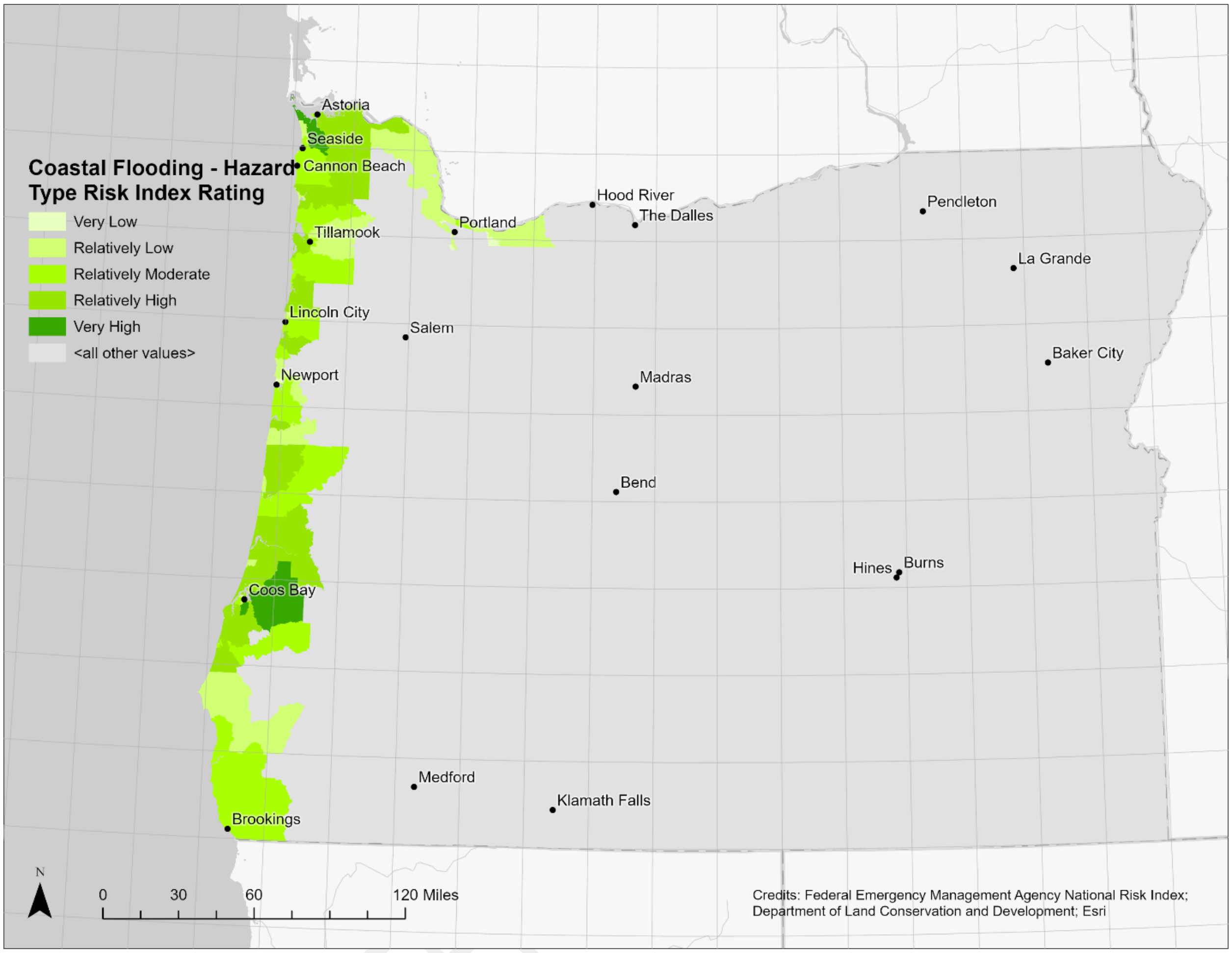
The maps in this section highlight places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

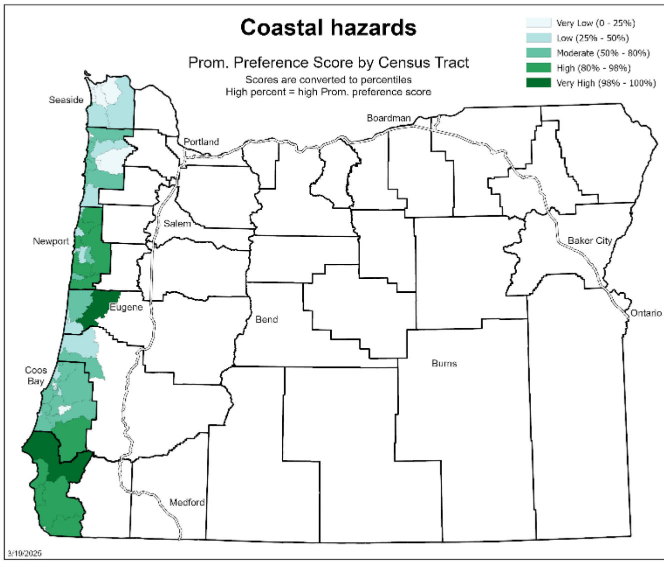
Figure 3.3.1-13 Coastal Flooding Risk Rating from the FEMA Risk Index Rating (NRI)



Source: Federal Emergency Management Agency, National Risk Index for Coastal Flooding. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.
Note: Ranking based on national percentiles.

Figure 3.3.1-14 and Figure 3.3.1-15 show risk rankings by census tract for coastal flooding from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.1-14 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.1-15 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

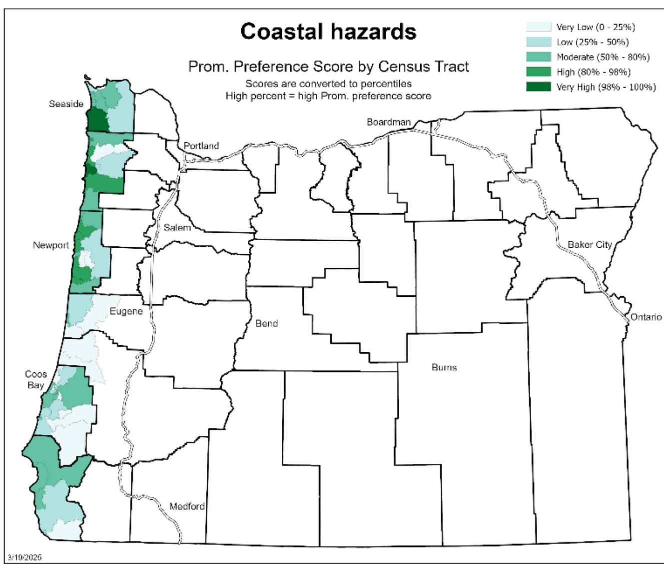
Figure 3.3.1-14 Coastal Hazards Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Coastal hazards	CFL_pct_bld	1	0.029	Percentage of SBFO buildings exposed to coastal flooding.
Coastal hazards	Hwy_FL_pct	1	0.029	Major roadways number of miles that are exposed to flood hazard.
Coastal hazards	CFL_pct_CF	1	0.029	Percentage of critical facilities exposed to coastal flooding.
Coastal hazards	Hist_CE_ct	1	0.029	Percentage of historic buildings exposed to coastal erosion.
Coastal hazards	SBFO_CE_pct	1	0.029	Percentage of SBFO buildings exposed to coastal erosion.
Coastal hazards	Port	1	0.029	Presence of marine port infrastructure
Coastal hazards	Bridge_Scour	1	0.029	Number of bridges that are at risk from scour during a 100-year flood.
Coastal hazards	CRS_Rate	1	0.029	Community Rating System (NFIP) score for communities.
Coastal hazards	ImpervSurf_Pct	1	0.029	Percentage of impervious surface.
Coastal hazards	FIRM_Diff	1	0.029	Number of years difference between median year built and FIRM date.
Coastal hazards	FL_Haz_Area	1	0.029	Area of tract in 100-year flood hazard.
Coastal hazards	RepeatLoss	1	0.029	Repetitive loss structures
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

Figure 3.3.1-15 Coastal Hazards Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Coastal hazards	CFL_pct_bld	1	0.083	Percentage of SBFO buildings exposed to coastal flooding.
Coastal hazards	Hwy_FL_pct	1	0.083	Major roadways number of miles that are exposed to flood hazard.
Coastal hazards	CFL_pct_CF	1	0.083	Percentage of critical facilities exposed to coastal flooding.
Coastal hazards	Hist_CE_ct	1	0.083	Percentage of historic buildings exposed to coastal erosion.
Coastal hazards	SBFO_CE_pct	1	0.083	Percentage of SBFO buildings exposed to coastal erosion.
Coastal hazards	Port	1	0.083	Presence of marine port infrastructure
Coastal hazards	Bridge_Scour	1	0.083	Number of bridges that are at risk from scour during a 100-year flood.
Coastal hazards	CRS_Rate	1	0.083	Community Rating System (NFIP) score for communities.
Coastal hazards	ImpervSurf_Pct	1	0.083	Percentage of impervious surface.
Coastal hazards	FIRM_Diff	1	0.083	Number of years difference between median year built and FIRM date.
Coastal hazards	FL_Haz_Area	1	0.083	Area of tract in 100-year flood hazard.
Coastal hazards	RepeatLoss	1	0.083	Repetitive loss structures

3.3.2 Droughts

Despite its rainy reputation, the state of Oregon is often confronted with continuing challenges associated with drought and water scarcity. Precipitation in Oregon follows a distinct spatial and temporal pattern; it tends to fall mostly in the cool season (October–March). The Cascade Mountains block rain-producing weather patterns, creating a very arid and dry environment east of these mountains (Figure 3.3.2-1). Moist air masses originating from the Pacific Ocean cool and condense when they encounter the mountain range, depositing precipitation primarily on the inland valleys and coastal areas.

Oregon's water-related challenges are greater than just the temporal and spatial distribution of precipitation in Oregon. A rapidly growing population in the American West has placed a greater demand on this renewable, yet finite resource. The two terms, drought and water scarcity, are not necessarily synonymous; distinctly, water scarcity implies that demand is exceeding the supply. The combined effects of drought and water scarcity are far-reaching and merit special consideration.

Drought is typically measured in terms of water availability in a defined geographic area. It is common to express drought with a numerical index that ranks severity. Most federal agencies use the Palmer Method which incorporates precipitation, runoff, evaporation, and soil moisture. However, the Palmer Method does not incorporate snowpack as a variable. Therefore, it does not provide a very accurate indication of drought conditions in Oregon and the Pacific Northwest, although it can be very useful because of its a long-term historical record of wet and dry conditions.

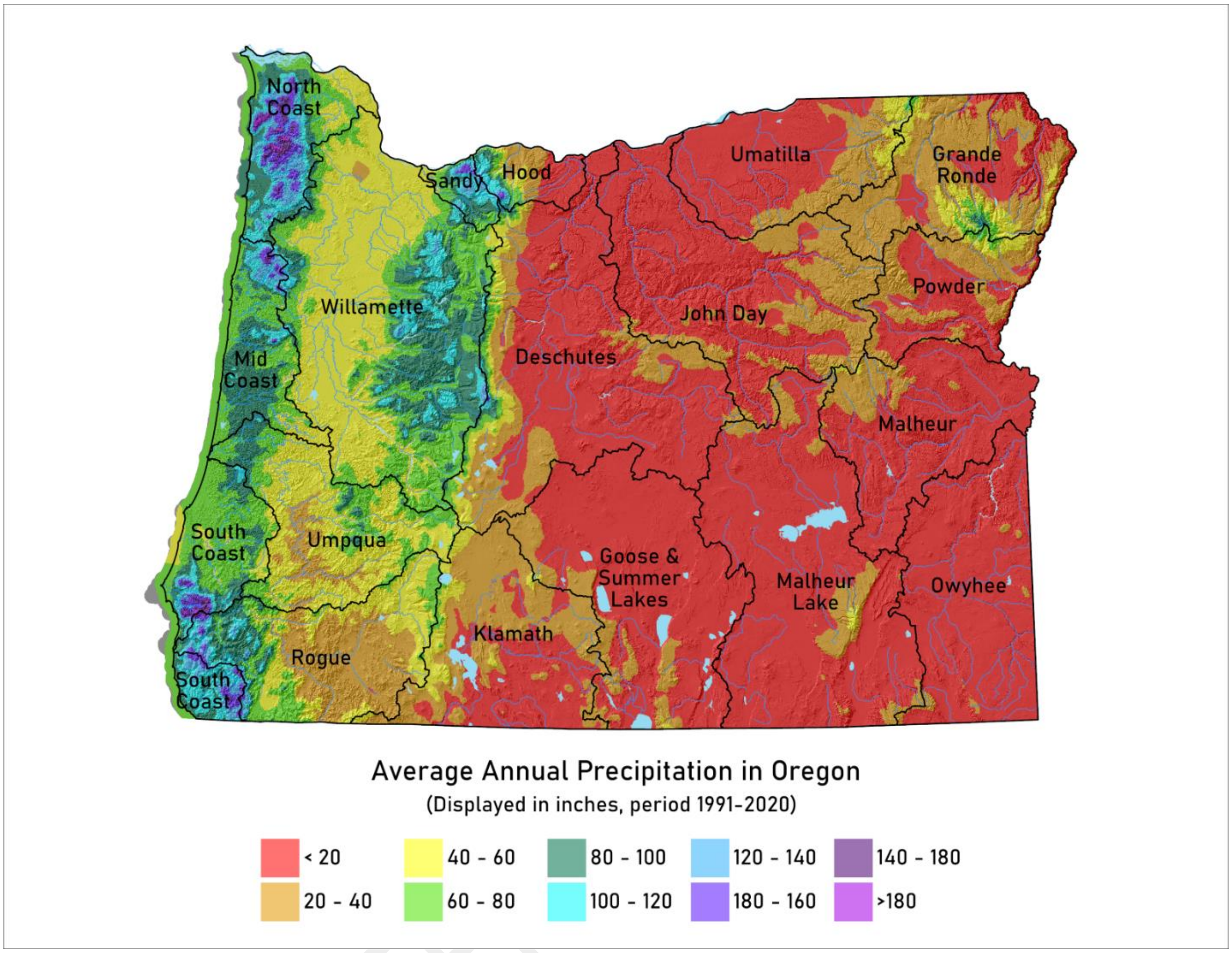
Snow droughts are expected to occur more often under climate change. There are two types of snow drought: dry and warm snow droughts. Dry snow drought is precipitation that falls as snow, but little precipitation falls. Warm snow drought is classified when ample precipitation occurs but falls as rain. The 2015 drought in Oregon was a "snow drought" and serves as a good example of what future climate projections indicate may become commonplace by mid 21st century (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Going forward, drought indices that can account for a changing climate, such as the Standard Precipitation-Evapotranspiration Index (SPEI), may provide a more accurate estimate of future drought risks.

Oregon's Emergency Operations Plan includes a Drought Annex for the purposes of coordinating state and federal agency response to drought emergencies caused by water shortages and to provide emergency water supplies for human consumption under conditions of inadequate supply. The Annex outlines several steps and lists major responsibilities of various federal, state, and local jurisdictions. It also includes a description of federal drought assistance programs and guidelines for water curtailment planning and program development.

3.3.2.1 Analysis and Characterization

Defining drought can be difficult given the issue of both water supply and demand. Redmond (2002) puts forth a simple definition that encapsulates both supply and demand, "drought is insufficient water to meet needs." Oregon's Legislative Assembly describes drought as a potential state emergency when a lack of water resources threatens the availability of essential services and jeopardizes the peace, health, safety, and welfare of the people of Oregon (Oregon Revised Statute §539.710).

Figure 3.3.2-1: Oregon Average Annual Precipitation, 1991–2020



Sources: PRISM Climate Group, Oregon State University (http://www.prism.oregonstate.edu/); map by Oregon Water Resources Department.

Droughts can be characterized by the dominant impact caused by increased demand or decreased supply. In the early 1980s, researchers with the National Drought Mitigation Center and the National Center for Atmospheric Research located more than 150 published definitions of drought. There clearly was a need to categorize the hazard by "type of drought." The following definitions are a response to that need. However, drought cannot always be neatly characterized by the following definitions, and sometimes all four definitions can be used to describe a specific instance of drought.

Meteorological or climatological droughts usually are defined in terms of the departure from a normal precipitation pattern and the duration of the event. Drought is a slow-onset phenomenon that usually takes at least three months to develop and may last for several seasons or years.

Agricultural droughts link the various characteristics of meteorological drought to agricultural impacts. The focus is on precipitation shortages and soil-water deficits. Agricultural drought is largely the result of a deficit of soil moisture. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.

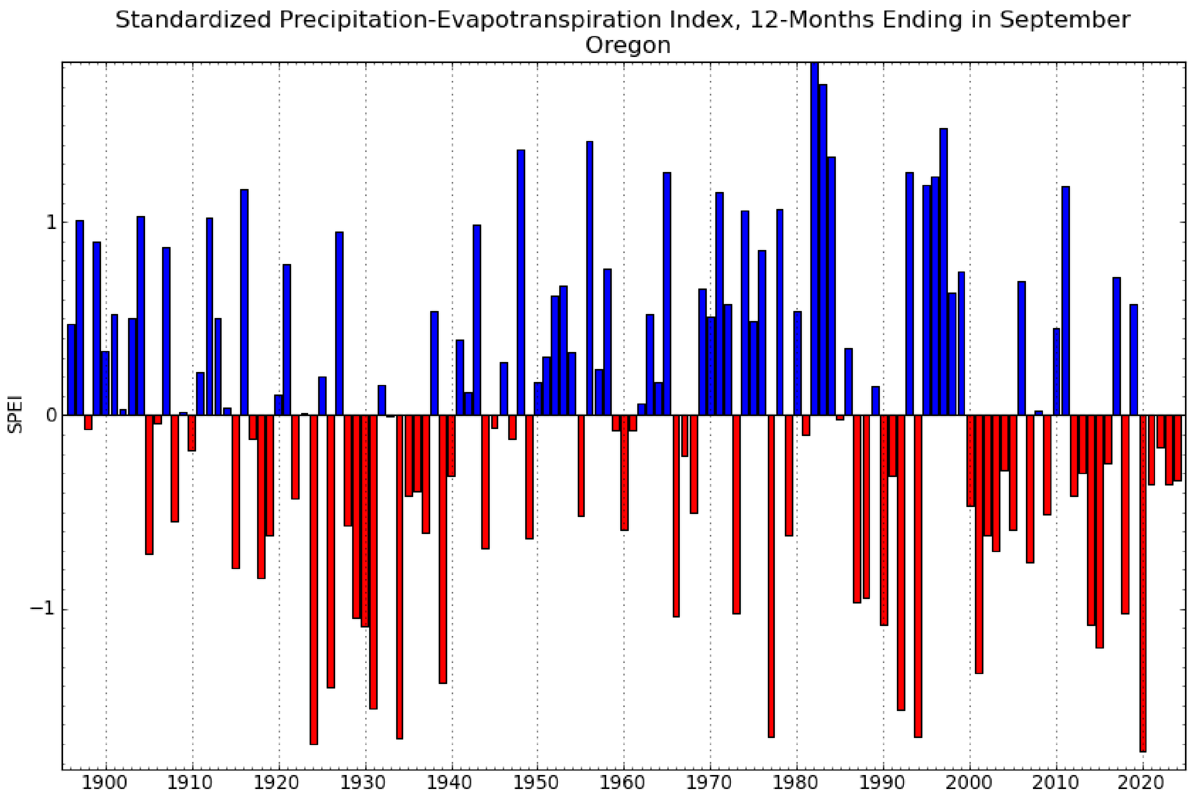
Hydrological droughts refer to deficiencies in surface water and sub-surface water supplies. It is reflected in the level of streamflow, lakes, reservoirs, and groundwater. Hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, the shortage will be reflected in declining surface and sub-surface water levels.

Socioeconomic droughts occur when physical water shortage begins to affect people, individually and collectively. Most socioeconomic definitions of drought associate it with supply, demand, and economic good. One could argue that a physical water shortage with no socio-economic impacts is a policy success.

3.3.2.2 History of Droughts in Oregon

Oregon records, dating back to the late 1800s, associate drought with a departure from expected precipitation. Droughts in the Pacific Northwest can persist for a few years, but rarely prolong for a decade. The Dust Bowl era (1930s) had many years with below average precipitation, which caused problems for agriculture, but every year in that decade was not considered to be a drought year. However, three water years in the 1930s fall in the top ten lowest statewide Standard Precipitation-Evapotranspiration Index (SPEI) values on record (Table 3.3.2-1). While droughts are often referred to as happening in a calendar year, it is more appropriate to define them by water year. The water year begins at the start of the cool, rainy season on October 1 and continues through September 30 of the following year. For example, Water Year 2024 started on October 1, 2023.

Figure 3.3.2-2: Water Year Standard Precipitation-Evapotranspiration Index (SPEI) for Oregon



Source: West Wide Drought Tracker, https://wrcc.dri.edu/wwdt/time/, with the following selections: Oregon, SPEI, 1895–2024, September, 12-month. Created 12-03-2024. Graphic courtesy OWRD

Table 3.3.2-1: Water Years with the Lowest SPEI Values, Averaged Statewide, on Record (1895–2024) for the State of Oregon

Rank	Water Year	SPEI Value
1	2020	-1.74
2	1924	-1.70
3	1934	-1.67
4	1994	-1.67
5	1977	-1.66
6	1992	-1.52
7	1931	-1.51
8	1926	-1.41
9	1939	-1.39
10	2001	-1.33

Source: West Wide Drought Tracker, https://wrcc.dri.edu/wwdt/time/, with the following selections: Oregon, SPEI, 1895–2024, September, 12-month

Low stream flows prevailed in western Oregon during the period from 1976-81, but the worst water year, by far, was 1977, the single driest year of the century. The Portland Airport received only 7.19 inches of precipitation between October 1976 and February 1977, only 31 percent of the average 23.16 inches for that period. This drought also impacted California and other parts of the West Coast. It is often acknowledged as one of the most significant droughts in Oregon's history and fittingly shows up as the fifth lowest SPEI value statewide.

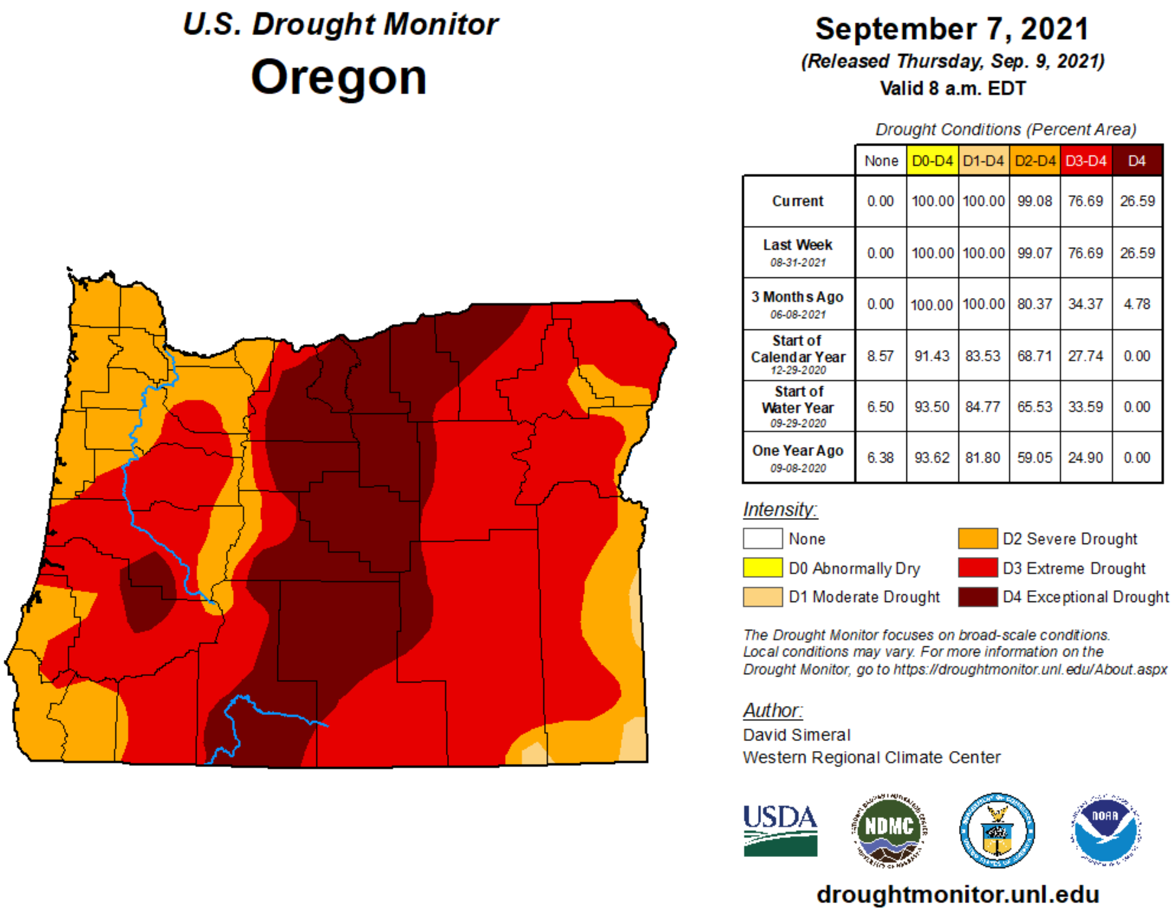
The 1992 drought was not as severe as the 1976-77 drought; however, it did occur toward the end of several years of drier than normal conditions in the late 1980s and early 1990s, making it the peak year for drought conditions. The Governor declared a drought emergency for all Oregon counties (Executive Order 92-21). Forests throughout the state suffered from a lack of moisture. Fires were common and insect pests, which attacked the trees, flourished.

In 2001 and 2002, Oregon experienced drought conditions, affecting six out of eight regions. During the 2005 drought, the Governor issued declarations for 13 counties, all east of the Cascades, and the USDA issued three drought declarations, overlapping two of the Governor's. State declarations were made for Baker, Wallowa, Wheeler, Crook, Deschutes, Klamath, Lake, Hood River, Wasco, Sherman, Gilliam, Morrow, and Umatilla Counties. Federal declarations were made in Coos, Klamath, and Umatilla Counties. Federal drought declarations, similar to declarations by Oregon's governor, provide emergency relief and response actions by various agencies. The U.S. Department of Agriculture, for example, can provide accessibility to emergency loans for crop losses. Since 2001, the Governor has declared a drought in 18 out of 24 years (2001–2024), in at least one Oregon county. Most of these declarations have involved one or more counties in Regions 4-8.

In 2015, Oregon had its warmest year on record. Winter precipitation amounts that year were near normal, but winter temperatures that were 5–6°F above average caused the precipitation that did fall to fall as rain instead of snow, reducing mountain snowpack accumulation. This resulted in record low snowpack across the state, earning official drought declarations for 25 of Oregon's 36 counties (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). At the peak of the drought which began in 2014, all of Oregon was in severe or extreme drought, according to the U.S. Drought Monitor. Recent research has indicated that human-caused climate change exacerbated the 2015 drought in Oregon (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). The 2015 drought in Oregon was a "snow drought" and serves as a good example of what future climate projections indicate may become commonplace by mid 21st century (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

2021 was Oregon's fourth warmest year on record, with average temperatures 2.9°F above normal. It was also the 16th driest year, with precipitation 6.54 inches below the average. July 2021 was the hottest July ever recorded in the state, with temperatures 6.6°F above normal, which contributed to a flash drought early in the summer. As a result, by September 2021, over 25 percent of Oregon was experiencing exceptional drought (the highest level on the U.S. Drought Monitor), and nearly the entire state was in severe drought conditions (Figure 3.3.2-3). By the end of the year, 26 of Oregon's 36 counties had received state drought declarations. Although the state's snowpack peaked above the historical median, overall precipitation was below normal. This, combined with the prolonged drought severity from the previous year (lowest SPEI on record), led to the increased severity of drought conditions despite the above-normal snowpack.

Figure 3.3.2-3 September 7, 2021 U.S. Drought Monitor Report for Oregon



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	99.08	76.69	26.59
Last Week 08-31-2021	0.00	100.00	100.00	99.07	76.69	26.59
3 Months Ago 06-08-2021	0.00	100.00	100.00	80.37	34.37	4.78
Start of Calendar Year 12-29-2020	8.57	91.43	83.53	68.71	27.74	0.00
Start of Water Year 09-29-2020	6.50	93.50	84.77	65.53	33.59	0.00
One Year Ago 09-08-2020	6.38	93.62	81.80	59.05	24.90	0.00

Source: U.S. Drought Monitor (http://droughtmonitor.unl.edu/)

3.3.2.3 Impacts

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on the state's agricultural sector, particularly east of the Cascade Mountains.

Even though drought may not be declared as often in Western Oregon as in counties east of the Cascades, when drought conditions do develop in the Willamette Valley, the impacts are widespread and severe when both winter snow and spring/summer rain are low. Reasons for broad and significant impact include:

- Higher population density and growing population in the Willamette Valley;
- Dependence on surface water supplies for many municipalities, agriculture and industries from large flood control reservoirs in the Willamette river system;

- Agriculture is a major industry becoming increasingly dependent on irrigation;
- Increased frequency of toxic algal blooms in the Willamette system reservoirs, resulting in restrictions on use of water from reservoirs for drinking (i.e., for human and animals). Affected waters may not be safe for agricultural irrigation, and other uses; necessitating purchasing and transporting water from alternative sources;
- Since drought is typically accompanied by earlier onset of snowmelt (e.g., during flood control or early storage season), little or no snowmelt runoff is stored until later;
- Earlier start to growing season, before the start of the irrigation season, means that crops may not be irrigated until the irrigation season begins;
- Insufficient number of farm workers available because the growing season began before the workers were scheduled to arrive; and
- Responsibilities to recovering anadromous fish.

These are relatively recent and developing concerns, in particular on livestock and some other agricultural operations, and therefore there is no single comprehensive source or other sources for information to assess economic impacts. Impacts of drought on state-owned facilities related to agriculture would include impacts to research conducted in outdoor settings, such as at extension stations and research farms.

Below-average snowfall in Oregon's higher elevations has a far-reaching effect on the entire state, especially in terms of hydroelectric power generation, irrigation, recreation, and industrial uses. In March of 2014, Mount Ashland Ski Resort in southern Oregon announced that it would be unable to open due to the lack of snow. The following year the Ski Resort had to make snow in order to open. The lack of snow has affected other regions of the state as well. In the Klamath Basin, the Natural Resources Conservation Service reports that the mountains are generally snow-free below 5,000 feet. The Taylor Butte SNOTEL site at elevation 5,030 feet was snow-free on March 1, 2014, a first for the site since it was installed in 1979. Five long-term snow measurement sites in the Klamath basin set new record lows for March 1 snowpack. In fact, 81 percent of measurement sites west of 115°W (near the eastern border of Nevada) set record low April 1 snowpack in 2015, a quarter of which recorded no snow for the first time ((Mote, et al., 2016)).

There also are environmental consequences. A prolonged drought in Oregon's forests promotes an increase of insect pests, which in turn, damage trees already weakened by a lack of water. In the Willamette Valley, for example, there has been an unusual pattern of tree mortality involving Douglas fir, grand fir, and western red cedar. Water stress brought on by drought and other factors is the central cause in these mortality events (Oregon Department of Forestry, 2008).

A moisture-deficient forest constitutes a significant fire hazard (see the **Wildfire** section of this Plan). The 2020 wildfire season was one of the most severe in the Pacific Northwest. The Oregon Forest Resources Institute's 2021 report on the 2020 Labor Day fires reported 919,700 acres burned across five megafires—fires greater than 100,000 acres-- and 12 fires ranging from 112 to 50,951 acres, with an estimated economic impact of $5.9 billion to Oregon's forest sector (OFRI 2021). In addition, drought and water scarcity add another dimension of stress to imperiled species.

The following information addresses the impact of a severe or prolonged drought on the population, infrastructure, facilities, economy, and environment of Oregon:

Population

Droughts can affect all segments of Oregon's population, particularly those employed in water-dependent activities (e.g., agriculture, hydroelectric generation, recreation, etc.). For example, in 2015 farmers in eastern Oregon's Treasure Valley received a third of their normal irrigation water (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Also, domestic water-users may be subject to stringent conservation measures (e.g., rationing) during times of drought and could see increases in electricity consumption and associated costs.

Infrastructure

Infrastructure such as highways, bridges, energy and water conveyance systems, etc., is typically unaffected by drought. However, drought can cause structural damage. An example would include be areas of severe soil shrinkage. In these uncommon situations, soil shrinkage would affect the foundation upon which the infrastructure was built. In addition, water-borne transportation systems (e.g., ferries, barges, etc.) could be impacted by periods of low water.

Critical/essential facilities

Facilities affected by drought conditions include communications facilities, hospitals, and correctional facilities that are subject to power failures. Storage systems for potable water, sewage treatment facilities, water storage for firefighting, and hydroelectric generating plants also are vulnerable. Low water also means reduced hydroelectric production especially as the habitat benefits of water compete with other beneficial uses.

State-owned or -operated facilities

A variety of state-owned or -operated facilities could be affected by a prolonged drought. The most obvious include schools, universities, office buildings, health-care facilities, etc. Impacts of drought on state-owned facilities related to agriculture would include impacts to research conducted in outdoor settings, such as at extension stations and research farms. There is no single comprehensive source or other sources for information to assess economic impacts to the state or state-owned facilities. Power outages are always a concern. Maintenance activities (e.g., grounds, parks, etc.) may be curtailed during periods of drought. The Oregon Parks and Recreation Department operates several campground and day-use facilities that could be impacted by a drought. For example, in 2015 visitation at Detroit Lake decreased 26 percent due to low water levels and unusable boat ramps (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

Economy

Drought has an impact on a variety of economic sectors. These include water-dependent activities and economic activities requiring significant amounts of hydroelectric power. The agricultural sector is especially vulnerable as are some recreation-based economies (e.g., boating, fishing, water or snow skiing). Whole communities can be affected. This was particularly evident during the 2001 water year when many Oregon counties sought relief through state and federal drought assistance programs.

Water Year 2001 was the third driest water year in Oregon's climate history; the drought was one of the most economically significant in the state's history. The community of Detroit, in Marion County, suffered economic hardships when lake levels became too low to support recreational summer activities. The drought directly affected over 200,000 irrigated acres in the Klamath River Basin. Farmers were among the first to be affected, followed by local agricultural support industries (e.g., pesticides, fertilizer, farm equipment, etc.), as well as Native American Tribes which depend on local fisheries.

The 2015 drought during the state's warmest year on record also saw major economic impacts, straining summer recreational activities such as skiing, boating, fishing, and hunting, as well as the local economies that depend on visitors. Detroit Lake, for example, saw a 26 percent decline in visitors due to low water levels and inaccessible boat ramps. Winter recreational activities also felt the impact of a record-low snowpack. Mt. Ashland ski resort was not able to open during the 2014-15 ski season.

Limited water supply and high temperatures damaged crops and reduced yields, and ranchers in multiple counties struggled with dry pastures and limited water for livestock. Heat-stressed cattle were fed supplemental rations to help provide necessary nutrients. Some ranchers shipped cattle to feedlots earlier than normal or weaned calves early, due to a lack of feed and water. There is no single comprehensive source or other sources for information to assess economic impacts of drought impacts on agriculture, particularly west of the Cascades.

The 2015 fire season for the Pacific Northwest was notable for its severity and cost. The Oregon Department of Forestry estimates that large-fire costs for state agencies amounted to $94.4 million, more than $70 million in additional expenses compared to the 10-year average of $22.3 million.

The 2020 wildfires in Oregon had a significant impact on agriculture and food sectors. According to the Oregon Wine Board, the 2020 crop year saw a 20 percent decline in industry revenues (Sorte et al. 2021). Wildfire smoke affected agricultural production by altering the taste of crops and resulted in the absorption of smoke toxicants (Fleishman, 2023).

Documenting drought conditions, especially its impacts on people and the environment, is an important component of understanding and preparing for future droughts. Using drought emergency relief funds, the state of Washington completed an economic assessment that quantifies the impacts of the 2015 drought on the state's farmers and ranchers, an effort that had not previously been done at the statewide level.

Oregon does not have the resources to conduct a thorough analysis of drought's impact to various sectors. Today, most impact-related data are collected anecdotally. The state should invest in ways to track and quantify the effects of drought and assist the most vulnerable jurisdictions.

Environment

Oregon has several fish species listed as threatened or endangered under the Endangered Species Act (ESA). Some of these species have habitat requirements that are jeopardized by the needs or desires of humans. For example, in times of scarcity, the amount of water needed to maintain habitat for fish species may conflict with the needs of consumptive uses of water. The state of

Oregon is committed to implementation of the ESA and the viability of a productive economic base. There are no easy solutions, only continuous work to resolve difficult drought situations.

There were several significant fish die-offs in 2015. Most noteworthy in the Willamette, Clackamas, John Day, and Deschutes Rivers and some hatcheries, where high water temperatures amplified the effects of naturally occurring parasites. Half of Oregon's hatcheries were affected by drought conditions in 2015. The Department of Fish and Wildlife implemented a daily fishing curtailment regulation in nearly every stream in Oregon in 2015. This was the first time that a statewide curtailment was implemented.

In late June 2021 Oregon experienced record-high air temperatures during an extreme heat wave ("heat dome"). This heat dome was the most intense in the observational record for the Pacific Northwest (Thompson et al. 2022). This resulted in extreme temperatures that lead to high rates of foliage scorch and heat stress. The U.S. Forest Service estimated that more than 888 mi^2 of forest were impacted in Oregon and Washington (Fleishman, 2023). The effects of this ranged from impaired metabolism of surviving leaves to eventual tree mortality (Filewod and Thomas, 2014).

3.3.2.4 Historic Drought Events

Table 3.3.2-2 Historic Droughts and Dry Periods in Oregon

Date	Location	Description
1928-41	Statewide	Prolonged drier than normal conditions that caused major problems for agriculture; the three Tillamook burns, in the normally wet coastal range, the first in 1933, were the most significant impacts of this very dry period.
1976-77	Western Oregon	The 1977 drought was one of the most significant on record in western Oregon.
1985–94	Statewide	Generally dry period, capped by statewide droughts in 1992 and 1994; 10 consecutive years of dry conditions caused problems throughout the state, such as fires and insect outbreaks.
2001-02	Affected all regions except Regions 2, 3	The second most intense drought in Oregon's history; 18 counties with state drought declaration (2001); 23 counties state-declared drought (2002); some of the 2001 and 2002 drought declarations were in effect through June or December 2003.
2003	Regions 5–8	Governor-declared drought issued in seven counties: Sherman, Wheeler, Crook, Baker, Wallowa, Malheur, and Harney.
2004	Regions 5–8	Governor-declared drought issued in four counties: Morrow, Klamath, Baker, and Malheur.
2005	Regions 5–7	Affected area: 13 of Oregon's 36 counties.
2007	Regions 6–8	Governor-declared drought emergency in Lake, Grant, Baker, Union, Malheur, and Harney Counties.
2008	Region 5	Governor-declared drought emergency in Sherman and Gilliam Counties.
2010	Region 6	Governor-declared drought emergency for Klamath County and contiguous counties.
2012	Region 6	Governor-declared drought emergency for the Lost River Basin, located in Klamath County and Lake County.
2013	Regions 5–8	Governor-declared drought in Gilliam, Morrow, Klamath, Baker, and Malheur Counties.

Date	Location	Description
2014	Regions 4, 6–8	Governor-declared drought in 10 counties: Klamath, Lake, Malheur, Harney, Jackson, Josephine, Crook, Wheeler, Grant, and Baker; Oregon experienced its third driest Nov.–Jan. period since 1895.
2015	statewide	Governor-declared drought in 25 counties, with federal declarations in all counties. Oregon experienced its warmest year on record (1895–2019) resulting in record low snowpack across the state. All of Oregon was in severe or extreme drought at the peak of the drought in August, according to the U.S. Drought Monitor.
2018	Regions 4 – 8, 1	Governor-declared drought in 11 counties.
2020	Region 1, 6	Governor-declared drought in 15 counties. Lowest SPEI on record (-1.74).
2021	Regions 1, 3 – 8	Governor-declared drought in 26 counties. Most of Oregon was in severe drought and over 25 percent of the state was in exceptional drought at the peak of the drought in September. Warmest July on record.
2022	Regions 4 – 8	Governor-declared drought in 17 counties.
2023	Regions 1, 4 – 8	Governor-declared drought in 13 counties.
2024	Regions 6 – 8	Governor-declared drought in 4 counties. Second warmest July on record.

Sources: Taylor and Hatton (1999); Governor-declared drought declarations obtained from the Oregon State Archives division

3.3.2.5 Risk Maps

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

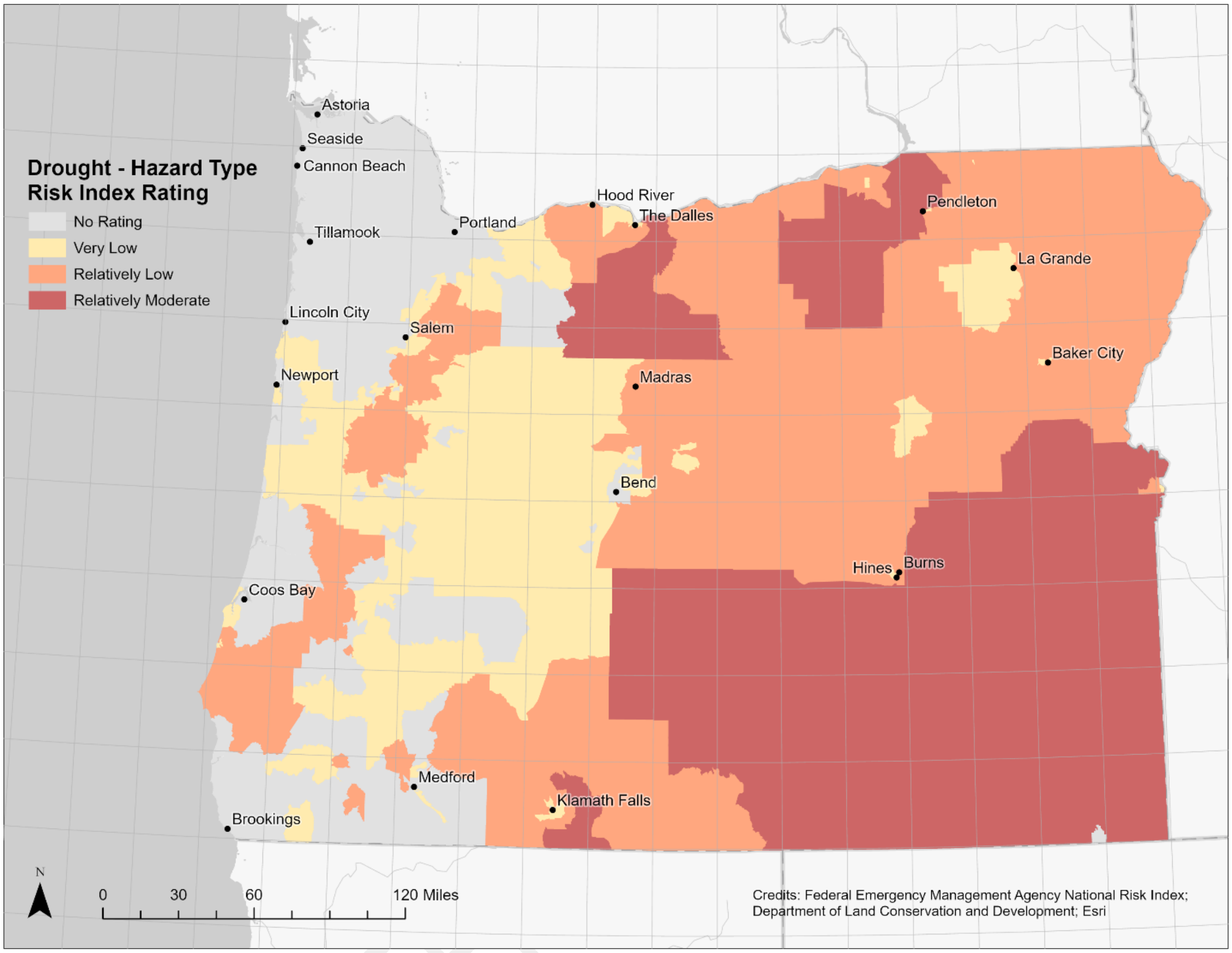
The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

The climate change maps show where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

Figure 3.3.2-4 Drought Risk Rating from the FEMA Risk Index Rating (NRI)

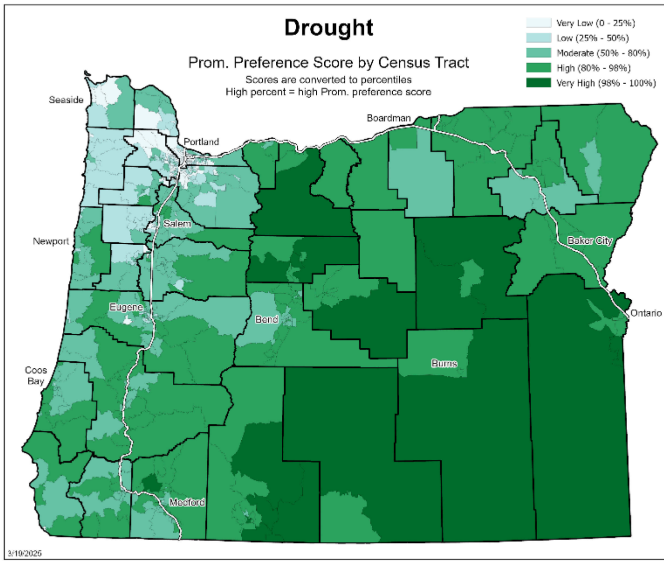


Source the Federal Emergency Management Agency, National Risk Index for Drought. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Note: Ranking based on national percentiles. Last updated by FEMA in March 2023.

Figure 3.3.2-5 and Figure 3.3.2-6 show risk rankings by census tract for drought from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.2-5 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.2-6 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

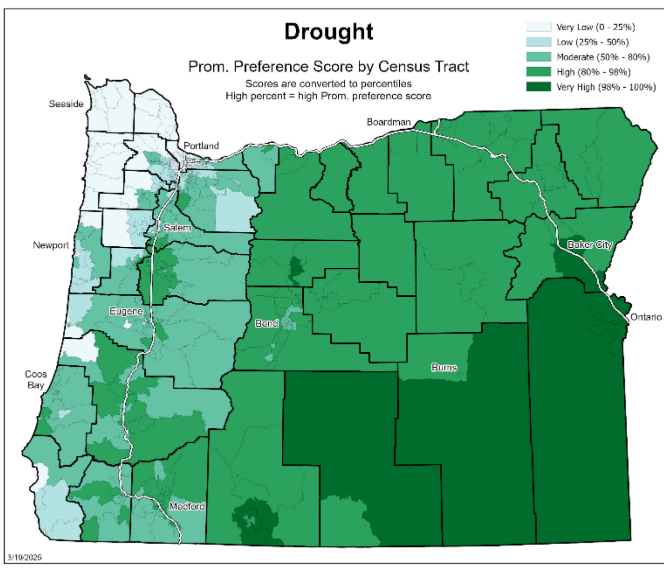
Figure 3.3.2-5 Drought Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Drought	Drght_NRI_rate	1	0.07	Drought rate from the NRI.
Drought	Drght_Events	1	0.07	Number of drought events from the NRI.
Drought	Drght_AL_AG	1	0.07	Annualized loss for agriculture from NRI.
Drought	Over90th	1	0.07	Mean days that are above the historic 90th percentile temp
Drought	Over90F	1	0.07	Mean days above 90 degrees Fahrenheit
General	EP_MINRTY	1	0.05	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.05	Housing tenure from the US Census.
General	EP_MOBILE	1	0.05	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.05	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.05	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.05	Rate of natural resource jobs.
General	PRED3_PE	1	0.05	Community Resilience Estimate
General	Hosp_Beds	-1	0.05	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.05	Percentage of members to a religious group
General	Watch	-1	0.05	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.05	County tax rate
General	CityTax	-1	0.05	City tax rate
General	Cultural	-1	0.01	Number of cultural-related buildings
General	Favors	-1	0.01	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.01	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.01	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.01	Neighborliness: Has visited neighbor's house

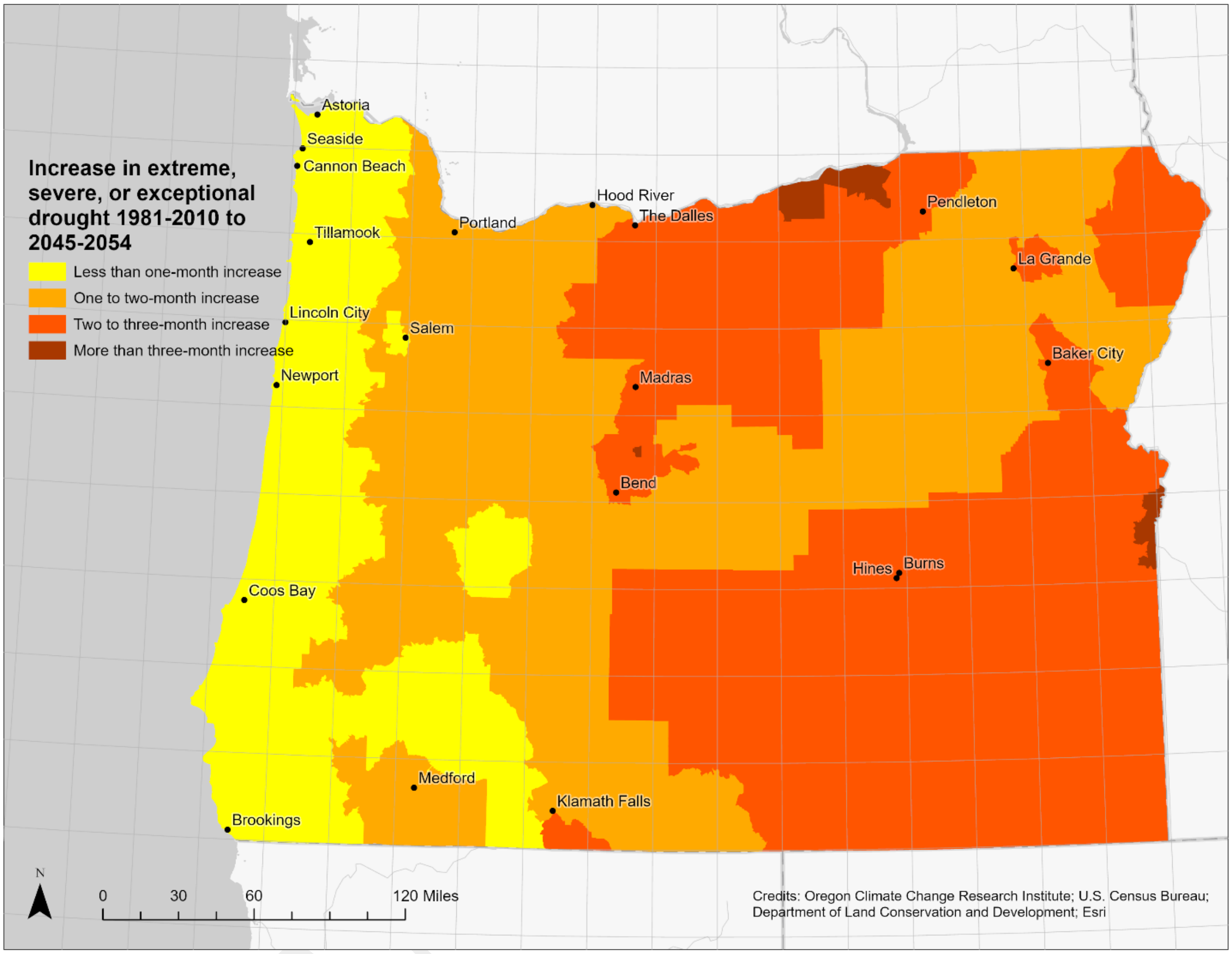
Figure 3.3.2-6 Drought Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Drought	Drght_NRI_rate	1	0.2	Drought rate from the NRI.
Drought	Drght_Events	1	0.2	Number of drought events from the NRI.
Drought	Drght_AL_AG	1	0.2	Annualized loss for agriculture from NRI.
Drought	Over90th	1	0.2	Mean days that are above the historic 90th percentile temp
Drought	Over90F	1	0.2	Mean days above 90 degrees Fahrenheit

Figure 3.3.2-7 Change in Drought Conditions: Change from 1981-2010 to 2045-2054 in months per year of severe, extreme, or exceptional drought as defined by The Standardized Precipitation-Evapotranspiration Index with an accumulation period of 12 months (SPEI12)



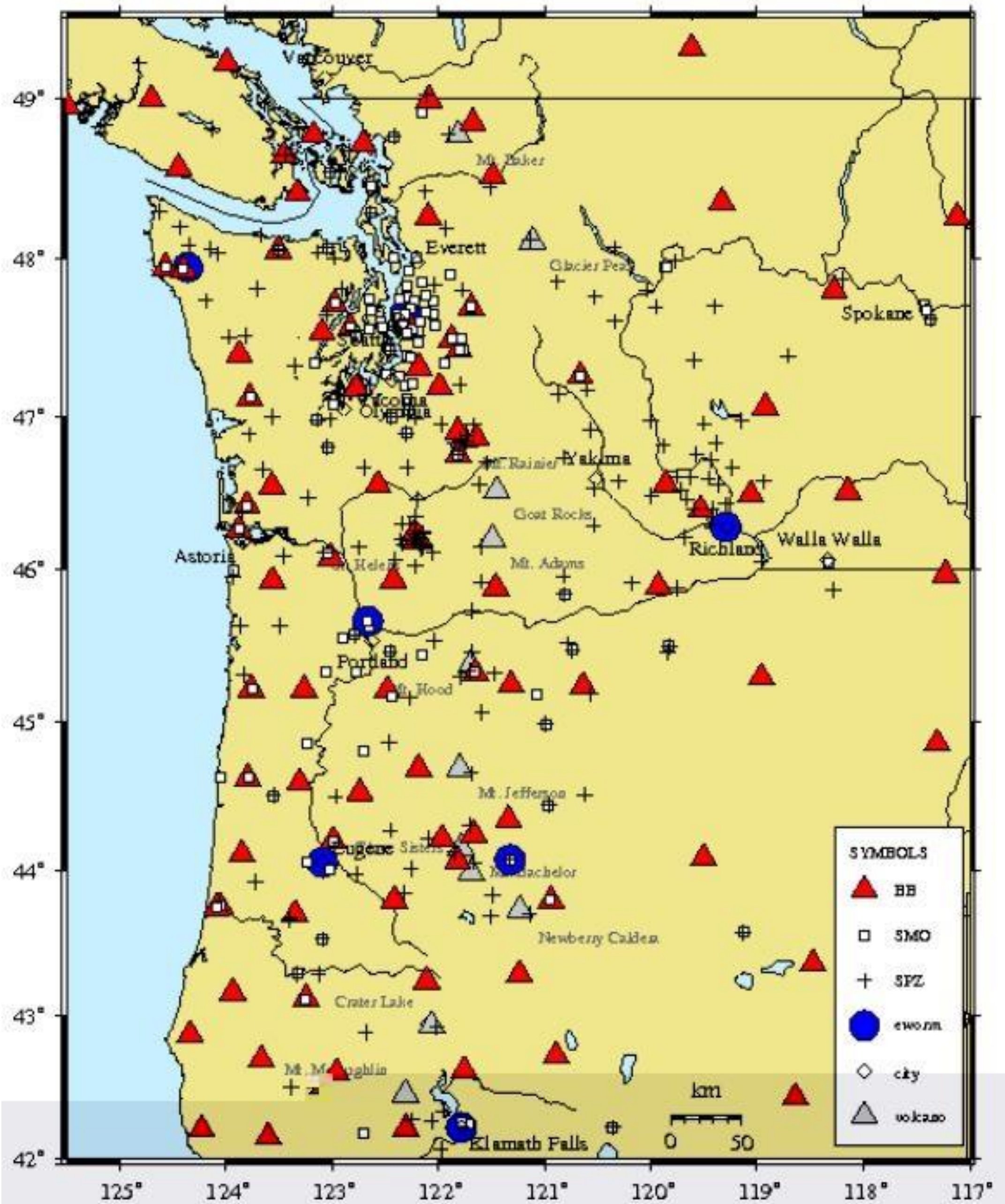
Source: Data provided by OCCR, 2025. Graphic produced by DLCD.

3.3.3 Earthquakes

Oregon has experienced few damaging earthquakes during its recorded history, leading to complacency and lack of attention to earthquake-resistant design and construction. Since the mid-1980s, an increasing body of geologic and seismologic research has changed the scientific understanding of earthquake hazards in Oregon, and in recent years several large and destructive earthquakes around the world have heightened public awareness. Recognized hazards range from moderate sized crustal earthquakes in eastern Oregon to massive subduction zone megathrust events off the Oregon coast. Indigenous peoples in the Pacific Northwest, who experienced the 1700 earthquake and tsunami, passed down their knowledge through oral histories and storytelling long before Western science fully recognized these hazards. All have the potential for significant damage as long as most of Oregon's buildings and infrastructure have inadequate seismic resistance. The scale of structural retrofit and replacement needed to make Oregon earthquake safe is huge, and will take decades to implement. To manage the human and economic impact of the next damaging earthquake will require thoughtful and comprehensive emergency response planning, based on realistic loss estimates driven by accurate and detailed geologic and seismologic, structural and cultural information. To minimize the human and economic impact of the next damaging earthquake will require a sustained program of public education, forward-thinking research, and structural replacement and retrofit, based on cost-effective earthquake resistant design and a combination of public funding and private sector incentives.

3.3.3.1 Analysis and Characterization

Figure 3.3.3-1 Earthquake Monitoring Stations in the Pacific Northwest

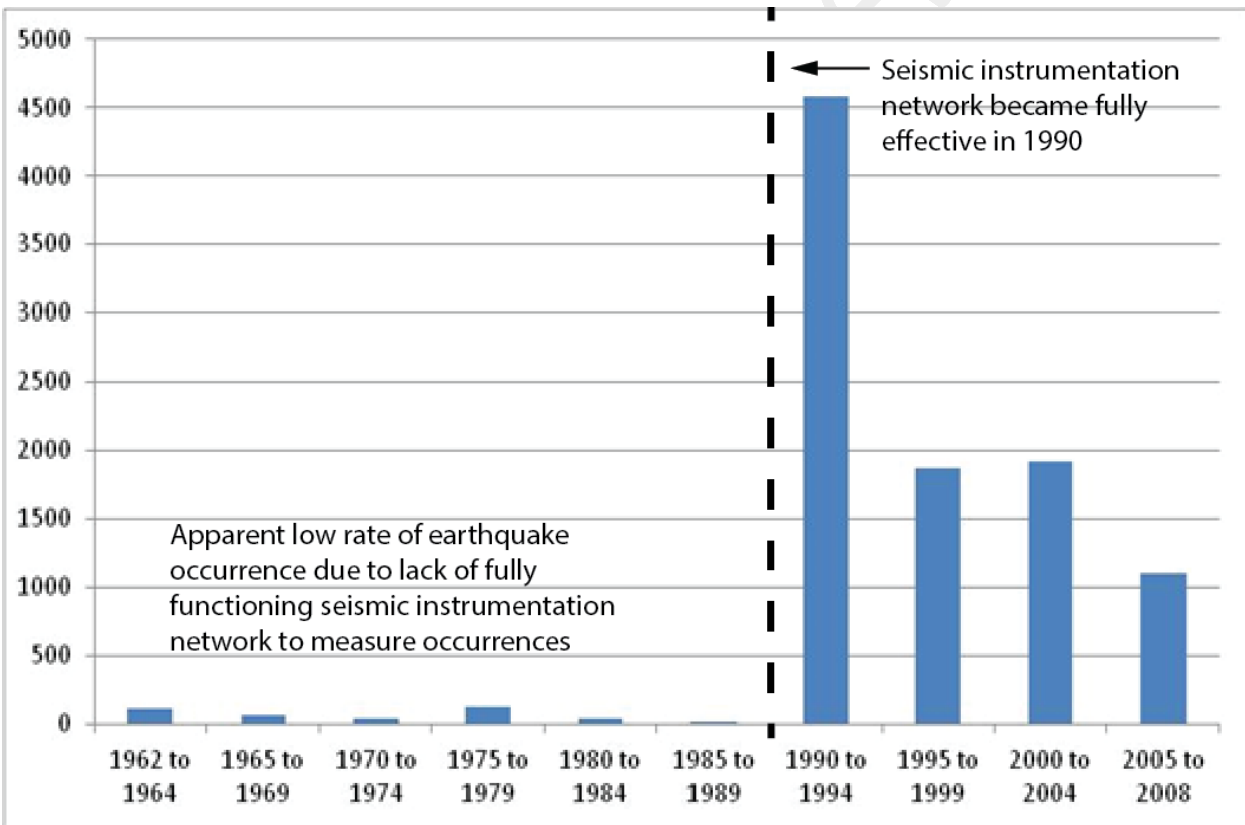


The Source: Pacific Northwest Seismic Network (http://www.pnsn.org/).Earthquake monitoring network system is operated out of the University of Washington by the Pacific Northwest Seismic Network.

Earthquake Sources

Earthquakes are a highly variable natural phenomenon. The vast majority occur when two masses of rock in the earth's crust abruptly move past each other along a large crack or fracture called a fault. The energy released as the two parts slide along the fault produces waves of shaking that people perceive as an earthquake. Faults typically build up stress over decades to millennia in response to large-scale movement of the earth's tectonic plates. Even the most active faults only produce damaging earthquakes at intervals of a century or more, and for many the intervals are much longer. As a result, it is very difficult to forecast the likelihood of an earthquake on a particular fault because scientists rarely have a long enough record to determine a statistically meaningful return period (average time between earthquakes).

Figure 3.3.3-2 Annual Rate of Earthquake Occurrence in Oregon, in 5-Year Increments



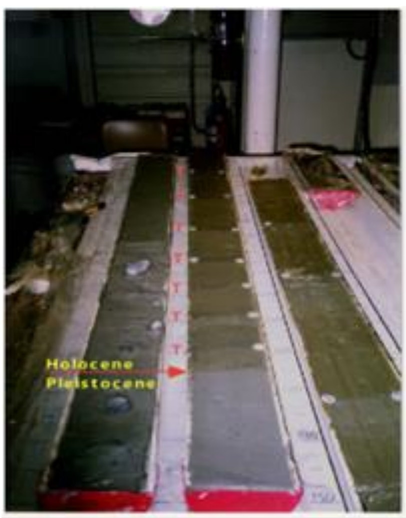
Note: Seismic instruments began operation in 1970, but the network only became fully effective in 1990. Spike in earthquake numbers in the early 1990s is due to aftershocks from the 1993 Scotts Mills and Klamath Falls earthquakes. This account is limited to earthquake recordings captured by seismic instruments, which excludes earthquakes experienced and documented by indigenous peoples prior to the development proliferation of modern seismic instruments.

The history of earthquakes in a region comes from three types of information. Instrumental data comes from networks of seismic recording instruments (seismographs) that are widely deployed in the Pacific Northwest.

Seismic networks can detect very small earthquakes, locate them to within a few miles, and determine their magnitude accurately. Seismographs have only existed for about a century, and in Oregon, the instrumental record is really only complete and modern from about 1990 on. Historical felt location data comes from verbal and written reports of earthquake effects. The felt record extends back to the mid-1800s for Oregon, but only locates moderate to large earthquakes, and those only with an accuracy of tens or even hundreds of miles.

Paleoseismic data use geologic records of earthquake effects to determine the approximate size and timing of earthquakes that happened in prehistoric times. The paleoseismic record can extend back for thousands or tens of thousands of years, but provides only approximate information about the size, time, and place of past large earthquakes.

Figure 3.3.3-3: Deep Sea Sediment Cores that Record Past Megathrust Earthquakes off the Oregon Coast

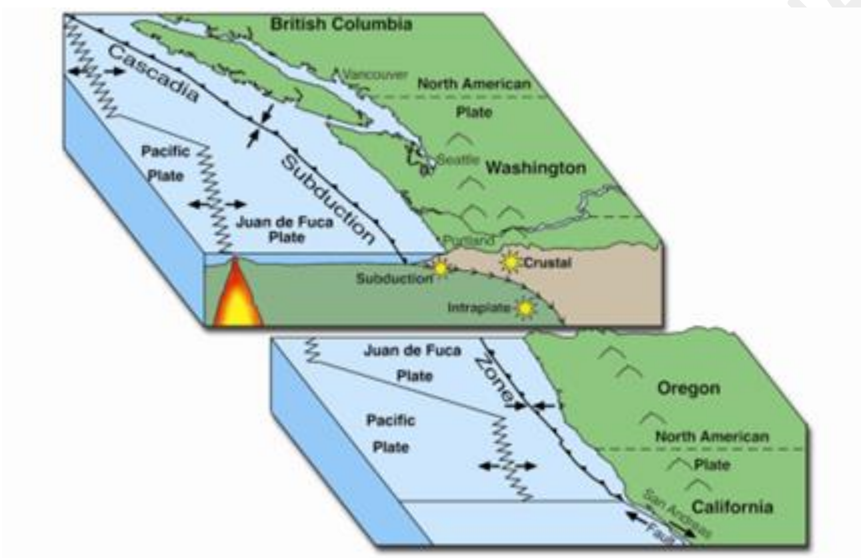


Source: Goldfinger, et. al. (2012)
Not: Red T's mark the top of each layer

In Oregon, the combined earthquake history derived from these three sources clearly outlines two major types of earthquake hazard and two less significant sources. By far the greatest is the hazard posed by infrequent **megathrust earthquakes** on the Cascadia Subduction Zone. The second major hazard comes from smaller **crustal earthquakes** on faults in or near populated areas, which includes all of Oregon's damaging historic earthquakes. Intraplate earthquakes in the subducting slab, which have been historically damaging in the Puget Sound area, are possible in Oregon but no damaging prehistoric or historic events are known. Finally, earthquakes associated with Oregon's many young volcanoes may produce damaging shaking in communities close to the volcano. The Cascadia Subduction Zone is the boundary between two of the earth's crustal plates. These continent-sized plates are in constant slow motion, and the boundaries between plates are the site of most earthquake activity around the globe. At the Cascadia Subduction Zone, the Juan De Fuca plate, located offshore of Oregon and Washington, slides to the northeast and under the North American plate, which extends from the Oregon coast clear to the middle of the Atlantic Ocean. The Juan de Fuca plate slides beneath the continent (subducts) at about 1.5 inches per year, a speed which has been directly measured using high-accuracy GPS. The fault that separates the plates extends from Cape Mendocino in Northern California to Vancouver Island in British Columbia, and slopes down to the east from the sea floor. The fault is usually locked, so that rather than sliding slowly and continuously, the 1.5 inches per year of subduction motion builds tremendous stress along the fault. This stress is periodically released in a megathrust earthquake, which can have a magnitude anywhere from 8.3 to 9.3.

Figure 3.3.3-4 is a schematic three-dimensional diagram with the generalized locations of the three types of earthquake sources found in Oregon: subduction zone, crustal, and intraplate.

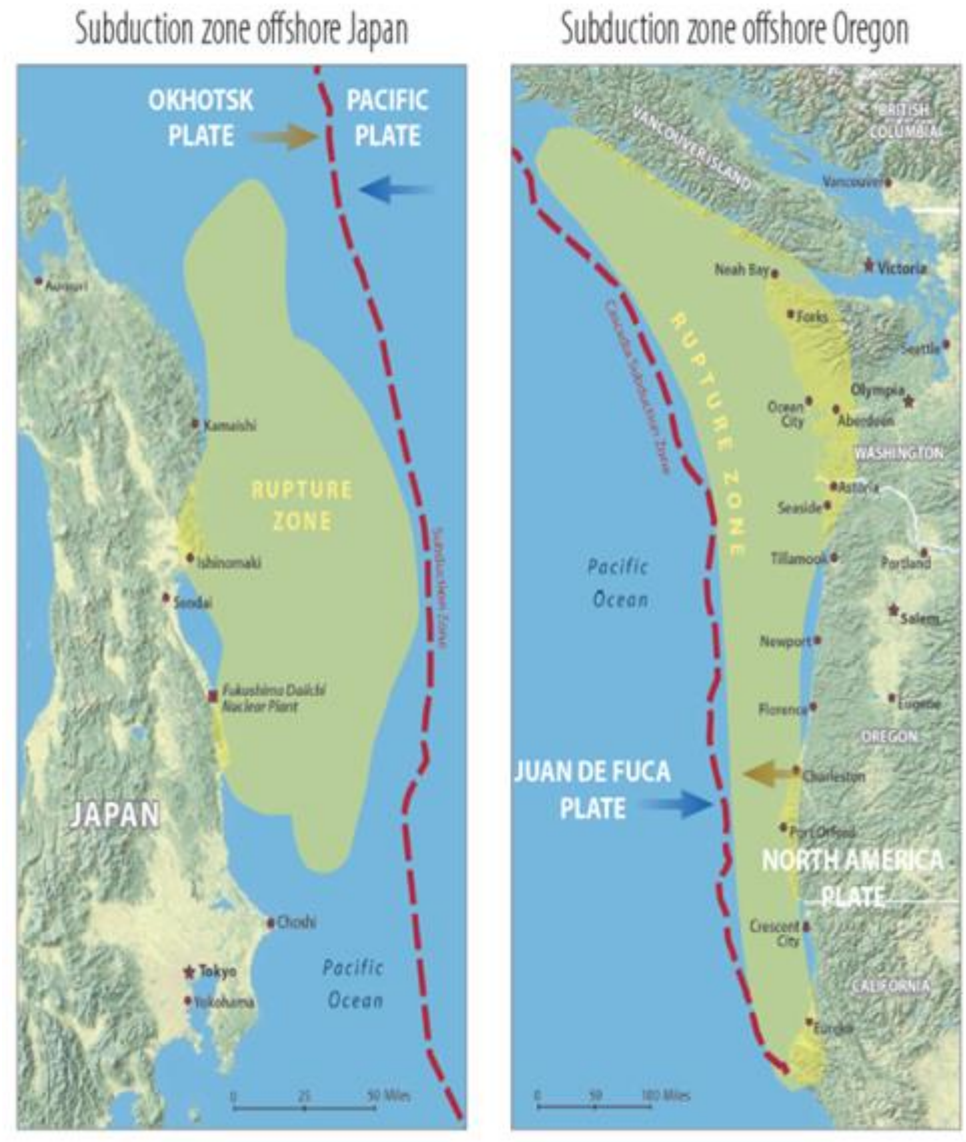
Figure 3.3.3-4: General Source Areas for Subduction Zone, Crustal Earthquakes, and Intraplate Earthquakes



Source: DOGAMI

The Cascadia Subduction Zone closely mirrors the subduction zone in northern Japan that produced the 2011 Tohoku earthquake (Figure 3.3.3-5). This magnitude 9 megathrust event and its associated tsunami captured the world's attention with unforgettable images of destruction on a massive scale. This is a window into Oregon's future, as this is the very type of earthquake that science says is likely on the Cascadia Subduction Zone. Particular attention must be paid to the incredibly destructive tsunami that accompanied the Tohoku earthquake, and community must plan for a similar tsunami in Oregon. (See the **Tsunami** section of this Plan for more information about tsunamis in Oregon.)

Figure 3.3.3-5: Comparison of the Northern Japan Subduction Zone in and the Cascadia Subduction Zone



Source: DOGAMI

Note: Yellow patches are the measured earthquake rupture zone in Japan, modeled earthquake rupture zone in Oregon.

Crustal earthquakes occur for the most part on shore on much smaller faults located in the North American plate. These are the more familiar “California-style” earthquakes with magnitudes in the 5 to 7 range. Although much smaller than the megathrust earthquakes, crustal earthquakes may occur much closer to population centers, and are capable of producing severe shaking and damage in localized areas. For many parts of eastern Oregon, crustal faults dominate the hazard, and they may also have a significant impact in the Portland region and Willamette Valley.

Intraplate earthquakes are a third type that is common in the Puget Sound, where they represent most of the historical record of damaging events. In Oregon, these earthquakes occur at much lower rates, and none have ever been close to a damaging magnitude. They contribute little to the aggregate hazard in most of Oregon.

3.3.3.2 Earthquake Effects

Earthquake damage is largely controlled by the strength of shaking at a given site. The strength of shaking at any point is a complex function of many factors, but magnitude of the earthquake (which defines the amount of energy released) and distance from the epicenter or fault rupture, are the most important. The ripples in a pond that form around a dropped pebble spread out and get smaller as they move away from the source. Earthquake shaking behaves in the same way: you can experience the same strength of shaking 10 miles from a magnitude 6 earthquake as you would feel 100 miles from a magnitude 9 earthquake.

Two measurement scales are used to describe the magnitude and intensity of earthquakes. To measure the magnitude, the “moment magnitude” (M_w, or M) scale uses the Arabic numbering scale. It provides clues to the physical size of an earthquake (NOAA-OAR-CPO-2014-2003692) and is more accurate than the previously used Richter scale for larger earthquakes. The second scale, the “modified Mercalli,” measures the shaking intensity at a point and is based on felt observations and is therefore more subjective than the mathematically derived moment magnitude. It uses Roman numerals to indicate the severity of shaking. It is important to understand the relationship between the intensity of shaking the amount of damage expected from a given earthquake scenario.

Table 3.3.3-1 gives an abbreviated description of the 12 levels of Modified Mercalli intensity.

Table 3.3.3-1 Levels of Modified Mercalli Intensity

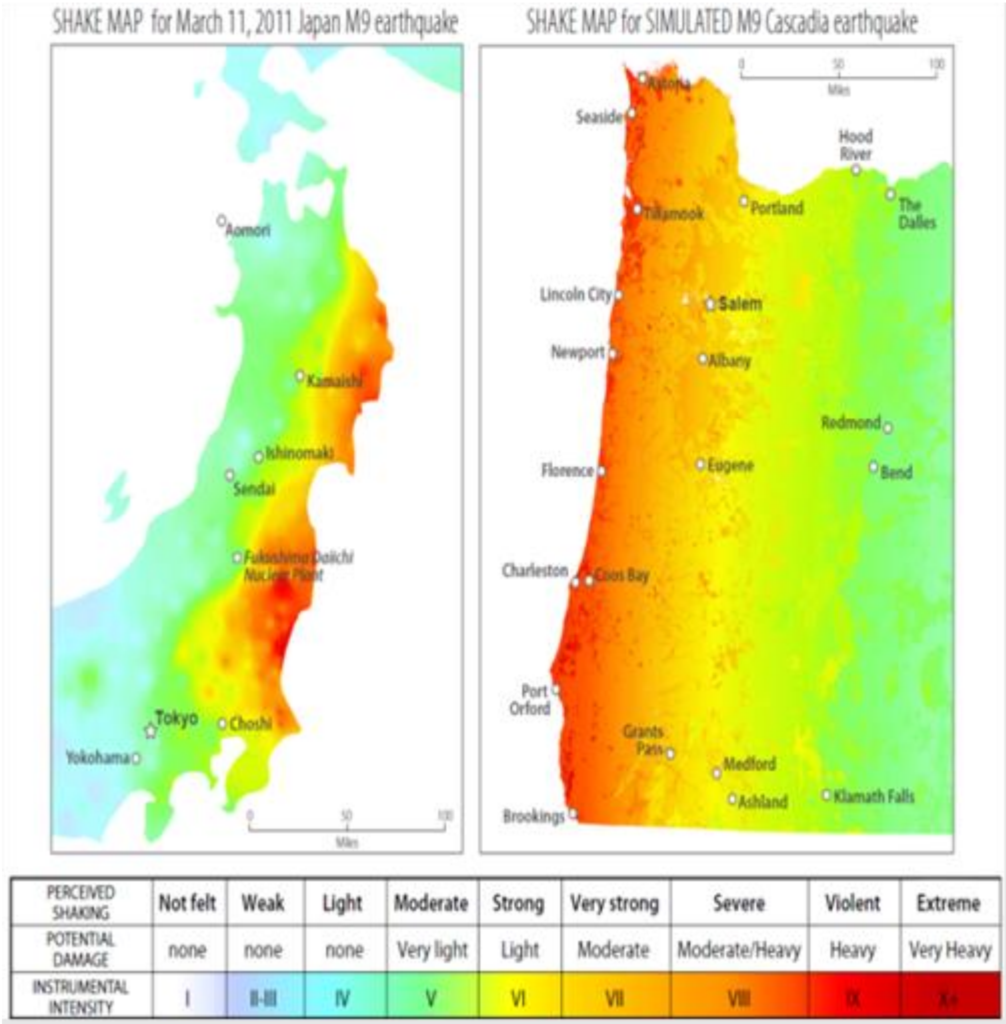
Level	Intensity
I	not felt except by a very few under especially favorable conditions
II	felt only by a few persons at rest, especially on upper floors of buildings
III	felt quite noticeably by persons indoors, especially on upper floors of buildings; many people do not recognize it as an earthquake; standing motor cars may rock slightly; vibrations similar to the passing of a truck; duration estimated
IV	felt indoors by many, outdoors by few during the day; at night, some awakened; dishes, windows, doors disturbed; walls make cracking sound; sensation like heavy truck striking building; standing motor cars rocked noticeably
V	felt by nearly everyone; many awakened; some dishes, windows broken; unstable objects overturned; pendulum clocks may stop
VI	felt by all, many frightened; some heavy furniture moved; a few instances of fallen plaster; damage slight
VII	damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken

Level	Intensity
VIII	damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse; damage great in poorly built structures; fall of chimneys, factory stacks, columns, monuments, walls; heavy furniture overturned
IX	damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse; buildings shifted off foundations
X	some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; rails bent
XI	few, if any (masonry) structures remain standing; bridges destroyed; rails bent greatly
XII	damage total; lines of sight and level are distorted; objects thrown into the air

Sources: http://earthquake.usgs.gov/learn/topics/mercalli.php, abridged from *The Severity of an Earthquake* (http://pubs.usgs.gov/gip/earthq4/severitygip.html); U.S. Geological Survey General Interest Publication 1989-288-913

Future megathrust earthquakes on the Cascadia Subduction Zone (CSZ) will occur off the coast, and the strength of shaking will decrease inland. Oregon coastal communities will experience violent to severe shaking, but the Portland area and Willamette Valley communities are far enough inland that they will feel very strong to severe. Because of the size of the megathrust fault, the shaking will impact all of Oregon west of the Cascades, will still be felt to the east of the Cascades, and will extend to northern California and British Columbia. The other unique characteristic of megathrust earthquakes is that the strong shaking will last for several minutes, in contrast to a large crustal earthquake, which might shake for only 30 seconds. The long duration of shaking contributes greatly to damage, as structures go through repeated cycles of shaking. Figure 3.3.3-6 shows a side-by-side comparison of ShakeMaps for (a) the 2011 M9 earthquake in Japan, and (b) a simulated M9 CSZ event in Oregon.

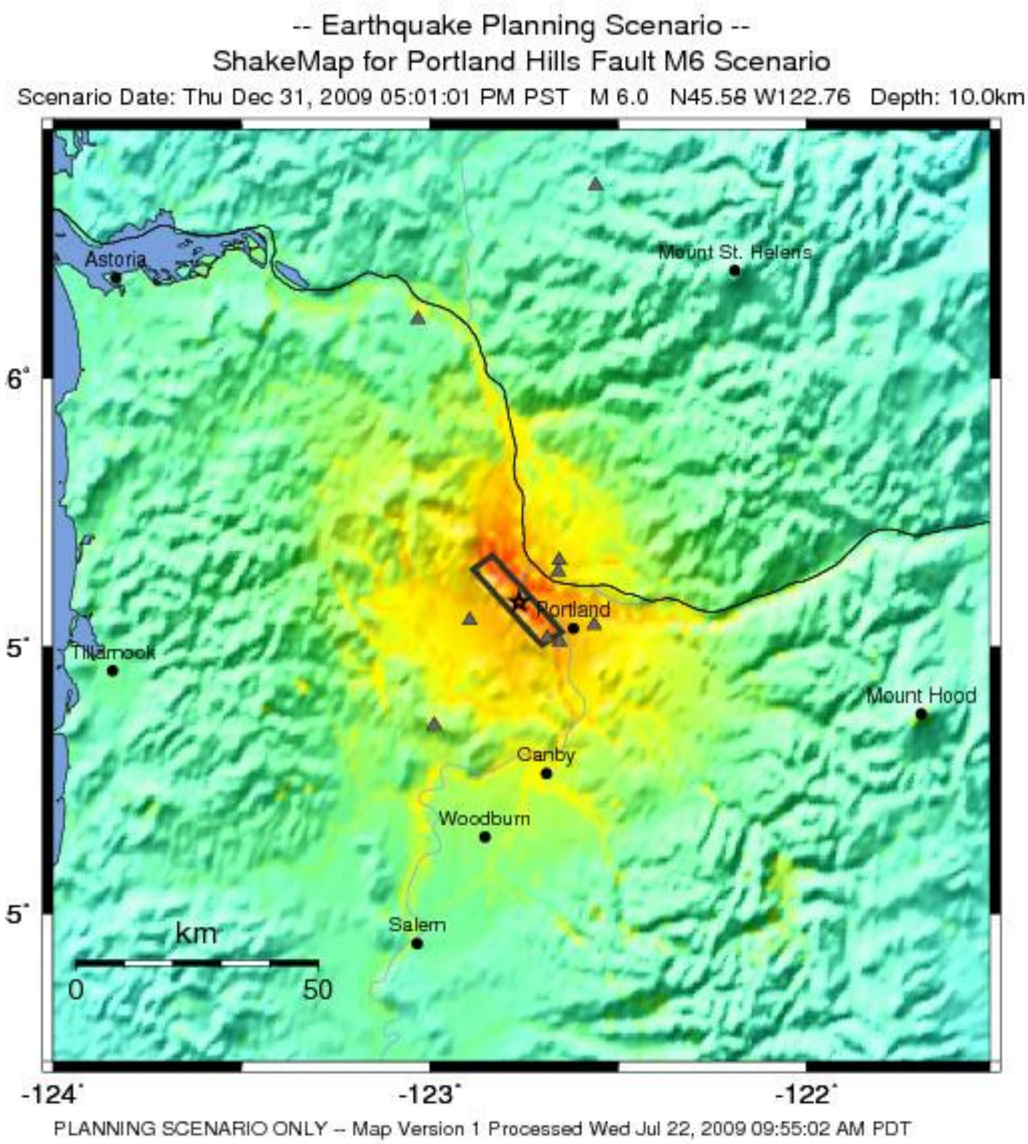
Figure 3.3.3-6: Comparison of Measured Shaking from Tohoku Earthquake and Simulated Shaking from M9 Cascadia Megathrust Earthquake.



Source: DOGAMI, *Cascadia* Winter 2012 (http://www.oregongeology.org/pubs/cascadia/CascadiaWinter2012.pdf)

Future crustal earthquakes will occur along one of many Oregon fault lines; the shaking will be strongest near the epicenter, and will decrease fairly quickly as you move away. So a magnitude 6 earthquake in Klamath Falls may cause significant damage near the epicenter, but will be only weakly felt in Medford or Eugene. Figure 3.3.3-7 shows a M6 crustal fault ShakeMap scenario along the Portland Hills fault.

Figure 3.3.3-7: Simulated Shaking from M6.0 Crustal Earthquake on the Portland Hills Fault.

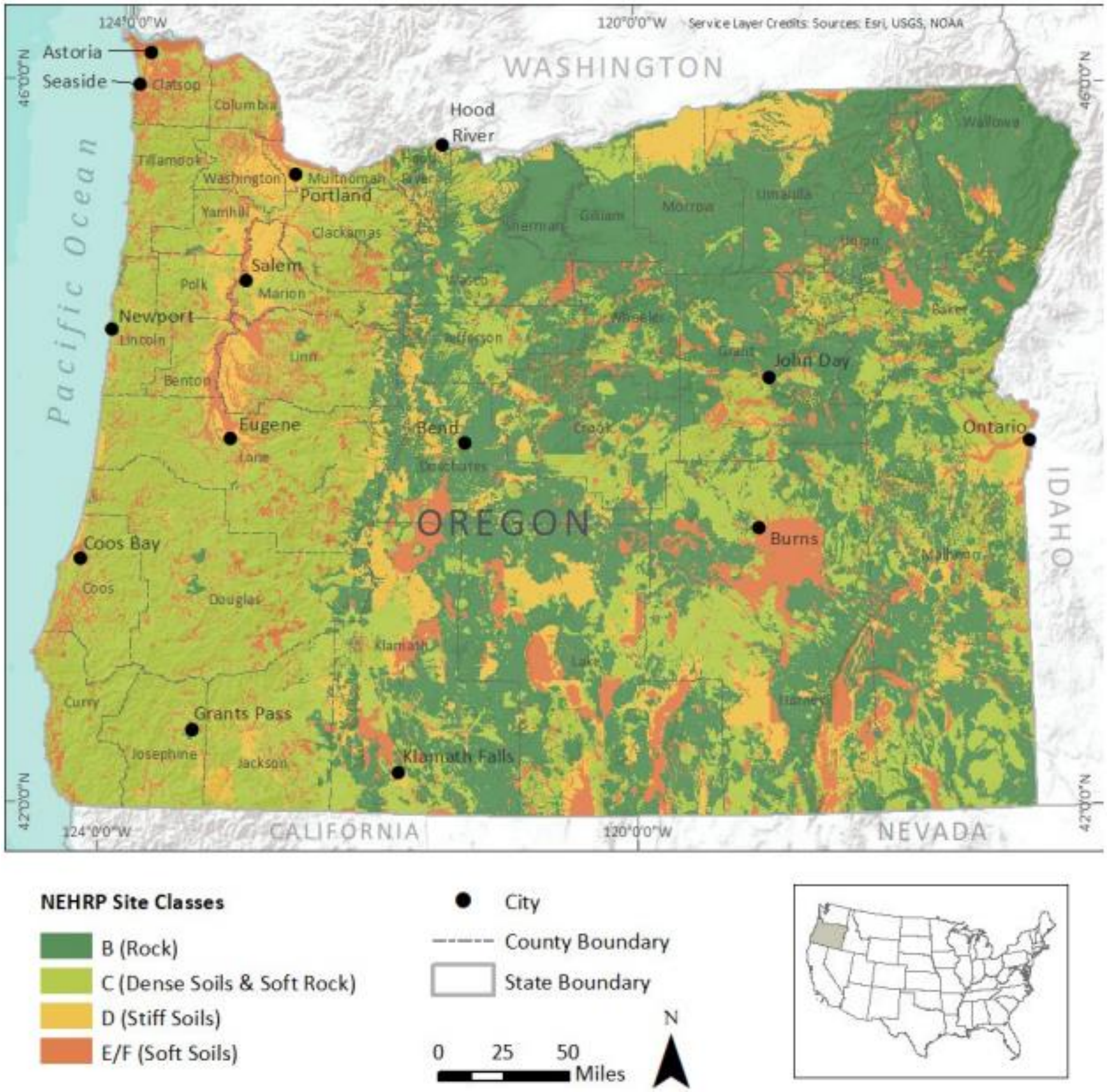


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: U.S. Geological Survey

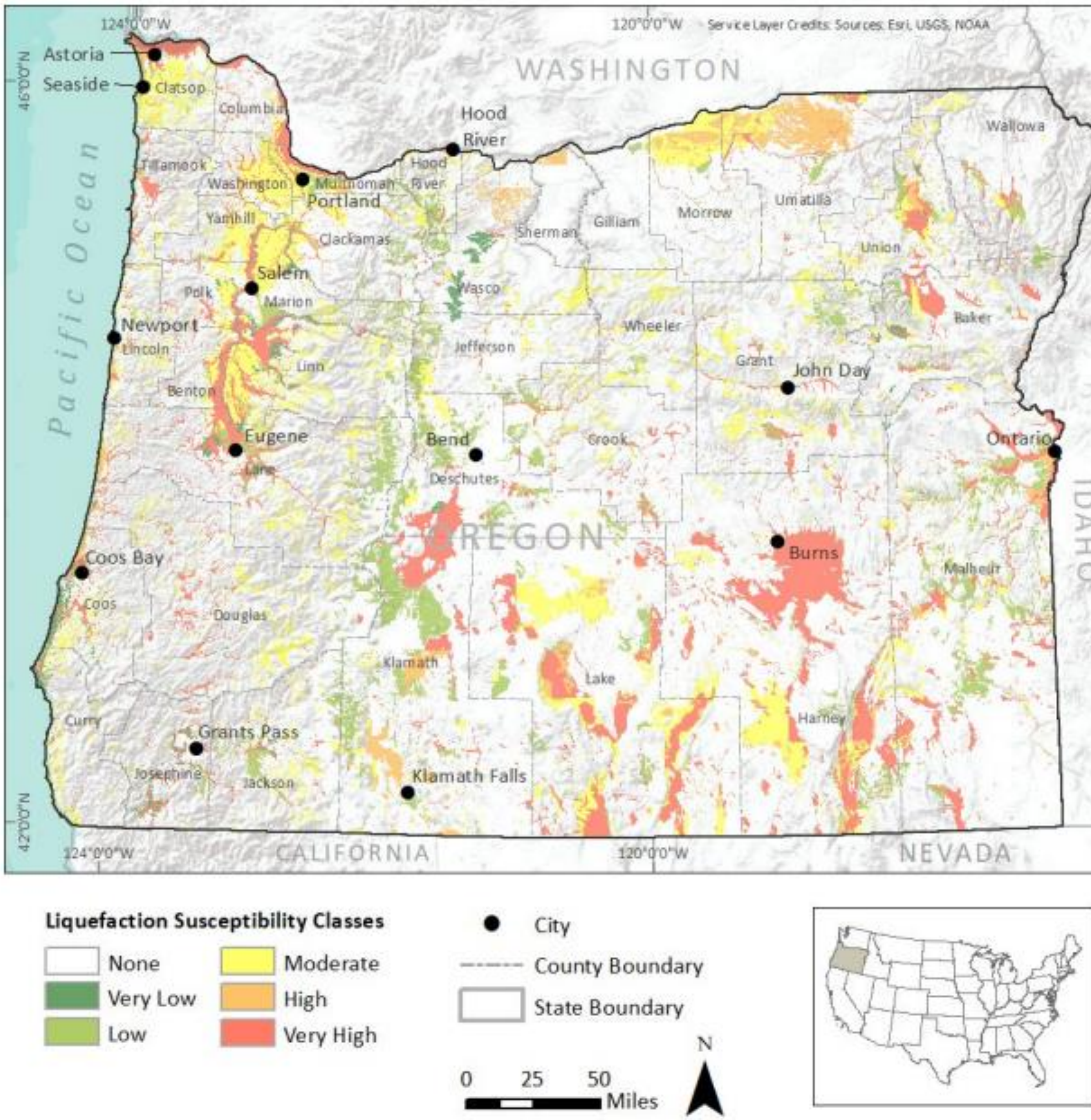
The other important factor in controlling earthquake damage is the contribution of local geology. Soft soils can strongly amplify shaking (Figure 3.3.3-8), loose saturated sand or silt can liquefy, causing dramatic damage, and new landslides can occur on steep slopes while existing landslide deposits may start to move again. These effects can occur regardless of earthquake source, and the geologic factors that cause them can be identified in advance by geologic and geotechnical studies. Liquefaction- and earthquake-induced landslides are both more likely to occur during the several minutes of shaking produced by a megathrust earthquake, and these effects are expected to be widespread during the next event (Figure 3.3.3-9, Figure 3.3.3-10, and Figure 3.3.3-11). In 2013, DOGAMI published a suite of statewide earthquake hazard maps with GIS files in Open-File Report O-13-06, Ground motion, ground deformation, tsunami inundation, coseismic subsidence, and damage potential maps for the 2012 Oregon Resilience Plan for Cascadia Subduction Zone earthquakes (Madin & Burns, 2013); http://www.oregongeology.org/pubs/ofr/p-O-13-06.htm). In 2021 DOGAMI updated those maps with more detailed geologic information using funds from Oregon DAS-GEO in the Oregon Seismic Hazard Database, release 1.0 (OSHD 1); DOGAMI - Digital Data Publication Preview - Oregon Seismic Hazard Database (OSHD), release 1.0 (OSHD-1). OSHD-1.0 is an update and extension of similar data published by Madin and Burns (2013) to support the 2013 Oregon Resilience Plan prepared by the Oregon Seismic Safety Policy Advisory Commission (OSSPAC, 2013). The coseismic geohazard layers are updated with many areas of new surficial geology mapping that have been done using high-resolution lidar topographic data, providing greatly improved accuracy and confidence in defining areas with different coseismic geohazard conditions. The Madin and Burns (2013) report was based on a single simulation of an Mw 9.0 Cascadia Subduction Zone earthquake, which does not significantly affect eastern Oregon. OSHD-1.0 adds the shaking maps and derivative products based on the USGS probabilistic model, which provide consistent hazard information across the entire state. In addition, OSHD-1.0 uses an ensemble of 30 Mw 9 Cascadia subduction earthquake simulations recently published by the USGS (Wirth and others, 2021), which better represents the possible variability of shaking.

