



City of Cottage Grove

NATURAL HAZARDS MITIGATION PLAN

APPENDICES

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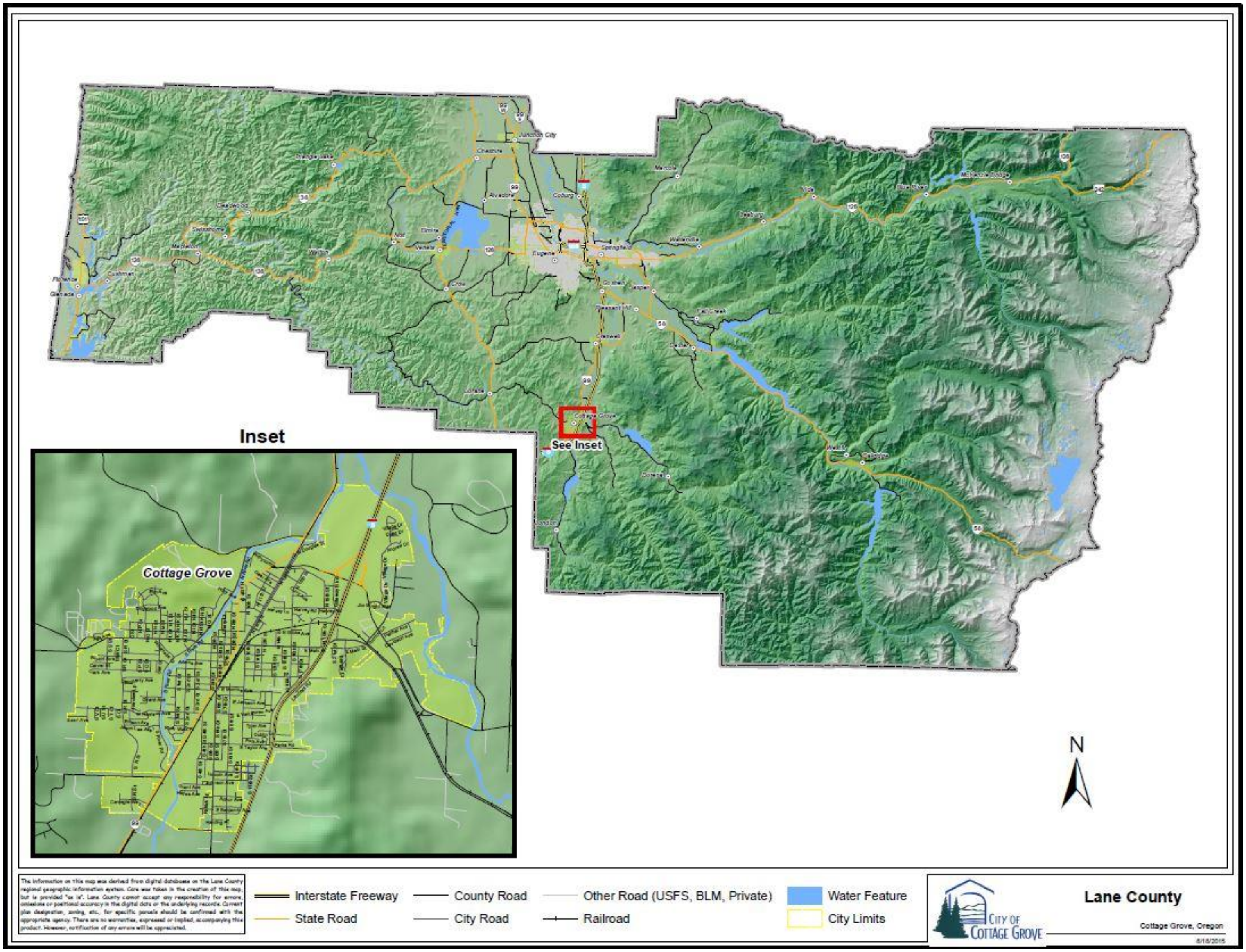

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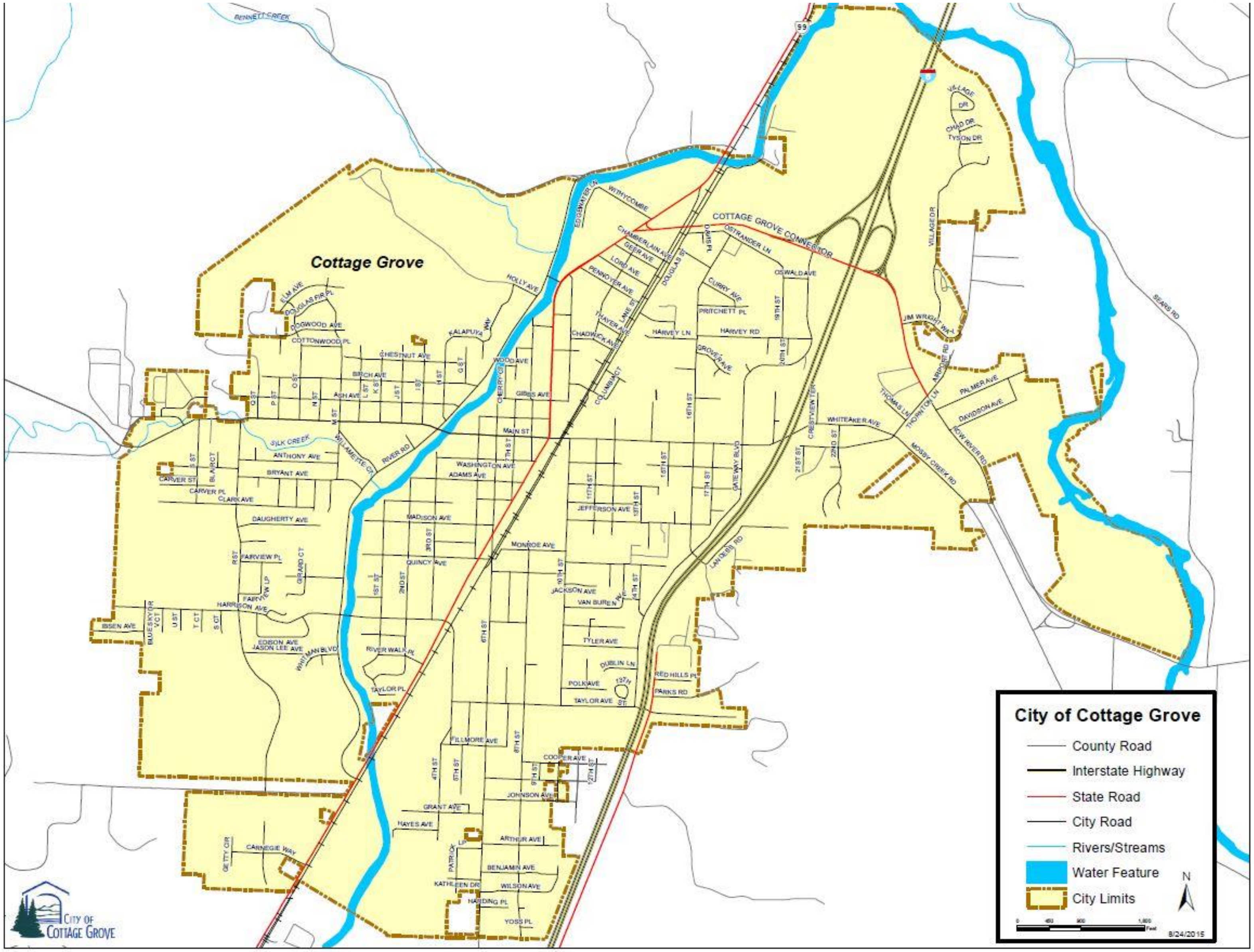

Figure 3. Flood Hazard Map of Cottage Grove (Plate 7, DOGAMI 2023)

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www.oregongeology.org

Flood Hazard Map of Cottage Grove, Oregon

PLATE 7

Flood Hazard Zone

100-Year Flood (1% annual chance)

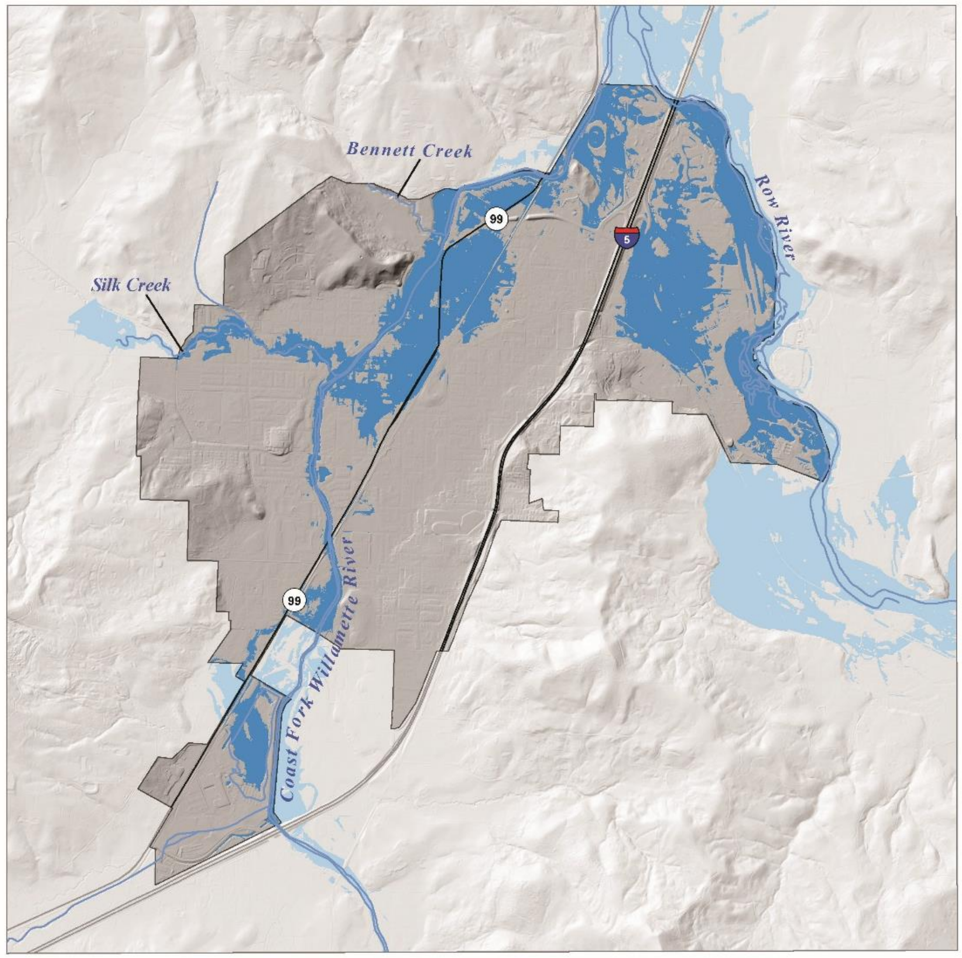
The flood hazard data show areas expected to be inundated during a 100-year flood event. Flooding sources include riverine. Areas are consistent with the regulatory flood zones depicted in Lane County's Digital Flood Insurance Rate Maps.

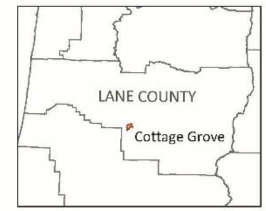
Map Elements

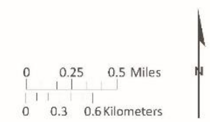
Cottage Grove Urban Growth Boundary

Streams

Major Roads







Community	Flood Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilites	Loss Estimate ($)	Loss Ratio
Cottage Grove	1,188	11%	451	0	6,851,000	0.4%

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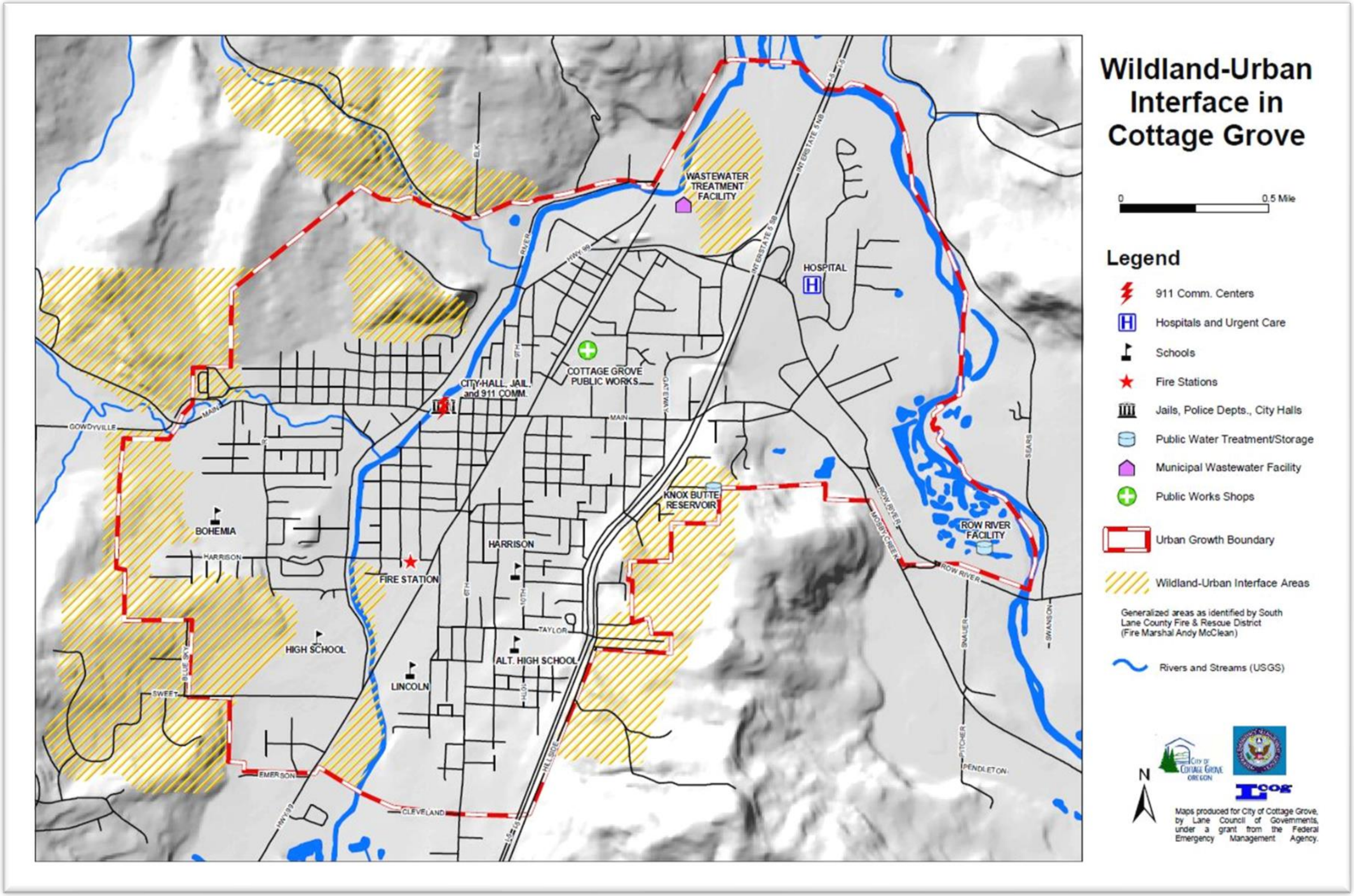
Data Sources:
Flood hazard zone (100-year): Lane County Flood Insurance Rate Map - Draft (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

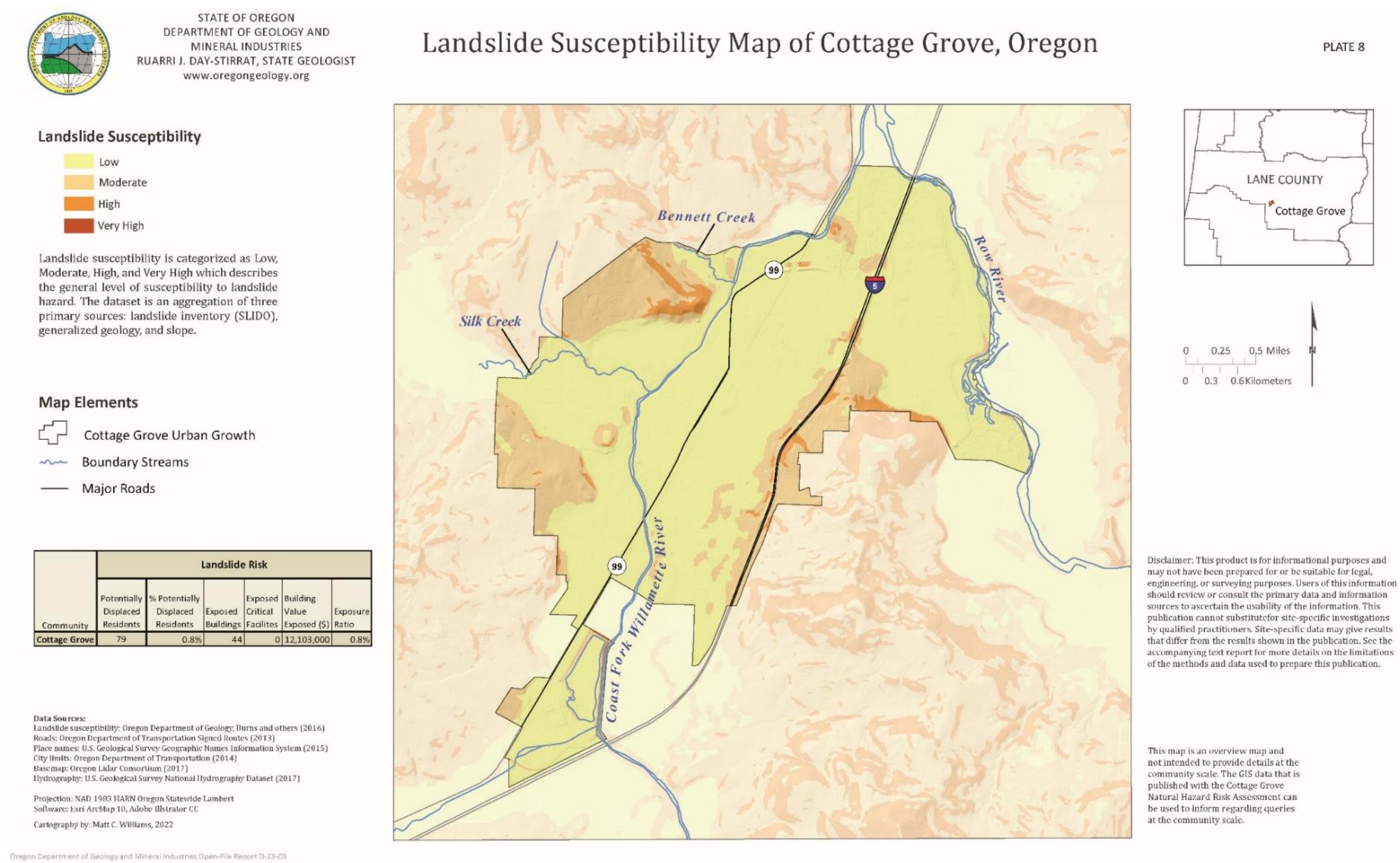
This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Cottage Grove Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Figure 4. Wildland-Urban Interface in Cottage Grove



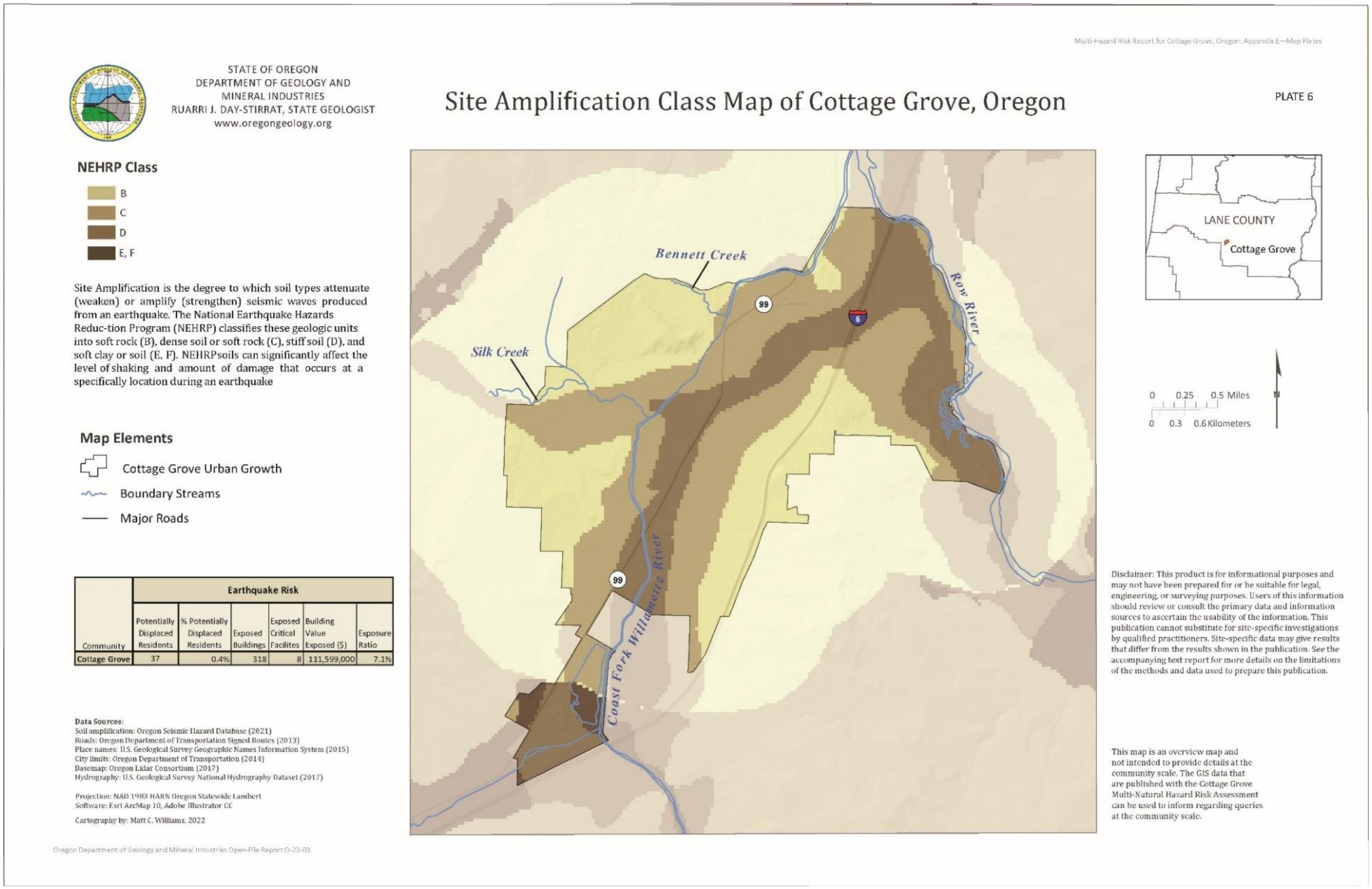
(2017 NHMP update)

Figure 5. Landslide Susceptibility Map of Cottage Grove



(Plate 8, DOGAMI 2023)

Figure 6. Seismic Wave Site Amplification Map of Cottage Grove



Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

(Plate 6, DOGAMI 2023)

Figure 7. Cascadia Subduction Earthquake Shaking Map of Cottage Grove

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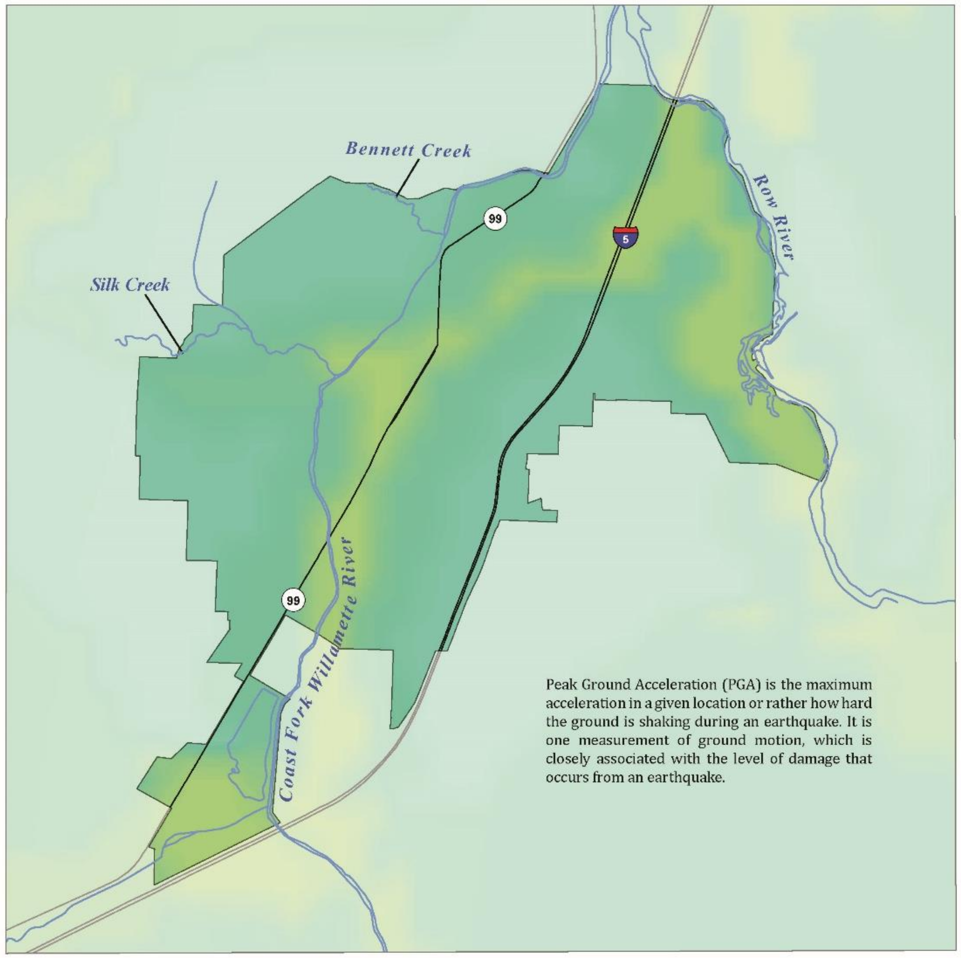
Cascadia Subduction Earthquake Shaking Map of Cottage Grove, Oregon

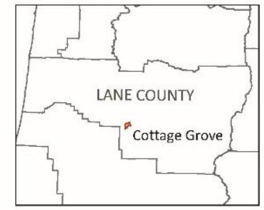
PLATE 3

Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215 - 0.401
VIII	Severe	Mod./Heavy	0.401 - 0.747
IX	Violent	Heavy	0.747 - 1.39
X	Extreme	Very Heavy	> 1.39

Map Elements

Cottage Grove Urban Growth Boundary
Streams
Major Roads





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

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Data Sources:
Earthquake peak ground acceleration: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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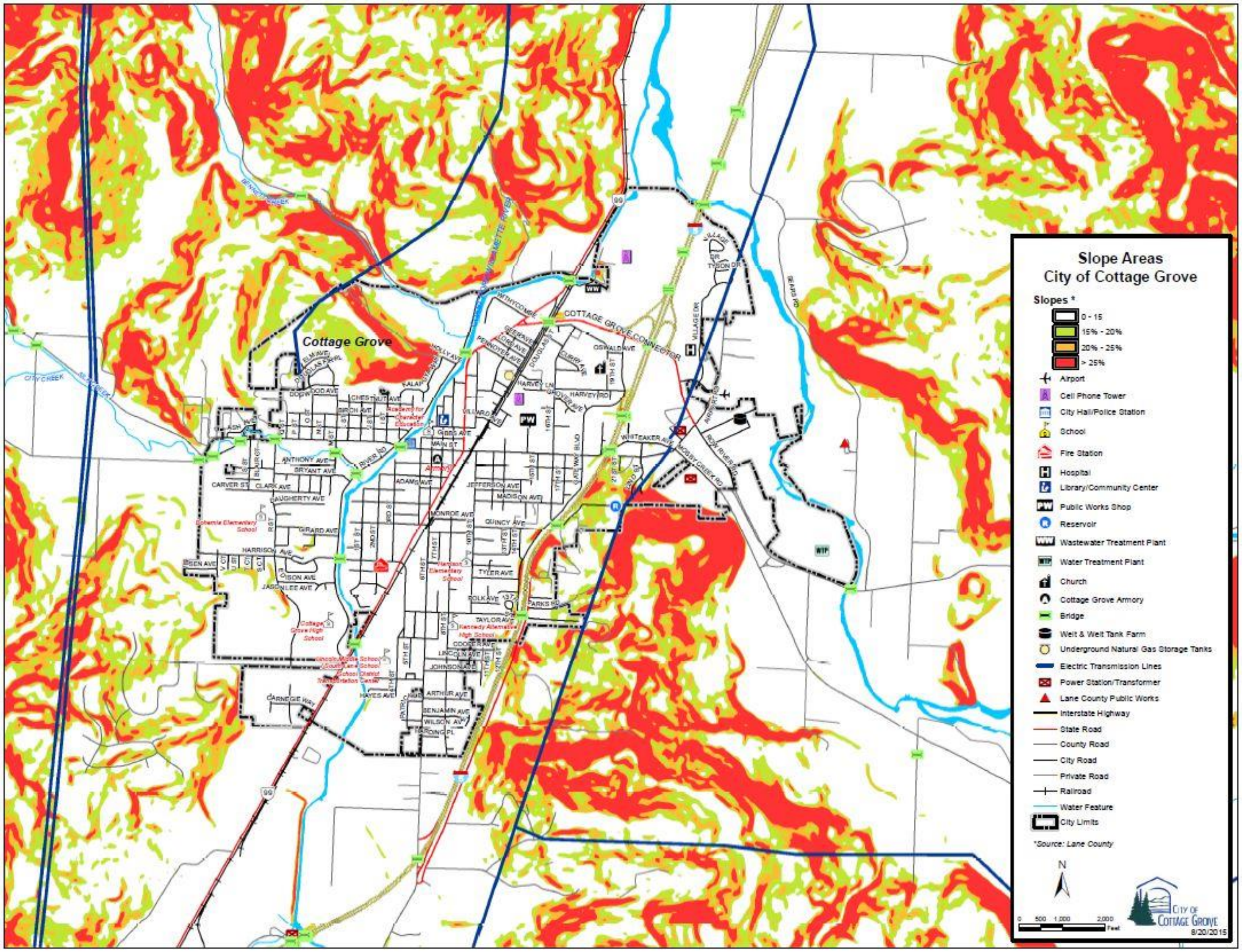
Oregon Department of Geology and Mineral Industries Open-File Report O-23-03

Figure 8: Slope Areas (2017 NHMP update)



Appendix B: Critical Facilities

Table 1. City of Cottage Grove Critical Facilities

Critical Facilities by Community	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
	Exposed	>50% Prob.	Exposed	Exposed
Bohemia School	-	X	-	-
Cottage Grove City Hall	-	X	-	-
Cottage Grove High School	-	X	-	-
Cottage Grove Sewage Treatment	-	X	-	-
Cottage Grove State Airport	-	X	-	-
Harrison Elementary School	-	X	-	-
Lane Community College	-	-	-	-
Lincoln Middle School	-	X	-	-
Peach Health Cottage Grove Community Hospital	-	X	-	-
South Lane Fire and Rescue	-	-	-	-

Source: DOGAMI Open File O-23-03 (Table A-2) Multi-hazard Risk Assessment for Cottage Grove, 2023.