Figure 3.3.3-8: Soils Map Showing Where Soils Can Amplify Earthquake Ground Shaking.



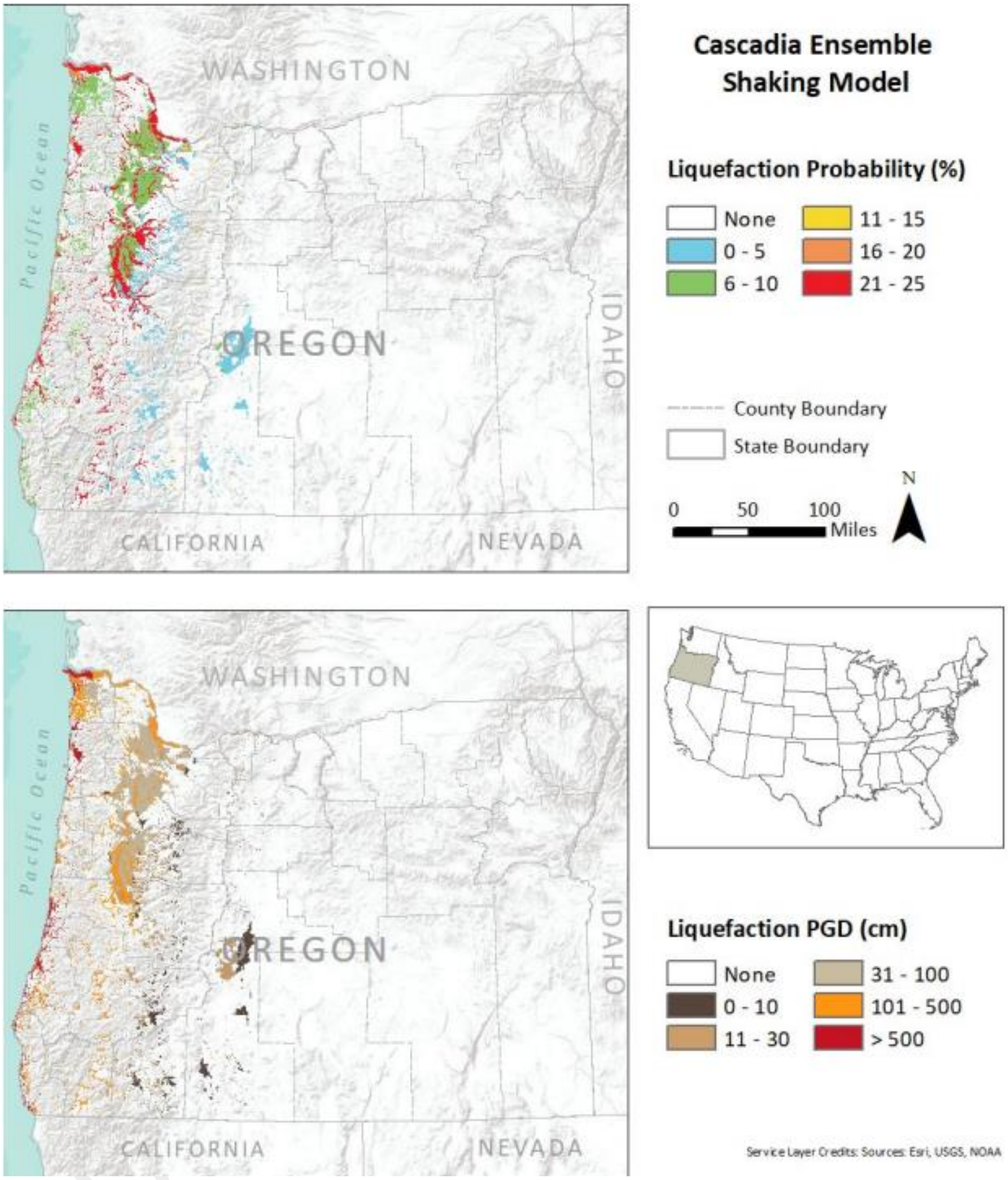
This NEHRP site class map shows areas where soils can amplify the earthquake ground shaking. NEHRP site class F soils (dark orange on map) are prone to produce the greatest amplification.
Source: Madin et al. (2021)

Figure 3.3.3-9: Liquefaction Susceptibility Class Map. This liquefaction susceptibility map shows areas where soils can liquefy due to the earthquake ground shaking. Areas in red are most prone to liquefy.



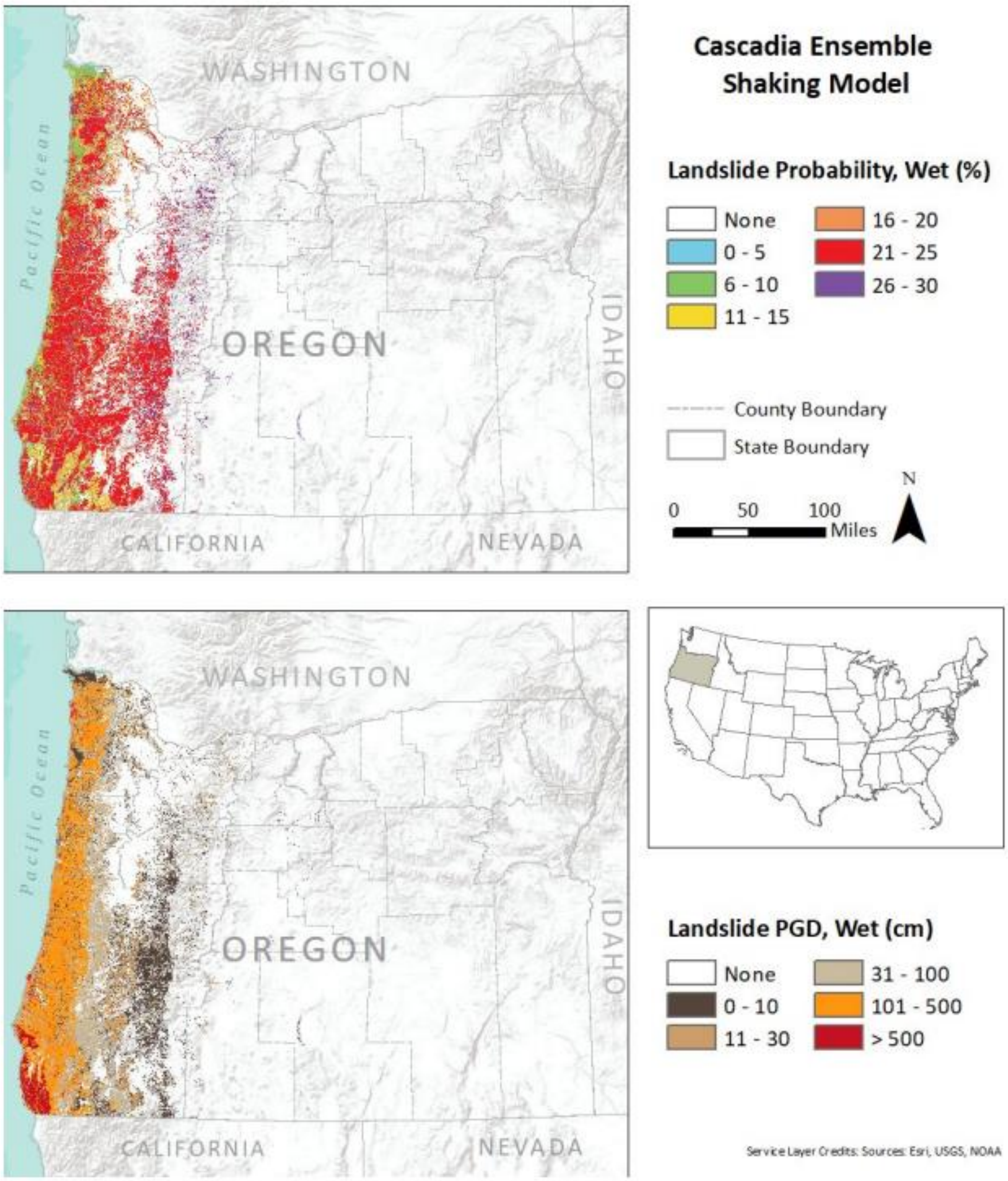
Source: Madin et al. (2021).

Figure 3.3.3-10: Liquefaction Probability and Lateral Spread PGD for the Cascadia ensemble shaking model. This liquefaction probability map shows the probability of soil liquefaction due to a magnitude 9 Cascadia earthquake. Areas in dark red have the highest probability.



Source: Madin et al. (2021).

Figure 3.3.3-11: Expected Displacement Map. This landslide hazard map shows areas and amount of expected landslide displacement due to a magnitude 9 Cascadia earthquake under wet conditions. Areas in red have the highest displacement.



Source: Madin et al. (2021).

3.3.3.3 Historic Earthquake Events

Table 3.3.3-2 lists historic earthquakes in Oregon from both CSZ events and combined crustal events.

Table 3.3.3-2 Historic Earthquakes in Oregon

Date	Location	Description
1873[1]	Del Norte County, Calif.	felt in Portland; localized chimney damage as far north as Port Orford, Oregon
1877[1]	Portland, Oregon	intensity VII; chimney damage
1892[1]	Portland, Oregon	intensity VI; affected area: 26,000 square kilometers; buildings swayed, people terrified and rushed into the street; felt in Astoria and Salem
1893[1]	Umatilla, Oregon	intensity VI-VII; damage to buildings in Umatilla
1896[1]	McMinnville, Oregon	intensity VI; three shocks in succession in McMinnville; main shock felt at Portland and Salem
1906[1]	Paisley, Oregon	intensity V; three additional shocks followed within 1.5 hours
1913[1]	Seven Devil's Mountains of western Idaho	intensity V; broke windows and dishes
1915[1]	Portland, Oregon	intensity V; three shocks reported; rattled dishes, rocked chairs, and caused fright at Portland
1923[1]	southern Oregon	intensity V; plaster fell at Alturas, California; tremor felt at Lakeview, Oregon
Apr. 8, 1927[1]	eastern Baker County,	maximum intensity V (Halfway and Richland); center: eastern Baker County; felt widely over eastern Oregon
July 15 – Nov. 1936[1]	Milton-Freewater, Oregon	intensity VII; magnitude 5.75; center: near the State line between Milton-Freewater, Oregon, and Walla Walla, Washington; affected area: 272,000 sq km in the two states and Idaho; ground cracking observed 6.5 km west of Freewater; marked changes in flow of well water chimneys damaged, plaster broken and walls cracked in Freewater and Umapine; total damage: $100,000; numerous aftershocks up to Nov. 17 (more than 20 moderate shocks during the night and stronger ones (V) on July 18 and Aug. 4 and 27)
Dec. 29, 1941[1]	Portland, Oregon	intensity VI; affected area: 13,000 sq km (Portland); felt at Hillsboro, Sherwood, Yamhill, and into Washington (Vancouver and Woodland); windows broken
Apr. 13, 1941[1]	Olympia, Wash.	magnitude 7.0; at Olympia, Washington, and a broad area around the capital city; fatalities: 8; damage: $25 million; affected area: 388,000 sq km; damage: widespread (Oregon); injuries: several (Astoria and Portland); maximum intensity: VIII (Clatskanie and Rainier); chimneys twisted and fell; damage to brick and masonry
Dec. 15, 1953[1]	Portland, Oregon	intensity: VI; minor damage (Portland area); affected area: 7,700 sq km; one cracked chimney and slight damage to fireplace tile; plaster cracking (Portland and Roy, Oregon, and Vancouver, Washington)
Nov. 16, 1957[1]	Salem, Oregon	intensity VI; affected area: 11,600 sq km (northwestern Oregon); frightened all in the city and cracked plaster (West Salem)
Aug. 18, 1961[1]	Albany/Lebanon, Oregon	intensity VI; magnitude 4.5; affected area: 18,000 sq km; felt region extended into Cowlitz County, Wash; damage: minor (Albany and Lebanon, south of the 1957 center); felt in both cities; two house chimneys toppled, and plaster cracked
Nov. 6, 1961[1]	Portland, Oregon	intensity VI; affected area: 23,000 sq km (northwestern Oregon and southwestern Washington); principle damage: plaster cracking; part of a chimney fell, and windows and lights broke
May 26 – June 11, 1968[1]	Oregon/Calif. border	intensity: VI; magnitude: 4.7; affected area: 18,000 sq km (in the two states); series of earthquakes near the Oregon-California border; chimneys fell or cracked, and

Date	Location	Description
		part of an old rock cellar wall fell; ground fissures in Bidwell Creek Canyon, near Fort Bidwell, California
1993[2]	Scott's Mills, Oregon	5.7 M_w; largest earthquake since 1981; felt from Puget Sound to Roseburg, Oregon[4]
1993[3]	Klamath Falls, Oregon	5.9 M_w and 6.0 M_w[3]; affected area: 130,000 sq km (southwestern Oregon and northern California); losses: concentrated in downtown area; intensity VII in downtown Klamath Falls and immediate vicinity and to the Oregon Institute of Technology, but surrounding experienced intensity VI[5]; fatalities: 2
2001[2]	Nisqually, Wash.	felt as far south as central Oregon
Jan. 4, 2015	NW Nevada	M4.1, 1.5 km deep
Jan. 22, 2015	NW Nevada	M4.5, 1.5 km deep
May 8, 2015	Pacific Ocean, west of Coos Bay, Oregon	M4.4, 10 km deep
Jul. 4, 2015	east of Springfield, Oregon	M4.0, 8 km deep
Jul. – Dec. 2015	NW Nevada	M4.0-4.7, 1.3-1.5 km deep; cluster of earthquakes
Nov. 29, 2019	Port Orford, Oregon	M4.5, 16.7 km deep
Feb. 8, 2020	Pacific Ocean west of Coos Bay, Oregon	M4.7, 10 km deep
Dec. 5, 2024	Cape Medocino, California	M 7.0 ; quake felt in Medford, Oregon

Sources:
(1) USGS. Oregon Earthquake History. Retrieved October 28, 2013, http://earthquake.usgs.gov/earthquakes/states/oregon/history.php ;
(2) USGS. Earthquake Archive. Retrieved October 28, 2013, http://earthquake.usgs.gov/earthquakes/search/ ;
(3) Sherrod (1993) ;
(4) Thomas, et al. (1996) ;
(5) Dewey (1993) ;
(6) Bott & Wong (1993) ;
(7) Pacific Northwest Seismic Network, Retrieved May 22, 2020, https://pnsn.org/events?custom_search=true

3.3.3.4 Risk Maps

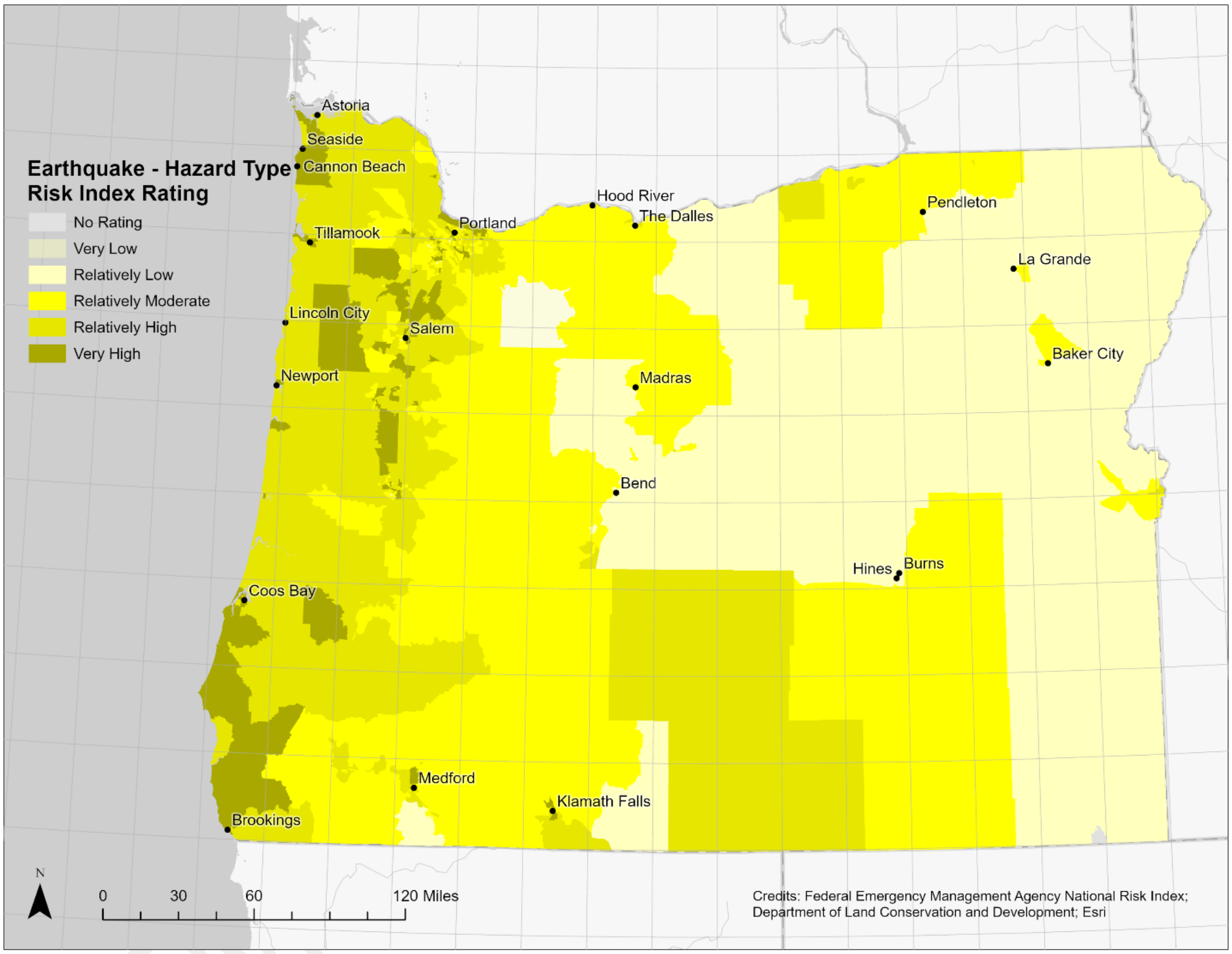
The maps in this section highlight places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

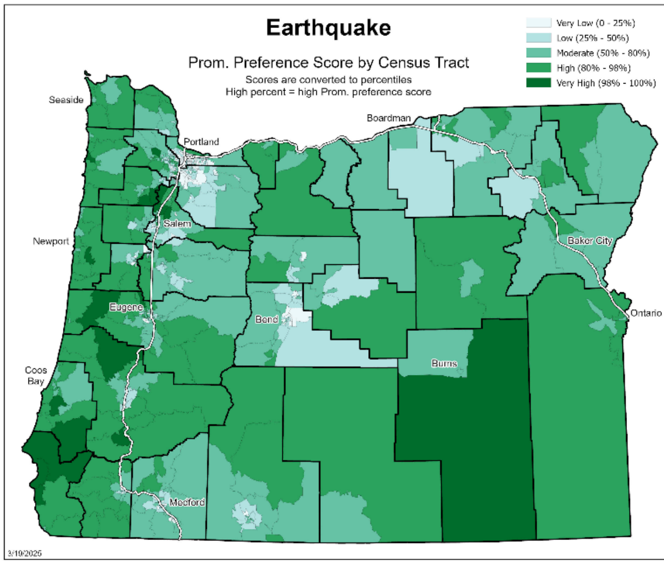
Figure 3.3.3-12: Earthquake Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Earthquake.



Source: Federal Emergency Management Agency, National Risk Index for Earthquake. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.3-13 and Figure 3.3.3-14 show risk rankings by census tract for earthquakes from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.3-13 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.3-14 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

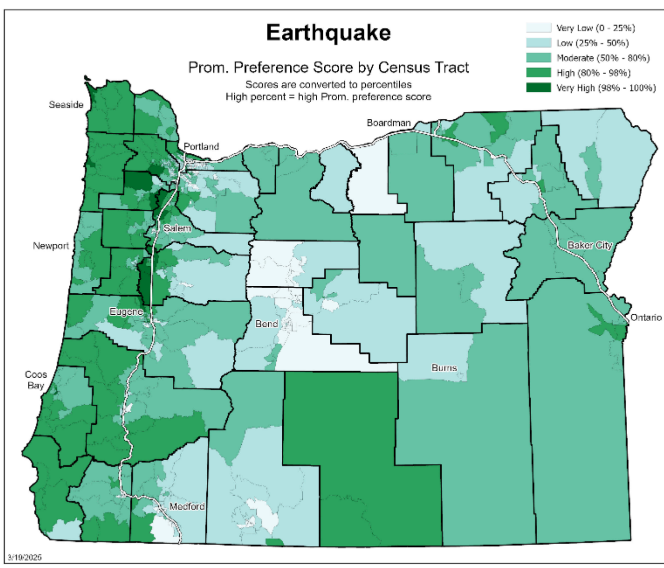
Figure 3.3.3-13: Earthquake Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard — Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Earthquake	LQ_pct_bld	1	0.035	Pct. SBFO buildings exposed to Moderate to Very High liq.
Earthquake	LQ_pct_CF	1	0.035	Pct. critical facilities exposed to Moderate to Very High liq.
Earthquake	EQCSZ_pct_CF	1	0.035	Pct. of red or yellow-tagged critical facilities (CSZ Deterministic).
Earthquake	EQ25_pct_CF	1	0.035	Pct. of yellow-tagged critical facilities (2500 Probabilistic).
Earthquake	Hist_LQ_ct	1	0.035	Pct. historic buildings exposed to Moderate to Very High liq.
Earthquake	Hwy_LQ_pct	1	0.035	Major roadway miles exposed to Moderate to Very High liq.
Earthquake	Erqk_NRI_rate	1	0.035	Earthquake risk from NRI.
Earthquake	LQ_Haz_Area	1	0.035	Area of tract in high or very high liquefaction hazard.
Earthquake	Bridges_LIQ	1	0.035	Number of bridges within high or very high liquefaction hazard.
Earthquake	PGA_2500	1	0.035	Average shaking in tract from 2500-year probabilistic earthquake.
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

Figure 3.3.3-14: Earthquake Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Earthquake	LQ_pct_bld	1	0.1	Pct. SBFO buildings exposed to Moderate to Very High liq.
Earthquake	LQ_pct_CF	1	0.1	Pct. critical facilities exposed to Moderate to Very High liq.
Earthquake	EQCSZ_pct_CF	1	0.1	Pct. of red or yellow-tagged critical facilities (CSZ Deterministic).
Earthquake	EQ25_pct_CF	1	0.1	Pct. of yellow-tagged critical facilities (2500 Probabilistic).
Earthquake	Hist_LQ_ct	1	0.1	Pct. historic buildings exposed to Moderate to Very High liq.
Earthquake	Hwy_LQ_pct	1	0.1	Major roadway miles exposed to Moderate to Very High liq.
Earthquake	Erqk_NRI_rate	1	0.1	Earthquake risk from NRI.
Earthquake	LQ_Haz_Area	1	0.1	Area of tract in high or very high liquefaction hazard.
Earthquake	Bridges_LIQ	1	0.1	Number of bridges within high or very high liquefaction hazard.
Earthquake	PGA_2500	1	0.1	Average shaking in tract from 2500-year probabilistic earthquake.

3.3.4 Extreme Heat

Extreme heat conditions are defined as weather that is much hotter and sometimes more humid than average for a particular time and place (EPA, 2016). Heat waves are generally defined as extreme heat conditions lasting at least three consecutive days. In 2021, a heat dome event in June and a heat wave in August together contributed to more than 100 deaths in Oregon (OHA Center for Health Statistics, 2024). Extreme heat is associated with more fatalities than any other severe weather event in the United States, yet heat-related illnesses and deaths are largely preventable. Extreme heat affects everyone, has wide-ranging health impacts, and can worsen certain health conditions, sometimes resulting in premature death and disability. Heat-related illness can occur when the body cannot cool itself or when sweating and dehydration causes an electrolyte imbalance, resulting in heat cramps, heat exhaustion, heatstroke or hyperthermia (CDC, 2024c). Multiple contributing factors can lead to heat-related deaths in addition to extreme heat. These factors may include chronic health conditions, age, sex, taking certain medications, and substance use (illicit drugs and alcohol).

Humidity, lack of acclimatization, and exposure to consecutive days of heat with limited overnight cooling, can increase susceptibility to heat-related illness. Humidity is an important factor in how hot it feels. As air becomes more humid, the human body is less able to cool off by sweating when temperatures are high. The body can adapt to heat through acclimatization, which is achieved by gradually increasing the amount of time spent in hot conditions (CDC, 2024b). People who are less acclimatized to heat are more susceptible to heat-related illness. Consecutive days of heat (three or more days) and minimal overnight cooling compromises the body's ability to regulate temperature and recover from high daytime temperatures.

Older adults (aged 65 and over), infants and children, people who are pregnant, people with chronic conditions including mental illness, people with lower income (without air conditioners and limited access to cooling centers), those experiencing homelessness, athletes, and outdoor and seasonal workers are at increased risk of heat-related illness (CDC, 2024a). Communities residing in urban areas (urban heat islands), emergency responders, people with disabilities, individuals who are socially isolated, and pets and service and support animals are also at risk of exposure to extreme heat (NIHHIS, n.d). Extreme heat is also associated with pre-term births and lower birth weight in babies (Dresser et al., 2024). Literature on the impacts of extreme temperatures among incarcerated populations is limited, but emerging studies suggest an association between ambient heat (indoor temperature) and increased mortality risk in incarceration settings (Skarha et al., 2023; Skarha et al., 2020).

Oregon Health Authority (OHA) set a goal to eliminate health inequities in Oregon by 2030. OHA is the first health agency in the nation to set such an ambitious goal. To be successful, state agencies must continue to identify the needs of communities at disproportionate risk of climate-driven environmental hazards in addition to increasing equitable access to health care. As climate-driven events increase in frequency, intensity and duration, all Oregonians need robust, equitable and climate-resilient systems to mitigate public health risks, protect natural resources, and to close the equity gap among those most vulnerable.

In 2023, OHA's Public Health Division established Public Health Advisory Board indicators to measure the public health system's progress in building community resilience to the health effects of climate change, such as reducing the incidence of heat-related illnesses and respiratory diseases. Current goals for reducing extreme heat impacts by 2030 include: Reducing heat-related illness by 50 percent ; Reducing heat-related hospitalizations by 60 percent ; and Reducing heat-related deaths by 70 percent .

OHA's Healthy Homes Grant Program received $30 million from the Oregon Legislature to provide grants to eligible entities that in turn provide home improvements for low-income and environment justice communities. These grant funds can be used in a variety of ways to improve the health and safety of occupants. Some specific examples that address heat include the installation of heat pumps, weatherization, and improvements to the home that reduce the reflection of heat on or around the residence, including planting trees and installing green or cool roofs. OHA selected 34 organizations statewide to receive this first round of grant funding, and the funds will be distributed in early 2025.

In the 2023-25 biennium, OHA is funding 194 community-based organizations (CBOs) nearly $42 million to implement activities that promote community health and well-being through the Public Health Equity Grant Program. Of these, 57 CBOs are engaged in climate and health adaptation work. CBOs are encouraged to focus on the priorities of the communities they serve, which includes heat mitigation. Examples of projects include access to greenspaces and community gardens, protection from wildfires, education and training, policy and advocacy, youth engagement, and nutrition and food sovereignty. The spectrum of these projects reflects the broad range of climate impacts across Oregon as well as the diverse opportunities for community-based climate solutions.

With support from public health modernization, local public health authorities (LPHAs) are receiving funds to support climate and health resilience work. By June 30, 2025, each LPHA is required to complete a local or regional climate adaptation plan. Plans will include an assessment of climate impacts within each respective jurisdiction (including heat) and will identify strategies to adapt to climate impacts. This is the second biennium where legislative investment has included a focus on climate and health adaptation planning and is a relatively new body of work. OHA provides direct technical assistance and has partnered with LPHAs to convene a community of practice to share resources and create opportunities for regional collaborations.

Effective June 15, 2022, Oregon Occupational Safety and Health Administration (OSHA) adopted a permanent rule to protect workers from heat-related illnesses. The rule applies when the heat index (apparent temperature) equals or exceeds 80 degrees Fahrenheit in indoor or outdoor work environments (Figure 3.3.4-1). Oregon OSHA also adopted rules for worker protection from wildfire smoke, effective July 1, 2022.

Following the heat dome event in 2021, the Oregon Legislature directed the Oregon Department of energy to conduct an Oregon cooling needs study with focus on households living in housing most vulnerable to heat. These housing types include publicly supported housing, manufactured and mobile homes, agricultural workforce housing, and RVs used as homes. The study found that the estimated total cost to provide the health and safety baseline level of cooling equipment to avoid the worst effects of extreme heat events is $604,400,000 (ODE, 2023).

Though there is no dollar value that can be placed on human life, CDC WISQARS provides medical costs and estimated value of statistical lives (based on actuarial models) of lives lost to heat death. Estimates for Oregon heat fatalities in recent years available are as follows:

Table 3.3.4-1: Deaths with heat as a contributing factor

Year	Number of Heat-Related Deaths	Total Medical Costs*	Total Value of Statistical Life*	Combined Medical Costs + Value of Statistical Life*
2018	4	$51,094.71	$37,092,857.14	$37,144,285.71
2019	3	$45,370.56	$25,826,666.67	$25,872,222.22
2020	2	$11,395.20	$21,360,000.00	$21,371,200.00
2021	134	$848,944.10	$1,040,372,670.81	$1,040,372,670.81

Year	Number of Heat-Related Deaths	Total Medical Costs*	Total Value of Statistical Life*	Combined Medical Costs + Value of Statistical Life*
2022	22	$239,184.85	$159,161,538.46	$159,402,692.31

*Estimated as a proportion of unintentional deaths from natural environmental causes.
Source: CDC Web-based Injury Statistics Query and Reporting System (WISQARS)

The cost of heat-related illness emergency department visits and hospitalizations in Oregon are as follows:

Table 3.3.4-2: Heat-Related Illness Emergency Department Visits

Year	Number of ED Visits*	Median Cost per Visit	Total Annual Cost
2018	545	$1,112.48	$966,688.55
2019	421	$1,070.54	$808,217.61
2020	364	$1,283.89	$984,847.12
2021	1105	$1,293.54	$3,862,789.57
2022	731	$1,342.78	$1,930,277.75
2023	613	$1,418.17	$1,050,564.33

*Includes patients that were treated and released from the ED and not admitted to the hospital. Represents hospital-specific cost to charge ratios.
Source: Oregon Health Authority Hospital Reporting Program, Office of Health Analytics

Table 3.3.4-3: Heat-related illness hospitalizations

Year	Number of Admissions	Median Cost per Visit	Total Annual Cost
2018	35	$8,210.82	$411,470.16
2019	29	$5,891.79	$357,927.77
2020	37	$11,478.39	$509,072.44
2021	181	$10,979.12	$3,292,879.89
2022	64	$14,956.59	$1,227,105.56
2023	74	$10,569.54	$1,153,341.66

Represents hospital-specific cost to charge ratios.
Source: Oregon Health Authority Hospital Reporting Program, Office of Health Analytics. See supplemental document for the methods to estimate costs.

3.3.4.1 Analysis and Characterization

Synoptic conditions that drive extreme heat events in the Pacific Northwest include, upper-level ridges—or large areas of high atmospheric pressure—and strong offshore flow. There are several ways to measure extreme heat. One common way is to count the number of days with temperatures above a certain threshold, such as days with temperatures above 90°F. Areas that climatologically see the greatest number of very hot temperature days include inland areas at lower elevations in eastern Oregon, as well as parts of southern Oregon, particularly the Rogue River Valley. Human-caused climate change is already contributing to the severity of such events (Vose, Easterling, Kunkel, LeGrande, & Wehner, 2017).

Oregon experienced some of the hottest years on record in 2021 and 2022 as measured by days at or above 90°F [Fleishman, 2023]. Recent extremely hot summers (2021, 2022, and 2023) 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. In 2021-2023, the average number of days per year with temperatures at or above 90°F was greater than the average from 2011-2020 in Portland, Salem, Eugene, The Dalles, Pendleton, Ontario and Medford. The hot summers of 2021, 2022, and 2023 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.

The National Weather Service issues extreme heat warnings when the NWS HeatRisk exceeds Major or Extreme HeatRisk. The heat index is a measure of how hot it feels combining both temperature and relative humidity. As relative humidity increases, a given temperature can feel even hotter. Figure 3.3.4-1 displays NOAA's National Weather Service rubric for temperature and relative humidity according to the danger of heat-related illnesses.

Figure 3.3.4-1:NOAA National Weather Service Heat Index.

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

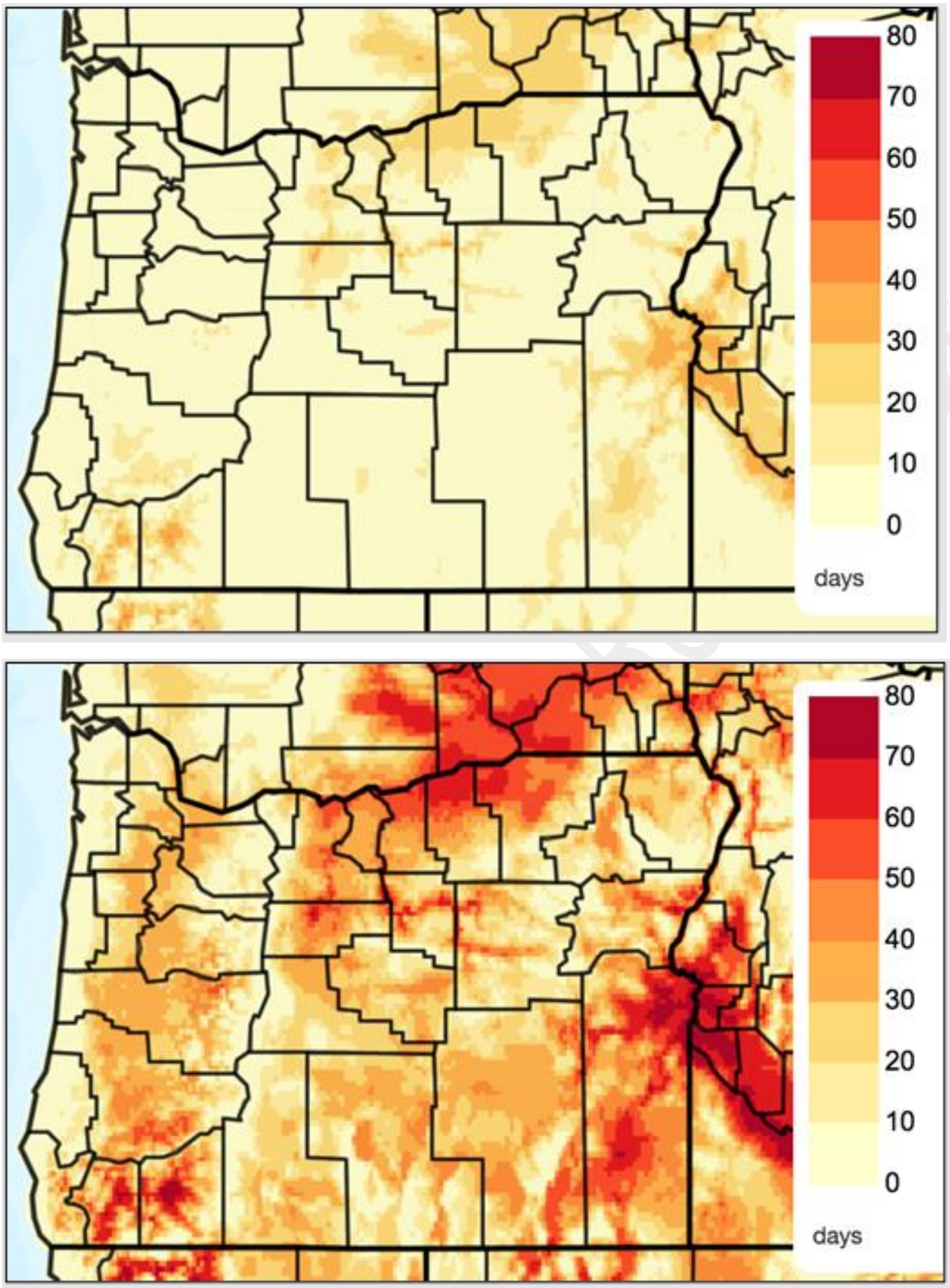
Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution — Extreme Caution — Danger — Extreme Danger

Source: https://www.weather.gov/phi/heat

There have historically been few places in Oregon that experience substantial number of days with heat index greater than 90°F. Under future climate change, however, nearly the entire state could see substantial increases in such extreme heat days (Figure 3.3.4-2).

Figure 3.3.4-2: Frequency of Days April–October with Heat Index ≥ 90°F in Historic (1971–2000, top) and Future (2040–2069, bottom) Periods under RCP 8.5



Note: Displayed is the multi-model mean derived from 18 downscaled CMIP5 climate models.
Source: Northwest Climate Toolbox, https://climatetoolbox.org/tool/climate-mapper

3.3.4.2 Historic Extreme Heat Events

Table 3.3.4-4: Historic Heat and Excessive Heat Events in Oregon

Date	Location	Notes
July 26–28, 1998	Region 2	A three-day heat wave brought record high temperatures to western Oregon. The high temperature of 99 degrees at Portland International Airport on the 26th eclipsed the previous record for that date of 98 set in 1988, and the high of 101 on the 28th broke the previous daily record of 99 set in 1973. In Eugene, the high of 102 on the 26th broke the previous daily record of 101 set in 1988, and the 105 degrees on the 27th tied the record high for the month of July. There was one reported death from heat-related illness.
July 10–14, 2002	Region 5–7	A record breaking heat wave shattered many daily record high temperatures across the state, with a few locations breaking all-time records.
June 24–26, 2006	Region 1–3, 5	A broad upper ridge of unusually high height coupled with a thermally induced surface trough of low pressure lingered over the Pacific Northwest for several days. This pattern resulted in persistent offshore flow, and therefore many days of record-smashing high temperatures. Many cities in Oregon saw record-breaking daily high temperatures for multiple days in a row.
July 20-24, 2006	Region 1–3, 5, 7	An unusually strong ridge of high pressure brought several days of record breaking hot and humid weather to NW Oregon. Many cities in Oregon saw record-breaking daily high temperatures for multiple days in a row. Many daily maximums were between 10 and 20 degrees above normal. A few sites reported record high minimum temperatures during this very humid event; a couple broke all-time record high minimums as well. 4500 homes lost power during this event. In north central and eastern Oregon, daily maximum temperatures between 100 and 113 degrees were observed at lower elevations, with temperatures 90 to 100 degrees at elevations up to 4000 feet. Several people were treated for heat related illness.
June 28–30, 2008	Region 2, 3, 5, 7	An upper level ridge and thermal trough across the Pacific Northwest produced temperatures above 100 degrees for two consecutive days breaking records in many locations. Two people died of heat-related illness.
August 15–17, 2008	Region 5–7	Excessive Heat Event: An upper level ridge and dry air brought excessive heat into eastern Oregon. Many locations experienced multiple days of at least 100 degree temperatures.
July 25–26, 2010	Region 5, 7	Excessive Heat Event: Temperatures topped 100 degrees for two successive days in Hermiston, Pendleton, 5 miles northeast of Pendleton, Ione, Echo, Arlington, and Umatilla.
August 1, 2011	Region 5	A dry weak westerly flow aloft under a broad upper level high pressure system combined with a surface thermal trough to bring several days of temperatures in the 90s.
July 1, 2014	Region 3	An upper level ridge combined with a surface thermal trough and low level offshore winds resulted in a hot day across Northwest Oregon where inland temperatures peaked in the upper 90s inland and the upper 80s along the coast.
June 7–9, 2015	Region 2	An unseasonably strong upper level ridge of high pressure resulted in hot temperatures early in June where high temperatures were in the low to mid 90s, which were around 20 degrees higher than the seasonal normals. The low temperatures were also

Date	Location	Notes
		unseasonably warm. The hospital visits for heat related illness for Northwest Oregon increased by 50 during this period.
June 26–28, 2015	Region 2, 3	Excessive Heat Event: A strong upper level ridge of high pressure resulted in hot temperatures across Northwest Oregon. Afternoon temperatures peaked in the low 90s to the low 100s, which are around 20 degrees warmer than the seasonal normals. Monsoonal moisture and onshore winds resulted in fairly high humidities (40 to 50 percent in the afternoons) making the temperatures feel 2 to 5 degrees warmer than they were. The mid-level moisture also added to an increase of thunderstorms around the region. Clouds from these thunderstorms limited overnight radiation cooling. Nighttime temperatures were in the mid 60s to low 70s, which are 10 to 15 degrees warmer than the seasonal normals. There were several new daily records set for the warmest low temperatures. The Multnomah County had 10 emergency room visits for heat related illnesses. There were two reported drownings, including one at nighttime.
July 1–5, 2015	Region 2, 3	A strong upper ridge over the region resulted in hot weather for the Willamette Valley where temperatures peaked 10 to 15 degrees Fahrenheit above the seasonal normal. High Temperatures were in the mid 90s to low 100s. The low temperatures were also unseasonably warm.
July 28–30, 2015	Region 2, 3	Excessive Heat Event: A strong upper level ridge resulted in excessively warm temperatures where the high temperatures were 15 to 20 degrees Fahrenheit above the seasonal normal. High temperatures were in the upper 90s to around 105 for the Willamette Valley. The daily maximum temperature of 105 degrees at Eugene broke the previous record of 99 last set in 2003. Emergency Preparedness officials opened cooling shelters. Several people were treated for heat related illnesses at medical centers. Local newspapers reported 3 separate incidents where children were left in hot cars in the Eugene area.
August 18–19, 2015	Region 2	Excessive Heat Event: Strong high pressure at the surface and aloft over the area resulted in excessively hot temperatures across northwest Oregon. Warming aloft combined with offshore winds and a thermal trough west of the Cascades contributed to the heat. Temperatures peaked in the mid to upper 90s which is 10 to 15 degrees above the seasonal normal in most areas. Daily high temperatures broke several records at area airports.
June 2–5, 2016	Region 3	Excessive Heat Event: Unseasonably strong ridge of high pressure resulted in a period of early-season hot temperatures across Northwest Oregon. Temperatures of 95 to 100 in early June lead to people seeking relief at local rivers. Three drownings were reported.
August 11–14, 2016	Region 2	Ridge of high pressure lead to hot temperatures across Northwest Oregon. Temperatures in the upper 80s to mid 90s lead to people seeking relief at local rivers. Two river drownings were reported in the Greater Portland Metro area during this heat event.
August 25-26, 2016	Region 1, 2	Ridge of high pressure and offshore winds brought temperatures along the North Oregon Coast up into the mid 80s to mid 90s on August 25. Inland, temperatures on August 25-26 reached the upper 90s. Temperatures in the mid 80s to mid 90s lead to people seeking relief at local rivers, lakes, and beaches. One swimmer drowned. News reported 8 runners were taken to the hospital with heat-related injuries during the Hood-to-Coast relay through Portland.
May 22-23, 2017	Region 2	Ridge of high pressure brought a couple days of warm weather. Temperatures climbed up into the upper 80s to low 90s in many locations across the area. Early season heat led

Date	Location	Notes
		people to seek relief in local rivers and lakes. While air temperatures were warm, river and lake temperatures were still cold, leading to two drownings across the area.
August 1–4, 2017	Region 2–4, 6	Excessive Heat Event: Strong high pressure brought record breaking heat to many parts of southwest, south central, and northwest Oregon. Region 2–3: The record-breaking heat led people to seek relief at local rivers. Two people drowned while swimming. Region 4: Reported high temperatures during this interval ranged from 98 to 112 degrees (Jackson), 95 to 110 degrees (Douglas), 87 to 109 degrees (Josephine, eastern Curry). Region 6: Reported high temperatures during this interval ranged from 82 to 102 degrees.
July 12–17, 2018	Region 2, 3, 4	Region 2–3: High pressure over the region led to a stretch of hot day July 12 through July 17th. Hot temperatures led people to cool off in local rivers. There were two drownings recorded on July 16 and July 18. Temperatures on July 16th near the Sandy River in Troutdale got up to 98 degrees Region 4: Strong high pressure coupled with very dry air brought very hot temperatures to the area during this interval. High temperatures ranged from 89 to 105 degrees (Jackson) and from 91 to 104 degrees (Josephine, eastern Curry).
June 11–12, 2019	Region 4 and eastern Curry County	Strong high pressure and a very dry air mass made for hot conditions over southwest Oregon during this interval. Reported high temperatures ranged from 95 to 101 degrees (Jackson), 89 to 101 degrees (Douglas), 88 to 105 degrees (Josephine, eastern Curry).
August 27-28, 2019	Region 4 and eastern Curry County	Excessive Heat Event: High pressure aloft forced a thermal trough near the coast to move inland, bringing hot and dry conditions to the inland west side valleys in southwest Oregon. Reported high temperatures in this zone ranged from 99 to 106 degrees on 08/27 and from 92 to 95 degrees on 08/28. Low temperatures on the morning of 08/28 ranged from 50 to 67 degrees.
June 26 – 28, 2021	Region 2	A 'heat dome' weather pattern caused extreme temperatures across the Portland Metro region, severely impacting people, transportation networks, and the economy. In the greater Portland Metro area, 93 deaths were reported.

Source: NOAA Storm Events Database https://www.ncdc.noaa.gov/stormevents

3.3.4.3 Risk Maps

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

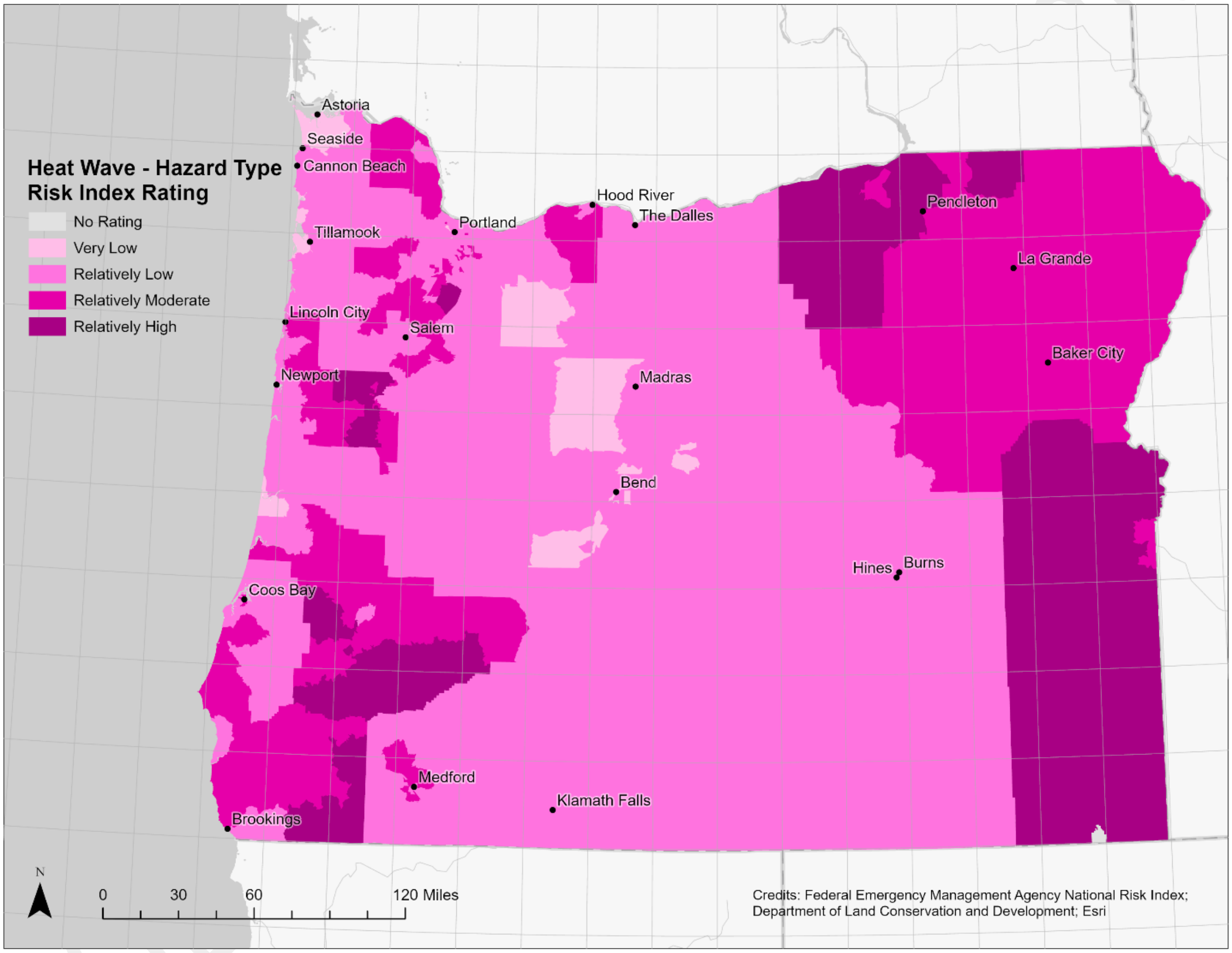
The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

The climate change maps show where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

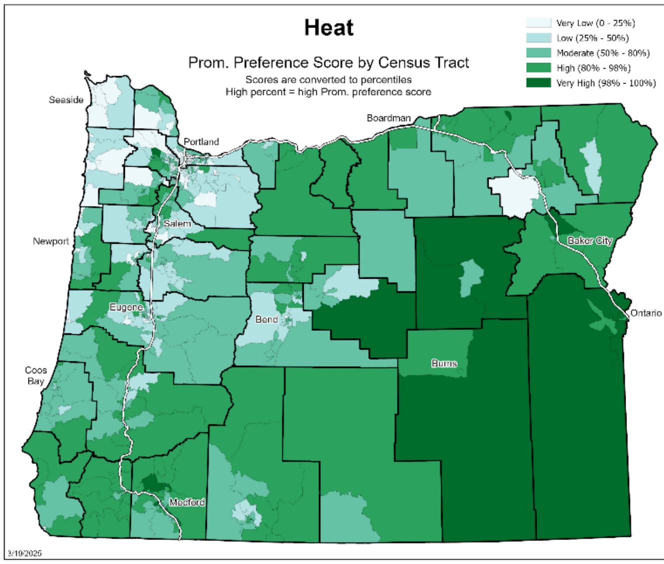
Figure 3.3.4-3: Heat Wave Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Heat Wave.



Source: Federal Emergency Management Agency, National Risk Index for Heat Wave. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.4-4 and Figure 3.3.4-5 show risk rankings by census tract for extreme heat from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.4-4 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.4-5 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

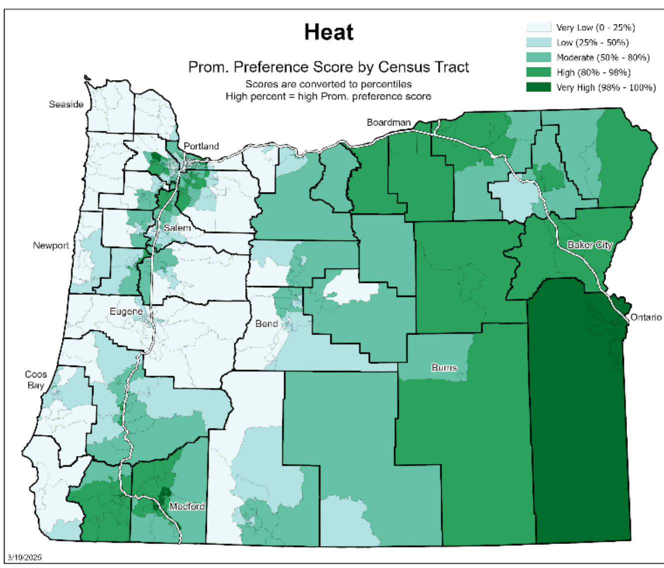
Figure 3.3.4-4: Extreme Heat Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Heat	Over90th	1	0.05	Mean days that are above the historic 90th percentile temp
Heat	Over90F	1	0.05	Mean days above 90 degrees Fahrenheit
Heat	Heat_Events	1	0.05	Number of heat events.
Heat	Heat_ALAG	1	0.05	Annualized loss to agriculture from heat.
Heat	Heat_ALPOP	1	0.05	Annualized loss to population from heat.
Heat	OutdoorJobs	1	0.05	Rate of jobs that occur outside.
Heat	TreeCan_avg	-1	0.05	Tree canopy density
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

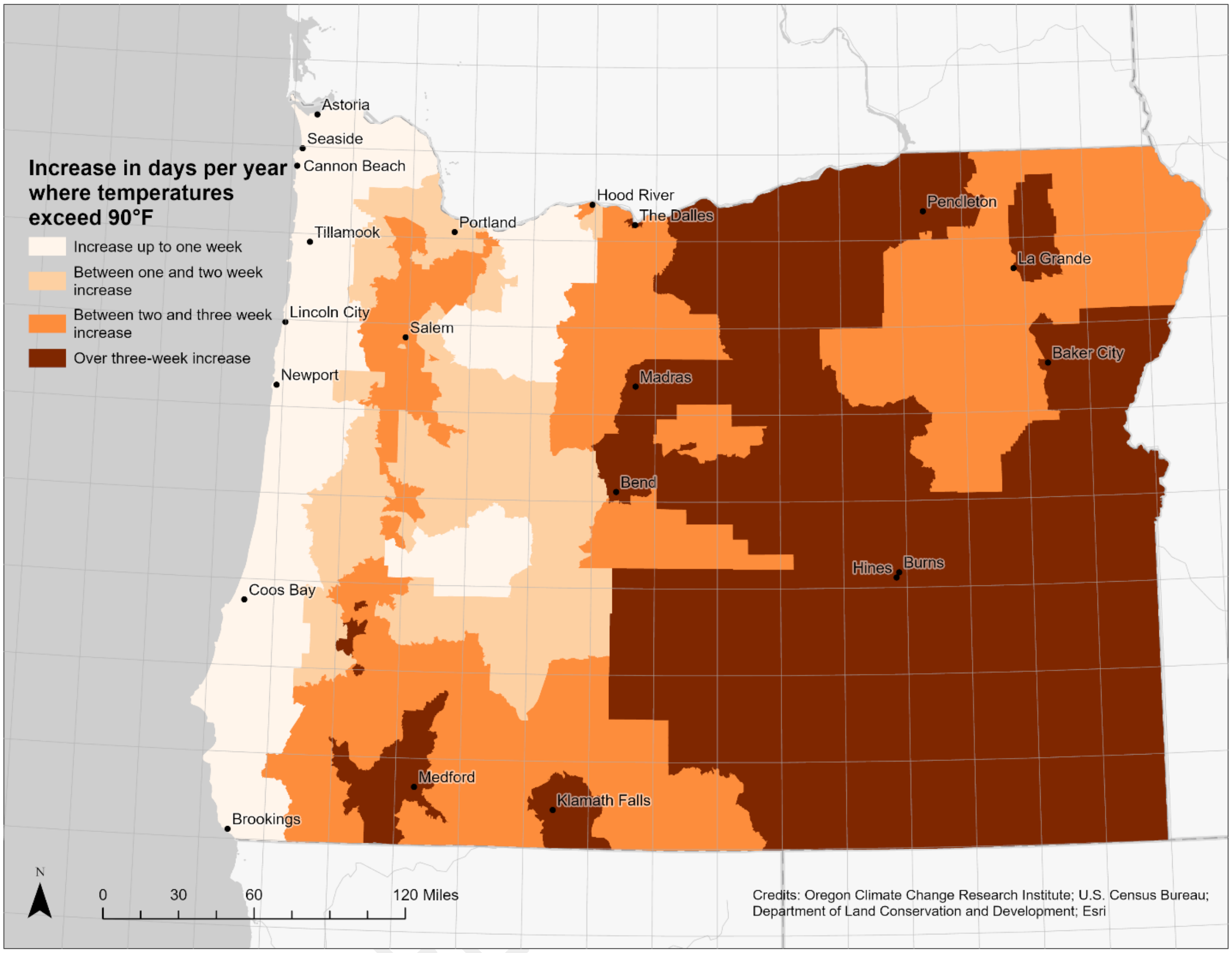
Figure 3.3.4-5: Extreme Heat Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included.



Indicators used for the hazard

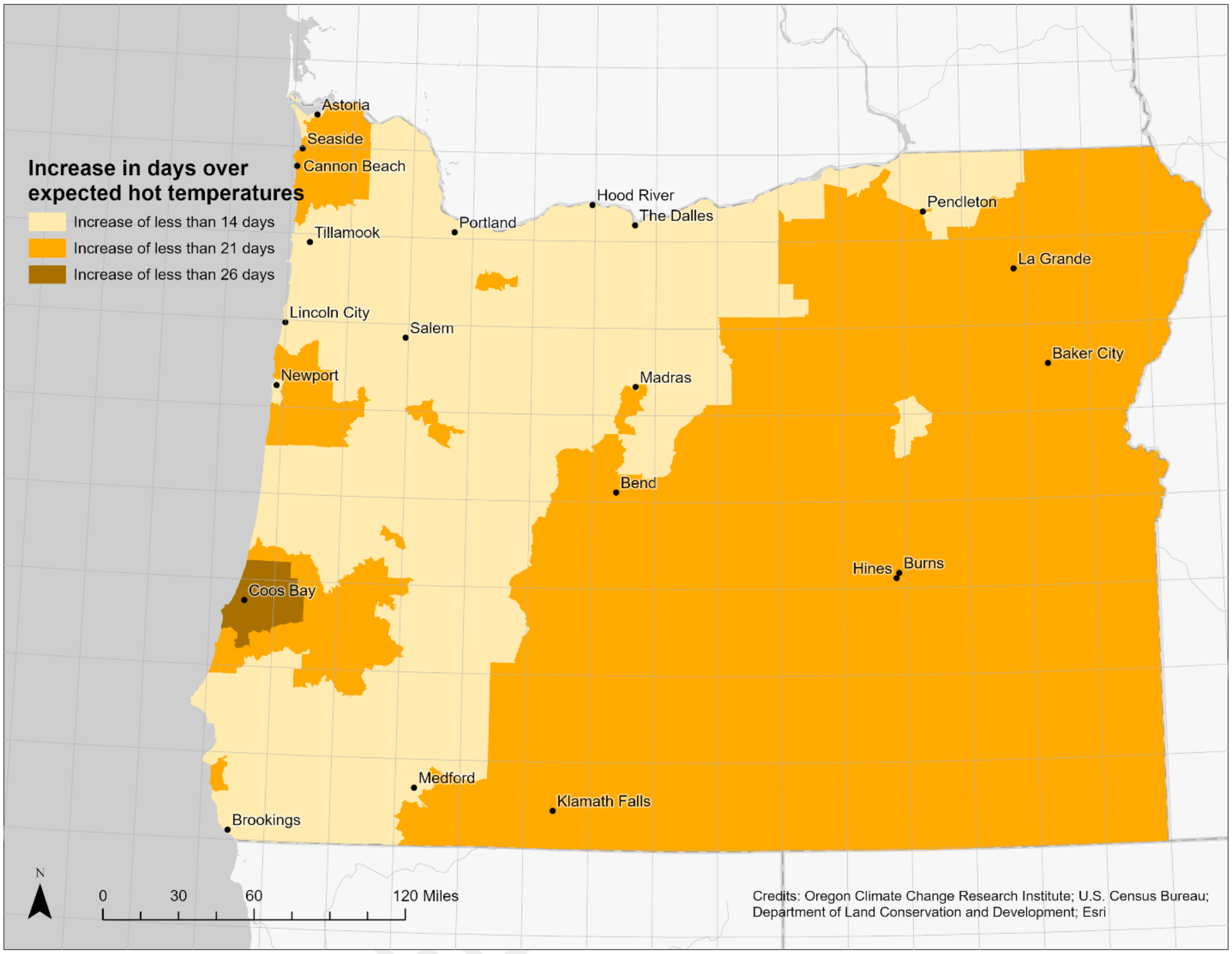
Hazard	Indicator Name	Direction	Weight	Short Description
Heat	Over90th	1	0.143	Mean days that are above the historic 90th percentile temp
Heat	Over90F	1	0.143	Mean days above 90 degrees Fahrenheit
Heat	Heat_Events	1	0.143	Number of heat events.
Heat	Heat_ALAG	1	0.143	Annualized loss to agriculture from heat.
Heat	Heat_ALPOP	1	0.143	Annualized loss to population from heat.
Heat	OutdoorJobs	1	0.143	Rate of jobs that occur outside.
Heat	TreeCan_avg	-1	0.143	Tree canopy density

Figure 3.3.4-6: Change in Days with Temperatures above 90°F: Change from 1981-2010 to 2045-2054 in mean number of days per year that temperatures equal or exceed 90°F.



Source: Derived from 52 ensemble members of 11 LOCA2 downscaled global climate models. Data provided by OCCRI, 2025. Graphic produced by DLCD.

Figure 3.3.4-7: Change in Days with Temperatures above Local 90th Percentile: Change in number of days per year in 2045-2054 that equal or exceed local 1981-2010 90th percentile temperature.



Source: Derived from 52 ensemble members of 11 LOCA2 downscaled global climate models. Data provided by OCCRI, 2025. Graphic produced by DLCD.

3.3.5 Floods

Floods are a common and widespread natural hazard in Oregon; the state has an extensive history of flooding. Across Oregon, flooding typically results from large-scale weather systems that generate prolonged rainfall or rain-on-snow events that result in large amounts of runoff. East of the Cascades, the largest floods are the result of heavy winter rains accompanied by snowmelt on frozen ground (USGS 1983, https://pubs.usgs.gov/wri/1982/4078/report.pdf); however, highly dangerous floods, such as the flash flood that occurred in Heppner in June 1903, can be produced by intense, localized thunderstorms. Other sources of flooding include channel migration, sediment accumulation, high tides, tsunamis, widespread vegetation removal, ice or debris jams, and, much less frequently, dam failures.

The National Flood Insurance Program (NFIP) identifies 260 communities in Oregon as flood-prone including locations in all 36 counties, 222 cities, and two Tribal Nations. Every county and all but two of these flood-prone cities participates in the NFIP, allowing residents to purchase NFIP flood insurance. Nine additional cities for which FEMA has not mapped Special Flood Hazard Areas also belong to the NFIP, indicating that they believe a flood hazard exists within their jurisdiction and that their residents should have access to NFIP flood insurance.

3.3.5.1 Analysis and Characterization

History of Flooding in Oregon

Oregon has an extensive history of flooding, summarized in Table 3.3.5-2: Historic Damaging Floods in Oregon. The deadliest recorded flood in Oregon's history occurred in Morrow County in June 1903 when a thunderstorm dropped 1.5 inches of rain and hail within a twenty-minute period along Willow Creek, upstream of the town of Heppner. Within minutes, a wall of water five-foot tall and about 500 feet wide, silt, and debris poured through Heppner lifting homes off foundations (Murphy, 1904, https://pubs.usgs.gov/wsp/0096/report.pdf). These floodwaters claimed 247 lives.

The Columbia River floods in May and June of 1948 are best remembered for destroying the entire city of Vanport (now Delta Park) on Memorial Day. Record flow levels on the Columbia River, caused by high winter rainfall and rapid melt of an above average snowpack, triggered the structural failure of a railroad embankment (Rantz 1949, https://pubs.usgs.gov/wsp/1080/report.pdf). Much of Vanport was destroyed in minutes and was never rebuilt. Nearly 19,000 people lost their homes and at least 18 people lost their lives.

The flood of record for many of Oregon's rivers took place in December 1964 and January 1965 during the "Christmas Flood." During this time, there were a series of atmospheric river-driven storms that affected much of the western United States; flooding was caused by snow melt and heavy rainfall on frozen ground (Waananen 1971, https://pubs.usgs.gov/wsp/1866a/report.pdf and USGS 2014, https://www.usgs.gov/news/featured-story/christmas-flood-1964). In Oregon, damages from these floods cost over $157 million and 20 Oregonians lost their lives. The storm that occurred from December 20th through 24th, 1964 produced two-thirds the normal annual rainfall in only five days. The ensuing floods and channel migration destroyed hundreds of homes and businesses, forced the evacuation of thousands of people, destroyed at least 30 bridges, and washed-out hundreds of miles of roads and highways.

In February 1996 and January of 1997, another series of devastating floods occurred across the West Coast and in Oregon (NOAA https://www.cnrfc.noaa.gov/storm_summaries/jan1997storms.php). Following an extended period of unseasonably cold weather and heavy snowfall in the Pacific Northwest, warming temperatures and rain began thawing the snowpack and frozen rivers throughout Oregon. On February 6, a strong atmospheric river, called a "Pineapple Express," reached Oregon. This warm, humid air mass brought record rainfall amounts, quickly melting the snowpack. At least twenty-five rivers reached flood stage. Many reached flood levels comparable to those reached in the 1964 flood. Twenty-seven of Oregon's 36 counties were included in the Presidential major disaster declaration due to this event. Statewide, the damage totaled over $280 million. An illustration of the relationship between precipitation and stream flow during the 1996-1997 floods and other flood events can be found in a Story Map produced by Hoch 2023 for the National Weather Service (https://storymaps.arcgis.com/stories/a633588248144b8d85859c5c14d1916c).

Between February 5th and 9th, 2020, another atmospheric river brought heavy precipitation to eastern Oregon which fell on top of a normal mountain snowpack (15-30+ inches). The heavy rain combined with snowmelt runoff resulted in widespread flooding, record breaking river discharges, heavy flood and channel migration damages, and a federally declared disaster for Umatilla, Union and Wallowa counties. One fatality occurred; Interstate 84 was closed for multiple miles; three bridges were completely washed out; and many homes, businesses, levees, utility systems, and irrigation canals were heavily damaged. The Oregon Office of Emergency Management estimated that Preliminary Damage Assessment public assistance costs were $26.7 million and an additional $17.4 million dollars in emergency relief funding was requested from the Federal Highway Administration (Stoelb, 2020).

Types of Flooding

Riverine Floods: Riverine flooding is the most common flood hazard in Oregon. It is caused by the passage of a larger quantity of water than can be contained within the normal stream channel. The increased stream flow is usually caused by heavy rainfall over a period of several days. Examples of riverine events are the flooding in February 1996, and December 1964 to January 1965. The most severe flooding conditions occur when heavy rainfall is augmented by rapid snowmelt. These rain-on-snow events occur on mountain slopes within the low elevation snow zones of the Pacific Northwest. These events make more water available for runoff than does precipitation alone by melting the snowpack (Van Heeswijk, Kimball, & Marks, 1996). If the ground is frozen, stream flow can be increased even more by the inability of the soil to absorb additional water. Rain falling on snow also is a major cause of mid-winter avalanches, which tend to coincide with flood events. Significant rain-on-snow events occur in years that are colder and wetter than normal because snow accumulates at lower elevations, and then is melted off during subsequent rain events (Ferguson, 2000). Rain-on-snow events, including those that occurred in 1861, 1943, 1964, 1977, and 1996 (Table 3.3.5-2), are associated with some of the State's most damaging floods.

Freshet Floods: While riverine flooding in Oregon is typically associated with winter moisture from Atmospheric Rivers on heavy snowpack, Springtime flooding from melting snow also poses a flood thread for some basins in Oregon. A freshet is a flood of a river from large volume of melted snow. For example, every spring, the stored water in the Columbia River snowpack melts and flows downstream and affects Oregon Communities. In the Willamette basin, this freshet threat is less because of frequent cycles of melt and accumulation that occurs over the winter months. Some small basins in Eastern Oregon can accumulate enough snow in the winter months to pose a threat of freshet flooding in the spring melt season. On the Columbia, freshet flooding has been most significant during the month of June in 1894, 1933, 1948, and 1956. The USGS gage at Vancouver, WA registered water levels above 26 ft for these years. The last high freshet experienced on the Columbia was in 2017 where the Vancouver gage measured 17.6 ft.

Flash floods: Flash flooding is caused by extremely intense rainfall over a short period of time, commonly within a single drainage. Flash floods usually occur in the summer during the thunderstorm season. The two key contributors to flash flooding are rainfall intensity and duration.

Topography, soil conditions, and ground cover also impact flooding. Flash floods, because of their intensity, often pick up large loads of sediment and other solid materials. In these situations, a flash flood may arrive as a fast-moving wall of debris, mud, and water.

Occasionally, floating debris or ice accumulates at a natural or man-made obstruction and restrict the flow of water. Water held back by the ice jam or debris dam can cause flooding upstream. Subsequent flash flooding can occur downstream if the obstruction suddenly releases. Areas subject to flash floods are not as obvious as a typical riverine floodplain. However, flash floods may be associated with recognizable locations such as canyons or arroyos. There is also always some potential for flash floods associated with dam failure.

The most notorious flash flood in Oregon was the June 1903 flood in Heppner which was previously summarized. More recent flash floods have occurred in Wallowa County in July 2002 and the City of Rufus in August 2003.

Alluvial fan flooding: 44 CFR Part 59.1 defines alluvial fan flooding as flooding occurring on the surface of an alluvial fan. Alluvial fans are fan-shaped deposits of water-transported material (alluvium) that typically form at the base of steep topographic features where there is a marked break in slope. FEMA notes that alluvial fans can make attractive, but dangerous, development sites. Attractive because they provide commanding views and good drainage, but dangerous because flood flows can happen quickly over unpredictable flow paths, at high velocity, and carry large amounts of debris (Federal Emergency Management Agency [FEMA], 1989). The potential for this type of flooding in Oregon is unstudied and past events (if any) have been poorly documented.

Coastal floods: Coastal areas have additional flood hazards. Winds generated by tropical storms or intense offshore low-pressure systems can drive ocean water inland and cause significant flooding. The height of storm surge is dependent on the wind velocity, water depth and the length of open water (the fetch) over which the wind is flowing. Storm surges are also affected by the shape of the coastline and by the height of tides. If King Tides are present during storm surges, there may be a higher likelihood of flooding.

Coastal flooding also may result from tsunamis. A tsunami is a series of traveling ocean waves generated by an earthquake or landslide that occurs below or on the ocean floor. Oregon's seven coastal counties and many coastal cities are susceptible to flood damage associated with tsunamis. Both "distant" tsunamis generated from seismic events in the Pacific basin and "near shore" tsunamis generated from activity associated with the Cascadia Subduction Zone can impact Oregon's coast. For more information, see the Tsunami chapter of this Plan.

Shallow area flooding: Some areas are characterized by FEMA as being subject to shallow flooding. These are areas that are predicted to be inundated by the 100-year flood with flood depths of one to three feet. Flooding events are expected to be low velocity events characterized by "sheet flows" of water.

Urban flooding: As land is converted from fields or woodlands to roads, roofs, and parking lots, it loses its ability to absorb rainfall. This transition from pervious surfaces to impervious surfaces results in more and faster runoff of water. During periods of urban flooding, streets can become swift moving rivers, and basements can fill with water. Storm drains may back up with yard waste, causing additional nuisance flooding.

Playa flooding: Playa flooding results from greater than normal runoff into a closed basin. Closed basin systems are those areas that have one or more rivers emptying into one or more lakes that have no outlet. In these situations, water can only leave the system through evaporation. Thus, if annual precipitation in the basin increases significantly, evaporation is not enough to reduce water levels. Lake levels rise and inundate the surrounding properties.

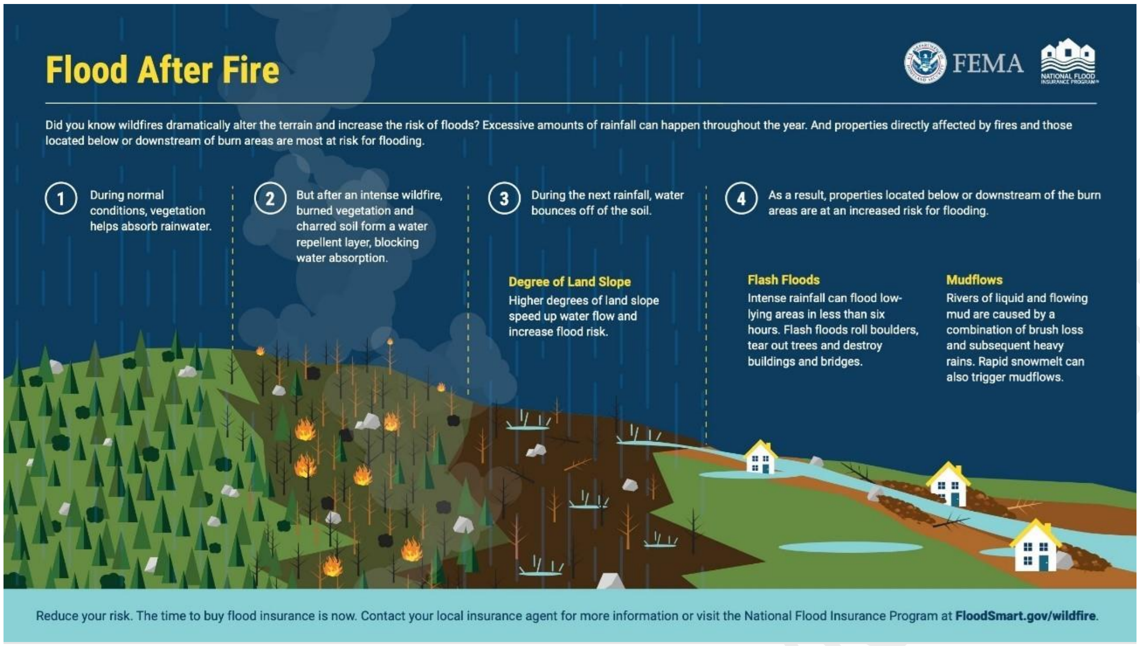
The best-known example of playa basin flooding in Oregon occurs at Malheur and Harney lakes in Harney County. During years with greater than average precipitation, the lakes flood adjacent ranches and public roads. Malheur and Harney lakes flooded during the years 1979 to 1986, and then gradually receded. During the wetter years of 1997 to 1999, these lakes again flooded. By 2005, following a number of dry years, they had receded significantly. In spring 2011, as a result of a heavy snowpack and persistent rainfall, Harney Lake's water level increased significantly with flooding observed in low-lying areas.

Ice jams: Ice jams happen in colder regions of the State during winter and early spring while rivers are frozen. Sudden warming at higher altitudes melts snow resulting in increased runoff which breaks the ice from reaches of frozen river below. On the way downstream, the floating ice can "jam" in a narrow reach of the drainage or against a road crossing which then dams melting water. As the ice weakens, water breaches the dam releasing a torrent of water.

Dam and levee failure: Dam and levee failures and accidents, though rare, can result in extreme flooding downstream of the dam or in the area behind the levee. Beyond the levee failure previously described in the 1948 Vanport flood, catastrophic dam failures have occurred in other parts of the country and around the world. The South Fork Dam failure (1889 Johnstown flood) resulted in over 2000 fatalities in western Pennsylvania. The Saint Francis Dam in southern California failed in 1928 with a loss of an estimated 600 people. Oregon's dam safety statutes (ORS 540.350 through 400) came into effect shortly after the Saint Francis disaster. Many historical dam failures were triggered by flood events, others by poor dam construction, and some have been triggered by earthquakes. Please review the dam safety chapter and information available through FEMA and the US Army Corps of Engineers for more information.

Flood after Wildfire: Wildfires dramatically change the landscape and ground conditions, which can lead to a higher risk of flooding. When a wildfire burns a portion of a watershed, the resulting burn scar increases the potential for flooding until vegetation is reestablished and ecosystems recover. Natural, unburned vegetation and soil normally act as a sponge during a rainfall event. However, the heat from a fire can bake the ground creating a surface that will not absorb water and can increase the speed with which water flows off the slope. When a wildfire compromises or eliminates these normal protective functions, the potential for significant flooding and debris flows increases. FEMA provides this infographic that summarizes this phenomenon (Figure 3.3.5-1):

Figure 3.3.5-1: Wildfires impact flooding in various ways



Source: https://community.fema.gov/PreparednessConnect/s/article/When-Disaster-Strikes-Twice-Flood-after-Fire
Note: FEMA has produced informational graphics to explain some of these (FEMA, 2022).

Because of changed soil conditions and removal of vegetation cover, chances of flash floods increase dramatically on a wildfire impacted basin. Areas of Eastern Oregon, where wildfires and flash floods are common are particularly vulnerable to this hazard.

The likelihood of flooding can depend on the terrain, how much time the ground has had to heal, vegetation regrowth and the severity of the fire on the landscape. These floodwaters typically transport surface debris such as downed trees and gravel, but still behave like water or in some cases mudflow. As water runs downhill through burned areas, it can create major erosion and pick up large amounts of ash, rocks, boulders, and burned trees, generating a debris flow (also commonly termed “mudflow”). Fast-moving, highly destructive debris flows are one of the most dangerous post-fire hazards, since they occur with little warning. High rainfall rates are the trigger for debris flows, rather than the total amount of rain. Their mass and speed make them particularly destructive. Debris flows can strip vegetation, block drainages, damage structures, and endanger human life. The force of the rushing water and debris can threaten life and property miles away from the burned area. Survivors of debris flows describe sounds of cracking, breaking, roaring, or a freight train.

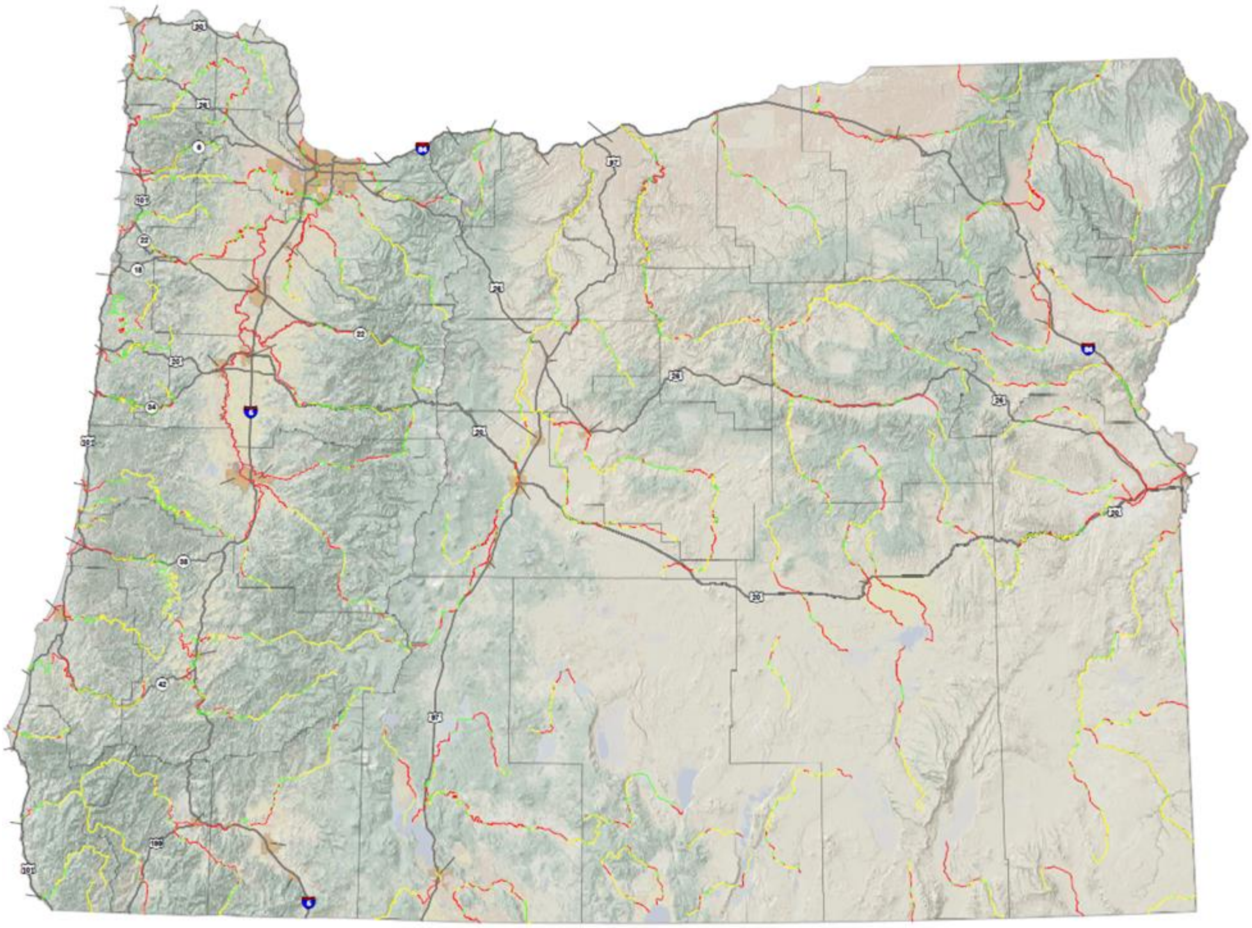
Wildfire recovery is dependent on many factors including soil conditions, vegetation makeup, stability of slopes, weather, and burn severity on the impacted landscape. Ecosystem resilience is highly variable across landscapes and not fully understood. Certainly, the need to know the period of increased impacts caused by wildfires is important, but the variability and lack of data makes it difficult to predict. In Oregon, areas of western Cascade burns have seen lingering effects from wildfires as trees that died during the wildfire or since are decomposing and destabilizing slopes. Eagle Creek, for example, has seen an uptick in the amount and extent of debris flows in the 5-7 since the Columbia Gorge wildfires. This is a particularly poignant point for those watersheds affected from the devastating 2020 wildfires. In general, Oregon can expect wildfires to affect watersheds for decades following a burn, but the actual recovery is highly dependent site conditions. Based upon floodplain management outreach efforts after the devastating 2020 wildfires in Oregon, approximately 650 structures were reported to be substantially damaged within the Special Flood Hazard Area in Oregon.

Channel Migration in Association with Flooding: Channel migration is the process by which streams move laterally over time. It is can be a gradual phenomenon that takes place over many years due to natural processes of erosion and deposition, but in some cases, usually associated with flood events, significant channel migration can happen rapidly. This process is particularly common on rivers with high sediment loads from upstream sources. Depending on the local stream conditions, the river may also avulse—a process in which the river rapidly shifts to occupy a completely new channel. Channel migration susceptibility is determined by the local bed and bank geology, stream discharge and power, available sediment supply, riparian vegetation, presence of large woody debris, channel slope and confinement, human structures and alterations, and other watershed characteristics.

Channel migration can and has created hazardous conditions within Oregon's developed riparian areas. Rapid migration can undercut structure foundations and damage infrastructure. The upper Sandy River in eastern Clackamas County is an example of where, high sediment loads, channel migration, and development intersect. A recent January 2011 flood resulted in temporary avulsion that washed out section of Lolo Pass Road and also bank erosion that damaged and destroyed several homes. The flooding in Umatilla County during February 2020 also resulted in widespread erosion damage and caused the river to migrate hundreds of feet very rapidly. Channel migration along the Umatilla River and other streams washed out roads, undermined homes and structures, and destroyed several bridges.

Channel migration is not a standard consideration of the NFIP and has not been mapped systematically in Oregon. DOGAMI has recently completed a statewide channel migration screening for major rivers in Oregon (Roberts & Anthony, 2017). This study classified nearly 7,000 river miles into high, medium, and low potential susceptibility to channel migration based on river and valley characteristics. DOGAMI selected and is currently mapping detailed channel migration zones in four counties in Oregon based on the results of the 2017 screening. The screening will continue to be used to prioritize future detailed channel migration zone mapping as funding becomes available. In 2024, a new group formed through the Northwest Regional Floodplain Management Association which brings together interested city, county, state and federal entities interested in CMZ in Oregon and Washington.

Figure 3.3.5-2: Channel migration screening overview map of Oregon showing major rivers with low (yellow), moderate (green), and high (red) susceptibility.



Source: Roberts & Anthony (2017)

Repetitive Loss and Severe Repetitive Loss:

Oregon currently has 425 repetitive loss (RL) or severe repetitive loss (SRL) structures listed in the state. DOGAMI obtained a combined list of repetitive and severe repetitive loss properties summary report from FEMA. Beginning October 2019, PIVOT became the NFIP's new system of record replacing the BureauNet System. The summary list provided by FEMA does not include addresses or property owner names. However, the list does include data such as community name, county location, zip code, NFIP insured, post or pre firm, dates of losses, occupancy type (single family or non-residential), and many other characteristics that can be used for analysis or to assist in identifying mitigation opportunities at the local level.

Definition: Repetitive loss structure means a structure covered under an NFIP flood insurance policy that (1) has incurred flood-related damage on two occasions, in which the cost of repair, on average, equaled or exceeded 25 percent of the value of the structure at the time of each such flood event; and (2) at the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage (44 CFR § 77.2 Definitions).