The prior NHMP update contained the following table that assesses exposure of critical infrastructure and key facilities based on land area impacted. It has been retained in the 2023 Cottage Grove NHMP update.

NHMP Critical Infrastructure and Key Facilities (% Land Area Impacted)	Flood (5%)	Landslide (<1%)	Earthquake (100%)	Winter Storm (100%)	Wildfire (20%)	Volcano (<1%)	Drought (100%)
Critical Facilities							
Cottage Grove City Hall	X		X	X			
Cottage Grove Police Department (911 Call Center and Dispatch), City Jail	X		X	X			
Cottage Grove Community Hospital	X		X	X			
City of Cottage Grove Public Works Shops (EOC #2)	X		X	X			
Water Treatment Facility (Row River)	X		X	X			X
Waste Water Treatment Plant	X		X	X	X		
South Lane County Fire and Rescue Fire Station #1	X		X	X			
Cottage Grove Schools	X		X	X			
Cottage Grove High School			X	X			
Our Lady of Perpetual Help Catholic Church (Red Cross Shelter)	X		X	X			
Knox Butte Reservoir		X	X	X	X		
Downtown Historical District			X				
Cottage Grove Lake Dam	X	X	X		X		X
Dorena Reservoir Dam	X	X	X		X		X

NHMP Critical Infrastructure and Key Facilities (% Land Area Impacted)	Flood (5%)	Landslide (<1%)	Earthquake (100%)	Winter Storm (100%)	Wildfire (20%)	Volcano (<1%)	Drought (100%)
Key Infrastructure							
Telephone Lines	X	X	X	X	X		
Wastewater Collection System	X		X	X			
Stormwater Collection System	X		X	X			
Cell Phone Towers	X		X	X			
Roads	X	X	X	X			
Cottage Grove State Airport	X		X	X	X		
NW Natural Gas Lines	X		X				
Overhead Power Lines	X	X	X	X	X		
Transportation Networks	X	X	X	X	X		
Bridges	X		X	X	X		
Central Oregon & Pacific Railroad Lines	X		X	X	X		
Water Treatment, Storage, and Distribution Lines	X		X	X			

Source: 2017 Cottage Grove NHMP

Figure 9: Cottage Grove Critical Facilities

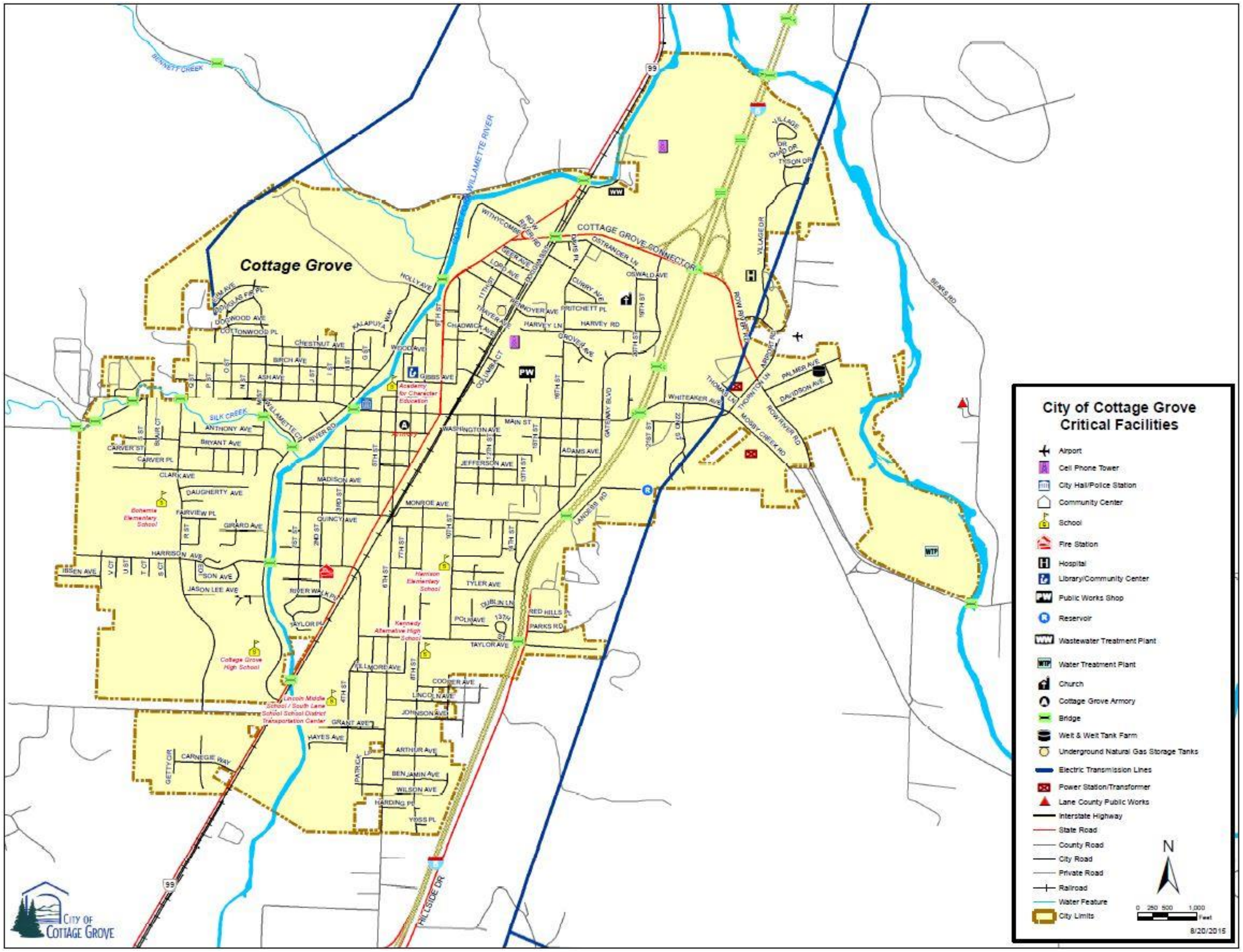
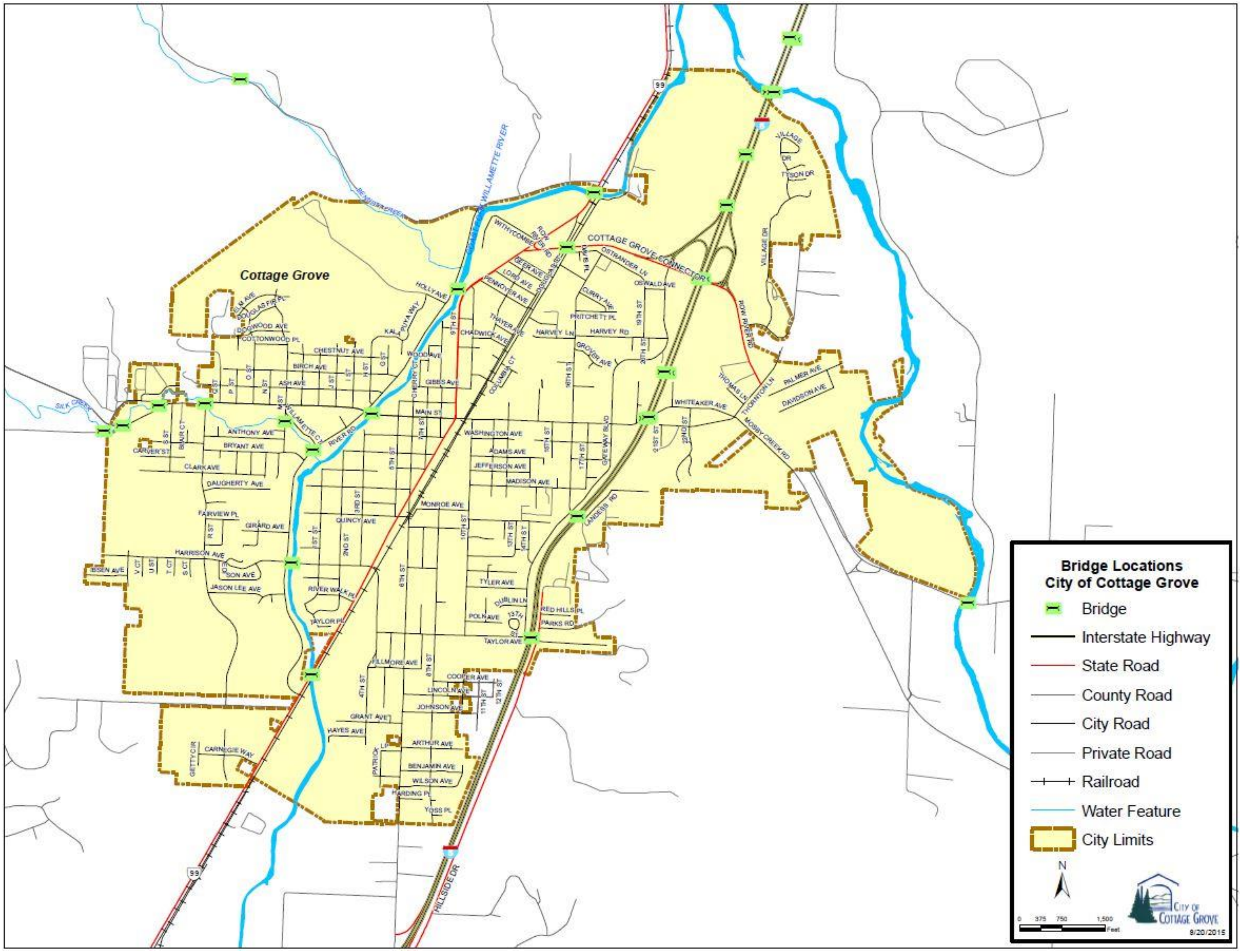


Figure 10: Cottage Grove Bridge Locations



Appendix C: DOGAMI Multi-hazard Risk Assessment

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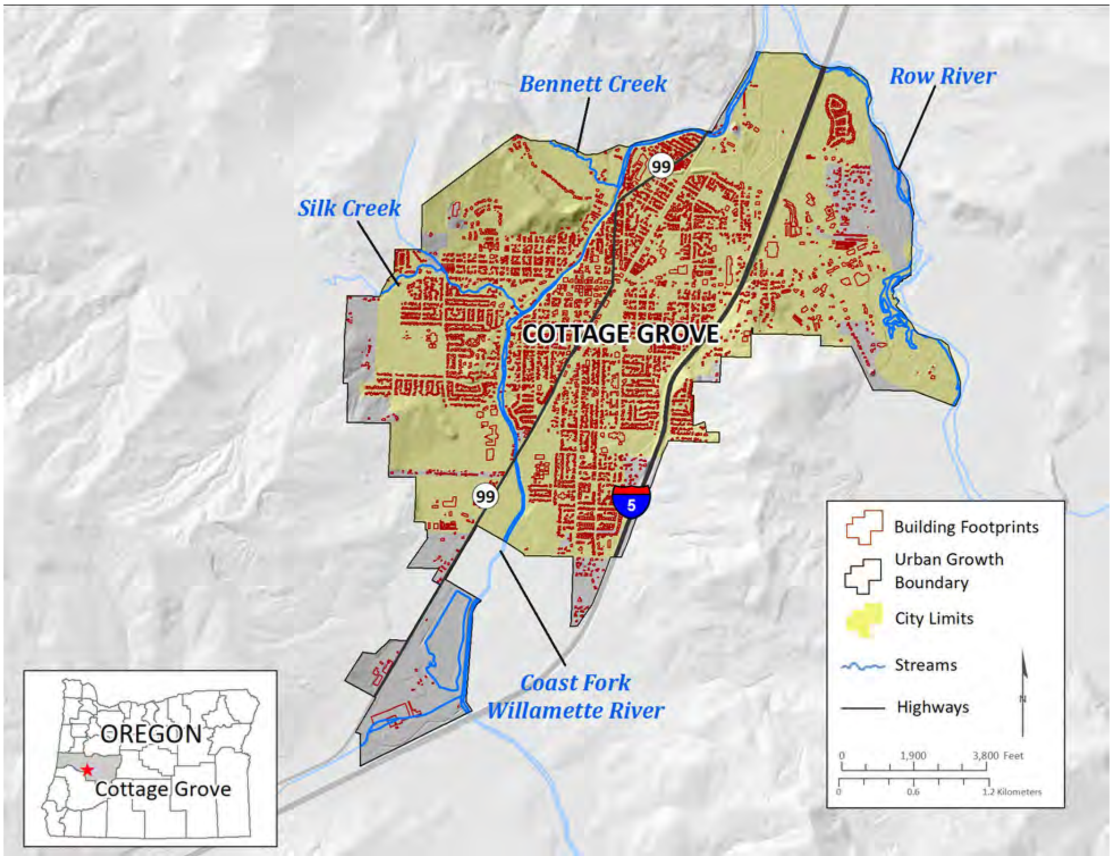
OPEN-FILE REPORT O-23-03

MULTI-HAZARD RISK REPORT FOR THE CITY OF COTTAGE GROVE, OREGON



by Matt C. Williams[1] and Nancy C. Calhoun[1]

2023

[1]Oregon Department of Geology and Mineral Industries, 800 NE Oregon Street, Suite 965, Portland, OR 97232

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Cover image: Study area of the Cottage Grove Risk Report. Map depicts Cottage Grove, Oregon and urban growth bourndary areas included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of multi-hazard risk assessment for the City of Cottage Grove, Oregon. The risk assessment can help a community better plan for disaster.

Oregon Department of Geology and Mineral Industries Open-File Report O-23-03
Published in conformance with ORS 516.030

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Appendix E

GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.7 format. Metadata is embedded in the geodatabase and is also provided as separate .xml format files.

Cottage_Grove_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

- Building_footprints (polygons)
- Communities (polygons)
- UDF_points (points)

Metadata in .xml file format:

Each dataset listed above has an associated, standalone .xml file containing metadata in the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata format

EXECUTIVE SUMMARY

This report was prepared for the City of Cottage Grove, Oregon, with funding provided by the Oregon Department of Land Conservation and Development (DLCD). It describes the methods and results of the natural hazard risk assessment performed in 2022 by the Oregon Department of Geology and Mineral Industries (DOGAMI). The purpose of this project is to provide the City of Cottage Grove with a detailed risk assessment information to enable them to compare hazards and act to reduce their risk. The risk assessment results quantify the impact of natural hazards to this community and enhance the decision-making process in planning for disaster.

We arrived at our findings and conclusions by completing three main tasks: compiling an asset database, identifying and using the best available hazard data, and performing natural hazard risk assessment.

- In the first task, we created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, FEMA Hazus®-MH general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. With these data we were able to represent accurate spatial locations and vulnerabilities on a building-by-building basis.
- The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI and were produced using high-resolution lidar topographic data. Each hazard dataset was the best available at the time of writing.
- In the third task, we analyzed risk using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using the Hazus-MH methodology, and (2) calculated the number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides and wildfire.

We performed this assessment using the best data available at the time of the study. However, it is important to note that some of the datasets used in this study will likely be updated and replaced within the next three years. The landslide hazard maps as well as the geohazard maps that inform the earthquake model are several decades old and not based on lidar topography. The flood dataset used was the draft FEMA flood depth maps produced in 2022. Changes to any of the datasets in the coming years will need to be incorporated into future, more accurate risk assessments.