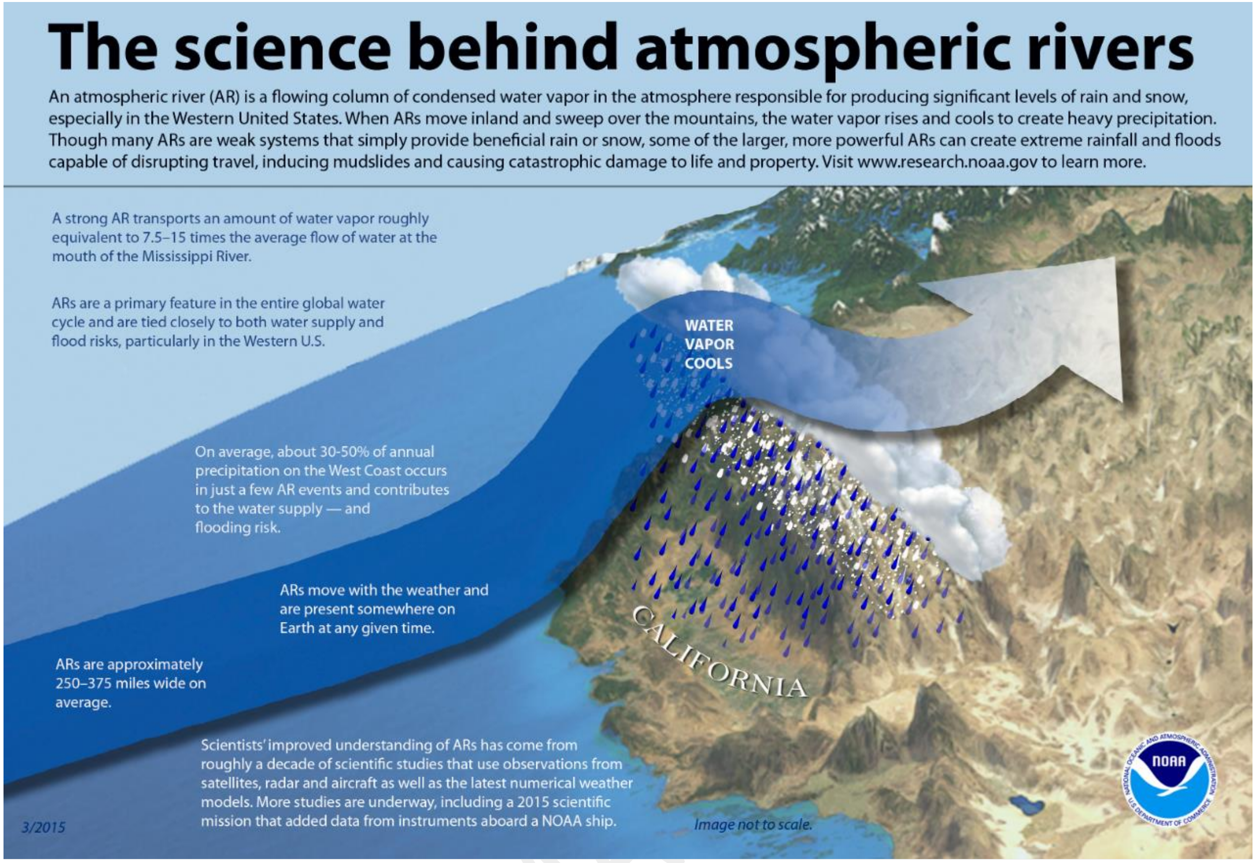
Definition: Severe repetitive loss structure means a structure covered under an NFIP flood insurance policy and has incurred flood-related damage (1) for which four or more separate claims have been made under flood insurance coverage, with the amount of each claim (including building and contents payments) exceeding $5,000 and with the cumulative amount of such claims payments exceeding $20,000; or (2) for which at least two separate flood insurance claims payments (building payments only) have been made, with the cumulative amount of such claims exceeding the value of the insured structure (44 CFR § 77.2 Definitions).

Beyond identifying vulnerable buildings, the RL and SRL list provided by FEMA has value for hazard mitigation planning because the locations of these properties may indicate areas of persistent or repetitive flood or drainage problems. The State will continue to encourage owners of RL and SRL properties to participate in mitigation programs and FEMA's mitigation grants. The following are additional considerations for mitigating these RL/SRL properties:

- Verification of the RL and SRL list should be completed by staff at the local level to ensure its accuracy and whether the subject property is verified as a repetitive loss property or if it has been mitigated or removed (demolished) as a basis for researching and selecting funding for future hazard mitigation projects.
- Local community (city or county) staff are encouraged to work directly with FEMA staff to obtain their local RL/SRL list. FEMA updated their sharing policy on data that includes personally identifiable information in 2023. Additional information on FEMA's policy: [Information Sharing Access Agreements | FEMA.gov]
- A strategy for mitigating these repetitive properties should include projects that are geographically balanced across the state, communities with approved local hazard mitigation plans, target buyouts in regions with high occurrence of repeat damage where critical salmonid habitats are present, and implement restoration projects that support sustainable land and water use practices benefiting both human communities and salmonid populations.

Atmospheric Rivers: Atmospheric Rivers (ARs) are a key source of flooding in Oregon and are common along the West Coast. During the Winter, long narrow bands of moisture are generated from warm tropical areas of the Pacific. Driven by Pacific Storms, these bands of water vapor release large amounts of rainfall when they interact with coastal topography. (Scripps Oceanography, 2020; https://www.youtube.com/watch?v=NULrvr8pTBg). The Willamette Flood of 1861, Christmas Flood of 1964, and the Great Flood of 1996 (the top three floods in Oregon's recorded history) were all produced by atmospheric rivers. Since these floods are driven by moisture from the Pacific, the threat of Atmospheric River is more pronounced for Western and Southwestern Oregon Communities.

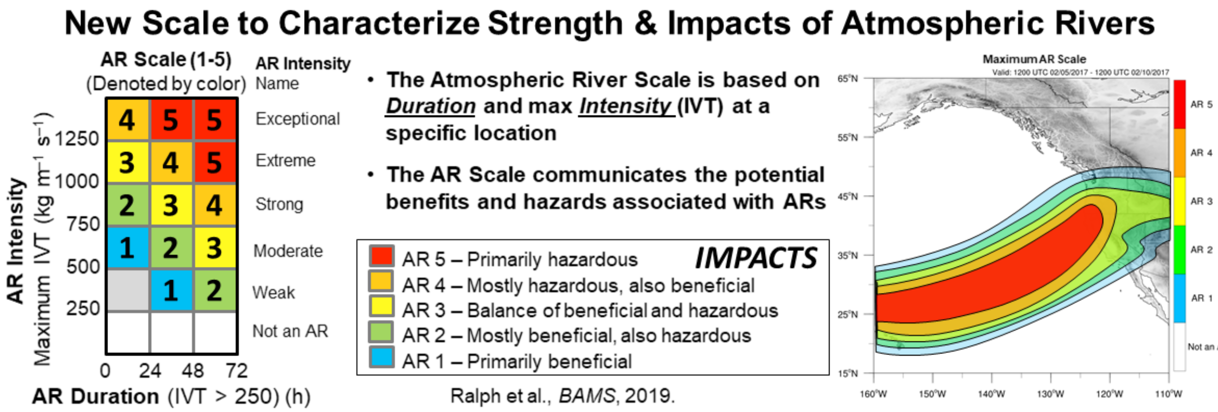
Figure 3.3.5-3: Infographic of the science behind atmospheric rivers



Source: NOAA

Climatological Characteristics of Atmospheric Rivers and Their Inland Penetration over the Western United States https://cw3e.ucsd.edu/wp-content/uploads/2014/05/Rutz_etal_2014_MWR.pdf .The Center for Western Weather and Weather Extremes (CWWWE) (https://cw3e.ucsd.edu/) has been researching Atmospheric Rivers in an effort to enhance existing forecasts for flooding. Using the duration of atmospheric impacts and the intensity of the available water vapor, the CWWWE has developed a categorization model for atmospheric rivers ranging from AR1 to AR5. The following figure summarizes this categorization developed by the CWWWE (Figure 3.3.5-4).

Figure 3.3.5-4: By using a categorization system, forecasts can be enhanced to contextualize the threat of flooding during the Winter Months when ARs are common



Source: Center for Western Weather and Water Extremes (https://cw3e.ucsd.edu/)

Using the grading of ARs (from 1 to 5) in addition to forecasts from the Weather Service, dam safety practitioners and communities can get a better sense of potential flood impacts and the severity of storms approaching the western coast. In addition, because the models used by the CWWWE are linked to water vapor, alerts of advanced warning can be sent ahead of official forecasts. The CWWWE have created automated alert systems that can be useful, during the winter, to stay appraised of weather conditions that might result in flooding.

El Niño and La Niña Events in Oregon and Relationship to Flooding

One of the most prominent aspects of Oregon's weather and climate is its variability. This variability ranges over many time and space scales, from small-scale phenomena such as wind gusts and localized thunderstorms, to larger-scale features like fronts and storms, to even more prolonged features such as droughts and periods of flooding. Fluctuations occur on multi-seasonal, multi-year, multi-decade and even multi-century time scales. Examples of these longer time-scale fluctuations include an abnormally hot and dry summer, an abnormally cold and snowy winter, a consecutive series of abnormally mild or exceptionally severe winters, and even a mild winter followed by a severe winter. Human inputs into the geophysical environment are also imposing cumulative impacts with measurable changes to global climate, sea-level and even localized weather. These human inputs along with the normal climate cycles may be working together in unpredictable ways and lead to future climate scenarios that do not resemble past, historic cycles. Under a warming climate, while it is still uncertain exactly how ENSO variability may change, recent research is more confident that the relationships between ENSO and its impacts around the globe will be stronger.

The El Niño Southern Oscillation (ENSO) Cycle

El Niño and La Niña are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific.

La Niña is sometimes referred to as the cold phase of ENSO and El Niño as the warm phase of ENSO. These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate.

El Niño and La Niña episodes typically last nine to 12 months, but some prolonged events may last for years. They often begin to form between June and August, reach peak strength between December and April, and then decay between May and July of the following year.

While their periodicity can be quite irregular, El Niño and La Niña events occur about every 3 to 5 years. Typically, El Niño occurs more frequently than La Niña.

The terms El Niño and La Niña represent opposite extremes of the ENSO cycle in an otherwise continuum of global climate events, with “average” conditions generally prevailing between those extremes. In the past three decades there have been several El Niños, with the 1982 to 1983 and 1997 to 1998 events having been the strongest on record, while the period between 1990 and 1995 was characterized by persistent El Niño conditions, the longest on record (Trenberth, 1999).

Table 3.3.5-1: Recent ENSO Events in Oregon

El Niño Events	La Niña Events
1982-1983	1988-1989
1994-1995	1995-1996
1997-1998	1999-2000
2002-2003	
2004-2005	
2006-2007	2007-2009
2009-2010	2010-2012
2014-2016	2016-2017
	2017-2018
2018-2019	2020-2023
2023-2024	

Source: NOAA, Multivariate ENSO Index (MEI) http://www.esrl.noaa.gov/psd/enso/mei/ and https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

In general, the longer time-scale phenomena are associated with changes in oceanic and atmospheric circulation that encompass areas far larger than a particular affected region. At times, these persistent features occur simultaneously over vast, and seemingly unrelated, parts of the hemisphere, or even the globe, resulting in abnormal weather, temperature, and rainfall patterns throughout the world. During the past several decades, scientists have discovered that important aspects of this interannual variability in global weather patterns are linked to a global-scale, naturally occurring phenomenon known as the El Niño Southern Oscillation (ENSO) cycle. A measure of this cycle is the Southern Oscillation Index (SOI), which is "calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin, Australia."

Historical El Niño and La Niña events in Oregon

The earliest systematic study of ENSO in the Northwest was by Redmond and Koch (1991). The results were sufficiently strong that the authors suggested a cause-effect relationship between the SOI and Oregon weather. They determined that the Southern Oscillation Index (SOI) can be used as a predictor for weather, especially for winter weather. Greatest correlations between SOI and winter weather patterns occur with about a four-month time lag with summer average SOI correlating well with weather in the Northwest during the following winter. SOI values less than zero represent El Niño conditions, near zero values are average, and positive values represent La Niña conditions.

In Oregon El Niño impacts associated with these climate features generally include warmer winter temperatures and reduced precipitation with drought conditions in extreme events.

What Oregonians should especially plan for and monitor, however, is La Niña. Severe flooding during the winters of 1995-96, 1998-99, and 2007-08 are attributable largely to the combination of heavy snows and warm, intense tropical rain. During La Niña events, heavy rain arrives in Oregon from the western tropical Pacific, where ocean temperatures are well above normal, causing greater evaporation, more extensive clouds, and a greater push of clouds across the Pacific toward Oregon. During February 1996, for example, severe flooding — the worst in the state since 1964 — killed several people and caused widespread property damage. Nearly every river in Oregon reached or exceeded flood stage, some setting all-time records. Debris flows and landslides were also numerous. (Note that debris flow events are typically associated with periods of heavy rainfall or rapid snowmelt on steeply sloping ground. The term "mudslide" is often used interchangeably but is poorly defined as a natural hazard. FEMA uses the terms "mudslide" and "mudflow" in the context of the National Flood Insurance Program, e.g., 44 CFR 59.1 and 206.2(a)(17).)

3.3.5.2 Future Conditions

Across the Pacific Northwest, overall warmer temperatures due to climate change are expected to result in greater winter runoff and streamflow. As more precipitation falls as rain and less as snow, the snow melt is expected to begin earlier in the year, and summer flows are predicted to be lower as a result of less seasonal precipitation (Dalton and others, 2022). Snow-dominated watersheds, those where snowmelt is a primary source of water, will experiencing shifts towards more rain and less snow due to climate change, potentially leading them to become rainfall-dominated systems. Unregulated streams are more likely to display the effects of climate change on discharge, since large dams operated to reduce flood risk often regulate discharges all year long and reduce peak flood flows.

According to Fleishman and the Oregon Climate Change Research Institute (OCCRI) (2023), thus far, Oregon's annual average temperature has increased by approximately 2.2 °F (1.1°C) per century since 1895, and, without significant reductions in greenhouse gas emissions, the annual temperature is projected to increase by 5°F (1.8°C) by the 2050s and 8.2°F (4.5°C) by the 2080s. Although Oregon has seen a statistically significant increase in temperature, there is no evidence yet of a change in the total precipitation across the state (Fleishman and OCCRI, 2023). However, this may be explained by substantial natural variability and relatively short periods of observation.

A literature review by the USACE (2022) completed in 2015 found strong evidence of decreasing trends in the Pacific Northwest region's annual streamflow, particularly in the spring and summer flows, and a decrease in the region's April 1st snow-water equivalent for the latter half of the 20th century. These patterns were broadly attributed to increasing temperature trends. Similarly, since the mid- to late 1900s, 20 of Oregon's glaciers have disappeared, and nearly all of Oregon has experienced an increased frequency and severity of drought conditions over the last 20 years (Fleishman and OCCRI, 2023).

Historically, atmospheric rivers impact Oregon rivers during winter months, from November to February. In recent years, atmospheric rivers have impacted the west coast later in the season. For example, a particularly strong atmospheric river impacted rivers in Oregon during early April of 2019. In 2021, a strong atmospheric river impacted Oregon as late as June. The system of water management in Oregon is designed based on winter flooding, therefore reservoirs start to fill beginning in March. Loss of this storage volume to meet water conservation needs means that late season atmospheric rivers can have a proportionately greater impact on river levels. These trends are not fully understood but are becoming more common and problematic for traditional flood risk management systems.

3.3.5.3 Historic Flood Events

Table 3.3.5-2 lists historic damaging floods in Oregon.

Table 3.3.5-2: Historic Damaging Floods in Oregon

Date	Location	Notes
Sep. 1861	Klamath, Willamette, and Umpqua	Klamath, Douglas, Lane, Linn, Benton, Marion, Polk, Yamhill, Clackamas, Multnomah Counties
June 1880	Columbia	Clatsop, Columbia, Multnomah, Hood River, Sherman, Gilliam, Morrow
Jan. 1881	Willamette Basin	Lane, Linn, Benton, Marion, Polk, Yamhill, Clackamas, Multnomah Counties
Dec. 1882	Umatilla	Umatilla County
June 1884	John Day	Grant, Wheeler, Wasco, Sherman Gilliam
May-June 1894	Columbia River Basin	Clatsop, Columbia, Multnomah, Hood River, Sherman, Gilliam, Morrow; rain on snowpack; highest flood stage ever recorded at Vancouver, Washington (33.6 ft)
June 1903	Willow Creek	flash flood in Heppner; 247 people killed
Apr. 1904	Silvies and Klamath	Harney, Klamath Counties
Feb. 1907	western Oregon and John Day	Grant, Wheeler, Wasco, Sherman, Gilliam
Nov. 1909	Deschutes, Willamette, Santiam, Umpqua, Coquille, and Rogue	Deschutes, Jefferson, Wasco, Linn, Douglas, Coos, Curry, Josephine, Jackson

Date	Location	Notes
Mar. 1910	Powder and Malheur	Baker, Malheur, Harney
June 1913	Columbia	Clatsop, Columbia, Multnomah, Hood River, Sherman, Gilliam, Morrow
Jan. 1923	Clackamas, Santiam, Sandy, Deschutes, Hood, and McKenzie	Clackamas, Linn, Multnomah, Deschutes, Jefferson, Wasco, Hood River, Lane Counties; record flood levels
Feb. 1925	Malheur	Malheur, Harney
Feb. 1927	Klamath, Willamette, Umpqua, Rogue, and Illinois	major flooding
May 1928	Columbia	Clatsop, Columbia, Multnomah, Hood River, Sherman, Gilliam, Morrow
Mar. 1931	Umatilla, Sandy, Clackamas, and Santiam	Umatilla, Clackamas, Multnomah, Linn
Mar. 1932	Malheur, Grande Ronde, John Day, and Umpqua	Malheur, Harney, Union, Wallowa, Grant, Wheeler, Wasco, Sherman, Gilliam, Douglas
Jan. 1933	Coquille	Coos County
Nov.–Dec. 1942	Willamette Basin	Lane, Linn, Benton, Clackamas, Multnomah; 10 deaths; $34 million damage
Dec. 1945	Coquille, Santiam, Rogue, and McKenzie	Coos, Linn, Jackson, Josephine, Curry and Lane Counties; 9 deaths and homes destroyed in Eugene area
Dec. 1946	Willamette, Clackamas, Luckiamute, and Santiam	
May - June 1948	Columbia River	Multnomah County, Wasco County; rain on snow; destruction of the City of Vanport
Mar. 1952	Malheur, Grand Ronde, and John Day	Malheur, Harney, Union, Wallowa, Grant, Wheeler, Wasco, Sherman, Gilliam counties; highest flood stages on these rivers in 40 years
Dec. 1955	Rogue, Umpqua, Coquille	DR-49. Jackson, Josephine, Curry, Douglas, Coos Counties; 11 deaths; major property damage
July 1956	central Oregon	DR-60. City of Mount Vernon, Grant County and City of Mitchell, Wheeler County; flash floods
Feb. 1957	SE Oregon	DR-69. $ Malheur, Baker, Wallowa Counties; 3.2 million in flood damages
Dec. 1961	Willamette Basin	Lane, Linn, Benton, Clackamas, Multnomah; $3.8 million in flood damages
Dec. 1964–Jan. 1965	Pacific Northwest	DR-184. All 36 counties; rain on snow; record flood on many rivers
Dec. 1967	central Oregon coast	Clatsop, Tillamook, Lincoln Counties; storm surge
Feb 1971	north coast	DR-301. Clatsop and Tillamook counties

Date	Location	Notes
Jan. 1972	western Oregon	DR-319. Clackamas, Clatsop, Coos, Douglas, Lane, Lincoln, Linn, Multnomah, Tillamook, Washington counties; record flows on coastal rivers
Jan. 1974	western Oregon	DR-413. Benton, Clackamas, Columbia, Coos, Curry, Douglas, Gilliam, Hood River, Jackson, Josephine, Lane, Lincoln, Marion, Polk, Tillamook, Wallowa, Wasco, Washington, Yamhill counties; $65 million in damages
Nov. –Dec. 1977	western Oregon	Multnomah, Clackamas counties; rain-on-snow event; $16.5 million in damages
1979 to present	Harney County	cyclical playa flooding on Harney and Malheur lakes
Dec. 1981	Umpqua and Coquille	Douglas and Coos Counties
Jan. 1982	Tillamook County	
Feb. 1982	Malheur and Owyhee Basins	Malheur and Harney Counties
Jan. 1990	Clatsop and Tillamook Counties	DR-853
July 1995	Fifteenmile Creek	DR-1061. Flash flood in Wasco County.
Feb. 1996	nearly statewide	DR-1099. Benton, Clackamas, Clatsop, Columbia, Coos, Deschutes, Douglas, Gilliam, Hood River, Jefferson, Josephine, Lane, Lincoln, Linn, Marion, Morrow, Multnomah, Polk, Sherman, Tillamook, Umatilla, Union, Wallowa, Wasco, Washington, Yamhill counties; damages totaling over $280 million
Nov. 1996	SW Oregon	DR-1149. Flooding, landslides, and debris flows; eight deaths in Douglas, Coos, and Lane Counties
Jan. 1997	SW and NE Oregon	DR-1160. Coos, Jackson, Josephine, Baker, Grant, Wallowa, Gilliam, Morrow, Umatilla, Wheeler, and Lake Counties
May–June 1998	Crook County and Prineville	DR-1221. Ochoco River
Dec. 1998	Lincoln and Tillamook Counties	
Nov. 1999	Coastal rivers in Lincoln and Tillamook Counties	heavy rainfall and high tides
Jan. 2000	Curry, Douglas, and Josephine Counties	A Flood Warning was issued for the South fork of the Coquille River from Myrtle Point to Coquille City, North and South Forks of the Coquille River. Brookings recorded 4.72 inches of rain, a record for the date. Two Small Stream Flood Advisories were issued, the first for Elk Creek, the second for Deer Creek. A Flood Warning was issued for the lower Rogue River from Agness to Gold Beach.
Feb. 2000	Coos County	A Flood Warning was issued for the South Fork of the Coquille River at Myrtle Point
July 2000	Deschutes County	A slow moving thunderstorm with heavy rain flooded the Becky Johnson Community Center and Health Clinic Campus.
Sept. 2000	Clackamas County	Heavy rain, estimated at 3 inches in places, plus glacial melt associated with abnormally warm temperatures, acted together

Date	Location	Notes
		to trigger floods and rock and mud slides on the western slopes of Mount Hood.
Apr. 2001	Wheeler	A slow moving thunderstorm produced an estimated 1 inch of rain over mountainous terrain in southeastern Wheeler County.
June 2001	Grant County	The Oregon Dept. of Transportation reported flash flooding on State Highway 26
July 2001	Douglas, Deschutes, and Lake Counties	A Flash Flood Warning was issued for East Central Douglas county. The Boulder Creek area was of special concern. A heavy slow moving thunderstorm dumped one inch of rain in one hour over Sunriver. Lakeview Police reported rock and/or mudslides on State Highway 140 at mileposts 22, 23.2, and 25.1. They also reported 0.25-inch hail up to an inch deep and 2 feet of water in spots on the same highway.
June 2002	Baker and Malheur Counties	Slow-moving thunderstorms dropped very heavy rainfall over the Rye Valley area near the Baker-Malheur County line.
July 2002	Wallowa County	flash flood above Wallowa Lake damaged Boy Scout Camp facility
August 2003	City of Rufus, Sherman County	flash flood (Gerking Canyon)
Dec. 2005–Jan. 2006	western and central Oregon,	
Nov. 2006	Clatsop, Hood River, Lincoln, and Tillamook Counties	DR-1672. Heavy precipitation and wind resulted in flooding, landslides, and mudslides (DR-1672)
Feb. 2007	western and central Oregon, and the Confederated Tribes of the Siletz Indians	DR-1683. Benton, Clatsop, Columbia, Lincoln, Polk, Tillamook, Wasco, Wheeler, Yamhill counties; severe winter storm and flooding
Dec. 2007	Northwestern Oregon, Southern Coast	DR-1733. Clatsop, Columbia, Polk, Tillamook, Washington, Yamhill counties; heavy precipitation and wind resulted in flooding, landslides, mudslides, and tree blow down
Dec. 2008	Tillamook County	Flooding caused by convergence of heavy precipitation and high tides
Jan. 2009	Tillamook and Washington Counties	severe winter storm/snow event which included snow, high winds, freezing rain, ice, blizzard conditions, mudslides, and landslide (flooding, post DR-1824)
Jan. 2011	Clackamas, Clatsop, Crook, Douglas, Lincoln, and Tillamook Counties	DR-1956. Severe winter storm, flooding, mudslides, landslides, and debris flows
Apr. 2011	Harney County	widespread basin flooding; Oregon DOT closed and breached U.S. 20 at milepost 132.6 on April 8, 2011, for flood relief; the breach was done at the request of Harney County Emergency Operations Center to avoid damage to nearby residences; larger culverts were later installed
May – June 2011	Union and Grant Counties	melting heavy snowpack caused riverine and playa flooding
June 2011	Heppner	persistent showers with heavy rainfall of 1 to 2 inches produced flooding on Willow and Hinton Creeks; flash flooding on Hinton and Willow Creeks damaged roads, bridges, and the Morrow County Fairgrounds; the Heppner elementary school was evacuated as a precaution

Date	Location	Notes
Jan. 2012	Columbia, Hood River, Tillamook, Polk, Marion, Yamhill, Lincoln, Benton, Linn, Lane, Douglas, Coos, and Curry Counties	heavy rain and wind; ice (DR-4055); flooding in the Willamette Valley; 130 homes and seven businesses were damaged in the City of Turner; 21 streets were closed in the City of Salem; the state Motor Pool lost 150 vehicles and thousands of gallons of fuel; Thomas Creek in the City of Scio overtopped, damaging several buildings
Nov. 2012	Curry, Josephine, and Lane Counties	heavy precipitation; the Curry Coastal Pilot reported over 2 million dollars in infrastructure damage in Brookings and another 2 million in Curry County due to recent heavy rains; sinkholes and overflowing sewage facilities were also reported; according to KVAL news, Eugene Public Works has opened its emergency command center to deal with numerous flooding incidents, including two flooded intersections
Sep. 2013	Multnomah and Tillamook Counties	heavy rain resulted in flooding of the Wilson River near Tillamook as well as urban flooding in the Portland Metro area; KPTV-KPDX Broadcasting reported that heavy rain resulted in flooding and damage to the Legacy Good Samaritan Medical Center and several businesses in Northwest Portland; besides damage to the hospital's emergency and operating room, some elective surgeries were cancelled
Feb. 2014	Lane, Coos, Marion, and Tillamook Counties	A series of fronts resulted in a prolonged period of rain for Northwest Oregon, and minor flooding of several of the area's rivers from February 12th through February 17th. Heavy rains caused the Coquille River at Coquille to flood. The flood was categorized as a moderate flood. The Nehalem River near Foss in Tillamook County exceeded flood stage on February 18th, 2014.
Feb. 2014	Douglas County	In Jackson County heavy rains caused a brief flood on Little Butte Creek at Eagle Point.
March 2014	Tillamook County	Heavy rain resulted in the Nehalem River to flood near Foss. The river reached flood stage around 2 pm March 6, and crested at 14.8 feet at 8 pm
March 2014	Union, Umatilla, and Grant Counties	Heavy rain fell across much of the northern Blue Mountains and Wallowa County throughout the first week of March. March 9th received very heavy rain with snow levels around 6000 ft. This allowed for a significant increase in runoff, which led to a quick rise in rivers for the period
August 2014	Clackamas County	Heavy rain caused the Sandy River to rapidly rise. A footbridge near Ramona Falls broke loose sending a man into the turbulent waters. The man drowned in the river.
Dec. 2014	Tillamook, Lincoln, Lane, Polk Clackamas, Benton, Coos, and Douglas Counties	A slow moving front produced heavy rain over Northwest Oregon which resulted in the flooding of eight rivers. The rain also caused a couple of land/rock slides that both blocked two highways. Heavy rain brought flooding to several rivers in southwest Oregon.
Feb. 2015	Curry, Coos, Douglas, Josephine, and Jackson Counties	Heavy rains caused flooding on the Rogue River at Agness and along the Coquille River at Coquille.
Nov. 2015	Tillamook County	A very moist frontal system produced heavy rain across the region resulting in flooding. Rain rates of 0.3 to 0.5 inch per hour were observed for several hours at many locations. The 5-day rainfall total

Date	Location	Notes
		ending in the morning on November 17th for Lees Camp, OR was 14.60 inches.
Dec. 2015	Tillamook, Lincoln, Washington, Clackamas, Multnomah, Lane, Yamhill, Clatsop, Columbia, Hood River, Polk, Coos, Douglas, Jackson, and Curry Counties	DR-4258. A moist Pacific front produced heavy rainfall across Northwest Oregon which resulted in river flooding, urban flooding, small stream flooding, landslides, and a few sink holes. After a wet week (December 5 through Dec 11), several rivers were near bank full ahead of another front on December 12th. Flooding from the Nehalem River and Rock Creek in Vernonia resulted in evacuation of homes and the implementation of the Vernonia Emergency Command Center. Heavy rain resulted in a landslide that closed OR-47 at mile marker 8. More than $15 million dollars in property damage reported in these counties combined.
Jan. 2016	Jackson, Josephine, Curry, and Coos Counties	Heavy rain brought flooding to some areas of southwest Oregon. Minor flooding on the Rogue at Agness and moderate flooding on the Coquille River at Coquille.
March 2016	Coos County	Heavy rains brought flooding to the Coquille River at Coquille
May 2016	Baker County	A strong thunderstorm dumped up to a quarter of an inch of rain over a 15-minute period over terrain scorched by wildfire in August of 2015 causing flash flooding and debris flows.
Oct. 2016	Tillamook County, Northern Oregon Coast	The combination of heavy rain, large swell, and high tides brought minor tidal overflow flooding during high tides to the North Oregon Coast.
Nov. 2016	Columbia, Tillamook, Lincoln, Benton, Washington, Polk, and Yamhill Counties	A moist Pacific front moving slowly across the area produced heavy rainfall, resulting in flooding of several rivers across Northwest Oregon and at least two landslides.
Dec. 2016	Josephine, Jackson, Douglas, Lane, Coos, and Curry Counties	DR-4296. Heavy rain brought some areal flooding to parts of southwest Oregon.
Jan. 2017	Columbia, Deschutes, Hood River, Josephine, Coos, and Curry Counties	An extended period of heavy rain combined with snowmelt to cause flooding of the Coquille River the South Fork of the Coquille River and, the Rogue River flooded at Agness flooded twice that month.
Feb. 2017	Marion, Polk, Yamhill, Washington, Columbia, Benton, Tillamook, Lane, Coos, Curry, Klamath, Wheeler and Malheur Counties	High river flows combined with high tide to flood some areas near the southern Oregon coast. Heavy rain combined with snow melt caused flooding along the Coquille River and the Rogue River twice this month in southwest Oregon. Heavy rain combined with snow melt caused flooding along the Sprague River in south central Oregon. Flows on the John Day river reached flood levels downstream of Monument due to the breaking up of an ice jam.
March 2017	Malheur, Harney, Wallowa, Umatilla, and Wheeler Counties	An extended period of snow melt, combined with a period of heavy rain, caused an extended period of flooding along portions of the John Day River, the Umatilla, and the Silvies Rivers. Flooding occurred on the Snake River near Ontario.
May 2017	Multnomah County and Wallowa County	Heavy rain from a strong thunderstorm in addition to a log jam caused the rapid rise of Oneonta Creek in the Oneonta Gorge. Two hikers were injured in the flash flood. In Wallowa County the Imnaha River at Imnaha had minor flooding early on May 6th, due to snow melt.

Date	Location	Notes
June 2017	Umatilla County	In Pendleton, heavy rain caused several small debris flows along Airport Road and several intersections were flooding with water about 5 to 6 inches deep. Rainfall amounts include 1.54 inches of rain at the NWS office at the Pendleton Airport, with 0.88 inch falling in 30 minutes.
Sept. 2017	Baker County	Thunderstorms producing heavy rain over the 2016 Rail Fire burned area on the Wallowa-Whitman National Forest resulted in flash flooding and debris flows.
Oct. 2017	Tillamook, Benton, and Clackamas Counties	A very potent atmospheric river brought strong winds to the north Oregon Coast and Coast Range on October 21st. What followed was a tremendous amount of rain for some locations along the north Oregon Coast and in the Coast Range, with Lees Camp receiving upwards of 9 inches of rain. All this heavy rain brought the earliest significant Wilson River Flood on record, as well as flooding on several other rivers around the area.
Jan. 2018	Lincoln and Clatsop Counties	A strong stationary low pressure system off the British Columbia coast brought impressively high seas into the Oregon Coast. Wave heights up to 37 feet were recorded at buoys off the coast, with top one-tenth wave heights up to 45 feet. Damaging surf caused severe beach erosion, damaged a couple buildings right along the beach, injured one person, and killed one person.
Feb. 2018	Umatilla County	Two to three inches of rain fell along the west slopes of the Blue Mountains from February 1st through 4th. The increased runoff caused high water levels and minor flooding along the Umatilla and Walla Walla Rivers.
May 2018	Grant and Wallowa Counties	Heavy rain from slow-moving thunderstorms caused rockslides and water on roadways within an area that includes Mount Vernon, John Day and Canyon City
June 2018	Lane County and Baker County	In Lane County an upper-level trough moved across the area from the southwest, generating strong thunderstorms which produced locally heavy rainfall, lightning, hail, and gusty winds. Thunderstorms with heavy rainfall developed over Southwest Baker County on June 20th, leading to flash flooding and debris flow on the Rail and Cornet-Windy Ridge fires' burn scar areas.
Oct. 2018	Morrow County	Moist upslope flow into the Blue Mountains produced heavy rain with rainfall rates of up to one inch per hour and storm total accumulations between one and three inches. Localized flooding was reported near the town of Heppner where water inside a residence forced an evacuation.
Dec. 2018	Tillamook County	A strong low-pressure system over the Gulf of Alaska brought a strong cold front through. This generated strong winds across northwest Oregon, and also brought heavy rain which caused flooding on the Tillamook River. Large seas also caused damage in spots along beaches.
Jan. 2019	Coos and Curry Counties	A weekend of very heavy rain led to rivers rising across southern Oregon. The Rogue River at Agness exceeded flood stage and the Coquille River at Coquille flooded as well.

Date	Location	Notes
Feb. 2019	Columbia, Washington and Multnomah Counties	Back-to-back low-pressure systems dropping south along the coast of British Columbia and Washington brought cold air south into NW Oregon as well as plenty of moisture. There was flooding along Fox Creek in Rainier and 40 county roads in Washington County. In Multnomah County, Northwest Rocky Point Road between U.S. 30 and Skyline Boulevard was closed because of a large crack in the road caused by heavy rains and snowmelt.
Feb. 2019	Douglas, Jefferson, Lane, Coos, and Curry Counties	DR-4432. Very heavy rain along with the melting of recent snowfall caused flooding at several locations in southern Oregon in late February. Deer Creek at Roseburg, South Fork of the Coquille at Myrtle Point, North Fork of the Coquille at Myrtle Point, the Coquille River at Coquille and the Rogue River at Agness all exceeded flood stage.
April 2019	Lane, Benton, Marion, Clackamas and Linn Counties	DR-4452. Linn County declared. A particularly strong atmospheric river took aim for the south Willamette Valley, sitting over areas south of Salem for two days, producing anywhere from 2.5 to 5 inches of rain over a 48 hour period. Some areas in the Cascades and Cascade Foothills saw 5 to 7 inches of rain over that 48 hour period. Heavy rain combined with snow melt from all the snow from a few weeks prior in this same area caused flooding along most rivers in this area as well as along the main-stem Willamette River up to around Oregon City.
April 2019	Douglas, Coos and Curry Counties	DR-4452. Douglas and Curry Counties declared. Two days of very heavy rainfall (compared to April normals) combined with snowmelt led to areal flooding in southwest and south central Oregon.
April 2019	Union, Grant, Umatilla, Wallowa and Wheeler Counties	DR-4452. Grant, Umatilla, and Wheeler Counties declared. Snow water equivalents near 200 percent of normal in the Blue Mountains coupled with warm temperatures and near record rainfall totals for April produced significant river flooding across eastern Oregon.
April 2019	Wheeler County	Total rainfall of 1.67 inches was recorded just east of Mitchell. This heavy rain over a short period of time triggered a flash flood through Huddleston Heights and Nelson Street, and off of High Street and Rosenbaum with mud and debris blocking roads in and around the town of Mitchell.
July 2019	Deschutes County	Slow moving thunderstorms produced localized flooding and minor mud flows around the Tumalo area during the evening of July 1st.
Aug. 2019	Crook and Wasco Counties	A powerful upper storm system combined with modest low- and mid-level moisture to yield scattered, strong to severe storms and flash flooding. Storms developed first across the higher terrain of central Oregon nearer the Cascades and adjacent Ochoco mountains. Storms then built northward with hail and damaging winds along the way.
Feb. 2020	Umatilla County, Confederated Tribes of the Umatilla, Union, and Wallowa Counties	DR-4519: Umatilla County, Confederated Tribes of the Umatilla Indian Reservation, Union, and Wallowa Counties resulting from severe storms, flooding, landslides, and mudslides during period of February 5 to February 9, 2020. Heavy snow, followed by heavy rain and snow melt lead to flooding and major declaration. Record flooding along the Umatilla River.

Date	Location	Notes
Sept. 2020	Clackamas, Douglas, Jackson, Klamath, Lane, Lincoln, Linn, and Marion Counties	DR-4562 Oregon Wildfires. Floodplain management outreach, substantial damage trainings, flood after fire campaign and outreach, support individual assistance, assist with substantial damage determinations per NFIP requirements for properties located in the SFHA. Approximately 651 structures in SFHA were determined to be substantially damaged due to the fires.
May 2021	Benton, Clackamas, Linn, Marion, Polk, Yamhill, Confederated Tribes of Grand Ronde	DR 4599 Ice Storm. Floodplain management outreach, deliver mitigation message to SFHA properties, ensure NFIP compliance for properties located in SFHA that may have incurred damages.
June 2022	Burns Paiute Indian Reservation	DR-4733: Burns Paiute Tribe Severe Storm, Flooding, Landslides, and Mudslides
Aug. 2023	Ione, Morrow County	Convective showers and thunderstorms over town of Ione with heavy downpour resulted in flash flooding across the town.
Dec. 2023	Tillamook, Clatsop, Lincoln Counties	A strong atmospheric river brought heavy rains on December 5th pushing many streams to flood stage along the north coast. Area of coast range received 12 to 16 inches of rain over a 5-day period.
April 2024	Benton, Clackamas, coos, Hood River, Lane, Lincoln, Multnomah, Sherman, Tillamook, Wasco, Confederated Tribe of Siletz Indians, Yamhill Counties	DR-4768 Winter Storm. Floodplain management outreach, provide information in NFIP, ensure local NFIP regulations are compliant with minimum floodplain regulations, and identify potential projects for RiskMap program.

Source: NOAA Storm Event Database, (http://www.ncdc.noaa.gov/stormevents/), January 2020; Planning for Natural Hazards: Flood TRG (Technical Resource Guide), July 2000, DLCD, Community Planning Workshop https://oregon-oem-geo.hub.arcgis.com/

3.3.5.4 Risk Maps

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

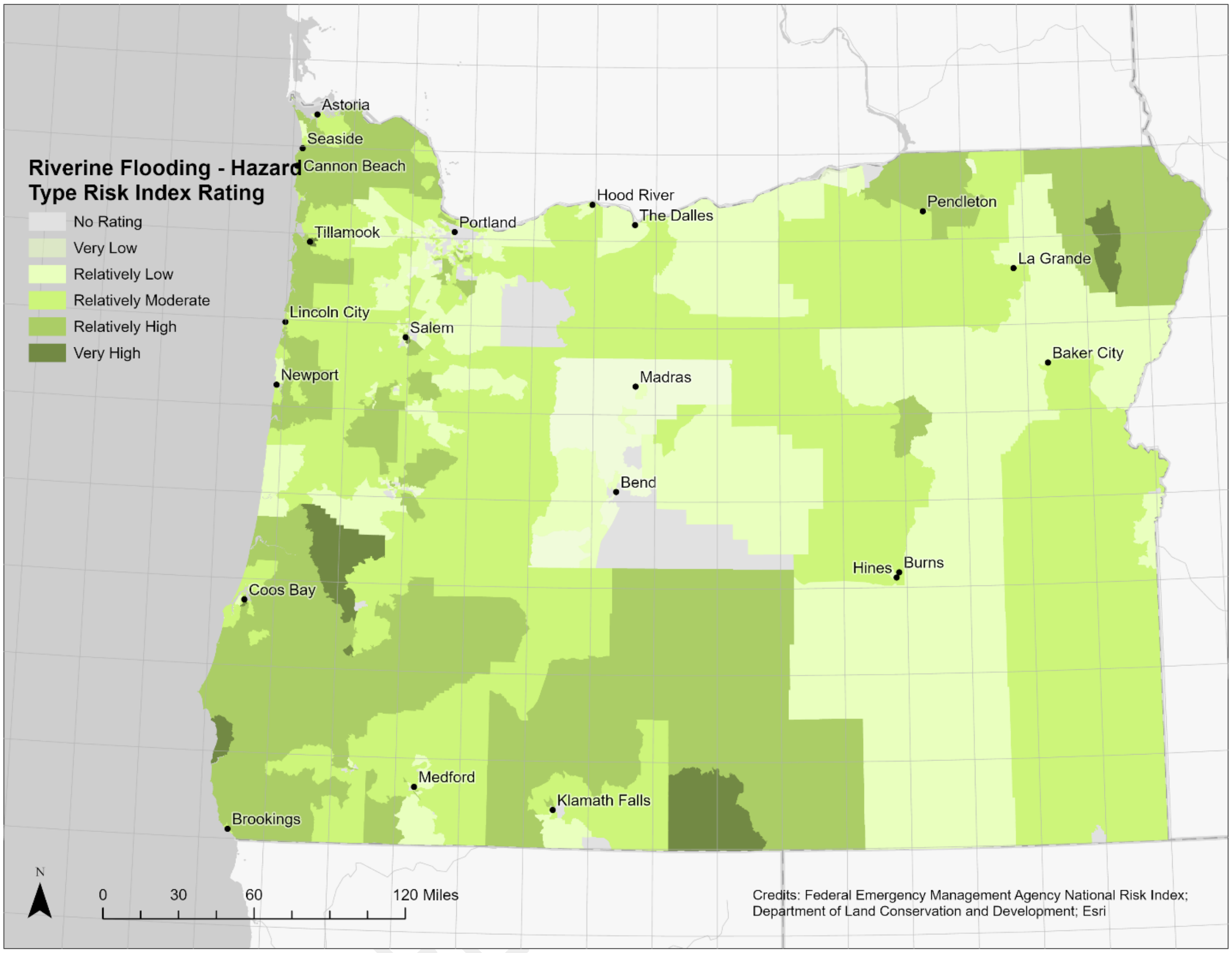
The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

The climate change maps show where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

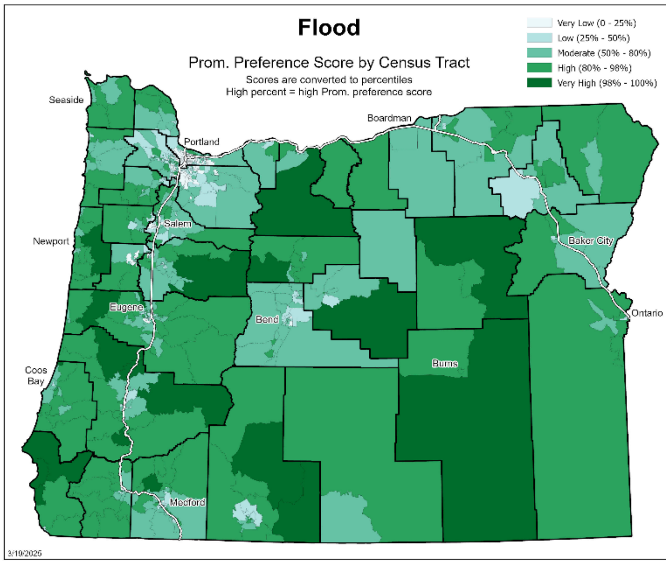
Figure 3.3.5-5: Riverine Flood Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Riverine Flood.



Federal Emergency Management Agency, National Risk Index for Riverine Flood. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov

Figure 3.3.5-6 and Figure 3.3.5-7 show risk rankings by census tract for flooding from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.5-6 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.5-7 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

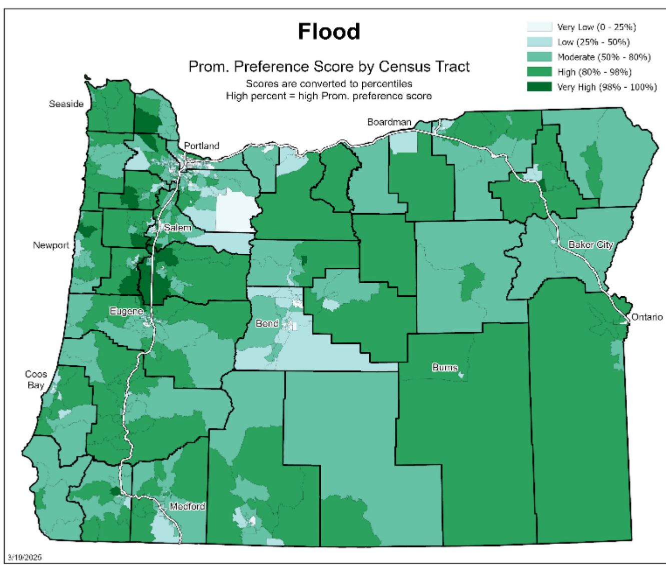
Figure 3.3.5-6: Flood Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Flood	Bridge_Scour	1	0.032	Number of bridges that are at risk from scour during a 100-year flood.
Flood	CRS_Rate	1	0.032	Community Rating System (NFIP) score for communities.
Flood	FL_pct_bld	1	0.032	Percentage of SBFO buildings exposed to flooding.
Flood	FL_pct_CF	1	0.032	Percentage of critical facilities buildings exposed to flooding.
Flood	ImpervSurf_Pct	1	0.032	Percentage of impervious surface.
Flood	Hwy_FL_pct	1	0.032	Major roadways number of miles that are exposed to flood hazard.
Flood	Bridge_Scour_pct	1	0.032	Percentage of bridges that are scoured from a 100 year flood.
Flood	Hist_FL_ct	1	0.032	Percentage of historic buildings exposed to flooding.
Flood	FIRM_Diff	1	0.032	Number of years difference between median year built and FIRM date.
Flood	FL_Haz_Area	1	0.032	Area of tract in 100-year flood hazard.
Flood	RepeatLoss	1	0.032	Repetitive loss structures
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

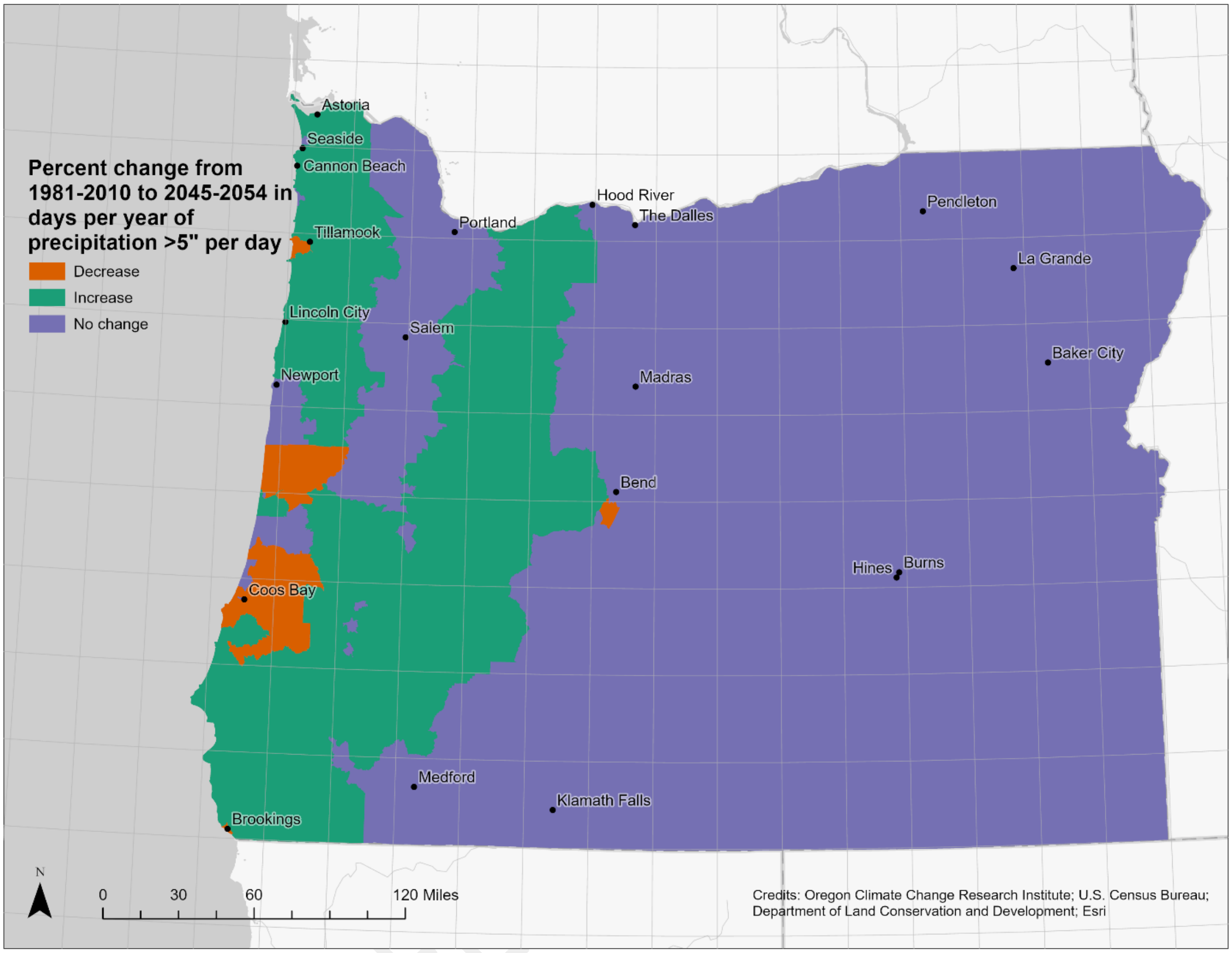
Figure 3.3.5-7: Flood Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included.



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Flood	Bridge_Scour	1	0.091	Number of bridges that are at risk from scour during a 100-year flood.
Flood	CRS_Rate	1	0.091	Community Rating System (NFIP) score for communities.
Flood	FL_pct_bld	1	0.091	Percentage of SBFO buildings exposed to flooding.
Flood	FL_pct_CF	1	0.091	Percentage of critical facilities buildings exposed to flooding.
Flood	ImpervSurf_Pct	1	0.091	Percentage of impervious surface.
Flood	Hwy_FL_pct	1	0.091	Major roadways number of miles that are exposed to flood hazard.
Flood	Bridge_Scour_pct	1	0.091	Percentage of bridges that are scoured from a 100 year flood.
Flood	Hist_FL_ct	1	0.091	Percentage of historic buildings exposed to flooding.
Flood	FIRM_Diff	1	0.091	Number of years difference between median year built and FIRM date.
Flood	FL_Haz_Area	1	0.091	Area of tract in 100-year flood hazard.
Flood	RepeatLoss	1	0.091	Repetitive loss structures

Figure 3.3.5-8: Change in Average Number of Heavy Precipitation Days: Change from 1981-2010 to 2045-2054 in days per year of precipitation that equals or exceeds 5 inches per day.



Source: Derived from 52 ensemble members of 11 LOCA2 downscaled global climate models. Data provided by Oregon Climate Change Research Institute, 2025. Graphic produced by DLCD.

3.3.6 Dam Failure

3.3.6.1 Dams in Oregon

Dams can fail and create flooding downstream. Although rare, a dam failure flood is usually much more severe than a natural flood and can cause severe flooding well above mapped floodplains. The greatest risk from dam failure is loss of life, though property and environmental damage from dam failures can also be severe. The priority emphasis for mitigation actions in this NHMP are non-federal dams with highest loss of life risk, as consistent the FEMA High Hazard Potential Dam (HHPD) program. The state dam safety program is part of the Oregon Water Resources Department and hereafter referred to as dam safety. Dam safety program staff reviewed existing data including dam inspections, risk analyses, design and construction records, dam breach inundation analyses, and determinations of populations at risk, buildings, roads and critical infrastructure downstream of dams to write this chapter of the Oregon Natural Hazards Mitigation Plan.

As of January 2024, there were 941 dams exceeding state jurisdictional size regulated by dam safety program. Dam safety program actions to address safety of these dams include:

a. Reviewing analysis, designs, specifications and associated reports for new dam construction and also for modification of existing dams;
b. Approving designs when shown to be safe and accepting as-built documents when construction or modification is complete and consistent with the approved design;
c. Reviewing plans for removal of significant hazard and high hazard dams and determining if changes to these plans are needed for safety;
d. Conducting routine inspections and notifying dam owners of outcomes with recommendations for maintenance and repair;
e. Cooperating with dam owners on dam safety issues;
f. Determining if maintenance actions, corrective actions, or any other actions are necessary to protect life, property, or public infrastructure. Communicating this information to dam owners, and issuing formal orders and enforcing if necessary cooperative actions are not taken;
g. Communicating, coordinating, and collaborating with dam owners, other agencies, and the public to improve dam safety in Oregon; and
h. Planning for and responding for potential and actual emergencies at dams.

There are another 240 dams exceeding National Inventory of Dams size thresholds owned or regulated by the federal government. The largest dams (height and water storage volume) in Oregon are under federal ownership or regulation.

Oregon dam safety law exempts very small dams (those that are under 10 feet in height or that store less than 3 million gallons). There are very roughly 20,000 such dams in Oregon, based on water right permit information.

3.3.6.2 Hazard Potential and Dam Safety

Oregon law (ORS 540.443 (3)) states “Dam failure” means a rapid, sudden and uncontrolled release of water or wastewater due to loss of dam integrity. The dam safety program follows national guidance for assigning hazard potential to dams and also for the contents of Emergency Action Plans (EAPs). Dams are rated according to the anticipated impacts of its potential failure. Oregon has adopted the following definitions of hazard potential for state-regulated dams. These definitions are essentially the same as federal/FEMA definitions:

- **High Hazard** means loss of life is expected if the dam fails.
- **Significant Hazard** means loss of life is not expected if the dam fails, but extensive damage to property or public infrastructure is likely.
- **Low Hazard** is assigned to all other state-regulated dams.

Maintaining correct hazard ratings is a dam safety priority, and therefore hazard ratings can and do change. Ratings may change for a number of reasons. For example, a dam’s original rating may not have been based on current inundation analysis methodologies, or new development may have changed potential downstream impacts. Also, very importantly, hazard is not risk. Risk depends on the probability of, and consequences of failure as described in the section titled Risk Analysis.

3.3.6.3 Emergency Action Plans

An "**Emergency Action Plan**" is defined by Oregon law as a plan that assists a dam owner or operator, and local emergency management personnel, to perform actions to ensure human safety in the event of a potential or actual dam failure. The content required in EAP's follows national guidance. State law (ORS 540.482) requires the owner of a dam that has a high hazard rating to develop an emergency action plan for the dam. Consistent with Federal criteria, an emergency action plan required under this section must include, but need not be limited to:

a) Means for emergency condition detection
b) Means for emergency level determination
c) Identification of, and information necessary for, notifications and communications to be made at each level of emergency condition
d) A description of actions expected to be undertaken to prevent dam failure or reduce the effects of dam failure
e) A map of dam failure inundation zones for varying conditions, including, but not limited to, dry weather conditions and high flood conditions
f) Procedures to be followed at the termination of an emergency.

Oregon dam safety requires an EAP for all dams confirmed to be high hazard potential. Dam safety works with owners to develop an EAP for dams which based on new dam breach inundation analysis have a change in hazard potential rating to high. All confirmed state regulated high hazard dams (with that rating prior to 2023) have an emergency action plan. Many of these EAPs do need updating and exercising, and the program is working with owners to accomplish the updates, often during the exercise of their EAP.

3.3.6.4 Historical Dam Failures

Failures of some dams can result in loss of life, damage to property, infrastructure, and the natural environment. The impacts of dam failures range from local impacts to waters below the dam and the owners' property to community destruction with mass fatalities. The 1889 Johnston Flood in Pennsylvania was caused by a dam failure that resulted in over 2000 lives lost. Oregon's first dam safety laws were developed in response to the St. Francis dam failure in California in 1928. That failure was due to unsafe design practice and caused about 500 people to die.

Oregon has records of at least 55 dam failures in the State. Many of these failures had very little or no impacts on people, structures or properties. The 21 dams with more serious to tragic effects are listed in Table 3.3.6-1.

Table 3.3.6-1: Oregon dam failures with damage (potential)

Year	Location	Description
1896	Goodrich dam west of Baker City in Baker Co.	Flood wave killed entire family of 7
1917	Killamacue dam west of Haines in Baker Co.	Property damaged
1920	Bonneyview dam east of Prineville in Crook Co.	Property damaged
1925	Bully Creek dam west of Vale in Malheur Co.	Multiple homes badly damaged, loss of livestock
1927	Cottonwood creek dam northwest of Lakeview in Lake Co.	Property damaged
1937	Spaulding Vaughn dam in Baker Co.	Property damaged
1941	Willow Creek (Malheur) dam west of Vale in Malheur Co.	Potential failure situation with more than 100 persons at risk, failure prevented
1949	Kern Brothers dam south of Burns in Harney Co.	Property damaged
1951	N. Indian Creek dam in northern Malheur Co.	Property damaged
1952	Rock Creek dam east of Burns in Harney Co.	Property damaged
1956	Goodrich dam west of Baker City in Baker Co.	Property damaged in the second failure of a dam at this site
1956	Sams Valley dam east of Gold Hill in Jackson Co.	Landslide related to reservoir filling threatened homes
1958	Vaughn Reservoir in rural Malheur Co.	Property damaged
1959	Currant Creek dam east of Antelope in Wasco Co.	Property damaged
1961	Woodrat Knob dam near Lake Creek in Jackson Co.	Major landslide on dam with persons evacuated, flooding prevented
1978	Kern Brothers dam south of Burns in Harney Co.	Property damaged including failure of Krumbo dam, second failure at this dam site
1982	Mann creek dam near Sweet Home in Linn Co.	Washed out multiple forest roads
1983	Star Mountain dam near Riverside in Malheur Co.	Washed out railroad and roads, damaged homes
1996	Powers Log Pond in Powers in south Coos Co.	Damaged road and limited damage to dwellings
2005	Simplot Lagoon south of Hermiston in Umatilla Co.	Washed out State Highway, major irrigation ditch and made 1 home unrepairable
2016	Heater Reservoir near Sublimity in Marion Co.	Flooded area occupied by Christmas tree packers, flooded paved road

Source: Oregon Water Resources Department Dam Safety Program records 2025

3.3.6.5 Laws and Rules

The Oregon Water Resources Department (OWRD) is the state authority for dam safety with specific authorizing laws and implementing regulations. Oregon's first dam safety laws were adopted in 1929. The 1929 laws were repealed in 2019, replaced by a new law contained in ORS 540. 443 to 491, ORS 540.990, and ORS 540.995. New dam safety rules authorized by this law have been in effect since 2020. Oregon dam safety law exempts very small dams (those that are under 10 feet in height or that store less than 3 million gallons). Oregon's new dam safety laws and rules were developed considering the joint Association of State Dam Safety Officials (ASDSO) and FEMA Model State Dam Safety Program.

3.3.6.6 Coordination

OWRD dam safety drafted this Section of the NHMP in coordination with Oregon Department of Land Conservation and Development staff responsible for most other elements of the Oregon NHMP. Dam safety also coordinates with the Oregon Department of Emergency Management and with dam owners, federal dam regulators, county and city emergency managers, and first responders. Dam safety program staff also develop language for state and local natural hazard mitigation plan sections on high hazard potential dams, and also assist with sections related to floods and extreme events.

Dam safety has specifically coordinated with the federal owners and regulators on preparations for a Cascadia earthquake and extreme flood, events where multiple dams may have impacts and need rapid situational awareness. Additional work is needed to ensure the Oregon Department of Emergency Management understands the risks associated with high hazard dams and is prepared to rapidly use information from the state and federal dam safety programs.

3.3.6.7 General Information Sharing

Information available from the OWRD dam safety program includes:

- Original design drawings and specifications;
- OWRD dam inspections;
- Safety and risk analyses completed for certain dams
- Status of maintenance and correction actions on dams
- Emergency Action Plans; and
- Inundation Maps for those dams with Emergency Action Plans.

Almost all of this information is considered public information and provided upon specific request. The Dam Safety Program provides accurate and timely information on its role in the safety of Oregon dams to other agencies, dam owners and the public. Dam safety uses many modes of communication including in person, phone, e-mail, postal mail, web information, and workshops. Well informed agency staff, dam owners, engineers, emergency managers, stakeholders, media and the general public are all essential to an effective dam safety program. A core message is that dam safety is the responsibility of the dam owner. One dam safety program's role is to assist dam owners in understanding this responsibility.

3.3.6.8 High Hazard Potential Dams in Oregon

The following table (Table 3.3.6-2) shows high hazard potential dams in Oregon. The National Inventory of dams was the information source for the federal dams, while the state dam safety database was the source for state regulated dams.

Table 3.3.6-2: High Hazard Potential Dams in Oregon

	Name	County	Rating	Regulator	Identification #
1.	Brownlee Dam	Baker	High	Federal	ID00056
2.	Mason Dam	Baker	High	Federal	OR00577
3.	Oxbow Hydro Dam	Baker	High	Federal	OR00258
4.	Thief Valley Reservoir	Baker	High	Federal	OR00592
5.	Unity Reservoir	Baker	High	Federal	OR00593
6.	Bull Run Dam 2 (Lower)	Clackamas	High	Federal	OR00317
7.	Faraday Diversion Dam	Clackamas	High	Federal	OR00551
8.	Faraday Forebay	Clackamas	High	Federal	OR00245
9.	North Fork Dam (Clackamas)	Clackamas	High	Federal	OR00550
10.	River Mill Dam	Clackamas	High	Federal	OR00552
11.	Timothy Lake	Clackamas	High	Federal	OR00545
12.	Willamette Falls	Clackamas	High	Federal	OR00596
13.	Ochoco Reservoir	Crook	High	Federal	OR00098
14.	Prineville Reservoir (Bowman)	Crook	High	Federal	OR00579
15.	Crane Prairie	Deschutes	High	Federal	OR00279
16.	Wickiup Reservoir (USBR)	Deschutes	High	Federal	OR00136
17.	Creekside Dam #1	Douglas	High	Federal	OR03902
18.	Creekside IWR	Douglas	High	Federal	OR03903
19.	Galesville Reservoir	Douglas	High	Federal	OR00748
20.	Lemolo Lake Dam	Douglas	High	Federal	OR00556
21.	Soda Springs Dam	Douglas	High	Federal	OR00555
22.	Olive Lake	Grant	High	Federal	OR00341
23.	Clear Branch Creek Dam	Hood River	High	Federal	OR00451
24.	Agate Dam	Jackson	High	Federal	OR00422
25.	Applegate Lake	Jackson	High	Federal	OR00624
26.	Emigrant	Jackson	High	Federal	OR00581
27.	Fish Lake (Jackson-USBR)	Jackson	High	Federal	OR00021
28.	Howard Prairie	Jackson	High	Federal	OR00580
29.	Hyatt Reservoir	Jackson	High	Federal	OR00591
30.	Lost Creek Reservoir (COE)	Jackson	High	Federal	OR00612
31.	Reeder Gulch Reservoir	Jackson	High	Federal	OR00110
32.	Haystack Equalizing Pond	Jefferson	High	Federal	OR00287
33.	Pelton Dam	Jefferson	High	Federal	OR00548
34.	Pelton Regulating Dam	Jefferson	High	Federal	OR00547
35.	Round Butte Dam	Jefferson	High	Federal	OR00549
36.	Gerber Reservoir	Klamath	High	Federal	OR00584
37.	Upper Klamath Lake	Klamath	High	Federal	OR00557

	Name	County	Rating	Regulator	Identification #
38.	Blue River Dam	Lane	High	Federal	OR00013
39.	Cottage Grove	Lane	High	Federal	OR00005
40.	Cougar Reservoir	Lane	High	Federal	OR00015
41.	Dexter	Lane	High	Federal	OR00006
42.	Dorena	Lane	High	Federal	OR00008
43.	Fall Creek Reservoir	Lane	High	Federal	OR00007
44.	Fern Ridge	Lane	High	Federal	OR00016
45.	Hills Creek Reservoir	Lane	High	Federal	OR00014
46.	Hult Log Storage Pond	Lane	High	Federal	OR00183
47.	Leaburg Dam	Lane	High	Federal	OR00553
48.	Lookout	Lane	High	Federal	OR00009
49.	Walterville Power Intake	Lane	High	Federal	OR00600
50.	Walterville Pumped S. Pond	Lane	High	Federal	OR00267
51.	Big Cliff Dam	Linn	High	Federal	OR00003
52.	Detroit Reservoir	Linn	High	Federal	OR00004
53.	Foster Reservoir	Linn	High	Federal	OR00012
54.	Green Peter Reservoir	Linn	High	Federal	OR00010
55.	Smith River	Linn	High	Federal	OR00541
56.	Trail Bridge Reg. Reservoir	Linn	High	Federal	OR00540
57.	Agency Valley Dam	Malheur	High	Federal	OR00589
58.	Bully Creek Dam	Malheur	High	Federal	OR00578
59.	Owyhee	Malheur	High	Federal	OR00582
60.	Rock Creek (Malheur)	Malheur	High	Federal	OR00623
61.	Warm Springs Reservoir (USBR)	Malheur	High	Federal	OR00082
62.	Willow Creek (Morrow)	Morrow	High	Federal	OR00212
63.	Bonneville Dam	Multnomah	High	Federal	OR00001
64.	Bull Run Dam 1 (Upper)	Multnomah	High	Federal	OR00327
65.	John Day Dam	Sherman	High	Federal	OR00011
66.	Cold Springs Reservoir (USBR)	Umatilla	High	Federal	OR00590
67.	Indian Lake Dam	Umatilla	High	Federal	OR00601
68.	McKay Reservoir (USBR)	Umatilla	High	Federal	OR00583
69.	McNary Dam	Umatilla	High	Federal	OR00616
70.	Hells Canyon Dam	Wallowa	High	Federal	OR00250
71.	Happy Canyon	Wasco	High	Federal	OR00694
72.	The Dalles Dam	Wasco	High	Federal	OR00002
73.	Wasco Dam	Wasco	High	Federal	OR00326
74.	Scoggins	Washington	High	Federal	OR00685
75.	North Fork	Benton	High	State	OR00348
76.	Buche (Clackamas)	Clackamas	High	State	OR00766
77.	Mompano	Clackamas	High	State	OR00500
78.	Bear Creek	Clatsop	High	State	OR00689
79.	Middle	Clatsop	High	State	OR00135
80.	Seaside City	Clatsop	High	State	OR01387
81.	Wickiup Lake (Astoria)	Clatsop	High	State	OR00136
82.	Pony Creek - Lower	Coos	High	State	OR00070

	Name	County	Rating	Regulator	Identification #
83.	Pony Creek - Upper	Coos	High	State	OR00200
84.	Barnes Butte	Crook	High	State	OR00284
85.	Joe Fisher	Crook	High	State	OR00248
86.	Johnson Creek (Crook)	Crook	High	State	OR00232
87.	Ferry Creek	Curry	High	State	OR00437
88.	North Canal Diversion	Deschutes	High	State	OR00566
89.	Sunriver Effluent	Deschutes	High	State	OR03790
90.	Bear Creek 3	Douglas	High	State	OR00614
91.	Berry Creek	Douglas	High	State	OR00640
92.	Cooper Creek (Sutherlin)	Douglas	High	State	OR00463
93.	Hayhurst Road	Douglas	High	State	OR01892
94.	Paris	Douglas	High	State	OR00320
95.	Plat I	Douglas	High	State	OR00443
96.	Updegrave	Douglas	High	State	OR00491
97.	Wageman	Douglas	High	State	OR00496
98.	Winchester	Douglas	High	State	OR00263
99.	Duggan	Jackson	High	State	OR00475
100.	Lake Creek	Jackson	High	State	OR00395
101.	Osborne Creek	Jackson	High	State	OR00401
102.	Sams Valley	Jackson	High	State	OR00400
103.	Wade	Jackson	High	State	OR00379
104.	Walch Dam	Jackson	High	State	OR00246
105.	Willow Creek	Jackson	High	State	OR00356
106.	Woodrat Knob	Jackson	High	State	OR00357
107.	Yankee	Jackson	High	State	OR00222
108.	Mays	Jefferson	High	State	OR00355
109.	McMullen Creek	Josephine	High	State	OR00513
110.	Strong	Josephine	High	State	OR00142
111.	Crescent Lake	Klamath	High	State	OR00381
112.	Bullard Creek F.R.S. (Lake)	Lake	High	State	OR03780
113.	Cottonwood	Lake	High	State	OR00373
114.	Drews	Lake	High	State	OR00049
115.	Santa Clara	Lane	High	State	OR00743
116.	Big Creek #1 (Lower)	Lincoln	High	State	OR00225
117.	Big Creek #2 (Upper)	Lincoln	High	State	OR00473
118.	Mill Creek	Lincoln	High	State	OR00472
119.	Olalla	Lincoln	High	State	OR00470
120.	Spring Lake	Lincoln	High	State	OR00532
121.	Foster Log Pond	Linn	High	State	OR00159
122.	Antelope	Malheur	High	State	OR00378
123.	Crowley	Malheur	Significant	State	OR00132
124.	Lonesome Lake	Malheur	High	State	OR03792
125.	Pole Creek	Malheur	High	State	OR00239
126.	Willow Creek 3 (Malheur)	Malheur	High	State	OR00390
127.	Franzen	Marion	High	State	OR00613

	Name	County	Rating	Regulator	Identification #
128.	Silver Creek	Marion	High	State	OR00622
129.	Portland #1 (Mt.Tabor)	Multnomah	High	State	OR00667
130.	Portland #5 (Mt.Tabor)	Multnomah	High	State	OR00670
131.	Portland #6 (Mt.Tabor)	Multnomah	High	State	OR00671
132.	Van Raden	Multnomah	High	State	OR00105
133.	Croft	Polk	High	State	OR00415
134.	Mercer	Polk	High	State	OR00524
135.	Jubilee Lake	Union	High	State	OR00453
136.	Morgan Lake	Union	High	State	OR00653
137.	Pilcher Creek	Union	High	State	OR00688
138.	Wolf Creek	Union	High	State	OR00220
139.	Wallowa Lake	Wallowa	High	State	OR00465
140.	Crow Creek	Wasco	High	State	OR00464
141.	Currant Creek	Wasco	High	State	OR00696
142.	Pine Hollow	Wasco	High	State	OR00480
143.	Rock Creek (Wasco)	Wasco	High	State	OR00147
144.	Younglife Waste A (Lower)	Wasco	High	State	OR00697
145.	Younglife Waste B (Middle)	Wasco	High	State	OR04030
146.	Younglife Waste C (Upper)	Wasco	High	State	OR04031
147.	Barney	Washington	High	State	OR00525
148.	Kay Lake	Washington	High	State	OR00394
149.	Rock Creek	Wheeler	High	State	OR00265
150.	Baker ER	Yamhill	High	State	OR00507
151.	McGuire	Yamhill	High	State	OR00514

Source: Oregon Water Resources Department, 2025

Figure 3.3.6-1: Federally-Regulated Dam Locations in Oregon

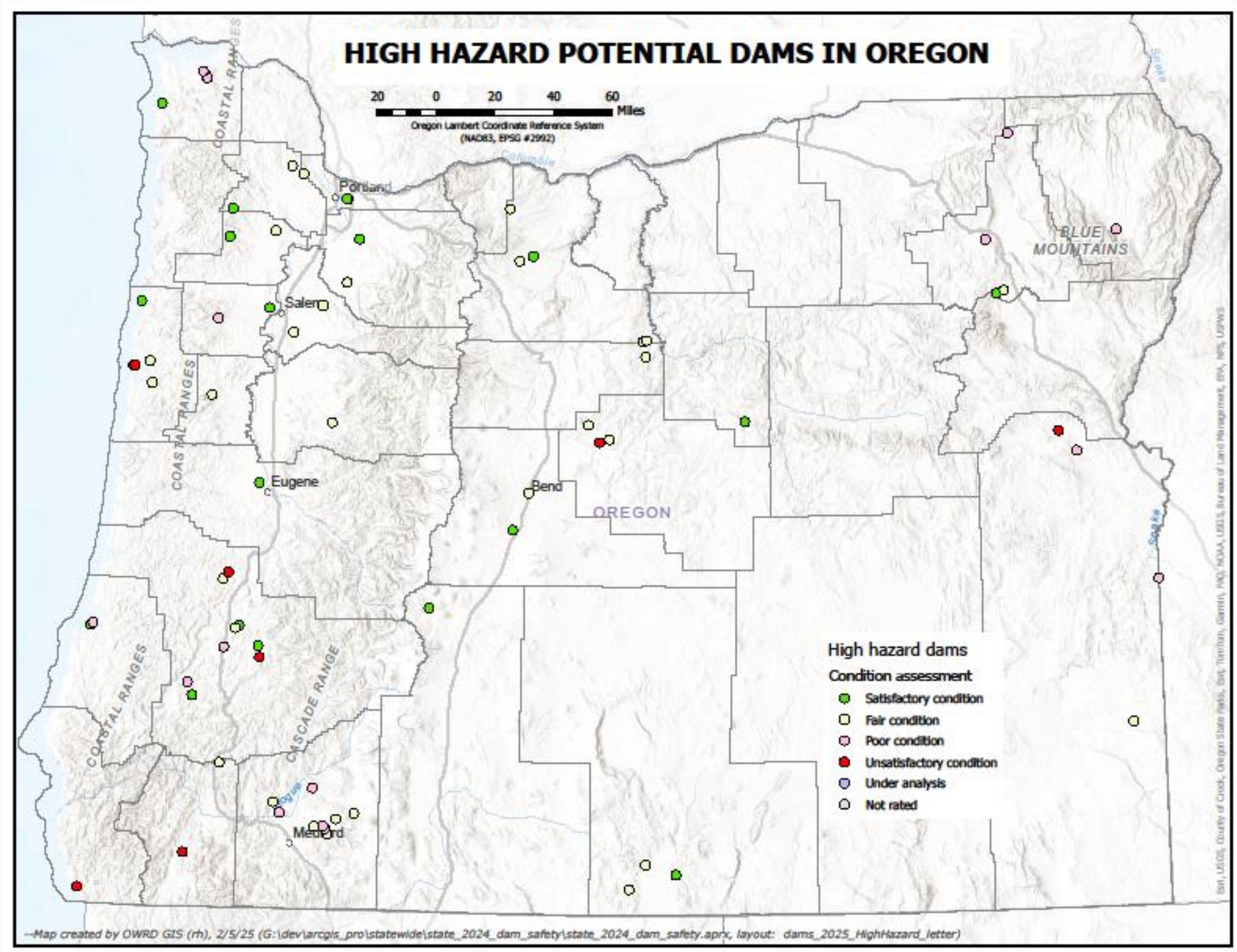
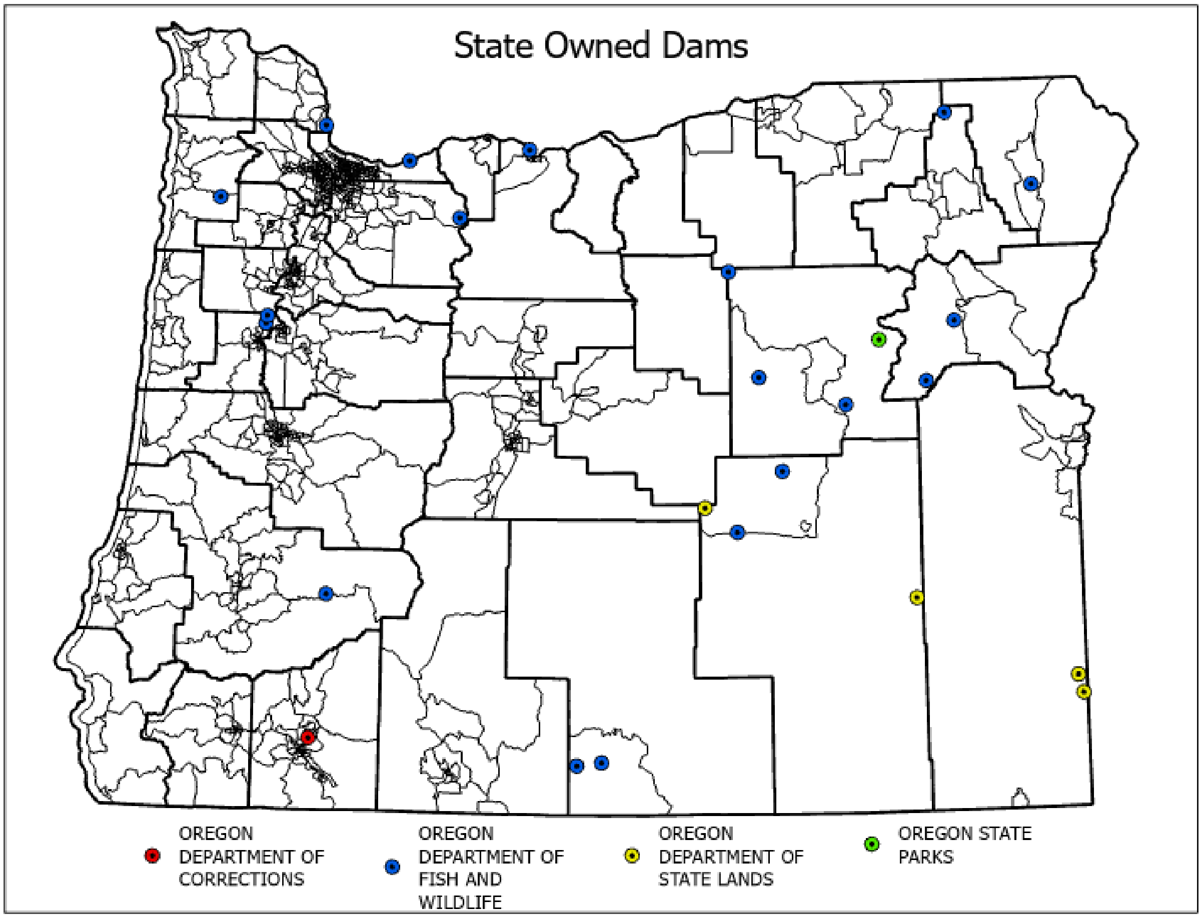


Figure 3.3.6-2: State Regulated Dams in Oregon



Oregon uses FEMA's condition classifications as a preliminary screen for risk of failure and for HHPD grant eligibility. These classifications can be very subjective, and for state regulated dams typically based on routine inspections results and visually apparent deficiencies. Condition classifications are not equivalent to risk as they do not consider expected loss of life, or fiscal effects from a dam failure. Oregon law contains specific definitions for unsafe and potentially unsafe conditions at dams, and these conditions, rather than condition classifications, trigger actions by the dam safety program. FEMA's condition classifications that were used initially to determine dams not meeting safe thresholds are as follow:

"Satisfactory" means no existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.

"Fair" means no existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action.

"Poor" means a dam safety deficiency is recognized for loading conditions that may realistically occur. Remedial action is necessary. A poor rating may also be used when uncertainties exist as to critical analysis parameters that identify a potential dam safety deficiency. Further investigations and studies are necessary.

“Unsatisfactory” means a dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.

“Not Rated” means the dam has not been inspected, is not under state jurisdiction, or has been inspected but, for whatever reason, has not been rated.

As of January 2025, 24 state-regulated high hazard dams in Oregon are currently assessed to be below accepted safety standards (in Poor or Unsatisfactory Condition, or in Fair condition with a suspected but unconfirmed potentially unsafe condition). The state only maintains non-federal conditions. Some federal agencies do not release this information. As the dam safety program conducts risk analysis over time, the number of dams determined to be unsafe or potentially unsafe may change.

Table 3.3.6-3: Condition classification of state regulated high hazard dams

Dam ID	Dam Name	File	County	District	Condition Assessment
OR00122	ANTELOPE	A-2	MALH	9	FAI
OR00507	BAKER, ER	B-49	YAMH	22	FAI
OR00284	BARNES BUTTE	B-38	CROO	24	UNS
OR00525	BARNEY	H-29	WASH	1	SAT
OR00449	BEAR CREEK	B-47	CLAT	1	POR
OR00614	BEAR CREEK 3	B-51	DOUG	15	FAI
OR00640	BERRY CREEK	B-52	DOUG	15	FAI
OR00225	BIG CREEK #1 (LOWER)	B-28A	LINC	1	UNS
OR00473	BIG CREEK #2 (UPPER)	B-28B	LINC	1	UNS
OR00766	BUCHE (CLACKAMAS)	B-64	CLAC	16	FAI
OR03780	BULLARD CREEK F.R.S. (LAKE)	B-9	LAKE	12	SAT
OR00463	COOPER CREEK (SUTHERLIN)	C-61	DOUG	15	FAI
OR00535	COTTONWOOD	C-6	LAKE	12	FAI
OR00381	CRESCENT LAKE	C-9	KLAM	11	SAT
OR00415	CROFT	C-59	POLK	22	SAT
OR00464	CROW CREEK	C-62	WASC	3	FAI
OR00696	CURRANT CREEK	C-64	WASC	21	FAI
OR00049	DREWS	D-3	LAKE	12	FAI

Dam ID	Dam Name	File	County	District	Condition Assessment
OR00475	DUGGAN	D-48	JACK	13	POR
OR00437	FERRY CREEK	F-25	CURR	14	UNS
OR00159	FOSTER LOG POND	LP-41	LINN	16	FAI
OR00613	FRANZEN	T-14	MARI	16	FAI
OR01892	HAYHURST ROAD	D-39	DOUG	15	UNS
OR00248	JOE FISHER	F-11	CROO	24	FAI
OR00232	JOHNSON CREEK (CROOK)	J-5	CROO	24	FAI
OR00453	JUBILEE LAKE	J-16	UNIO	6	POR
OR00394	KAY LAKE	C-57	WASH	18	FAI
OR00395	LAKE CREEK	L-24	JACK	13	FAI
OR03792	LONESOME LAKE	L-15	MALH	9	POR
OR00355	MAYS	M-37	JEFF	21	FAI
OR00514	MCGUIRE	M-43	YAMH	1	SAT
OR00513	MCMULLEN CREEK	M-46	JOSE	14	UNS
OR00524	MERCER	D-35	POLK	22	POR
OR00135	MIDDLE	M-10A	CLAT	1	POR
OR00472	MILL CREEK	M-9	LINC	1	FAI
OR00500	MOMPANO	M-53	CLAC	20	SAT
OR00653	MORGAN LAKE	M-64	UNIO	6	POR
OR00566	NORTH CANAL DIVERSION	N-12	DESC	11	FAI
OR00348	NORTH FORK	N-9	BENT	22	FAI
OR00470	OLALLA	O-10	LINC	1	FAI
OR00401	OSBORNE CREEK	O-15	JACK	13	POR
OR00320	PARIS	P-31	DOUG	15	UNS
OR00688	PILCHER CREEK	P-42	UNIO	8	SAT
OR00480	PINE HOLLOW	P-39	WASC	3	SAT
OR00443	PLAT I	P-38	DOUG	15	SAT
OR00239	POLE CREEK	P-9	MALH	9	POR

Dam ID	Dam Name	File	County	District	Condition Assessment
OR00070	PONY CREEK - LOWER	P-6	COOS	15	POR
OR00200	PONY CREEK - UPPER	P-14	COOS	15	SAT
OR00667	PORTLAND #1 (MT.TABOR)	P-50A	MULT	20	SAT
OR00670	PORTLAND #5 (MT.TABOR)	P-50B	MULT	20	SAT
OR00671	PORTLAND #6 (MT.TABOR)	P-50C	MULT	20	SAT
OR00147	ROCK CREEK (WASCO)	R-4	WASC	3	FAI
OR00265	ROCK CREEK LAKE (WHEELER)	R-7	WHEE	4	SAT
OR00400	SAMS VALLEY	S-39	JACK	13	FAI
OR00743	SANTA CLARA	S-68	LANE	2	FAI
OR01387	SEASIDE CITY	S-113	CLAT	1	FAI
OR00622	SILVER CREEK	S-66	MARI	16	FAI
OR03811	SPRING LAKE	S-77	LINC	1	SAT
OR00142	STRONG	S-101	JOSE	14	FAI
OR03790	SUNRIVER EFFLUENT LAGOON	LG-73	DESC	11	SAT
OR00491	UPDEGRAVE	U-8	DOUG	15	SAT
OR00105	VAN RADEN	V-9	MULT	18	FAI
OR00379	WADE	W-45	JACK	13	FAI
OR00496	WAGEMAN	W-79	DOUG	15	POR
OR00246	WALCH DAM	W-34	JACK	13	POR
OR00465	WALLOWA LAKE	W-2	WALL	7	POR
OR00136	WICKIUP LAKE (ASTORIA)	M-10B	CLAT	1	POR
OR00212	WILLOW CREEK	W-29	JACK	13	FAI
OR00390	WILLOW CREEK 3 (MALHEUR)	W-6	MALH	9	UNS
OR00263	WINCHESTER	W-1A	DOUG	15	POR
OR00220	WOLF CREEK	W-62	UNIO	8	FAI
OR00357	WOODRAT KNOB	W-43	JACK	13	POR
OR00222	YANKEE	Y-6	JACK	13	FAI
OR00697	YOUNGLIFE WASTE A (LOWER)	R-24A	WASC	21	FAI

3.3.6.9 Risk Assessment and Analysis

The FEMA High Hazard Potential Dam (HHPD) grant program and the new Model State Dam Safety Program both recognize the need for risk assessments, especially for deficient high hazard potential dams. The 2015 FEMA publication Federal Guidelines for Dam Safety Risk Management provides definitions and conceptual guidance for risk analysis by dam safety programs and was used to develop methods. *Risk* in the simplest terms for dam safety applications, and for this work, is the product of the likelihood (probability) of a sudden dam failure and the consequences of that dam failure or uncontrolled release of water.

For HHPD grant eligibility and for current state of the practice dam safety program management, a consistent evaluation of the risks posed by regulated dams is needed. Oregon dam safety staff developed an assessment protocol for use on state regulated dams to support FEMA grant processes. Seventeen high hazard dams with known or suspected major safety deficiencies have been assessed, including quantitative evaluation of events associated with failures, loadings in those events, and loss of life from catastrophic failure.

3.3.6.10 Events and general risks to dams

Under normal loading conditions dams are generally at very low risk of failure. Specific events are associated with most dam failures. The events most likely to result in failure vulnerability in Oregon include:

- An extreme flood that exceeds spillway capacity and causes an earthen dam to fail;
- Record high water levels in a dam that has no protection against internal erosion;
- Movement of the dam in an earthquake; and
- A large rapidly moving landslide impacting the dam or reservoir.

Floods: Oregon's two largest historical floods occurred in 1861 and 1903. There is very little data on the precipitation leading up to these flood events, or on specific peak flood flows. The 1861 storm occurred up and down the west coast. This storm was a long duration atmospheric river event (very different mechanism and moisture source from the eastern 2/3 of the country). The 1903 event was an extreme intermountain (arid region thunderstorm). Given the short period of record and the lack of extreme floods in Oregon there has been low confidence in estimates of the size of extreme floods in much of the state using existing methods. Hydrometeorological Report No. 57 (HMR 57 for the Pacific Northwest) does not well represent the meteorological physics of atmospheric rivers. Dam safety has two projects underway to address this issue as described later in the chapter.

High Reservoir Levels: While internal erosion observations can occur at typical reservoir levels, (Fell et al., 2015) provide evidence that most internal erosion failures occur at the highest reservoir level experienced by that dam. Based on stream gage data and other information, it is unlikely any of the dams in the project have experienced greater than a 0.2 percent annual exceedance probability (500-year) flood. Therefore, it is reasonable to use a reservoir level calculated at the 0.2 percent AEP inflow to make a consistent comparison of risk for these dams as described later in this chapter.

Earthquakes: The western part of the state is subject to a very large Cascadia Subduction Zone earthquake, the last one occurring in 1700. There is no record of a very large earthquake in Oregon since that time (two earthquakes near magnitude 6 occurred in 1991). Almost all existing dams in Oregon were designed before there was an understanding of the Cascadia Subduction Zone hazard. Most Oregon dams were designed before there was any awareness of the occurrences of subduction zone earthquakes in the Pacific Northwest. Phase 1 studies were completed by the Corps of Engineers and the Water Resources Department from 1971 to 1982 and used an acceleration of 0.05 standard gravitational acceleration (g) for analysis of these dams. The 2500-year return earthquake accelerations are now 0.6 to 1 g at coastal Oregon dams.

The full Cascadia rupture earthquake has a 14-20 percent occurrence probability every 50 years, with at least one paper indicating an even higher risk. This is equivalent to about a 0.3 percent annual chance of occurrence. The eastern Oregon faults closest to some of the HHPD analysis dams are believed to have been last active in the past up to 16,000 years ago.

Landslides in Oregon have occurred in high precipitation events, and during large earthquakes. Oregon's geologic units closer to the coast tend to have weaker rocks and very steep slopes, further increasing seismic and landslide risk. A number of Oregon dams are located on or near landslide deposits, and one dam is under formal reservoir level restriction because higher reservoir levels trigger movement at the toe of the existing landslide (the reservoir is in the large graben formed when the landslide moved in the distant past).

Wildfire   Intense wildfire in the watershed above dams can increase peak stream flows and increase debris loading that could block spillways. Oregon has experienced an increase in large wildfire occurrence and severity over the last decade or so. The years 2020 and 2024 were especially serious. In 2024 wildfires in 2024 burned significant portions of watersheds above several high hazard dams, including two that were in Unsatisfactory or Poor condition.