The findings and conclusions of this report show the potential impacts of hazards in the City of Cottage Grove. An earthquake can cause widespread damage and losses throughout the community. Hazus-MH earthquake simulations illustrate the potential reduction in earthquake damage through seismic retrofits. Our findings also indicate that many of the critical facilities in the study area that were built before seismic building code standards are at high risk from earthquake hazard. Areas along much of the Coast Fork Willamette River are at risk from flooding. Our analysis shows that new landslide mapping based on improved methods and lidar information will increase the accuracy of mapping. Wildfire risk is low for the study area, but moderate and high wildfire hazard areas are present to the east and south. We also found that the 100-year flood poses the greatest potential of population displacement compared to other hazard scenarios analyzed in this study.

The information presented in this report is designed to increase awareness of natural hazard risk, to support public outreach efforts, and to aid local decision-makers in developing comprehensive plans and natural hazard mitigation plans. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. The results of this study are designed to be used to help communities identify and prioritize mitigation actions that will improve community resilience.

Selected Cottage Grove Results
Total buildings: 5,776
Total estimated building value: $1.56 billion

Cascadia Subduction Zone (CSZ) Magnitude (Mw) 9.0 Earthquake	**100-year Flood (2022 FEMA draft data)**
Red-tagged buildings[a]: 28 Yellow-tagged buildings[b]: 290 Loss estimate: $112 million	Number of buildings damaged: 451 Loss estimate: $6.9 million
Landslide (High and Very High-Susceptibility)	**Wildfire (High Risk):**
Number of buildings exposed: 44 Exposed building value: $12 million	Number of buildings exposed: 0 Exposed building value: $0

[a]Red-tagged buildings are considered uninhabitable due to complete damage
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage

1.0 INTRODUCTION

Key Terms:

- *Vulnerability:* Characteristics that make people or assets more susceptible to a natural hazard.
- *Risk:* Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard.

A *natural hazard* is an environmental phenomenon that can negatively impact humans, and risk is the likelihood that a hazard will result in harm. A natural hazard risk assessment analyzes and quantifies how different types of hazards could affect the built environment, population, the cost of recovery, and identifies potential risk. Risk assessments provide the basis for developing mitigation plans, strategies, and actions, so that steps can be taken to prepare for a potential hazard event.

This report is a multi-hazard risk assessment analyzing individual buildings and resident population in the City of Cottage Grove, Oregon. Cottage Grove is situated at the southern extent of the Willamette Valley between the Oregon Coast Range and the Cascade Mountains. The city is subject to many natural hazards, including earthquake, riverine flooding, landslides, and wildfire. This report provides a detailed and comprehensive analysis of these natural hazards and provides a comparative perspective not previously available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to the community.

1.1 Purpose

The purpose of this project is to help the City of Cottage Grove better understand their risk and increase resilience to earthquakes (including liquefaction and site amplification), riverine flooding, landslides, and wildfire natural hazards that are present in their communities. This is accomplished by the best available, most accurate, and detailed information about these hazards to assess the number of people and buildings at risk.

The main objectives of this study are to:

- compile and/or create a database of critical facilities, tax assessor data, buildings, and population distribution data,
- incorporate and use existing data from previous geologic, hydrologic, and wildfire hazard studies,
- perform exposure and Hazus–based risk analysis, and
- share this report widely so that all interested parties have access to its information and data.

The body of this report describes our methods and results. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to analyze risk. Results for each hazard type are reported on a study area basis within each hazard section, and community-based results are reported in detail in **Appendix A**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size citywide hazard maps. These appendices can be helpful in clarifying the summarized results in each hazard section.

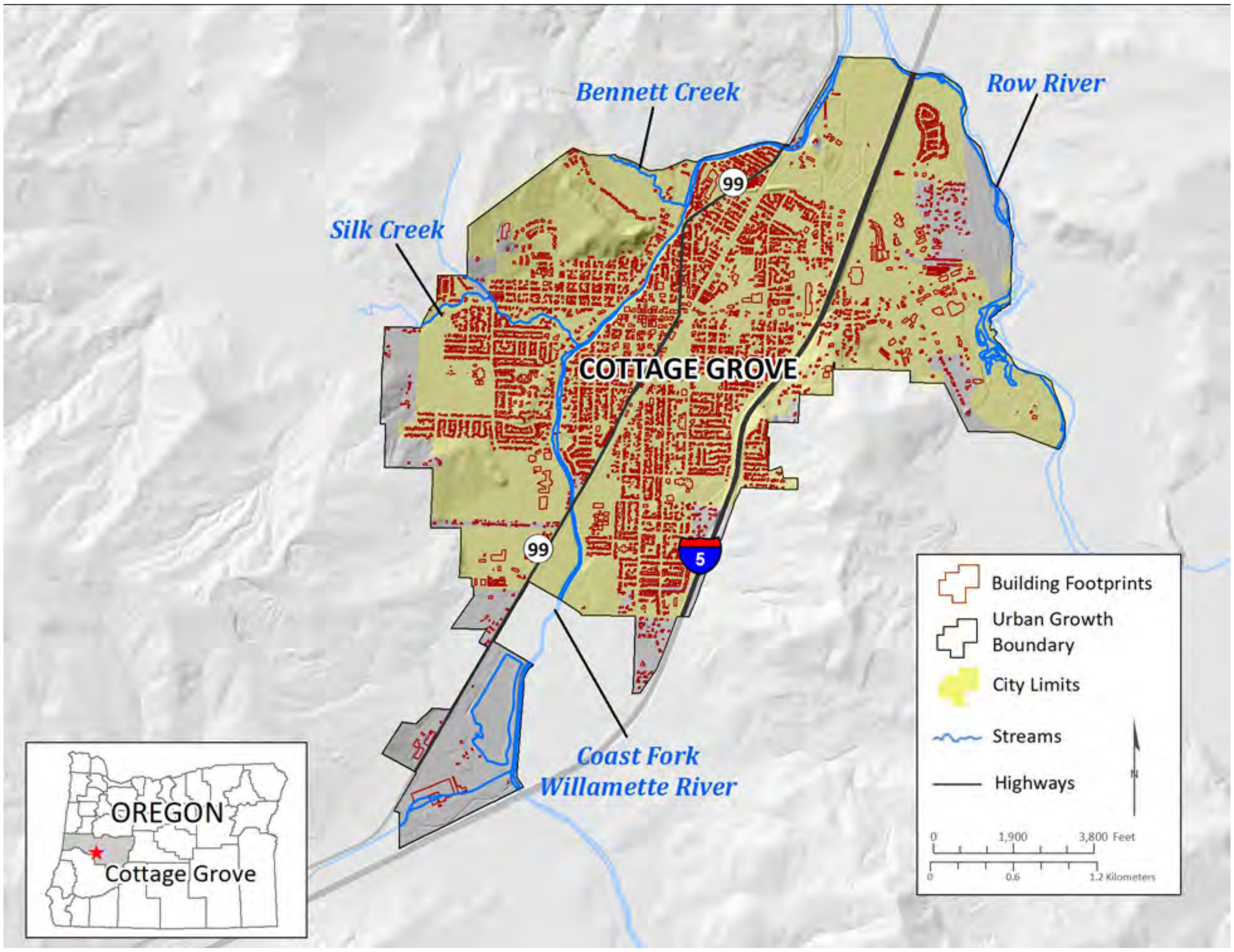
1.2 Study Area

The study area for this project includes the entire incorporated jurisdiction of Cottage Grove, Oregon and expanded to include the urban growth boundary (UGB) (**Figure 1-1**). Cottage Grove is located in Lane County in the central-western part of the state, south of Eugene, Oregon along Interstate 5. The study area covers approximately 5 square miles (13 square kilometers).

Cottage Grove is located at the confluence of the Coast Fork Willamette River and the Row River which is considered the southernmost extent of the Willamette Valley (**Figure 1-1**). At approximately 650 feet (198 meters) Cottage Grove is at a transition zone between the gentler terrain of the valley and the rugged terrain of the mountains. Additional streams within Cottage Grove are Silk Creek and Bennett Creek.

The population of the study area is approximately 10,000 based on an estimated population in 2020 from the Portland State University (PSU) Population Research Center https://www.pdx.edu/population-research/population-estimate-reports. Most of the residents in the study area reside within the city limits (9,500) and the remaining residents live within the urban growth boundary (500).

Figure 1-1. Study area: Cottage Grove, Oregon.



1.3 Project Scope

For this risk assessment, we limited the project scope to natural hazard impacts on buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, or the environment. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler methodology, in which buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), city and county population numbers from the 2010 U.S. Census data (U.S. Census Bureau, 2010a) was used to distribute people into residential structures on a census block basis. Permanent resident counts were then adjusted on a citywide basis to current estimates from the PSU Population Research Center (https://www.pdx.edu/population-research/sites/g/files/znldhr3261/files/2022-04/2021%20Annual%20Population%20Report%20Tables.pdf).

A critical component of this risk assessment is a citywide building inventory developed from building footprint data and the Lane County tax assessor database (acquired 2022). The other key component is a suite of datasets that represent the currently best available science for a variety of natural hazards. The geologic hazard scenarios were selected by DOGAMI staff based on their expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The Oregon Department of Forestry (ODF) provided recommendations on the use of wildfire datasets for risk analysis. The following is a list of the natural hazards and the risk assessment methodologies that were applied. See **Table 1-1** for data sources.

Earthquake Risk Assessment

- Hazus-MH loss estimation from a CSZ earthquake magnitude (Mw) 9.0 event. Includes earthquake induced or "coseismic" liquefaction, soil amplification class, and landslides

Flood Risk Assessment

- Hazus-MH loss estimation to four recurrence intervals (10%, 2%, 1%, and 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (low to very high)

Wildfire Risk Assessment

- Exposure based on Fire Risk Index (low to high)

Table 1-1. Hazard data sources for Cottage Grove.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake	CSZ Mw 9.0	Statewide	DOGAMI OSHD 1.0 (Madin and others, 2021)
-Coseismic landslide	Susceptibility – wet (3-10 hazard classes)	″	″
-Coseismic liquefaction	Susceptibility (1-5 classes)	″	″
-Coseismic soil amplification class	National Earthquake Hazards Reduction Program (A-F classes)	″	″
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	FEMA – draft data generated for 2022 Lane County National Flood Insurance Program mapping
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI O-16-02 (Burns and others, 2016)
Wildfire	Risk (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Gilbertson-Day and others, 2018)

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.3.1 or the report by Burns and others (2016) for more information.

1.4 Previous Studies

One previous risk assessment has been conducted that included the study area by DOGAMI. Wang (1998) used Hazus-MH to estimate the impact from a Mw 8.5 Cascade Subduction Zone (CSZ) earthquake scenario on the state of Oregon. The results of this study were arranged into individual counties. Lane County was estimated to experience 5.5% loss ratio in the Mw 8.5 CSZ scenario, due to its proximity to the earthquake source.

We did not compare the results of this project with the results of these previous studies, because the previous Wang (1998) study utilized a much lower level of detailed building information and site-specific earthquake hazard inputs. Additionally, this study analyzed a different earthquake scenario from the previous studies. Comparative analysis was not part of the scope of this project.

2.0 METHODS

We used a quantitative approach to assess the level of risk of buildings and people from natural hazards. The two modes of analysis were Hazus-MH loss estimation and exposure analysis.

2.1 Hazus-MH Loss Estimation

According to FEMA (FEMA, 2012a, p. 1), "Hazus provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis. Hazus can be used to conduct loss estimation for floods and earthquakes […]. The multi-hazard Hazus is intended for use by local, state, and regional officials and consultants to assist mitigation planning and emergency response and recovery preparedness. For some hazards, Hazus can also be used to prepare real-time estimates of damages during or following a disaster."

Key Terms:

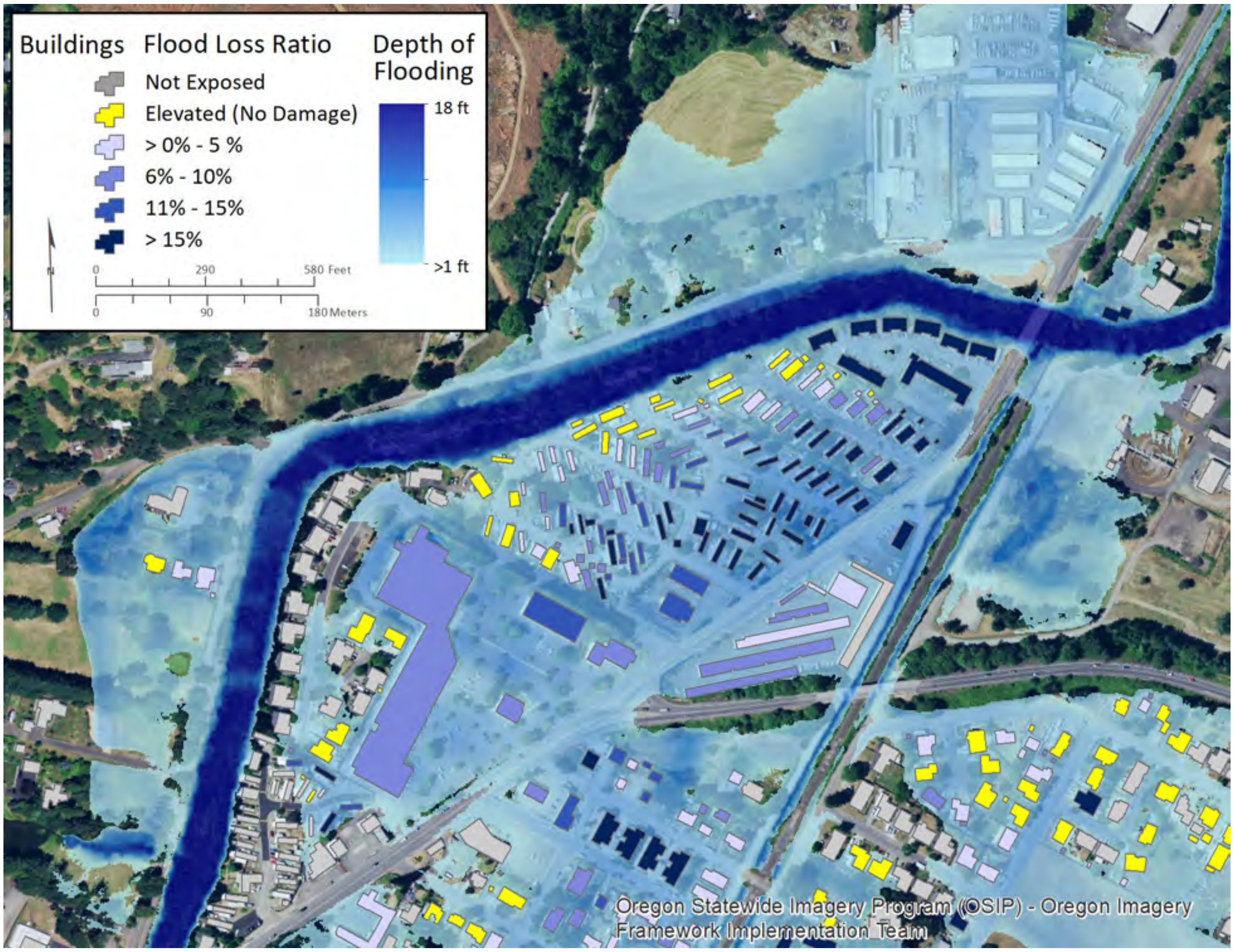
- *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology. This is measured as the cost to repair or replace the damaged building in US dollars.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

Hazus-MH can be used in different modes depending on the level of detail required. Given the high spatial precision of the building inventory data and quality of the natural hazard data available for this study, we chose the user-defined facility (UDF) mode. This mode makes loss estimates for individual buildings relative to their "cost," which we then aggregate to the community level to report loss ratios. Cost used in this mode are associated with rebuilding using new materials, also known as replacement cost. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building area (in square feet) by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus-MH database.