Cascading Effects   Cascading effects are also possible, although there are not many large state regulated high hazard dams upstream from other large dams. An exception is some of the coastal municipal water supply dams, especially some of the dams for the Cities of Astoria, Newport, and Coos Bay/North Bend. These are also the dams with some of the higher vulnerabilities to a Cascade Subduction Zone earthquake.

Climate Change Flood producing storms can be made more severe by climate change and locally by wildfire. Oregon has experienced higher temperatures and less rainfall and now officially significantly dryer and hotter summers that contribute to the increased wildfire occurrence. Oregon has not yet experienced increased flooding precipitation, but that could be expected anytime.

3.3.6.11 Potential Impacts from dam failures

Life loss is by far the most critical effect of some dam failures and is the basis of the high hazard potential designation. The *Population at Risk* (PAR) for a dam is the number of people or households that could be affected by a dam failure. It is normally higher than expected life loss since it assumes people are in homes, and also because it usually includes all areas that are likely to be inundated, not the depth or velocity of inundation. Life loss depends on the depth and velocity of flood flows, the resilience of the structure, and very importantly, if there was sufficient warning and people are able to move to safer locations. Homelessness poses a challenge in that population in potential inundation areas may not be identified. Dam safety has evaluated PAR below dams mostly for the HHPD grant eligibility dams.

Dam failures can damage or destroy homes, businesses, roads, water treatment and other infrastructure. Several municipal water supply reservoirs are directly above the treatment plants for that water and would be destroyed by a failure of those dams. This is most critical for Oregon coastal communities, with the greatest apparent risk from a Cascadia event. Lack of water would reduce fire fighting and essential water supplies at a time that the need is greatest.

Environmental risk is not directly regulated by dam safety, however most of the dams on streams with essential anadromous salmonid habitat are rated high or significant hazard, so receive higher levels of inspections and safety actions due the hazard rating. If there is infrastructure or other structures downstream but loss of life is unlikely, dams are rated significant hazard.

3.3.6.12 Vulnerabilities to and from HHPD eligible dams

Initial risk detail is found in the summary of 17 Oregon 2021 HHPD eligible dams risks follows. Where applicable this includes: the location and size of population at risk; potential impacts to institutions and critical infrastructure/facilities/community lifelines; and economic, environmental, social impacts, and potential multi-jurisdictional impacts from dam failure:

Dam Name	Barnes Butte	NID OR00284	File B-38	
Type	Embankment	Year Constructed	1956	
Height	32.5 ft	Normal Storage	340 ac-ft	
Owner (private)	Individual	County Crook	Uses	Recreation
PAR daytime	1,787 people	PAR nighttime	1,648 people	

Initial information on dam vulnerabilities: The US Army Corps of Engineers (USACE) Phase 1 report for this dam indicated the spillway is significantly undersized for a PMF. The OWRD dam safety files contain a letter from the owner stating that the spillway was widened. This was not correct, and the spillway remains in roughly the same condition as it was when the Phase 1 report was completed about 40 or so years ago. A team of consultants are finalizing a report on alternatives for addressing the spillway of this dam.

Condition Classification: POOR

PAR detail: The dam is 1.5 miles from downtown Prineville, a town with a current population of 11,227 people. Over 10 percent of the population is in the area that would be flooded by a catastrophic dam breach. The dam owner is an individual ranch owner, and other than the owner there is no dam operator. Water is used mostly for recreation. The owner has a house on the reservoir, but at times is in another state. The critical infrastructure most at risk is US Highway 26. The average PAR of 1,718 was used for the risk analysis since flooding in this location is equally likely in day or night conditions.

Notices and Enforcement: The prior dam owner was notified that the spillway was undersized after the Phase 1 report. The most recent dam safety program formal notice was dated March 12, 2024, and stated in part: “The spillway capacity analysis is near complete, and the results indicate that the current spillway cannot pass the Probable Maximum Flood (PMF), the largest flood theoretically possible for the dam’s drainage basin. In addition, the analysis indicates that even if the spillway is returned to the as-designed condition, it would not have sufficient capacity to pass the PMF. Inability of the dam to pass the PMF in the current or as-designed condition results in a Potentially Unsafe condition with Barnes Butte Dam as defined by ORS 540.443 (7)."

Dam Name	Big Creek 1	NID OR00225	File B-28A
Type	Embankment	Year Constructed	1951
Height	21 ft	Normal Storage	200 ac-ft
Owner (public)	City of Newport	County Lincoln	Uses Municipal supply
PAR daytime	16 people	PAR nighttime	35 people

Initial information on dam vulnerabilities: This dam is one of the closest dams to the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0. During geotechnical exploration for a modification to the inlet structure, SPT blow counts of 0 were found in the dam, and in the 60 feet of soft alluvial material forming the dam's foundation. This dam is immediately downstream from the larger Big Creek 2 dam.

Both dams are to be replaced by one dam. Analysis for this project is underway. Due to the high estimated cost, the city is still working on funding.

Condition Classification: POOR

PAR detail: The homes at risk and the Cities water treatment plant are all within ¼ mile of this dam. The average PAR of 26 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated January 22, 2021. This analysis indicated that both dams will deform significantly during a Cascadia Subduction Zone (CSZ) earthquake. For both dams, the deformation could cause the dam crest to drop below the water line which could lead to overtopping of the dam crest and subsequent catastrophic failure of the dam. The dam is determined to be Potentially Unsafe.

Dam Name	Big Creek 2	NID OR00473	File B-28B
Type	Embankment	Year Constructed	1968/1977
Height	26 ft	Normal Storage	970 ac-ft
Owner (public)	City of Newport	County Lincoln	Uses Municipal supply
PAR daytime	26 people	PAR nighttime	52 people

Initial information on dam vulnerabilities: This dam is one of the closest dams to the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0. During geotechnical exploration for a modification to the inlet structure for the lower dam, SPT blow counts of 0 were found in the dam and in the 40-60 feet of soft alluvial material forming the dam's foundation. This dam is immediately upstream from the smaller Big Creek 1 dam. Investigations for replacing both dams with a single dam that can withstand a Cascadia earthquake are underway.

During preliminary review of all design documents, inconsistencies were found with the design documentation and actual on the ground conditions. A recent OWRD dam safety inspection identified water under pressure squirting into a large-corrugated metal culvert that was constructed as the interior (glory hole) spillway for the dam. A subsequent investigation by a consulting engineer occurred after OWRD sent a notice of an unsafe dam. These investigations confirmed discontinuous internal erosion at the base of large diameter spillway pipe. Leakage into the low-level conduit (control outlet) has also been observed during video scoping. A part of the short-term repairs for this issue have been completed.

Condition Classification: UNSATISFACTORY

PAR detail: The dam is about one mile from the population at risk. The dam owner maintains personnel (operators) at the water treatment plan (very critical and essential infrastructure) below the dam. Failure of the dam would destroy this water treatment plant, and Newport does not have an alternate treatment source. This would eliminate water supply for this City of 10,500 people. This City will be cut off from outside ground transport after a major earthquake, so for a significant time would need air dropped water and other supplies. The average PAR of 39 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated January 22, 2021.

The notice stated department conducted a routine dam inspection on October 15th, 2018, during which inspectors observed corrosion of, and leakage through, the corrugated metal pipe (CMP) portion of the overflow spillway for Big Creek Dam #2. The leakage occurs at locations throughout the length of the CMP portion of the spillway. This is determined to be an Unsafe Condition.

This analysis also indicated that both Big Creek dams will deform significantly during a Cascadia Subduction Zone (CSZ) earthquake. For both dams, the deformation could cause the dam crest to drop below the water line which could lead to overtopping of the dam crest and subsequent catastrophic failure of the dam. The condition is determined to be Potentially Unsafe.

Dam Name	Bear	NID OR00449	File B-47
Type	Concrete gravity	Year Constructed	1912/1950
Height	90 ft	Normal Storage	700 ac-ft
Owner (public)	City of Astoria	County Clatsop	Uses Municipal supply
PAR daytime	20 people	PAR nighttime	57 people

Initial information on dam vulnerabilities: This dam is one of the closest dams to the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0. A consultants analysis indicated this dam is likely to survive this earthquake will little deformation. However, the spillway for the dam is undersized, and since the dam is concrete, the main vulnerability is high flow erosion of the abutments and toe of the dam. Engineering consultant analysis of abutment and toe scour protection are underway.

Condition Classification: POOR

PAR detail: The dam is 2-7 miles from a mostly semi-rural population. The dam owner maintains a dam operator on site, as water is used for the municipal water supply for the City of Astoria. There will likely be warning prior to major overtopping of this dam. This dam is most vulnerable in a winter flood event, so the nighttime PAR of 57 will be used for risk analysis.

Notices and Enforcement:. The dam safety program sent the most recent formal notice dated September 16, 2025, stating

> "In every dam safety inspection conducted by the department, since at least 2011, the control mechanism for the low-level conduit valve has not been cycled and the conduit controls cannot be safely operated. A properly functioning low-level conduit is a key safety feature of a dam. It allows the reservoir to be drained in the event of an emergency and lowered prior to a major flood event. It is particularly important for Bear Creek dam since the spillway is not capable of safely passing a large flood event. Because it has not been operated our inspection have been unable to determine the condition of the conduit controls. The dam was built around 1912, so the conduit and controls are well over 100 years old. The non-functional low-level control is a Potentially Unsafe condition at Bear Creek Dam.
>
> The other Potentially Unsafe condition is the spillway that is significantly undersized to pass the Probable Maximum Flood. The City and the dam safety program have cooperated on an analysis of necessary spillway capacity and alternatives for safely passing this flood. Several engineering consultants have been working on this project. Specific findings and alternatives are in the *Bear Creek Spillway Modifications 30 percent design report from Cornforth Consultants dated March 27, 2024*. The current lack of capacity makes this a Potentially Unsafe condition. This is the most complex of the three Potentially Unsafe Conditions, and this condition drives the need for the other Corrective Actions".

Dam Name	Duggan	NID OR00475	File D-48
Type	Embankment	Year Constructed	1963
Height	23 ft	Normal Storage	50 ac-ft
Owner (private)	Individual	County Jackson	Uses Recreation
PAR daytime	6 people	PAR nighttime	11 people

Initial information on dam vulnerabilities: There was no USACE Phase 1 report for this dam. OWRD dam safety inspections have found the spillway mostly filled in by the owner to make use of their ATV easier. The valve for the low-level conduit is inoperable, the dam is covered by medium sized trees, and the outlet is obscured by dense blackberry growth and cannot be inspected until this is cleared.

Condition Classification: POOR

PAR detail – The dam is 1/4 mile from semi-rural population. The dam owner had been out of the country for several years, and the property renter has avoided OWRD attempts at contacts. Other than for yearly OWRD inspections the dam is unwatched, though can be seen from a public road. The average PAR of 9 is appropriate for this dam. No critical infrastructure would be affected by failure.

Notices and Enforcement: The dam safety program sent a formal notice dated August 22, 2016. From past inspections, inspectors have determined that the controls for the low-level conduit of this dam are inoperable. As a result, it is not possible to drain this reservoir in the event of an emergency. From the most recent inspection, there has been no substantial progress clearing trees from the dam or clearing around the conduit inlet and outlet. As a result, it is not possible for Department staff to conduct a complete safety inspection of this dam. Consequently, Duggan dam has been determined to be UNSAFE.

Dam Name	Ferry	NID OR00437	File F-25
Type	Embankment	Year Constructed	1914/1966
Height	65 ft	Normal Storage	167 ac-ft
Owner (public)	City of Brookings	County Curry	Uses Former Municipal Supply
PAR daytime	84 people	PAR nighttime	25 people

Initial information on dam vulnerabilities: This dam is the closest Oregon dam to the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0. The dam was not designed for any seismic loading.

This dam was reclassified from low hazard to high hazard in 2014. There had been no review of hazard rating since construction of the dam. The dam is in an area with the highest intensity rainfalls in Oregon and has overtopped by a small amount in the past (in less than a 1 percent AEP flood). The dam has three penetrating conduits, none of which are functional, and some may be pressurized. OWRD dam safety inspections have found a large landslide moving slowly into the spillway. Engineering consultant analysis for removal of the dam is in progress, and the city tentatively plans to remove the dam if funding support is available.

Condition Classification: UNSATISFACTORY

PAR detail: The dam is 1 mile from several houses, and 2-3 miles from a small commercial and recreational port. The dam owner is the Coty of Brookings, with a small public works staff and does not dam safety expertise There is no dam operator, as water is no longer used as part of the municipal supply. Use of an average PAR (daytime and nighttime) of 55 is reasonable for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated April 12, 2021. The following safety issues result in a Potentially Unsafe condition with Ferry Creek Dam:

- none of the conduits are functional and the condition of the conduits is unknown
- seismic risk
- insufficient spillway capacity

Dam Name	McMullen	NID OR00513	File M-46
Type	Embankment	Year Constructed	1960
Height	45ft	Normal Storage	1675 ac-ft
Owner (public)	County	County Josephine	Uses Recreation
PAR daytime	85 people	PAR nighttime	243 people

Initial information on dam vulnerabilities: Unti1 2014 this dam had been classified as a significant hazard dam. A dam breach inundation analysis was conducted for the dam, and as a result it was reclassified to a high hazard dam. The dam has had a history of issues beginning with a greatly undersized spillway causing the dam to nearly overtop the year after construction. An overflow was constructed, and the concrete surface for that spillway is failing

This dam is also close the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0.

Engineering consultant analysis has confirmed the spillway is significantly undersized and the dam is vulnerable to high seismic deformation. OWRD dam safety inspections have found significant wave erosion, spillway issues, and a non-functional outlet.

Condition Classification: UNSATISFACTORY

PAR detail: The dam is 1-2 miles from the unincorporated community of Selma and there is a main highway downstream. The County Parks Department manages the reservoir and is the dam owner. The dam has a real time reservoir level gage that is monitored by the County and has reservoir level warnings set that are delivered to OWRD dam safety. The average PAR of 164 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated February 2, 2021, the lack of an operating control structure and deterioration of the conduit result in an Unsafe condition at McMullen Dam. In addition, a potentially Unsafe condition exists with the insufficient spillway capacity and seismic stability of McMullen Dam.

Dam Name	Morgan	NID OR00653	File M-64
Type	Embankment	Year Constructed	c 1900
Height	22 ft	Normal Storage	780 ac-ft
Owner (public)	City of LaGrande	County Union	Uses Recreation
PAR daytime	11,128 people	PAR nighttime	6,362 people

Initial information on dam vulnerabilities: A USACE Phase 1 report exists for this dam, but this report did not investigate the conduit condition and had no evaluation of internal erosion risk. The dam, built in around 1900 for hydro power. The dam may be a puddle core fill. OWRD dam safety inspections have found the conduit may be made of clay and tin, and it is pressurized and not operable. Engineering consultant analysis is in progress.

Condition Classification: POOR

PAR detail: The City of LaGrande is directly downstream from this dam in a very high-risk setting. The dam is 1-3 miles from a dense population. The breach flow would travel down a very steep canyon (1400 elevation drop over 1 mile) to the edge of the city. It is very possible that the flow will remove all debris from the canyon and have unusually high velocity. There is no dam operator or operation, as the valve is inoperable (and the conduit appears to be pressurized). During the winter and early spring when highest water levels occur the very steep road to the dam has deep snow, is unplowed and is not accessed. The regional hospital is at the base of this canyon. The average PAR of 8,745 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent the most recent formal notice on September 16, 2024. This stated "In every dam safety inspection conducted by the department, since at least 2011, the control mechanism for the low-level conduit valve has not been functional and the conduit outlet has been buried. On August 21st, 2021, the outlet to the conduit was unburied. Inspectors were unable to determine if the conduit was pressurized and it was not clear what material the conduit was made of; it did not appear to be any type of material any of the engineers on site were familiar with. The conduit outlet was reburied to prevent vandalism.

A properly functioning and durable low-level conduit is a key safety feature of a dam. It allows the reservoir to be drained in the event of an emergency. Inspectors have been unable to determine the condition of the low-level conduit. The dam was built around 1900, so the conduit is well over 100 years old, past the design life of most conduit materials. A failing conduit may lead to internal erosion and then to complete dam failure. The unknown conduit condition results in the determination of a Potentially Unsafe condition at Morgan Lake Dam."

Dam Name	Osborne	NID OR00401	File O-15
Type	Embankment	Year Constructed	1964
Height	60 ft	Normal Storage	438 ac-ft
Owner (private)	Ranch	County Jackson	Uses Irrigation
PAR daytime	123 people	PAR nighttime	229 people

Initial information on dam vulnerabilities: There was no Phase 1 report for this dam. OWRD dam safety inspections have found that corrugated metal culverts were used for the low-level conduits in all the dams on this ranch. The pipes are severely deteriorated, and it was unclear whether they were encased on concrete. Engineering consultant inspection for the owner has not yet provided sufficient information for a safety determination on the condition of the conduit

Condition Classification: POOR

PAR detail: The main population is in Eagle Point 15 miles below the dam, with some structures within 3 miles of the dam. A State Highway would also be affected by a dam breach. The dam owner is a large private ranch, with no specified dam operator.

The average PAR of 176 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated November 1, 2018. The Department notice stated that the condition of the conduit was a serious safety concern and the conduits either needed to be relined, replaced, or grouted shut if an alternate location was selected for new pipes.

Dam Name	Pole	NID OR00239	File P-9
Type	Embankment	Year Constructed	1909
Height	58 ft	Normal Storage	1525 ac-ft
Owner (private)	Farmer Association	County Malheur	Uses Irrigation
PAR daytime	37 people	PAR nighttime	103 people

Initial information on dam vulnerabilities: The USACE Phase 1 report for this dam indicated the dam did not have a spillway and was the primary safety concern. The dam still does not have a spillway. It is filled mostly by diversion from a creek but is also located on a small channel. The Engineering consultant analysis for spillway alternatives is in progress.

Condition Classification: POOR

PAR detail: The dam is about 2 miles from the very small town of Brogan. The dam owner is a private company made up of local farmers. One of their employees manages dam operations but does not live on site. Dam breach will flood one US highway. Population and critical infrastructure at risk. The average PAR of 70 is appropriate for this dam.

Notices and Enforcement: The prior dam owner was notified that the spillway was undersized after the Phase 1 report. The dam safety program sent the latest formal notice dated April 14, 2021, notifying the owner of a Potentially Unsafe Condition - There is no spillway at this dam.

Analysis for spillway alternatives is complete.

Dam Name	Lower Pony	NID OR0070	File P-6
Type	Embankment	Year Constructed	1986
Height	32 ft	Normal Storage	380 ac-ft
Owner (public)	Coos Bay North Bend	County Coos	Uses Municipal supply
PAR daytime	687 people	PAR nighttime	408 people

Initial information on dam vulnerabilities: This dam is one of the closest dams to the Cascadia subduction zone, which based on geomorphic evidence has produced long duration earthquakes, up to around magnitude of 9.0.

OWRD file review and a preliminary geotechnical investigation indicate there is loose sand in the dams' foundation, and if confirmed could have a high potential for liquefaction in the Cascadia earthquake. Engineering consultant analysis will be in progress shortly.

Condition Classification: POOR

PAR detail – The dam is 0.5 to 3 miles from to population in the City of North Bend. The dam owner is the public water supply entity for over 25,000 people. Loss of the dam would destroy the water treatment system and eliminate water supply for this entire population. There are dam operators on site most of the time. The average PAR of 548 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated April 6, 2021. The notice stated that initial analysis indicates a layer of loose sand below the dam. This indicates likely significant deformation of the dam in a Subduction Zone type very large earthquake. As a result, this dam was determined to be in Potentially Unsafe condition.

Dam Name	Wageman	NID OR00496	File W-79
Type	Embankment	Year Constructed	1971
Height	40 ft	Normal Storage	50 ac-ft
Owner (private)	Individual	County Douglas	Uses Recreation/irrigation
PAR daytime	6 people	PAR nighttime	12 people

Initial information on dam vulnerabilities: There is no USACE Phase 1 report for this dam. OWRD dam safety inspections have found indicators of holes and leakage though these holes in the CMP low level conduit, which is only 8 inches in diameter so cannot be scoped. Inspections have also found the spillway choked with debris and trees, and uneven. Engineering consultant analysis has developed repair alternatives for this dam.

Condition Classification: POOR

PAR detail: The dam is about 2000 feet from the owners' house, with several homes within 2 miles of the dam. The dam owner is an individual that lives below the dam, with no dam operator. The owner would like to resume using the water for crop irrigation and recreation/wildlife. The average PAR of 9 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated February 2, 2021. The notice stated that seepage indicates that there are holes in the conduit and when the conduit is pressurized during operation, water is seeping into the dam from the conduit. This is a Potentially Unsafe condition because the holes in the conduit are a potential route for internal erosion.

Dam Name	Wallowa	NID OR00465	File W-2
Type	Concrete	Year Constructed	1920, 1927
Height	35 ft	Normal Storage	42,750 ac-ft
Owner (public)	Irrigation District	County Wallowa	Uses Irrigation

PAR daytime	1,131 people	PAR nighttime	1,334 people

Initial information on dam vulnerabilities: The USACE Phase 1 report for this dam indicated the dam could not quite pass a probable maximum flood, and that at a water level near the crest the dam might slide due to uplift at the base of the dam. A replacement dam or major rehabilitation is being designed at this time. This risk analysis relied on the Phase 1 report, since the Corps conducted the Phase 1 analysis, and had structural engineering expertise on the team.

Condition Classification: POOR

PAR detail: The dam is about 5 miles from the City of Enterprise. The dam owner employs a dam operator that lives on site. In addition, there is real time monitoring of reservoir levels that is monitored by the owner and OWRD. The average PAR of 1,233 is appropriate for this dam. There is no atypical critical infrastructure at high risk.

Notices and Enforcement: The dam safety program and the dam owner agreed to a water level restriction for this dam. The restriction was developed in the early 1980's.

Dam Name	Willow Ck 3 (Malheur)	NID OR00390	File W-6
Type	Embankment	Year Constructed	1911
Height	125 ft	Normal Storage	49,000 ac-ft
Owner (private)	Farmer Company	County Malheur	Uses Irrigation
PAR daytime	3,426 people	PAR nighttime	3,518 People

Initial information on dam vulnerabilities: Since 1942 this dam has been under a formal restriction due to leakage above elevation 3386 (about 30 feet below the dam crest). The USACE Phase 1 report for this dam investigated this situation in detail, and at that time it was not clear if the restriction was sufficiently safe in an extreme flood event. OWRD dam safety inspections and monitoring of reservoir levels have found this restriction was exceeded once in the last 12 years. There have also been issues with valve operability at the dam.

Condition Classification: POOR

PAR detail – The City of Vale is about 35 miles downstream, while the City of Ontario is about 50 miles downstream from this dam. The dam owner has one employee for two dams and its ditches, and there is remote monitoring of reservoir level. The average PAR 3,472 is appropriate for this dam. Failure of the dam would also close a major US highway.

Notices and Enforcement: The original restriction is in place, so the dam is considered unsafe if its level exceeds the restricted level. The dam safety program most recently sent a formal notice dated April 19, 2021, that stated an extreme flood will cause the dam to rise much above the restricted level and trigger leakage and movement and possible dam failure - Potentially Unsafe Condition.

Dam Name	Woodrat Knob	NID OR00357	File W-43
Type	Embankment	Year Constructed	1956
Height	90 ft	Normal Storage	1320 ac-ft
Owner (private)	Ranch	County Jackson	Uses Irrigation
PAR daytime	227 people	PAR nighttime	500 people

Initial information on dam vulnerabilities: There was no Phase 1 report for this dam. This dam experienced a near catastrophic landslide that extended from the toe of the dam to the upstream edge of the crest in 1961. OWRD dam safety inspections have found deterioration of all corrugated metal pipes (for the mid-level conduit and drains in the toe berm. The original low-level conduit is strongly believed to remain in the dam. Engineering consultant investigation has not yet identified this pipe and has not yet confirmed the other pipe is fully encased in concrete with that concrete intact.

Condition Classification: POOR

PAR detail: The main population is in Eagle Point 15 miles below the dam, with some structures within 3 miles of the dam. A State Highway would also be affected by a dam breach. The dam owner is a large private ranch, with no specified dam operator.

The average PAR of 364 is appropriate for this dam.

Notices and Enforcement: The dam safety program sent a formal notice dated November 1, 2018, stating that the condition of the conduit was a serious safety concern and the conduits either needed to be relined, replaced, or grouted shut if an alternate location was selected for new pipes

3.3.6.13 Semi Quantitative Risk Assessment of HHPD eligible dams

An HHPD grant funded semi quantitative risk analysis of the 17 Oregon dams eligible was completed for the FY19 and FY 20 eligible dams. Another major dam risk evaluation project used multiple funding sources to conduct deterministic engineering assessments of many dams. Analyzed dams included both eligible high hazard dams and also municipal water supply dams, with priorities based in part on the semi quantitative risk analysis. In addition, projects to advance the state of the practice for determination of probable maximum precipitation and also precipitation recurrence frequency in Oregon are underway.

OWRD dam safety staff developed dam-specific risks due to dam failure for each of the 17 dams. Modes of failure most likely to cause dam failures were evaluated for each dam, as was a dam specific mode if there were unusual conditions at that dam. The modes of failure analyzed were as follow:

a. Overtopping in flood exceeding spillway capacity
b. Spillway blockage or erosion
c. General internal erosion
d. Internal erosion conduit
e. Seismic deformation - Cascadia subduction zone

f. Landslide into dam or reservoir
g. Dam specific vulnerabilities

Methodology and assumptions for risk data and inundation modeling are best described in the project HHPD Grant # EMW-2020-GR-00204 report to FEMA. This semi-quantitative risk analysis methodology was completed and applied to the 17 eligible dams in accordance with the scope of work contained in the Oregon FEMA HHPD FY19 and FY 20 grant applications. Existing file information was comprehensively reviewed with inspection elements based in information and gaps in the dam safety program files for those dams.

The product is a consistent procedure and includes a rating of confidence in the information. Results are calculated in terms of expected loss of life on an annualized basis. The probability of failure for each potential failure mode (PFM), the combined probability of failure, the PAR, and the annualized per capita life loss risk were determined for each dam and the information was then entered into tables at the end of this document. The combined risk of failure is determined to an order of magnitude only. The combined failure risk (across all PFMs) only considers the highest risk modes of failure, and for convenience was additive.

Risks that are at least one order of magnitude less than the highest risk PFM for that dam are not included in the risk summary and are not listed or considered a principal failure mode. All risks may be one or two orders of magnitude off, depending on the confidence in the data behind the estimates, as indicated in the last row of the analysis table under each PFM. A summary table showing the dam's name and the annualized per capita life loss risk is provided in Table 3.3.6-4. The table is arranged from highest to lowest risk.

Table 3.3.6-4: Highest Apparent Risk Dams and Affected Communities

Rank/Dam Name	Annual life loss risk	Affected Community
1 Morgan	3.5E-01	La Grande in Union County
2 Barnes Butte	3.4E-01	Prineville in Crook County
3 Willow 3 Malheur	1.7E-01	Vale and Ontario in Malheur County
4 Lower Pony	1.6E-01	Coos Bay and North Bend in Coos Co.
5 Ferry	1.3E-01	Brookings in Curry County
6 Big # 2	8.8E-02	Newport in Lincoln County
7 McMullen	6.6E-02	Rural Josephine County
8 Pole	2.5E-02	Brogan and Vale in Malheur County
9 Wallowa	6.2E-03	Joseph Enterprise and Wallowa
10 Walch	5.6E-03	Shady Cove in Jackson County
11 Big # 1	5.0E-03	Newport in Lincoln County

Rank/Dam Name	Annual life loss risk	Affected Community
12 Jubilee	4.0 E-03	Rural Union County
13 Osborne	3.5E-03	Eagle Point in Jackson County
14 Bear	3.0E-03	Rural Clatsop County
15 Woodrat	2.2E-03	Eagle Point in Jackson County
16 Wageman	6.0E-04	Rural Douglas County
17 Duggan	2.0E-04	Rural Jackson County

The analysis resulted in a risk-based ranked list of dams that is being used to prioritize HHPD eligible dams for further dam safety actions and also for future HHPD funding. In addition, the analysis indicated that the most significant safety issue affecting Oregon dams is overtopping during flood events, with internal erosion and seismic risk being close second and third. Many of the dams evaluated under this risk analysis have an apparent risk of failure higher than the accepted tolerance level outlined in the document Federal Guidelines for Dam Safety Risk Management (FEMA P-1025).

Given the high risk of life loss from some of these dams, in the short term the Oregon dam safety priority must be on protecting life for determinations of dams needing funding support for rehabilitation or removal.

Limitations of analysis

Limitations to this analysis and means to address them are as follows:

Precipitation Event Duration: The analysis is limited to one event duration, the 24-hour precipitation event. A more thorough analysis would take into consideration other event durations. Oregon does not have up-to-date precipitation estimates that provide spatial and temporal distributions. Lack of this information is a major limitation in determining risk accurately. The probable maximum and frequency precipitation analysis projects described later should address this situation.

Peak Discharge Estimates: For eastern Oregon, some of the peak discharge estimates produced from the regional regression model (OWRD Peak Discharge Calculator) for eastern Oregon are likely incorrect; the regression model underestimates the peak discharge. Since peak discharge estimates were used to calibrate HEC-HMS models, inaccurate values led to inaccurate inputs into some of the hydraulic models which in turn led to inaccurate reservoir level determination for some dams in eastern Oregon. A precipitation frequency analysis for Oregon which could be used to determine more accurate peak discharge estimates in the future is now underway.

Dam Construction practices: Many Oregon dams were constructed under different design standards than applied to new dams. Designs did not usually include geotechnical investigation, and hydrologic calculations are minimal and were designed without zoning or filters. Most of the dams were constructed without an engineer on site to verify the construction followed design. As a result, recent investigations have found dams to be less that homogenous. The semi-quantitative analysis therefore needed to make significant assumptions about the dams, which are described in the formal reports on file.

3.3.6.14 Deterministic Assessments and Analyses

Rehabilitation or removal of dams requires specific engineering and analysis to verify the risk identified in the risk assessment, and to develop the specific actions to correct the deficiencies at the dam. As described later in the funding section, the OWRD dam safety program was provided funding for dam safety analysis by the Oregon legislature in 2021 and 2023. Staff used results of the risk analysis and inspection history to determine the priority analysis types and the specific dams needing that analysis. Dam safety then drafted contract language and is managing the contracts with consultants conducting the analyses. This analysis work was focused on the following issues:

- Extreme Precipitation Determination
- Precipitation Frequency Analysis
- Dam Breach Inundation Analyses
- Seismic Assessments and Analyses
- Spillway Capacity Analyses and Spillway Design
- Conduit Condition Assessments
- Structural Repair/Protection Assessments
- Dam Removal Design Plan

All analyses will be complete by 2026. More detail is provided for each analysis type below.

Extreme Precipitation Determination

The purpose of this project is to develop a current understanding of the extreme precipitation possible in Oregon, and how this would change with specific climate related and measurable factors. This project is critical for safety of Oregonians, not just below dams, but in any location that could be affected by changes in extreme flooding. The analysis and report will improve understanding of the mechanics of precipitation in an extreme atmospheric river event. The project results will be used to determine the accuracy of and potential need to update the National Weather Service’s HMR 57, a document used to determine extreme precipitation in Pacific Northwest States. It is the document used to begin analysis for the safety of a high hazard from overtopping in an extreme flood.

This project produced a final Phase 1 report. Phase 2 is underway. The goal of Phase 2 is to develop statewide Atmospheric River (“AR”)-based Probable Maximum Precipitation (“PMP”). This includes a procedure for determining PMP in Oregon. The document will provide the appropriate amount of information for an engineer to determine the PMP for any given watershed area above a dam, and then to calculate the flood flow and volume caused by that extreme precipitation (including potential snowmelt). The document will also contain guidance on determining the PMF. The expert engineering hydrology contractor assembled a technical review team of experts to develop and review methods to identify the most extreme potential conditions that could result in the greatest reasonable possible depths, areas and durations in Oregon. As of January 1, 2025, that project is 50 percent complete.

Precipitation Frequency Analysis

Oregon is one of the few states without a NOAA Atlas 14 precipitation frequency analysis and map. Atlas 14 documents are developed by NOAA technical staff and this development is normally funded by State Transportation Agencies. The Oregon Department of Transportation had a less detailed precipitation analysis developed in 2008 and generally does not design highways for extreme precipitation events as dams are designed for, so did not support funding a NOAA Atlas 14 for Oregon. Dam safety has been provided resources and has contracted for an Oregon statewide precipitation frequency analysis.

Risk-informed design for dams requires hydrological loads since they are one of the main hazards for dams and levees. Due to the high consequences, extremely rare events (e.g., return periods over 100,000 year recurrence) must be considered. Methods for hydrologic loading estimation include flow frequency analysis and stochastic flood modeling. Flow frequency analysis presents limited applicability due to limited periods of gauge record and non-stationary streamflow data. Stochastic flood modeling is usually the recommended approach and involves using probabilistic methods to simulate and analyze the occurrence, magnitude, and impacts of flood. Precipitation frequency estimates are one of the primary inputs for stochastic flood modeling. The goal of this project is to generate areal and point precipitation frequency analysis for Oregon for multiple seasons, durations, and return periods. As of January 1, 2025, that project is 50 percent complete.

Dam Breach Inundation Analyses

Dam Breach Inundation Analyses is the means by which hazard potential (rating) is determined. It is an essential dam safety program function, as limited resources can be focused on dams where the effects of dam failure are serious. This type of analysis required by Oregon Administrative rule 690-020-0100 and 0120, both to determine hazard rating changes, and as part of an emergency action plan for a high hazard dam. Dam safety funding has been awarded for a total of 23 dams.

Seismic Assessments and Analyses

The potential for a massive earthquake generated by the Cascadia subduction zone movement was not recognized when most Oregon dams were constructed. The subduction zone is offshore, so the dams closer to the coast will experience the most severe shaking, and projects were prioritized in large part by proximity to the coastline and also by use for municipal water supply.

Dam safety contracts have been awarded for a total of 9 dams. A full seismic investigation is being conducted for Lower Pony Creek dam with funds other than HHPD funds. The other eight projects are seismic assessments using original design information, which in many cases is quite limited.

Spillway Capacity Analyses and Spillway Design

Inadequate spillway capacity is the second most common mode of dam failure. Dam safety funding has been awarded for a total of 10 dams. This includes more detailed analysis and design alternatives for five HHPD eligible dams: Willow 3, Pole, Barnes Bute, Bear and Walsh.

Conduit Condition Assessments and Repair/Replacement Alternative

Many Oregon dams were constructed using corrugated metal pipes for the low level conduit. Corrugated metal pipes have a life span of 20 to 50 years, and most of these pipes have been in the dams for between 50 and 70 years. Most are badly corroded, and some have no remaining material at the base of the pipe. Corroded conduits can be a path for internal erosion, the most common cause of dam failure. One HHPD eligible dam (Upper Big Creek) has experienced an internal erosion event that was identified during a dam safety inspection and subsequently.

Dam safety funding has been awarded for a total of 6 conduit evaluations.

Dam Removal Design Plan

The owner of one HHPD eligible dam is fully supportive of dam removal. Ferry Creek dam in Curry County is no longer used for municipal water supply. Based on the semi quantitative risk assessment this dam has the highest combined risk of failure of the Oregon eligible dams (but not highest PAR). The dam is almost shovel ready for removal, with a removal design and permits in progress.

3.3.6.15 Dam Safety Mitigation Strategy

Dam Safety Mitigation Goal

Leverage Federal HHPD funds with other funds and resources to improve the safety of high hazard dams in Poor or Unsatisfactory Condition and to ensure effective response to protect people, property and infrastructure below dams after an earthquake, flood, internal erosion situation or other emergency.

Dam Safety Mitigation Actions and Funding

1. Continue assessing risk for state-regulated HHPDs.

   Semi-quantitative risk assessment work is a very important means of prioritization for dam safety projects. The most significant dam vulnerabilities must be identified to direct subsequent deterministic analysis consistent with current dam safety community design practice.

   Dam safety has been able to use limited funds available to the dam safety program, but this work continues at a slow rate with the given funding.

2. Support an initiative to develop funding for rehabilitation efforts

   To remove or rehabilitate a deficient dam requires funding for:

- deterministic analysis
- development of drawings and specifications
- obtaining permits to assure safety and environmental protection
- construction to modify or remove the dam

Oregon has no specific state fund for this work. This would be a new funding source, as such dependent on Executive and Legislative Branch direction as to how it would work. A few dams have received legislative earmarks for major rehabilitation, though this funding was not directly based on dam safety prioritization. This project would consider criteria that would be cost- effective, environmentally sound and technically feasible. Any such project would need to meet state fish passage and other state environmental requirements.

3. Complete floodplain management plans for inundation areas below priority High Hazard dams. Floodplain Management Plans are required for a dam to be eligible for HHPD funding and may also be the best source of information about dam and other flood risk for local governments and persons in potential inundation areas. They may help local governments better make decisions about actions before and during flood and dam breach events. OWRD has been leading exercises with dam owners, the local government emergency manager and first responders. Dam safety communicates the need for additional actions including evacuation maps to prepare residents for potential flooding. This action is low cost, cost- effective, environmentally sound, and technically feasible to reduce risks so jurisdictions are better prepared for dam related and other flooding. OWRD has been allocating resources for this, dependent on the level of dam safety funding.

4. Re-evaluate extreme precipitation potential.

   Current guidance for dam safety determinations of extreme flood potential uses technically out of date procedures and neglects recent climate information. Technically correct spillway capacity and loading decisions cannot be made for dams with a hydrologic deficiency without this information. This information is needed to evaluate use of Probable Maximum Flood, or a rare Annual Exceedance Food is more cost effective and still safe and environmentally protective.

   Overtopping in an extreme flood is the second most common cause of dam failure, preventing dam failure is environmentally sound, and technically feasible. Properly designed spillways that can pass outflows from a Probable Maximum Flood would eliminate failure risk during an extreme flood. This action directly contributes to the dam safety mitigation goal. It is already funded by state general fund and ARPA funds.

Local Coordination and Capabilities

Regulation of dams in Oregon is at the State level. Local governments have actively participated and contributed to EAP exercise and updates, and at exercises have been advised to use inundation maps to develop evacuation maps. In general, current local policies, programs, and capabilities do not include mitigation actions for dams, except for selected dams that were eligible for HHPD funding. The issue is mostly new to past developments below dams. Oregon land use effective at limiting new development to Cities. Dam owners are responsible for the safety of their dams, not downstream residents.

At this time, the main safety challenge is that residents are usually not aware of the relatively much higher risk from deficient dams, and how this is very different than for dams up to current safety standards. Inundation maps for state regulated dams in Oregon are public information.

Inundation maps are only required for dams rated high hazard. Oregon dam safety law does not provide a mechanism to get this information to persons at risk from high hazard dams in Unsatisfactory or Poor Condition.

The biggest opportunity for implementing mitigation actions to reduce risks to and from high hazard potential dams through local capabilities is develop a process to share information on those high hazard dams with much elevated risk with persons and property owners that are affected by this risk. This information has been included in floodplain management plans as part of local natural hazard mitigation plans. For local jurisdictions with HHPD eligible dams, Oregon dam safety has drafted sections on local mitigation for dams with those DLCD staff. If Oregon land use planning Goal 7 rules were updated or interpreted to include actions around dams with verified deficiencies and with people, property or infrastructure at risk, local capabilities would be improved.

Emergency Planning Exercises

Dam Safety has engaged local jurisdictions that have been identified as having high- hazard potential dams, dam owners/operators, and the Oregon Department of Emergency in the exercising and updating of Emergency Action Plans for dams.

Dam safety has developed a standard template for Emergency Action Plans and also for Exercises. The objectives listed in the exercise include the following:

- Ensure all responsible parties understand their role and the roles of others during a dam safety emergency
- Understand dam specific vulnerabilities including the importance of freeboard and rate of change of water level
- Demonstrate ability to determine emergency level through technical evaluation
- Learn how to communicate dam safety related conditions so that accurate information flows from the dam owner to emergency managers to persons at risk
- Ensure contact information, the EAP, and inundation maps are up to date
- Understand how to use inundation maps and that they are not an evacuation plan map
- Coordinate communication and public information needs across state and local agencies

Exercises facilitated by dam safety staff include the following HHPD dams: Bear, Big 1 and 2, McMullen, Pole, Willow 3, Lower Pony Creek, and Barnes Butte. Dam safety identifies the most significant vulnerabilities to and from high hazard potential dams and tailors the exercise to address actions to protect persons and reduce risk of dam failure.

Local Natural Hazards Mitigation Plans

Dam safety and DLCD staff have assisted local governments in HHPD dam mitigation for the following jurisdictions:

- Newport for the two Big Creek dams
- Wallowa County for Wallowa Lake dam
- LaGrande for Morgan Lake dam
- Malheur County for Willow Creek 3 and Pole Creek dams

- Curry County for Ferry Creek dam
- Crook county for Barnes Butte dam.

Funding Sources and Staffing for Dam Safety Actions

The Oregon dam safety program relies on several funding sources to mitigate vulnerabilities to and from high hazard potential dams. Funding has been increasing since the new dam safety law was adopted in 2019, including a one-time funding for dam safety analysis, and ARPA funding dedicated to eligible water supply dams.

Current dam safety funding sources include the following:

1. Dam Safety annual fee charged to state regulated dam owners based on the hazard rating of the dam
2. Dam Safety design review fee
3. The state General Fund for dam safety program with supports three positions and vehicles
4. A one-time state General Fund for dam safety analysis contracts
5. State Authorized ARPA funds for analysis of water supply dams
6. FEMA HHPD for rehabilitation of high hazard potential dams.
7. FEMA National Dam Safety Program grant for all eligible dam safety program activities.

As of January 1, 2025, there are 4 engineering positions in dam safety. This level of staffing is an increase from the single engineer covering the State prior to 2016. Engineers now conduct inspections of significant hazard dams and determine risk and eligibility for FEMA grant funding, in particular to address high hazard dams that are unsafe or potentially unsafe. Dam Safety is authorized to work cooperatively to address safety issues before a dam becomes dangerous.

Staff also developed and managed contracts for the extra 1-million dollars in state general fund, and 4-million dollars in ARPA funds, and the FEMA HHPD funds awarded to Oregon since 2019.

Funds for Rehabilitation/Removal

The dam safety program has been effective in applications for HHPD funds for risk analysis, design alternatives and designs for eligible dams. Dam safety is allowed by law to utilize funds from any source, including dam owners and local government to support its dam safety actions.

There is currently no state fund for rehabilitation or removal of deficient dams. The 2020 Oregon NHMP included a specific Mitigation Action to address this situation, and a task force was proposed in state legislation. No action was taken on this legislation. A dam safety rehabilitation and removal fund was also included in the state's formal Integrated Water Resource Strategy from 2017. Oregon still needs a statewide funding source and funding policy to assist dam owners in addressing dams with safety deficiencies.

Funding Prioritization

Funding actions for dams are prioritized differently than mitigation actions for other hazards in part because the HHPD requirements are very different and the costs are much higher. Oregon uses the risk methodology developed by the Oregon Water Resources dam safety program to assess projects based on failure modes, potential consequences resulting from a dam incident, and considers the expected risk reduction and other benefits of the project. The Oregon dam safety program also assesses the loss of the resource and benefits of the dam.

More specifically, for each dam the dam safety program will evaluate as applicable:

- Is semi-quantitative or other risk assessment that meets FEMA criteria complete
- Is deterministic analysis of work needed to rehabilitate or remove the dam completed
- Are the designs and permits ready
- Is the dam public or private
- Is the dam needed for municipal supply or for livelihood/employment
- Can the dam owner's provide significant funding and implement the project

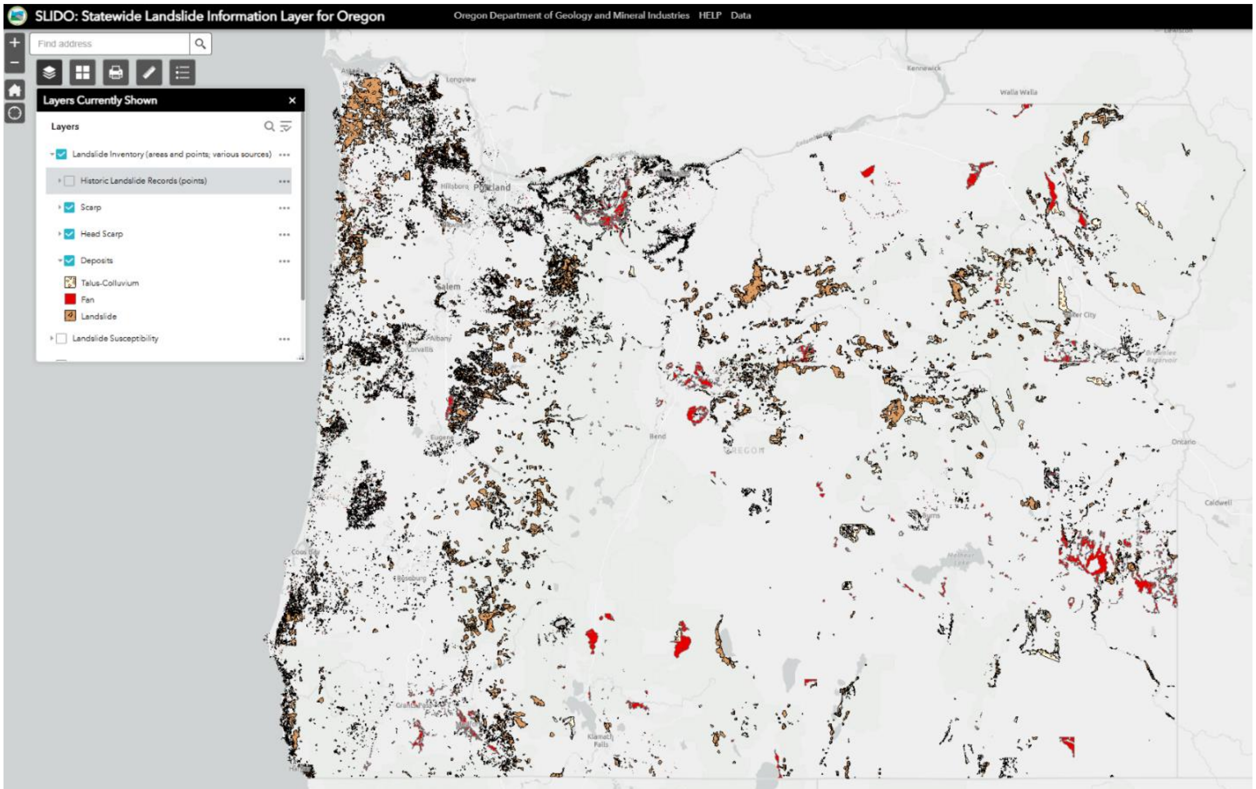
Limitation

The lack of formal mechanism other than the HHPD grant for providing owners funding for essential dam safety work is the main limitation. Dam safety will continue to work with agency management to address this deficiency through the state's normal legislative process.

3.3.7 Landslides

One of the most common and devastating geologic hazards in Oregon is landslides. Landslides can be found throughout the state of Oregon, as seen in the current statewide landslide inventory database, SLIDO R4.4, in Figure 3.3.7-1 and Table 3.3.7-1. Systematic lidar (light detection and ranging)-based landslide mapping has not been performed statewide; however, in general, the areas of the state with more relief and steeper slopes, such as the Oregon Coast Range Mountains and the Cascade Range Mountains, tend to have more landslides. In general counties in Oregon have 10-80 percent high-very high landslide susceptibility as shown in Table 3.3.7-1 derived from the LANDSLIDE SUSCEPTIBILITY OVERVIEW MAP OF OREGON.

Figure 3.3.7-1: Statewide Landslide Inventory SLIDO R4.4



Source: Franczyk, J.J., Burns, W.J., Calhoun, N.C., 2019. Statewide Landslide Information Database for Oregon, release 4 (SLIDO-4.0), Oregon Department of Geology and Mineral Industries, Digital Data Series

Table 3.3.7-1: Landslide susceptibility exposure area and percent of Oregon Counties

	County	Area, ft²	Landslide Susceptibility Exposure, ft²				Landslide Susceptibility Exposure, %				
			Low	Moderate	High	Very High	Low	Moderate	High	Very High	High + Very High
1	Baker	85,745,041,556	18,427,313,309	28,591,102,078	36,652,548,721	2,074,077,447	21.5%	33.3%	42.7%	2.4%	45.2%
2	Benton	18,898,991,855	4,992,678,348	6,847,896,474	6,304,116,636	754,300,397	26.4%	36.2%	33.4%	4.0%	37.3%
3	Clackamas	52,482,820,515	12,355,700,886	16,302,031,666	18,117,009,949	5,708,078,013	23.5%	31.1%	34.5%	10.9%	45.4%
4	Clatsop	22,700,260,108	2,057,579,309	2,998,727,490	8,227,272,218	9,416,681,090	9.1%	13.2%	36.2%	41.5%	77.7%
5	Columbia	18,493,573,546	3,374,518,239	4,776,747,887	8,769,151,149	1,573,156,271	18.2%	25.8%	47.4%	8.5%	55.9%
6	Coos	45,354,938,031	5,041,191,570	9,481,330,213	27,924,790,190	2,907,626,058	11.1%	20.9%	61.6%	6.4%	68.0%
7	Crook	83,235,830,831	31,141,381,608	32,866,611,254	15,526,337,997	3,701,499,972	37.4%	39.5%	18.7%	4.4%	23.1%
8	Curry	45,638,104,103	2,650,164,204	9,240,540,460	29,689,033,857	4,058,365,582	5.8%	20.2%	65.1%	8.9%	73.9%
9	Deschutes	85,109,220,479	56,546,695,507	21,081,050,738	7,454,901,368	26,572,866	66.4%	24.8%	8.8%	0.0%	8.8%
10	Douglas	141,317,397,747	12,133,858,652	34,455,769,154	86,836,593,291	7,891,176,650	8.6%	24.4%	61.4%	5.6%	67.0%
11	Gilliam	33,662,136,614	12,523,087,774	10,703,927,449	10,212,038,271	223,083,120	37.2%	31.8%	30.3%	0.7%	31.0%
12	Grant	126,193,657,306	21,247,595,262	47,465,778,299	49,675,296,954	7,804,986,790	16.8%	37.6%	39.4%	6.2%	45.5%
13	Harney	285,145,843,006	179,502,123,490	70,358,116,375	33,801,473,019	1,484,130,121	63.0%	24.7%	11.9%	0.5%	12.4%
14	Hood River	14,582,414,844	1,451,272,957	4,745,622,963	7,427,134,785	958,384,139	10.0%	32.5%	50.9%	6.6%	57.5%
15	Jackson	78,133,339,144	13,872,632,498	24,452,787,551	34,772,529,510	5,035,389,585	17.8%	31.3%	44.5%	6.4%	50.9%
16	Jefferson	49,946,523,725	16,986,526,937	16,904,142,211	14,442,672,705	1,613,181,872	34.0%	33.8%	28.9%	3.2%	32.1%
17	Josephine	45,768,477,096	5,686,920,023	8,136,650,857	31,328,675,574	616,230,642	12.4%	17.8%	68.5%	1.3%	69.8%
18	Klamath	171,143,448,274	102,628,506,245	48,063,317,411	19,450,752,096	1,000,872,523	60.0%	28.1%	11.4%	0.6%	11.9%
19	Lake	233,060,448,824	158,329,067,591	51,170,622,619	20,371,153,624	3,189,604,990	67.9%	22.0%	8.7%	1.4%	10.1%
20	Lane	128,802,991,658	16,755,013,466	38,682,477,990	64,663,344,708	8,702,155,495	13.0%	30.0%	50.2%	6.8%	57.0%
21	Lincoln	27,673,176,599	1,939,016,555	5,560,163,586	17,098,652,531	3,075,343,928	7.0%	20.1%	61.8%	11.1%	72.9%
22	Linn	64,272,873,796	18,507,907,440	13,731,267,567	23,983,676,960	8,050,021,829	28.8%	21.4%	37.3%	12.5%	49.8%
23	Malheur	276,601,766,018	141,882,833,248	85,058,608,415	45,456,525,427	4,203,798,928	51.3%	30.8%	16.4%	1.5%	18.0%
24	Marion	33,185,295,063	14,072,342,462	7,642,297,819	9,550,677,782	1,919,977,000	42.4%	23.0%	28.8%	5.8%	34.6%
25	Morrow	56,628,190,492	24,805,570,909	20,356,455,504	11,380,627,588	85,536,491	43.8%	35.9%	20.1%	0.2%	20.2%
26	Multnomah	12,223,672,777	4,712,992,825	3,638,767,903	3,250,418,931	621,493,118	38.6%	29.8%	26.6%	5.1%	31.7%
27	Polk	20,738,900,872	6,469,153,617	4,251,225,794	9,539,951,545	478,569,915	31.2%	20.5%	46.0%	2.3%	48.3%
28	Sherman	23,057,239,569	11,360,531,905	6,323,824,280	5,342,690,616	30,192,769	49.3%	27.4%	23.2%	0.1%	23.3%
29	Tillamook	31,340,756,476	2,581,502,742	2,662,963,451	19,610,618,770	6,485,671,513	8.2%	8.5%	62.6%	20.7%	83.3%
30	Umatilla	89,769,773,294	31,779,595,578	31,033,819,776	26,074,546,107	881,811,833	35.4%	34.6%	29.0%	1.0%	30.0%
31	Union	56,832,962,984	13,721,146,622	21,385,787,806	18,471,463,366	3,254,565,190	24.1%	37.6%	32.5%	5.7%	38.2%
32	Wallowa	87,790,890,515	14,105,102,624	22,837,879,148	49,487,844,531	1,360,064,213	16.1%	26.0%	56.4%	1.5%	57.9%
33	Wasco	66,503,203,674	18,224,397,082	27,164,026,064	17,382,971,537	3,731,808,991	27.4%	40.8%	26.1%	5.6%	31.8%
34	Washington	20,258,824,921	6,371,254,612	5,934,460,272	7,147,799,469	805,310,569	31.4%	29.3%	35.3%	4.0%	39.3%
35	Wheeler	47,835,198,973	4,792,578,409	17,939,448,483	19,167,910,975	5,935,261,107	10.0%	37.5%	40.1%	12.4%	52.5%
36	Yamhill	20,024,032,738	5,285,461,212	4,235,189,720	9,399,065,951	1,104,315,854	26.4%	21.2%	46.9%	5.5%	52.5%

Source: Burns, W.J., Mickelson, K.A., Madin, I.P., 2016. Statewide landslides susceptibility overview map of Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-16-02.

DOGAMI found that in order to truly understand the landslide hazard in Oregon, lidar (light detection and ranging) topographic data must be collected and used during the mapping of existing landslides and modeling of future susceptibility. Completing this type of mapping and modeling is one of DOGAMI's long-term goals.

Average annual repair costs for landslides in Oregon exceed $10 million and individual severe winter storm losses can exceed $100 million (Wang, Summers, & Hofmeister, 2002). As population growth continues to expand and development into landslide susceptible terrain occurs, greater losses are likely to result.

Landslides in Oregon are typically triggered by periods of heavy rainfall and/or rapid snowmelt. Earthquakes, volcanoes, and human activities also trigger landslides.

Three main factors influence an area's susceptibility to landslides: geometry of the slope, geologic material, and water. Certain geologic formations are more susceptible to landslides than others. In general, locations with steep slopes are most susceptible to landslides, and the landslides occurring on steep slopes tend to move more rapidly and therefore may pose life safety risks.

3.3.7.1 Analysis and Characterization

El Niño Southern Oscillation and Effects on Landslides

The strongest impacts of intra-seasonal variability on the U.S. occur during the winter months over the western U.S. During the winter this region receives the bulk of its annual precipitation. Storms in this region can last for several days or more and are often accompanied by persistent atmospheric circulation features. Of particular concern are the extreme precipitation events which are linked to flooding and landslide. There is strong evidence for a linkage between weather and climate in this region from studies that have related the El Niño-Southern Oscillation (ENSO) to regional precipitation variability. From these studies it is known that extreme precipitation events can occur at all phases of the El Niño-Southern Oscillation (ENSO) cycle, but the largest fraction of these events occur during La Niña episodes and during ENSO-neutral winters. During La Niña episodes much of the Pacific Northwest experiences increased storminess, increased precipitation and more overall days with measurable precipitation. The risk of flooding and rain-induced landslides (and debris flows) in this region can be related to La Niña episodes.

Source: NOAA/Climate Prediction Center, http://www.cpc.noaa.gov/products/intraseasonal/intraseasonal_faq.html#usimpactsSource: NOAA/Climate Prediction Center, http://www.cpc.noaa.gov/products/intraseasonal/intraseasonal_faq.html#usimpacts

The term "landslide" encompasses a wide range of geologic processes and a variety of nomenclatures that can lend itself to confusion. The general term landslide refers to a range of mass movement including rock falls, debris flows, earth slides, and other mass movements. One very important thing to understand is the fact that all landslides have different frequencies of movements, triggering conditions, and very different resulting hazards.

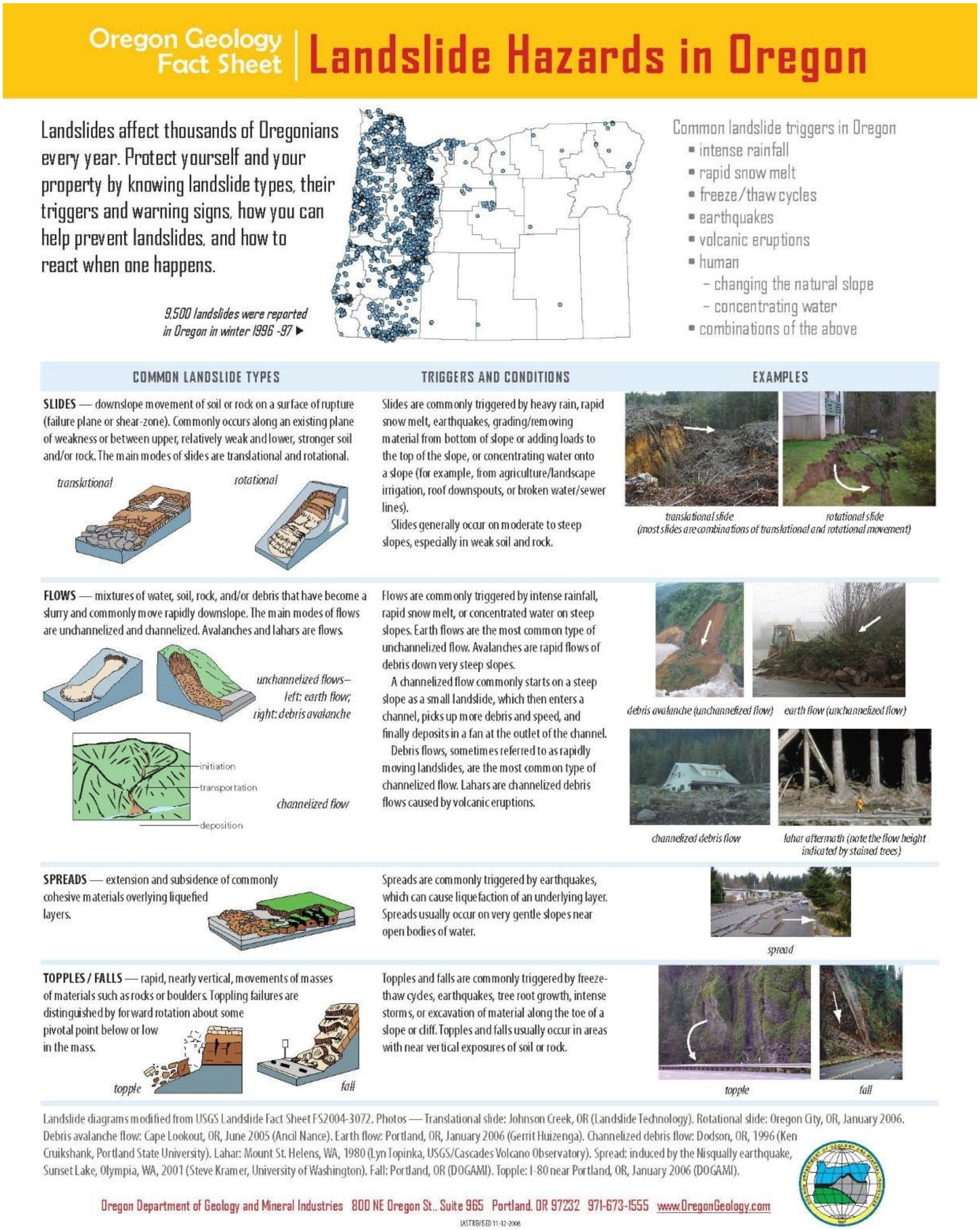
All landslides can be classified into one the following six types of movements: (a) slides, (b) flows, (c) spreads, (c) topples, (d) falls, and (f) complex (Figure 3.3.7-2). Most slope failures are complex combinations of these distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard associated with the landslide, the landslide characteristics, identification methods, and potential mitigation alternatives.

These types of movements can be combined with other aspects of the landslide such as type of material, rate of movement, depth of failure, and water content for a better understanding of the type of landslide.

One potentially life-threatening type of landslide is the channelized debris flow or "rapidly moving landslide," which initiates upslope, moves into and down a steep channel (or drainage) and deposits material, usually at the mouth of the channel. Debris flows are also commonly initiated by other types of landslides that occur on slopes near a channel. They can also initiate within the channel in areas of accelerated erosion during heavy rainfall or snowmelt. Rapidly moving landslides have caused most of the recent landslide related injuries and deaths in Oregon. Debris flows or rapidly moving landslides following storms caused eight deaths in Oregon in 1996, a La Niña year.

Areas that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. This commonly leads to distinctive geomorphology that can be used to identify landslide areas, although over time the geomorphic expression may become subtle, making the landslide difficult to identify. Other types of landslides tend to occur in the same locations and produce distinctive geomorphology, such as channelized debris flows, which form a fan at the mouth of the channel after repeated events. This is also true for the talus slopes, which form after repeated rock fall has taken place in an area.

Figure 3.3.7-2: Common Types of Landslides in Oregon.



Source: DOGAMI, Landslide Hazards in Oregon fact sheet (http://www.oregongeology.org/pubs/fs/landslide-factsheet.pdf)

Previously impacted areas are particularly important to identify, as they may pose a substantial hazard for future instability and help identify areas that are susceptible to future events. Large, slow moving landslides frequently cause significant property damage, but are far less likely to result in serious injuries. The 1997 Tillamook County, and the 2005 Oregon City slides are examples.

The velocity of landslides varies from imperceptible to tens of miles per hour. Some volcanic induced landslides have been known to travel between 50 to 150 miles per hour. On less steep slopes, landslides tend to move slowly and cause damage gradually. Debris flows typically start on steep hillsides as shallow landslides, enter a channel, then liquefy and accelerate. Canyon bottoms, stream channels, and outlets of canyons can be particularly hazardous. Landslides can move long distances, sometimes as much as several miles. The Dodson debris flows in 1996 started high on Columbia River Gorge cliffs and traveled down steep canyons to form debris fans in the Dodson-Warrendale area.

Post-fire debris flows are also a threat in areas of Oregon burned by wildfires. In 2017, the Eagle Creek Fire occurred in the Columbia River Gorge, then in 2021 and 2022 hundreds of post-fire debris flows were triggered during atmospheric river type storms. One of these resulted in a fatality.

Landslide recurrence interval is highly variable. Some large landslides move continuously at very slow rates. Others move periodically during wet periods. Very steeply sloped areas can have relatively high landslide recurrence intervals (10 to 500 years on an initiation site basis).

Because debris flows can be initiated at many sites over a watershed, in some cases recurrence intervals can be less than 10 years. Slope alterations can greatly affect recurrence intervals for all types of landslides, and also cause landslides in areas otherwise not susceptible. Most slopes in Western Oregon steeper than 30 degrees (about 60 percent) have a risk of rapidly moving landslide activity regardless of geologic unit. Areas directly below these slopes in the paths of potential landslides are at risk as well.

Based on the Oregon Department of Forestry Storm Impacts Study, the highest debris flow hazard occurs in western Lane County, western Douglas County, and Coos County. The combination of steep slopes and geologic formation (sedimentary rock units) contributes to the increased hazard. The debris flow hazard is also high in much of the Oregon Coast Range and Cascade Range Mountains and in the Columbia River Gorge.

Deep landslides are generally defined as having a failure plane within the regional bedrock unit (generally greater than 15 feet deep), whereas the failure plane of shallow landslides is commonly between the thin soil mantle and the top of the bedrock. Deep landslide hazard is high in parts of the Coast Range. Deep landslides are fairly common in pyroclastic rock units of the Western Cascade Range Mountains, and in fine-grained sedimentary rock units of the Oregon Coast Range. Deep landslides also occur in semi-consolidated sedimentary rocks at or near the Oregon coast and in the Troutdale Formation in the northern portions of the Willamette Valley.

Infrequent very large landslides and debris flows may occur in any of the larger mountain ranges or in deep gorges throughout Oregon.

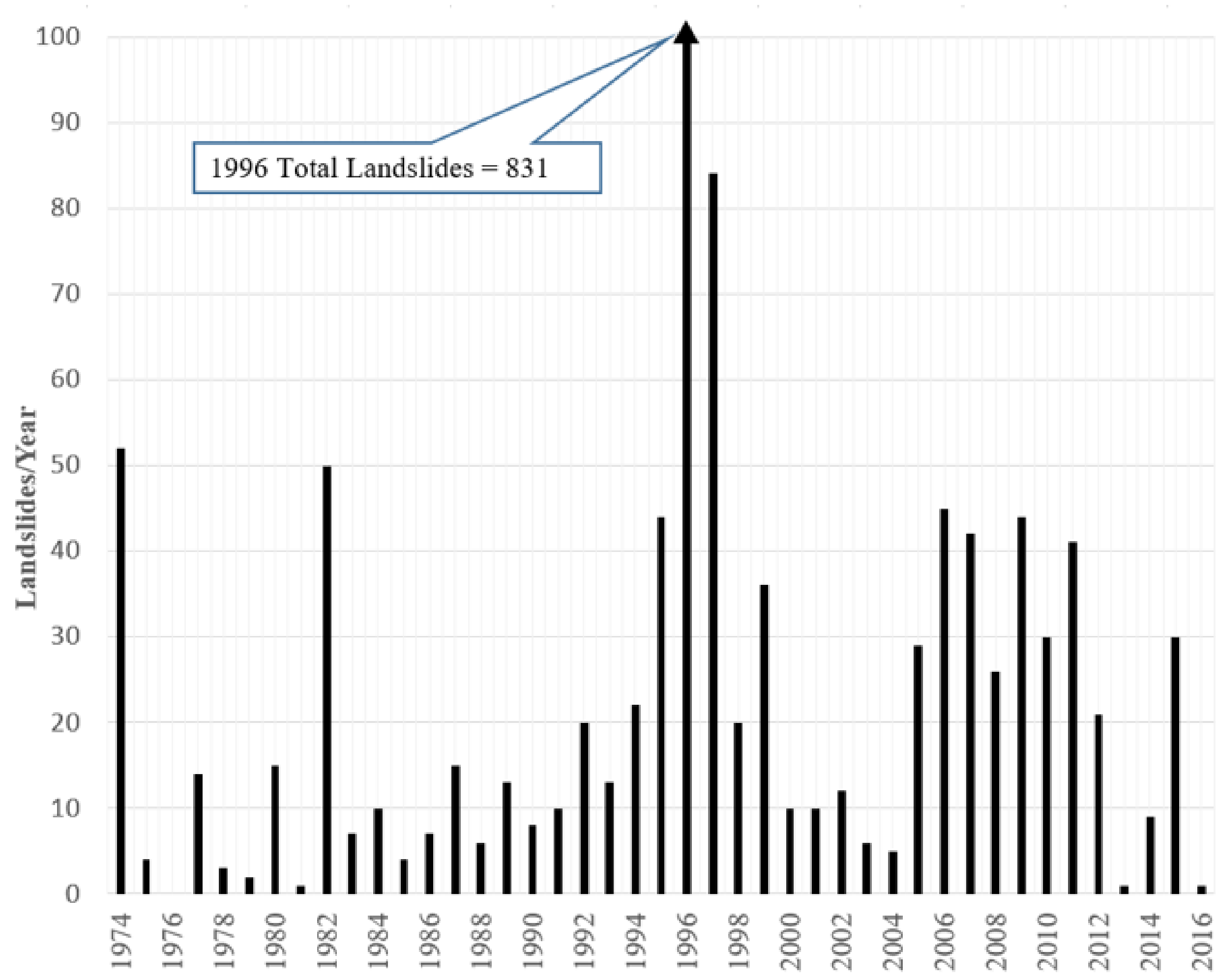
During 1996 and 1997, heavier than normal rains caused over 700 landslides within the Portland Metropolitan region, which totaled over $40 million for mitigation (Burns, Burns, James, & Hinkle, 1998). In the City of Portland, 17 homes were completely destroyed and 64 were badly damaged. There were no serious injuries associated with the landslides in Portland or in other urban areas within Oregon during the 1996 storms.

The Oregon Department of Forestry Storm Impacts Study estimated that tens of thousands of landslides occurred on steep slopes in the forests of Western Oregon during 1996. Areas with recent logging, especially clear cutting, and areas near forest roads had a higher likelihood of landslides. The Oregon Department of Geology and Mineral Industries Slope Failures in Oregon inventoried thousands of reports of landslides across the state resulting from the 1996-1997 storms. There are a significant number of locations in Oregon that are impacted frequently (every 10 to 100 years) by dangerous landslides. The number of injuries and deaths in the future will be directly related to vulnerability: the more people in these areas, the greater the risk of injury or death.

3.3.7.2 Historic Landslide Events

Oregon has declared 41 major disaster declarations from 1955 through 2024. Thirty seven of these are related to storm events causing flooding and landslides. One of the most significant of these disasters is the 1996 and 1997 storms, which caused thousands of landslides in Oregon. The City of Portland has some of the best landslide records in Oregon. When examining these records of 1,806 landslides, 831 of these occurred during February 1996 storm. Further examination of the data found incomplete records or lack of data collection from 1928 to 1973. Excluding the year 1996, there is an average of 20 landslides per year, from 1974 to 2016. This highlights the fact that large storm events like the February 1996 storm can cause the majority of landslides in Oregon and result in large disasters from damage and losses. However, landslides are still an annual chronic hazard.

Figure 3.3.7-3: Portland landslide events

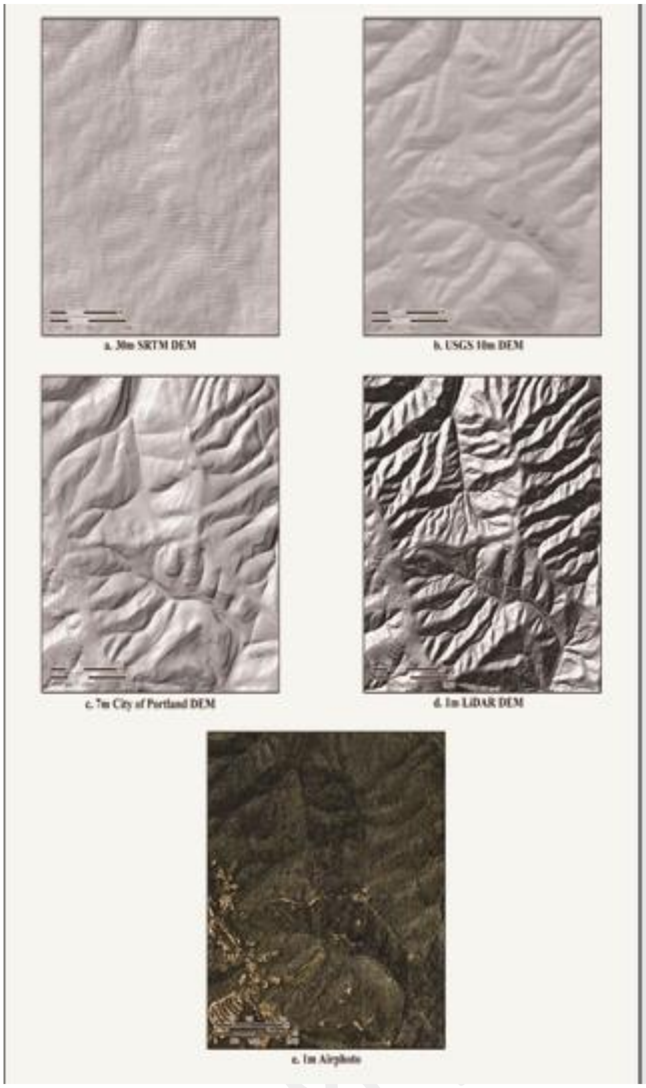


Source: Burns, W.J., Calhoun, N.C., Franczyk, J.J., Koss, R.J., Bordal, M.G., 2017. Estimating Losses from Landslides in Oregon, In De Graff, J.V. and Shakoor, A. (eds.), Landslides: Putting Experience, Knowledge and Emerging Technologies into Practice, AEG Special Publication No. 27, p. 473-482.

Landslides are found in every county in Oregon as shown in Table 3.3.7-1. There is a 100 percent probability of landslides occurring in Oregon in the future. Although DOGAMI does not know exactly where and when they will occur, they are more likely to happen in the general areas where landslides have occurred in the past. Also, they will likely occur during intense rainfall events like atmospheric river type storms which are projected to increase in frequency under future climate change, or during a future earthquake or volcanic eruption.

In order to reduce losses from landslides, areas of landslide hazard must first be identified. The first step in landslide hazard identification is to create an inventory of past landslides. Once this inventory is created, it can be used to create susceptibility maps which display areas that are likely to have landslides in the future. Once the landslide hazards are identified on inventory and susceptibility maps, the risk can be quantified, mitigation projects prioritized and implemented.

Figure 3.3.7-4: Visual Comparison of five remote sensing data sets



Note: The air photo is draped over a DEM so that it appears to have the 3-dimensional view provided by a stereo-pair
Source: Burns, W. J., 2007, Comparison of remote sensing datasets for the establishment of a landslide mapping protocol in Oregon. AEG Special Publication 23: Vail, Colo., Conference Presentations, 1st North American Landslide Conference.

In 2005, DOGAMI began a collaborative landslide research program with the U.S. Geological Survey (USGS) Landslide Hazards Program to identify and understand landslides in Oregon. In order to begin the extensive undertaking of mapping existing landslides throughout Oregon, a pilot project area was selected to compare remote sensing data/images for effectiveness. The remote sensing data sets compared included (Burns W. J., 2007) (Figure 3.3.7-4)

1. 30-m (98 ft) digital elevation model (DEM) from the Shuttle Radar Topography Mission;
2. 10-m (33 ft) DEM derived from USGS topographic quadrangles;
3. Photogrammetric and ground-based 1.5-m (5 ft) interval contour data;
4. Stereo aerial photographs from 1936 to 2000; and

5. Lidar imagery with an average of 1 data point per square meter (3.2 ft) and with a vertical accuracy of about 5 cm (6 in).

Two key findings of the pilot project were: (a) the use of the lidar data resulted in the identification of between 3 to 200 times the number of landslides identified using the other data sets, and (b) the ease and accuracy of mapping the spatial extent of the landslides identified from lidar data were greatly improved compared to other mapping methods.

When examining the results of the comparison of remote sensing data, several debris flow fans at the mouths of channels or potential channelized debris flow deposits were identified with serial stereo-pair aerial photos, which did not get identified on the lidar-derived DEMs (Digital Elevation Model). Dense development has taken place in Oregon in the last 40 years, which can mask landslide features, especially if major earthwork has taken place. In most of the populated areas of Oregon, if historic air photos are available, at least one review of (greater than 40 years old) photos should be performed.

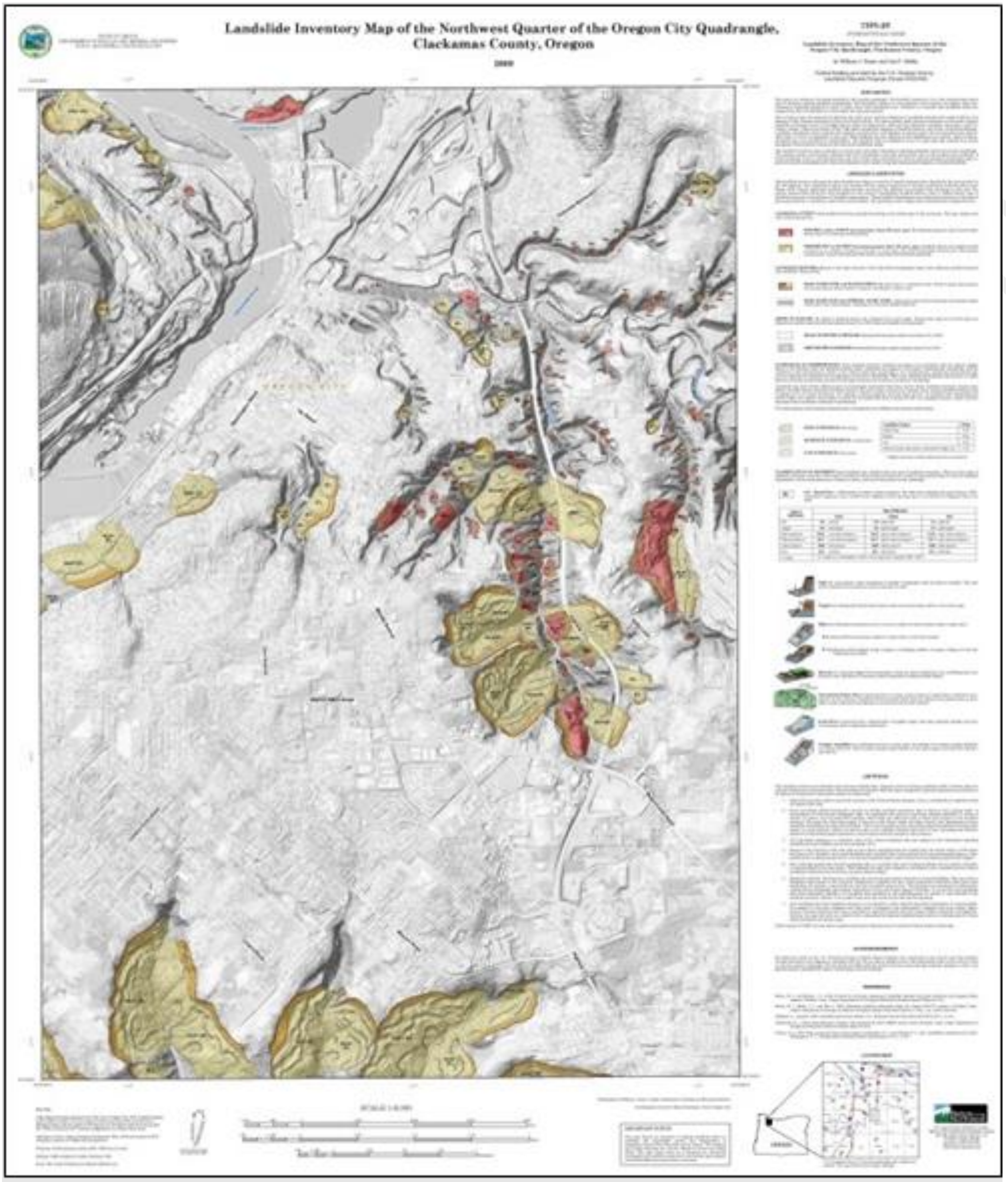
In order to develop accurate large-scale landslide inventory maps, DOGAMI recommends the following minimal requirements:

1. All previously identified landslides from geologic maps, previous landslide studies, and other local sources should be compiled.
2. The mapper should have experience identifying all types and ages of landslides within the area being studied.
3. Lidar data should be used to identify landslides and accurately locate the extents of previously mapped landslides (from step 1).
4. An orthophoto of similar age to the lidar data should be used to minimize the misidentification of man-made cuts and fills as landslides.
5. The mapper should use at least one set of historical stereo-pair aerial photography to locate landslides in the area being studied.

Non-spatial data should also be collected at the time of the mapping so that a comprehensive database can be formed. Non-spatial data should generally include confidence of interpretation, movement class, direction of movement, etc. and are described in detail in section 6.0 of this paper. A comprehensive check of spatial (map) and non-spatial data should be developed and implemented including technical review of mapped landslides and field checks where possible.

A protocol was developed by DOGAMI so that analysts can produce consistent lidar-based landslide inventory maps at an accelerated rate without having to describe how the mapping was done every time a new area is mapped (Burns & Madin, 2009). The results of following this protocol in any particular area include a very detailed database and map of the landslide inventory (Figure 3.3.7-5).

Figure 3.3.7-5: Example of a Lidar-Based Landslide Inventory (Oregon City, Oregon)

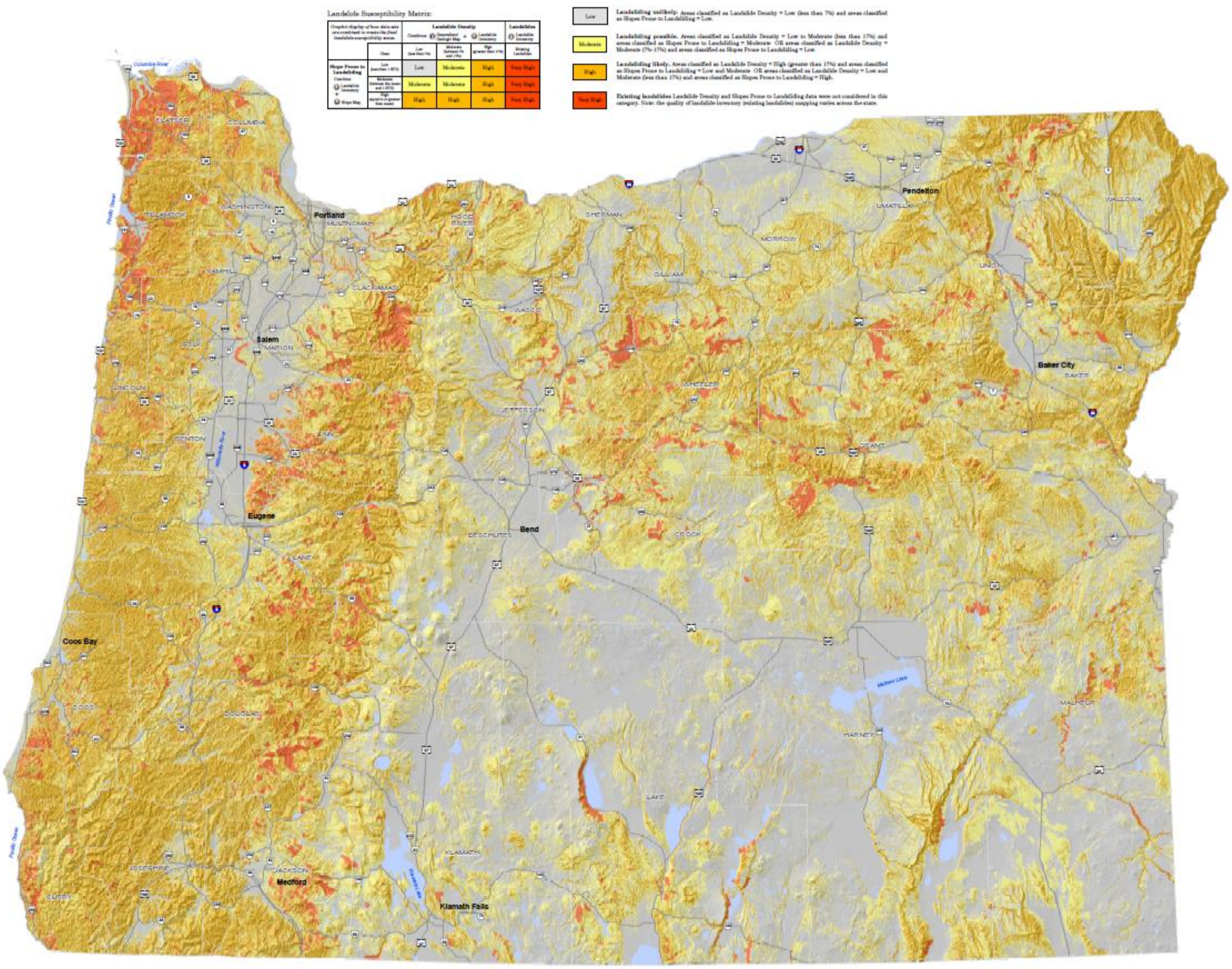


Source: Burns & Mickelson (2010)

With an accurate landslide inventory in hand, the next step in a complete landslide hazard mapping program is developing susceptibility. DOGAMI has completed a shallow landslide, deep landslide, and channelized debris flow susceptibility mapping protocols, which are being implemented in regions of

Oregon as needed and when funding is available. Because implementing these methods will take some time, a generalized landslide susceptibility map was created in 2016 (Figure 3.3.7-6).

Figure 3.3.7-6: Statewide Landslide Susceptibility Overview Map.



Source: Burns, W.J., Mickelson, K.A., Madin, I.P., 2016. Statewide landslides susceptibility overview map of Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-16-02.

There are many details which can affect the landslide risk. Some are related to the hazard and some are related to the assets. Below are lists of some of these details. This list is not comprehensive, but does provide insight into the overall landslide risk in Oregon.

Landslide Hazard:

- Spatial extent - Location of previous landslides and locations of future landslides can have a dramatic impact on landslide risk. For example, a landslide in a wilderness can have minimal risk versus a landslide in a dense urban area can result in significant damage and losses.
- Type of landslide – Different types of landslides have different sizes and rates of movement. Some types move very fast and present life safety concerns. Some are very large and can damage entire

neighborhoods. Some damage infrastructure (roads, electric, water) which can affect large regions of Oregon.

- Magnitude – The size of the landslide can have a very large range from 10 ft to 10 miles. The size of the events can have a large affect on the damage and losses.
- Frequency – How often landslides occur can increase or decrease the level of risk. For example, as previously noted, during large storm events the number of landslides can increase dramatically which can change how much damage and losses occur.

Assets:

- Built environment – Some buildings and infrastructure are more or less vulnerable to landslides depending on the construction type and geotechnical analysis and stabilization during construction. For example, a flexible conduit can withstand ground movement while a stiff conduit may fail.
- People – Every single person is unique which results in variable vulnerability to landslides. For example, one person may be aware of the life safety concern with debris flow and able to evacuate before an event while others may be unaware or unable to evacuate.
- Economy – Every community has different levels of economic resources. A community with a lot of economic resource may be able to mitigate landslide hazards and thus reduce risk, however the opposite can also be a reality.
- Environment – The environment can benefit or hinder from landslide impacts. For example, debris flow can deposit coarse grained material which can become salmon eggs in gravel nests.
- Culture (archaeology, historic sites, traditional activities) – Cultural sites can be vulnerable to landslides because they were generally constructed before scientists understood where landslides hazards may happen in the future. These sites can also be very dependent on stable ground, such as cemeteries, which can be easily severely damaged by landslides.
- Governance – Every community has different priorities and willingness to perform risk reduction within their community. If landslide risk reduction is not a priority or if the community lacks willingness to reduce landslide risk, the landslide risk may remain higher than it would in a proactive willing community.

3.3.7.3 Risk Maps

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

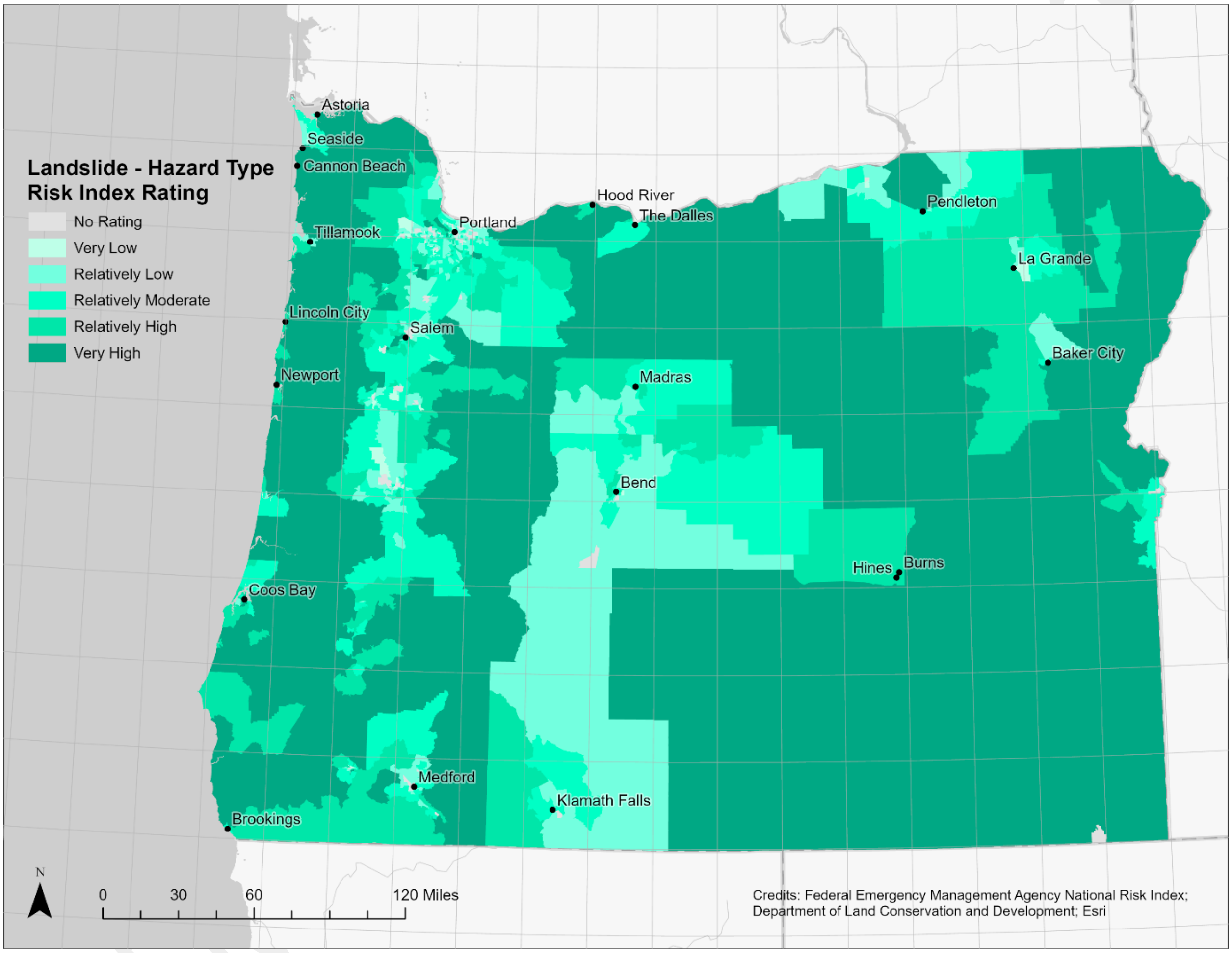
The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

The climate change maps show where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

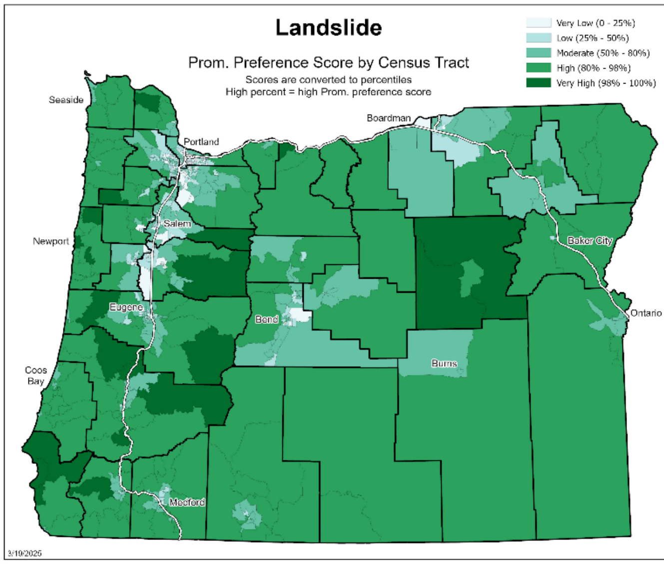
Figure 3.3.7-7: Landslide Risk Rating from the NRI. Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Landslide.



Source: Federal Emergency Management Agency, National Risk Index for Landslide. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.7-8 and Figure 3.3.7-9 show risk rankings by census tract for landslides from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.7-8 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.7-9 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

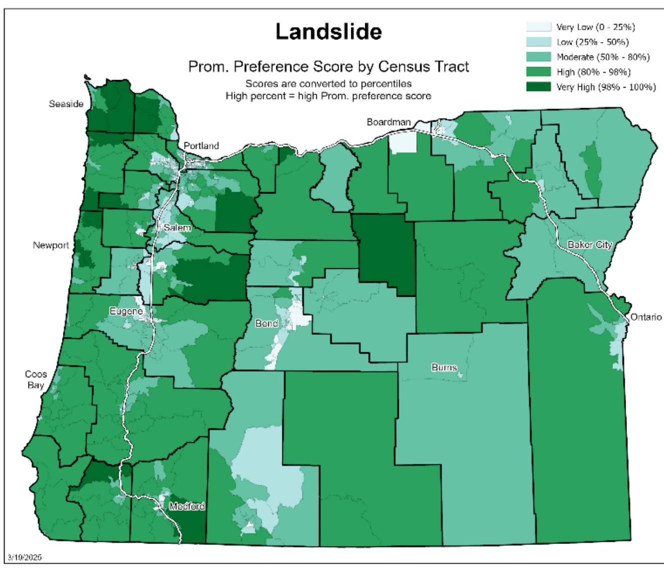
Figure 3.3.7-8: Landslide results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Landslide	LSS_pct_bld	1	0.07	Percentage of SBFO buildings exposed to existing landslide deposit.
Landslide	LSS_pct_CF	1	0.07	Percentage of critical facilities exposed to existing landslide deposit.
Landslide	Hwy_LSS_pct	1	0.07	Major roadway miles that are exposed to existing landslide deposits.
Landslide	Hist_LSS_ct	1	0.07	Percentage of historic buildings exposed to existing landslide deposit.
Landslide	LSS_Haz_Area	1	0.07	Area of tract in high or very high landslide hazard.
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

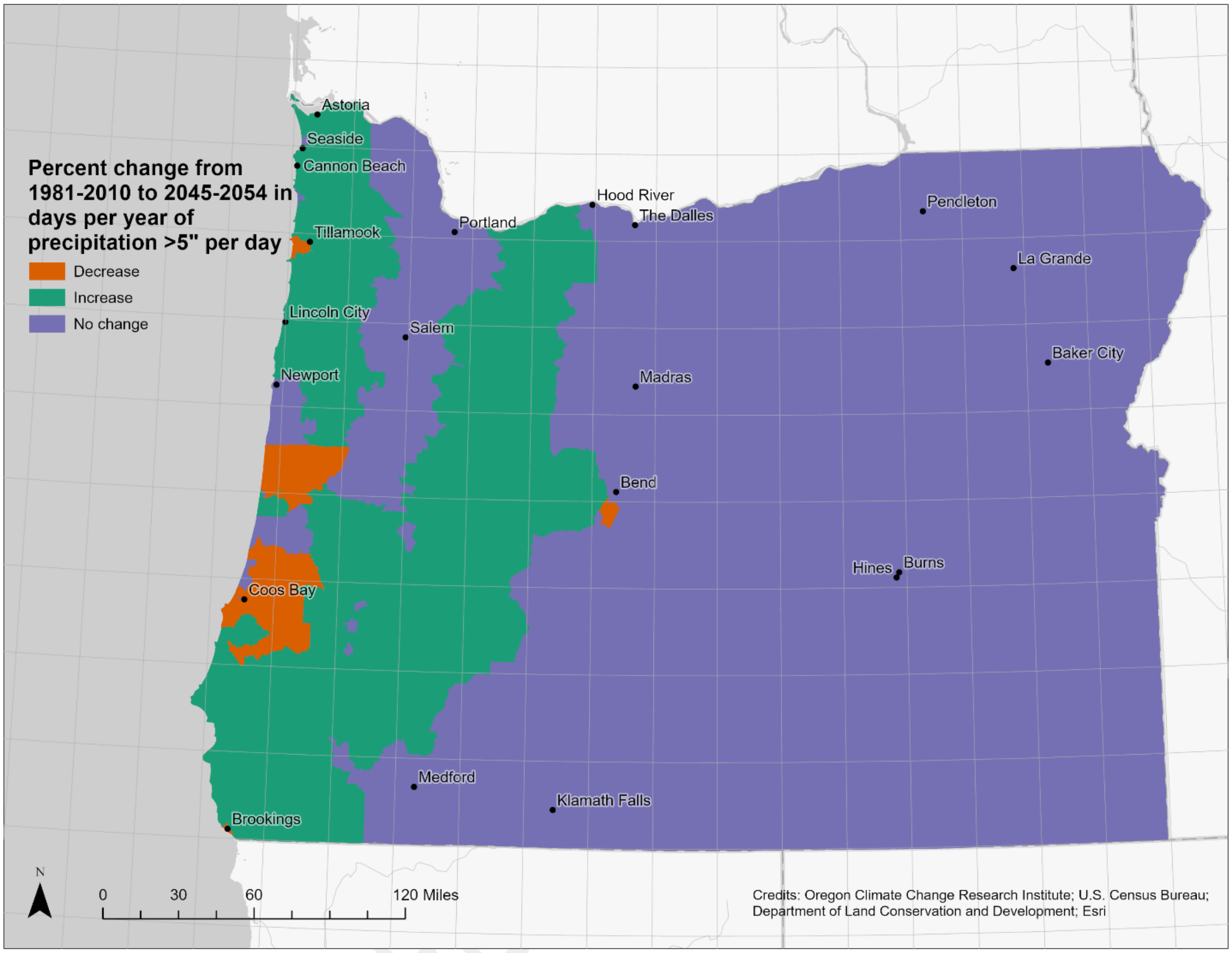
Figure 3.3.7-9: Landslide results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included.



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Landslide	LSS_pct_bld	1	0.2	Percentage of SBFO buildings exposed to existing landslide deposit.
Landslide	LSS_pct_CF	1	0.2	Percentage of critical facilities exposed to existing landslide deposit.
Landslide	Hwy_LSS_pct	1	0.2	Major roadway miles that are exposed to existing landslide deposits.
Landslide	Hist_LSS_ct	1	0.2	Percentage of historic buildings exposed to existing landslide deposit.
Landslide	LSS_Haz_Area	1	0.2	Area of tract in high or very high landslide hazard.

Figure 3.3.7-10: Change in Average Number of Heavy Precipitation Days: Change from 1981-2010 to 2045-2054 in days per year of precipitation that equals or exceeds 5 inches per day.



Source: Derived from 52 ensemble members of 11 LOCA2 downscaled global climate models. Data provided by Oregon Climate Change Research Institute, 2025. Graphic produced by DLCD.

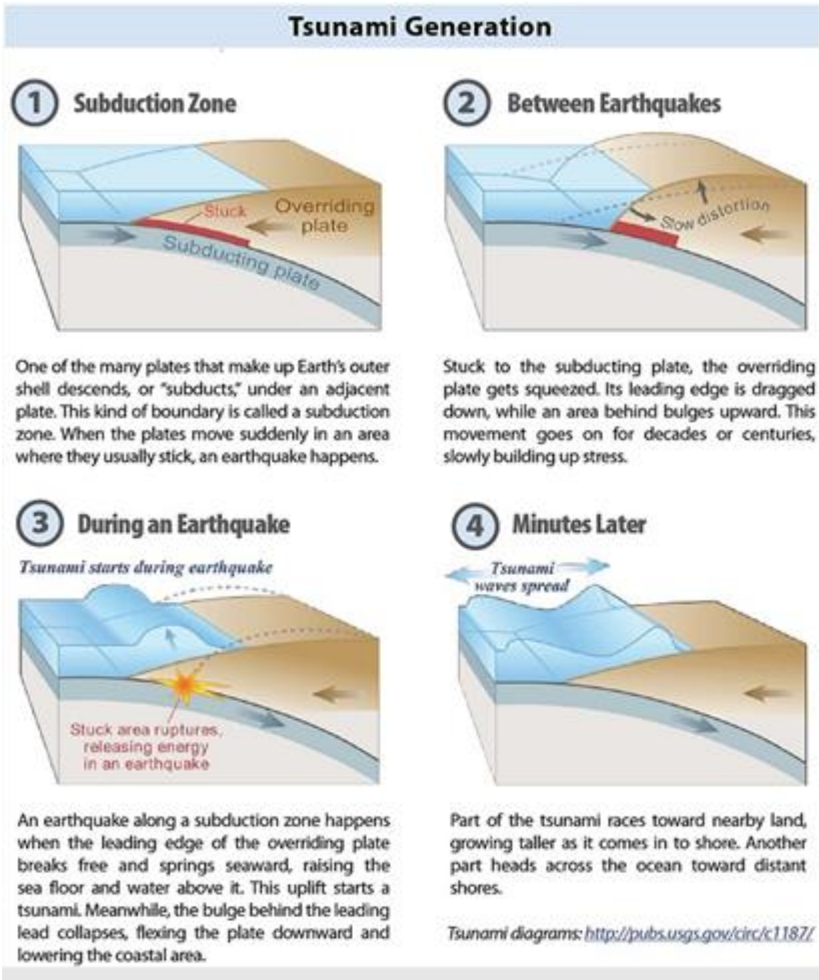
3.3.8 Tsunamis

Tsunamis are a series of water waves that may be produced by a variety of mechanisms such as seismic activity (earthquakes), aerial and submarine landslides, and volcanic eruptions. Tsunamis are almost exclusively confined to coastal margins, although they can form in inland lakes and waterways as a result of localized thrust faulting and from landslides. Earthquakes are the primary triggering mechanism, accounting for over 90 percent of tsunamis that are generated globally (Goda et al., 2025), while landslides and volcanoes produce comparatively fewer tsunamis. Landslide-induced tsunamis occur when a mass ground failure is initiated either below or above the water surface, with the tsunami wave being largely a function of the displaced landslide mass. Along low-lying coastal margins, tsunamis are often more destructive than the earthquake that caused them. Loss of lives from the tsunami can often be many times the loss of lives from the earthquake ground shaking. Property and infrastructure damage can extend miles inland and cause long lasting impacts on both the ability to recover and rebuild.

Tsunamis caused by earthquakes are the result of an abrupt, vertical uplift of the seafloor, which triggers a displacement of ocean water (Figure 3.3.8-1). The initial tsunami wave therefore mimics the shape and size of the sea floor movement that causes it, but quickly evolves into a series of waves that travel away from the source of disturbance. In the deep ocean, tsunami waves may be only a few feet high and can travel at speeds of 300–600 mph. As the tsunami travels across the deep ocean, the tsunami may interact with underwater sea mounts and islands such that refraction and diffraction processes can serve to focus and defocus the wave in different directions. These processes become especially important as the tsunami nears and eventually crosses the continental shelf, resulting in further modifications to the tsunami wave as they interact with underwater banks and canyons.

As the tsunami travels across the continental shelf, the water depth decreases. This causes the forward speed of the tsunami to begin to slow due to the frictional interaction of the tsunami with the seafloor. In order to maintain energy conservation, the tsunami wave height increases dramatically. By the time the tsunami wave strikes the coastline, it may be traveling at 30 mph and be anywhere from a few feet in height, to many 10s of feet high, depending on the proximity of the earthquake source relative to the coast, the amount of fault movement (uplift) on the subduction zone, the local coastal bathymetry (water depths), and shape of the coastline. When the wave makes landfall, the water is mobilized into a surging mass that floods inland until it runs out of mass and energy. The wave then retreats, carrying with it debris from onshore. Some of the tsunami energy is reflected off of the coastline and then can return again and again over many hours, being “trapped” on the continental shelf due to the processes of reflection and refraction. Successive waves then batter the coast with this debris. Swimming through such turbulent, fast-moving, debris-laden water is next to impossible, making survival for those caught in a tsunami wave very slim.

Figure 3.3.8-1: Generation of a Tsunami by Subduction Zone Earthquakes



Source: DOGAMI, *Cascadia,* Winter 2012 (http://www.oregongeology.org/pubs/cascadia/CascadiaWinter2012.pdf)

Tsunamis may be differentiated into two general categories: those tsunamigenic events that occur locally near the coast, and those events that may be produced in the far-field thousands of miles from a particular coast. Distant tsunami sources reflect those areas where the expected wave arrival times are generally greater than about 3 hours, allowing for extended alert and evacuation times. Conversely, locally generated tsunami result in wave arrival times measured in minutes and often result in large loss of life.

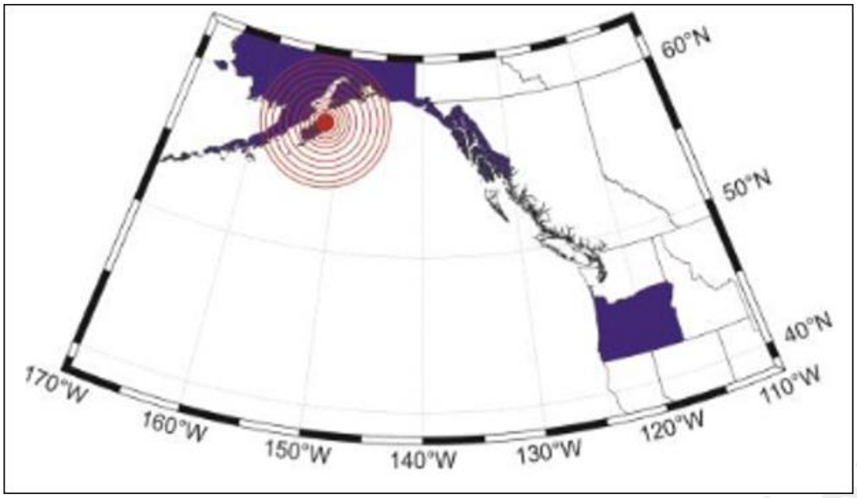
The largest tsunamis are the product of megathrust earthquakes (Moment magnitude M_W > ~8.0) that occur along subduction zones. The Cascadia Subduction Zone (CSZ) is one such region that has a long history of producing major earthquakes that can result in tsunamis. The CSZ is a 600-mile-long fault zone located offshore the coast of Oregon, Washington and Northern California and is a region where the Juan de Fuca oceanic plate is descending beneath the North American continental plate (Figure 3.3.8-2). The fault interface is located approximately 30 to 60 miles from the Oregon Coast, while the rate of convergence at the plate boundary is about 1.6 inches per year. Given that the last time the CSZ ruptured was in 1700, an estimated 43 ft of strain has already accumulated within the lock zone, as Cascadia builds towards the next megathrust earthquake and accompanying tsunami.

Figure 3.3.8-2: Cascadia Subduction Zone (CSZ) Active Fault Map. The fault, indicated by the triangles, is the contact where the Juan de Fuca Plate plunges beneath the North American continental plate.

Source: DOGAMI

Most locally generated tsunamis will produce significantly higher waves that travel farther inland (overland and up rivers) when compared with distant tsunamis generated in the far-field. Tsunami modeling undertaken by DOGAMI has revealed that a locally generated CSZ tsunami could range in height from about 20 ft to 100 ft in height; for comparison, modeling of a distant tsunami produced tsunami heights that ranged from 6 ft to ~25 ft. A local tsunami would reach the coast in as little as 10-20 minutes, with much of the open coast being fully inundated in about 30-35 minutes. Furthermore, the largest tsunami wave to strike the open coast is expected to be the initial (first) wave. However, in some upriver locations such as the middle to upper Columbia River estuary (upriver of Wanau in Clatsop County) or in the Umpqua River, the largest tsunami wave may occur several hours later after the first tsunami wave has reached the open coast, where they could combine with later occurring high tides. Modeling undertaken by DOGAMI has indicated that a CSZ tsunami wave will break up into a series of waves that will continue to strike the coast for a day or more, with the most destructive waves occurring in the first 12 hours after a local CSZ earthquake.

Figure 3.3.8-3: The greatest threat to the Oregon coast from a distant tsunami is an earthquake occurring in the eastern Aleutian Islands, Alaska. Tsunamis originating from this source would strike the coast in approximately 4 hours.



Since the Oregon Coast is part of the Pacific Basin (so called "ring of fire"), the coast is susceptible to both distant and local tsunami hazards. Aside from the CSZ, major subduction zone regions around the Pacific Basin that have a history of producing large tsunami include the Aleutian Islands in Alaska, the Kuril Island region, Japan, Tonga and potentially even Chile. However, the closest significant distant tsunami threat to the Oregon Coast is from the eastern Aleutian Islands (Figure 3.3.8-3). For example, the M_W 9.2 Good Friday 1964 Alaska tsunami reached the Oregon Coast in about four hours and killed four people in the Newport area on the central Oregon coast. In contrast, the March 11, 2011, Tōhoku Japan tsunami reached the Oregon Coast in about 9.5 hours.

3.3.8.1 Analysis and Characterization

The entire Oregon coastal zone is vulnerable to tsunami impact. Distant tsunamis caused by earthquakes on the Pacific Rim strike the Oregon coast frequently, but only a few of them have caused significant damage or loss of life. Local tsunamis caused by earthquakes on the CSZ happen much less frequently but will cause catastrophic damage and, without effective mitigation actions, great loss of life.

Notable Distant Tsunamis

There have been at least 30 distant (far-field) earthquake events over the past 160 years that have triggered a tsunami that eventually struck the Oregon Coast. The majority (19) of the tsunamis were small, with maximum water levels < 1 ft and resulted in no impact to ports and harbors on the coast. Five events produced tsunamis with heights that ranged from 1 to 2 ft, and another five produced maximum tsunami heights that exceeded 2 ft. Those events that produced the largest tsunami on the Oregon Coast included events in 1873 (Northern California), 1946 (Alaska), 1960 (Chile), 1964 (Alaska) and 2011 (Japan). Of these, the 1964 Alaska tsunami produced the largest observed water levels on the Oregon Coast that ranged from 8 to 12 ft. Table 3.3.8-1 provides a summary of recent distant tsunamis that have been observed on the Oregon Coast and their accompanying impact.

The March 1964 earthquake occurred at the eastern end of the Aleutian Islands, beneath Prince William Sound and extended westward to include the megathrust south of Kodiak Island. The earthquake ruptured a 500-mile-long section of the Aleutian Subduction Zone and produced a massive tsunami; the earthquake shaking lasted about three and half minutes. The tsunami arrived along the Alaska coastline between 20 and 30 minutes after the earthquake, devastating villages in its path. Damages were estimated to be over $100 million (1964 dollars). One hundred and thirty one people drowned. The tsunami spread across the Pacific Ocean and caused damage and fatalities in other coastal areas, including Oregon, where the tsunami killed four people and caused an estimated $750,000 to $1 million in damage. Damage was particularly significant in northern Oregon at Cannon Beach and to a lesser extent in Seaside, where observations of higher wave heights (~12 - 16 ft) were seen at the open coast, while smaller waves (~6 ft) were observed on the southern Oregon Coast near the Chetco River. In Crescent City, California, there were 10 fatalities, while damage to property and infrastructure was estimated to range from $11 to 16 million.

On December 26th 2004, a megathrust earthquake (M_W 9.2–9.3) struck the Indonesian Island of Sumatra, producing a massive tsunami that reached 100 ft in height. Although this event did not produce a tsunami on the Oregon Coast, the event is especially noteworthy simply because of the scale of the event and large loss of life. The destruction and loss of life was particularly devastating in the Aceh province in north Sumatra, close to the earthquake source and where the tsunami inundation was particularly extensive, with tsunami waves travelling well inland and up rivers and streams. Having struck Sumatra, the tsunami travelled across the Indian Ocean where it eventually impacted Sri Lanka and India, and northward into the Andamen Sea where it stuck the coast of Thailand. The tsunami killed 227,898 people and displaced some 2 to 3 million people, and its economic impact continues to be felt to the present.

On March 11th 2011, a megathrust earthquake (M_W 9.1) struck the northeast coast of Japan, inundating much of the Sendai Plain. Tsunami wave runup heights were observed to reach over 100 ft. The tsunami killed ~18,500 people, displaced some 450,000 people, and resulted in an estimated $250 billion in total losses. Furthermore, the earthquake and tsunami destroyed 121,992 buildings (282,920 buildings experienced partial collapse and 730,359 buildings were partially damaged) and damaged 4,198 roads and 116 bridges. Over 28,000 boats were either damaged or destroyed, along with 319 ports.

Figure 3.3.8-4: Damage to a port on the Chetco river caused by the 2011 Japan tsunami.

On the US West Coast, the 2011 Japan tsunami caused about $10 million in damage to ports and marinas on the southern Oregon Coast (Figure 3.3.8-4); over ~$20 million in damage was recorded at Crescent City in Northern California, along with one fatality. Oregon received a Presidential Declaration of Disaster (DR-1964) which brought millions of dollars of financial aid to repair and mitigate future tsunami damage. Debris from tsunami-damaged buildings in Japan floated across the Pacific Ocean and began arriving on the Canadian and U.S. West Coast in December 2011 and continued to arrive several years after the event.

Several smaller tsunami events have occurred since 2011. In January 2022, the Hunga Tonga-Hunga Ha'apai volcano erupted, sending waves across the Pacific Ocean towards Oregon. The eruption and tsunami caused widespread damage to buildings and four deaths in Tonga. Tsunami warnings were issued on Oregon's coast. Although there were reports of strong currents and small sea level changes, there was no damage; several ports on the California coast experienced some damage.

Table 3.3.8-1: Historic distant tsunamis observed on the Oregon Coast

Date	Origin of Event	Affected Oregon Community	Damage	Remarks
Apr. 1868	Hawaii	Astoria		observed
Aug. 1868	N. Chile	Astoria		observed
Aug. 1872	Aleutian Islands	Astoria		observed
Nov. 1873	N. California	Port Orford		debris at high tide line
Apr. 1946	Aleutian Islands	Bandon		barely perceptible
Apr. 1946		Clatsop Spit		water 3.7 m above MLLW

Date	Origin of Event	Affected Oregon Community	Damage	Remarks
Apr. 1946		Depoe Bay		bay drained; water returned as a wall
Apr. 1946		Seaside		wall of water swept up Necanicum River
Nov. 1952	Kamchatka	Astoria		observed
Nov. 1952		Bandon	log decks broke loose	
May 1960	S. Cent. Chile	Astoria		observed
May 1960		Seaside	bore on Necanicum River damaged boat docks	
May 1960		Gold Beach		observed
May 1960		Newport		observed for about 4 hours
May 1960		Netarts	some damage observed	
Mar. 1964	Gulf of Alaska	Cannon Beach	bridge and motel unit moved inland; $230,000 damage	
Mar. 1964		Coos Bay	$20,000 damage	
Mar. 1964		Depoe Bay	$5,000 damage; 4 children drowned at Beverly Beach	
Mar. 1964		Florence	$50,000 damage	
Mar. 1964		Gold Beach	$30,000 damage	
Mar. 1964		Seaside	1 fatality (heart attack); damage to city: $41,000; private: $235,000; four trailers, 10–12 houses, two bridges damaged	
May 1968	Japan	Newport		observed
Apr. 1992	N. California	Port Orford		observed
Oct. 1994	Japan	coast		tsunami warning issued, but no tsunami observed
Mar. 2011	Japan	coast	$6.7 million; extensive damage to the Port of Brookings	tsunami warning issued, observed ocean waves
Oct. 2012	Haida Gwaii, BC	coast		M 7.7 caused a tsunami with local runup of more than 7 meters and amplitudes up to 0.8 meter on tide

Date	Origin of Event	Affected Oregon Community	Damage	Remarks
				gauges 4000 kilometers away in Hawaii. Source: NOAA
Jan. 2018	Kodiak Is., AK	coast		minor tsunami impacts in AK, HI and US west coast; the largest tsunami amplitude was recorded at 25cm in Crescent City CA 4-5 hrs after the magnitude 7.9 earthquake

Sources: Lander, et al., (1993); FEMA, 2011, Federal Disaster Declaration; NOAA, https://www.ngdc.noaa.gov/hazel/view/hazards/tsunami/event-more-info/5673, downloaded on 4/15/20

Most recently, in December 2024 a shallow M_W 7.0 earthquake occurred on the Mendocino fault offshore northern California, triggering tsunami warnings for southern Oregon and northern California. These latter events, while non-life threatening, tested Oregon's tsunami preparedness, including emergency alert systems and evacuation orders.

Local Tsunamis Produced on the Cascadia Subduction Zone

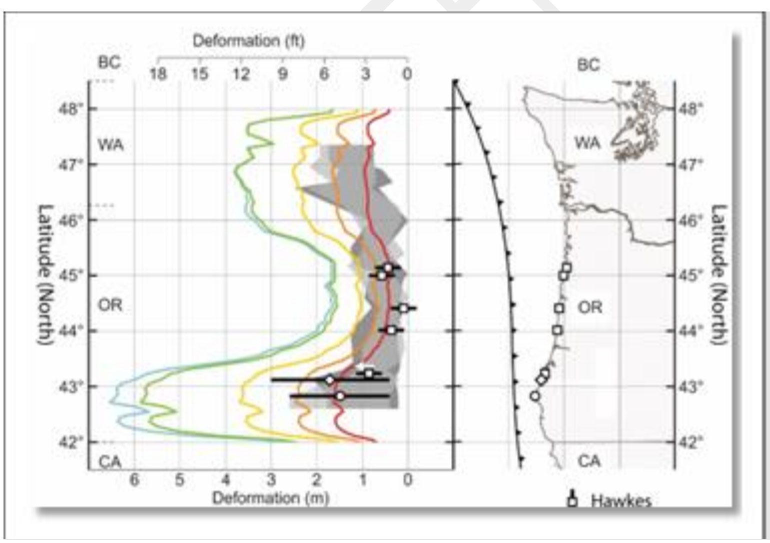
Locally generated tsunamis that occur on the CSZ are relatively low probability hazards when compared with other natural hazards that affect Oregon's coastline. The most recent occasion on which the CSZ last ruptured, occurred at 9 PM January 26, 1700. The megathrust earthquake is estimated to have had a magnitude of approximately 9.0. The earthquake generated a tsunami that caused death and damage as far away as Japan, where it was well-documented in the literature of the time. The earthquake and tsunami left behind geologic "footprints" in the form of (a) tsunami sand sheets in marshes, (b) layers of marsh vegetation covered by tide-borne mud when the coast abruptly subsided, and (c) submarine sand and silt slurries shaken off the continental shelf by the earthquake (turbidites). The widespread and large body of oral traditional history of the Thunderbird and Whale stories passed down by First Nations people depict both strong ground shaking and marine flooding that may have been inspired by this event. Although this earthquake undoubtedly produced tsunami waves that reached on the order of 30–40 feet at the coast, geologic evidence from numerous estuaries, coastal lakes and analyses of offshore turbidite deposits suggests that the 1700 earthquake was probably an average size event for this subduction zone. Some Cascadia earthquakes have been many times larger, so, while devastating, the 1700 earthquake and tsunami were far from the worst case.

Geologists working in the Cascadia region have identified evidence for at least 19 full margin earthquake ruptures of the CSZ over the past 10,000 years, along with another 26 smaller (partial) earthquake ruptures that characterized the southern Oregon Coast. Based on these data, the average recurrence of a local CSZ tsunami is estimated to be 480-505 years; average recurrence for a partial rupture of the southern end of the CSZ is ~220 years. Although infrequent, the risk of a CSZ tsunami impacting the Oregon Coast remains high. Scientists estimate the conditional probability of an earthquake on the CSZ at 16 percent –22 percent in the next 50 years, while a partial rupture of the CSZ impacting affecting the southern Oregon Coast has a higher probability of 37 percent –43 percent in the next 50 years.

In 2013, the Oregon Department of Geology and Mineral Industries (DOGAMI) completed an analysis of a suite of locally generated Cascadia tsunamis and earthquakes, separating the results into five size classes with “T-shirt” names, S, M, L, XL, and XXL. The XL or XXL events have probably only happened once or twice in the last 10,000 years, but estimated tsunami heights from these events are comparable to those experienced in the 2011 Japan and 2004 Sumatra tsunamis, the largest known. In addition to the CSZ tsunami inundation scenarios, DOGAMI also simulated two distant (far-field) tsunami events originating from the eastern Aleutian Islands in Alaska. These included the 1964 Alaska event and a larger hypothetical maximum Alaska earthquake and tsunami termed AKmax.

The CSZ tsunami wave tends to arrive at the coast as a fast-moving surge of rising water. As the tsunami enters coastal bays and rivers, the narrowing of the landform causes channeling of the wave energy, causing it to move as a high-velocity current or a breaking wave that travels up an estuary as a bore (wall of turbulent water like the waves at the coast after they break). This inland wave of water can often cause most or all of the damage, and the current may be just as destructive when it is retreating from the land as when it is advancing. For example, in Seaside the damage from the 1964 Alaskan tsunami occurred along the Necanicum River and Neawanna Creek, well inland from the coast. In addition, storm waves and wind waves may ride on top of the tsunami waves, further compounding the level of destruction.

Figure 3.3.8-5: Measured and modeled coastal subsisdence determined for the coasts of Oregon and Washington



Source: Witter et al., 2011

During Cascadia earthquakes there is also the added effect of coastal subsidence, or the drop in elevation of the land relative to sea level, during the earthquake (Figure 3.3.8-5). This is due to the release of the accumulated strain that caused the western edge of the North American Plate to bend and bulge. The new earthquake models used for the local tsunami scenarios indicate that portions of the Oregon coast could drop several feet (central Oregon Coast) to as much as 20 feet on the southern Oregon Coast.

DOGAMI completed coastwide tsunami inundation modeling in 2013 and eventually produced a series of tsunami inundation maps (TIMS) for the Oregon Coast. The inundation maps reflected the five local Cascadia tsunami scenarios (S, M, L, XL, and XXL) and two Alaska distant tsunami inundation scenarios (AK64 and AKmax). All seven are depicted on tsunami inundation maps produced by DOGAMI, plus digital files for use in geographic information systems (GIS). The five local CSZ-sourced inundation scenarios involve increasing amounts of movement (slip) on the subduction zone fault, ranging from 30 feet (S scenario) to 144 feet (XXL scenario). The seven inundation lines were eventually reduced to two zones for use in evacuation planning: AKmax inundation is the distant (orange) tsunami evacuation zone, and XXL is the local (yellow) tsunami evacuation zone. Evacuation brochures illustrating these zones and evacuation routes are available for all population centers, and both zones can also be viewed for any part of the coast using an interactive map portal and mobile phone apps at www.oregontsunami.org. The evacuation zones are critical for life safety planning and preparation. All seven scenarios were modeled on a mean higher high tide (MHHW), while the five CSZ scenarios include the effects of subsidence from the earthquake fault process (release of strain on the North American Plate). In addition to the TIMS, DOGAMI has now completed evacuation modeling for every coastal community on the Oregon Coast, which led to the development of "Beat the Wave" evacuation brochures for the XXL local CSZ tsunami. In addition to highlighting the main evacuation routes out of the tsunami inundation zone, the maps include information about how quickly people must travel in order to beat the wave.

3.3.8.2 Risk Maps

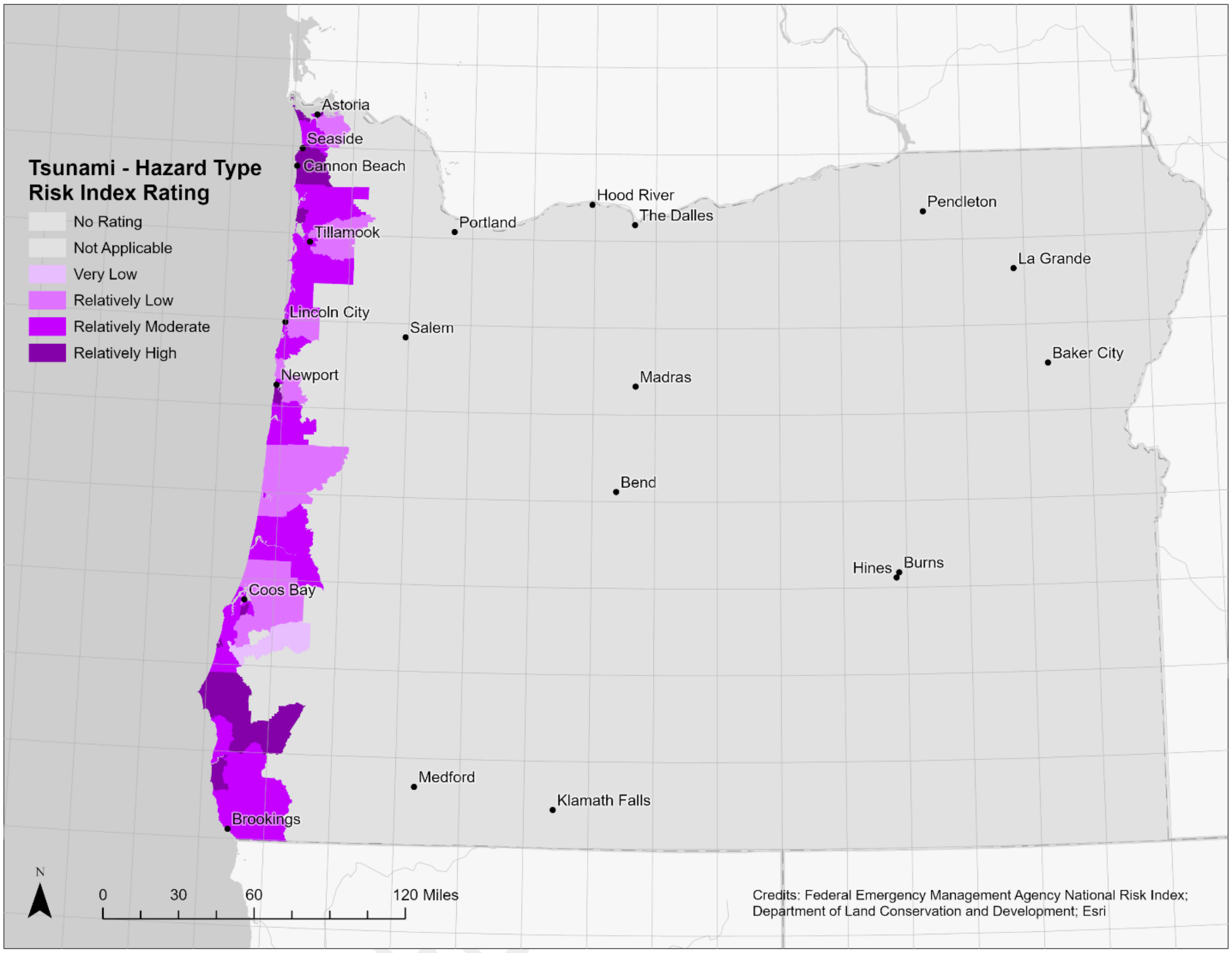
The maps in this section highlight places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

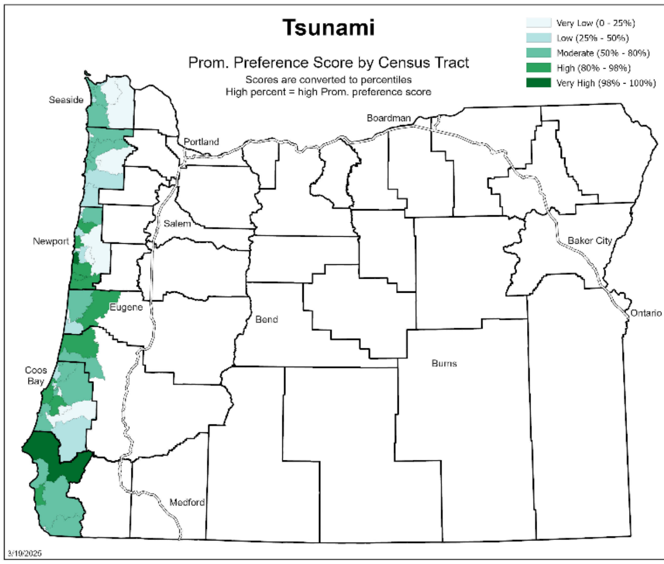
Figure 3.3.8-6: Tsunami Risk Rating from the NRI. Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Tsunami.



Federal Emergency Management Agency, National Risk Index for Tsunami. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.8-7 and Figure 3.3.8-8 show risk rankings by census tract for tsunamis from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.8-7 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.8-8 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

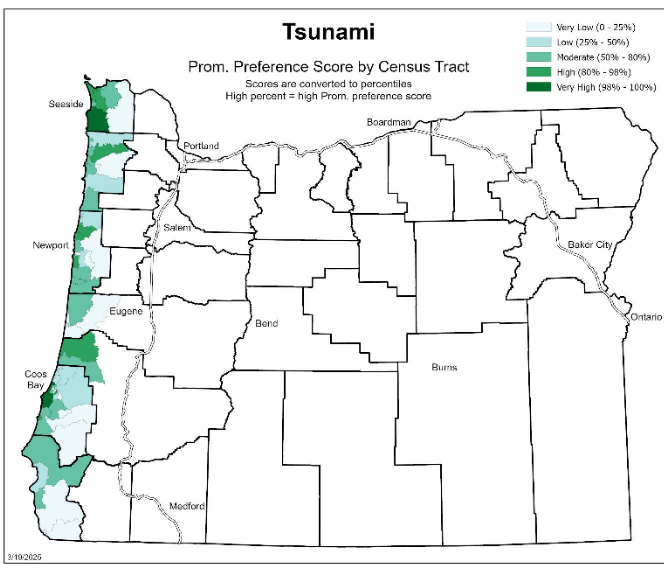
Figure 3.3.8-7:Tsunami. Results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Tsunami	TSU_pct_bld	1	0.07	Percentage of SBFO buildings exposed to any sized CSZ tsunami.
Tsunami	TSU_pct_CF	1	0.07	Percentage of critical facilities exposed to any sized CSZ tsunami.
Tsunami	Port	1	0.07	Presence of marine port infrastructure
Tsunami	Bridges_TSU	1	0.07	Number of bridges that are within a tsunami inundation zone.
Tsunami	Hist_Tsu_ct	1	0.07	Percentage of historic buildings exposed to any sized CSZ tsunami.
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

Figure 3.3.8-8: Tsunami. Results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included.



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Tsunami	TSU_pct_bld	1	0.2	Percentage of SBFO buildings exposed to any sized CSZ tsunami.
Tsunami	TSU_pct_CF	1	0.2	Percentage of critical facilities exposed to any sized CSZ tsunami.
Tsunami	Port	1	0.2	Presence of marine port infrastructure
Tsunami	Bridges_TSU	1	0.2	Number of bridges that are within a tsunami inundation zone.
Tsunami	Hist_Tsu_ct	1	0.2	Percentage of historic buildings exposed to any sized CSZ tsunami.

3.3.9 Volcanic Hazards

Volcanic eruptions are potentially destructive natural phenomena, constructed as magma ascends and then erupts onto the earth's surface. Volcanic eruptions are typically focused around a single vent area, but vary widely in explosivity. Therefore, volcanic hazards can have far reaching consequences. Volcanic hazards may occur during eruptive episodes or in the periods between eruptions.

Volcanic hazards may be divided into two categories based on the range of their impact from the eruptive center or active vent. *Proximal* volcanic hazards have an impact limited to a distance of about 30 miles or less from the active vent. *Distal* volcanic hazards have an impact far beyond the active vent. Proximal and distal hazards are individual to each volcano. In addition to the 30-mile threshold, proximal and distal zone boundaries are based on:

- Frequency and magnitude of past events at the volcano, as recorded by their deposits;
- Modeling that predicts the extent, depth, and travel time of future events; and
- Experience and judgment derived from observations and understanding of events at other volcanoes.

Eruptive events may include proximal hazards such as:

- Lava flows;
- Pyroclastic surges and flows (fast-moving combination of very hot ash, lava, and gases);
- Lahars (volcanic mudflows or debris flows);
- Debris avalanches (landslides);
- Release of volcanic gases; and
- Tephra fall (shower of ejected rock fragments and particles);

As well as distal hazards such as:

- Lahars;
- Eruption columns and clouds; and
- Ashfall.

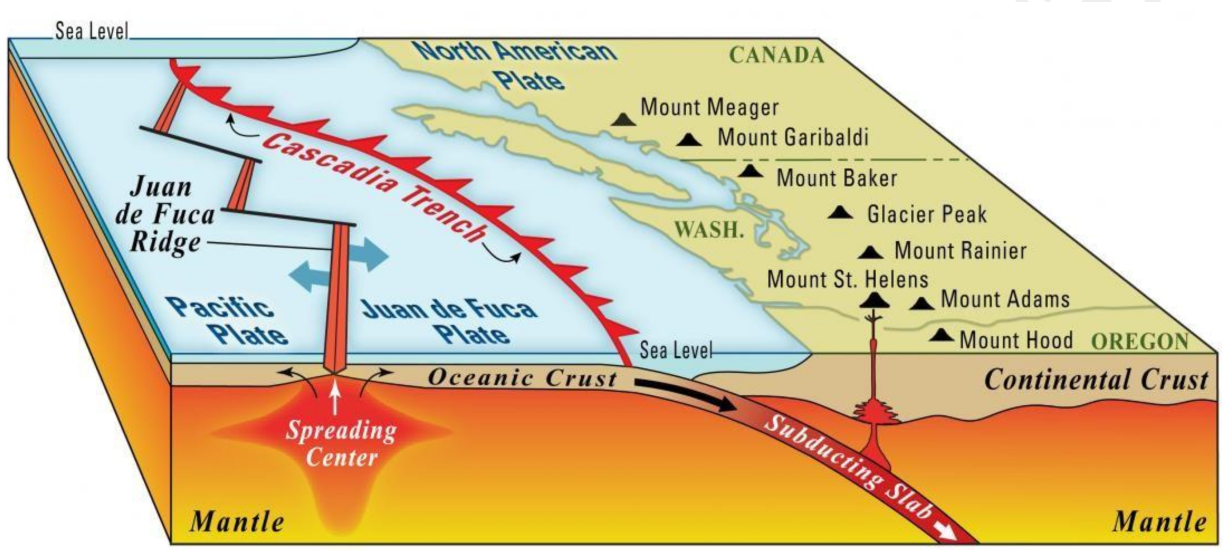
Eruptions may last from days to weeks or years, and have the potential to dramatically alter the landscape for decades. Unlike other geologic hazards (e.g., earthquakes, tsunamis), impending eruptions are often foreshadowed by a number of precursors including ground movements, earthquakes, and changes in heat output and volcanic gases. Scientists use these clues to recognize a restless volcano and to prepare for events that may follow. Hazards occurring between eruptive periods are typically related to earthquakes or natural erosion, which may trigger debris avalanches or debris flows on the flanks of the volcano. Such events often occur without warning.

Potentially hazardous volcanoes in Oregon are present along the crest of the Cascade Range and to a lesser extent in the High Lava Plains. The volcanoes within these regions provide some of Oregon's most spectacular scenery and popular recreational areas, yet the processes that led to their formation also present significant challenges and hazards to communities within the region. The catastrophic eruption of Washington's Mount St. Helens in 1980 and subsequent activity demonstrate both the power and detrimental consequences that Cascade-type volcanoes can have on the region. Lessons learned at Mount St. Helens led the U.S. Geological Survey (USGS) to establish the Cascades Volcano Observatory (CVO) in Vancouver, Washington. Scientists at CVO continually monitor volcanic activity within the Cascade Range, and in cooperation with the Oregon Department of Geology and Mineral Industries (DOGAMI), study the geology of volcanic terrains in Oregon (Ewart, Diefenbach, & Ramsey, 2018).

3.3.9.1 Analysis and Characterization

The volcanic Cascade Range extends southward from British Columbia into northern California. The volcanoes are a result of the complex interaction of tectonic plates along the Cascadia Subduction Zone (CSZ). Subduction is the process that results in the Juan de Fuca plate (oceanic crust) subducting, or sinking, underneath the North American plate (continental crust) on which people live (Figure 3.3.9-1). As the subducted plate descends, it heats up and begins to melt. This provides the reservoir of heat and molten rock needed to create the magma chambers that lie kilometers deep, beneath the Cascades.

Figure 3.3.9-1: Generalized Subduction Zone Setting.



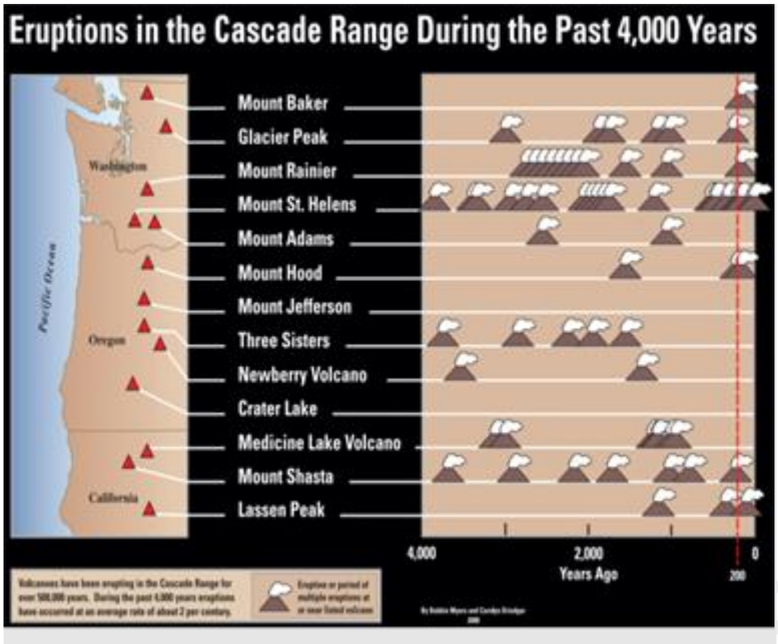
Source: Cascades Volcano Observatory Popular Graphics image gallery, http://volcanoes.usgs.gov/vsc/multimedia/cvo_popular_graphics_gallery.html

Stratovolcanoes like Mount Hood, also called composite volcanoes, are generally tall, steep, conical shaped features, built up through layering of volcanic debris, lava, and ash. Eruptions tend be explosive, for example, the violent 1980 eruption of Mount St. Helens, and they produce volcanic mudflows (lahars) that can travel far from the mountain. Future eruptions are likely to be similar and present a severe hazard to the surrounding area.

Volcanoes also pose other hazards because of their geology and resulting geomorphology. The relatively high elevation of volcanoes usually results in a meteorological effect called *orographic lifting*, which causes high precipitation and snow on the mountains that can result in flooding. The geologic material tends to be relatively weak and, when combined with the steep slopes, can cause frequent and hazardous landslides. Cascade Mountain Range volcanoes are also located near the active CSZ and nearby potentially active crustal faults, which contribute to moderate seismic hazard in the area.

The volcanoes of the Cascade Range have a long history of eruption and intermittent quiescence. Note that in Figure 3.3.9-2, each volcano has a different frequency of eruption. Not all Cascade volcanoes have been active in the recent past. This is typical of a volcanic range and is one of the reasons forecasting eruptions can be difficult.

Figure 3.3.9-2: Eruptions in the Cascade Range During the Past 4,000 Years



Source: Myers and Driedger (2008)

Several smaller volcanoes, including Diamond Craters and Jordan Craters, in the High Lava Plains of southeast Oregon have experienced eruptions in the last 6,000 years. Generally nonexplosive eruptions at these sites have built complexes of lava flow fields and cinder cones. Unlike the far-reaching effects that may be generated by large, potentially explosive stratovolcanoes in the Cascade Range, hazards associated with future eruptions in sparsely populated southeast Oregon are most likely limited to localized lava flows.

Eruptive Hazards

Each eruption is a unique combination of hazards. Not all hazards will be present in all eruptions, and the degree of damage will vary. It is important to know that during an active period for a volcano many individual eruptions may occur and each eruption can vary in intensity and length. For example, while Mount St. Helens is best known for its catastrophic May 1980 eruption, periodic eruptions of steam and ash and the growth of a central lava dome have continued to pose a hazard since that time.

Proximal Hazards

Lava Flows

Lava flows are streams of molten rock that erupt relatively non-explosively from a volcano and move downslope. Hazards associated with lava flow events include ashfalls near vents; extensive damage or total destruction of objects in the lava flow path(s) by burning, crushing, or burial; and disruption of local stream drainages. Lava flows are generally not life threatening because people can usually outwalk or outrun them. The Parkdale Lava Flow, located along the north flank of Mount Hood, erupted from a small vent about 7,600 years ago (Figure 3.3.9-3)

Figure 3.3.9-3: Oblique Air-View of the Parkdale Lava Flow. The flow erupted around 7,600 years ago from a small vent located about 6 miles south of Parkdale, Oregon.

Image source: Bill Burns, DOGAMI

Pyroclastic Flows and Surges

Pyroclastic flows are avalanches of rock and gas at temperatures of 600 to 1,500 °F. They typically sweep down the flanks of volcanoes at speeds of up to 150 miles per hour. Pyroclastic surges are a more dilute mixture of gas and rock. They can move even more rapidly than a pyroclastic flow and are more mobile. Both generally follow valleys, but surges especially may have enough momentum to overtop hills or ridges. Because of their high speed, pyroclastic flows and surges are difficult or impossible to escape. If it is expected that they will occur, evacuation orders should be issued as soon as possible for the hazardous areas. Objects and structures in the path of a pyroclastic flow are generally destroyed or swept away by the impact of debris or by accompanying hurricane-force winds. Wood and other combustible materials are commonly burned. People and animals may also be burned or killed by inhaling hot ash and gases. The deposit that results from pyroclastic flows is composed of a combination of ash, pumice, and rock fragments. These deposits may accumulate to hundreds of feet thick and can harden to a resistant rock called tuff. Pyroclastic flows and surges are considered a proximal hazard, but in some instances may extend tens or even hundreds of miles from the volcanic vent.

Lahars

Cascade Range volcanoes and the floodplains that drain them contain abundant evidence for past lahar events. Lahars or volcanic debris flows are water-saturated mixtures of soil and rock fragments originating from a volcano. These sediment gravity flows can travel very long distances (over 62 miles) and travel as fast as 50 miles per hour in steep channels close to a volcano; further downstream, where they reach gently sloping valley floors, speeds generally slow to 10 to 20 miles per hour. The largest of these flows are known to transport boulders exceeding 30 ft in diameter. Lahars are often associated with eruptions, but they can also be generated by rapid erosion of loose rock during heavy rains or by sudden outbursts of glacial water. Highly erodible, unconsolidated lahar deposits may be easily remobilized by normal rainfall, snowmelt, and streams for years after their deposition.

Hazards associated with lahars include direct impact and burial by the advancing flow (Figure 3.3.9-4), burial of valuable infrastructure or agricultural land, and secondary flooding due to temporary damming and breakouts along tributary streams. Because of their relatively high viscosity, lahars can move, or even carry away, vehicles and other large objects such as bridges. Municipalities, industries, and individuals who take their water from streams affected by lahars may have water quality and/or quantity issues. Wildlife could be adversely affected by changes in streams, including the deposition of debris in streambeds and floodplains. For example, salmonids trying to spawn could find it impossible to swim upstream. Long-term drainage pattern alteration and increased sedimentation rates downstream may persist for decades following such an event.

Figure 3.3.9-4: Trees Buried in Volcanic Sediment, Sandy River, Oregon. Trunks of forest trees, initially growing on a terrace above the Sandy River (Oregon) at Oxbow Regional Park, were buried by rapid deposition of sediment following a dome-building eruption at Mount Hood in

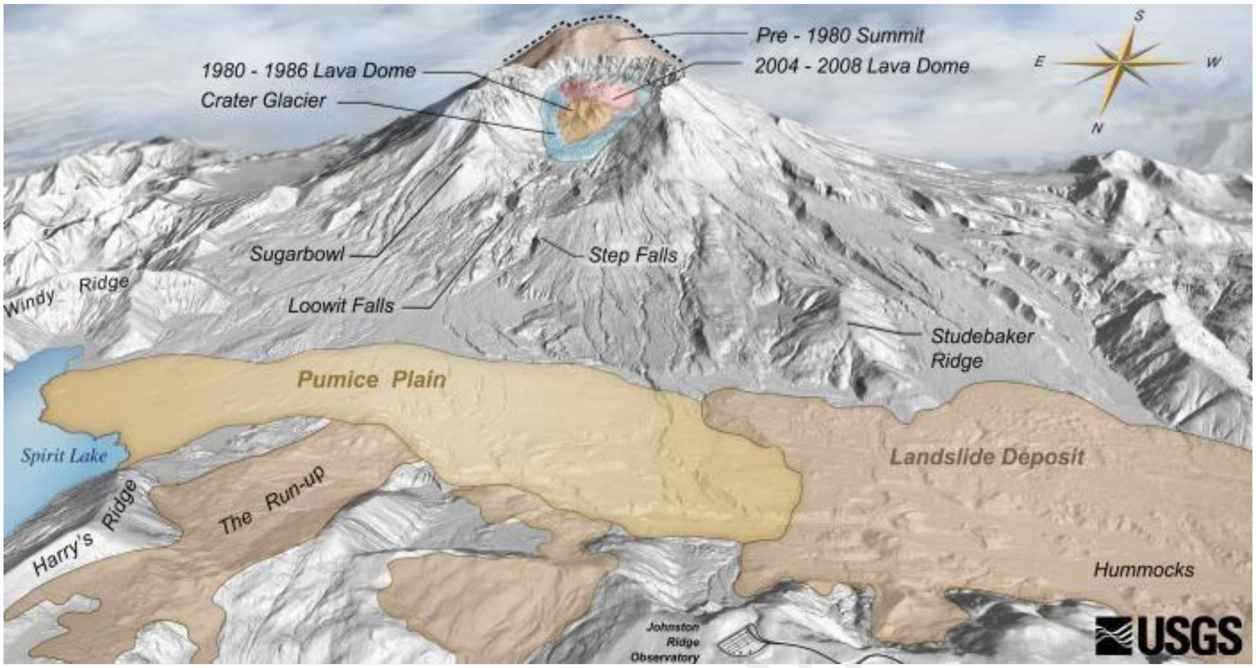
1781. Erosion during a flood about a week before the photo was taken exposed this "ghost forest."

Source: T.C. Pierson, U.S. Geological Survey, 1/15/2009

Landslides

Because the stratovolcanoes that form the Cascade Mountains are composed of layers of weak fragmented rock and lava, they are prone to landslides. Landslides range in size from small to massive summit or flank failures like the one in May 1980 at Mount St Helens (Figure 3.3.9-5). They may be triggered by volcanic activity or during times of excessive rainfall or snowmelt. Speeds of movement range from slow creep to more catastrophic failure. If enough water is incorporated into the material, the failure will become a lahar.

Figure 3.3.9-5: Mount St. Helens.



Source: USGS, Geology and history summary for Mount St. Helens, http://volcanoes.usgs.gov/volcanoes/st_helens/st_helens_geo_hist_101.html

Volcanic Gases

Magma contains dissolved gases that provide the driving force causing most volcanic eruptions. As magma rises towards the surface and pressure decreases, gases are released from the liquid portion of the magma (melt). These gases continue to travel upward and are eventually released into the atmosphere, both during and between eruptions. The majority of the gas emitted at volcanoes is water vapor (steam), derived from recent precipitation and groundwater. However, toxic gases including carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen halides, and fluorine may also be released. Depending on their concentrations, toxic gases can have both short-term effects and long-term effects on human and animal lives, property, agriculture, and the natural environment. Some examples of gas hazards:

- Carbon dioxide is heavier than air and can be trapped in low areas in concentrations that are deadly to people and animals;
- Sulfur dioxide, Hydrogen sulfide, and Fluorine are respiratory poisons;
- Sulfur Dioxide reacts with atmospheric water to create acid rain, causing corrosion and harming vegetation; and
- Fluorine can be absorbed onto volcanic ash particles that later fall to the ground, poisoning livestock grazing on ash-coated grass and also contaminating domestic water supplies.

Tephra

Tephra includes both solid and molten rock fragments, ranging in size from fine ash dust to larger "volcanic bombs" up to 3 feet in diameter. The largest rock fragments and volcanic bombs usually fall back to the ground within 2 miles of the vent. Tephra deposits pose significant risks to lives, structures, and property in the proximity of volcanic vents. Fine tephra is extremely slippery, hampering driving and walking, and can damage the lungs of small infants, the elderly, and those with respiratory problems. Fist-sized and larger bombs, flying as airborne projectiles, can cause significant injury or death. Tephra is disorienting by reducing visibility. If tephra accumulates in sufficient thickness it may collapse roofs, may topple or short-circuit electric transformers and power lines and clog other infrastructure such as water and sewage treatment facilities. Tephra clouds also commonly generate lightning that can interfere with electrical and communication systems and start fires.

Distal Hazards

Lahars

Lahars are both proximal and distal volcanic hazards. Please see the discussion of lahars in the *Proximal Hazards* section (above).

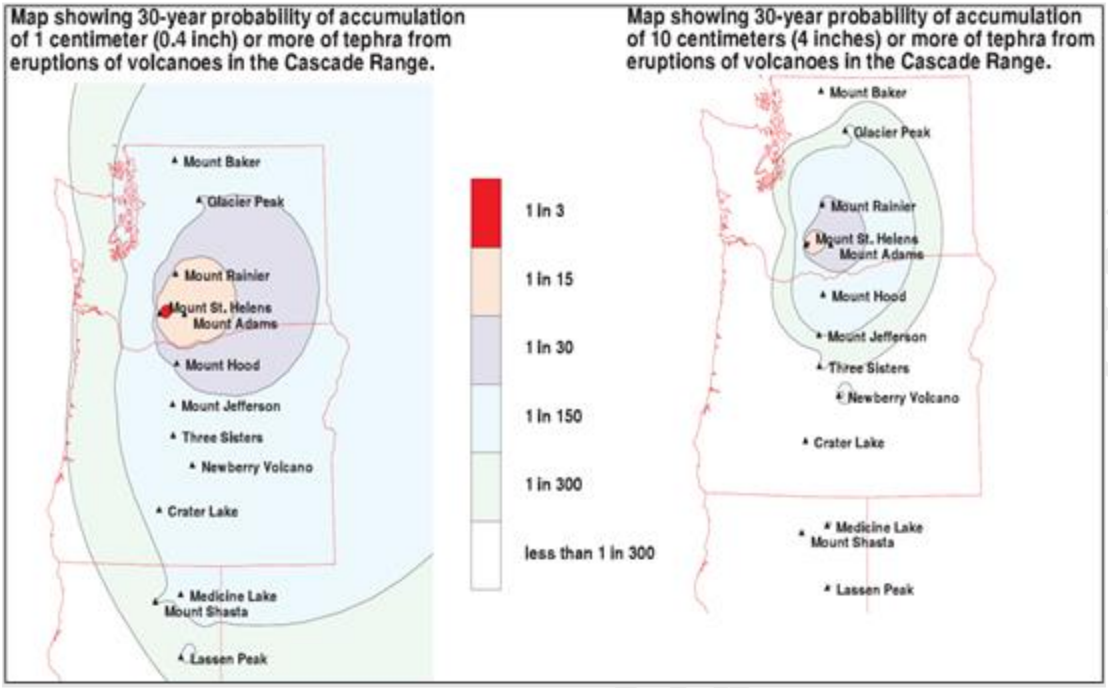
Eruption Columns and Clouds

Eruption columns and clouds occur during explosive volcanic eruptions as small fragments of volcanic glass, minerals, and rock, less than about 0.1 inch across, rise high into the air. Depending on the power of the eruption, columns can grow rapidly and reach more than 12 miles above a volcano, forming an eruption cloud. Large eruption clouds can extend hundreds of miles downwind, resulting in falling ash over enormous areas; the wind carries the smallest ash particles the farthest.

Ashfall

Dust-sized ash particles are the by-products of many volcanic eruptions. Ash, when blown into the air, can travel large distances causing significant problems for distal hazard zones. During ash-dominated eruptions, deposition is largely controlled by the prevailing wind direction. The predominant wind pattern over the Cascade Range is from the west to the east. Previous eruptions documented in the geologic record indicate most ashfall drifting to and settling in areas to the east of the Cascade volcanoes. The probable geographic extent of volcanic ashfall from select volcanic eruptions in the Pacific Northwest is shown in Figure 3.3.9-6.

Figure 3.3.9-6: Probable Geographic Extent of Volcanic Ashfall from Select Volcanic Eruptions in the Pacific Northwest.



Source: Scott, et al. (1997a)

Within a few miles of the vent, the main ashfall hazards to man-made structures and humans include high temperatures, being buried, and being hit by falling fragments. Within 10–12 miles, hot ashfall may set fire to forests and flammable structures.

Structural damage can also result from the weight of ash, especially if it is wet. Four inches of wet ash may cause buildings to collapse. Accumulations of a half inch of ash can impede the movement of most vehicles, disrupt transportation, communication, and utility systems, and cause problems for human and animal respiratory systems. It is extremely dangerous for aircraft, particularly jet planes, as volcanic ash accelerates wear to critical engine components, can coat exposed electrical components, and erodes exposed structure. Ashfall may severely decrease visibility, or even cause darkness, which can further disrupt transportation and other systems. Recent work by the Volcano Hazards Group of the U.S. Geological Survey has attempted to rank the relative hazard of volcanoes in North America. According to this study, Oregon has four Very High Threat Volcanoes: Crater Lake, Mount Hood, Newberry Volcano, and South Sister (Ewert, et al., 2005).

Ashfall can severely degrade air quality and trigger health problems. In areas with considerable ashfall, people with breathing problems might need additional services from doctors or emergency rooms. In severe events an air quality warning could be issued, informing people with breathing problems to remain inside

Ashfall can create serious traffic problems as well as road damage. Vehicles moving over even a thin coating of ash can cause clouds of ash to swell. This results in visibility problems for other drivers, and may force road closures. Extremely wet ash creates slippery and hazardous road conditions. Ash filling roadside ditches and culverts can prevent proper drainage and cause shoulder erosion and road damage. Blocked drainages can also trigger debris flows if the blockage causes water to pool on or above susceptible slopes. Removal of ash is extremely difficult as traditional methods, such as snow removal equipment, stir up ash and cause it to continually resettle on the roadway.

Non-Eruptive Hazards

Earthquakes

Earthquake effects are a significant threat along the Cascade Mountains and come from three main sources: the CSZ, crustal faults, and volcanic activity. The CSZ is generally over 150 miles away, but it produces earthquakes as a large as M9.0 every 240 to 500 years. Crustal earthquakes occur in the North American plate at relatively shallow depths of approximately 6 to12 miles below the surface. However, some can rupture through the surface. The distance from a potentially active fault is critical to the evaluation of the earthquake shaking hazard. Volcanic earthquakes are usually small and frequent, but they can be as large as or larger than the M4.5 earthquake on Mount Hood in 2002. During 2002, a swarm of earthquakes ranging from M3.2 to M4.5 occurred on the southeast flank of Mount Hood. The damaging effects of all three kinds of earthquakes can be enhanced by amplification of shaking in soft soils, liquefaction, or induced landslides.

Flooding and Channel Migration

The relatively high elevation of volcanoes usually results in the meteorological effect called orographic lifting, which causes high precipitation and snow on the mountains. The result can be very high levels of rainfall and/or rapid snowmelt that can result in flooding.

Floods cause damage to assets through inundation of water and by erosion and deposition of soil and/or large objects. Defining the hazard associated with inundation by flooding is done by calculating the area that is likely to be flooded during different levels of flooding. Larger floods are less frequent than smaller floods, so flood levels may be defined by their return period. The longer the return period, the deeper the flood waters, and hence the larger the area that is inundated. Some common return periods used in flood hazard mapping include 10-year, 25-year, 100-year, and 500-year floods. Most flooding on Cascade Range volcanoes occurs when heavy, warm rain during large winter or spring storms falls on accumulations of low-elevation snow. Channel migration hazards can occur slowly, for example, by continuous erosion along a cutbank meander and deposition onto a point bar during high flows, or very rapidly during storm events through avulsion or rapid abandonment of the current river channel for a new one. Such rapid migration can not only destroy structures but even remove the land beneath structures.

For more information on flooding and channel migration zones see the **Flood** section.

Landslides

The general term *landslide* refers to a range of geologic events including rock falls, debris flows, earth slides, and other mass movements. Most landslides that occur on volcanoes are large deep-seated landslide complexes or debris flows. Deep-seated landslides have failure surfaces usually tens of feet below the surface and can cover large areas from acres to square miles. These types of landslides tend to move relatively slowly, but they can lurch forward if shaken by an earthquake or if disturbed by removal of material from the toe, by addition of material to the head, or by addition of water into the slide mass. Debris flows tend to initiate in the upper portion of a drainage, picking up water, sediment, and speed as they come down the drainage. As they reach the mouth of the confined or steep portion of the drainage, they tend to spread out and deposit the majority of the material, generally creating a fan. Debris flows are also commonly initiated by other types of landslides that occur on slopes near a channel. They can also initiate within the channel in areas of accelerated erosion during heavy rainfall or snowmelt.

Characterization of Individual Volcanoes

The history of volcanic activity in the Cascade Range is contained in its geologic record. The ages, eruptive history, and hazards associated with each volcano vary considerably. Cascade volcanoes may be characterized by intermittent periods of activity, followed by longer periods of relative quiescence. The incompleteness of eruptive records, even at relatively well-studied volcanoes, makes prediction of probability and recurrence intervals of future eruptions difficult to determine. Table 3.3.9-1 lists Cascade Volcanoes in southwest Washington and Oregon that can affect Oregon communities. The discussion that follows further details those volcanic centers from Table 3.3.9-1 for which the U.S. Geological Survey has developed hazard assessments and ranked as having a high to very high threat potential. Threat potential is described as very high, high, moderate, low, or very low based upon eruption history, distance to population centers, and potential impacts to aviation (Ewert, et al., 2005). From north to south these high-threat volcanoes are:

- Mount St. Helens (Wolfe & Pierson, 1995)
- Mount Adams (Scott, Iverson, Vallance, & Hildreth, 1995)
- Mount Hood (Scott, et al., 1997), (Burns W. J., et al., 2011b)
- Mount Jefferson (Walder, Gardner, Conrey, Fisher, & Schilling, 1999)
- The Three Sisters Region (Scott, Iverson, Schilling, & Fisher, 2001)
- Newberry Volcano (Sherrod, Mastin, Scott, & Schilling, 1997)
- Crater Lake (Bacon, Mastin, Scott, & Nathenson, 1997)

Digital hazard data for some of these volcanoes have been produced by Schilling (1996); Schilling, et al. (1997), Schilling, et al. (2008a), (2008b), (2008c). For a detailed inventory of each volcano's history and hazards, please refer to the appropriate report referenced above or Table 3.3.9-1. Further information can also be obtained from the U.S. Geological Survey Cascade Volcano Observatory at http://volcanoes.usgs.gov/observatories/cvo/.

Table 3.3.9-1 Prominent Volcanoes in the Cascade Range of Oregon and Southwest Washington

Volcano Name	Elevation	Volcano Type	Most Recent Eruptions	USGS Threat Potential	Nearby Towns	Remarks/Hazard Study
Mount St. Helens (Washington)	8,363 ft	strato-volcano	1980–1986; 2004–2008	high to very high	Portland, Castle Rock (Washington), Olympia (Washington),	major explosive eruption and debris avalanche in 1980; widespread ashfall;

Volcano Name	Elevation	Volcano Type	Most Recent Eruptions	USGS Threat Potential	Nearby Towns	Remarks/Hazard Study
					Vancouver (Washington), Yakima (Washington)	(Wolfe & Pierson, 1995)
Mount Adams (Washington)	12,277 ft	strato-volcano	about 520,000 to 1,000 YBP	high to very high	Portland, Hood River, Vancouver (Washington), Yakima (Washington)	numerous eruptions in last 15,000 year; major debris avalanches effecting White Salmon River at 6,000 and 300 YBP; (Scott, Iverson, Vallance, & Hildreth, 1995)
Mount Hood	11,240 ft	strato-volcano	1760–1865	high to very high	Portland, Sandy, Welches, Brightwood, Parkdale, Hood River	pyroclastic flows in the Upper White River drainage; lahars in Old Maid Flat; lava dome at Crater Rock; steam explosions; Scott (1997a); Schilling, et al. (2008a)
Mount Jefferson	10,495 ft	strato-volcano	280,000 to 15,000 YBP	low to very low	Idanha, Detroit, Warm Springs, Madras, Lake Billy Chinook	potentially active and capable of large explosive eruptions; recent history of lava domes, small shields, and lava aprons; Walder, et al. (1999); Schilling, et al. (2007)
Mount Washington	7,796 ft	mafic volcano		low to very low		no hazard study
North Sister	10,085 ft	mafic volcano	300,000 to 120,000 YBP	high to very high	Sisters, Bend, Redmond, Sunriver, La Pine, Blue River, McKenzie Bridge, Vida, Springfield	deep glacial erosion; ashfall, pyroclastic flows, lava flows and domes, and lahars; Scott, et al. (2001); Schilling, et al. (2008c)
Middle Sister	10,047 ft	strato-volcano	about 40,000 to 14,000 YBP	high to very high	Sisters, Bend, Redmond, Sunriver, La Pine, Blue River, McKenzie Bridge, Vida, Springfield	potentially active, capable of large explosive eruptions, ashfall, pyroclastic flows, lava flows and domes, and lahars;

Volcano Name	Elevation	Volcano Type	Most Recent Eruptions	USGS Threat Potential	Nearby Towns	Remarks/Hazard Study
						Scott (2001); Schilling, et al. (2008c)
South Sister	10,358 ft	strato-volcano	about 50,000 to 2,000 YBP	high to very high	Sisters, Bend, Redmond, Sunriver, La Pine, Blue River, McKenzie Bridge, Vida, Springfield	potentially active, capable of large explosive eruptions, ashfall, pyroclastic flows, lava flows and domes, and lahar; most silicic of the cones in the Three Sisters complex; phase of uplift started in 1997 within a broad area about 6 km west of South Sister; Scott (2001); Schilling, et al. (2008c)
Broken Top	9,152 ft	strato-volcano	300,000–100,000 YBP	low to very low	Bend, Sunriver, La Pine	deep glacial erosion; lava flows, pyroclastic flows, ashfall; no hazard study
Mount Bachelor	9,068 ft	mafic volcano	about 18,000 to 7,700 YBP	moderate	Bend, Sunriver, La Pine	lava flows and near vent cinder and ashfall; no hazard study
Newberry Volcano	7,986 ft	shield volcano/ caldera	about 400,000 to 1,300 YBP	high to very high	Bend, Sunriver, La Pine	potentially active and capable of large explosive eruptions; lava flows and near vent cinder and ashfalls; present-day hot springs; (Sherrod, Mastin, Scott, & Schilling, 1997); Schilling, et al. (2008b)
Mount Thielsen	9,187 ft	shield volcano	> 250,000	low to very low	Chemult	Deep glacial erosion; Lava flows, pyroclastic eruptions; no hazard study.
Crater Lake Caldera (Mount Mazama)	8,159 ft	caldera	about 420,000 to 7,700 YBP	high to very high	Grants Pass, Roseburg, Chemult, La Pine, Fort	lava flows, pyroclastic flows, ashfall; source of the widespread

Volcano Name	Elevation	Volcano Type	Most Recent Eruptions	USGS Threat Potential	Nearby Towns	Remarks/Hazard Study
					Klamath, Chiloquin, Klamath Falls	Mazama ash; Bacon, et al. (1997)
Mount McLaughlin	9,496 ft	strato-volcano	>80,000 YBP	low to very low	Medford, Grants Pass, Klamath Falls	lava flows, pyroclastic flows; no hazard study

YBP is years before present.
Sources: U.S. Geological Survey, Cascades Volcano Observatory: http://volcanoes.usgs.gov/observatories/cvo/; Wolfe and Pierson (1995); Scott, et al. (1995), (1997a), (2001); Sherrod, et al. (1997); Bacon, et al. (1997); Walder, et al. (1999)

Mount St. Helens (Washington)

The May 18, 1980, eruption of Mount St. Helens is the best-known example of volcanism to most Oregonians. That eruption included a debris avalanche, as part of the volcanic edifice collapsed (Figure 3.3.9-6). This caused a lateral blast of rock, ash, and gas that devastated areas to the north of the volcano. Lahars rushed down the Toutle and Cowlitz River valleys, reaching the Columbia River and halting shipping for some time. All other river valleys on the volcano experienced smaller lahars. Pyroclastic flows devastated an area up to five miles north of the volcano. Ashfall deposits affected people as far away as Montana, and ash circled the earth in the upper atmosphere for over a year.

Except for the debris avalanche and lateral blast, the events of this eruptive period are typical of a Mount St. Helens eruption and can be expected to occur again (Table 3.3.9-1). The primary hazards that will affect Oregonians are ashfall and lahars that affect the Columbia River. Since the major eruptive activity in the early 1980s, Mount St. Helens has experienced two episodes of dome building activity. The latest activity lasted from 2004 until 2008. Another eruption from Mount St. Helens is very likely in the near future.

Mount Adams (Washington)

Mount Adams, located 35 miles north of Hood River, Oregon, is the largest active volcano in Washington State and among the largest in the Cascade Range (Table 3.3.9-1). The volcano was active from about 520,000 to about 1,000 years ago. Eruptions from Mount Adams within the last 500,000 years have mainly consisted of effusive lava flows; highly explosive events are rare in the geologic record of Mount Adams. Eruptions have also occurred from 10 vents in the vicinity of Mount Adams since the last period of glaciation about 15,000 years ago. Approximately 6,000 and 300 years ago, debris avalanches from the southwest face of Mount Adams generated clay-rich lahars that traveled down the White Salmon River. The summit of Mount Adams contains a large section of unstable altered rock that can spawn future debris avalanches and lahars.

Potential hazards from Mount Adams include lava flows near the central vent area and lahars that could reach and disrupt the Columbia River channel. Such lahars may have little or no advanced warning.

Mount Hood

The last major eruption of Mount Hood occurred in approximately 1781 (244 years ago) (Table 3.3.9-1 and Table 3.3.9-2). The Sandy River that drains the volcano's northwest side was originally named the Quicksand River by Lewis and Clark, who traversed the area only a couple of years after an eruption. Lahars had filled the river channel with debris, much of which has now been scoured away. There were two other minor periods of eruptions during the last 500 years, the last in the mid-1800s. Typically, these involved lava flows near the summit, pyroclastic flows, and lahars but little ashfall. From its recent eruptive history, the volcano is most likely to erupt from the south side, but planning should be done assuming eruptions could be centered anywhere on the mountain. A large eruption could generate pyroclastic flows and lahars that could inundate the entire length of the Sandy and White River valleys. An eruption from the north flank could affect the Hood River Valley.

Due to its proximity to the Portland Metro area, major east-west highways, the Bull Run Reservoir (which supplies water to a majority of Portland area residents), and ski and summer recreation areas, Mount Hood poses the greatest potential volcanic hazard to Oregonians. In addition, a large volume of debris and sediment in lahars could affect shipping lanes in the Columbia River and operation of Bonneville and The Dalles dams.

In recent years, numerous debris flows caused by winter storms have flowed down river drainages. OR-35 is periodically closed for repair work after these events damaged the bridge over the White River. If a volcanic event occurred, the same drainages would be affected.

Table 3.3.9-2 Notable Geologic Events near Mount Hood

Date or Age	Event	Deposits
A.D. 1859, 1865, 1907?	minor explosive eruptions of Mount Hood	scattered pumice
late 19th century	late neoglacial advance	prominent, sharp-crested moraines
late 18th century	Old Maid eruptive period	lava dome, pyroclastic-flow and lahar deposits, tephra
about 500 years ago	debris flows in Zigzag River	debris-flow deposits
1,000 years ago	debris flows in upper Sandy River	debris-flow deposits
1,500 years ago	Timberline eruptive period	lava dome, pyroclastic-flow and lahar deposits, tephra
7,700 years ago	eruptions from vent near Parkdale; Mount Mazama ashfall	Basaltic andesite of Parkdale lava flow; about 5 cm of Mazama ash
11,000 to 20,000 years ago	waning phases of Evans Creek glaciation	moraines
13,000 to 20,000 years ago	Polallie eruptive period	lava domes, pyroclastic-flow and lahar deposits, tephra
20,000 to 25,000 years ago	maximum of Evans Creek glaciation	belts of moraines in most valleys

Date or Age	Event	Deposits
20,000 to 30,000 years ago	Mount Hood dome eruptions	lava domes, pyroclastic-flow and lahar deposits
30,000(?) to 50,000(?) years ago	Mount Hood lava-flow eruptions	andesite lava flows of Cathedral Ridge and Tamanawas Falls

Source: Bill Burns, DOGAMI, modified from Scott, et al. (1997b)

Mount Jefferson

Mount Jefferson is located in a relatively unpopulated part of the Cascade Range. The last eruptive episode at Mount Jefferson was about 15,000 years ago. Research at stratovolcanoes around the world indicates that Mount Jefferson should be regarded as dormant, not extinct.

The steep slopes of the volcano provide the setting for possible debris flows and lahars, even without an eruption. These would be confined to valleys, generally within 10 miles of the volcano.

A major eruption, however unlikely in the short term, could generate pyroclastic flows and lahars that would travel up to a few dozen miles down river valleys. Two reservoirs could be affected by pyroclastic flows from a major eruption: Detroit Lake and Lake Billy Chinook. An explosive eruption could spew ash for hundreds of miles in the downwind direction.

Many smaller volcanoes are located between Mount Jefferson and Mount Hood to the north and Three Sisters to the south. Eruptions from any of these would be primarily erupt *cinders* and ash to form cinder cones.

Three Sisters Region

North Sister has probably been inactive for at least 100,000 years (Table 3.3.9-1). Middle Sister last erupted between 25,000 and 15,000 years ago. South Sister had a very small ongoing uplift, which began in 1996 and became undetectable by 2003. The uplift was about one inch a year and likely indicated movement of a small amount of magma. At this writing, there is no indication that the uplift will ever develop into a volcanic eruption. However, that possibility cannot be ruled out. Hence, the Cascade Volcano Observatory has increased their monitoring of the area over the past several years.

Future eruptions at South Sister (and possibly Middle Sister) are likely to include lava flows, pyroclastic flows, and lahars. The possibility exists for lahars to travel many miles down valley floors, if an eruption melts a large amount of snow and ice. Ashfall would likely be contained within 20 miles of the vent.

Newberry Volcano

Newberry Volcano, unlike the stratovolcanoes of the Cascade Range, is a shield volcano with broad, relatively gently sloping flanks composed of stacked basaltic lavas flows (Table 3.3.9-1). The volcano is about 400,000 years old and has had thousands of eruptions both from the central vent area and along its flanks. The present 4 by 5 mi wide caldera at Newberry Volcano's summit formed about

75,000 years ago by a major explosive eruption and collapse event. This was the most recent of at least three caldera-forming eruptions that lofted pumice and ash high into the air and spread pyroclastic flows across the volcano's surface. The most recent eruption was 1,300 years ago when the "Big Obsidian Flow," a glassy rhyolitic lava flow, erupted within the caldera. Future eruptions are likely to include lava flows, pyroclastic flows, lahars, and ashfall. Newberry Volcano has attracted interest for its geothermal potential. The heat under the volcano, with temperatures in some areas in excess of 509˚ F, is evidence that it is only dormant.

Crater Lake Caldera

About 7,700 years ago, Mount Mazama erupted with great violence, leaving the caldera that Crater Lake now occupies (Table 3.3.9-3). Layers of ash produced from that eruption have been found in eight western states and three Canadian provinces. The countryside surrounding Crater Lake was covered by pyroclastic flows. Wizard Island is the result of much smaller eruptions since that cataclysm. The most recent eruption was about 5,000 years ago and occurred within the caldera. No eruptions have occurred outside the caldera since 10,000 years ago.

This potentially active volcanic center is contained within Crater Lake National Park. The western half of the caldera is considered the most likely site of future activity. Effects from volcanic activity (e.g., ashfall, lava flows) are likely to remain within the caldera. If an eruption occurs outside the caldera, pyroclastic flows and lahars could affect valleys up to a few dozen miles from the erupting vent. The probability of another caldera-forming eruption is very low, as is the probability of eruptions occurring outside the caldera.

Other Volcanic Areas of Oregon

On the scale of geologic time, volcanic eruptions may occur in other parts of Oregon. However, on a human time scale, the probability of an eruption outside the Cascades is so low as to be negligible.

Although the high, snow-topped mountains of the Cascades are Oregon's most visible volcanoes, other potential eruptive centers exist. These include smaller peaks, such as the Belknap shield volcano in central Oregon, which had a lava flow about 1,400 years ago. Several smaller volcanoes, including Diamond Craters and Jordan Craters, in the High Lava Plains of southeast Oregon have experienced recent eruptions in the last 7,000 years. Generally non-explosive eruptions at these sites have built complexes of lava flow fields and cinder cones. Hazards associated with future eruptions in sparsely populated southeast Oregon would most likely include lava flows covering many square miles; ash and volcanic gases derived from these eruptions may be regionally significant.

3.3.9.2 Historic Volcanic Events

Table 3.3.9-3: Historic Volcanic Events in Oregon over the Last 20,000 Years

Date	Location	Description
about 18,000 to 7,700 YBP	Mount Bachelor, central Cascades	cinder cones, lava flows

Date	Location	Description
about 20,000 to 13,000 YBP	Polallie Eruptive episode, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
about 13,000 YBP	Lava Mountain, south-central Oregon	Lava Mountain field, lava flows
about 13,000 YBP	Devils Garden, south-central Oregon	Devils Garden field, lava flows
about 13,000 YBP	Four Craters, south-central Oregon	Four Craters field, lava flows
about 7,780 to 15,000 YBP	Cinnamon Butte, southern Cascades	basaltic scoria cone and lava flows
about 7,700 YBP	Crater Lake Caldera	formation of Crater Lake caldera, pyroclastic flows, widespread ashfall
about 7,700 YBP	Parkdale, north-central Oregon	eruption of Parkdale lava flow
<7,000 YBP	Diamond Craters, eastern Oregon	lava flows and tephra in Diamond Craters field
< 7,700 YBP; 5,300 to 5,600 YBP	Davis Lake, southern Cascades	lava flows and scoria cones in Davis Lake field
about 10,000 to <7,700 YBP	Cones south of Mount Jefferson; Forked Butte and South Cinder Peak	lava flows
about 4,000 to 3,000 YBP	Sand Mountain, central Cascades	lava flows and cinder cones in Sand Mountain field
< 3,200 YBP	Jordan Craters, eastern Oregon	lava flows and tephra in Jordan Craters field
about 3,000 to 1,500 YBP	Belknap Volcano, central Cascades	lava flows, tephra
about 2,000 YBP	South Sister Volcano	rhyolite lava flow
about 1,500 YBP	Timberline eruptive period, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
about 1,300 YBP	Newberry Volcano, central Oregon	eruption of Big Obsidian flow
about 1,300 YBP	Blue Lake Crater, central Cascades	Spatter cones and tephra
1760–1810	Crater Rock/Old Maid Flat on Mount Hood	pyroclastic flows in upper White River; lahars in Old Maid Flat; dome building at Crater Rock
1859/1865	Crater Rock on Mount Hood	steam explosions/tephra falls
1907 (?)	Crater Rock on Mount Hood	steam explosions
1980	Mount St. Helens (Washington)	debris avalanche, ashfall, flooding on Columbia River
1981–1986	Mount St. Helens (Washington)	lava dome growth, steam, lahars

Date	Location	Description
1989–2001	Mount St. Helens (Washington)	hydrothermal explosions
2004–2008	Mount St. Helens (Washington)	lava dome growth, steam, ash
2009--2025	Mount St. Helens (Washington)	Short term increases in small earthquakes

Note: YBP is years before present.
Sources: U.S. Geological Survey, Cascades Volcano Observatory: http://volcanoes.usgs.gov/observatories/cvo/;
Wolfe and Pierson (1995); Sherrod, et al. (1997); Scott, et al. (1997a), (2001); Bacon, et al. (1997); Walder, et al. (1999)

3.3.9.3 Risk Maps

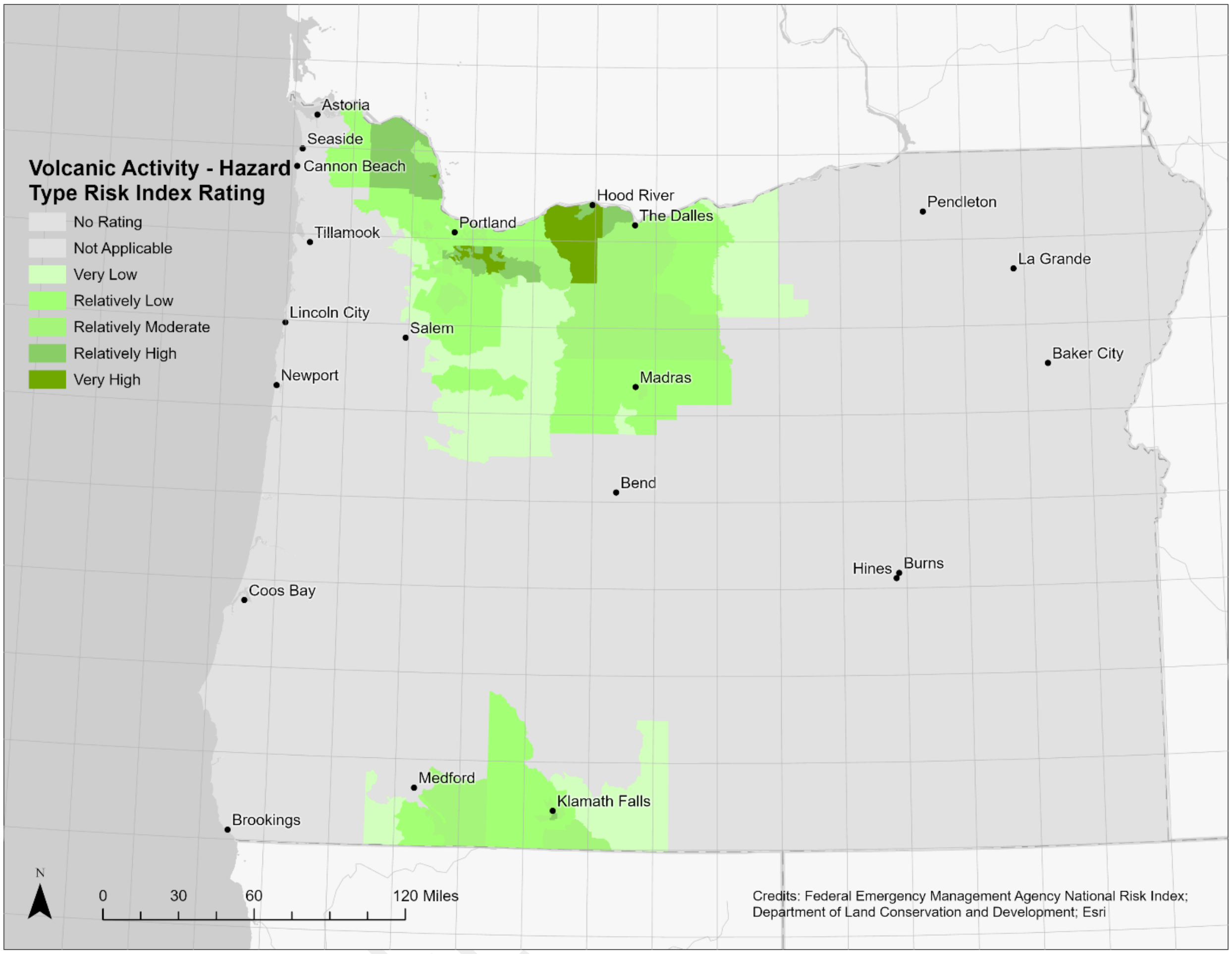
The maps in this section highlight places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

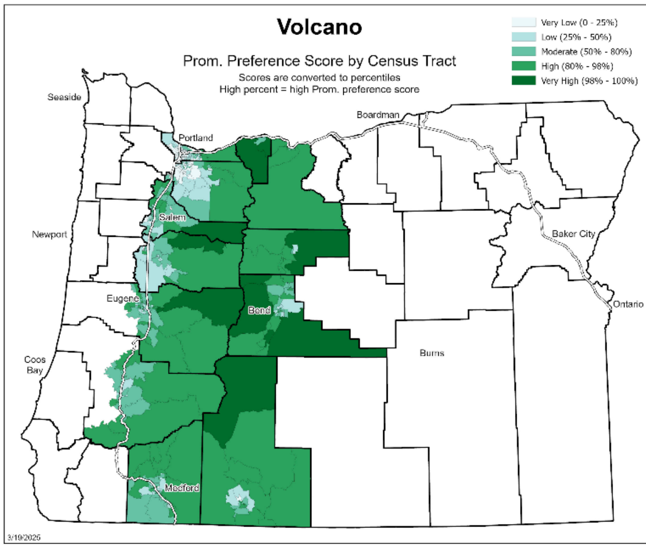
Figure 3.3.9-7: Volcanic Activity Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Volcanic Activity.