Damage functions are at the core of Hazus-MH. The damage functions stored within the Hazus-MH data model were developed and calibrated from the observed results of past disasters. Estimates of loss are made by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity and building characteristics. **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis.

We used Hazus-MH version 5.0, which was the latest version available when we began this risk assessment.

Figure 2-1. 100-year flood zone and building loss estimates example in City of Cottage Grove, Oregon.



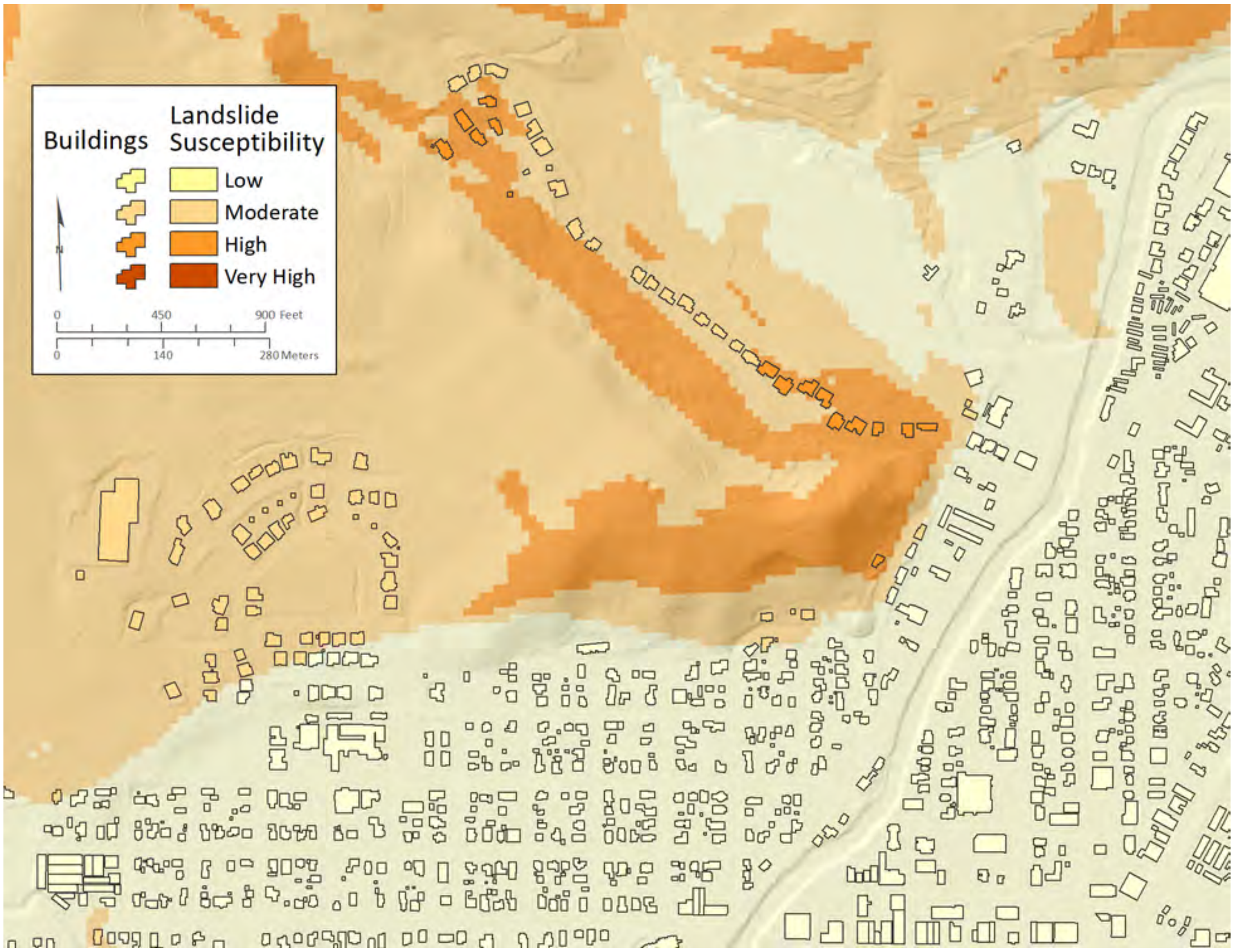
2.2 Exposure

> ***Key Terms:***
> - *Exposure:* Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.
> - *Building value:* Total monetary value of a building. This term is used in the context of exposure.

Since loss estimation using Hazus-MH is not available for all types of hazards, we used exposure analysis to assess the level risk for Cottage Grove for landslide and wildfire hazards. Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative to the more detailed loss estimation method for those natural hazards that do not have available damage models like in Hazus. It provides a way to easily quantify what is and what is not threatened. Exposure results are communicated in terms of total building value exposed, rather than a loss estimate. For example, **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility.

Exposure is used for landslides and wildfires. For comparison with loss estimates, exposure is also used for the 1% annual chance flood, that is a flood that has a 1% chance of occurrence in any given year.

Figure 2-2. Landslide susceptibility areas and building exposure example in Cottage Grove, Oregon.

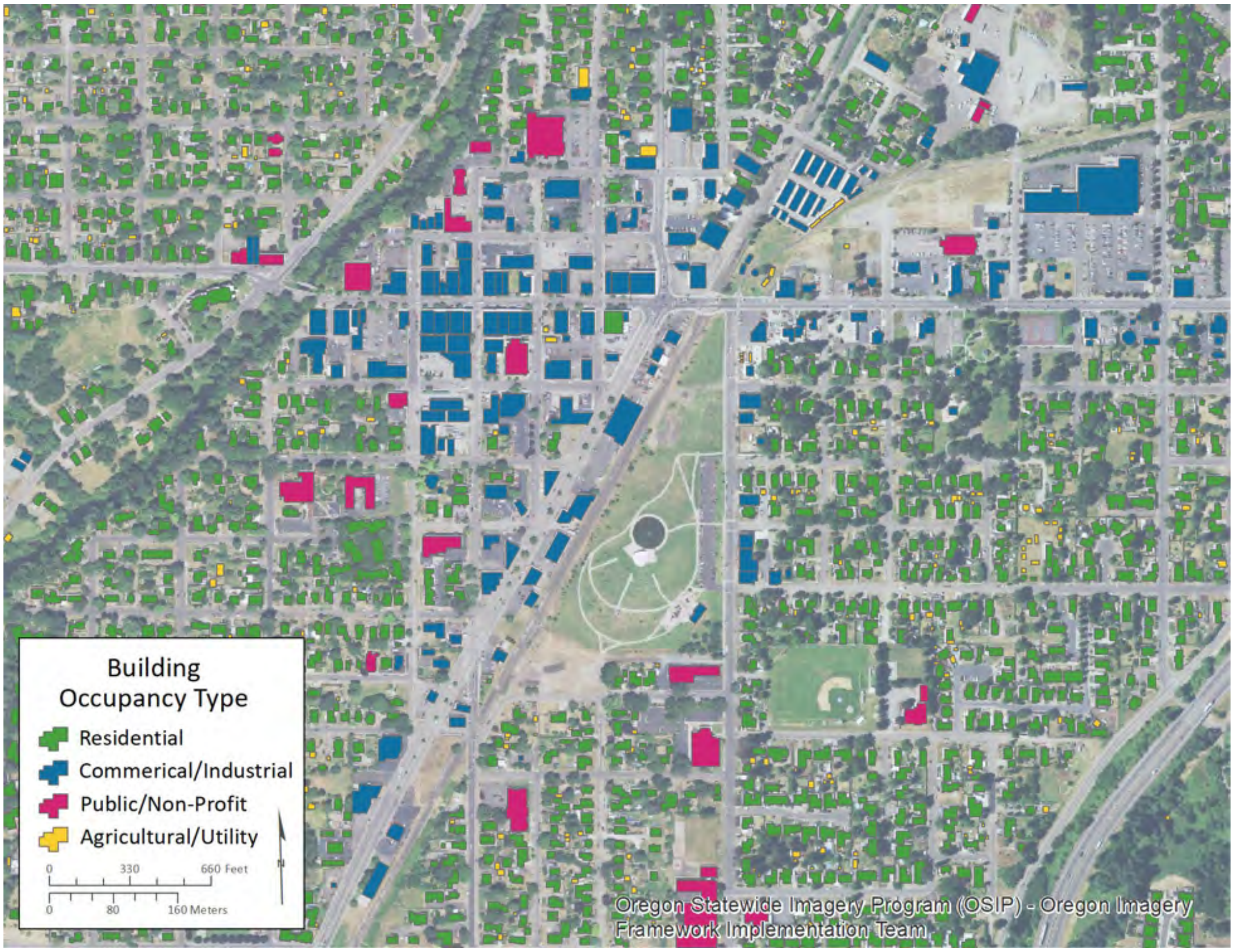


2.3 Building Inventory

A key piece of the risk assessment is the building inventory. This inventory consists of all buildings larger than 100 square feet (9.3 square meters), as determined from existing building footprints (Williams, 2021). A variety of building inventory occupancy types used in the Hazus-MH and exposure analyses are present in Cottage Grove (**Figure 2-3**). See also **Appendix B** Table B-1, and **Appendix E**, Plate 1 and Plate 2.

To use the building inventory within the Hazus-MH methodology, we converted the building footprints to points and migrated them into a UDF database with standardized field names and attribute domains. The UDF database formatting allows for the correct damage function to be applied to each building. Hazus-MH version 2.1 technical manuals (FEMA, 2012a, 2012b, 2012c) provide references for acceptable field names, field types, and attributes. The fields and attributes used in the UDF database (including building seismic codes) are discussed in more detail in Appendix **C.2.2**.

Figure 2-3. Building occupancy types, City of Cottage Grove, Oregon.



The building count and value of the City of Cottage Grove is 5,776 buildings and $1.56 billion of building value (**Table 2-1**). A table detailing the occupancy class distribution is included in **Appendix B: Detailed Risk Assessment Tables**.

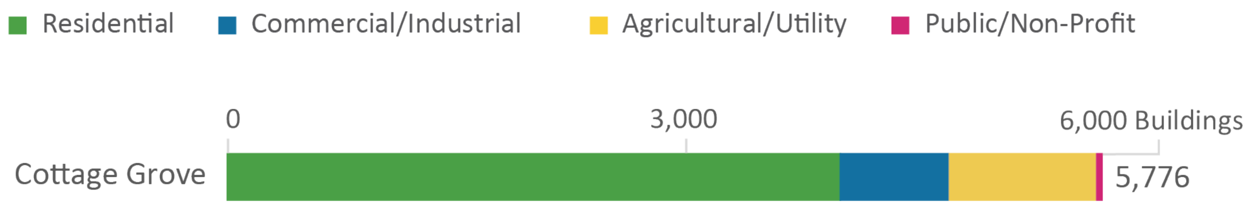
Table 2-1. Cottage Grove building inventory.

Community	Total Number of Buildings	Estimated Total Building Value ($)
Cottage Grove	5,776	1,561,735,000

The building inventory was developed from a building footprint dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021), which covers all of Cottage Grove. The building footprints provide a location and 2D outline of a structure. The total number of buildings within the study area was 5,776.

Lane County supplied assessor data and we formatted it for use in the risk assessment. The assessor data contains an array of information about each building (i.e., improvement). Tax lot data, which contains property boundaries and other information about the property, was obtained from the county assessor and was used to link the buildings with assessor data. The linkage between the two datasets resulted in a database of UDF points that contain attributes for each building. These points are used in the risk assessment for both loss estimation and exposure analysis. The building occupancy composition is primarily residential and some commercial (**Figure 2-4**).

Figure 2-4. Building count in Cottage Grove by occupancy class.



Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. We embedded identifying characteristics into the critical facilities in the UDF database so they could be highlighted in the results. Critical facilities data came from the DOGAMI Statewide Seismic Needs Assessment (SSNA; Lewis, 2007). We updated the SSNA data by reviewing Google Maps™ data. The critical facilities we identified include hospitals, schools, fire stations, police stations, and emergency operations. In addition, we included other buildings based on specific community input and structures that would be essential during a natural hazard event, such as public works and water treatment facilities. Communities that have critical facilities that can function during and immediately after a natural disaster are more resilient than those with critical facilities that are inoperable after a disaster. Various critical facilities are present within Cottage Grove **Table 2-2** Critical facilities are individually listed in **Appendix A**.

Table 2-2. Cottage Grove critical facilities inventory.

	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
Community	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
	(all dollar amounts in thousands)													
Cottage Grove	1	11,838	5	89,288	2	6,336	0	0	0	0	2	3,281	10	110,743

Note: Facilities with multiple buildings were consolidated into one building.

* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

One purpose of the UDF database design was so that we could estimate the number of people at risk from natural hazards. Within the UDF database, the 2010 U.S. Census population of permanent residents per census block was distributed proportionally among residential buildings based on building area. This census block-based distribution was further adjusted with the PSU Population Research Center estimates for 2021. The difference in population between the 2010 U.S. Census and the PSU estimate were evenly distributed to all residential structures in the study area so that the total population was equal to the PSU population estimate. We did not examine the impacts of natural hazards on non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution includes vacation homes, which in many communities make up some of the total residential building stock (U.S. Census Bureau, 2010b).

From the Census and PSU Population Research Center data, we assessed the risk of the 10,373 residents of Cottage Grove that could be affected by a natural hazard. For each natural hazard, except for the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers four natural hazards (earthquake, flood, landslide, and wildfire) that pose a risk to Cottage Grove. The assessment describes both localized vulnerabilities and the widespread challenges that impact the community. The loss estimation and exposure results, as well as the rich dataset included with this report, can lead to greater understanding of the potential impact of natural disasters. The community can use the results to update plans as part of the work toward becoming more resilient to future disasters.

In this section, hazard data sources are described, and results are presented for Cottage Grove. Detail results are in **Appendix A: Community Risk Profile**.

3.1 Earthquake

An earthquake results from a sudden movement of rock on each side of a fault in the earth's crust that abruptly releases strain accumulated over a long period of time. The movement along the fault produces waves of strong shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause casualties, economic disruption, and extensive property damage (Madin and Burns, 2013).

Two earthquake-induced hazards are liquefaction and coseismic landslides. Liquefaction occurs when saturated soils suddenly lose bearing capacity due to ground shaking, causing the soil to behave like a liquid; this action can be a source of tremendous damage. Coseismic landslides are mass movement of rock, debris, or soil induced by ground shaking. All earthquake loss estimates in this report include damage derived from shaking itself, and from liquefaction and landsliding.

3.1.1 Data sources

Hazus-MH offers two scenario methods for estimating loss from earthquake, probabilistic and deterministic (FEMA Hazus-MH, 2012b). A probabilistic scenario uses U.S. Geological Survey (USGS) National Seismic Hazard Maps which are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the annual frequency of exceeding a set of ground motions as a result of all possible earthquake sources (U.S. Geological Survey, 2017). A deterministic scenario is based on a specific seismic event, which in this case is the CSZ Mw 9.0 event. We used the deterministic method along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

The CSZ Mw 9.0 of Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Cottage Grove. This CSZ scenario by Madin and others (2021) includes information necessary for successful Hazus analysis. Other potentially damaging scenarios lacked detailed seismic data such that adequate results would be produced. A well understood earthquake scenario, like the CSZ, adds to the accuracy of the results.

To thoroughly characterize the risk of earthquake hazard in Cottage Grove, we also ran a Hazus scenario using a nearby crustal fault. We selected the Metolius Fault as a plausible source of a damaging earthquake for the Cottage Grove and surrounding areas. The Hazus results, using the same building inputs and site-specific data (coseismic landslide, liquefaction, and National Earthquake Hazard Reduction Program (NEHRP) soils) as the CSZ Mw 9.0 scenario, show that a Mw 7.4 earthquake from the Metolius Fault would produce damages between $300,000 to $400,000; this is less than 1% of the Cascadia impact. Because the damages were so slight in comparison to the CSZ Mw 9.0 scenario, we only used the CSZ result to characterize earthquake risk in Cottage Grove.