Source: Federal Emergency Management Agency, National Risk Index for Volcanic Activity. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from [National Risk Index | FEMA.gov].

Figure 3.3.9-8 and Figure 3.3.9-9 show risk rankings by census tract for volcanoes from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.9-8 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.9-9 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

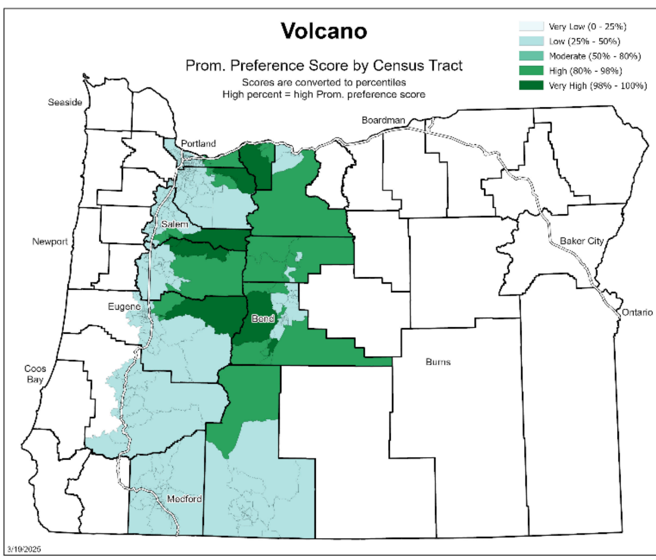
Figure 3.3.9-8: Volcano results of Oregon Risk Assessment using PROMETHEE Ranking with Socioeconomic Indicators Included.



Indicators used for the hazard Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Volcano	LAH_pct_bld	1	0.117	Percentage of SBFO buildings exposed to volcanic lahar hazard of any size.
Volcano	LAH_pct_CF	1	0.117	Percentage of critical facilities exposed to volcanic lahar hazard of any size.
Volcano	Hist_Lahar_ct	1	0.117	Percentage of historic buildings exposed to volcanic lahar hazard of any size.
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

Figure 3.3.9-9: Volcano results of Oregon Risk Assessment using PROMETHEE Ranking without Socioeconomic Indicators Included



Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Volcano	LAH_pct_bld	1	0.333	Percentage of SBFO buildings exposed to volcanic lahar hazard of any size.
Volcano	LAH_pct_CF	1	0.333	Percentage of critical facilities exposed to volcanic lahar hazard of any size.
Volcano	Hist_Lahar_ct	1	0.333	Percentage of historic buildings exposed to volcanic lahar hazard of any size.

3.3.10 Wildfires

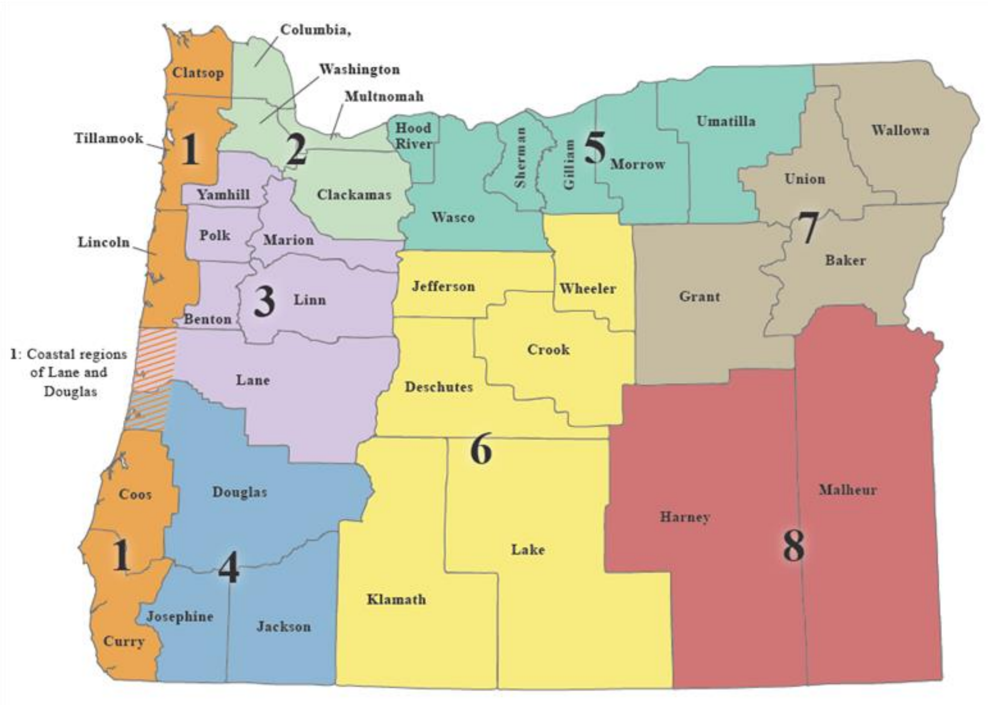
Non-regulatory map: *This wildfire risk assessment and maps are not regulatory. The Oregon Department of Forestry and Oregon State University developed a statewide wildfire hazard map as required by the Oregon Legislature for use in building codes, defensible space requirements, and grant programs. To learn more about the regulatory statewide wildfire hazard maps, visit Oregon Department of Forestry's wildfire page.*

Wildfires are common and widespread in Oregon. The state has a long and extensive history of wildfire. A significant portion of Oregon's forestland is ecosystems dependent upon fire for their health and survival. Wildfires frequently threaten communities, especially in the wildland-urban interface (WUI) where structures and other human development meet or intermingle with natural vegetative fuels.

Oregon has an excess of 41 million acres (more than 64,000 square miles) of forest and rangeland that is susceptible to damage from wildfire. In addition, significant agricultural areas of the Willamette Valley, north central, and northeastern Oregon grow crops such as wheat that are also susceptible to damage by wildfire.

The majority of wildfires take place between June and October, though fire season has been increasing in length since 1970 and is now, on average, 78 days longer than it used to be. This lengthening of the fire season is largely due to declining mountain snowpack and earlier spring snowmelt—a result of warming temperatures (Fleishman 2025). These fires primarily occur in Oregon NHMP Natural Hazard Regions 4, 5, 6, and 7 (Figure 3.3.10-1); however, even areas classified as low or moderate are susceptible to wildfire if the right combination of fuels, weather, and ignition conditions exist. Historically, Oregon's largest wildfires have burned in the Coast Range (Regions 1 and 2) where the average rainfall is high, but heavy fuel loads created a low-frequency, high-intensity fire environment during the dry periods. However, the relationship between anthropogenic climate change and increasing frequency and intensities of wildfire in the western United States is increasingly evident. Between 2020 and 2024, Oregon faced several high intensity fire seasons, including the 2020 Labor Day fires which resulted in more than one million acres burned and wildfires in the summer of 2024 which burned nearly two million acres.

Figure 3.3.10-1: Oregon NHMP Natural Hazards Regions



Extreme winds can occur in all of Oregon's eight regions. The most persistent high winds occur along the Oregon Coast and the Columbia River Gorge. The Columbia River Gorge is the most significant east-west gap in the mountains between California and Canada. It serves as a funnel for east and west winds, where direction depends solely on the pressure gradient. Once set in motion, the winds can attain speeds of 80 mph. Wind is a primary factor in fire spread, and can significantly impede fire suppression efforts.

Historically, 70 percent of the wildfires suppressed on land protected by the Oregon Department of Forestry (ODF) result from human activity. The remaining 30 percent result from lightning. Typically, large wildfires result primarily from lightning in remote, inaccessible areas.

El Niño Southern Oscillation and Wildfire Hazards

El Niño winters are often warmer and sometimes drier than average. Sometimes this leads to above average fire seasons.

Unfortunately, El Niño is not a great predictor of above average fire seasons. Long-term drought is a much more accurate predictor.

Source: Oregon Department of Forestry

Large wildfires can have significant financial and social costs. Not only can they impact lives and property, they can also have negative short- and long-term economic and environmental consequences.

Life safety enhancement and cost savings may be realized by appropriate mitigation measures, starting with coordinated fire protection planning by local, state, tribes, federal agencies, the private sector, and community organizations. Additionally, individual WUI property owners play an important role in this coordinated effort.

Wildfire suppression costs escalate dramatically when agencies must adjust suppression tactics to protect structures. The cost of mobilizing personnel and equipment from across the state is significant. Non-fire agencies may also incur costs for providing or supporting evacuations, traffic control, security, public information, and other services during WUI fire incidents. These costs vary widely and have not been well documented.

The number of people living in Oregon's WUI areas is increasing. Where people have moved into these areas, the number of wildfires has escalated dramatically. Many Oregon communities (incorporated and unincorporated) are within or abut areas subject to serious wildfire hazards. In Oregon, more than one million tax lots have been identified within the WUI, which greatly complicates firefighting efforts and significantly increases the cost of fire suppression. While Oregon's Emergency Conflagration Act helps protect WUI communities that have depleted their local resources when threatened by an advancing wildfire, the escalating number of fires has led to the recognition that high fire risk communities need to provide mitigation and an appropriate level of local fire protection. Collaboration and coordination are ongoing among several agencies to promote educational efforts through programs like Firewise USA® and Fire Adapted Communities through the National Cohesive Wildfire Strategy.

Construction in vulnerable areas increases risk for certain populations. Oregon's Statewide Planning Goal 4 and Goal 7 play critical roles in guiding development in these areas. Measures to enhance life safety and save costs include Community Wildfire Protection Plans (CWPPs), coordinated fire protection planning, and coordination by local, state, tribal, federal agencies, the private sector, and community organizations. Many communities incorporate their CWPPs into their Natural Hazards Mitigation Plans (NHMPs).

Wildfire mitigation discussions are focused on reducing overabundant, dense forest fuels, particularly on public lands. The Healthy Forest Restoration Act aims to create fuel breaks by reducing overly dense vegetation and trees in an effort to protect communities at risk of wildfire, improve water quality, and restore resilient forest ecosystems. It provides funding and guidance to reduce or eliminate hazardous fuels in national forests, other public lands, and private ownership, improve forest fire fighting, and research new methods to reduce the impact of invasive insects, and requires collaboration between federal agencies and local communities to identify and prioritize fuel reduction and forest restoration projects.

Oregon continues to make efforts in fuels management and forestry resilience and health in and near WUI areas. Sustaining the work over the years requires a substantial, ongoing capacity and financial commitment. Progress is often challenging because fuel mitigation methods vary and are often up to landowners to maintain. Recurring WUI fires continue to bring the issue into public focus, work as a catalyst to unite communities and stakeholders in a common set of objectives, and create collaborative approaches to mitigate fuels.

3.3.10.1 Analysis and Characterization

History of Wildfire

Wildfires have been a feature of the Oregon landscape for thousands of years. Prehistoric fires resulted from lightning events and in controlled forms of active management practices by Native Americans. The Blue Mountains in northeastern Oregon were named so by early immigrants because of the existence of a perpetual, blue-colored wildfire smoke haze that lingered over the region. Between 1840 and 1900, wildland fires burned at least two million acres of forestland in western Oregon. It is believed settlers caused many of these fires. Following the establishment of the U.S. Forest Service and ODF, in 1905 and 1911, respectively, an aggressive and coordinated system of fire prevention and suppression emerged. However, it took several decades before significant gains were made.

Major wildfires in 1933, 1939, 1945, and 1951 burned across more than 355,000 acres in the northern Coast Range and became known collectively as the "Tillamook Burn."

Better suppression and more effective fire prevention campaigns combined to reduce large wildfire occurrences following World War II. Suppression improvements included the establishment of organized and highly trained crews, which replaced the previous system of hiring firefighters on an as-needed basis. Additional improvement resulted from construction of an extensive system of forest roads, lookouts and guard stations, the use of aircraft for the detection of fires and the delivery of fire suppression retardant, the invention and modification of modern and efficient fire suppression equipment, and refinements in weather forecasting and fire reporting. Prevention benefited from war-era campaigns, which united prevention activities with patriotism, and birthed movements such as the Smokey Bear campaign and the Keep Oregon Green Association.

A pattern of frequent, large WUI fires emerged during the 1970s as people began flocking to more rural settings. Suburban growth increased and continued through the 1980s. This introduced substantially more structures into what had previously been wildland areas that historically depended on periodic fires to sustain a healthy forest ecosystem.

By the early 1990s, frequent, destructive WUI fires had become a major concern of the State Forester, the State Fire Marshal, and the Oregon Legislature. By the mid-1990s, over 100 structures had been destroyed by wildfires. Thousands more had been threatened and suppression costs were increasing sharply. The same trends were occurring in surrounding states, at an even greater pace.

Project Wildfire

Project Wildfire is the result of a Deschutes County effort to create long-term wildfire mitigation strategies and provide for a disaster-resistant community. Project Wildfire is the community organization that facilitates, educates, disseminates and maximizes community efforts toward effective fire planning and mitigation.

Project Wildfire achieves its mission by:

- Developing long-term wildfire prevention and education strategies designed to reach an ever-changing community.
- Creating disaster resistant communities through collaboration with community members and a network of specialized partners.
- Reducing the severity and amount of damage caused by wildfire in wildland urban interface (WUI) areas through hazardous fuels reduction programs.
- Reducing the impact of fuels reduction on the environment by recycling the woody biomass resulting from hazardous fuels reduction projects.

Source: Oregon Department of Forestry, Project Wildfire (http://www.projectwildfire.org/http://www.projectwildfire.org/)

In response to increased costs and risk of fires in the WUI, the Oregon Forestland-Urban Interface Fire Protection Act was passed in 1997. The Act recognized that "…*forestland-urban interface property owners have a basic responsibility to share in a complete and coordinated protection system*..." During the 1990s, prevention and mitigation of WUI fires included enactment of the Wildfire Hazard Zone process and the inclusion of defensible space requirements in the land use planning process. The Act and Wildfire Hazard Zone process were superseded by Oregon Senate Bill 762 in 2021. Additionally, significant efforts were made to increase voluntary landowner participation, through aggressive awareness campaigns, such as FireFree, Project Wildfire, Project Impact, Firewise USA®, and other locally driven programs.

Through the years, Oregon's wildfire suppression system continued to improve. Firefighters benefited from improved training, coordination, and equipment. Better interagency initial attack cooperation, the growth of private crew and fire engine wildfire suppression resources, formation of structural incident management teams, and regional coordination of fire suppression are additional examples of these continued improvements. Technology has improved as well with the addition of lightning tracking software and fire detection cameras to support or replace deteriorating lookout towers.

Nevertheless, the frequency of wildfires threatening WUI communities continues to underscore the need for urgent action. The summer of 2002 included 11 Emergency Conflagration Act incidents, with as many as five running concurrently. More than 50 structures burned and, at one point, the entire Illinois Valley in Josephine County seemed under siege from the Biscuit Fire, Oregon's largest wildfire on record at that time. This wildfire threatened the homes of approximately 17,000 people, with over 4,000 homes under imminent evacuation alert. At almost 500,000 acres, it was the nation's largest wildfire of the year. The summer of 2013 once again brought to bear one of the worst fire seasons in Oregon. For the first time since 1951, more than 100,000 acres burned on lands protected by ODF. Five incident management teams were deployed in a period of three days following a dry lightning thunderstorm event in late July that sparked nearly 100 fires in southern Oregon from more than 300 lightning strikes. Another storm that passed over central and eastern Oregon in mid-August produced significant fires that threatened the communities of John Day and The Dalles.

Beginning September 7, 2020, several fires ignited under critically hot and dry conditions and spread dramatically during multiple days of high winds, resulting in five simultaneous "megafires"– fires greater than 100,000 acres in size – and a total of 21 fires. The 2020 Labor Day wildfires burned more than 1.2 million acres across Oregon, causing unprecedented deaths and damage to homes, livelihoods, and the natural environment, including more than 5,000 homes and businesses destroyed. Many fires threatened or crossed the WUI, placing over 500,000 Oregonians under some level of evacuation notice, with more than 40,000 people that had to evacuate their homes. The Oregon Forest Resources Institute's 2021 report on the 2020 Labor Day fires reported an estimated economic impact of $5.9 billion to Oregon's forest sector (OFRI 2021). Other after effects of the fires included unhealthy air quality levels for 12 days or more in many parts of the state, landslides, debris flows, and reduced drinking water quality.

In the summer of 2024, nearly two million acres burned across the state, far exceeding previous years' acreage burned, including five megafires. Between July and September, central and eastern

Oregon experienced multiple periods of excessive heat. These hot conditions aided in additional curing of fuels across the region, increasing the susceptibility of the land to fire development and growth, in conjunction with multiple periods of thunderstorms that produced abundant lightning. These wildfires not only damaged vast areas of land, but also damaged electric utilities and other infrastructure and threatened communities, destroying homes and other structures.

Figure 3.3.10-2: Average Acres Burned: This chart shows wildfire acres burned by decade in Oregon for all agencies from 2005-2024.

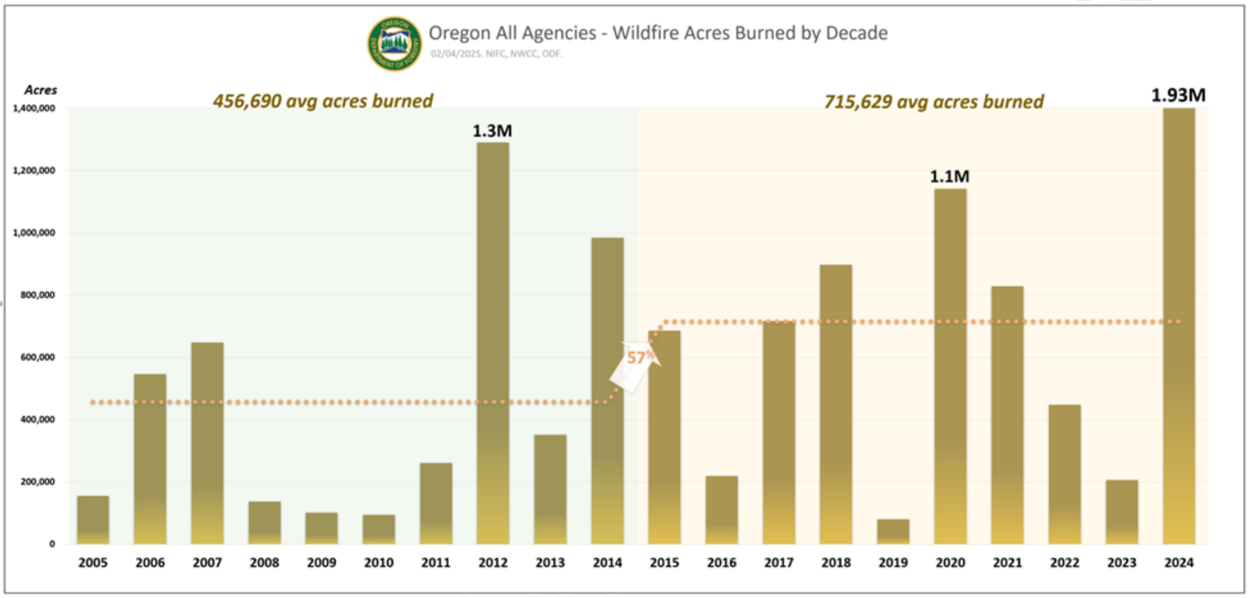
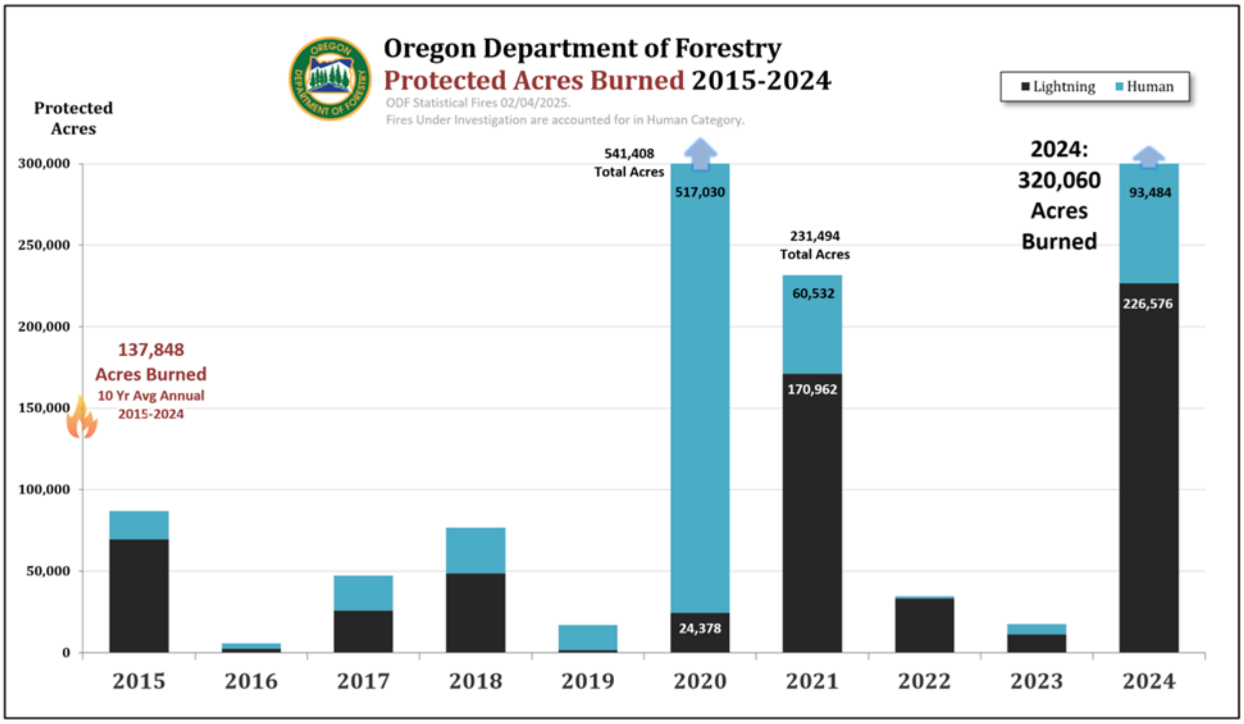


Figure 3.3.10-3: ODF Protected Acres Burned: This chart illustrates the sharp spike in acres burned in 2020, 2021, and 2024.



Federal disaster declarations related to the 2020 wildfires included DR-4562 (Major Disaster) – Oregon Wildfires and Straight-line Winds, EM-3542 (Emergency) – Oregon Wildfires, and several Fire Management (FM) Assistance declarations. In early January 2025, FEMA declared a major disaster for Oregon (DR-4854) in response to summer 2024 wildfires. Between 2020 and 2024, there were 38 FM declarations across Oregon.

Since 1996, Oregon has had 135 declared Conflagrations under Oregon's Emergency Conflagration Act. The Conflagration Act is invoked when the Governor determines threats to life, safety, and property exist because of the fire, and the threats exceed the capabilities of local firefighting personnel and equipment.

Senate Bill 762: Responding to Wildfire Risks

In 2021, the Oregon Legislature passed Senate Bill 762, a comprehensive wildfire preparedness and resiliency bill to help Oregon be better prepared to meet the increased wildfire threat. To rise to the challenge wildfire poses to Oregonians, several state agencies are working in coordination with local and federal partners to tackle the issue. These efforts aim to give people and communities the tools and knowledge to be better protected against wildfire, and are ongoing as of this writing.

Types of Wildfire

Wildfires burn primarily in vegetative fuels located outside highly urbanized areas. Wildfires may be broadly categorized as agricultural, forest, range, or WUI fires.

Agricultural

Fires burning in areas where the primary fuels are flammable cultivated crops, such as wheat. This type of fire tends to spread very rapidly, but is relatively easy to suppress if adequate resources are available. Structures threatened are usually few in number and generally belong to the property owner. There may be significant losses in terms of agricultural products from such fires.

Forest

The classic wildfire; these fires burn in fuels composed primarily of timber and associated fuels, such as brush, grass, and logging residue. Due to variations of fuel, weather, and topography, this type of fire may be extremely difficult and costly to suppress. In wilderness areas these types of fires are often monitored and allowed to burn for the benefits brought by the ecology of fire, but also pose a risk to private lands when these fires escape these wilderness areas.

Range

Fires that burn across lands typically open and lacking timber stands or large accumulations of fuel. Such lands are used predominantly for grazing or wildlife management purposes. Juniper, bitter-brush, and sage are the common fuels involved. These fires tend to spread rapidly and vary from being easy to difficult to suppress. They often occur in areas lacking both wildland and structural fire protection services.

Wildland-urban interface (WUI)

These fires occur in portions of the state where urbanization and natural vegetation fuels are mixed together. This mixture may allow fires to spread rapidly from natural fuels to structures and vice versa. Such fires are known for the large number of structures simultaneously exposed to fire. Especially in the early stage of WUI fires, structural fire suppression resources may be quickly overwhelmed, which may lead to the destruction of a large number of structures. Nationally, wildland interface fires have frequently resulted in catastrophic structure losses.

Secondary Hazards

Increased risk of landslides and erosion are secondary hazards associated with wildfires that occur on steep slopes. Wildfires tend to denude the vegetative cover and burn the soil layer creating a less permeable surface prone to sheetwash erosion. This - in turn - increases sediment load and the likelihood of downslope failure and impact.

Wildfires can also impact water quality (e.g., drinking water intakes). During fire suppression activities some areas may need coordinated efforts to protect water resource values from negative impact.

Wildfire smoke may also have adverse effects on air quality and visibility, and create nuisance situations. Strategies to limit smoke from active wildfires are limited, but interagency programs exist to alert the public of potential smoke impact areas where hazardous health or driving conditions may occur.

Source: Unknown

Common Sources of Wildfire

For statistical tabulation purposes, wildland fires are grouped into nine categories based on historically common wildfire ignition sources.

Figure 3.3.10-4: Fires By General Cause: This graphic illustrates the general causes of wildfire across the state from 2015-2024.

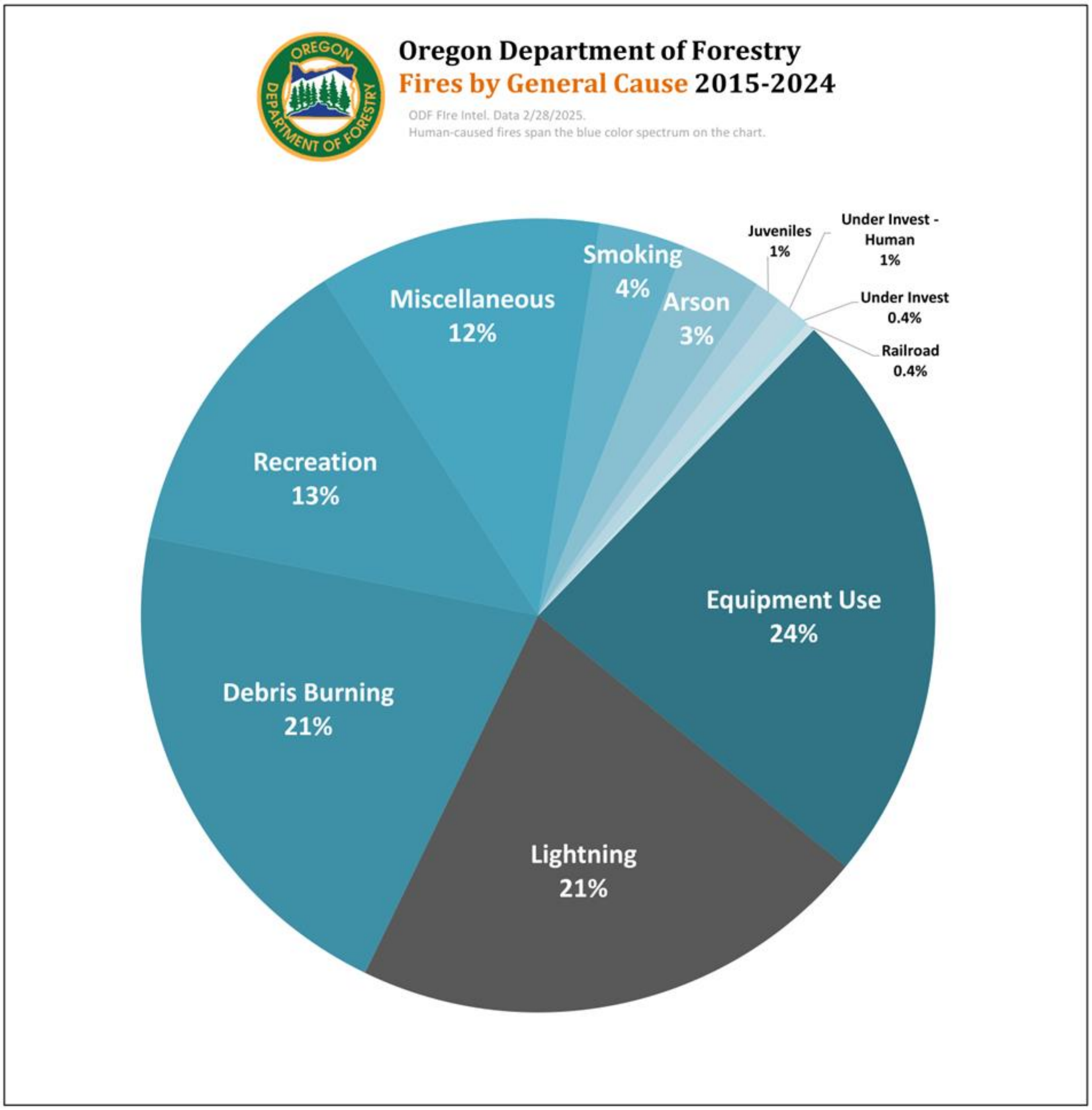
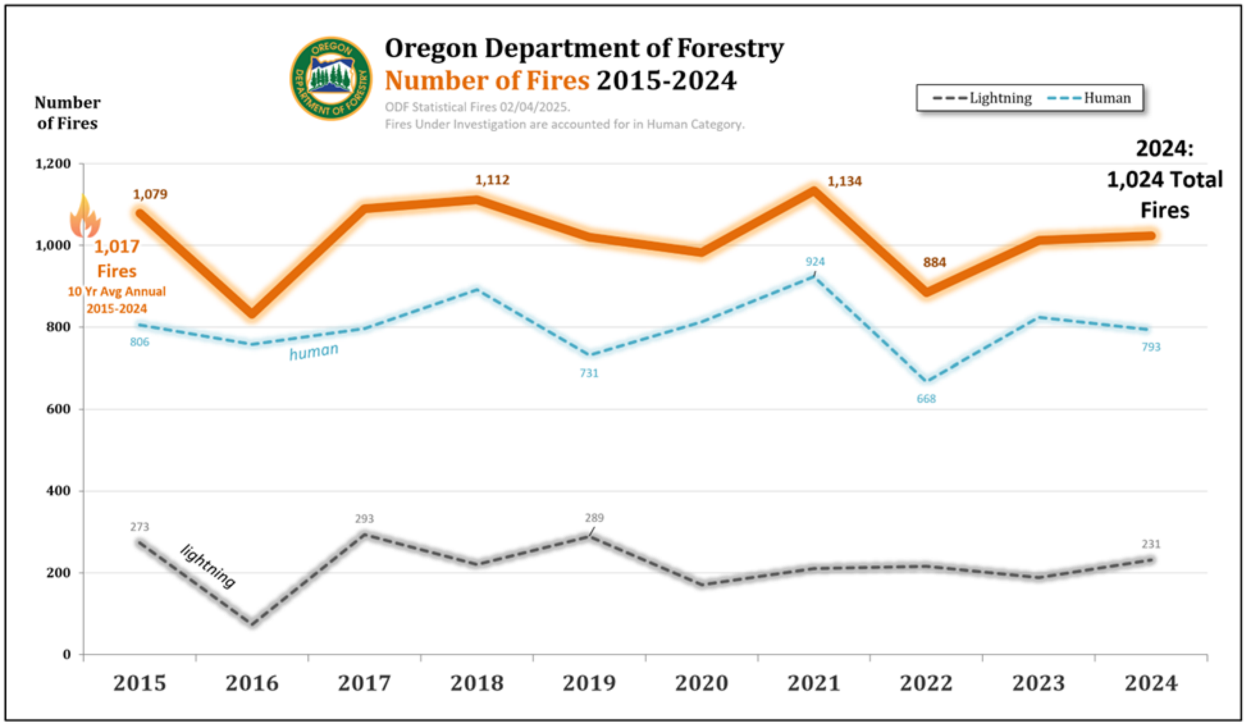


Figure 3.3.10-5: Number of Fires: This graphic illustrates the total number of fires due to human activity and lighting strike from 2015-2024.



Lightning

There are tens of thousands of lightning strikes in Oregon each year. Of the nine categories, lightning is the second highest ignition source of wildfires between 2015 and 2024 at 21 percent , along with debris burning.

Equipment use

This source ranges from small weed eaters to large logging equipment; many different types of equipment may readily ignite a wildfire, especially if used improperly or illegally. Although fire agencies commonly limit or ban certain uses of fire-prone equipment, the frequency of fires caused by equipment has increased. Increases in fires from this source may be related to the expansion of the wildland urban interface, which results in more people and equipment being in close proximity to forest fuels. Equipment use was the highest cause of all fires between 2015 and 2024 at 24 percent , pointing to the need for continued focus on this source.

Recreation

The trend in fires caused by people recreating in and near Oregon's forests has continued to rise. Recreation is the third highest cause of fires between 2015 and 2024 at 13 percent . This trend may reflect the state's growing population as well as a greater interest in outdoor recreation opportunities. Local, state, and federal land management and recreation agencies should continue to focus on strategies to engage visitors and local residents alike.

Debris burning

Historically, debris burning activities have been a leading source of human-caused wildfires. Between 2015 and 2024, debris burning was the second highest cause of wildfires at 21 percent , along with recreation. Partnering fire protection agencies, primarily through local fire defense boards, continue to seek solutions to curb ignitions and escapements. Besides consistent messaging during fire season that draws attention to the illegal activity, fire prevention professionals provide additional education to encourage alternatives to burning and safe burning practices during fall and winter months when fire danger is less severe.

Juvenile

Concerted efforts by local fire prevention cooperatives to deliver fire prevention messages directly to school classrooms and the Oregon State Fire Marshal's aggressive youth intervention program has helped address this ignition source. Between 2015 and 2024, juveniles caused 1 percent of fires. In 1999, according to the ODF, juveniles were reported to have started 60 wildland fires. Conversely, juveniles accounted for just 6 fires on ODF protected land in 2024. Additionally, parents or guardians, under Oregon Law, are responsible for damages done by fires started by their children. ORS 30.765 covers the liability of parents; ORS 163.577 holds parents or guardians accountable for child supervision, ORS 477.745 makes parents liable for wildfire suppression costs of a fire by a minor child, and ORS 480.158 holds a parent liable for fireworks-caused fires. Additionally, parents may be assessed civil penalties.

Arson

Oregon experienced a rapid rise in the frequency of arson caused fires in the early '90s. 1992 was the worst fire season for arson with 96 fires attributed to the category. In response, the state instituted aggressive arson prevention activities with solid working relationships with local law enforcement and the arson division of the Oregon State Police. Between 2015 and 2024, only 3 percent of fires were attributed to arson.

Smoking

Fires caused by smoking and improperly discarded cigarettes has slightly risen to 4 percent between 2015 and 2024.

Railroad

Wildfires caused by railroad activity are relatively infrequent. In the early twentieth century, this had been a major cause of fires, but has been decreasing for many years. Between 2015 and 2024, the number of railroad-caused fires was just 0.4 percent . In the past few decades, Oregon has responded to railroad-caused fires with aggressive fire investigation and cost recovery efforts. ODF works with the railroad on hazard abatement along tracks and requires water cars and chase vehicles during high fire danger. The resulting quick return to normal fire incidence showed that railroad fires are very preventable.

Miscellaneous

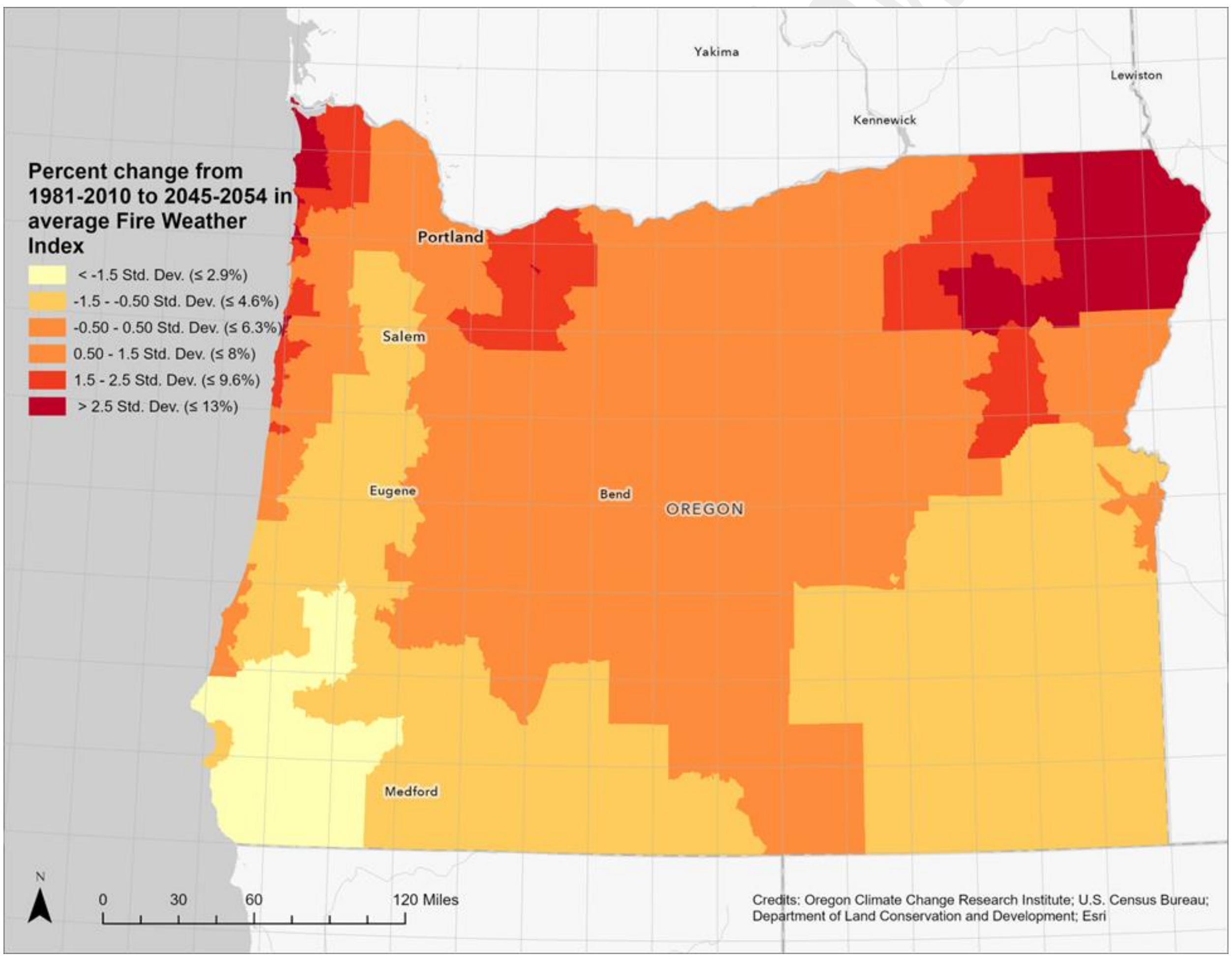
Wildfires resulting from a wide array of causes: automobile accidents, burning homes, pest control measures, shooting tracer ammunition and exploding targets, and electric fence use are a few of the causes in this category. The frequency of such fires has been rising in recent years.

Smoke Exposure

The effect of wildfire smoke exposure on public health is a growing topic of interest for public health and natural hazard mitigation. The Oregon Climate Assessment estimates that the number of smoke wave day-related all-cause mortality events, per six years, could exceed 151 adults and 192 older adults by the year 2050, with a total economic loss of 1.63 billion for all adults and 2.08 billion for older adults. Additionally, the number of smoke wave related emergency department visits could increase by about two-thirds by 2050, a dramatic increase from 2005 rates, according to the Oregon Climate Assessment (Fleishman 2025). The intersecting nature of wildfire hazards necessitates mitigation actions that address multiple risks to support multi-hazard resiliency.

3.3.10.2 Fire Weather Index

Figure 3.3.10-6: This map illustrates future statewide changes in average Fire Weather Index, measured in standard deviations.



Source: Data and map courtesy Oregon Climate Change Research Institute

3.3.10.3 Historic Wildfire Events

Table 3.3.10-1: Historic Wildfires in Oregon

Date	Location	Description
1902	Clackamas, Multnomah	**Columbia Fire/Yacolt Burn** 170,000 acres caused 38 deaths in the Lewis River area, 9 deaths in Windy River, and 18 deaths in the Columbia River Gorge.
1933-1951	Tillamook, Washington, Yamhill and Clatsop	**Tillamook Burn** was a series of large fires that struck in 6-year intervals burning a combined total of 355,000 acres and killing 35 people.
1936	Coos	**Bandon Fire** was a 287,000-acre fire that destroyed 100's of homes and killed 10 people.
2002	Josephine	**Biscuit fire** burned nearly 500,000 acres starting from lighting strikes and the product of the joining of 4 different fires and burned over 4 months long.
2006	Harney	**South End Complex** burned 117,553
2010	Jackson	**Oak Knoll Fire** in Ashland destroyed 11 homes in less than 45 minutes
2011	Wasco	**High Cascade Complex** burned on the east side of Mount Hood into **Warm Springs**, consuming 101,292 acres
2012	Tillamook, Washington, and Yamhill	**Holloway Fire** burned more than 245,000 acres in Oregon from a lightning strike and also burned more than 215,000 acres in Nevada. One firefighter was killed.
2012	Malheur and Harney	**Long Draw Fire** consumed 557,648 acres and was started by lightning.
2013	Josephine, Douglas	**Douglas Complex** burned about 49,000 acres started by lightning strikes. Made up of 3 fires: Rabbit Mountain, Dad's Creek, and Farmer's Fire.
2013	Jefferson	**Sunnyside Turnoff** started by a firecracker that was thrown into vegetation. It grew to 51,480 acres on the Warm Springs Indian Reservation.
2014	Wallowa	**Buzzard Complex** burned over 400,000 acres and significantly impacted rangeland and cattle farms.
2014	Grant	**South Fork Complex** started with lightning strikes burning 62,476 acres.

Date	Location	Description
2015	Grant	**Canyon Creek Complex** burned 110,422 acres started by lightning. It destroyed more private property than any Oregon wildfire for 80 years before it. It destroyed 43 homes and almost 100 other structures.
2015	Wallowa	**Grizzly Bear Complex** burned 82,659 acres started by lightning. Destroyed 2 homes and dozens of other structures.
2015	Jefferson	**County Line 2** burned over 67,000 acres.
2015	Baker	**Cornet Windy Ridge** burned 103,887 Acres started by lightning strike.
2017	Curry	**Chetco Bar** burned 191,125 acres and started by lightning strike.
2017	Multnomah and Hood River	**Eagle Creek Fire** burned 48,831 acres and was caused by a 15-year- old playing with fireworks.
2017	Lake and Harney	**Cinder Butte** burned over 52,000 acres of rangeland that was human caused and threatened Tribal Archaeological Sites.
2017	Wasco	**Nena Springs** burned more than 68,000 acres, was human cause and did significant damage to the Confederate Tribes of Warm Springs.
2018	Josephine	**Klondike** burned more than 175,258 acres and eventually merged into the Taylor Creek Fire that had burned 52,839 acres.
2018	Wasco	**Boxcar** burned 100,207 acres and started due to lightning.
2018	Jackson and Douglas	**Miles** burned 54,134 acres and was a combination of merged fires: Sugar Pine, South Umpqua Complex, and the Miles fire.
2018	Josephine	**Taylor Creek** burned 52,839 acres started by a lightning strike.
2018	Wasco	**Substation** burned 78,425 acres moving over 18 miles in just days.
2018	Lake	**Watson Creek** burned over 58,900 acres.
2020	Wasco	**Mosier Creek** burned 985 acres.
2020	Wasco	**White River** burned 17,404 acres from August 17 – September 10, 2020.
2020	Klamath	**Oregon Two Four Two 404** burned 14,473 acres over 17 days.

Date	Location	Description
2020	Clackamas, Linn, Jefferson, Marion, and Warm Springs Indian Reservation	**Beachie Creek Lionshead Complex** burned 193,566 acres from September 7 – October 15, 2020.
2020	Lane	**Holiday Farm** burned 173,393 acres from September 8 – October 3, 2020.
2020	Jackson	**Almeda Glendower** burned 3,200 acres over 8 days.
2020	Clackamas	**Riverside** burned 138,054 acres from September 8 – October 15, 2020.
2020	Lincoln	**Echo Mountain Fire Complex** burned 1,879 acres from September 8 – September 22, 2020.
2020	Douglas, Lane	**Archie Creek** burned from September 8 – October 15, 2020.
2020	Josephine	**Slater Fire** burned 166,127 acres from September 9 – November 3, 2020.
2020	Clackamas	**Clackamas County Fire Complex** burned 11,210 acres from September 8 – October 6, 2020.
2020	Lake	**Brattain** burned 50,951 acres from September 12 – 29, 2020.
2021	Deschutes	**Oregon 0419** burned 90 acres.
2021	Klamath, Lake	**Bootleg** burned 413,717 acres from July 10 – August 15, 2021
2021	Lake	**Patton Meadow** burned 8,946 acres from August 15 – 31, 2021.
2022	Wasco	**Miller Road** burned 10,847 acres over 5 days.
2023	Klamath	**Golden** burned 2,137 acres.
2023	Marion	**Liberty** burned 25 acres.
2024	Josephine	**Upper Applegate** burned 1,142 acres.
2024	Baker, Malheur	**Durkee** burned 294,265 acres from July 17 – August 13, 2024
2024	Baker	**Town Gulch Fire** burned 18,220 acres in August 2024.
2024	Deschutes	**Darlene 3** burned 3,903 acres.
2024	Jackson	**Salt Creek Road** burned 4,102 acres from July 7 – 24, 2024

Date	Location	Description
2024	Wasco	**Larch Creek** burned 18,286 acres.
2024	Gilliam, Morrow, and Wheeler	**Lone Rock** burned 137,222 acres from July 13 – August 12, 2024.
2024	Grant, Harney	**Falls Fire** burned 151,689 acres from July 10 – September 1, 2024.
2024	Lane, Douglas	**Lane 1** burned 25,265 acres from July 17 – October 1, 2024.
2024	Grant, Morrow, Umatilla	**Battle Mountain Complex** burned 162,389 acres.
2024	Harney	**Telephone Fire** burned 38,954 acres July 22 – September 1, 2024.
2024	Grant	**Boneyard** burned 52,473 acres from July 17 – August 10, 2024.
2024	Grant	**Courtrock Fire** burned 20,023 acres from July 17 – August 17, 2024.
2024	Deschutes	**Mile Marker 132** burned 78 acres.
2024	Wallowa	**Winding Waters Complex** burned 728 acres from July 25 – August 13, 2024.
2024	Jefferson	**Elk Lane** burned 5,640 acres and was started by a lightning strike.
2024	Douglas	**Dixon Fire** burned 1,970 acres from August 10 – 21, 2024.
2024	Washington	**Lee Falls** burned 240 from August 8 – 10, 2024.
2024	Klamath	**Copperfield** burned 3,822 acres from September 2 – 10, 2024.
2024	Crook, Grant, Wheeler	**Rail Ridge** burned 176,661 acres from September 2 – October 10, 2024.
2024	Wheeler	**Shoe Fly Fire** burned 26,893 acres from September 2 – 22, 2024.
2024	Fossil Complex	**Fossil Complex** burned 24,430 acres from September 5 – 24, 2024.

Source: Oregon Department of Forestry, 2025, and InciWeb the Incident Information System, accessed 3/3/2025.

3.3.10.4 Risk Maps

Non-regulatory map: *This wildfire risk assessment and maps are not regulatory. The Oregon Department of Forestry and Oregon State University developed a statewide wildfire hazard map as required by the Oregon Legislature for use in building codes, defensible space requirements, and grant programs. To learn more about the regulatory statewide wildfire hazard maps, visit Oregon Department of Forestry's wildfire page.*

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

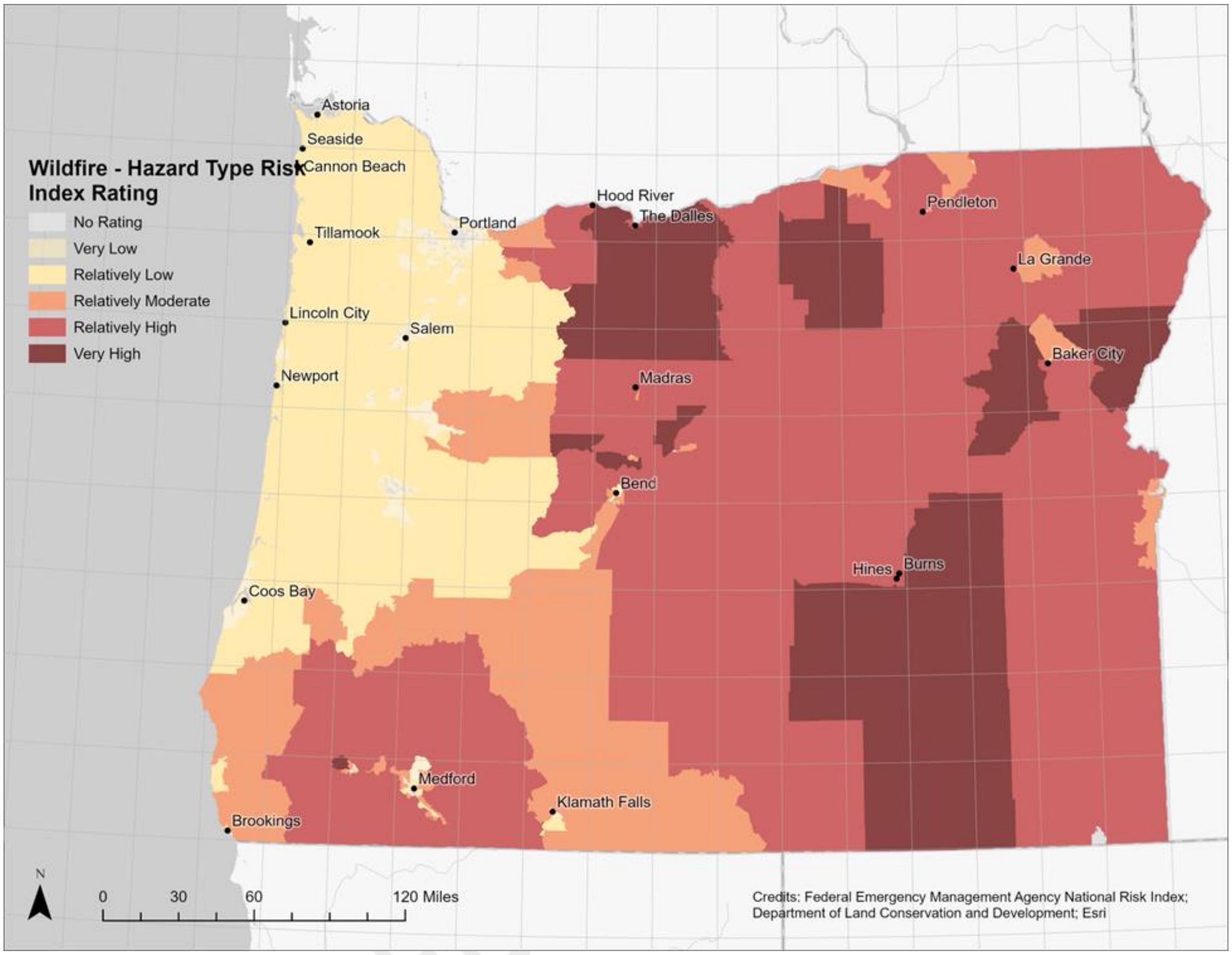
The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

In contrast to the National Risk Index, the Oregon Natural Hazards Risk Assessment used indicators of harm based on percentages rather than counts of exposed entities or monetary loss. This captures the potential for disruption within a census tract. The higher the percentage of entities affected, the more disruption to those living or working in the census tract.

The Oregon Natural Hazards Risk Assessment produced two statewide summary maps showing distribution of potential harm. The first map uses both socioeconomic and hazard factors. The second map uses hazard factors alone. The maps show the importance of recognizing the cost of disruption not only to buildings and infrastructure, but also to people, especially vulnerable populations. Both types of losses can be mitigated.

The climate change maps show where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

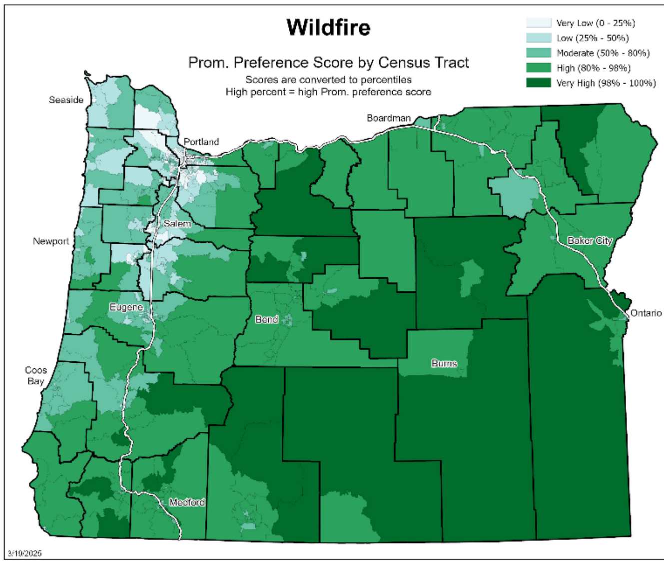
Figure 3.3.10-7: Wildfire Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for wildfire.



Federal Emergency Management Agency, National Risk Index for wildfire. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.10-8 and Figure 3.3.10-9 show risk rankings by census tract for wildfire from the Oregon Natural Hazards Risk Assessment. Darker colors show census tracts with higher risk. Figure 3.3.10-8 shows census tracts ranked using hazard and socioeconomic vulnerability indicators. Figure 3.3.10-9 shows census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators. Cities are included for locational reference only and do not show risk by city. Chapter 9 has additional details and examples of the information available from the risk assessment model.

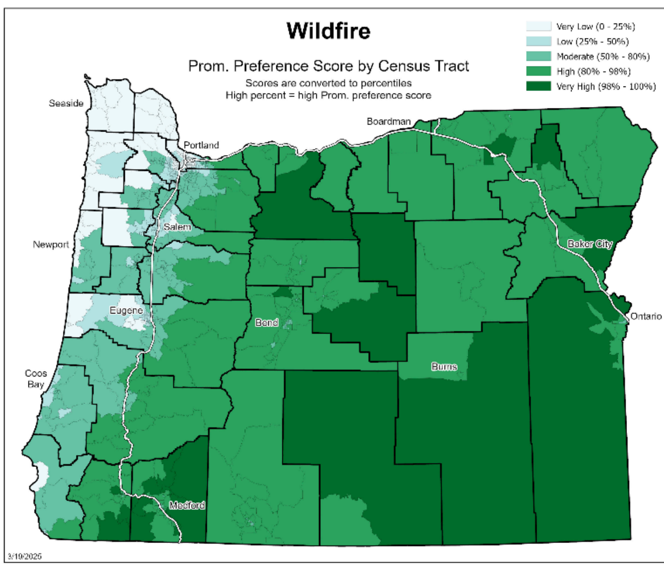
Figure 3.3.10-8: Census tracts ranked using hazard and socioeconomic vulnerability indicators.



Indicators used for the hazard   Hazard indicators are worth 35% of the total weight.

Hazard	Indicator Name	Direction	Weight	Short Description
Wildfire	WF_pct_bld	1	0.05	Percentage of SBFO buildings exposed to Medium and High Burn Probability.
Wildfire	WF_pct_CF	1	0.05	Percentage of critical facilities exposed to Medium and High Burn Probability .
Wildfire	BurnProb	1	0.05	Burn probablility from the QPNW.
Wildfire	Hwy_WF_pct	1	0.05	Percentage of highway within High Burn Probability zones
Wildfire	Hist_WF_ct	1	0.05	Percentage of historic buildings exposed to Medium and High Burn Probability.
Wildfire	Over90th	1	0.05	Mean days that are above the historic 90th percentile temp
Wildfire	Over90F	1	0.05	Mean days above 90 degrees Fahrenheit
General	EP_MINRTY	1	0.046	Percentage of Black, Indigenous, and People of Color (2020 Census).
General	HousingTenure	-1	0.046	Housing tenure from the US Census.
General	EP_MOBILE	1	0.046	Percentage of people that live in mobile homes
General	Median_Yrblt	-1	0.046	Median year built of general building stock based on HAZUS default.
General	HospitalDistMile	1	0.046	Distance from tract centroid to nearest hospital.
General	NatResrcJobs	1	0.046	Rate of natural resource jobs.
General	PRED3_PE	1	0.046	Community Resilience Estimate
General	Hosp_Beds	-1	0.046	Estimated number of hospital beds based on square footage .
General	Pct_Adherents	-1	0.046	Percentage of members to a religious group
General	Mitigation	-1	0.046	Number of migitation projects (grouped by zip code and evenly distributed to overlaying tracts)
General	Watch	-1	0.046	Neighborliness: Will watch neighbor's house
General	CountyTax	-1	0.046	County tax rate
General	CityTax	-1	0.046	City tax rate
General	Cultural	-1	0.009	Number of cultural-related buildings
General	Favors	-1	0.009	Neighborliness: Willing to do favors for neighbor
General	Advice	-1	0.009	Neighborliness: Seeks advice from neighbor
General	Parties	-1	0.009	Neighborliness: Attended parties that occur in neighborhood
General	Visits	-1	0.009	Neighborliness: Has visited neighbor's house

Figure 3.3.10-9: Census tracts ranked using only hazard indicators, without using socioeconomic vulnerability indicators.

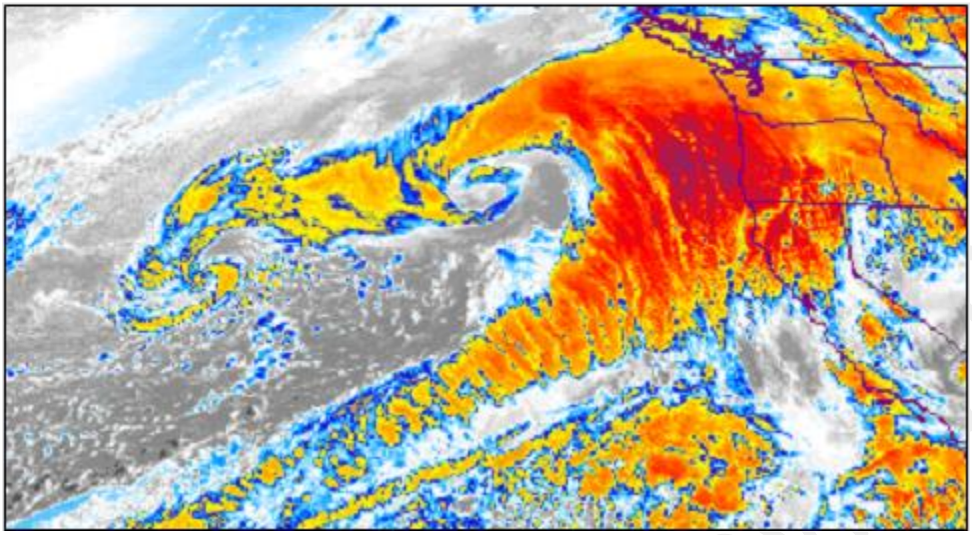


Indicators used for the hazard

Hazard	Indicator Name	Direction	Weight	Short Description
Wildfire	WF_pct_bld	1	0.143	Percentage of SBFO buildings exposed to Medium and High Burn Probability.
Wildfire	WF_pct_CF	1	0.143	Percentage of critical facilities exposed to Medium and High Burn Probability .
Wildfire	BurnProb	1	0.143	Burn probablility from the QPNW.
Wildfire	Hwy_WF_pct	1	0.143	Percentage of highway within High Burn Probability zones
Wildfire	Hist_WF_ct	1	0.143	Percentage of historic buildings exposed to Medium and High Burn Probability.
Wildfire	Over90th	1	0.143	Mean days that are above the historic 90th percentile temp
Wildfire	Over90F	1	0.143	Mean days above 90 degrees Fahrenheit

3.3.11 Windstorms

Figure 3.3.11-1: Satellite Image of the Type of Severe Pacific Storm that Can Bring High Winds to Western Oregon.



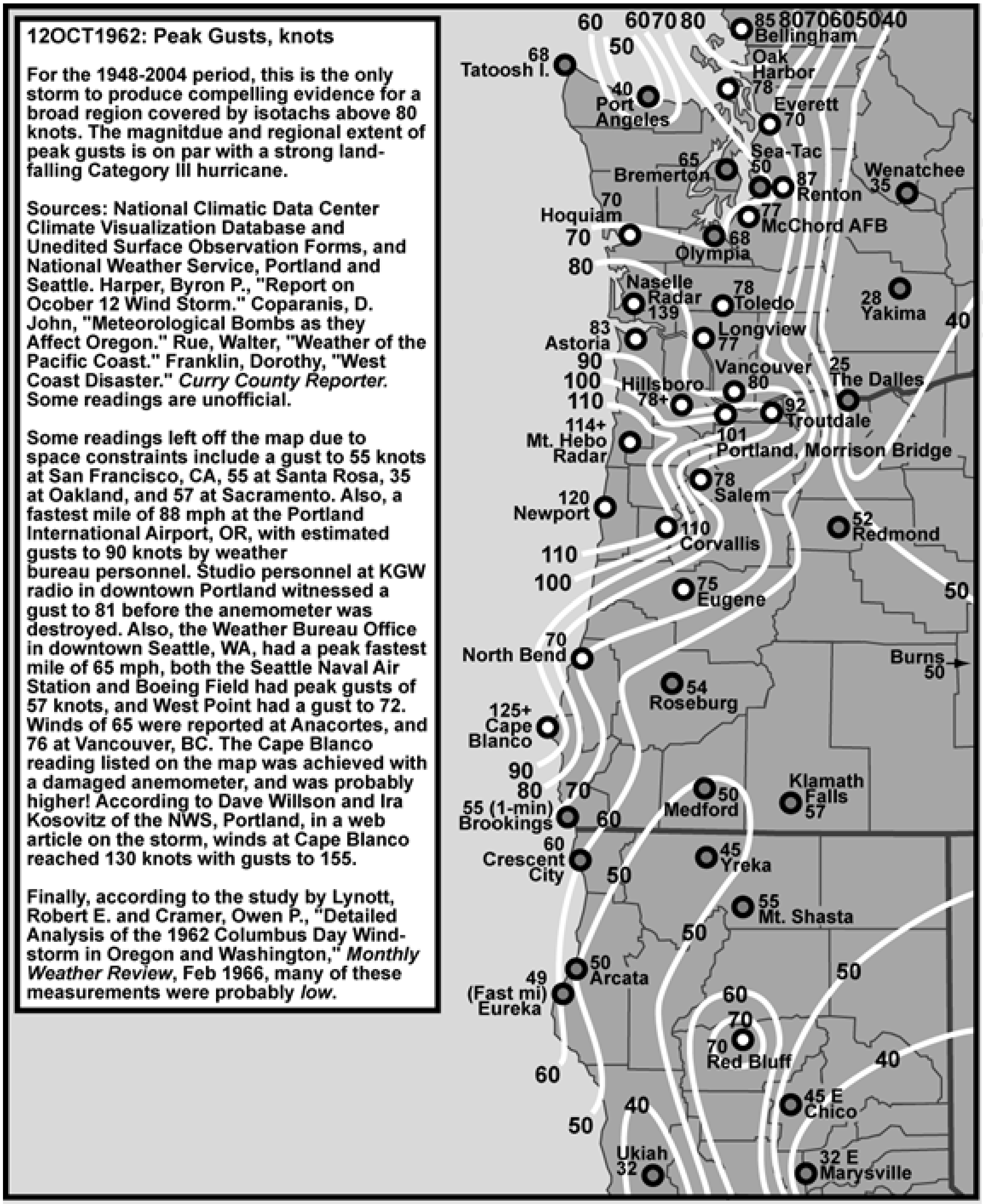
Source: NOAA

This section covers most kinds of windstorm events in Oregon, including the wind aspects of Pacific storm events. The precipitation aspects of Pacific storm events are covered earlier in the **Flood** section. Winds specifically associated with blizzards and ice storms are covered in the **Winter Storm** section. Wildfires driven by high winds are covered in the Wildfire section.

3.3.11.1 Analysis and Characterization

High winds can be among the most destructive weather events in Oregon; they are especially common in the exposed coastal regions and in the mountains of the Coast Range. Most official wind observations in Oregon are sparse, taken at low-elevation locations where both the surface friction and the blocking action of the mountain ranges substantially decrease the speed of surface winds. Furthermore, there are few long-term reliable records of wind available. Even the more exposed areas of the coast are lacking in any long-term set of wind records. From unofficial, but reliable observations, it is reasonable to assume that gusts well above 100 mph occur several times each year across the higher ridges of the Coast and Cascades Ranges. At the most exposed Coast Range ridges, it is estimated, that wind gusts of up to 150 mph and sustained speeds of 110 mph will occur every 5–10 years.

Figure 3.3.11-2: Peak Gusts for Windstorm on October 12, 1962



Source: Wolf Read, Climatologist, Oregon Climate Center, Oregon State University

Pacific storms can produce high winds and often are accompanied by significant precipitation and low barometric pressure. These storms usually produce the highest winds in Western Oregon, especially in the coastal zone. These storms are most common from October through March. The impacts of these storms on the state are influenced by storm location, intensity, and local terrain.

Figure 3.3.11-3: Unstable Trees Near Electric Lines Left after a Logging Operation

Note: Unstable trees near electric lines left after a logging operation near electric lines pose a serious threat of personal injury, forest fire, and outages should high winds develop. Forest owners and workers need to coordinate their "leave trees" with electric utilities to prevent dangerous conditions as depicted here.
Source: Randy Miller, PacifiCorp

The historian Lancaster Pollard documented exceptional storms that occurred in 1880, 1888, 1920, 1931, and 1962. On January 29, 1920 a hurricane off the mouth of the Columbia River had winds estimated at 160 miles per hour (Pitzer, 1988).

One easterly windstorm that affected much of Oregon, particularly northern Oregon, was the northeasterly gale of April 21-22, 1931. This storm proved to be very destructive. Dust was reported by ships 600 miles out to sea. "While officially recorded wind speeds were not extreme, sustained wind speeds observed were 36 mph at Medford, 32 mph at Portland, 28 mph at Baker, and 27 mph at Roseburg. Unofficial wind measuring equipment reported winds of up to 78 mph. Damage was heavy to standing timber and fruit orchards." (http://www.wrh.noaa.gov/Portland/windstorm.html; for more information on this 1931 storm, see Appendix **9.1.4**.)

Effects

The damaging effects of windstorms may extend for distances of 100 to 300 miles from the center of storm activity. Isolated wind phenomena in the mountainous regions have more localized effects. Near-surface winds and associated pressure effects exert loads on walls, doors, windows, and roofs, sometimes causing structural components to fail.

Positive wind pressure is a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Negative pressure also affects the sides and roof: passing currents create lift and suction forces that act to pull building components and surfaces outward. The effects of high-velocity winds are magnified in the upper levels of multi-story structures. As positive and negative forces impact and remove the building protective envelope (doors, windows, and walls), internal pressures rise and result in roof or leeward building component failures and considerable structural damage.

Debris carried along by extreme winds can directly contribute to loss of life and indirectly to the failure of protective building envelope components. Upon impact, wind-driven debris can rupture a building, allowing more significant positive and internal pressures. When severe windstorms strike a community, downed trees, power lines, and damaged property are major hindrances to response and recovery.

The most destructive winds are those which blow from the south, parallel to the major mountain ranges. The Columbus Day Storm of 1962 was a classic example of a south windstorm. The storm developed from Typhoon Freda remnants in the Gulf of Alaska, deepened off the coast of California and moved from the southwest, then turned, coming into Oregon directly from the south. This was the most damaging windstorm in Oregon of the last century. Winds in the Willamette Valley topped 100 mph, while in the Coast Range they exceeded 140 mph. The Columbus Day Storm was the equivalent of a Category IV hurricane in terms of central pressure and wind speeds.

In terms of damage, "throughout the Willamette Valley, undamaged homes were the exception, not the rule. In 1962 dollars, the Columbus Day Storm caused an estimated $230 280 million in damage to property in California, Oregon, Washington and British Columbia combined, with $170 200 million happening in Oregon alone. This damage figure is comparable to eastern hurricanes that made landfall in the 1957–1961 time period... The Columbus Day Storm was declared the worst natural disaster of 1962 by the Metropolitan Life Insurance Company. In terms of timber loss, about 11.2 billion board feet was felled... in Oregon and Washington combined" (http://www.climate.washington.edu/stormking/) "The storm claimed 46 lives, injured hundreds more, and knocked power out for several million people" (http://www.wrh.noaa.gov/pqr/info/pdf/pacwindstorms.pdf).

Other Issues

The Hazard Mitigation Survey Team (HMST) Report developed in response to the February 7, 2002 windstorm the recommended that "differences in definitions of easements and allowable practices within them ('easement language') for private versus public, and urban forests vs. rural forests should be resolved." Recent wildfires, particularly the Camp Fire in California (2018), have brought attention to the importance of vegetation management within and adjacent to utility power line right of ways. Many stakeholders are now coming to the table to address the following issues that were highlighted in the report as well as newly identified.

- "Land use actions being proposed by agencies with nonutility interests, which would affect land for which utilities have an interest, should be coordinated and should address vegetation management as it affects utility system operations."
- "Agencies and organizations should be identified to work with federal and state landowners to streamline processes by which electric utilities conduct hazard mitigation work on those lands..." Currently, ODOT issues permits for right-of-way work and ODF issues permits for the use of power equipment in forested areas.

Other areas of ongoing concern from this HMST Report are:

- Under Coordination — Utility providers should receive notification, from property owners, of planned treeharvesting operations near utility lines.
- Under Vegetation Management — Diseased, damaged, and hazard trees near power lines that could fall or hit utility lines should be removed. Some "leave trees" remaining after new building developments and tree harvesting operations pose a threat to utility line safety and reliability. See the International Society of Arboriculture's website and brochure for information about managing tree hazards and risk at https://www.treesaregood.org/portals/0/docs/treecare/TreeRisk.pdf.
- Under Engineering, Construction, and Compliance — "During initial planning and design of utility lines, identify types of geographic areas already known to pose hazards during windstorms. Inventory and analyze areas of repetitive failures to determine alternate designs and construction methods that will mitigate future damages... Consider selective undergrounding of lines where repetitive tree damage occurs, keeping in mind excavations can undermine tree root zones and create new hazards."

Increasing wildfire probability due to climate change has accelerated the need to resolve the following:

- Access to State and Federal Lands – Many utilities have identified difficulty in gaining access to these lands for vegetation management. The Oregon Department of Forestry is improving its processes to accelerate issuing permits. The Bureau of Land Management (BLM) recently updated and simplified its process for granting access to utility right-of-ways on its lands. BLM processes are consistent across all of the properties it owns. US Department of Forestry has been the most challenging to work with and there is now pressure at the Federal level to simplify and accelerate the permitting process.
- Ability to Remove Vegetation Outside of the Utility Easement — This issue is controversial in forest lands, urban areas, and rural areas. Managers of protected lands are hesitant to disturb the natural ecosystems by removing vegetation that has been identified as a potential hazard. Likewise, individuals in both urban and rural areas are very protective of vegetation that adds beauty and character to an area.

Emerging concerns include:

- Impacts of intense windstorms that can significantly reduce efficiency and impair operations of renewable energy facilities (e.g., solar panels and wind turbines), in particular, on agricultural land where producers produce renewable energy to supply their operations and to sell to diversify their revenue streams. To date, little or no data have been collected on economic impacts of this issue.

- Impacts of intense wind and precipitation events that damage crops (e.g., grain, corn, orchards); cause uncontrolled discharges from permitted animal waste holding facilities that subsequently reach waterways and can adversely impact downstream water quality and shellfish farms. Little or no data have been collected or compiled on the economic impacts of this issue.

3.3.11.2 Historic Windstorm Events

Table 3.3.11-1: Historic Windstorms in Oregon

Date	Location	Comments
Oct. 1962	W. Oregon and locations east of Cascades, Oregon	Columbus Day Storm: Oregon's most famous and most destructive windstorm; barometric pressure low of 960 mb*
Mar. 1963	W. Oregon	second strongest windstorm in the Willamette Valley since 1950
Oct. 1967	most of western and central Oregon	an intense 977 mb low produced a sudden, destructive blow (*)
Nov. 1981	Oregon coast and N. Willamette Valley, Oregon	back-to-back storms on Nov. 13 and 15
Jan. 1993	North Coast Range, Oregon	Inauguration Day Storm; major disaster declaration in Washington State
Dec. 1995	NW Oregon	FEMA-1107-DR-Oregon (*); strongest windstorm since Nov. 1981; barometric pressure of 966.1 mb (Astoria), and Oregon record low 953 mb (off the coast)
Feb. 2002	south and central coast, Southern Willamette Valley, Oregon	FEMA-1405-DR-Oregon; surprise windstorm
Feb. 2007	NW and central coast and north central Oregon	FEMA-1683-DR-Oregon; severe winter storm with a wind component
Dec. 2007	Oregon coast and Willamette Valley, Oregon	FEMA-1733-DR-Oregon; severe winter storm, including flood and landslide events
Dec. 2015	Regions 1-4	FEMA-4258-DR: severe winter storms, straight-line winds, flooding, landslides, and mudslides
Oct. 2016	Manzanita, Oceanside in Tillamook County	tornadoes; EF2 in Manzanita with estimated damages of $1M; EFU in Oceanside with no damage
Jul. 2018	Portland, Multnomah County	tornado; EF0; damage to trees and homes

Date	Location	Comments
Apr. 2019	Curry, Douglas, Linn, Wheeler, Grant, and Umatilla	FEMA-4452-DR: Severe storms, straight-line winds, flooding, landslides, and mudslides
Feb. 2020	Regions 5 and 7: Umatilla, Union, Wallowa Counties	FEMA-4519-DR: Severe storms, tornadoes, straight-line winds and flooding
Sep.-Nov. 2020	Benton, Clackamas, Columbia, Coos, Deschutes, Douglas, Jackson, Jefferson, Josephine, Klamath (& Klamath TDSA), Lake, Lane, Lincoln, Linn, Marion, Multnomah, Tillamook, Wasco, Washington, Yamhill	FEMA-4562-DR: Oregon Wildfires and Straight-line Winds
Jan. 2024	Benton, Clackamas,Coos, Hood River, Lane, Lincoln, Multnomah, Sherman, Siletz Indian Reservation, Tillamook, Wasco	FEMA-4768-DR: Oregon Severe Winter Storms, Straight-line Wind, Landslides, and Mudslides

*For comparison, surface barometric pressures associated with Atlantic hurricanes are often in the range of 910 to 960 mb. The all-time record low sea level barometric pressure recorded was associated with Typhoon Tip in the Northwest Pacific Ocean on October 12, 1979 at 870 mb.

Sources: Oregon Climate Service, http://www.ocs.oregonstate.edu/; Pitzer (1988); https://www.fema.gov/disaster/; https://www.ncdc.noaa.gov/stormevents/; https://www.weather.gov/pqr/07-01-2019

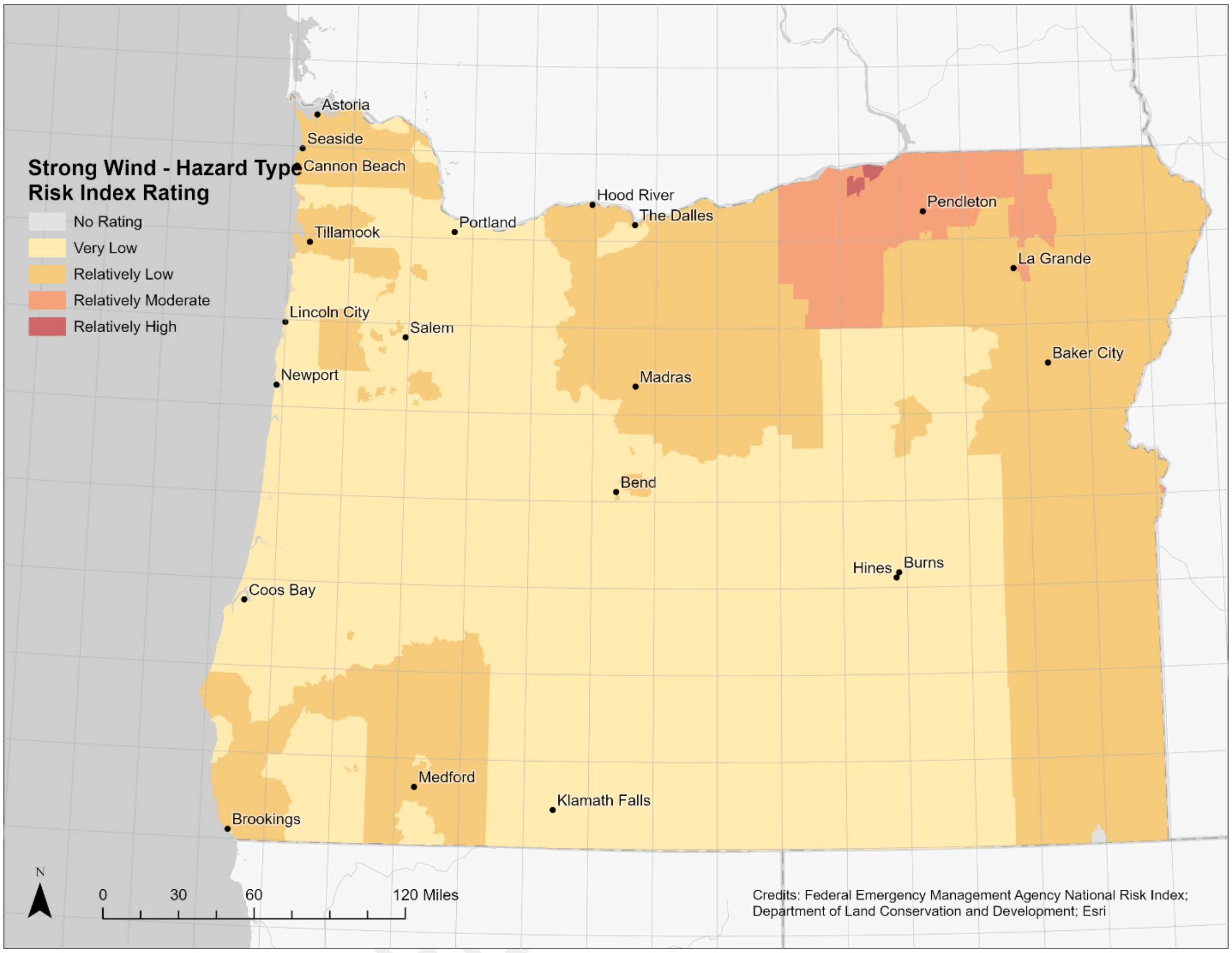
3.3.11.3 Risk Maps

The maps in this section highlight places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

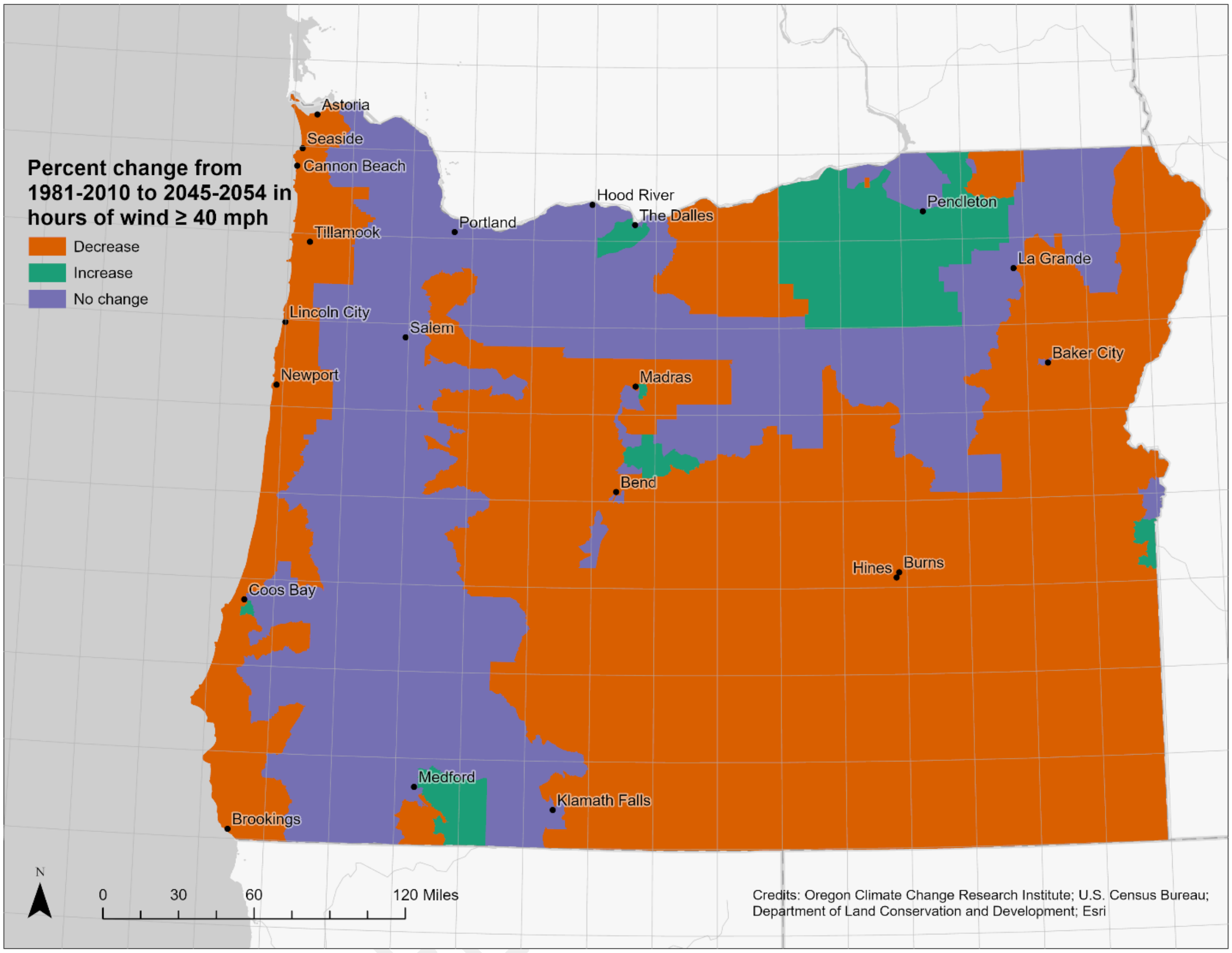
The climate change map shows where risk is projected to increase. Areas with a high risk and a high increase in risk would be especially good places to work with communities to find mitigation projects.

Figure 3.3.11-4: Strong Wind Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency



Source: Federal Emergency Management Agency, National Risk Index for Strong Wind. Ranking based on national percentiles. Last updated by FEMA in March 2023. Data accessed on February 12, 2025 from National Risk Index | FEMA.gov.

Figure 3.3.11-5: Change in Hours of High Wind: Percent change from 1981-2010 to 2045-2054 in hours of wind >= 40 mph.



Source: Derived from an ensemble of 14 regional climate model simulations that cover the period 1980-2100. Data provided by OCCRI, 2025. Graphic produced by DLCD.

3.3.12 Winter Storms

Winter storms are among nature's most impressive spectacles. The combination of heavy snow, ice accumulation, and extreme cold can severely impact areas across the state, halting the activities of day-to-day life, as snow and ice blanket the ground, making travel extremely hazardous. In addition, the accumulation of snow and ice on vegetation can down trees, powerlines, and telecommunication. Compounding extremely cold temperatures with hazardous travel and power outages shows how vulnerable communities are to winter storms.

This section will focus generally on snow, ice, and extreme cold. Heavy wind events will, for the most part, be covered in the **Windstorm** section. While heavy precipitation events, which sometimes lead to flooding, are covered in the **Flood** section. Analysis and Characterization

According to the National Weather Service (2003) — "Most snowstorms need two ingredients: cold air and moisture. Rarely do the two ingredients occur at the same time over western Oregon, except in the higher elevations of the Coast Range and especially in the Cascades. But snowstorms do occur over eastern Oregon regularly during December through February. Cold arctic air sinks south along the Columbia River Basin, filling the valleys with cold air. Storms moving across the area drop precipitation, and if conditions are right, snow will occur.

However, it is not that easy of a recipe for western Oregon. Cold air rarely moves west of the Cascades Range. The Cascades act as a natural barrier, damming cold air east of the range. The only spigot is the Columbia River Gorge, which funnels the cold air into the Portland area. Cold air then begins deepening in the Columbia River valley, eventually becoming deep enough to sink southward into the Willamette valley. If the cold air east of the Cascades is deep, it will spill through the gaps of the Cascades and flow into the western valleys via the many river drainage areas along the western slope. The cold air in western Oregon is now in place. The trick is to get a storm to move near or over the cold air, which will use the cold air and produce freezing rain, sleet, and/or snow. Sometimes, copious amounts of snow are produced. Nearly every year, minor snowfalls of up to six inches occur in the western interior valleys. However, it is a rare occurrence for snowfalls of over a foot in accumulations [sic]."

Figure 3.3.12-1: Troutdale Area - December 1996

Source: National Weather Service

Figure 3.3.12-2: Shielded snow gauge used in the pacific northwest to register snowfall, 1917

Source: National Weather Service

Snow is relatively rare along the coast in Oregon. There is, however, a noticeable relationship between latitude and snowfall. Appendix **9.1.6** shows average annual snowfall at various Oregon stations. Notice, in particular, Crater Lake, one of the snowiest measurement stations in the United States, which once reported nearly 900 inches of snow in one season (Taylor & Hannan, The climate of Oregon: from rain forest to desert, 1999).

Ice storms and freezing rain can cause severe problems when they occur. The most common freezing rain events occur in the proximity of the Columbia Gorge. The Gorge is the most significant east-west air passage through the Cascades. In winter, cold air from the interior commonly flows westward through the Gorge, bringing very cold air to the Portland area. Rain arriving from the west falls on frozen streets, cars, and other sub-freezing surfaces, creating severe problems. As one moves away from the Gorge, temperatures moderate as the marine influence becomes greater and cold interior air mixes with milder west-side air. Thus freezing rain is often confined to areas in the immediate vicinity of the Gorge: Corbett, Troutdale, perhaps as far west as Portland Airport. Downtown Portland and the western and southern suburbs often escape with no ice accumulation (Taylor & Hannan, The climate of Oregon: from rain forest to desert, 1999)
.