The following hazard layers used for the loss estimation analysis are derived from work conducted by Madin and others (2021): landslide susceptibility (wet), liquefaction susceptibility, and NEHRP soils. The liquefaction and landslide susceptibility layers together with peak ground acceleration (PGA) from Madin and others (2021) were used by the Hazus-MH tool to calculate probability and magnitude of permanent ground deformation. While the datasets used in the analysis to represent ground deformation (landslide susceptibility, liquefaction susceptibility, and NEHRP soils) were the best data available, substantial mischaracterizations of these hazards may be present that would reduce the impact of earthquake hazard within the community.

The statewide datasets developed by Madin and others (2021) are compilations of studies of varying accuracies and methodologies from across the state of Oregon. The liquefaction data used in the study area was derived from the work of O'Connor (2001). The mapping conducted in the O'Connor study was not done with geohazards in mind. Because liquefaction was specific looked at, there is uncertainty in how the sediments in the study area would react in a given seismic event.

3.1.2 Study area results

Because an earthquake can affect a wide area, every building in Cottage Grove will by shaken by a CSZ Mw 9.0 earthquake. Hazus-MH loss estimates (see **Appendix B** Table B-2) for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the total building replacement value to obtain a loss estimate (FEMA, 2012b). We performed this assessment using the best data available at the time of the study. However, it is important to note that some of the datasets used in the study will likely be updated and replaced within the next three years. New data should be incorporated into future risk assessments.

In keeping with earthquake damage reporting conventions, we used the Applied Technology Council (ATC)-20 post-earthquake building safety evaluation color-tagging system to represent damage states (Applied Technology Council, 2015). Red-tagged buildings correspond to a Hazus-MH damage state of "complete," which means the building is uninhabitable. Yellow-tagged buildings are in the "extensive" damage state, indicating limited habitability. The number of red or yellow-tagged buildings we report for each community is based on an aggregation of the probabilities for individual buildings (FEMA, 2012b).

Critical facilities were considered non-functioning if the Hazus-MH earthquake analysis showed that a building or complex of buildings had a greater than 50-percent chance of being at least moderately damaged (FEMA, 2012b). Because building specific information is more readily available for critical facilities and due to their importance after a disaster, we chose to report the results of these buildings individually.

The number of potentially displaced residents from an earthquake scenario described in this report was based on the formula: ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]) (FEMA, 2012b). The probability of damage state was determined in the Hazus-MH earthquake analysis results.

Cottage Grove CSZ Mw 9.0 earthquake results:

- Number of red-tagged buildings: 28
- Number of yellow-tagged buildings: 290
- Loss estimate: $111,599,000
- Loss ratio: 7.1%
- Non-functioning critical facilities: 8
- Potentially displaced population: 37

The results indicate that Cottage Grove could incur a moderate level of loss (7%) due to a CSZ Mw 9.0 earthquake. Much of the contributing factors to damage are soils that are susceptible to seismic shaking. The Coast Fork Willamette River floodplain is composed of seismically reactive soils where the majority of the buildings in Cottage Grove are located. Since these soils amplify ground shaking, the probability of earthquake damage is greater for structures built in these areas.

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a small amount of the estimated damage from the earthquake hazard in Cottage Grove. Landslide exposure results show that 0.8% of buildings in Cottage Grove are within a very high or high susceptibility zone. This indicates that a similar percentage of the earthquake loss estimated in this study may be due to coseismic landslide.

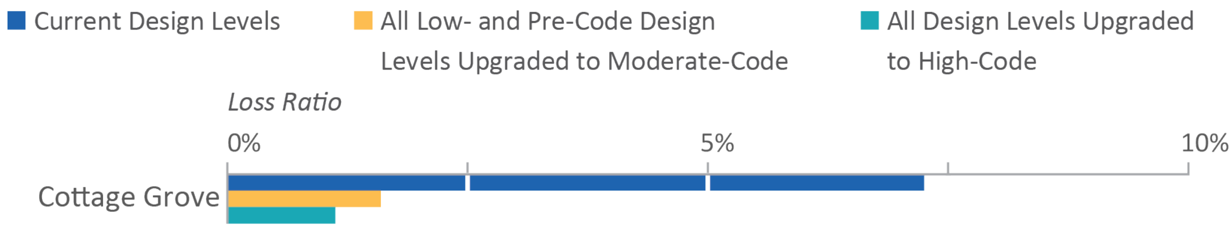
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in loss estimates. The first seismic building codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. Nearly 85% of Cottage Grove's buildings were built before the 1990's. In Hazus-MH, manufactured homes are one occupancy type that performs poorly in earthquake damage modeling. Communities that are composed of an older building stock and more vulnerable occupancy types are expected to experience more damage from earthquake than communities with fewer of these vulnerabilities.

If buildings could be seismically retrofitted to higher code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that loss ratios drop from 7.1% to 1.8%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, areas of high landslide or liquefaction may need additional geotechnical mitigation to have an effect on losses. **Figure 3-1** illustrates the reduction in loss estimates from the probabilistic Mw 7.0 earthquake through two simulations where all buildings are upgraded to moderate code standards or to high code standards.

Key Terms:

- *Seismic retrofit:* Structural modification to a building that improves its resilience to earthquake.
- *Design level:* Hazus-MH terminology referring to the quality of a building's seismic building code (i. e. pre, low, moderate, and high). Refer to **Appendix C.2.3**for more information.

Figure 3-1. CSZ Mw 9.0 earthquake loss ratio in Cottage Grove, with simulated seismic building code upgrades.



3.1.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to earthquake hazard:

- A cluster of manufactured homes in the northeastern portion of Cottage Grove are more vulnerable to earthquake damage relative to other structures.
- Many high value buildings in commercial areas in Cottage Grove are built with more vulnerable building materials compared to wood-built structures.
- Critical facilities in the study area that were built before seismic building code standards are at risk to be non-functioning due to an earthquake like the one simulated in this study.

3.2 Flooding

In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Floods are a commonly occurring natural hazard in Cottage Grove and have the potential to create public health hazards and public safety concerns, close and damage major highways, destroy railways, damage structures, and cause major economic disruption. Flood issues like flash flooding, ice jams, post-wildfire floods, and dam safety were not examined in this report.

Floods vary greatly in size and duration, with smaller floods more likely than larger floods. A typical method for determining flood risk is to identify the size of a flood that has a particular probability of occurrence. This report uses floods that have an annual probability of occurrence of 10%, 2%, 1%, and 0.2%, henceforth referred to as 10-year, 50-year, 100-year, and 500-year scenarios, respectively. The size of floods estimated at these probabilities is based on a computer model that is based on recorded precipitation and stream levels.

The major streams within Cottage Grove are the Coast Fork Willamette River, Row River, Silk Creek, and Bennett Creek. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain.

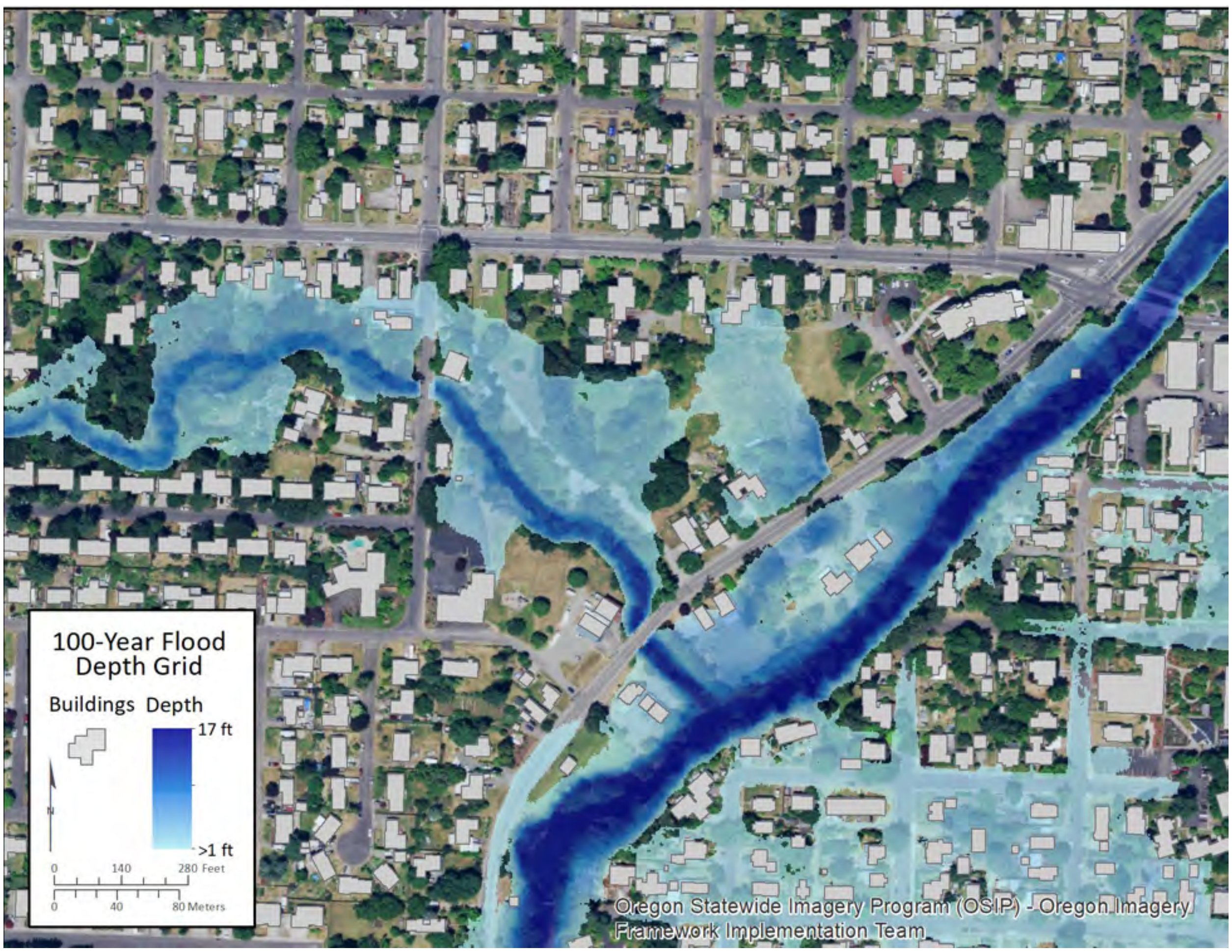
Floods commonly adversely impact human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of flooding or removing the structure through FEMA's property acquisition ("buyout") program.

3.2.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps for Cottage Grove were in the process of being updated by FEMA as of April 2022; this is the primary data source for the flood risk assessment in this report. In doing this update, FEMA provided DOGAMI depth grids for flood risk assessment. These depth grids are considered draft and are subject to possible change. FEMA approved of their usage in this report as they are considered the best available for the study area. Further information regarding the National Flood Insurance Program (NFIP) can be found on the FEMA website: https://www.fema.gov/flood-insurance. These were the only flood data sources that we used in the analysis.

The depth grids provided by FEMA were used in this risk assessment to determine the level to which buildings are impacted by flooding. Depth grids are raster GIS datasets in which each digital pixel value represents the depth of flooding at that location within the flood zone **(Figure 3-2)**. Though considered draft at the time of this analysis, the depth grid data are the best available flood hazard data. Depth grids for four flooding scenarios (10-, 50-. 100-, and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis. Each flood scenario is designated by a recurrence interval or the probability in any given year of a flood of that magnitude occurring. For example, the 100-year flood has a 1% annual chance of occurring.

Figure 3-2. Flood depth grid example of confluence of Silk Creek with Coast Fork Willamette River in Cottage Grove, Oregon using FEMA 2022 draft flood data.



Building loss estimates are determined in Hazus-MH by overlaying building data on a depth map. Hazus-MH uses individual building information, specifically the first-floor height above ground and the presence of a basement, to calculate the loss ratio from a particular depth of flood.

For Cottage Grove, occupancy type and basement presence attributes were available from the assessor database for most buildings. Where individual building information was not available from assessor data, we used oblique imagery and street level imagery to estimate these important building attributes. Only buildings in a flood zone or within 500 feet (152 meters) of a flood zone were examined closely to attribute buildings with more accurate information for first-floor height and basement presence. Because our analysis accounted for building first-floor height, buildings that have been elevated above the flood level were not given a loss estimate—but we did count residents in those structures as displaced. We did not look at the duration that residents would be displaced from their homes due to flooding. For information about structures exposed to flooding but not damaged, see the **Exposure analysis** section below.

3.2.2 Study area results

For this risk assessment, we imported the community UDF data and depth grids into Hazus-MH and ran a flood analysis for four flood scenarios (10-, 50-, 100-, and 500-year). We used the April 2022 draft 100-year flood scenario as the primary scenario for reporting flood results (also see **Appendix E** Plate 4). The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. See **Appendix B** Table B-4 for multi-scenario cumulative results. We performed this assessment using the best data available at the time of the study. However, it is important to note that the FEMA flood depth maps may still be amended before they are adopted. New data should be incorporated into future risk assessments.

Cottage Grove 100-year flood loss (FEMA 2022 draft data):

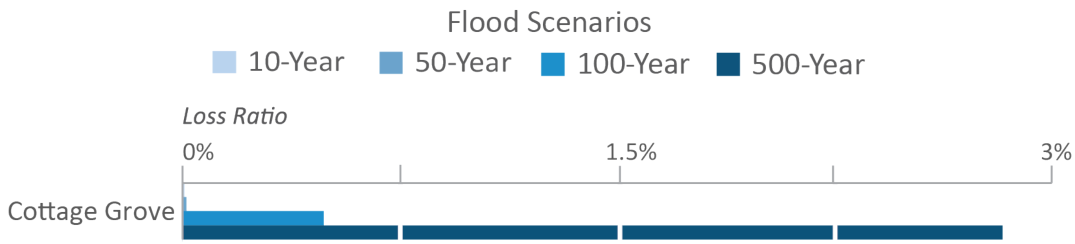
- Number of buildings damaged: 451
- Loss estimate: $6,851,000
- Loss ratio: 0.4%
- Non-functioning critical facilities: 0
- Potentially displaced population: 1,188

3.2.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is over $6.8 million. While the overall loss ratio for flood damage in Cottage Grove is 0.4%, 100-year flooding has a significant impact to areas where development exists near streams. Because most residents are not within flood designated zones, the loss ratio may not be as helpful as the actual replacement cost and number of residents displaced to assess the level of risk from flooding. The Hazus-MH analysis provides flood damage results at the building-level so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Cottage Grove are along the Coast Fork Willamette River floodplain. While the majority of the 100-year flooding is shallow, it is present in the entire area between the Coast Fork Willamette and Highway 99 throughout the community. Flooding is more severe in the northern portion of Cottage Grove at the Highway 99 bridge over the Coast Fork Willamette River. The 500-year is less probable but is likely to cause much more extensive damage (**Figure 3-3**).

Figure 3-3. Ratio of flood loss estimates for Cottage Grove (FEMA 2022 draft data).



3.2.4 Exposure analysis

Separate from the Hazus-MH flood analysis, we did an exposure analysis by overlaying building locations on the 100-year flood extent. We did this to estimate the number of buildings that are elevated above the level of flooding and the number of displaced residents, both of which are not considered in the Hazus analysis. This was done by comparing the number of non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Some (12%) of Cottage Grove's buildings were found to be within designated flood zones. Of the 700 buildings that are exposed to flooding, we estimate that 249 are above the height of the 100-year flood. This evaluation also estimates that 1,188 residents might have mobility or access issues due to surrounding water. See **Appendix B** Table B-5 for community-based results of flood exposure.

3.2.5 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to flood hazard:

- Widespread shallow flooding throughout Cottage Grove between Coast Fork Willamette River and Highway 99.
- Flooding most severe in the area near the Highway 99 bridge over the Coast Fork Willamette River.

3.3 Landslide Susceptibility

Landslides are mass downhill movements of rock, debris, or soil. There are many different types of landslides in Oregon. In area around Cottage Grove the most common are debris flows and shallow- and deep-seated landslides. Landslides can occur in many sizes, at different depths, and with varying rates of movement. Generally, they are large, deep, and slow moving or small, shallow, and rapid. Some factors that influence landslide type are hillside slope, water content, and geology. Many triggers can cause a landslide: intense rainfall, earthquakes, or human-induced factors like excavation along a landslide toe or loading at the top. Landslides can cause severe damage to buildings and infrastructure. Fast-moving landslides may pose life safety risks and can occur throughout Oregon (Burns and others, 2016).

3.3.1 Data sources

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) for the landslide analysis. This statewide susceptibility layer is an analysis of multiple landslide datasets. Burns and others (2016) used the Statewide Landslide Information Database for Oregon (SLIDO) inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. Mapped landslides from SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016).

SLIDO, release 3.2 (Burns and Watzig, 2014) is an inventory of mapped landslides in the state of Oregon. SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state. Some landslide mapping for the area around Cottage Grove was done as recently as 2002 but before lidar was available for high-accuracy mapping.

Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure (see **Appendix B** Table B-6). We combined high and very high susceptibility zones to provide a general sense of community risk for planning purposes (see **Appendix E**, Plate 5).

The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose a real risk to communities were not examined for this report.

3.3.2 Study area results

The landslide exposure results are tabulated below for the high and very high categories and shown for all categories in **Figure 3-4**. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results. We performed this assessment using the best data available at the time of the study. However, it is important to note that the landslide maps for this area are incomplete and an upcoming study will likely update and replace the source data within the next three years. New data should be incorporated into future risk assessments.

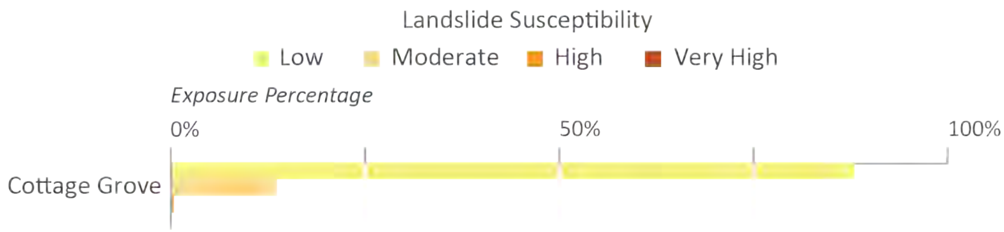
Cottage Grove landslide exposure (High and Very High susceptibility):

- Number of buildings: 44
- Value of exposed buildings: $12,103,000
- Percentage of total value exposed: 0.8%
- Critical facilities exposed: 0
- Potentially displaced population: 79

The amount of exposure to landslide hazard in Cottage Grove is low, with less than 1% of building value exposed to high or very high susceptibility. Much of Cottage Grove is built on stream sediments within the Coast Fork Willamette River floodplain, which tend to have low landslide hazard. Sloped areas surrounding the city are at higher risk for landslide. Existing landslides are present south of the city.

Landslide hazard is ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for Cottage Grove. A complete lidar-based landslide inventory for the Cottage Grove area would provide much more accurate and detailed results.

Figure 3-4. Landslide susceptibility exposure for Cottage Grove.



3.3.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to landslide hazard:

- Areas surrounding Cottage Grove are at greater risk to landslide hazard than within the city.
- Some areas in Cottage Grove may be at higher risk than what the data show, due to incomplete mapping of landslides.

3.4 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property in many communities. The most common severe wildfire conditions include: hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development (Gilbertson-Day and others, 2018). Post-wildfire geologic hazards can also present risk. These usually include flood, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

The Lane County Community Wildfire Protection Plan (CWPP), from 2020, recommends that the county develop policies that address fire restriction enforcement, fuel breaks, wildland urban interface standards, and building code enforcement related to emergency access. Forests cover large areas around Cottage Grove and many homes in the UGB are adjacent to wildfire risk areas. Contact the Lane County Planning Department for specific requirements related to the county's land use plan.

3.4.1 Data sources

The Pacific Northwest Quantitative Wildfire Risk Assessment (PNRA): Methods and Results (Gilbertson-Day and others, 2018) is a comprehensive report that includes a database developed by the United States Forest Service (USFS) for the states of Oregon and Washington. The steward of this database in Oregon is the Oregon Department of Forestry (ODF). The database was created to assess the level of risk residents and structures have to wildfire. For this project, the burn probability dataset, a dataset included in the PNRA database, was used to measure the risk to Cottage Grove.

Using guidance from ODF, we categorized the Burn Probability dataset into low, moderate, and high-hazard zones for the wildfire exposure analysis. Burn probability is derived from simulations using many elements, such as, weather, ignition frequency, ignition density, and fire modeling landscape (Gilbertson-Day and others, 2018).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. Within the study area, no wildfire data was available in urbanized areas. This indicates that there is minimal risk to wildfire hazard, because the omission implies low to no probability of wildfire risk (see **Appendix B**, Table B-8). We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.4.2 Study area results

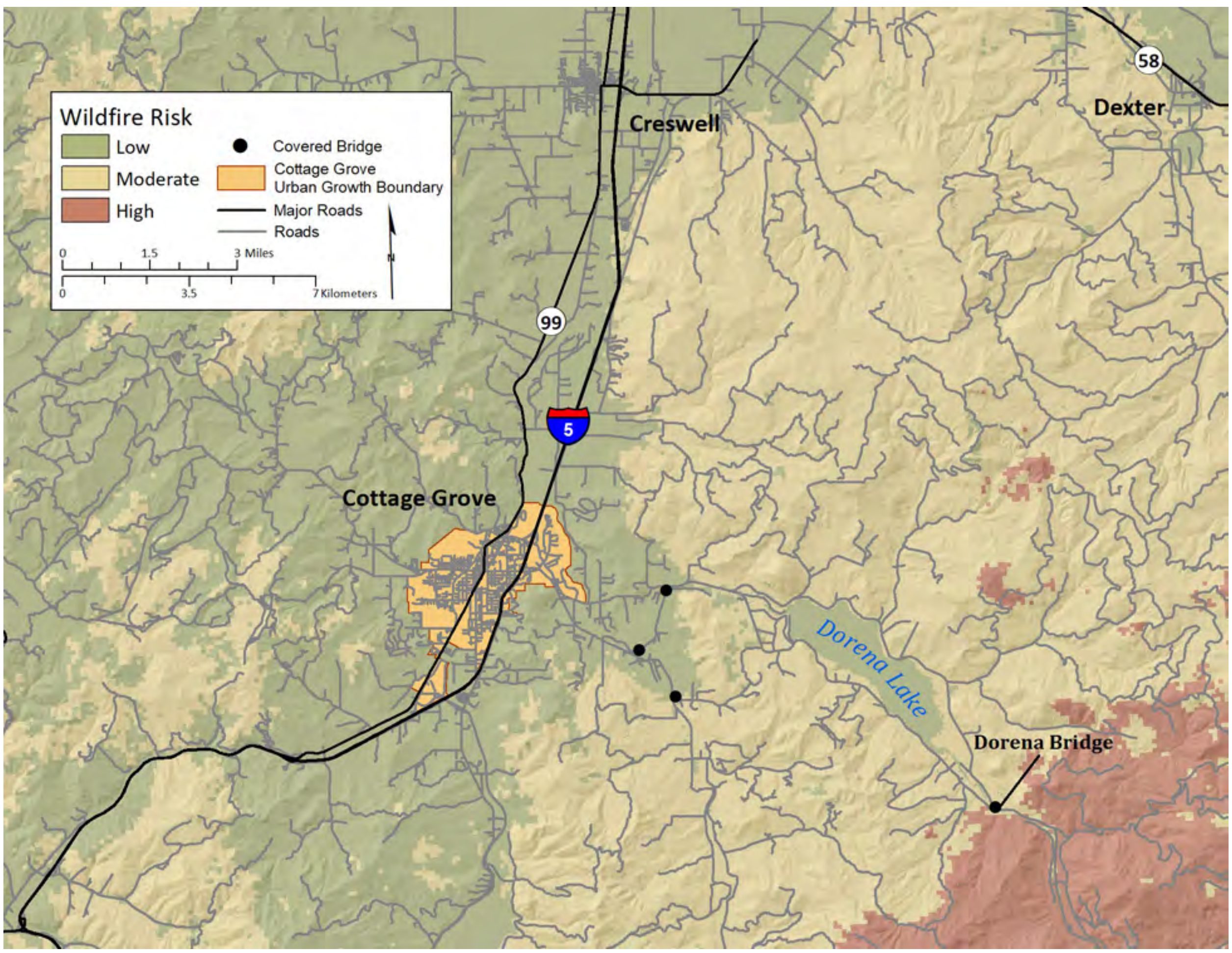
High to moderate wildfire hazard is present for large portions of the surrounding area but is low in Cottage Grove. The wildfire risk increases to moderate at 1 mile (1.6 kilometers) east and south of the incorporated boundary of Cottage Grove. The wildfire hazard continues to increase to high levels further into the Cascade Mountains to the east. Wildfire adjacent to Cottage Grove could still pose a risk related to evacuation routes and hazardous smoke.

Cottage Grove wildfire exposure (High hazard):

- Number of buildings: 0
- Value of exposed buildings: $0
- Percentage of total value exposed: 0%
- Critical facilities exposed: 0
- Potentially displaced population: 0

While wildfire risk is low for Cottage Grove, the risk of wildfire is still present. Low probability events do occur and often have a larger impact than high probability events. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results; we did not produce a wildfire specific map plate, due to the data indicating a uniformly low wildfire risk within the study area. High wildfire hazard exists in surrounding forested areas (**Figure 3-5.** Wildfire hazard areas near Cottage Grove).

Figure 3-5. **Wildfire hazard areas near Cottage Grove.**



3.4.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to wildfire hazard:

- Dorena Bridge is within an area of high wildfire risk. Other historical covered bridges in the area are at risk from wildfire due to their proximity to high-risk zones.

- While the probability of wildfire hazard is low, it is still a possibility in Cottage Grove. Nearby wildfire prone areas also pose a risk related to evacuation routes and hazardous smoke.

4.0 CONCLUSIONS

The purpose of this study is to provide a better understanding of potential impacts from multiple natural hazards at the community scale. We accomplished this by using the latest natural hazard mapping and loss estimation tools to quantify expected damage to buildings and potential displacement of permanent residents, or determine which buildings and residents are exposed to a hazard. This comprehensive and detailed approach to the analysis provides new context for the city's risk reduction efforts. However, new landslide and coseismic geohazard maps will be produced in the next three years, and the FEMA flood maps may change before they are adopted by Cottage Grove. This risk assessment should be updated based on the new maps. We note several important findings based on the results of this study:

- **Moderate overall damage and losses can occur from an earthquake—**Based on the results of a CSZ Mw 9.0 earthquake, every building and resident in Cottage Grove would experience moderate impact and disruption. Results show that an earthquake can cause building losses of 7% in the study area. The high vulnerability of the building inventory (building type) and the number of buildings constructed on seismically amplifying soils contribute to the estimated levels of losses expected in the study area. Lidar-based geohazard mapping would increase the accuracy of the earthquake hazard results.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking—**Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We found that retrofitting to at least moderate code was the most efficient mitigation strategy because the additional benefit from retrofitting to high code was minimal. In our simulation of upgrading buildings to at least moderate code, the estimated loss for the entire study area was reduced from 7.1% to 1.8%. Communities with older buildings that were constructed below the moderate seismic code standards are both the most vulnerable and have the greatest potential for risk reduction. Although seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced landslide will also be present near the perimeter of Cottage Grove.
- **Cottage Grove is at significant risk from flooding—**Most of the buildings in Cottage Grove are built along the Coast Fork Willamette River in areas that are prone to flooding. Flood mapping was recently revised and represents the best available data to estimate risk. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages for a community relative to other hazards we examined. This is due to the difference between loss estimation and exposure results, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazards. The areas that are most vulnerable to flood hazard are along both banks of the Coast Fork Willamette River over to Highway 99 through commercial and residential portions of Cottage Grove.
- **Elevating structures in the flood zone reduces vulnerability—**Flood exposure analysis was used in addition to Hazus-MH loss estimation to identify buildings that were not damaged but that were within the area expected to experience a 100-year flood. By using both analyses in this way, the number of elevated structures within the flood zone could be quantified. This showed possible mitigation needs in flood loss prevention and the effectiveness of past activities. The flood depth

maps show that floods would occur over a wide area but would be relatively shallow, so that, many buildings exposed to flood hazard would be above the flood elevation. A large number (249) of buildings in the flood hazard area are higher than the base flood elevation (BFE). Based on the number of buildings exposed to flooding throughout the city, many would benefit from elevating above the level of flooding.

- **New landslide mapping would increase the accuracy of estimating landslide risk**—The landslide hazard data used in this risk assessment was created before the advent of modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results.
- **Wildfire risk is low for the overall study area**—Exposure analysis shows that buildings throughout the community are within low wildfire hazard areas. Nearby areas to the east and south of Cottage Grove are considered moderate wildfire risk zones.
- **Most of the study area's critical facilities are at significant risk to earthquake hazard**—Critical facilities were identified and were specifically examined for this report. We estimate that 80% (8 of 10) of Cottage Grove's critical facilities will be non-functioning after a CSZ 9.0 Mw earthquake. We found no exposure of critical facilities to flood, landslide, or wildfire.
- **The biggest cause of displacement to population is flood hazard**—Potential displacement of permanent residents from natural hazards was estimated in this report. We estimate that 11% of the population in the city could be displaced due to a flood. A small percentage of residents are vulnerable to displacement from earthquake, landslide, and wildfire hazards.
- **The results allow comparisons across hazards and prioritize their needs**—The study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard within areas in the community. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns of the community.

5.0 LIMITATIONS

There are several limitations to keep in mind when interpreting the results of this risk assessment.

- **Loss estimation for individual buildings** – Hazus-MH is a model of reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of uncertainty in building characteristics.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards and the inability to perform loss estimations due to the lack of Hazus-MH damage functions. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged or how many buildings might be impacted in a single event.

- **Population variability** – Cottage Grove has some vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations (U. S. Census Bureau, 2010b) and unpublished data from the PSU Population Research Center. As a result, we are slightly underestimating the number of people that may be in harm's way on a summer weekend.
- **Data accuracy and completeness** – Some datasets in our risk assessment had incomplete coverage or lacked high-resolution data within the study area. We used lower-resolution data to fill gaps where there was incomplete coverage or where high-resolution data were not available. Assumptions to amend areas of incomplete data coverage were made based on reasonable methods described within this report. However, we are aware that some uncertainty has been introduced from these data amendments at an individual building scale. At community-wide scales the effects of the uncertainties are lower. Data layers in which assumptions were made to fill gaps are building footprints, population, some building specific attributes, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors, identifying or repairing these problems was beyond the scope of the project and are areas needing additional research.
- **Changing Conditions** – This assessment did not account for potential changes in climate, land use, or population. Human-induced climate change poses a significant and widespread risk to people around the world. In Oregon, climate change is expected impact future floods, wildfires, and landslides, but quantifying this impact was beyond the scope of this study.

6.0 RECOMMENDATIONS

The following actions are needed to better understand hazards and reduce risk to natural hazard through mitigation planning. These implementation areas, while not comprehensive, touch on all phases of risk management and focus on awareness and preparation, planning, emergency response, mitigation funding opportunities, and hazard-specific risk reduction activities.