Freezing rain (also known as an ice storm) is rain that falls onto a surface with a temperature below freezing. The cold surface causes the rain to freeze so the surfaces, such as trees, utilities, and roads, become glazed with ice. Even small accumulations of ice can cause a significant hazard to property, pedestrians, and motorists. According to the Oregon Climate Change Research Institute (OCCRI) report Projections of Freezing Rain and Ice Accretion, frequency of freezing rain is primarily affected by changes in wind, rain, and a warming climate (Rupp et al. 2024).

Sleet is rain that freezes into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects; however, it can accumulate like snow and cause roads and walkways to become hazardous.

Black ice can fool drivers into thinking water is on the road. What they may not realize is that condensation, such as dew, freezes when temperatures reach 32 °F or below, forming a thin layer of ice. This shiny ice surface is one of the most dangerous road conditions. Black ice is likely to form under bridges and overpasses, in shady spots and at intersections.

Meteorologists define *heavy snow* as six inches or more falling in less than twelve hours, or snowfall of eight inches or more in twenty-four hours. A *blizzard* is a severe winter weather condition characterized by low temperatures and strong winds blowing a great deal of snow. The National Weather Service defines a blizzard as having wind speeds of 35 mph or more, with a visibility of less than a quarter mile. Sometimes a condition known as a *whiteout* can occur during a blizzard. This is when the visibility drops to zero because of the amount of blowing snow.

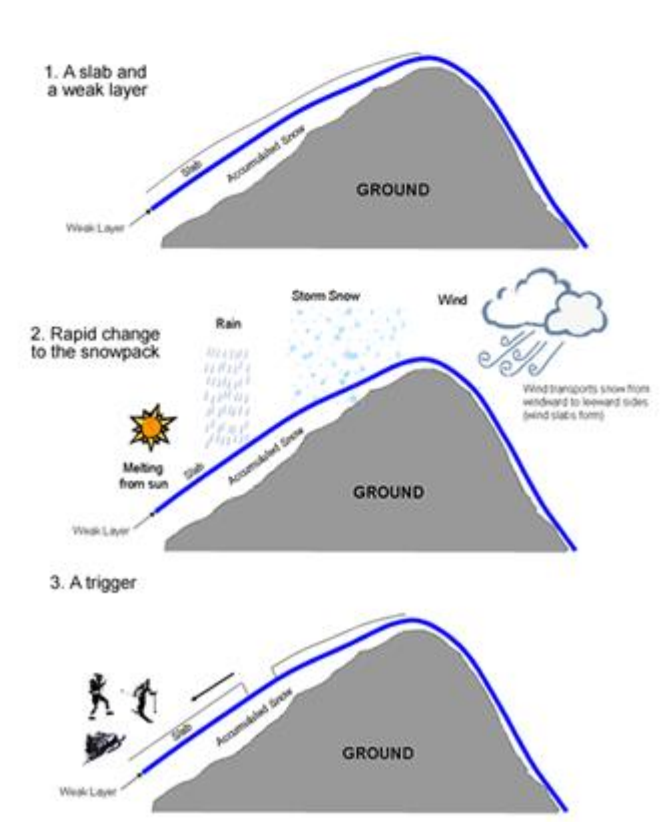
Wind blowing across your body makes you feel colder. The *wind chill* factor is a measure of how cold the combination of temperature and wind makes you feel. Wind chill of 50°F or lower can be very dangerous: exposed skin can develop frostbite in less than a minute, and a person or animal could freeze to death after just 30 minutes of exposure.

A snow avalanche is a mass of snow falling down a mountain or incline. Three variables interact to determine whether an avalanche is possible:

- *Terrain:* the slope must be steep enough to avalanche,
- *Snowpack:* the snow must be unstable enough to avalanche, and
- *Weather:* changing weather can quickly increase instability.

According to the Northwest Weather and Avalanche Center, avalanches don't happen by accident and most human involvement is a matter of choice, not chance. Most avalanche accidents are caused by slab avalanches that are triggered by the victim or a member of the victim's party. However, any avalanche may cause injury or death and even small slides may be dangerous.

Figure 3.3.12-3: Ingredients for a Slab Avalanche



Source: Northwest Weather and Avalanche

On average, about 30 people in the United States are killed in avalanches each year. For the 21 years between 1985 and 2006. With five fatalities, Oregon ranks 10th among the states for avalanche fatalities. This is based on statistics from the Colorado Avalanche Information Center. Avalanche victims are almost exclusively backcountry recreationists — snowmobilers, climbers, snowboarders, snowshoers, skiers, and hikers. Nationally snowmobilers lead the list with twice as many fatalities as any other activity.

According to Portland Mountain Rescue, most avalanche victims triggered the very avalanche that caught them. The group advises people to be aware of the constantly changing conditions in the backcountry and take a certified avalanche class to increase their avalanche awareness.

Ski areas are different from the backcountry. It is very rare for someone to get caught in an avalanche within a ski area. Professional snow safety crews rely on explosives and ski compaction to stabilize ski area snowpack.

3.3.12.1 Historic Winter Storm Events

Table 3.3.12-1: Historic Winter Storms in Oregon

Date	Location	Description
Dec. 16–18, 1884	Linn, Marion, Washington, Multnomah, Hood River and Wasco Counties	heavy snow in the Columbia River Basin from Portland to The Dalles and along the Cascades foothills in the Willamette Valley; 1-day snow totals: Albany, 16.0 inches; The Dalles, 29.5 inches; Portland, 12.4 inches
Dec. 20–23, 1892	Linn, Marion, Washington, Multnomah, and Umatilla Counties	substantial snow across most of northern Oregon; greatest snowfall in the northwest part of the state; totals from 15 to 30 inches with Albany, 15.0 inches; Corvallis, 14.0 inches; Portland, 27.5 inches; Forest Grove, 28.0 inches; Pendleton, 8.0 inches
Jan. 5–10, 1909	Josephine, Jackson, Douglas Lane, Linn, Marion, Clackamas, Hood River, and Wasco Counties	heavy snowfall in mountainous areas; 34.5 inches at Siskiyou Summit; many locations, particularly in western Oregon, received more snow in this 6-day period than they normally would receive in an entire year; snow totals: Ashland, 9.1 inches; Eugene, 15.1 inches; Forest Grove, 29.0 inches; Lakeview, 17.0 inches; Portland, 19.3 inches; The Dalles, 14.5 inches
Jan. 11–15, 1916	Josephine, Jackson, Douglas Lane, Linn, Marion, Clackamas, Hood River, and Waco Counties	5-8 inches of snow in western Oregon, except for the southwestern interior and the coastal areas; McMinnville had the most snow in one day, with 11 inches falling on January 12; another 24 inches at Siskiyou Summit; higher elevations in the Cascades received very heavy snowfall
Jan. 30–Feb. 3, 1916	Hood River, Clackamas, Marion, Wasco, Jefferson, and Multnomah Counties	snow and ice storm along the northern Oregon border; heaviest snowfall in the Hood River Valley with 29.5 inches in one day at Parkdale, and 81.5 inches total; heavy snow especially in the higher Cascades with Government Camp 41.0 inches in a day and storm total of 87.5 inches; the ice inflicted severe damage to electric light, telephone and telegraph companies, fruits and ornamental trees; many locations, earlier snow had not melted, resulting in substantial snow depths
Dec. 9–11, 1919	statewide	one of three heaviest snowfall-producing storms to hit Oregon on record; lowest statewide average temperature since record keeping began in 1890; the Columbia River froze over, closing the river to navigation from the confluence with the Willamette River upstream; nearly every part of the state affected; snow totals (inches): Albany, 25.5; Bend, 49.0; Cascade Locks, 21.5; Eugene, 8.5; Heppner, 16.0; Parkdale, 63.0; Pendleton, 15.0; Siskiyou Summit, 50.0
Feb. 10, 1933	statewide	cold outbreak across state; the city of Seneca, in northeast Oregon, recorded the state's all-time record low temperature of −54°F; the next day high was nearly 100 degrees warmer at 45°F

Date	Location	Description
Jan. 31–Feb. 4, 1937	statewide	heavy snowfalls in the western slopes of the Cascades and the Willamette Valley; deep snowdrifts blocked major highways and most minor roads in northern Oregon and passes of the Cascade Mountains for several days
Jan. 5–7, 1942	Columbia, Clackamas, Multnomah, Washington, Marion, Linn, Yamhill, and Polk Counties	considerable sleet, followed by freezing rain in some areas; freezing rain, resulting in heavy accumulations of ice in upper and middle Willamette Valley; roads and streets dangerous for travel, orchard and shade trees damaged, and telephone, telegraph, and power wires and poles broken down.
Mid Jan.–Feb, 1950	statewide	extremely low temperatures injured a large number of orchard and ornamental trees and shrubs, and harmed many power and telephone lines and outdoor structures; severe blizzard conditions and a heavy sleet and ice storm together caused several hundred thousand dollars damage and virtually halted traffic for two to three days; Columbia River Highway closed between Troutdale and The Dalles leaving large numbers of motorists stranded, removed to safety only by railway; damage to orchard crops, timber, and power services, costing thousands in damages.
Jan. 9–20, 1950	Columbia, Washington, Multnomah, Hood River, Wasco, Clackamas, Yamhill, Marion, Polk, Linn, Benton, and Lane Counties	frequent snowstorms throughout January; snow heavier during this January than ever before on record; snow plus high winds created widespread blowing and drifting of snow; deep snowdrifts closed all highways west of the Cascades and through the Columbia River Gorge; sleet 4-5 inches in northwestern Oregon; sleet turned to freezing rain, creating havoc on highways, trees, and power lines; hundreds of motorists stranded in the Columbia River Gorge, only rescued by train; hundreds of thousands of dollars of damage occurred; winds reached 60–70 mph in gusts along the coast and excess of 40 mph in Portland and Grants Pass; outdoor work and school halted due to impeded traffic, down power lines, and community isolation; in Portland 32.9 inches of snow fell (5.8 inches was the January average)
Dec. 5–7, 1950	Washington, Multnomah, Hood River, Wasco, Sherman, Gilliam, Morrow, and Umatilla Counties	severe ice storm with light freezing rain over the Columbia Basin east of the Cascades; heavy ice accretions on trees, highways, power and telephone lines causing accidents due to broken limbs, slippery pavements, and down power lines; heavy snowfall across Oregon; Crater Lake reported 93 inches of snow for December
Jan. 18, 1956	Washington, Multnomah, Hood River, Wasco, Sherman, Gilliam, Morrow, and Umatilla Counties	freezing rain mixed with snow. Ice coated trees, highways, and utility lines; traffic accidents due to slick surfaces; trees heavy with ice broke, sometimes on top of houses
Jan. 11–12, 1960	Columbia, Clackamas, Multnomah, Washington,	light to moderate snows and freezing rain produced dangerous highway conditions; automobile accidents, but no known fatalities; accidents blocked arterial highways, creating serious traffic jams

Date	Location	Description
	Marion, Linn, Yamhill, and Polk Counties	
Jan. 30–31, 1963	Columbia, Clackamas, Multnomah, Washington, Marion, Linn, Yamhill, Polk, Hood River, Waco, Jefferson, and Deschutes Counties	substantial snowfall amplified by moderate to severe icing created hazardous conditions on highways; power lines downed due to ice or felled trees; injuries, one reported death, and statewide school closures due to the icy streets and highways
Jan. 25–31, 1969	Douglas, Coos, Josephine, Jackson, Columbia, Clackamas, Multnomah, Washington, Marion, Linn, Yamhill, and Polk Counties	snowfall records throughout Lane, Douglas, and Coos Counties were surpassed by incredible numbers; 2-3 feet on the valley floors; heavier amounts at higher elevations; at Eugene, a snow depth of 34 inches. Total January snowfall was 47 inches, nearly 7 times the normal monthly snowfall. Roseburg reported 27 inches and monthly snowfall of 35.2 inches; along the coast, where the average snowfall is generally less than 2 inches, January snowfall totals ranged 2-3 feet, with snow depths of 10–20 inches reported; hundreds of farm buildings and several large industrial buildings collapsed under the weight of the heavy wet snow; heavy losses in livestock; entire communities completely isolated for nearly a week; traffic on major highways west of the Cascades and central Oregon halted; total losses estimated $3 to $4 million
Jan. 17–19, 1970	Washington, Multnomah, Hood River, Wasco, Sherman, Gilliam, Morrow, and Umatilla Counties	Stagnant and cold air in the Columbia River Basin east of the Cascades had surface temperatures well below freezing for a week. Ice accumulated on tree branches up to 1.5 inches. Damage was mostly destroyed orchards and utilities.
Nov. 22-23, 1970	Columbia, Washington, Multnomah, Hood River, Wasco, Clackamas, Yamhill, Marion, Polk, Linn, Benton, and Lane Counties	freezing rain across western Oregon, especially in Corvallis, Albany, Salem, Independence, and Dallas; ice accumulations up to 0.5 inches broke thousands of tree limbs and telephone lines; hazardous traffic conditions, power and phone outages, and felled trees
Feb. 4–6, 1972	Columbia, Clackamas, Multnomah, Washington, Marion, Linn, Yamhill, and Polk Counties	several days of sub-freezing temperatures across Oregon followed by warm moist air across northwestern Oregon; glazed roads were hazardous; 140 persons in Portland treated for sprains, fractures or head injuries; some ambulance services doing twice their normal business
Jan. 11–12, 1973	Columbia, Clackamas, Multnomah, Washington, Marion, Linn, Yamhill, and Polk Counties	rains beginning in the Willamette Valley glazed streets and highways in the Portland area and into the Gorge; auto, bus and truck accidents and persons injured in falls; hospitals reported “full house” conditions; glaze of 0.25–0.75 inches in the Portland area
Jan. 1978	Columbia Gorge, Willamette Valley,	over an inch of rain froze, covering everything with ice; power outages (some for more than 10 days); areas east of Portland hit hardest

Date	Location	Description
	Portland, Oregon and Vancouver, Washington	
Jan. 9–10, 1979	Portland and Multnomah Counties	severe ice storm in Portland area as a Pacific storm moved across the state; temperatures ranged from low teens to 33°F; half inch of rain turned to ice
Jan. 5, 1986	Multnomah, Hood River, Wasco Counties	roads covered with ice and caused power outages to several thousand houses
Feb. 1–8, 1989	statewide	heavy snow across state; up to 6–12 inches of snow at the coast, 9 inches in Salem, more than a foot over the state; numerous record temperatures set; wind chill temperatures 30–60 degrees below 0°F; power failures throughout state, with home and business damage resulting from frozen plumbing; several moored boats sank on the Columbia River because of ice accumulation; five weather-related deaths (three auto accidents caused by ice and snow, and two women froze to death); damage estimates exceeded one million dollars
Feb. 14–16, 1990	Columbia, Clackamas, Multnomah, Washington, Hood River, Wasco, Marion, Linn, Yamhill, and Polk Counties	24–35 inches of snow in Cascade Locks and Hood River; up to 28 inches in the North Coast Range, 16 inches at Timberline Lodge; the Willamette Valley had 2–4 inches with up to 1 foot in higher hills around Portland; 10-15 inches of snow in the North Coast Range, 20–35 inches in the North Cascades, 1-2 feet in the South Cascades; snow in south-central areas included 9 inches at Chemult, 6–8 in Klamath Falls and Lakeview; 6 inches at Tipton Summit in the northeast mountains and Juntura in the southeast.
Jan. 6-7, 1991	all of eastern Oregon	constant precipitation all over Oregon; freezing rain in Willamette Valley made transportation difficult; two auto fatalities; 1–6 inches of new snow in high ground of eastern Oregon; 12 inches of snow in the Columbia Gorge
Jan. 16–18, 1996	Columbia Gorge, Willamette Valley, Portland, Oregon Columbia, Clackamas, Multnomah, Washington, Hood River, Wasco, Marion, Linn, Yamhill, and Polk Counties	freezing rain with heavy accumulations of glaze ice in the Gorge, Northern Cascades and extreme eastern Portland Metro area; numerous minor traffic accidents due to power outages; freezing rain in the Willamette Valley as far south as Eugene
Feb. 2–4, 1996	Columbia Gorge, Willamette Valley, Portland, Oregon Columbia, Clackamas, Multnomah, Washington, Hood River, Wasco,	ice storm caused disruption of traffic and power outages in the Willamette Valley and Coast Range valleys; freezing rain in the Willamette Valley; traffic accidents, including a 100 car pileup near Salem; one traffic fatality near Lincoln City

Date	Location	Description
	Marion, Linn, Yamhill, and Polk Counties	
Dec. 26–30, 1996	Columbia Gorge, Willamette Valley, Portland, Oregon Columbia, Clackamas, Multnomah, Washington, Hood River, Wasco, Marion, Linn, Yamhill, and Polk Counties	ice storm paralyzed the Portland Metro area and the Columbia Gorge; ice accumulations of 4-5 inches in the Columbia Gorge; I-84 through the Gorge closed for 4 days; widespread electricity outages and hundreds of downed trees and power lines in the Portland area
Dec.28, 2003– Jan. 9, 2004	statewide storm	

DR-1510. $10,289,394 of assistance. Baker, Benton, Clackamas, Clatsop, Columbia, Crook, Deschutes, Douglas, Gilliam, Grant, Harney, Hood River, Jefferson, Lake, Lane, Lincoln, Linn, Malheur, Marion, Morrow, Multnomah, Polk, Sherman, Tillamook, Umatilla, Union, Wallowa, Wasco, Wheeler, Yamhill declared. The most significant winter storm in several years brought snowfall to most of Oregon. The largest snowstorm to hit the Siskiyou Pass in Jackson County in a quarter century. I-5 shut down for nearly a day as ODOT maintenance crews and Oregon State Police troopers dug stranded motorists out of snowdrifts reaching 5-6 feet. Two feet of snow in the Blue Mountains in eastern Oregon. Roadside snow levels exceeded six feet along the Tollgate Highway, OR-204. The eastbound lanes of I-84 closed at Ladd Canyon east of La Grande. Additional segments of I-84 eastbound at Pendleton closed as stranded motorists filled truck stops, motels and restaurants in the La Grande area.

Wet snow on highways in the Willamette Valley, toppled power lines and trees. Oregon 34 east of Philomath closed for 30 hours while crews removed trees. Snow on the Siskiyou Pass made national news and was a top story on the CNN website. 150 miles of I-5 from Ashland to south of Redding, California closed, leaving 100 to 200 vehicles stranded on the Siskiyou Pass overnight. The American Red Cross opened a shelter on the Southern Oregon University campus, and reports out of cities from Redding to Medford confirmed that all motels were full. Emergency service delivered gasoline, food, and water to stranded motorists and hard-to-reach areas. One fatality related to the storm. (Heart attack after helping a stranded motorist.)

I-5 North on the Siskiyou Pass closed for 19 hours. The snow event turned into a major ice storm. Icy roads made driving hazardous. Trees damaged or destroyed by ice adhering to the branches. Downed power lines, often due to falling trees, caused power outages. Businesses, school districts, and government offices closed or hours shortened. Several hundred flights cancelled at the Portland International Airport. Thousands of passengers stranded at the airport. The MAX light rail system also was shut down by the storm. ODOT closed I-84 through the Columbia Gorge twice, for almost 70 hours total. Freight trucks and passenger cars had to detour over Mount Hood where, ironically, road conditions were better than they were in downtown Portland where all vehicles were required to chain up. ODOT closed US-101 over the Astoria Megler Bridge for about 14 hours as large chunks of ice fell off the bridge's superstructure. Many other highways in the state were closed. Freezing rain also in eastern Oregon. Minus 30 degrees reported in Meacham. 60 mph wind gusts in Union County created whiteout conditions, prompting the closure of I-84 between La Grande and Baker City. 2 fatalities.

President Bush issued a major disaster declaration for 26 Oregon counties affected by the winter storm, later extended to 30 of Oregon's 36 counties.

Estimated the cost of damages to public property at $16 million. A frigid arctic air mass, heavy snow, sleet and freezing rain, strong east winds and blizzard conditions through and near the Columbia River Gorge snarled travel,

Date	Location	Description

forced school and business closures, and resulted in widespread power outages and properly damage in Northwestern Oregon. 2-6 inches of snow along the North Oregon Coast, 2–8 inches in the Willamette Valley, 5–8 inches in the Portland Metro area, and up to 27 inches in the Cascade Mountains. Up to 2 inches of sleet and freezing rain followed the snowfall.

In Portland this winter storm:

- limited or halted most forms of travel
- resulted in the cancellation of over 1,300 flights at Portland International Airport, stranding 90,000 passengers
- shut down Portland's light rail train system
- closed most businesses and schools

Blizzard conditions in the Columbia River Gorge:

- closed I-84 between Troutdale and Hood River
- closed Washington State Route 14 between Washougal, and White Salmon, Washington
- Halted east-west travel through the Gorge and stranded hundreds of trucks at both ends of the Gorge

Weight from snow and ice buildup:

- downed trees and power lines, leaving 46,000 customers without power, and collapsed roofs at Portland's Gunderson Steel and Rail, Fred Meyer stores in Gateway and Clackamas, and a barn in Forest Grove that killed 4 horses
- collapsed a Scappoose marina roof, sinking 4 boats and damaging many others
- snowfall in the Cascades ranged from 8 inches at Blue Box Pass and Bennett Pass to 27 inches at Timberline Lodge and White River

Date	Location	Description
Mar. 8–10, 2006	Lane, Linn, Benton, Marion, Jefferson, Polk, Yamhill, Clackamas Counties	snow fell up to a few inches at the coast and through the Willamette Valley; 2–4 feet in the Coast Range, Cascades, and Cascade Foothills; many school closures
Jan. 2–Feb. 9, 2008	Hood River, Wasco, Sherman, Gilliam, Morrow, Umatilla, Union, Grant, Baker, Wheeler, Jefferson Deschutes, Crook Counties	heavy snow and freezing rain across eastern Oregon; 5–13 inches of snow; a multi-vehicle accident closed I-84, 15 miles west of Arlington, for 5 hours; 36 Oregon National Guard personnel helped with snow removal in Detroit and Idanha with over 12 feet of record snow. Inmate crews removed snow that cracked walls and collapsed roofs
Dec. 2008	northern Oregon coast	third unusually cold storm system that season with heavy snow in northwest Oregon; heavy snowfall across northwest Oregon; 11–24 inches of snow in the north Oregon Coast Range
Dec. 9–11, 2009	Marion, Linn, Lane Counties	freezing rain covered the central valley with a coating of ice; south of Salem, numerous road closures due to accidents caused by icy roadway; I-84 from Troutdale to Hood River closed for 22 hours

Date	Location	Description
Nov. 29-30, 2010	Hood River, Multnomah, Wasco Counties	4-5 inches of snow reported in Cascade Locks and Hood River; 1/2 inch of ice in Corbett
Jan. 12–18, 2012	Hood River, Wasco Counties	4.5 inches of new snow reported in Hood River; I-84 closed due to ice and snow east of Troutdale
Jan. 2012	Multnomah County	snow and ice east of Troutdale; I- 84 closed for 9 hours
Feb. 6–10, 2014	Lane, Benton, Polk, Yamhill, Columbia, Clackamas, Multnomah, Washington, Linn, Marion, Hood River, Lincoln, Tillamook and Clatsop Counties	DR-4169 Linn, Lane, Benton and Lincoln Counties declared. A strong winter storm system affected the Pacific Northwest during the February 6–10, 2014 time period bringing a mixture of arctic air, strong east winds, significant snowfall and freezing rain to several counties in northwest Oregon; a much warmer and moisture-laden storm moved across northwest Oregon after the snow and ice storm (Feb. 11-14), which produced heavy rainfall and significant rises on area rivers from rain and snowmelt runoff; during the 5-day period Feb. 6–10, 5 to 16 inches of snow fell in many valley locations and 2 to10 inches in the coastal region of northwest Oregon; freezing rain accumulations generally were 0.25 to 0.75 inches; the snowfall combined with the freezing rain had a tremendous impact on the region
Feb. 11–14, 2014	Lane, Benton, Polk, Yamhill, Columbia, Clackamas, Multnomah, Washington, Linn, Marion, Hood River, Lincoln, Tillamook and Clatsop Counties	another weather system moved across northwest Oregon during the February 11–14 time frame; this storm was distinctly different from the storm that produced the snow and ice the week prior and brought abundant moisture and warm air from the sub-tropics into the region; as this storm moved across the area, 2 to 7 inches of rain fell across many counties in western Oregon; the heavy rainfall combined with warm temperatures led to snowmelt and rainfall runoff that produced rapid rises on several rivers, which included flooding on three rivers in northwest Oregon
March 2, 2014	Hood River County, Upper Hood River Valley, Central Columbia River Gorge	East winds brought very cold air from east of the Cascades through the Columbia River Gorge as a moist front pushed in from the Pacific. The combination of the cold air mass and frontal precipitation resulted in snow and ice for the Gorge. There were numerous reports of snow and ice in the Central Columbia River Gorge with generally 6 to 8 inches of snow. There was a quarter of an inch of ice on top of the snow in Hood River and White Salmon, and as much as 0.4 to 0.5 inch of ice in Parkdale where the cold air held on the longest.
Nov. 13, 2014	Clackamas, Marion, Linn, Multnomah and Hood River Counties (North Cascade foothills and Western Columbia River Gorge)	An early cold snap hit the Pacific Northwest before moist Pacific air moved in and resulted in one of the earliest snow, sleet, and freezing rain events in northwestern Oregon. Sleet and freezing rain in particular created hazardous commutes for tens of thousands in the western and eastern suburbs of Portland. Farther south, 1/2 of freezing rain accumulated on trees in the coast range foothills outside of Corvallis and Dallas, Oregon. Upwards of a quarter of an inch of ice fell around Dallas, Oregon. Some snow fell, but accumulations were primarily restricted to the Cascade valleys and the central Columbia

Date	Location	Description
		River Gorge. Spotters reported around 6 to 8 inches of snow for the Cascade Foothills followed by a quarter of an inch of ice. A combination of heavy snow and ice resulted in slick driving conditions for the Western Columbia River Gorge. Areas in the gorge measured a quarter of an inch of ice whereas other areas had 5 to 8 inches of snow.
Dec. 6–23, 2015	Statewide	DR-4258. Clatsop, Columbia, Multnomah, Clackamas, Washington, Tillamook, Yamhill, Polk, Lincoln, Linn, Lane, Douglas, Coos, and Curry Counties declared. Severe winter storms, straight-line winds, flooding, landslides, and mudslides. On December 12, A series of systems brought heavy precipitation to southern Oregon. Several pacific storm systems moved across the region over the Dec 12-13 weekend from southern Oregon to northeast Oregon. Another series of storms moved across Oregon on Dec 16-17 and Dec 21-23. Each storm system brought several inches of snow to the mountain areas. Snowfall amounts in inches include: 21.0 10 miles west of La Pine, 14.0 at Tollgate, 12.0 13 miles southwest of Mitchell, and 9.0 6 miles east southeast of Granite. Another in a long series of storms brought heavy snow to portions of south central Oregon. The cooperative observer at Chemult reported 17 inches of snow in 24 hours ending Dec. 17th. A narrow but long-lived band of precipitation moved across Wallowa County the morning of December 19th. Several reports of moderate snow occurred over the Joseph and Enterprise areas. Snowfall amounts in inches ranged from 5 to 6 inches, with northern Wallowa County receiving reports of up to 9 inches just outside of Flora. On December 21st heavy snow fell over portions of central Washington and Oregon due to a cold front. Snowfall amounts are as followed: 14” recorded at the Milk Shakes Snotel and 10” in 24 hours 5 miles north northwest of La Pine. Also on the 21st a series of storms made for a long lasting winter storm over southwest and south central Oregon. Initially the heavy snows were limited to higher altitudes...but a colder air mass moved in towards the end of the event and snow fell in areas that rarely see snow...such as the southwest Oregon valley floors. Moist onshore winds produced a steady stream of showers over the foothills of the Cascades with snow levels between 1000 and 2000 feet. This resulted in heavy snow for the Northern Oregon Cascades and Coast Range. At one point after the storm, 25,000 people were without power. Several highways around Crater Lake were closed for a week due to heavy snow and fallen trees blocking the roads.
Mar. 13, 2016	Clackamas, Marion, Linn and Lane Counties (North Oregon Cascades and Cascades in Lane County)	A strong low pressure system generated frequent and persistent snow showers over the northern and central Oregon Cascades. Several SNOTEL stations measured 16 to 24 inches of snow over a 24 to 30 hour period above 3500 feet.
Dec. 8, 2016	Multnomah, Clackamas, Washington, Columbia,	A strong frontal system brought strong east winds to the North Willamette Valley and a mix of snow, sleet, and freezing rain down to

Date	Location	Description
	and Hood River Counties (Greater Portland Area and Western Columbia River Gorge)	the Valley Floor. Four to six inches of snow fell along interstate 84 before turning to sleet and freezing rain. One to 1.5 inches of ice accumulation was also reported. The Portland Metro area generally had 1-2 inches of snow, with 0.2 to 0.3 inch of ice accumulation. Ice accumulations were higher in the West Hills and near the Columbia River Gorge, with 0.8 inch of ice accumulation reported at Council Crest in SE Portland. The NWS Office in Parkrose had 0.4 inch of ice accumulation.
Dec. 14–17, 2016	Lane, Lincoln, Benton, Marion, Clackamas Josephine and Linn Counties (Central Coast Range, Southern Willamette Valley, Cascade foothills in Lane County, Northern Cascade foothills)	DR-4296. Lane and Josephine counties declared. Severe winter storm and flooding. East winds ahead of an approaching low pressure system brought temperatures down below freezing across the area ahead of the approaching precipitation. This lead [sic] to a mix of freezing rain, sleet, and snow across the area. While areas farther north saw more of a snow/sleet mix before a changeover to freezing rain then rain, areas in Lane County saw freezing rain for most of this event, causing power outages, damage to trees, and many car accidents around Eugene and Springfield. Snow [was] followed by sleet and freezing rain. The freezing rain turned into a major ice storm occurred in Eugene and the vicinity with 0.5 to 1.0 inch of ice accumulation observed. There was significant damage to trees and power lines, and fairly widespread power outages across the region. 15,000 people were without power. There was a report of 0.4 inch of ice accumulation near Sodaville.
Dec. 19, 2016	Hood River County (Upper Hood River Valley and Central Columbia River Gorge)	A warmer low pressure system moved into to Northwest Oregon, bringing high winds along the North and Central Oregon Coast. Cold east winds through the Columbia River Gorge continued for the first part of the event, leading to light accumulations of snow and sleet in portions of far northwest Oregon and higher accumulations in the Columbia River Gorge and Hood River Valley. Estimate the Columbia Gorge had around 0.2 to 0.5 inch of ice accumulation as temperatures in the lower 30s with reports of snow and freezing rain in Hood River. A frontal system brought high winds to the Central Oregon Coast, heavy snow to the Cascades and a mix of ice and snow in the Columbia River Gorge and Hood River Valley. SNOTELs and other stations reported a range of 12 to 25 inches of snow. Some specific reports include 25 inches at Mt Hood Meadows, 22 inches at Timberline, 14 inches at Government Camp and 12 inches at McKenzie Snotel.
Dec. 26-27, 2016	Linn, Marion, Clackamas Counties (North Oregon Cascades)	A frontal system brought high winds to the Central Oregon Coast, heavy snow to the Cascades and a mix of ice and snow in the Columbia River Gorge and Hood River Valley. Estimate the Columbia Gorge had around 0.2 to 0.5 inch of ice accumulation as temperatures in the lower 30s with reports of snow and freezing rain in Hood River. SNOTELs and other stations reported a range of 12 to 25 inches of snow in the Cascades. Some specific reports include 25 inches at Mt

Date	Location	Description
		Hood Meadows, 22 inches at Timberline, 14 inches at Government Camp and 12 inches at McKenzie Snotel.
Jan. 7–10, 2017	Multnomah, Clackamas, Washington, Columbia, Lane, Benton, Polk, Yamhill, Linn, Marion, Josephine and Hood River Counties (Greater Portland Area, Central Coast Range, Central and Southern Willamette Valley, North Cascades foothills, Western and Central Columbia Gorge, Upper Hood River Valley and the Siskiyou Mountains)	DR-4328. Columbia, Hood River, Deschutes and Josephine Counties declared. Severe Winter Storms, Flooding, Landslides, And Mudslides. A storm system moving across southern Oregon produced heavy snow across portions of central and northeast Oregon. Also heavy snow fell over portions of the Columbia River Gorge. A broad shortwave trough brought multiple rounds of precipitation, including a wintry mix of snow and ice for many locations across Northwest Oregon. Strong easterly pressure gradients generated high winds through the Columbia River Gorge as well on January 8. General snowfall totals of 2-4 inches were reported, with the greatest total being 4.5 inches. Major ice accumulations occurred after the snow, with several locations reporting 0.50-1.00. The combination of snow and ice resulted in significant power outages and closures across the area.
Feb. 3-4, 2017	Multnomah and Hood River Counties (Western and Central Columbia River Gorge, Upper Hood River Valley)	Fronts associated with a low pressure system passing north into the Olympic Peninsula brought heavy snow and ice to the Columbia Gorge. The Hood River area reported 4 to 6 inches of snow turning to ice in the western-most part of this zone.
Feb. 8-9, 2017	Wasco, Sherman, Gilliam, Wheeler, Jefferson, Crook, and Grant Counties (Eastern Columbia River Gorge, Eastern Cascades, Central Oregon, Ochoco-John Day Highlands)	A strong Pacific storm system brought snow, sleet and freezing rain to many areas of the Interior Northwest February 7th through 9th. Winter storm produced a total snow accumulation of 5.25 inches with an ice accumulation of 0.25 inches on top of the snow. Occurred 5 miles SSW of Chenoweth in Wasco county.
Dec. 24, 2017	Multnomah and Hood River Counties (Western Columbia River Gorge	Low pressure system moving into the Pacific Northwest pulled cold air from the Columbia Basin west into the Willamette Valley, through the Columbia River Gorge. As this system started to bring moisture and precipitation into NW Oregon, temperatures were around or below freezing, allowing for a mix of snow and ice to fall all the way to the Valley Floor around the Portland Metro, in the Columbia River Gorge, and the Hood River Valley. Local Broadcast Meteorologist reported getting 2.5 inches of snow and 0.2 inch of ice in Corbett. Also, a Skywarn Spotter in Cascade Locks reported getting 4.8 inches of snow.
Feb. 22–26, 2019	Coos, Curry, Douglas, Lane, Deschutes, Jefferson, Wheeler, Wasco, Sherman, Gilliam, Morrow, Umatilla, Crook, Grant, Baker, Malheur and Union Counties (Oregon Coast	DR-4432. Jefferson, Lane, Douglas, Coos and Curry Counties declared. Severe Winter Storms, Flooding, Landslides, And Mudslides. Persistent troughing off the coast of the Pacific Northwest focused a stream of mid-level moisture over the Inland Northwest resulting in a long duration snow event as the plume drifted north and south several times between the 22nd and 27th of February. Snowfall rates were greatly enhanced over central Oregon with the proximity of a nearly

Date	Location	Description
	Range, South and Central Coast, North Central and Central Oregon, Blue Mountains, Eastern Columbia River Gorge, Eastern Cascades, Grand Ronde Valley, Lower Columbia Basin, John Day Basin)	stationary surface boundary where snowfall rates were in excess of 1 inch per hour. The low pressure system moved south into eastern Washington, bringing a cold front southeastward across western Oregon. The front then stalled across the southern Willamette Valley and Lane County Cascades as colder and colder air moved in aloft. What started as rain at low elevations turned to snow during the afternoon of the 23rd. The stalled front kept producing snow over the same areas through the next 24 hours with a direct tap of moisture from the Pacific Ocean. Storm total snowfall amounts were measured at: 40 inches in Sisters, 33 inches in Bend, 30 inches in Redmond, 26 inches in Meacham, 22 inches in Prineville, 21 inches in Elgin, 16 inches in Mitchell, 14 inches in Lostine and La Grande, 12 inches in Pendleton and Joseph and 10 inches in John Day. In Bend a few roofs collapsed under the weight of the snow.
Jan. 15-16, 2020	Multnomah, and Hood River Counties (Western and Central Columbia River Gorge)	A 980 mb low located near 45N/130W along with an attendant warm front moved into the southern Oregon Coast and overran a cold air mass originating from the Columbia River Gorge. This resulted in snow that gradually transitioned to freezing rain in the Gorge on Wednesday night into Thursday. The amounts of snow and ice varied greatly across the Columbia River Gorge, with heaviest amounts in the Central Columbia River Gorge zone. The combination of snow, ice, and wind resulted in the closure of I-84 between Troutdale and Cascade Locks. Based on ODOT and spotter reports, 4 to 10 inches fell in the stretch from Corbett to Cascade Locks, followed by a few hours of light freezing rain. Additionally, east winds gusted to 56 mph at Corbett, with higher gusts at Crown Point (although the anemometer was frozen).
Feb. 11-15, 2021	Benton, Clackamas, Linn, Marion, Polk, Yamhill, Grand Ronde Indian Reservation	DR-4599: Oregon Severe Winter Storm
Jan. 10-22, 2024	Benton, Clackamas,Coos, Hood River, Lane, Lincoln, Multnomah, Sherman, Siletz Indian Reservation, Tillamook, Wasco	DR-4768: Oregon Severe Winter Storms, Straight-line Wind, Landslides, and Mudslides

Source: The National Weather Service; https://www.fema.gov/disaster; https://www.ncdc.noaa.gov/stormevents

Figure 3.3.12-4: Rescuing snowbound vehicles, Old Oregon Trail Highway between Kamela and Meacham, 1923

Source: ODOT

Figure 3.3.12-5 Stranded Motorists on I-5 Southbound at Siskiyou Pass, Late December 2003. Note: Vehicles being towed out the "wrong way"

Source: ODOT

Figure 3.3.12-6 Detroit, Oregon, February 2, 2008, Buried from the 12 Feet of Snow.

Source: ODOT

Figure 3.3.12-7 Trees Collapse from Weight of the Snow on Oregon 62 near Prospect, February 2, 2008

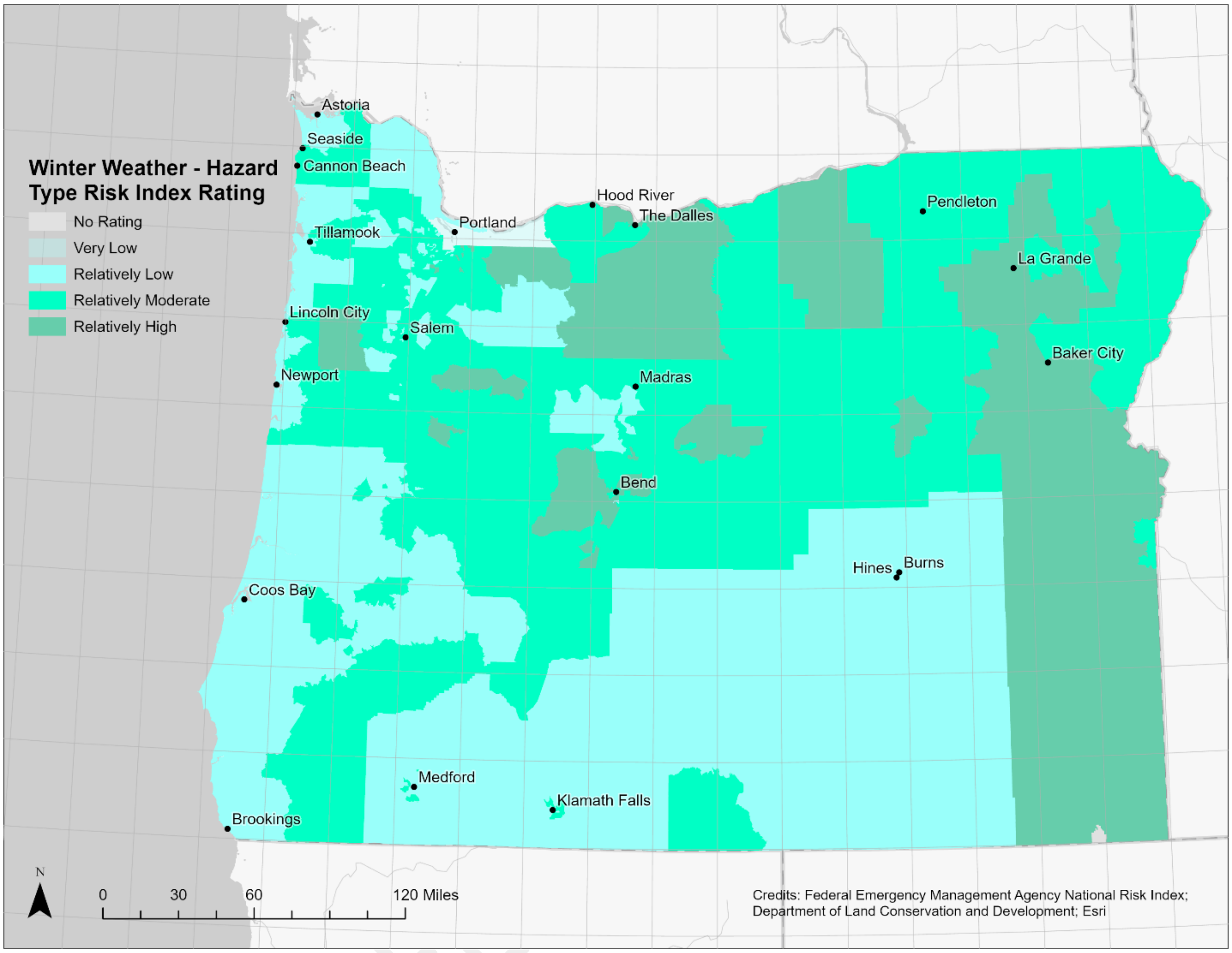
Source: ODOT

3.3.12.2 Risk Maps

The map in this section highlights places where the state might work with communities to develop mitigation projects.

The National Risk Index produces a measure of monetary losses experienced over the period of record. This emphasizes historic costs of harm and would direct mitigation resources to where the costs have been the greatest. Mitigation in these locations would save money over the long term.

Figure 3.3.12-8 Winter Weather Risk Rating from the NRI: Risk Index Rating from the Federal Emergency Management Agency, National Risk Index for Winter Weather.



Source: Federal Emergency Management Agency, National Risk Index for Winter Weather.
Ranking based on national percentiles. Last updated by FEMA in March 2023.
Data accessed on February 12, 2025 from National Risk Index | FEMA.gov

3.4 Changes in Development

3.4.1 Overview

Understanding what development has occurred in hazardous areas and how much more development could potentially occur in hazardous areas is important for assessing risk. Overall, Oregon has limited development and potential future development in hazardous areas. In most counties, recent development and potential development in all hazard areas is five percent or less. The outliers are counties with higher population and greater development overall: Multnomah County and to a lesser degree, Clackamas, Washington, and Jackson Counties.

3.4.2 Method

DLCD analyzed recent development by comparing land cover in hazard areas from 2019 to 2023. We calculated future potential development by measuring the area of undeveloped land in hazard areas designated for medium to high-density development in local comprehensive plans.

DLCD calculated changes in land cover between 2019 and 2023 using the Annual Impervious Descriptor Surface product from the National Land Cover Database (NLDC) (USGS, Annual National Land Cover Database, Collection 1, October 2024). The NLCD data consists of 30m x 30m LANDSAT imagery pixels interpreted and classified into impervious surface thematic classes called “Impervious Descriptor” classes. The NLCD 2019 data has 11 Impervious Descriptor classes while 2023 only has three. Therefore, DLCD aggregated the 2019 classes into the three 2023 classes: unclassified, road, and urban. From the three Impervious Descriptor classes, DLCD determined three types of change in land cover: 1) change from “unclassified” to “road” or “urban” class equals “undeveloped to developed”; 2) change from “road” to “urban” class equals “developed to increased developed”; and 3) all other pixels were classified as “no change detected.” Note there were no pixels in the study areas that changed from “urban” or “road” to “unclassified” or from “urban” to “road.”

DLCD calculated changes in the three, aggregated, Impervious Descriptor classes between 2019 and 2023 in ArcGIS Pro using a raster change function. We then converted the resulting impervious change raster and the 2023 Impervious Descriptor raster to vector format in order to overlay with the remaining vector data: counties, census tracts and comprehensive plans. DLCD then overlayed (intersect) this master vector dataset individually with each, available natural hazard type dataset producing a separate impervious dataset for each hazard. DLCD used these datasets to calculate the acres and percentage of land within each hazard area that changed from “undeveloped to developed”, “developed to increased developed” and “no change detected.” The results are in tables for individual hazards below.

DLCD determined potential future development using city and county comprehensive plan land use designations, where available, and the amount of "unclassified” area from the 2023 Impervious Descriptor data. We used the “unclassified” descriptor as undeveloped land because the impervious fraction of the pixel is below the threshold for an “Impervious Descriptor.” DLCD generalized the local comprehensive plan designations into six intensities of prescribed development from high to none: medium- to high-density; sparse; limited; unbuildable; federal or tribal land; and unknown. “Unknown” typically means that comprehensive plan information for that area was unavailable. Within each natural hazard area and each development intensity class, we calculated the acres and percentage of land designated as “unclassified” in the 2023 NLCD Impervious Descriptor data. For potential future development we focus on just those areas designated as “medium- to high-density" development, assuming the “unclassified” areas could be built out, but the sparse and limited development areas are more likely to remain undeveloped. The results are in tables in sections for individual hazards below.

3.4.3 Hazard Specific Analysis

DLCD determined changes in development and potential future development for all counties that are directly exposed to seven of the twelve total natural hazards. The remaining five hazards (high hazard potential dams, windstorm, winter storm, heat, and drought) are not included.

The tables in sections below show vulnerability ratings for each county taken from county NHMP risk assessments, the total area of hazard exposure for each county in acres, the percent of each county’s total area that falls within that hazard zone, the percentage of the hazard area that changed from pervious to impervious between 2019 and 2023 (past change), and the percent of the hazard zone that is developable (future potential change). Local risk assessment ratings are included to help understand the relationship between the hazards that counties have identified as high, moderate, and low risk, and how development has changed and has the potential to change within those hazard zones.

3.4.3.1 Coastal Flood

For coastal flooding, the hazard-prone areas are areas with a 1 percent annual chance of flood in parts of counties within the coastal zone (Benton, Clatsop, Columbia, Coos, Curry, Douglas, Lincoln, Lane, and Tillamook) determined from 2024 digital Flood Insurance Rate Maps (D-FIRM) produced by the Federal Emergency Management Agency.

Past change in development, 2019-2023, in coastal flood hazard areas was moderate to high, ranging from 1.5 percent in Douglas County to 5.1 percent in Curry County. Tillamook and Clatsop Counties have the highest percentage of developable land at 7 percent each. The other coastal counties are much lower ranging from 0-2 percent .

Table 3.4.3-1: Coastal flood changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Benton	-	533	0.1 percent	2.4 percent	0.4 percent *
Clatsop	M	5,332	0.9 percent	2.0 percent	3.7 percent
Columbia	-	1,302	0.3 percent	4.6 percent	2.9 percent
Coos	L	11,557	1.1 percent	2.3 percent	2.3 percent
Curry	M	2,517	0.2 percent	5.1 percent	0 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Douglas	L	3,950	0.1 percent	1.5 percent	1.1 percent
Lane	-	4,609	0.2 percent	2.2 percent	2.1 percent
Lincoln	L	5,384	0.8 percent	3.4 percent	0.8 percent
Tillamook	M	5,317	0.7 percent	2.1 percent	4.3 percent

*Future potential development in Benton County is likely higher than indicated because the city of Siletz was excluded due to lack of comprehensive plan information.

Figure 3.4.3- and Figure 3.4.3- show the past changes in development within hazard areas in the coastal zone, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3- shows the change at the census tract level. Census tracts with the most change in impervious in coastal flood areas are located in Tillamook and around Coos Bay. Figure 3.4.3- shows change at a county level. Columbia and Curry Counties have the highest change in development in hazard zones followed by Lincoln County.

Figure 3.4.3-1: Change in impervious surface in coastal zone flood hazard areas by census tract

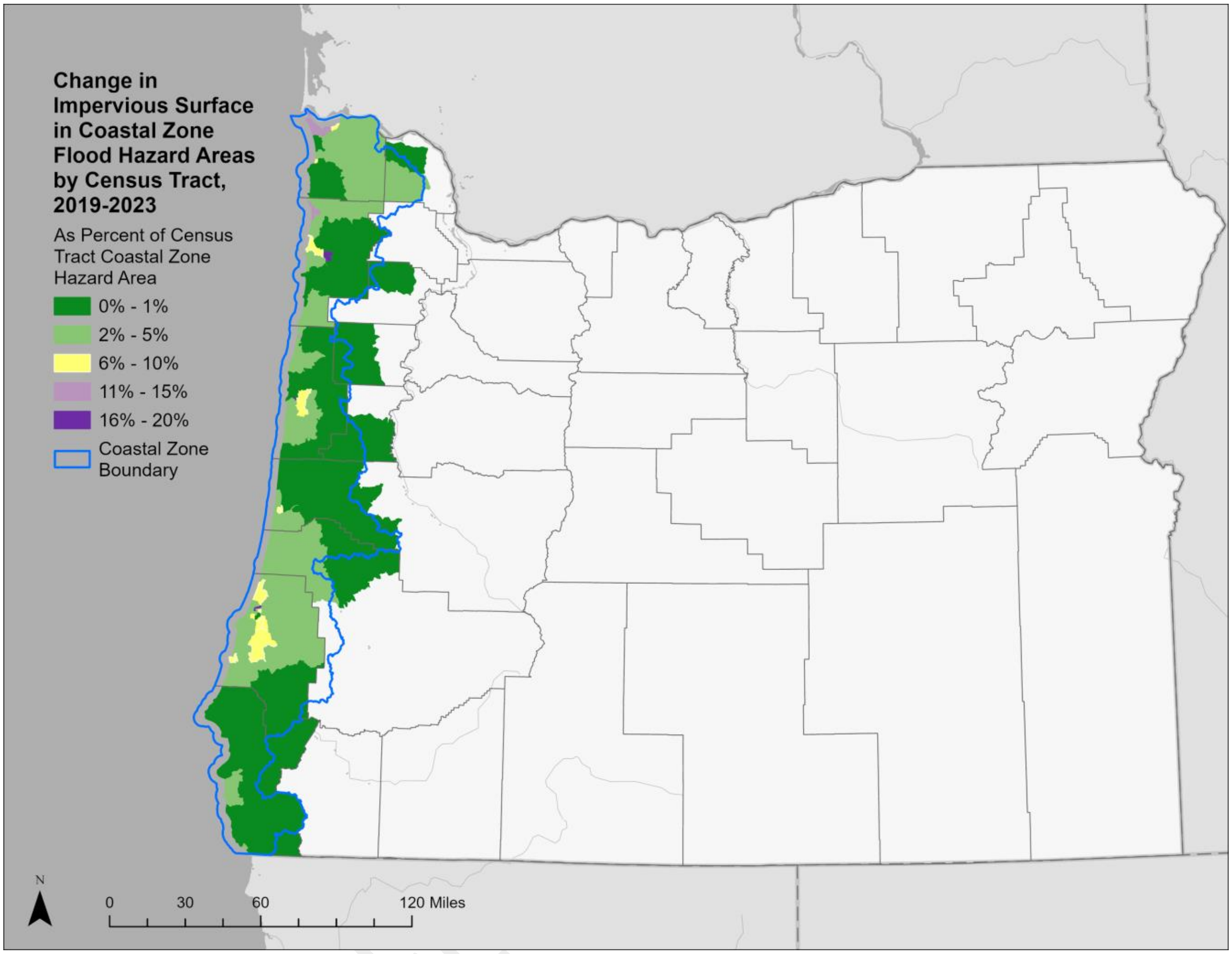


Figure 3.4.3-2: Change in impervious surface in coastal flood hazard areas by county

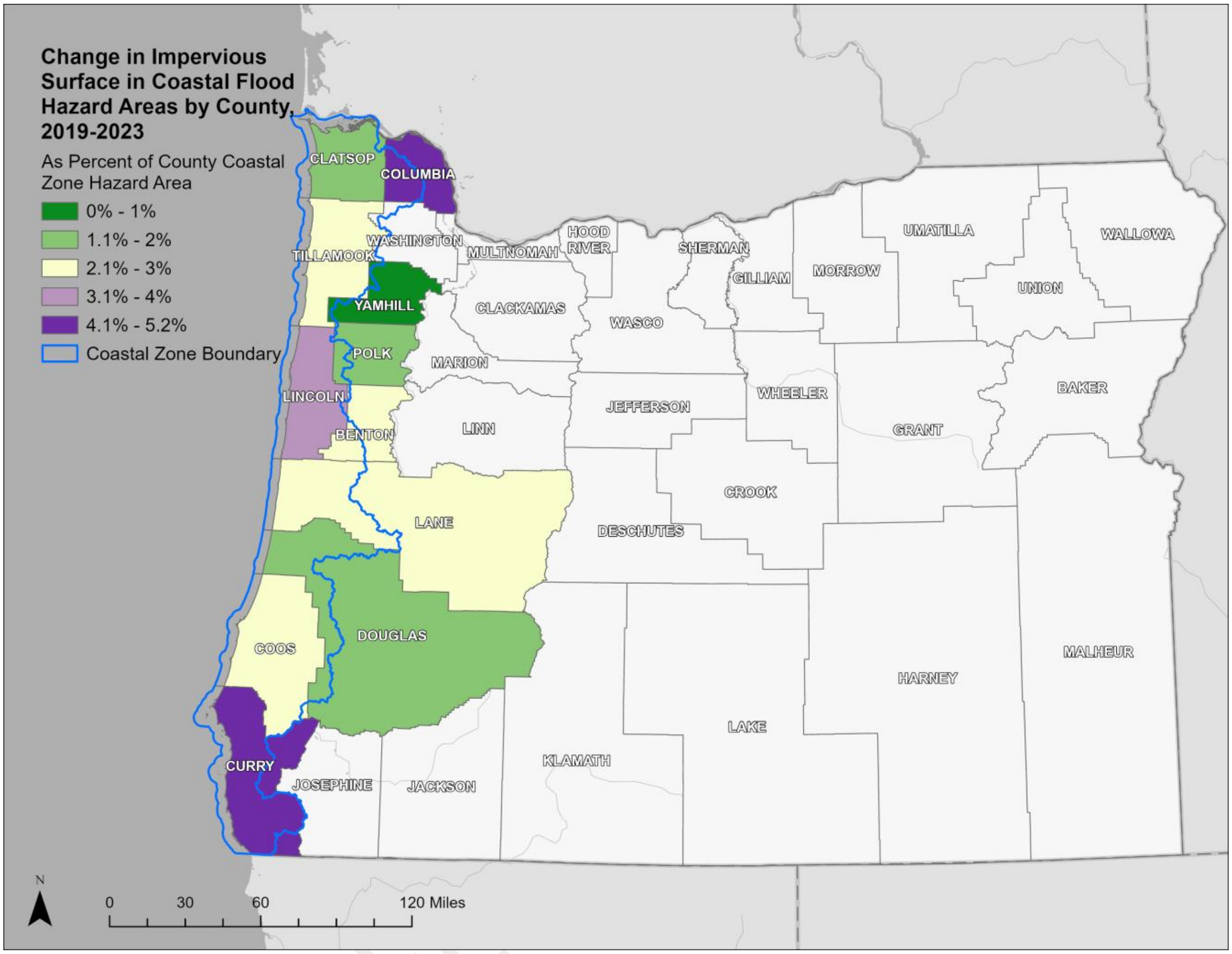


Figure 3.4.3- and Figure 3.4.3- show the potential future changes in development within hazard areas in the coastal zone, or the percentage of the hazard area in medium or high-density development designations that are not yet developed. Figure 3.4.3- shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in coastal flood areas are in and around Tillamook and Coos Bay. Figure 3.4.3- shows change at a county level. Clatsop and Tillamook Counties have the highest potential change in development in hazard zones.

Figure 3.4.3-3: Future growth potential in coastal zone flood hazard areas by census tract

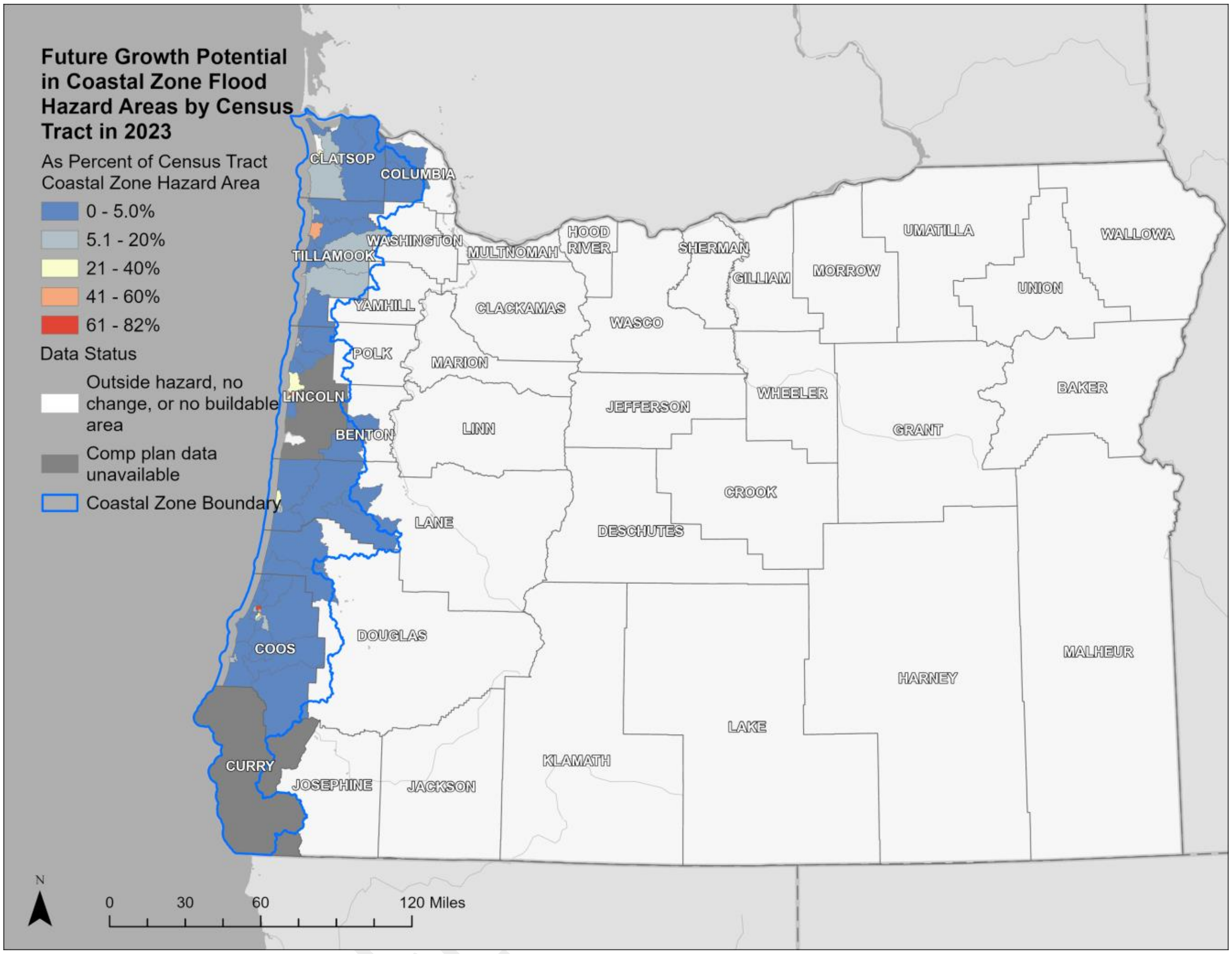
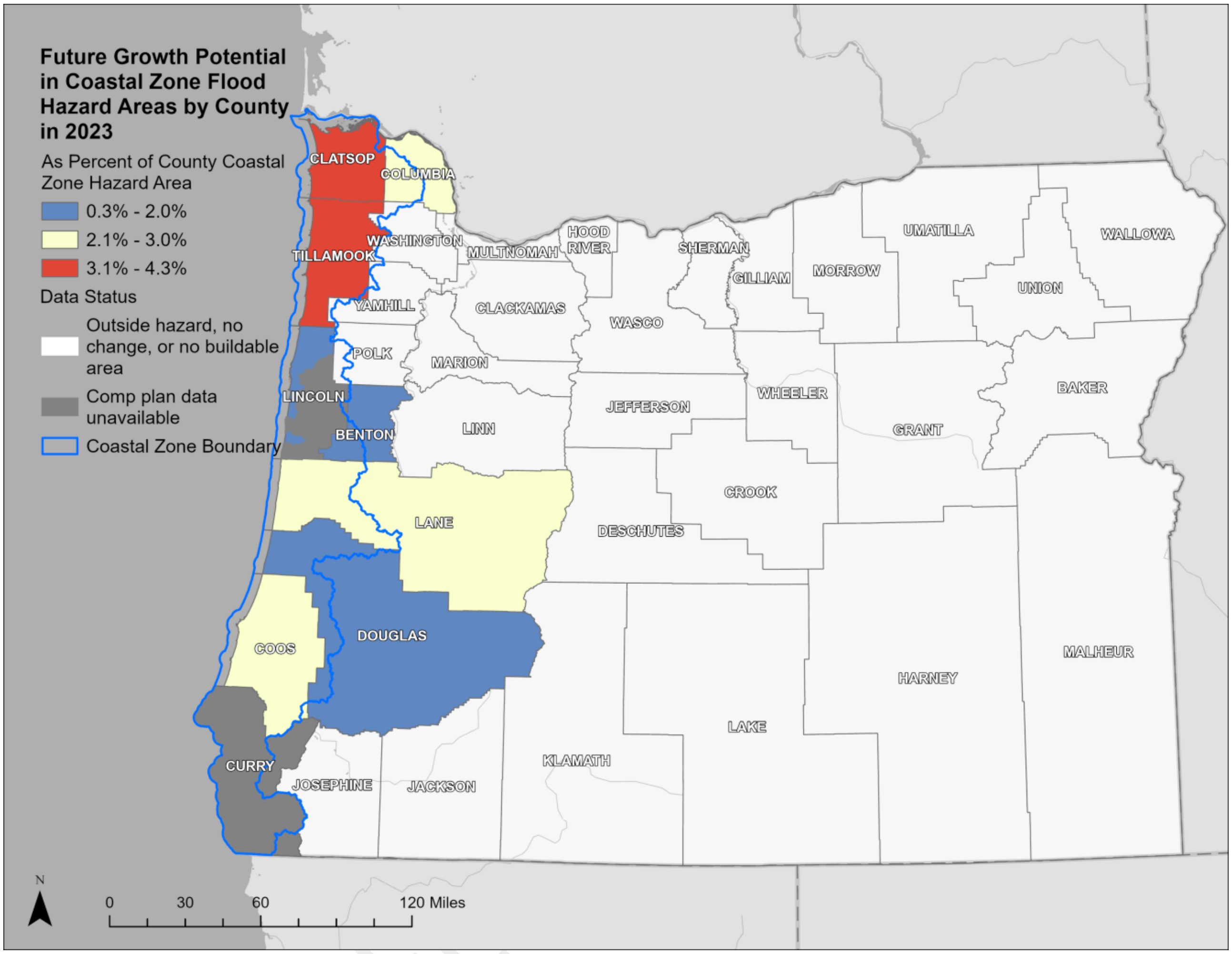


Figure 3.4.3-4: Future growth potential in coastal zone flood hazard areas by county



3.4.3.2 High Hazard Potential Dams

The hazard-prone areas for high hazard potential dams were not available for analysis of changes in development.

3.4.3.3 Drought

For drought there are no specific hazard-prone areas. Drought is a hazard throughout Oregon.

3.4.3.4 Earthquakes

For earthquakes, the hazard-prone areas are areas of moderate to very high susceptibility to liquefaction or moderate to high probability of damaging shaking determined from data in the Oregon Seismic Hazard Database (OSHD) produced by the Department of Geology and Mineral Industries (DOGAMI). Areas subject to earthquake damaging shaking and liquefaction combined cover every county. This broad distribution of hazard means the proportion of the hazard area that has had increases in development and potential future development are very small.

For earthquake, the area of the county area within the hazard zone varies greatly and ranges from 2 percent to 100 percent . The past change in development generally ranges from 1-3 percent , with the exception of Washington County at 5 percent and Multnomah County at 6 percent . Potential future development for most counties ranges from 0-2 percent with two exceptions: Multnomah County and Marion County have 6 percent and 3 percent developable land in the hazard zone respectively.

Table 3.4.3-2: Earthquake changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Baker	H	261,803	13 percent	0 percent	0 percent
Benton	L	434,750	100 percent	2 percent	2 percent
Clackamas	H	347,918	29 percent	2 percent	0 percent
Clatsop	H	574,258	99 percent	2 percent	1 percent
Columbia	H	437,575	99 percent	2 percent	0 percent
Coos	H	1,043,994	99 percent	2 percent	1 percent
Crook	H	184,046	10 percent	0 percent	0 percent
Curry	H	1,051,074	96 percent	1 percent	0 percent
Deschutes	H	229,579	12 percent	1 percent	0 percent
Douglas	H	1,608,594	49 percent	1 percent	0 percent
Gilliam	M	15,921	2 percent	0 percent	0 percent
Grant	M	378,788	13 percent	0 percent	0 percent
Harney	L	1,644,859	25 percent	0 percent	0 percent
Hood River	M	101,633	30 percent	2 percent	0 percent
Jackson	H	426,904	24 percent	1 percent	0 percent
Jefferson	L	92,910	8 percent	0 percent	0 percent
Josephine	H	1,033,943	98 percent	3 percent	0 percent
Klamath	H	1,207,654	31 percent	1 percent	0 percent
Lake	H	1,463,200	27 percent	0 percent	0 percent
Lane	H	1,262,815	43 percent	1 percent	0 percent
Lincoln	H	637,944	98 percent	1 percent	1 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Linn	M	575,836	39 percent	1 percent	1 percent
Malheur	L	749,155	12 percent	0 percent	0 percent
Marion	H	425,936	55 percent	3 percent	3 percent
Morrow	H	291,640	22 percent	1 percent	0 percent
Multnomah	H	194,437	65 percent	6 percent	6 percent
Polk	H	476,841	100 percent	2 percent	1 percent
Sherman	L	34,060	6 percent	0 percent	0 percent
Tillamook	H	722,612	99 percent	1 percent	2 percent
Umatilla	H	565,893	27 percent	1 percent	0 percent
Union	M	259,801	20 percent	1 percent	0 percent
Wallowa	H	96,286	5 percent	0 percent	0 percent
Wasco	M	220,529	14 percent	0 percent	0 percent
Washington	H	465,233	100 percent	5 percent	2 percent
Wheeler	H	154,462	14 percent	0 percent	0 percent
Yamhill	H	451,797	98 percent	3 percent	0 percent

Figure 3.4.3- and Figure 3.4.3- show the past changes in development within hazard areas across the state, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3- shows the change at the census tract level. Census tracts with the most change in impervious in earthquake areas are clustered around the Portland metro region, the Willamette Valley, Bend, Hermiston, Grants Pass, and the Rogue Valley. Figure 3.4.3- shows change at a county level. Multnomah and Washington Counties have the highest change in development in hazard zones.

Figure 3.4.3-5: Change in impervious surface in earthquake hazard areas by census tract

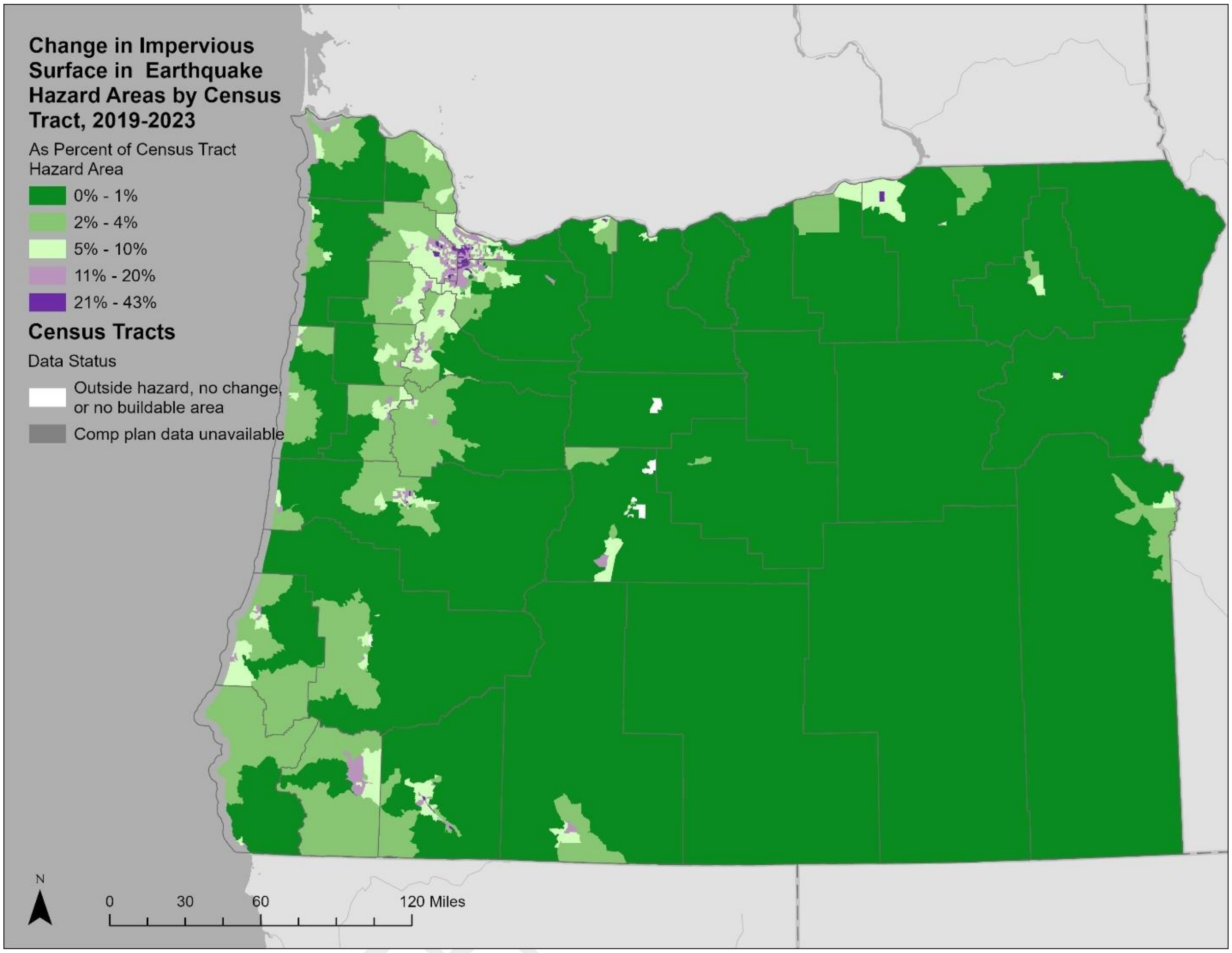


Figure 3.4.3-6: Change in impervious surface in earthquake hazard areas by county

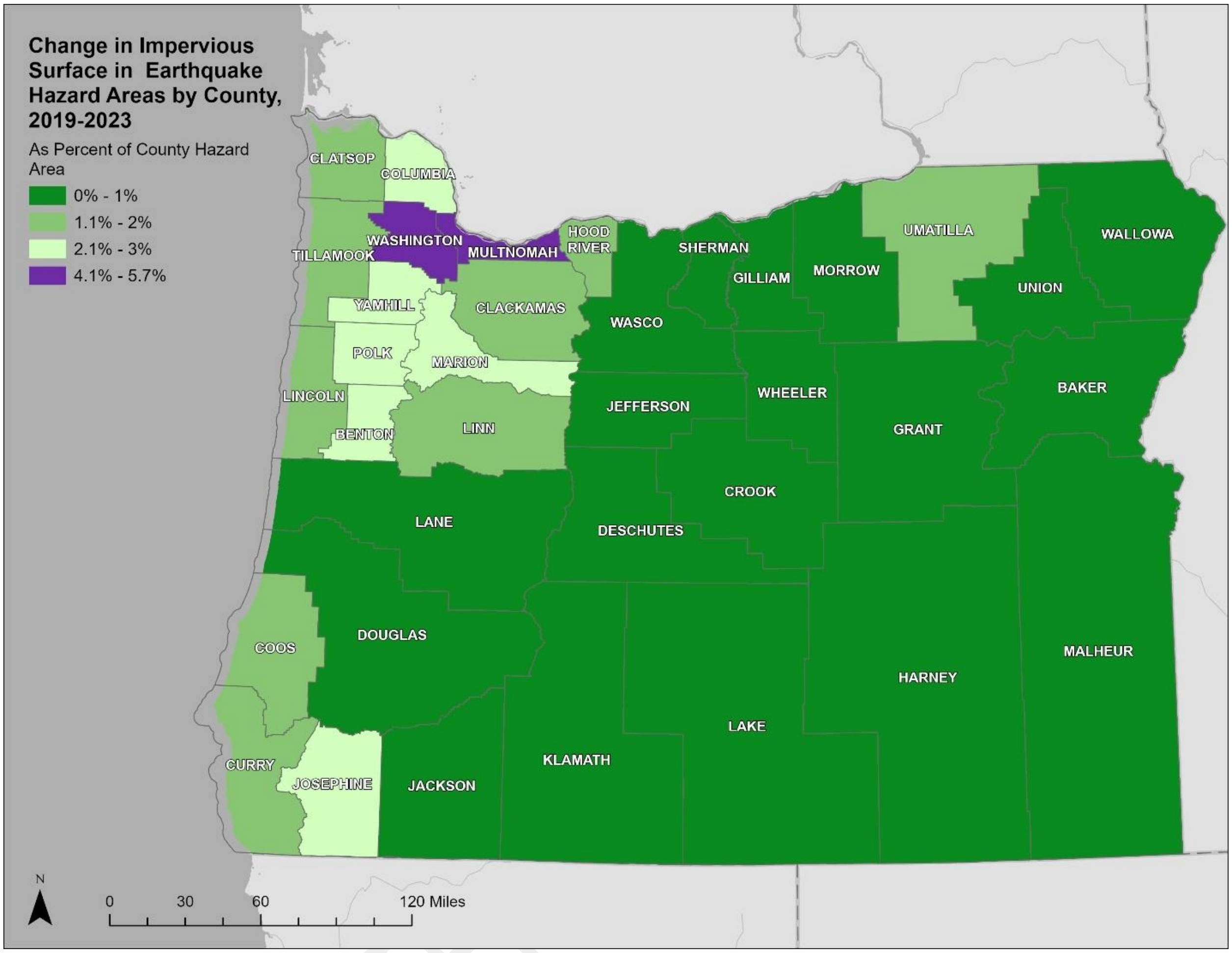


Figure 3.4.3- and Figure 3.4.3- show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3- shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in earthquake areas are mainly clustered around the Portland metro region and the Willamette Valley. Figure 3.4.3- shows change at a county level. Multnomah County has the highest potential change in development in hazard zones followed by Marion County.

Figure 3.4.3-7: Future growth potential in earthquake hazard areas by census tract

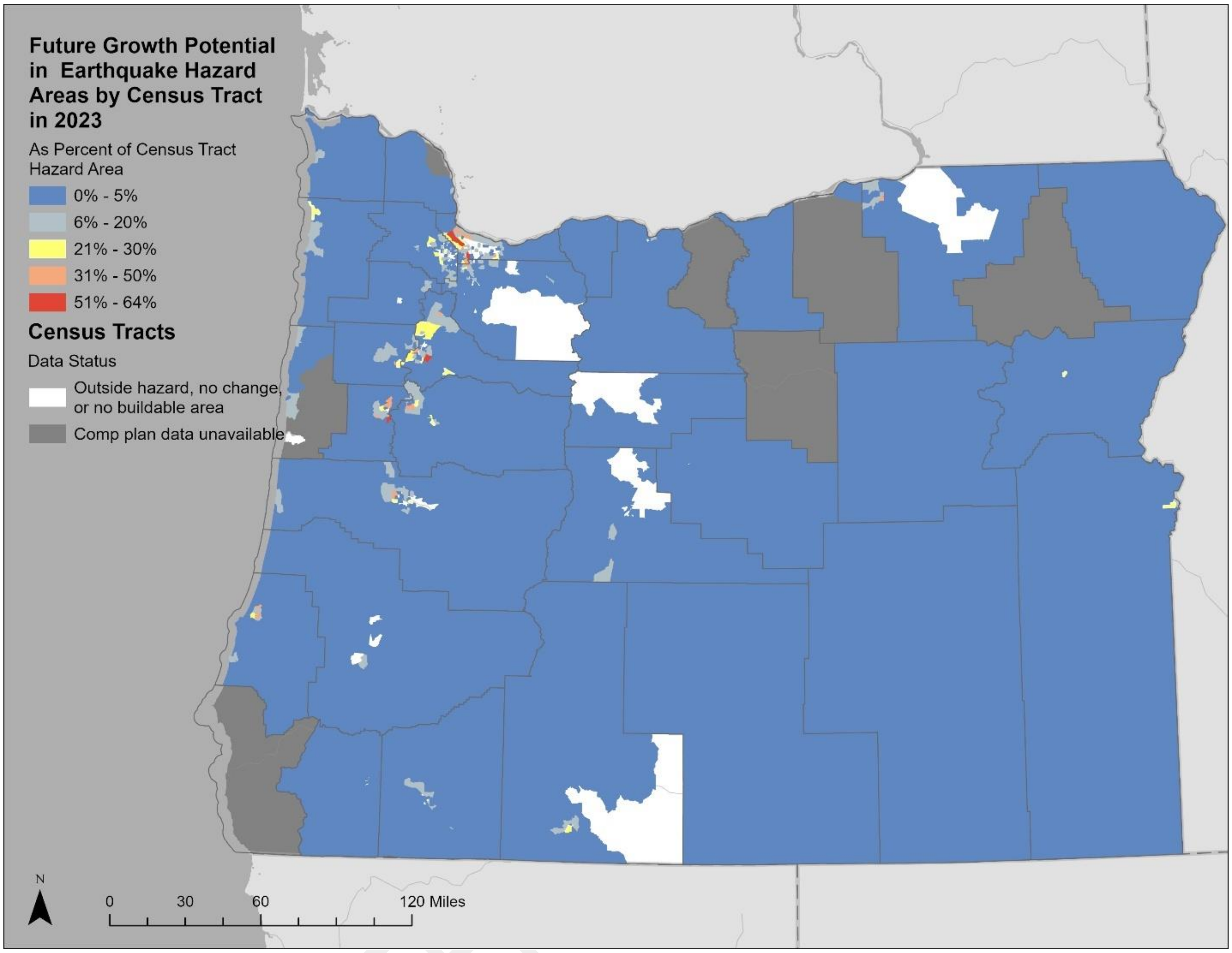
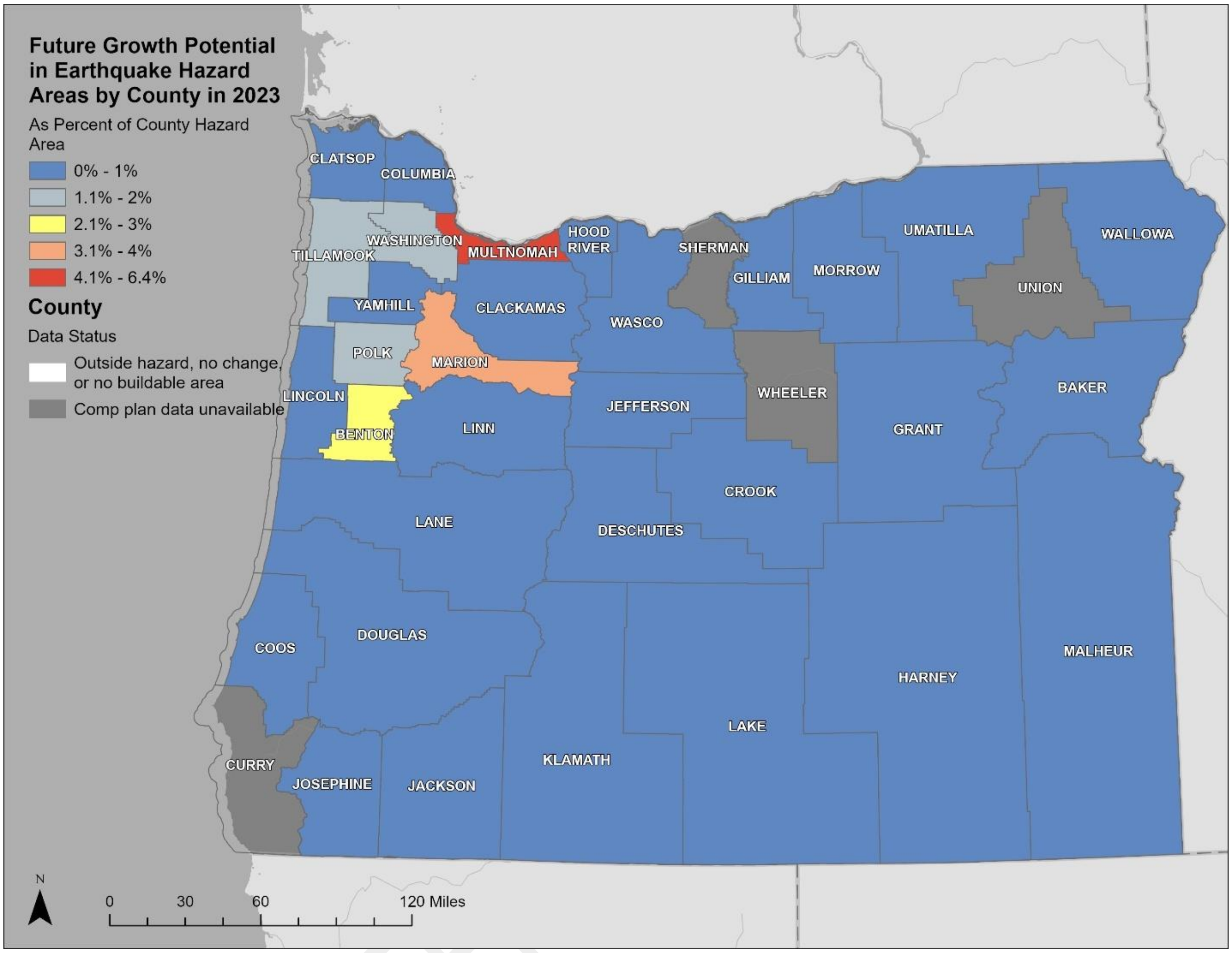


Figure 3.4.3-8: Future growth potential in earthquake hazard areas by county



3.4.3.5 Extreme Heat

For extreme heat there are no specific hazard-prone areas. Extreme heat is a hazard throughout Oregon.

3.4.3.6 River Flood

For river flooding, the hazard-prone areas are areas with a 1 percent annual chance of flood determined from 2024 digital Federal Emergency Management Agency Flood Insurance Rate Maps (D-FIRM). Portions of Oregon do not yet have D-FIRMS and these areas were included using paper FIRMs that were digitized by DOGAMI.

For river flooding, past change in development generally ranges from 0-7 percent . Potential future development has a large range with many counties ranging from 0-4 percent but several major exceptions. 23 percent of the hazard zone in Multnomah County is developable land. 11 percent of Marion County's hazard and 8 percent of Clackamas County's hazard area are also developable.

Table 3.4.3-3: Riverine flood changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Baker	M	56,543	3 percent	4 percent	1 percent
Benton	H	58,821	14 percent	2 percent	2 percent
Clackamas	M	23,086	2 percent	8 percent	8 percent
Clatsop	H	29,239	5 percent	2 percent	6 percent
Columbia	H	56,071	13 percent	3 percent	1 percent
Coos	H	65,957	6 percent	2 percent	2 percent
Crook	H	23,793	1 percent	3 percent	1 percent
Curry	M	16,270	1 percent	5 percent	0 percent
Deschutes	L	11,662	1 percent	4 percent	7 percent
Douglas	M	67,322	2 percent	4 percent	1 percent
Gilliam	M	26,506	3 percent	4 percent	0 percent
Grant	H	14,506	1 percent	4 percent	2 percent
Harney	-	246,449	4 percent	0 percent	0 percent
Hood River	L	9,760	3 percent	4 percent	0 percent
Jackson	M	36,110	2 percent	7 percent	2 percent
Jefferson	M	14,734	1 percent	4 percent	1 percent
Josephine	M	22,761	2 percent	6 percent	1 percent
Klamath	M	296,854	8 percent	1 percent	0 percent
Lake	H	212,045	4 percent	0 percent	0 percent
Lane	H	138,531	5 percent	4 percent	2 percent
Lincoln	M	29,426	5 percent	3 percent	1 percent
Linn	M	112,209	8 percent	2 percent	2 percent
Malheur	M	57,558	1 percent	2 percent	2 percent
Marion	H	57,466	7 percent	3 percent	11 percent
Morrow - North	L	26,715	2 percent	3 percent	0 percent
Morrow - South	M				
Multnomah	M	36,533	12 percent	5 percent	23 percent
Polk	M	40,347	8 percent	2 percent	3 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Sherman	L	10,558	2 percent	5 percent	0 percent
Tillamook	H	28,219	4 percent	2 percent	4 percent
Umatilla	H	19,279	1 percent	7 percent	2 percent
Union	M	40,587	3 percent	4 percent	0 percent
Wallowa	M	11,244	1 percent	6 percent	2 percent
Wasco	M	15,638	1 percent	4 percent	4 percent
Washington	M	41,201	9 percent	3 percent	3 percent
Wheeler	H	16,644	2 percent	3 percent	0 percent
Yamhill	H	42,482	9 percent	2 percent	1 percent

Figure 3.4.3-9 and Figure 3.4.3-10 show the past changes in development within hazard areas across the state, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3-9 shows the change at the census tract level. Census tracts with the most change in impervious in flood zones are clustered around the Portland metro region, Bend, Hermiston, and the Rogue Valley. Figure 3.4.3-10 shows change at a county level. Clackamas County has the highest change in development in hazard zones followed by Umatilla, Josephine, and Jackson Counties.

Figure 3.4.3-9: Change in impervious surface in riverine flood hazard areas by census tract

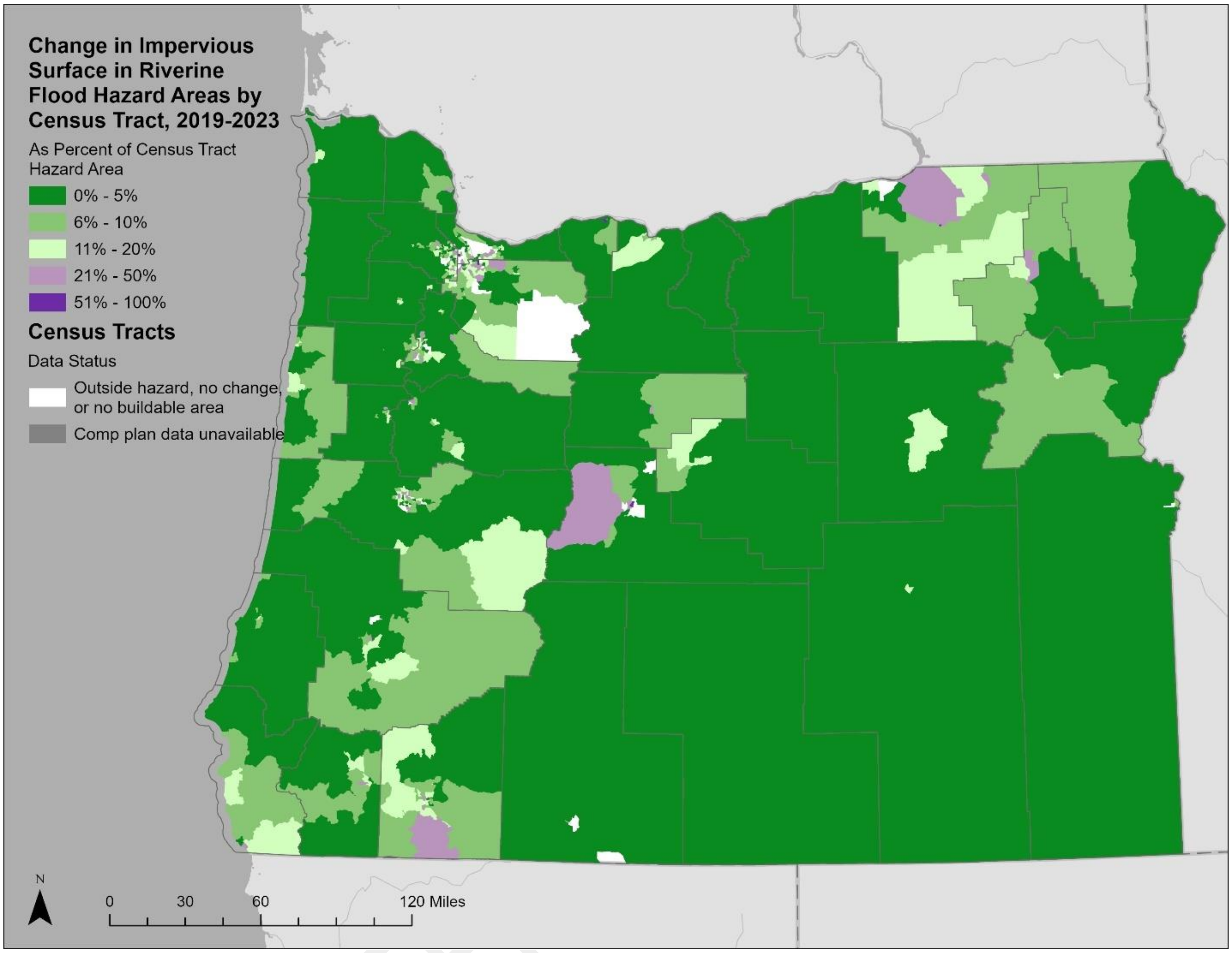


Figure 3.4.3-10: Change in impervious surface in riverine flood hazard areas by county

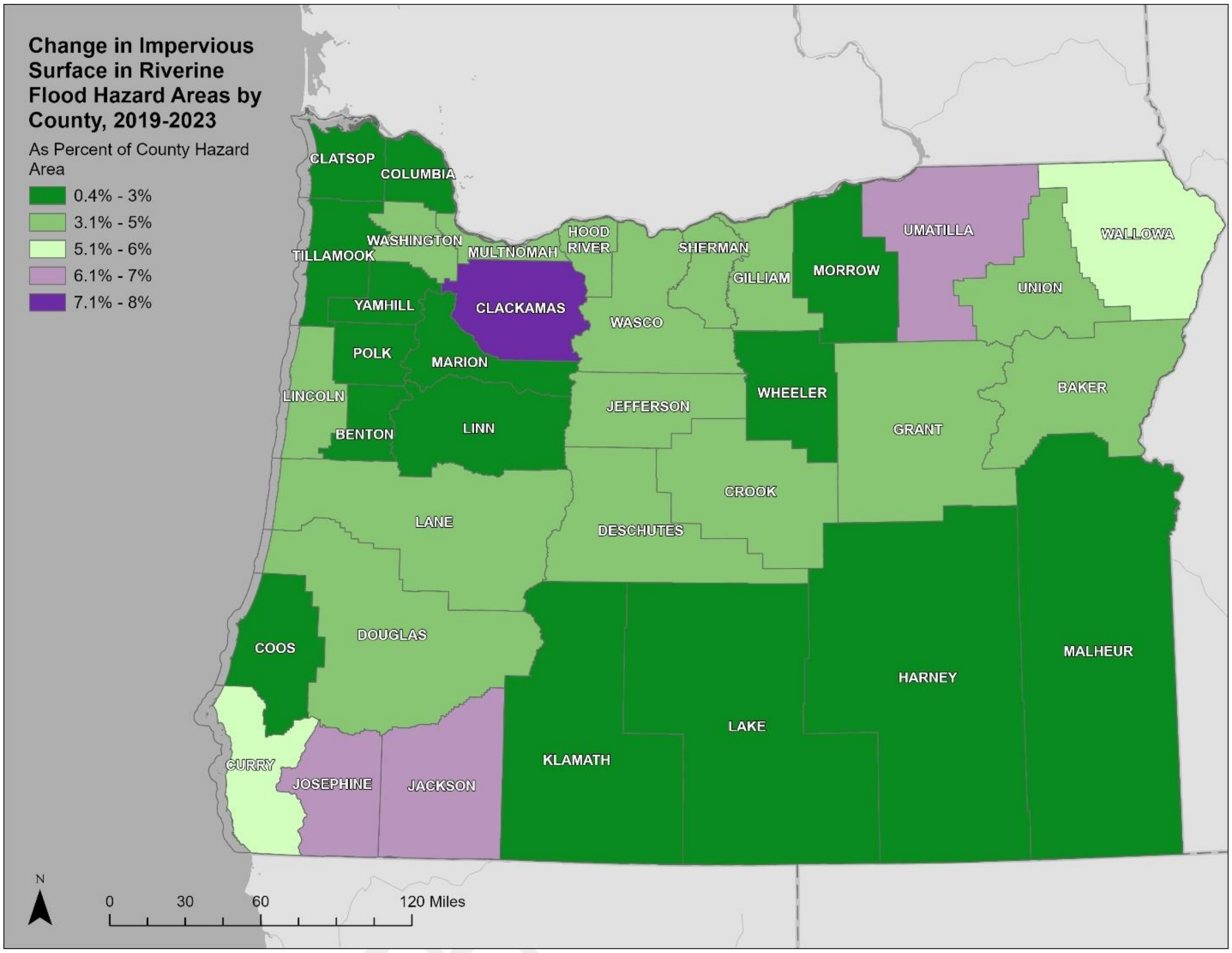


Figure 3.4.3-11 and 3Figure 3.4.3-12 show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3-11 shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in flood zones are clustered around the Portland metro region, the Willamette Valley, Hermiston, Bend, and Newport. Figure 3.4.3-12 shows change at a county level. Multnomah County has the highest potential change in development in hazard zones followed by Marion County.

Figure 3.4.3-11: Future growth potential in riverine flood areas by census tracts

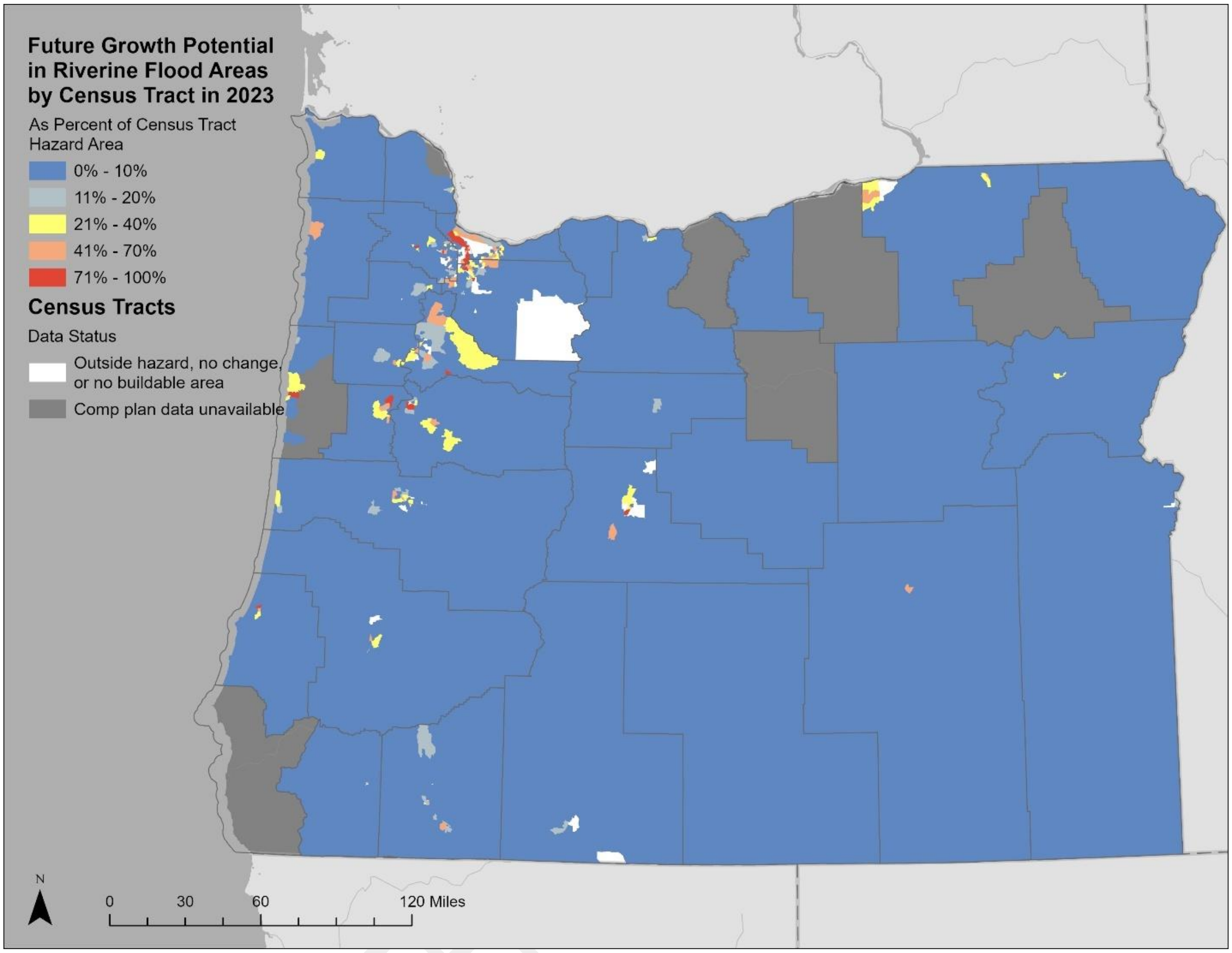
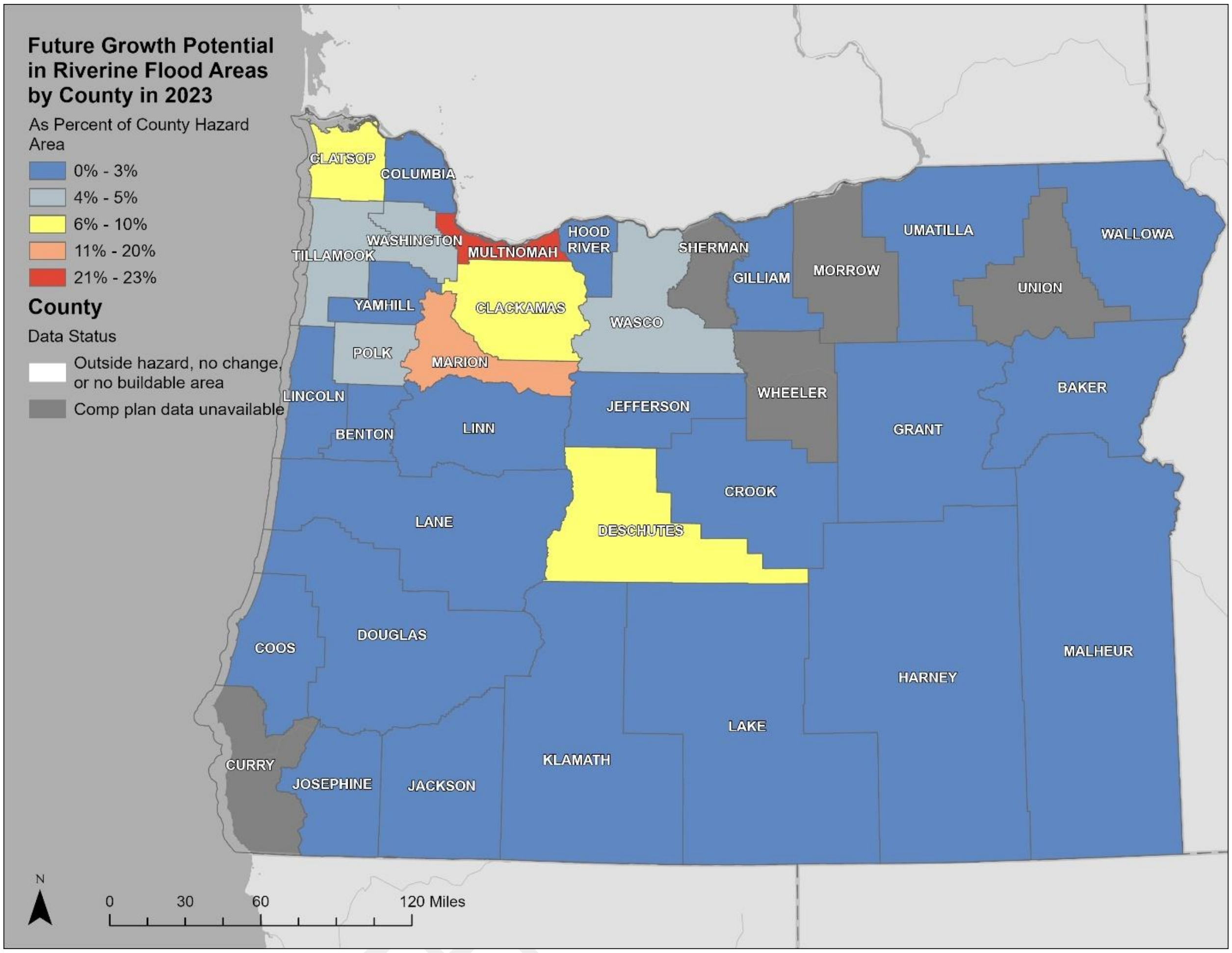


Figure 3.4.3-12: Future growth potential in riverine flood areas by county in 2023



3.4.3.7 Landslides

For landslides, the hazard-prone areas are areas of high and very high susceptibility ratings from the statewide landslide susceptibility data set (SLIDO) produced by DOGAMI.

Changes in development in landslide areas are generally low. Past changes in development generally range from 0-2 percent , except Multnomah County with 4 percent . Potential Future development is generally even lower, mostly ranging from 0-1 percent , except Multnomah County at 9 percent .

Table 3.4.3-4: Landslide changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Baker	L	889,203	45 percent	1 percent	0 percent
Benton	M	162,245	37 percent	1 percent	0 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Clackamas	L	547,078	45 percent	2 percent	0 percent
Clatsop	L	405,335	70 percent	1 percent	0 percent
Columbia	-	237,452	54 percent	2 percent	0 percent
Coos	H	708,288	67 percent	1 percent	0 percent
Crook	L	441,660	23 percent	1 percent	0 percent
Curry	H	774,926	71 percent	1 percent	0 percent
Deschutes	L	171,822	9 percent	1 percent	0 percent
Douglas	M	2,175,395	67 percent	1 percent	0 percent
Gilliam	H	239,569	31 percent	0 percent	0 percent
Grant	L	1,319,592	46 percent	1 percent	0 percent
Harney		810,044	12 percent	0 percent	0 percent
Hood River	M	192,521	56 percent	1 percent	0 percent
Jackson	L	916,540	51 percent	1 percent	0 percent
Jefferson	L	368,665	32 percent	0 percent	0 percent
Josephine	L	733,636	70 percent	1 percent	0 percent
Klamath	M	469,629	12 percent	1 percent	0 percent
Lake	L	541,150	10 percent	1 percent	0 percent
Lane	H	1,684,988	57 percent	1 percent	0 percent
Lincoln	H	463,358	71 percent	1 percent	1 percent
Linn	L	735,899	50 percent	1 percent	0 percent
Malheur	L	1,140,120	18 percent	0 percent	0 percent
Marion	H	264,365	34 percent	2 percent	1 percent
Morrow - North	L	263,239	20 percent	1 percent	0 percent
Morrow - South	M				
Multnomah	M	89,120	30 percent	4 percent	9 percent
Polk	L	230,590	48 percent	2 percent	1 percent
Sherman	M	123,343	23 percent	0 percent	0 percent
Tillamook	H	599,242	82 percent	1 percent	1 percent
Umatilla	M	618,868	30 percent	1 percent	0 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Union	L	498,749	38 percent	1 percent	0 percent
Wallowa	M	1,167,800	58 percent	0 percent	0 percent
Wasco	L	484,874	32 percent	1 percent	0 percent
Washington	L	182,662	39 percent	2 percent	1 percent
Wheeler	H	576,291	52 percent	0 percent	0 percent
Yamhill	L	241,518	52 percent	2 percent	0 percent

Figure 3.4.3-13 and Figure 3.4.3-14 show the past changes in development within hazard areas across the state, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3-13 shows the change at the census tract level. Census tracts with the most change in impervious in landslide areas are clustered around the Portland metro region, Bend, Hermiston, the Central Willamette Valley and the Rogue Valley. Figure 3.4.3-14 shows change at a county level. Multnomah County has the highest change in development in hazard zones followed by Washington County.

Figure 3.4.3-13: Change in impervious surface in landslide hazard areas by census tract

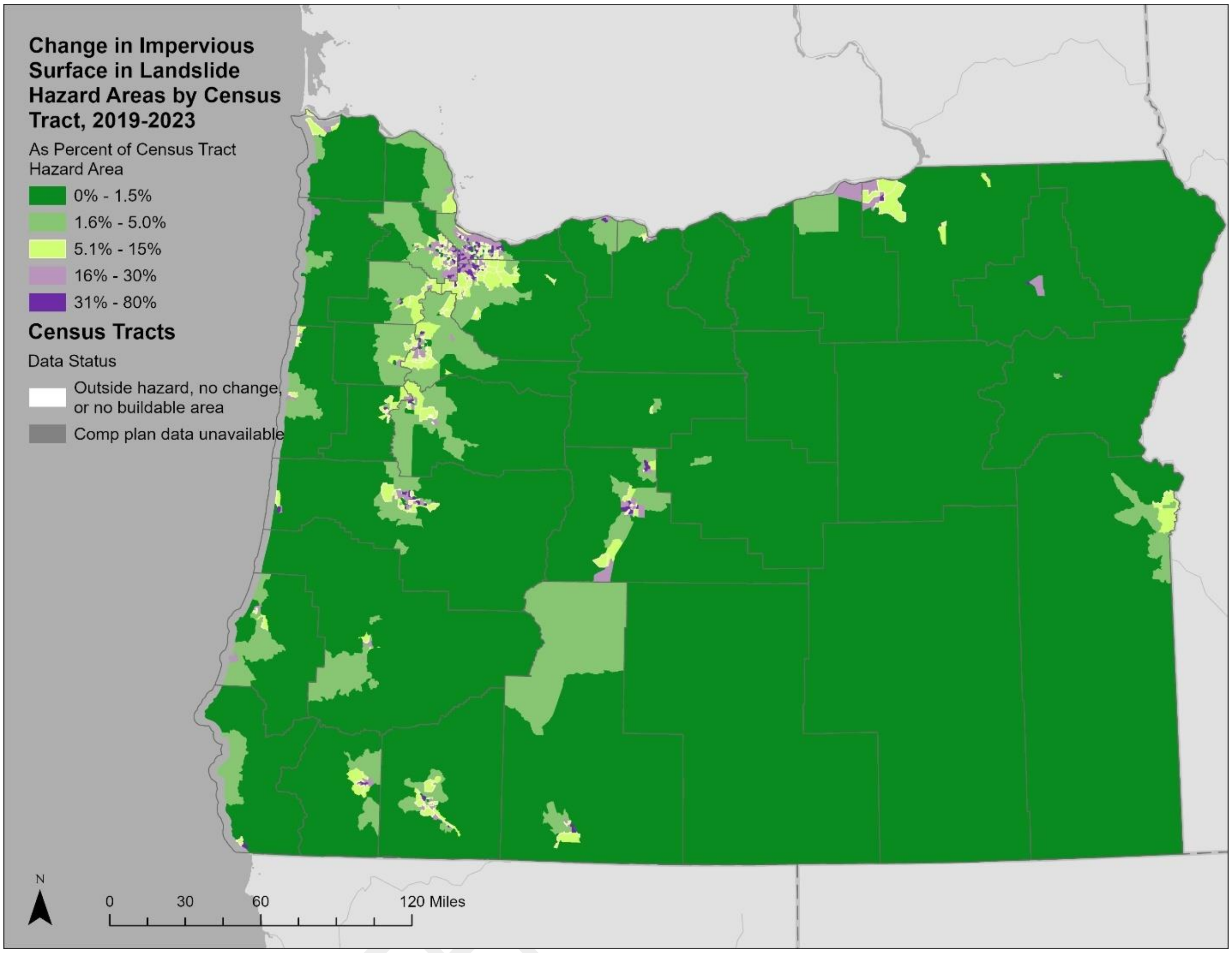


Figure 3.4.3-14: Change in impervious surface in landslide hazard areas by county

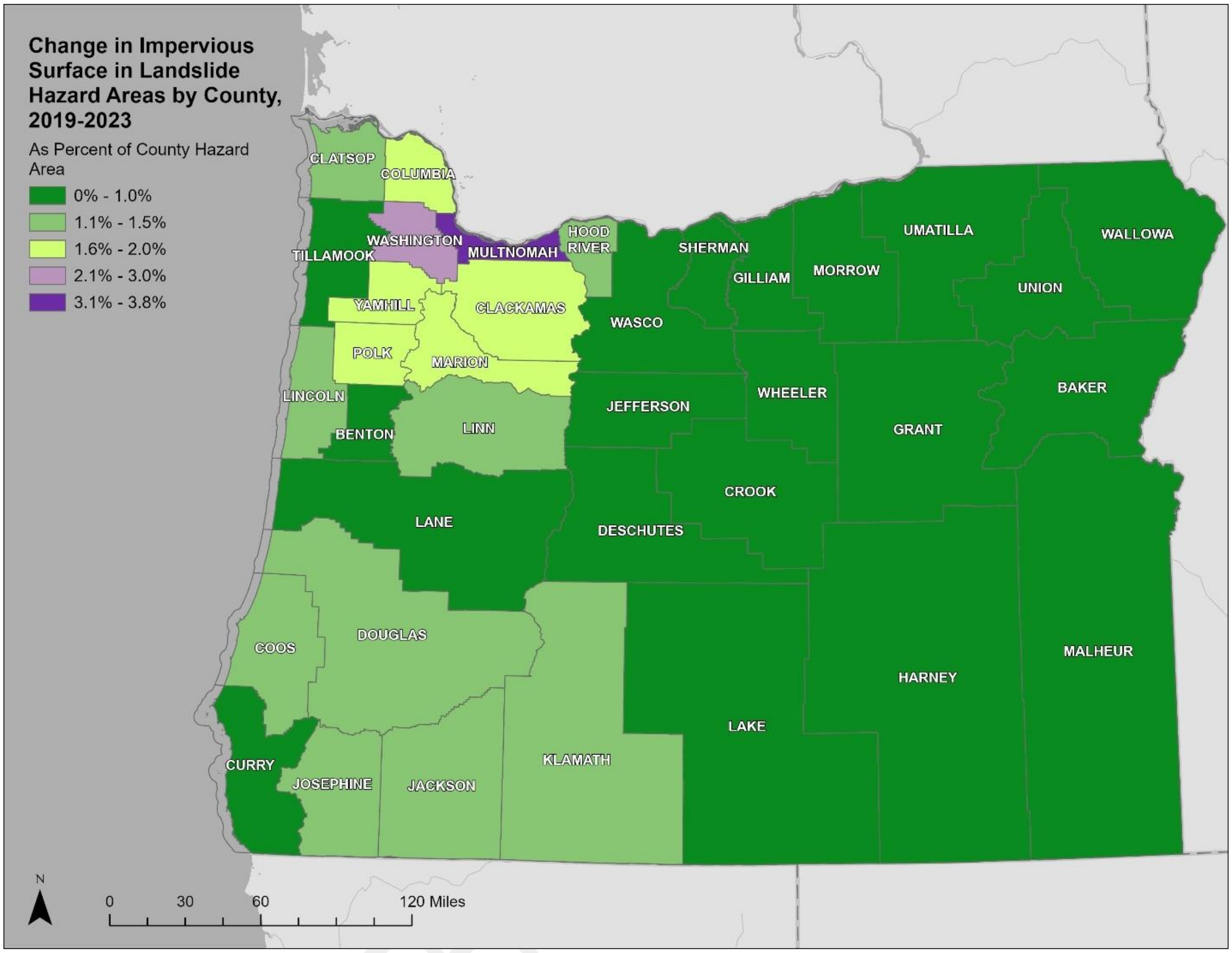


Figure 3.4.3-15 and 3Figure 3.4.3-16 show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3-15 shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in landslide areas are clustered around the Portland metro region, Corvallis, and Bend. Figure 3.4.3-16 shows change at a county level. Multnomah County has the highest potential change in development in hazard zones followed by Tillamook County.

Figure 3.4.3-15: Future growth potential in landslide hazard areas by census tract

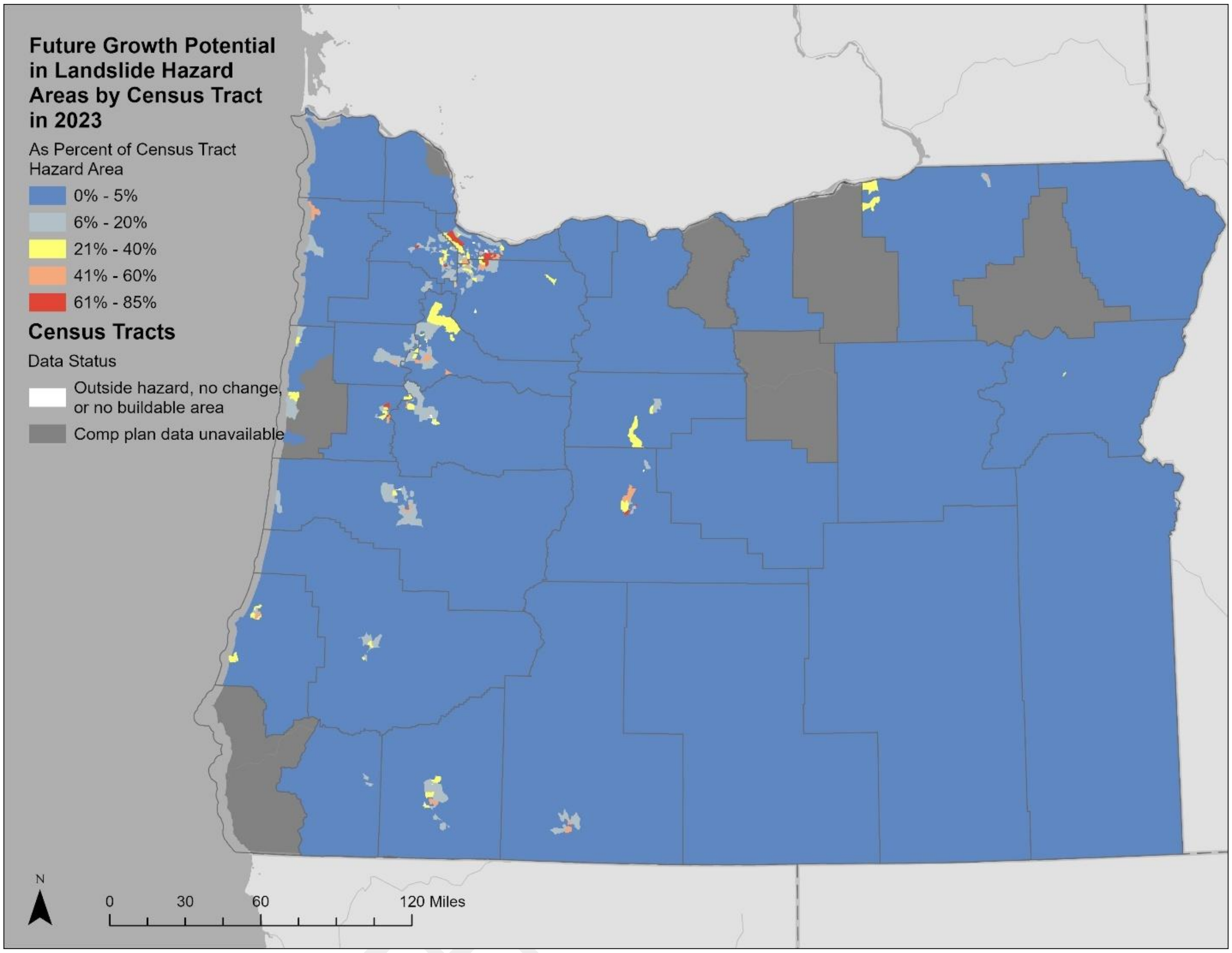
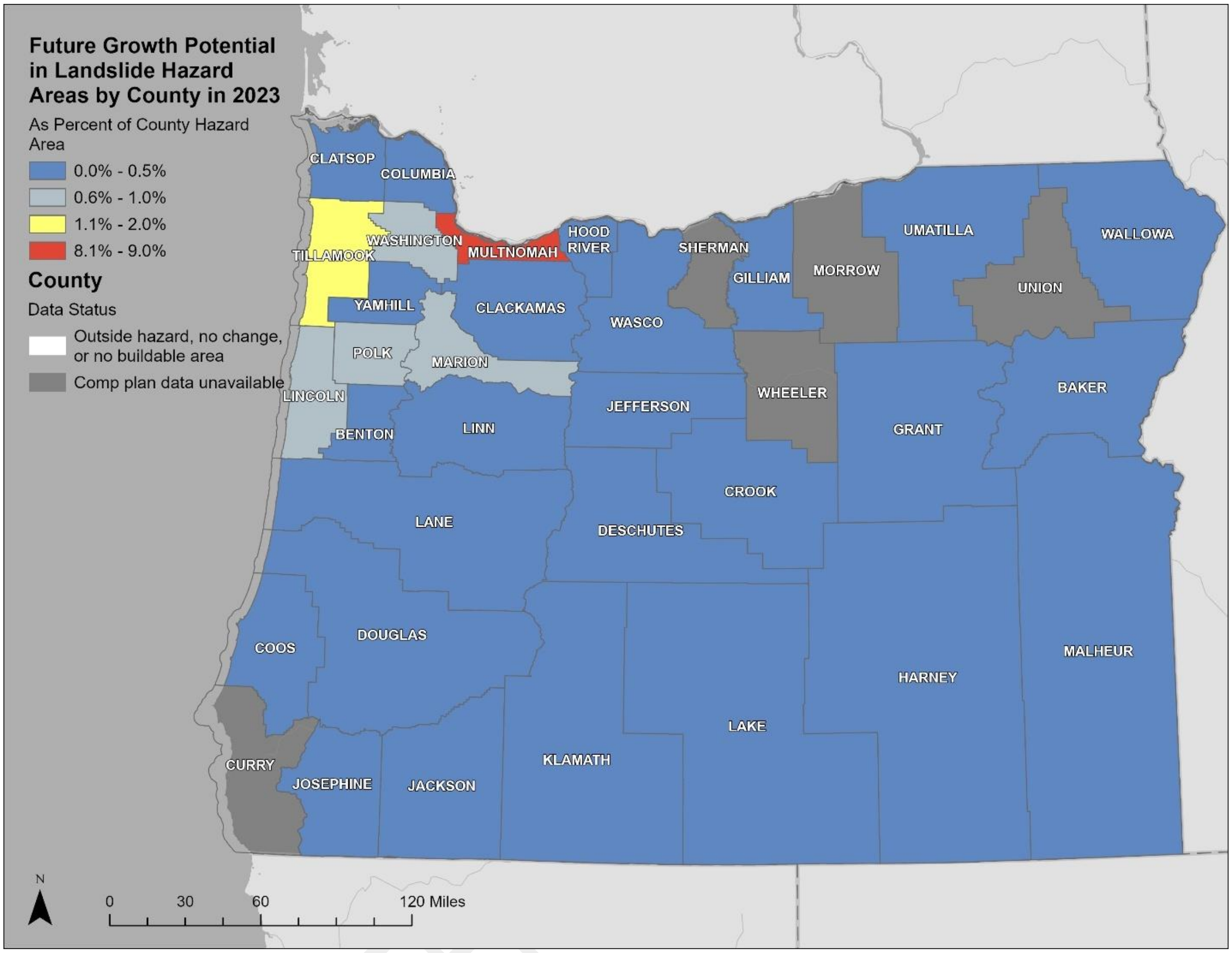


Figure 3.4.3-16: Future growth potential in landslide hazard areas by county



3.4.3.8 Tsunamis

For tsunamis, the hazard-prone areas are areas of exposure to any size (small through extra-extra-large) Cascadia subduction zone tsunami as determined from tsunami inundation data produced by DOGAMI.

For tsunami, past changes in development are a similar range to coastal flooding, 2-5 percent . Potential future changes in development for most coastal counties range from 0-4 percent , but in Tillamook County approximately 9 percent of the hazard zone is still developable.

Table 3.4.3-5: Tsunami changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Clatsop	H	57,790	10 percent	5 percent	4 percent
Coos	H	85,038	8 percent	3 percent	2 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Curry	H	56,870	5 percent	4 percent	0 percent
Douglas	M	29,606	1 percent	2 percent	1 percent
Lane	M	25,803	1 percent	2 percent	3 percent
Lincoln	H	48,105	7 percent	4 percent	3 percent
Tillamook	H	57,604	8 percent	3 percent	9 percent

Figure 3.4.3-17 and Figure 3.4.3-18 show the past changes in development within hazard areas at the coast that area affected by tsunami, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3-17 shows the change at the census tract level. Census tracts with the most change in impervious in tsunami areas are near Seaside and in areas along the south coast. Figure 3.4.3-18 shows change at a county level. Clatsop has the highest change in development in hazard zones followed by Lincoln, Coos, and Curry Counties.

Figure 3.4.3-17: Change in impervious surface in tsunami hazard areas by census tract

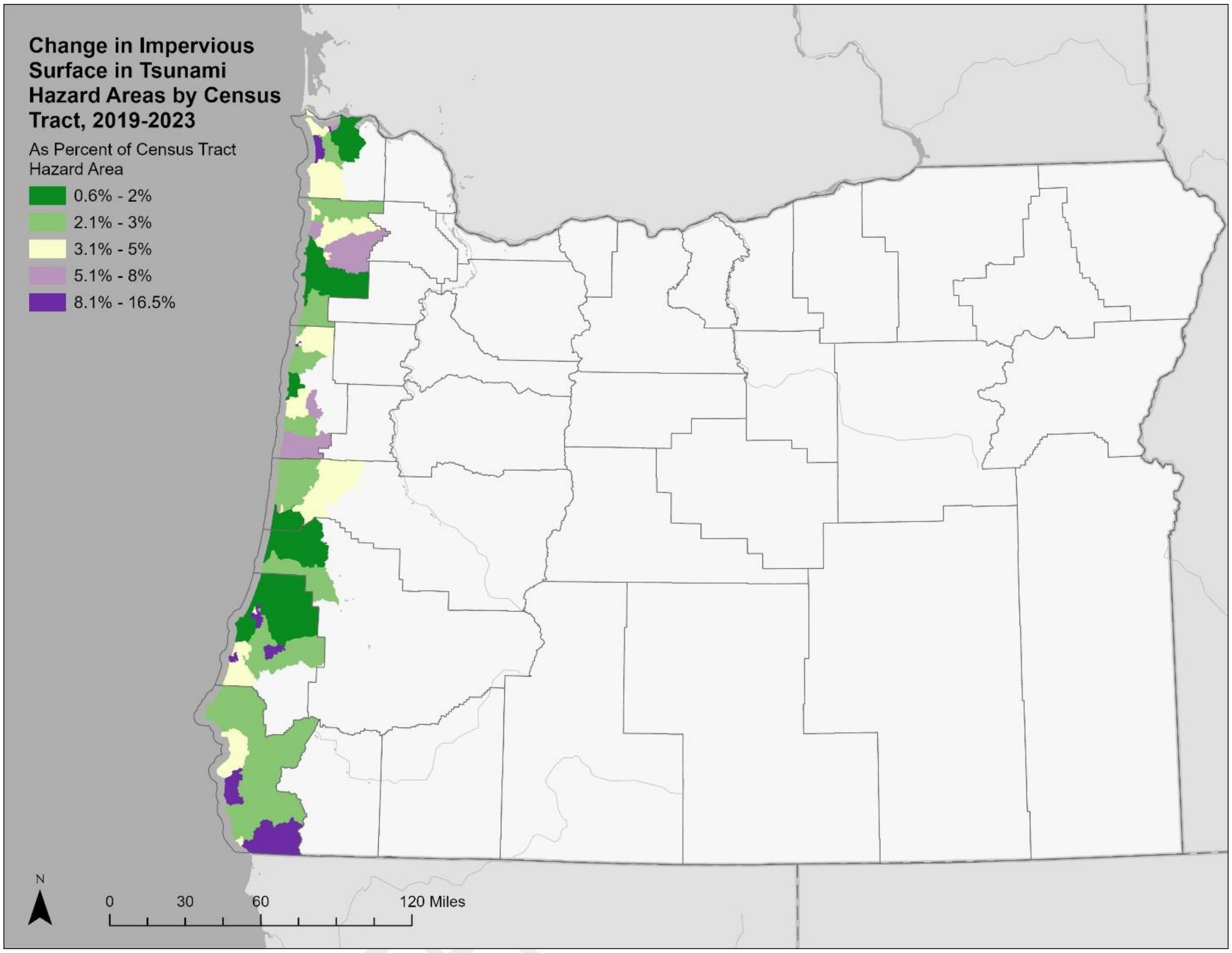


Figure 3.4.3-18: Change in impervious surface in tsunami hazard areas by county

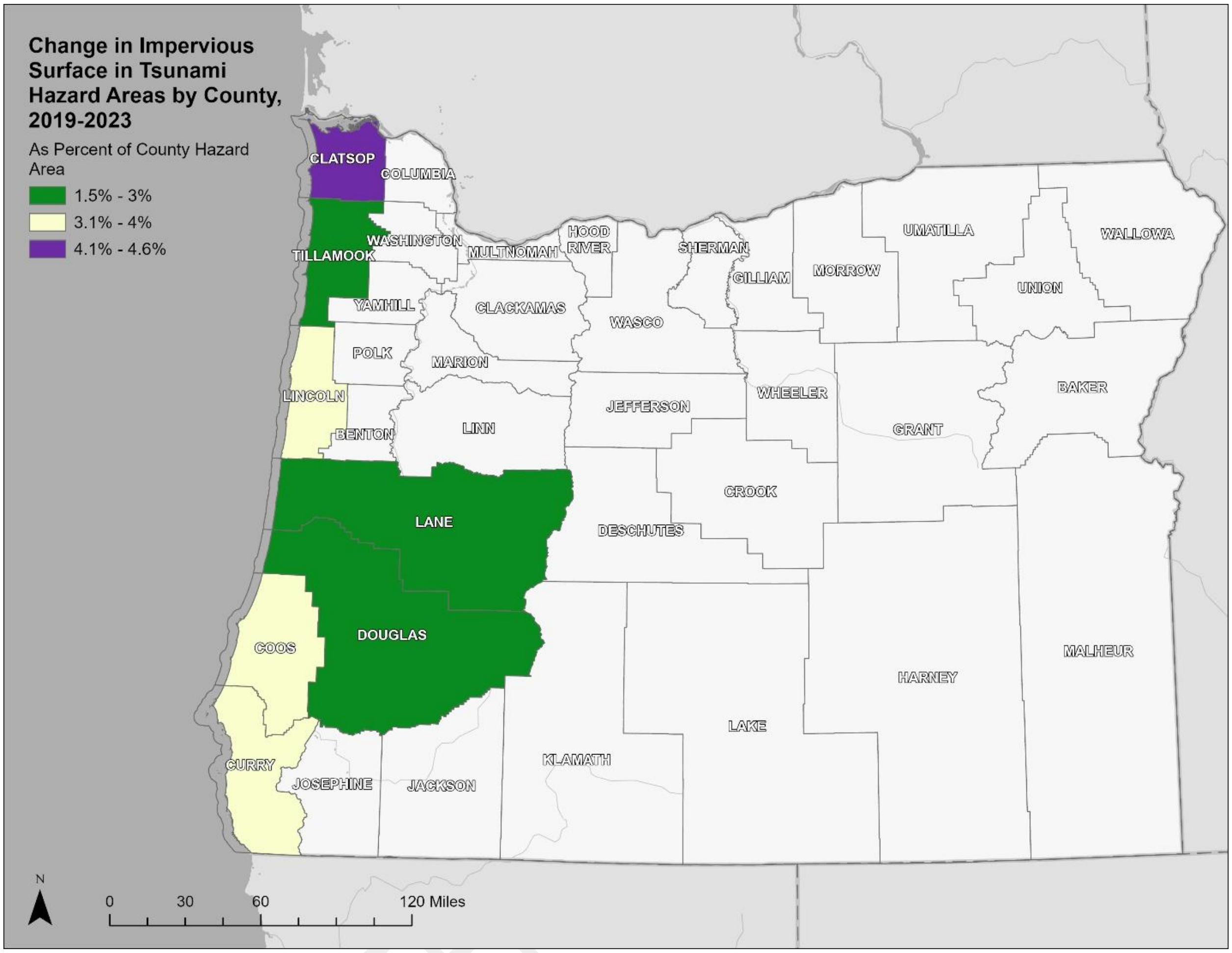


Figure 3.4.3-19 and Figure 3.4.3-20 show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3-19 shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in tsunami areas are around Coos Bay. Figure 3.4.3-20 shows change at a county level. Tillamook County has the highest potential change in development in hazard zones followed by Clatsop and Lincoln Counties.

Figure 3.4.3-19: Future growth potential in tsunami hazard areas by census tract

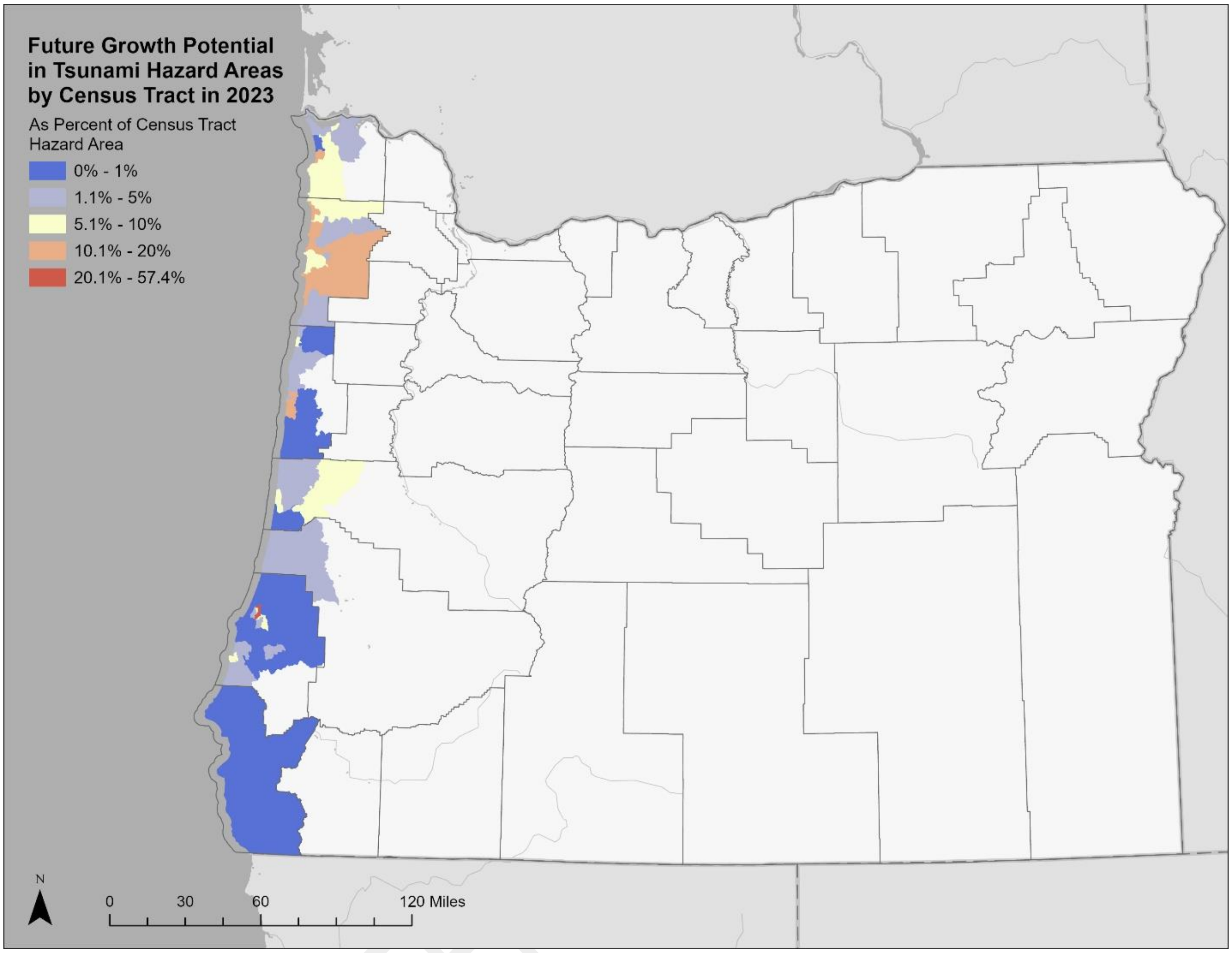
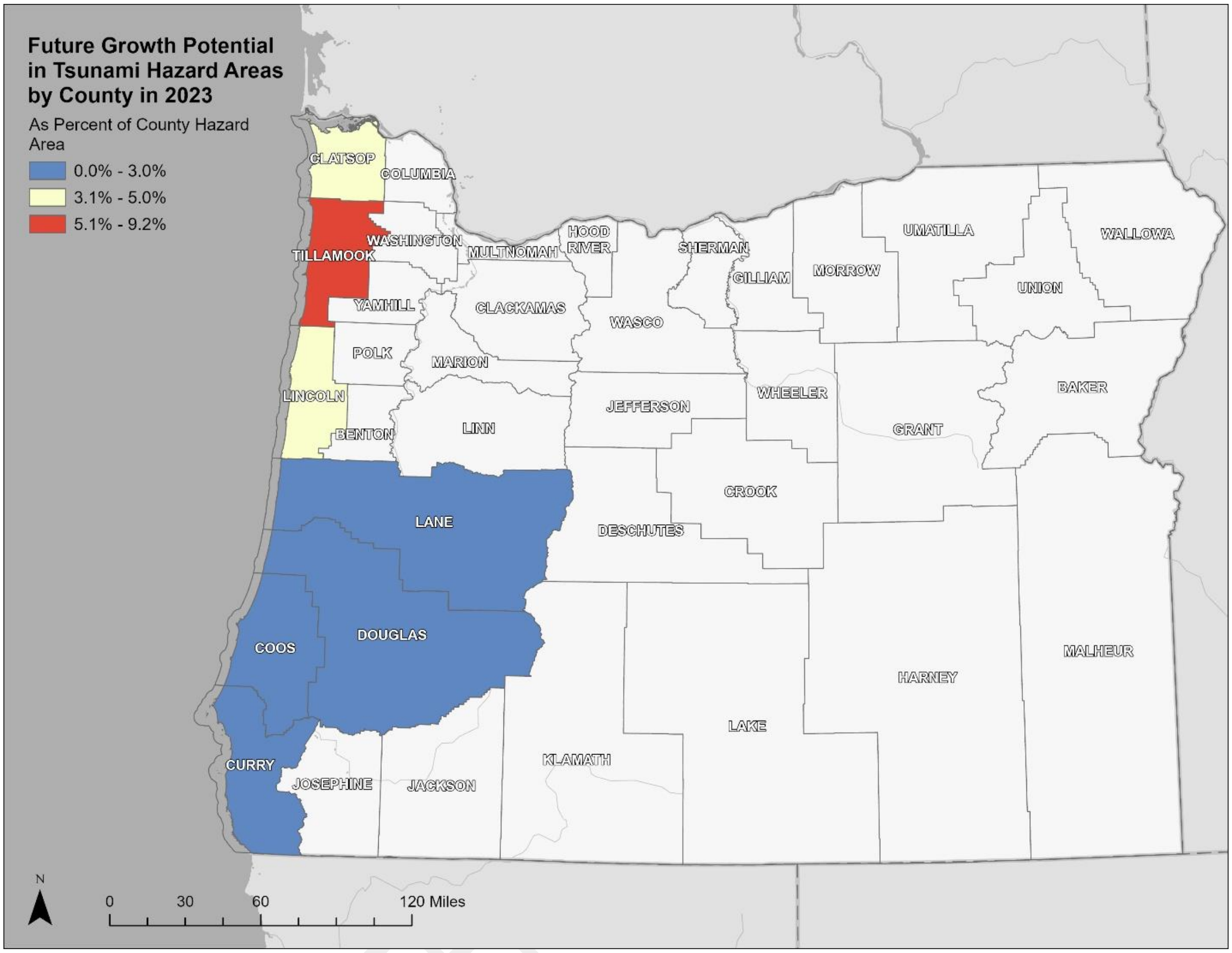


Figure 3.4.3-20: Future growth potential in tsunami hazard areas by county



3.4.3.9 Volcanoes

For volcanoes, the hazard-prone areas are lahar inundation zones from the US Geological Survey (Mt. Jefferson, Sister, and Crater Lake) and from the Oregon Department of Geology and Mineral Industries (Mt. Hood).

Past changes in development in areas at risk of volcano hazard generally range from 0-4 percent , except Multnomah County at 7 percent . Potential future change generally ranges from 0-2 percent except Marion County at 4 percent and Multnomah County at 8 percent .

Table 3.4.3-6: Volcano changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Clackamas	L	54,065	4 percent	3 percent	2 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Deschutes	H	298,629	15 percent	2 percent	0 percent
Hood River	L	86,055	26 percent	4 percent	0 percent
Jefferson	L	57,338	5 percent	1 percent	0 percent
Klamath	H	66,807	2 percent	0 percent	0 percent
Lake	H	27,278	1 percent	2 percent	0 percent
Lane	L	62,942	2 percent	3 percent	0 percent
Linn	M	39,742	3 percent	3 percent	1 percent
Marion	M	35,948	10 percent	3 percent	4 percent
Multnomah	L	11,029	4 percent	7 percent	8 percent
Wasco	H	7,607	0 percent	4 percent	0 percent

Figure 3.4.3-21 and Figure 3.4.3-22 show the past changes in development within hazard areas across the state, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3-21 shows the change at the census tract level. Census tracts with the most change in impervious in volcanic lahar zones are clustered in Deschutes County around Bend and La Pine. Figure 3.4.3-22 shows change at a county level. Multnomah County has the highest change in development in hazard zones followed by Wasco County.

Figure 3.4.3-21: Change in impervious surface in volcanic lahar hazard areas by census tract

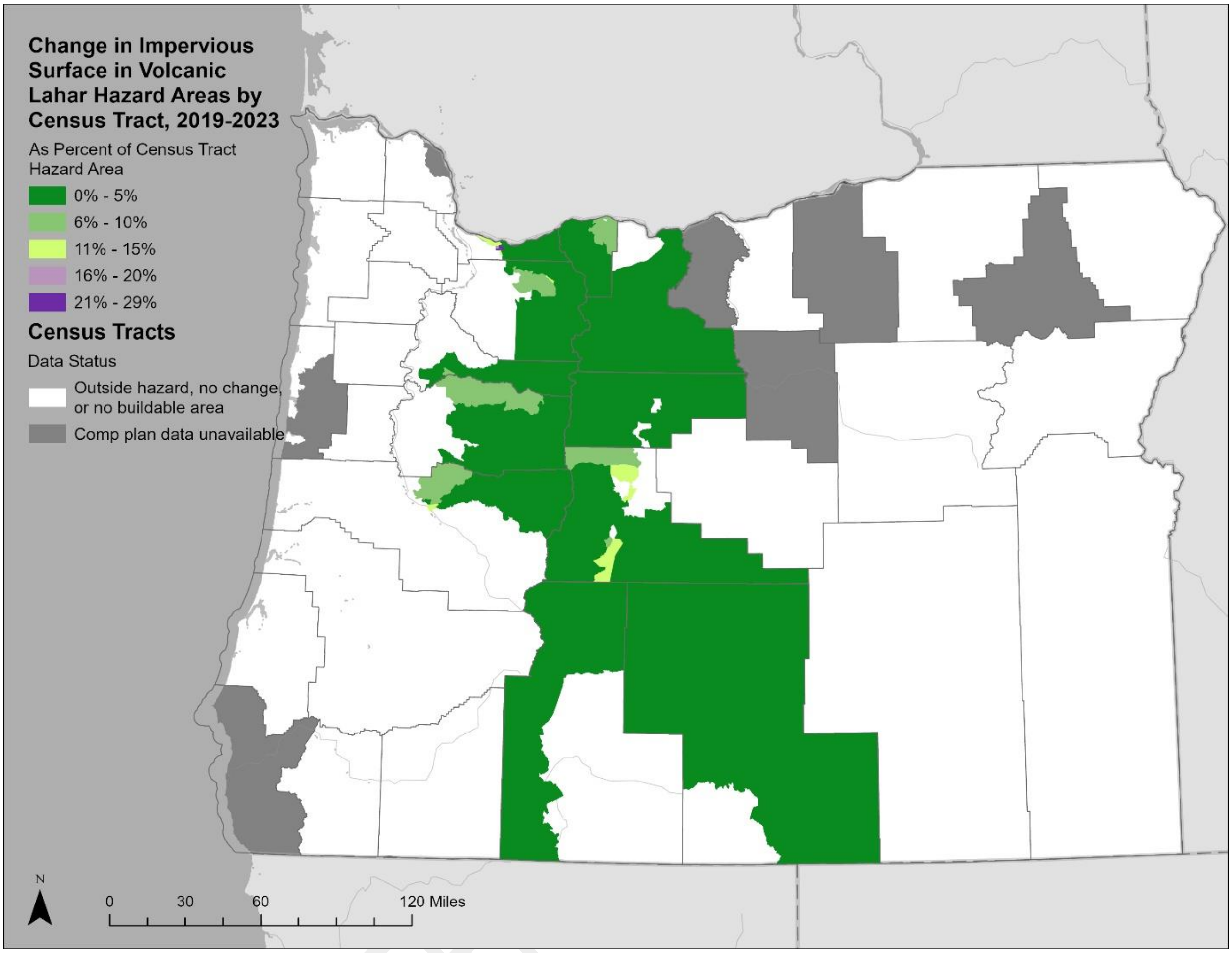


Figure 3.4.3-22: Change in impervious surface in volcanic lahar hazard areas by county

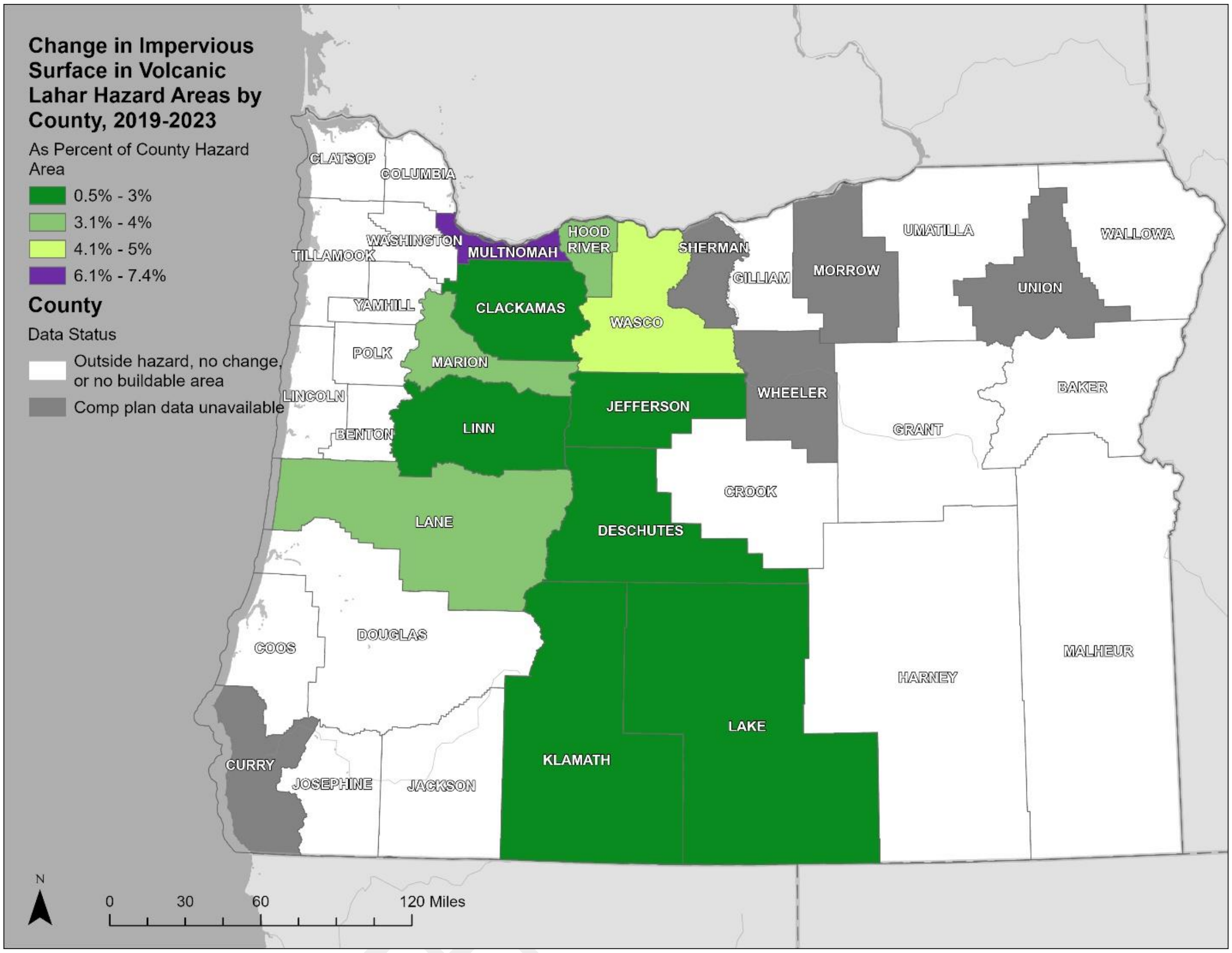


Figure 3.4.3-23 and Figure 3.4.3-24 show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3-23 shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in volcano lahar zones are concentrated around Bend. Figure 3.4.3-24 shows change at a county level. Multnomah County has the highest potential change in development in hazard zones followed by Marion County.

Figure 3.4.3-23: Future growth potential in volcanic lahar hazard areas by census tract

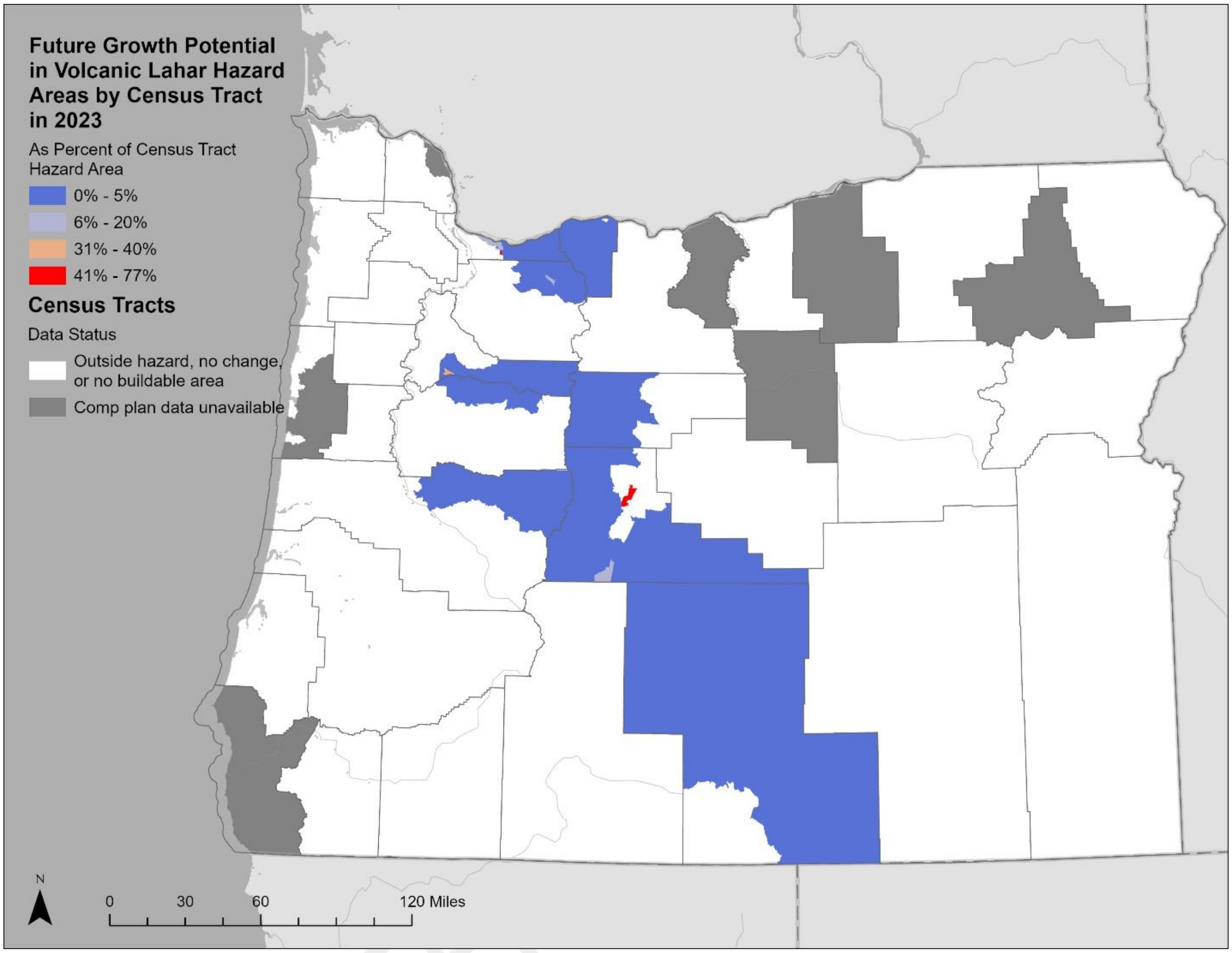
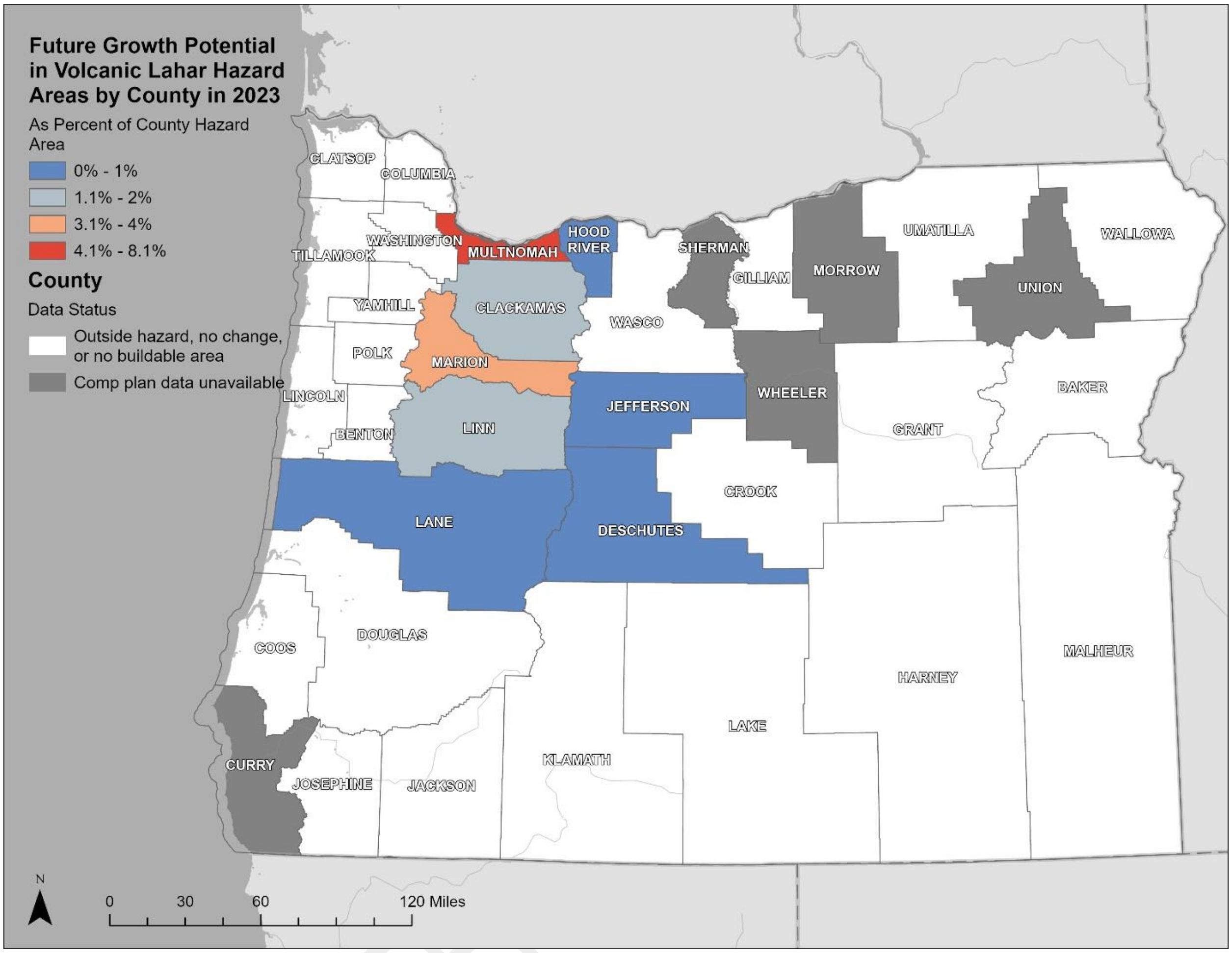


Figure 3.4.3-24: Future growth potential in volcanic lahar hazard areas by county



3.4.3.10 Wildfires

For wildfires, the hazard-prone areas are areas of moderate to high burn probability determined from Wildfire Burn Probability data produced by the Oregon Department of Forestry.

Changes in development for wildfire hazard areas is very low, likely because a large amount of hazard area is within forested areas. The past changes in development range from 0-3 percent , with Hood River having the highest percent at 3 percent . Potential future changes are very low. The majority of counties have 0 percent of the hazard zone as developable, except Jackson and Jefferson Counties where it is 1 percent , which could translate to a large amount of development and exposure within the much smaller wildland-urban interface.

Table 3.4.3-7: Wildfire changes in development summary table

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Baker	H	1,903,427	96 percent	1 percent	0 percent
Clackamas	M	540,946	45 percent	1 percent	0 percent
Coos	M	79,204	8 percent	1 percent	0 percent
Crook	M	1,426,293	75 percent	1 percent	0 percent
Curry	H	720,662	66 percent	1 percent	0 percent
Deschutes	H	1,210,062	62 percent	2 percent	0 percent
Douglas	H	1,787,965	55 percent	2 percent	0 percent
Gilliam	H	730,520	93 percent	1 percent	0 percent
Grant	H	2,884,905	100 percent	1 percent	0 percent
Harney		6,062,957	93 percent	0 percent	0 percent
Hood River	H	285,691	84 percent	3 percent	0 percent
Jackson	H	1,703,884	95 percent	2 percent	1 percent
Jefferson	H	1,044,310	91 percent	1 percent	1 percent
Josephine	H	1,002,886	95 percent	3 percent	0 percent
Klamath	H	2,240,187	57 percent	2 percent	0 percent
Lake	H	4,461,977	83 percent	1 percent	0 percent
Lane	H	1,169,179	39 percent	1 percent	0 percent
Linn	M	664,935	45 percent	1 percent	0 percent
Malheur	M	6,016,742	95 percent	0 percent	0 percent
Marion	H	135,751	17 percent	1 percent	0 percent
Morrow - North	L	1,060,889	81 percent	1 percent	0 percent
Morrow - South	H				
Multnomah	H	71,828	24 percent	1 percent	0 percent
Sherman	H	472,314	89 percent	1 percent	0 percent
Umatilla	H	1,613,893	78 percent	1 percent	0 percent
Union	M	1,156,237	89 percent	1 percent	0 percent

County	Local Risk Assessment Rating (From Local NHMP)	Total Hazard Area in acres	percent of County Within Hazard Area	percent Haz Area Changed from Perv. to Imperv. (Past Change)	percent Hazard Zone Developable (Potential Future Change)
Wallowa	H	1,918,723	95 percent	1 percent	0 percent
Wasco	H	1,505,782	98 percent	1 percent	0 percent
Wheeler	H	1,091,643	99 percent	1 percent	0 percent

Figure 3.4.3-25 and Figure 3.4.3-26 show the past changes in development within hazard areas across the state, or the percentage of the hazard area that changed from pervious to impervious between the 2019 and 2023 NLCD data. Figure 3.4.3-25 shows the change at the census tract level. Census tracts with the most change in impervious in wildfire zones are clustered around Bend, Mt. Hood and Hood River, Hermiston, and the Rogue Valley and Grants Pass. Figure 3.4.3-26 shows change at a county level. Hood River County has the highest change in development in hazard zones followed by Jackson and Josephine Counties.

Figure 3.4.3-25: Change in impervious surface in wildfire hazard areas by census tract

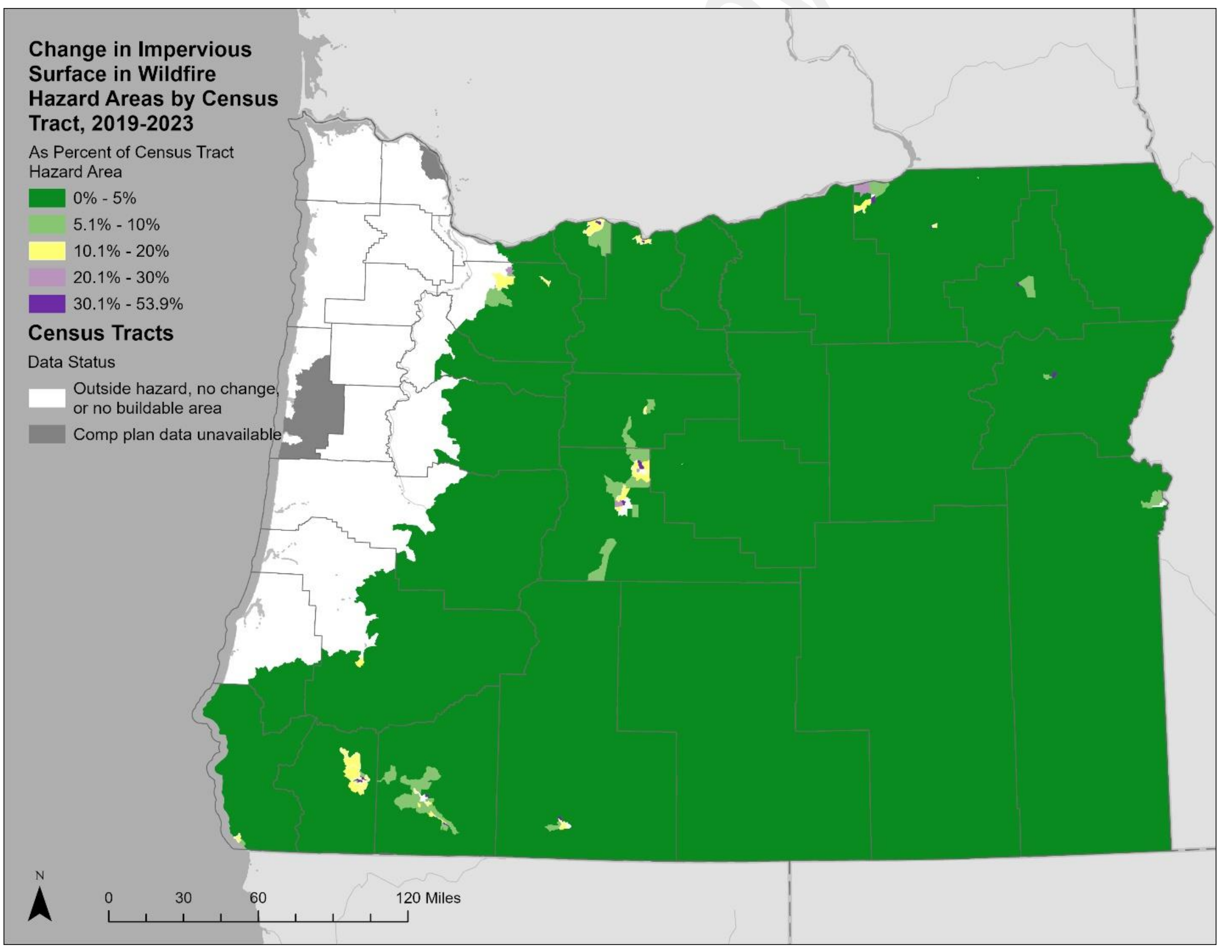


Figure 3.4.3-26: Change in impervious surface in wildfire hazard areas by county

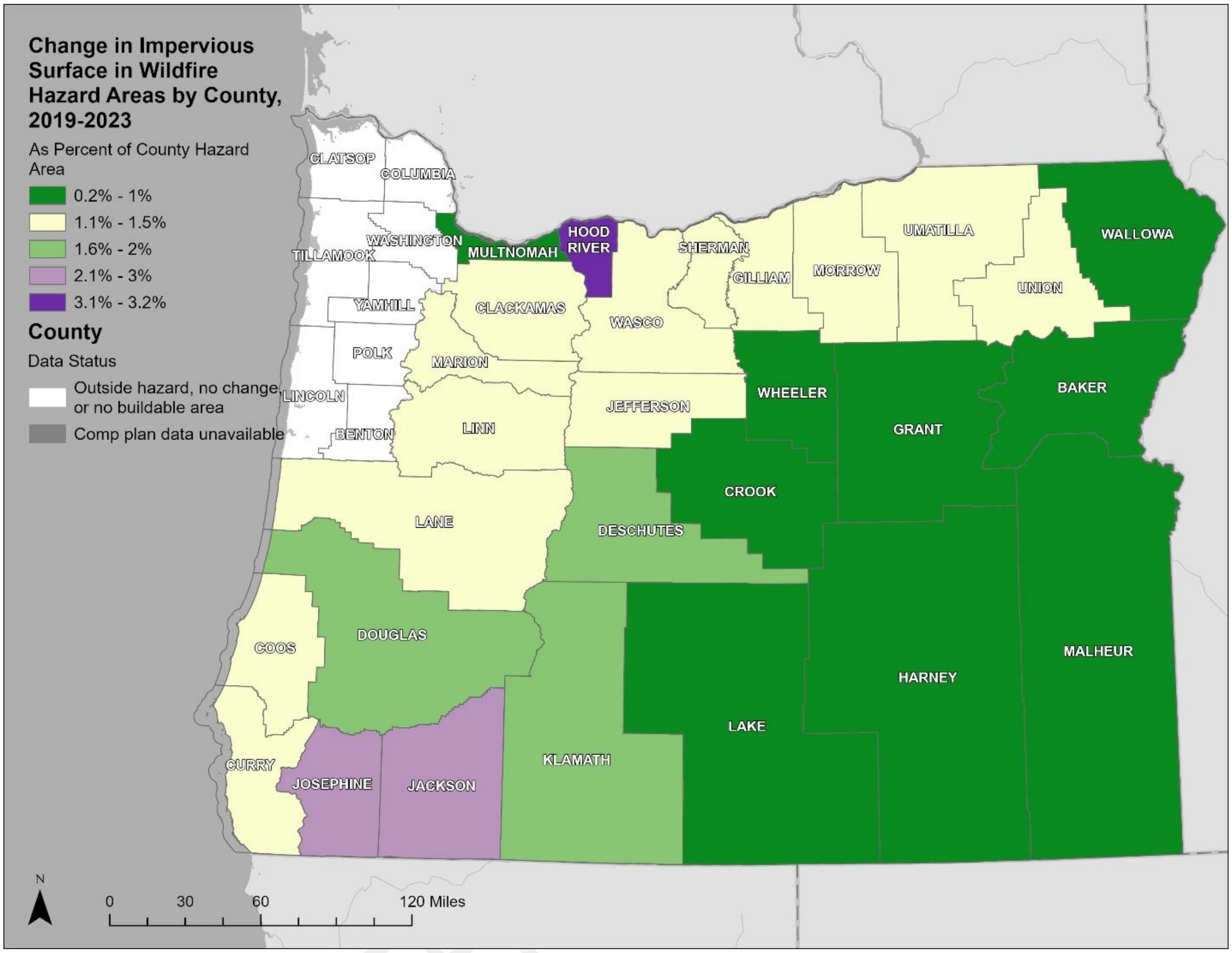


Figure 3.4.3-27and Figure 3.4.3-28 show the potential future changes in development within hazard areas across the state, or the percentage of the hazard area located in medium or high density development designations that are not yet developed. Figure 3.4.3-27 shows the potential future change at the census tract level. Census tracts with the most percentage of developable land in wildfire hazard areas are clustered around Bend and Madras, Roseburg, the Rogue Valley, and Klamath. Figure 3.4.3-28 shows change at a county level. Jefferson and Jackson Counties have the highest potential change in development in hazard zones followed by Deschutes County.

Figure 3.4.3-27: Future growth potential in wildfire areas by census tract

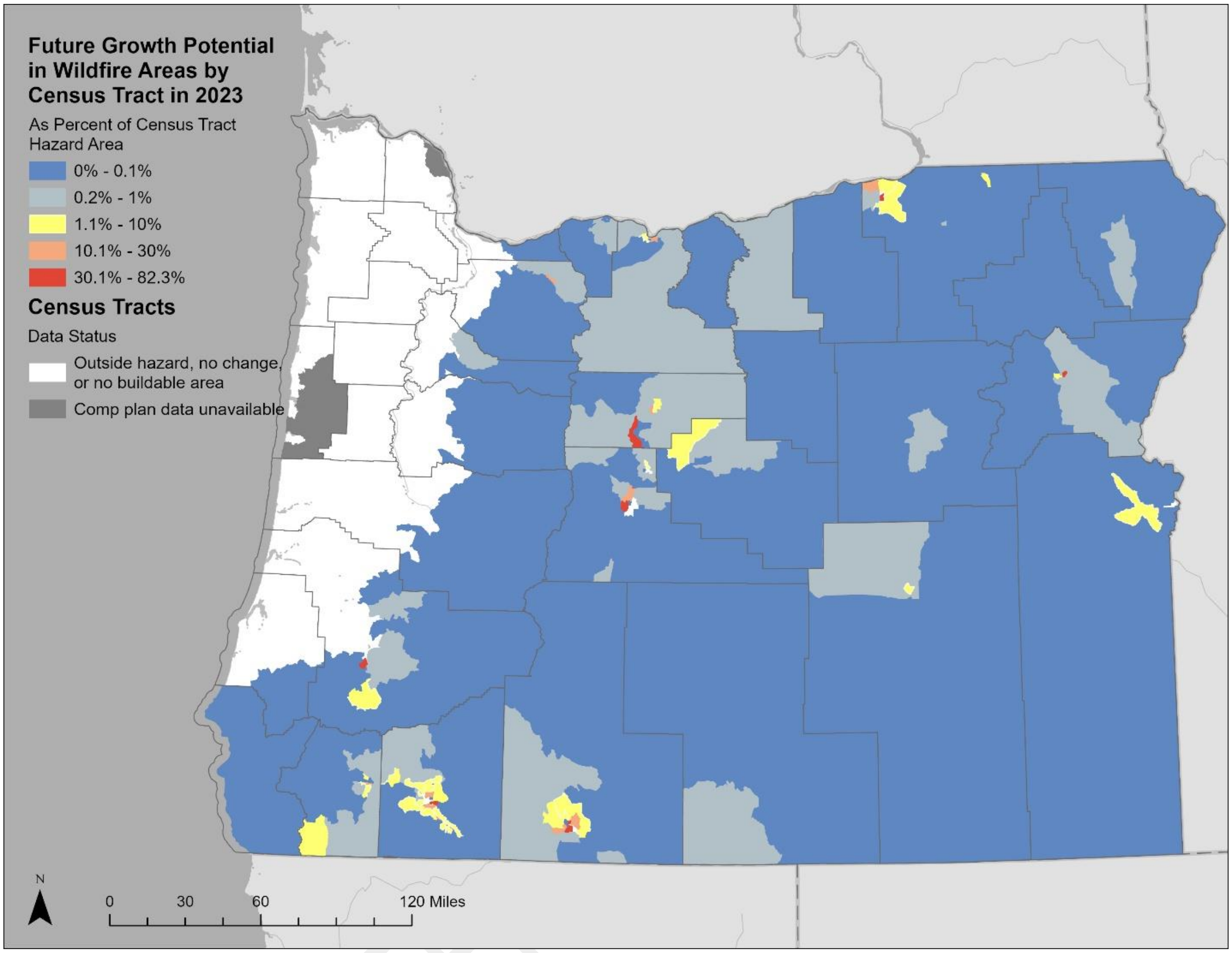
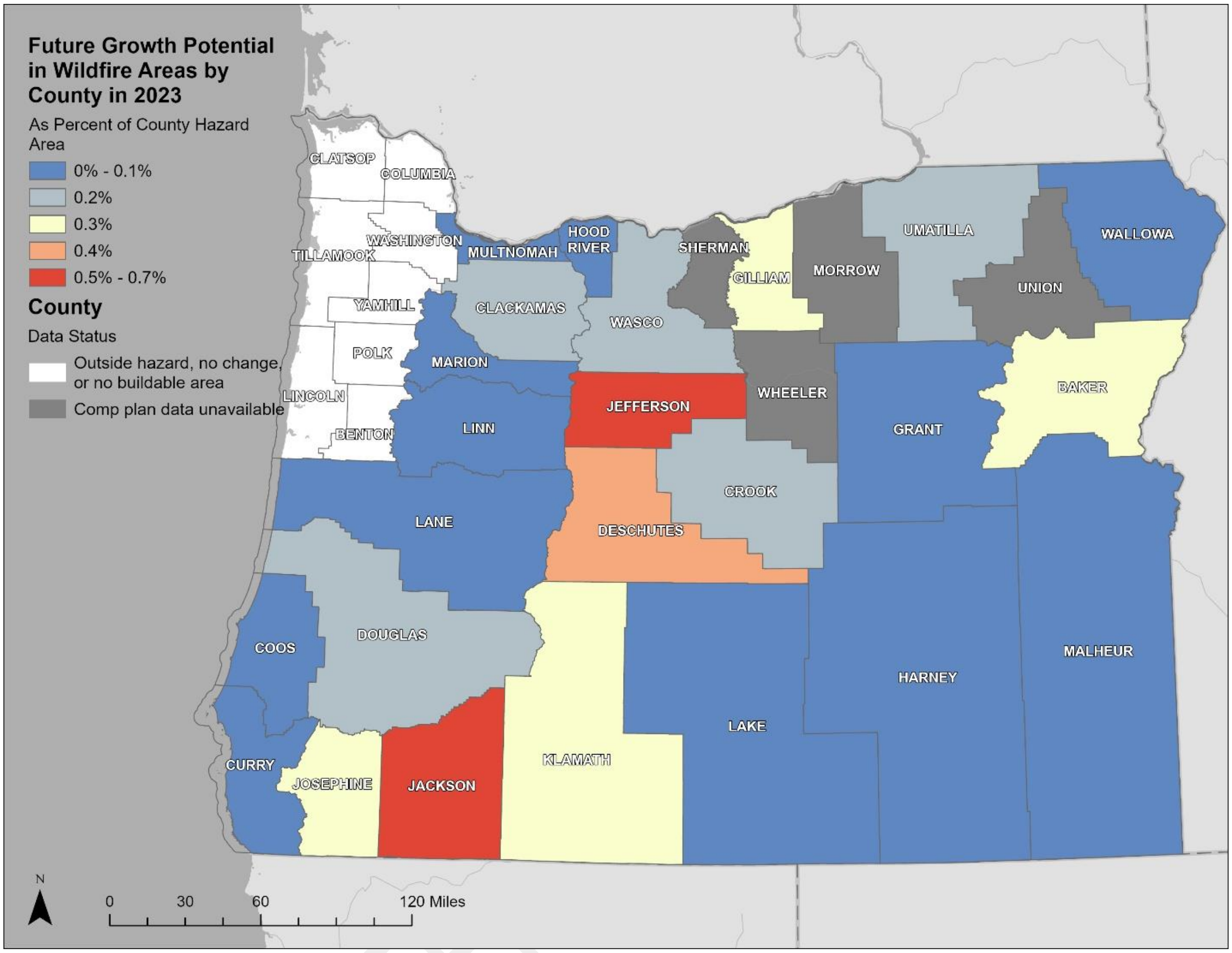


Figure 3.4.3-28: Future growth potential in wildfire areas by county



3.4.3.11 Windstorms

The changes in development analysis did not include areas at risk from windstorms because a windstorm hazard data set was not available.

3.4.3.12 Winter Storms

The changes in development analysis did not include areas at risk from winter storms because there is no comprehensive definition of winter storms that can be mapped.

3.4.4 Change in population demographics

In addition to physical changes in development, changes in population and population demographics can affect hazard vulnerability. Understanding whether population has increased or decreased in counties with certain vulnerabilities can help for understanding where to direct mitigation efforts. Understanding increases and decreases in social vulnerability can similarly help in understanding where vulnerabilities to hazards will be amplified for socially vulnerable groups.

The Social Vulnerability Index (SVI) is a measure used by the Centers for Disease Control and Prevention to identify and quantify communities experiencing social vulnerability. Overall vulnerability is calculated using 16 U.S. Census Variables that identify communities that may need support before, during, and after disasters. The CDC groups these variables into four themes – socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation. The table below shows the change in SVI index scores from the 2016 social vulnerability index to 2022. Both the absolute index score and the change should be considered in understanding changes in vulnerability. The 2016 SVI used 15 variables, including income. The 2022 SVI did not include income. The 2022 SVI included new variables for health insurance and housing cost. Scores in the table are based on a statewide comparison and range from 0 to 1.

Table 3.4.4-1 shows the overall change in population and change in SVI for counties in Oregon

Table 3.4.4-1: Population and Social Vulnerability Index by County

County	2020 Population	2023 Population	Population Change (2020-2023)	2016 SVI Index Score	2022 SVI Index Score	Change in SVI (2022 -2016)
Baker	16,090	16,796	4.4 percent	0.60	0.23	-0.37
Benton	92,168	96,359	4.5 percent	0.17	0.37	0.20
Clackamas	415,084	422,308	1.7 percent	0.06	0.11	0.06
Clatsop	39,656	41,343	4.3 percent	0.20	0.26	0.06
Columbia	52,117	53,178	2.0 percent	0.09	0.00	-0.09
Coos	64,175	64,832	1.0 percent	0.77	0.63	-0.14
Crook	23,733	25,651	8.1 percent	0.46	0.09	-0.37
Curry	22,889	23,463	2.5 percent	0.31	0.31	0.00
Deschutes	191,749	203,026	5.9 percent	0.00	0.03	0.03
Douglas	110,015	111,807	1.6 percent	0.69	0.34	-0.34
Gilliam	1,896	2,002	5.6 percent	0.23	0.29	0.06
Grant	7,174	7,238	0.9 percent	0.29	0.43	0.14
Harney	7,310	7,515	2.8 percent	0.74	0.74	0.00
Hood River	23,270	23,958	3.0 percent	0.40	0.71	0.31
Jackson	218,781	222,563	1.7 percent	0.71	0.57	-0.14
Jefferson	24,048	24,973	3.8 percent	0.94	0.97	0.03
Josephine	87,097	88,069	1.1 percent	0.63	0.77	0.14
Klamath	67,606	69,812	3.3 percent	0.91	0.86	-0.06
Lake	7,896	8,254	4.5 percent	0.83	0.83	0.00
Lane	377,749	382,628	1.3 percent	0.54	0.66	0.11
Lincoln	49,336	50,632	2.6 percent	0.37	0.60	0.23
Linn	127,216	129,794	2.0 percent	0.57	0.49	-0.09
Malheur	30,632	31,701	3.5 percent	1.00	1.00	0.00
Marion	343,742	346,532	0.8 percent	0.89	0.94	0.06
Morrow	11,425	12,249	7.2 percent	0.80	0.80	0.00

County	2020 Population	2023 Population	Population Change (2020-2023)	2016 SVI Index Score	2022 SVI Index Score	Change in SVI (2022 -2016)
Multnomah	809,869	803,863	-0.7 percent	0.43	0.51	0.09
Polk	84,730	88,553	4.5 percent	0.34	0.46	0.11
Sherman	1,686	1,908	13.2 percent	0.03	0.14	0.11
Tillamook	26,782	27,471	2.6 percent	0.49	0.40	-0.09
Umatilla	77,319	80,087	3.6 percent	0.97	0.91	-0.06
Union	26,502	26,192	-1.2 percent	0.51	0.54	0.03
Wallowa	7,065	7,532	6.6 percent	0.11	0.17	0.06
Wasco	26,274	26,603	1.3 percent	0.86	0.89	0.03
Washington	595,761	600,266	0.8 percent	0.14	0.20	0.06
Wheeler	1,417	1,434	1.2 percent	0.26	0.06	-0.20
Yamhill	106,087	108,122	1.9 percent	0.66	0.69	0.03

Source: U.S. Census Bureau American Community Survey 5- Year Estimates; Centers for Disease Control and Prevention (CDC) Social Vulnerability Index

Malheur County has the highest 2022 SVI score (1.0) and has had no change in SVI score between 2016 and 2022. Jefferson County (0.97) and Marion County (0.94) are the next highest. Both had an increase in SVI score from 2016 to 2022. Columbia County has the lowest SVI score of 0, which was a -0.9 change from 2016. Columbia is followed by Deschutes (0.03), Crook (0.09), and Wheeler (0.06) Counties. Deschutes had a slight increase between 2016 and 2022 while Crook and Wheeler had significant decreases.

The county with the highest increase in SVI between 2016 and 2022 is Hood River County (0.31 increase), followed by Lincoln County (0.23 increase) and Benton County (0.20 increase). The counties with the greatest decrease in SVI scores are Baker and Crook Counties (both 0.37 decrease) followed by Wheeler County (0.20 decrease).

Counties with a high social vulnerability index and high growth rate may have higher risk and need more hazard mitigation. The counties with SVI over 0.8 with over 3 percent in population growth are shown in Table 3.4.4-2

Table 3.4.4-2: High SVI counties with high population growth (over 3 percent population growth in counties with over 0.8 SVI score)

County	2022 SVI Index Score	Population Growth 2020-2023
Malheur	1.00	3.5 percent
Jefferson	0.97	3.8 percent
Umatilla	0.91	3.6 percent
Klamath	0.86	3.3 percent
Lake	0.83	4.5 percent
Morrow	0.80	7.2 percent

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