6.1 Awareness and Preparation

Natural hazard awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community will become a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the time a community needs to recover from a disaster, commonly referred to as "resilience."

This report is intended to provide local officials with a comprehensive and authoritative profile of natural hazard risk to underpin their public outreach efforts.

Messaging can be tailored to stakeholder groups. For example, outreach to homeowners could focus on actions they can take to reduce risk to their property. The DOGAMI Homeowners Guide to Landslides (https://www.oregongeology.org/Landslide/ger_homeowners_guide_landslides.pdf) provides a variety of risk reduction options for homeowners who live in areas susceptible to landslides. This guide is one of many existing resources. Agencies partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

This report can help local decision-makers develop their local plans by identifying geohazards and associated risks to the community. The primary framework for accomplishing this is through the comprehensive planning process. The comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

Another framework is the natural hazard mitigation plan (NHMP) process. NHMP plans focus on characterizing natural hazard risk and identifying actions to reduce risk. Additionally, the information presented here can be a resource when updating the mitigation actions and inform the vulnerability assessment section of the NHMP plan.

While there are many similarities between this report and an NHMP, the primary difference is that the risk assessment is not a planning document. Additional difference can be the hazards or critical facilities that are examined in each report. Differences between the reports may be due to data availability or limited methodologies for specific hazards. The critical facilities considered in this report may not be identical to those listed in a typical NHMP due to the lack of damage functions in Hazus-MH for non-building structures and to different considerations about emergency response during and after a disaster.

6.3 Emergency Response

Critical facilities will play a major role during and immediately after a natural disaster. This study can help emergency managers identify vulnerable critical facilities and develop contingency plans. Additionally, detailed mapping of potentially displaced residents can be used to re-evaluate evacuation routes and identify vulnerable populations to target for early warning.

The building database that accompanies this report presents many opportunities for future pre-disaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and targeted for awareness campaigns. These campaigns can be aimed at pre-disaster mitigation through, for example, improvements of the structural connection of a building's frame to its foundation. Emergency response entities can benefit from the use of the building dataset through identification of potential hazards and populated buildings before and during a disaster. Both reduction of the magnitude of the disaster and a decrease in the response time contribute to a community's overall resilience.

6.4 Mitigation Funding Opportunities

Several funding options are available to communities that are susceptible to natural hazards and have specific mitigation projects they wish to accomplish. State and federal funds are available for projects that demonstrate cost effective natural hazard risk reduction. The Oregon Office of Emergency Management (OEM) State Hazard Mitigation Officer (SHMO) can provide communities assistance in determining eligibility, finding mitigation grants, and navigating the mitigation grant application process. OEM has produced a document that can assist local officials in applying for mitigation funds (https://www.oregon.gov/OEM/Documents/Oregon_Hazard_Mitigation_Grant_Program_Handbook.pdf).

At the time of writing this report, FEMA has five programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP), HMGP Post-Fire Assistance, Pre-Disaster

Mitigation (PDM) Grant Program, and Building Resilient Infrastructure and Communities (BRIC) grant program, Flood Mitigation Assistance (FMA) (https://www.fema.gov/grants/mitigation). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 Earthquake

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 80% of critical facilities (**Appendix A: Community Risk Profile**) will be damaged by an earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify buildings that would benefit from seismic upgrades.
- Create modern liquefaction and ground motion amplification maps.

6.5.2 Flood

- Map areas of potential flood water storage.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.
- Create channel migration zone maps.

6.5.3 Landslide

- Create modern landslide inventory and susceptibility maps.
- Monitor ground movement in high susceptibility areas.
- Consider land value losses due to landslide in future risk assessments.

6.5.4 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.

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9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILE

A risk analysis summary for Cottage Grove is provided in this section to encourage ideas for natural hazard risk reduction. Increasing disaster preparedness, public hazards communication, and education, ensuring functionality of emergency services, and ensuring access to evacuation routes are actions that this community can take to reduce their risk. This appendix contains community specific data to provide an overview of the community and the level of risk from each natural hazard analyzed. In addition, a list of critical facilities and assumed impact from individual hazards is provided.

A.1 City of Cottage Grove

Table A-1. City of Cottage Grove.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Cottage Grove		10,373	5,776		10		1,561,735,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	1,188	11%	451	0	6,851,000	0.4%
Earthquake	CSZ Mw 9.0	37	0.4%	318	8	111,599,000	7.1%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	79	0.8%	44	0	12,103,000	0.8%
Wildfire	High Hazard	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with “First floor height” above the level of flooding (base flood elevation).

Table A-2. City of Cottage Grove.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Bohemia School	-	X	-	-
Cottage Grove City Hall	-	X	-	-
Cottage Grove High School	-	X	-	-
Cottage Grove Sewage Treatment	-	X	-	-
Cottage Grove State Airport	-	X	-	-
Harrison Elementary School	-	X	-	-
Lane Community College	-	-	-	-
Lincoln Middle School	-	X	-	-
Peach Health Cottage Grove Community Hospital	-	X	-	-
South Lane Fire and Rescue	-	-	-	-

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Cottage Grove building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per Watershed Total	Building Value ($)	Value of Buildings per Watershed Total
Cottage Grove	4,390	974,422	62%	459	355,404	23%	838	62,722	4%	89	169,186	11%	5,776	100.0%	1,561,735	100.0%

Table B-2. Earthquake loss estimates.

(all dollar amounts in thousands)

			Total Earthquake Damage							
			Buildings Damaged				All Buildings Changed to At Least Moderate Code			
	Total Number of Buildings	Total Estimated Building Value ($)	Yellow-Tagged Buildings	Red-Tagged Buildings	Sum of Economic Loss ($)	Loss Ratio	Yellow-Tagged Buildings	Red-Tagged Buildings	Sum of Economic Loss ($)	Loss Ratio
Cottage Grove	5,776	1,561,735	290	28	111,599	7.1%	28	1	27,536	1.8%

Table B-3. Flood loss estimates.

(all dollar amounts in thousands)

			10% (10-yr)			2% (50-yr)			1% (100-yr)			0.2% (500-yr)		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Loss Estimate ($)	Loss Ratio	Number of Buildings	Loss Estimate ($)	Loss Ratio	Number of Buildings	Loss Estimate ($)	Loss Ratio	Number of Buildings	Loss Estimate ($)	Loss Ratio
Cottage Grove	5,776	1,561,735	3	3	0.0%	20	66	0.0%	700	6,851	0.4%	1,871	43,664	2.8%

Table B-4. Flood exposure.

			1% (100-yr)				
Community	Total Number of Buildings	Total Population	Potentially Displaced Residents from Flood Exposure	% Potentially Displaced Residents from flood Exposure	Number of Flood Exposed Buildings	% of Flood Exposed Buildings	Number of Flood Exposed Buildings Without Damage
Cottage Grove	5,776	10,373	1,188	11%	700	12%	249

Table B-5. Landslide exposure.

			(all dollar amounts in thousands)								
			Very High Susceptibility			High Susceptibility			Moderate Susceptibility		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed
Cottage Grove	5,776	1,561,735	0	0	0%	44	12,103	0.8%	760	191,918	12%

Table B-6. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Hazard			Moderate Hazard		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed
Cottage Grove	5,776	1,561,735	0	0	0%	0	0	0%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 5.0 and ArcGIS® Desktop® 10.7

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Cottage Grove for use in both the flood and earthquake modules of Hazus-MH. The Lane County assessor database (acquired in 2022) was used to determine which tax lots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

The Oregon Department of Geology and Mineral Industries (DOGAMI) used the SBFO-1 (Williams, 2021) dataset to help precisely locate the centroid of each building. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. When buildings were partially within the inundation zone, the building point was moved to the centroid of the portion of the building within the inundation zone. An iterative approach was used to further refine locations of building points for the flood module by generating results, reviewing the highest value buildings, and moving the building point over a representative elevation on the lidar digital elevation model to ensure an accurate first floor height.

C.2.2 Attributing building points

Populating the required attributes for Hazus-MH was achieved through a variety of approaches. The Lane County assessor database was used whenever possible, but in many cases that database did not provide the necessary information. The following is list of attributes and their sources:

- **Longitude** and **Latitude** – Location information that provides Hazus-MH the x and y-position of the UDF point. This allows for an overlay to occur between the UDF point and the flood or earthquake input data layers. The hazard model uses this spatial overlay to determine the correct hazard risk level that will be applied to the UDF point. The format of the attribute must be in decimal degrees. A simple geometric calculation using GIS software is done on the point to derive this value.
- **Occupancy class** – An alphanumeric attribute that indicates the use of the UDF (e.g., 'RES1' is a single-family dwelling). The alphanumeric code is composed of seven broad occupancy types (RES = residential, COM = commercial, IND = industrial, AGR = agricultural, GOV = public, REL = non-profit/religious, EDU = education) and various suffixes that indicate more specific types. This code determines the damage function to be used for flood analysis. It is also used to attribute the Building Type field, discussed below, for the earthquake analysis. The code was interpreted from "Stat Class" or "Description" data found in the Lane County assessor database. When data was not available, the default value of RES1 was applied throughout.
- **Cost** – The replacement cost of an individual UDF. Loss ratio is derived from this value. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus database.

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Lane County assessor database. When not available, the year of "1900" was applied.
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for tax lots with multiple UDFs. The value distribution method will ensure that UDFs with the highest square footage will be the most expensive on a given tax lot. This value is also used to pro-rate the **Number of People** field for Residential UDFs within a census block. The value was obtained from DOGAMI's building footprints; where (RES) footprints were not available, we used the Lane County assessor database.
- **Number of stories** – The number of stories for an individual UDF, along with Occupancy Class, determines the applied damage function for flood analysis. The value was obtained from the Lane County assessor database when available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used for attribution.
- **Foundation type** – The UDF foundation type correlates with First Floor Height values in feet (see Table 3.11 in the Hazus-MH Technical Manual for the Flood Model [FEMA, 2012a]). It also functions within the flood model by indicating if a basement exists or not. UDFs with a basement have a different damage function from UDFs that do not have one. The value was obtained from the Lane County assessor database when available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used to ascertain if one exists or not.
- **First floor height** – The height in feet above grade for the lowest habitable floor. The height is factored during the depth of flooding analysis. The value is used directly by Hazus-MH, where Hazus-MH overlays a UDF location on a depth grid and using the **first floor height** determines the level of flooding occurring to a building. It is derived from the Foundation Type attribute or observation via oblique imagery or Google Street View™ mapping service.
- **Building type** – This attribute determines the construction material and structural integrity of an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information was unavailable from the Lane County assessor data, so instead it was derived from a statistical distribution based on **Occupancy class**.
- **Building design level** – This attribute determines the seismic building code for an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information is derived from the **Year Built** attribute (Lane County Assessor) and state/regional Seismic Building Code benchmark years.
- **Number of people** – The estimated number of permanent residents living within an individual residential structure. It is used in the post-analysis phase to determine the amount of people affected by a given hazard. This attribute is derived from default Hazus database (United States Census Bureau, 2010a) of population per census block and distributed across residential UDFs and adjusted based on population growth estimates from PSU Population Research Center.
- **Community** – The community that a UDF is within. These areas are used in the post-analysis for reporting results.

C.2.3 Seismic building codes

Oregon initially adopted seismic building codes in the mid-1970s (Judson, 2012). The established benchmark years of code enforcement are used in determining a "design level" for individual buildings.

The design level attributes (pre code, low code, moderate code, and high code) are used in the Hazus-MH earthquake model to determine what damage functions are applied to a given building (FEMA, 2012b). The year built or the year of the most recent seismic retrofit are the main considerations for an individual design level attribute. Seismic retrofitting information for structures would be ideal for this analysis but was not available for Lane County. Table C-1 outlines the benchmark years that apply to buildings within the eastern part of Lane County (including Cottage Grove).

Table C-1. Cottage Grove seismic design level benchmark years.

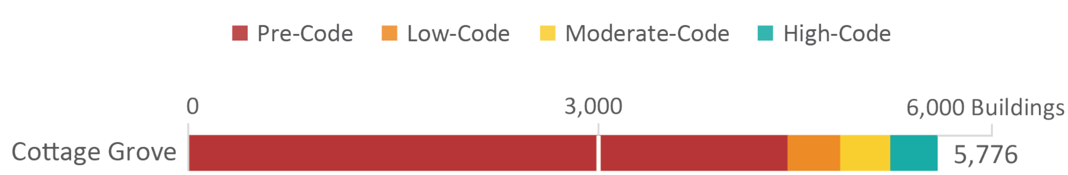
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976 1976–1991 1992–2003 2004–2016	Pre Code Low Code Moderate Code High Code	Interpretation of Judson (Judson, 2012)
Manufactured Housing	prior to 2003 2003–2010	Pre Code Low Code	Interpretation of OR BCD 2002 Manufactured Dwelling Special Codes (Oregon Building Codes Division, 2002)
	2011–2016	Moderate Code	Interpretation of OR BCD 2010 Manufactured Dwelling Special Codes Update (Oregon Building Codes Division, 2010)
All other buildings	prior to 1976 1976–1990 1991–2016	Pre Code Low Code Moderate Code	Business Oregon 2014-0311 Oregon Benefit-Cost Analysis Tool, p. 24 (Business Oregon, 2015)

Table C-2 illustrates the current state of seismic building codes for the county.

Table C-2. Seismic design level in Cottage Grove.

		Pre Code		Low Code		Moderate Code		High Code	
Community	Total Number of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings
Cottage Grove	5,776	4,431	77%	476	8.2%	438	7.6%	431	7.5%

Figure C-1. Seismic design level in Cottage Grove, Oregon.



C.3 Flood Hazard Data

FEMA developed flood hazard data in 2022 for a revision of the Coast Fork Willamette River and its tributaries. The hazard data were based on new flood studies and new riverine hydrologic and hydraulic analyses. For riverine areas, the flood elevations for the 10-, 50-, 100- and 500-year events for each stream cross-section were used to develop depth of flooding raster datasets or "depth grids."

A 2-meter, lidar-based depth grid was developed for each of the 10-, 50-, 100-, and 500-year annual chance flood events. The depth grids were imported into Hazus-MH for determining the depth of flooding for areas within the FEMA flood zones.

Once the UDF database was developed into a Hazus-compliant format, the Hazus-MH methodology was applied using a Python (programming language) script developed by DOGAMI. The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF's Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03). We also used landslide and liquefaction susceptibility data and National Earthquake Hazard Reduction Program (NEHRP) soil classification derived from Madin and others (2021). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate permanent ground deformation and associated probability.

During the Hazus-MH earthquake analysis, each UDF was analyzed given its site-specific parameters (ground motion and ground deformation) and evaluated for loss, expressed as a probability of a damage state. Specific damage functions based on Building type and Building design level were used to calculate the damage states given the site-specific parameters for each UDF. The output provided probabilities of the five damage states (None, Slight, Moderate, Extensive, Complete) from which losses in dollar amounts were derived.

C.5 Post-Analysis Quality Control

Ensuring the quality of the results from Hazus-MH flood and earthquake modules is an essential part of the process. A primary characteristic of the process is that it is iterative. A UDF database without errors is highly unlikely, so this part of the process is intended to limit and reduce the influence these errors have on the final outcome. Before applying the Hazus-MH methodology, closely examining the top 10 largest area UDFs and the top 10 most expensive UDFs is advisable. Special consideration can also be given to critical facilities due to their importance to communities.

Identifying, verifying, and correcting (if needed) the outliers in the results is the most efficient way to improve the UDF database. This can be done by sorting the results based on the loss estimates and closely scrutinizing the top 10 to 15 records. If corrections are made, then subsequent iterations are necessary. We continued checking the "loss leaders" until no more corrections were needed.

Finding anomalies and investigating possible sources of error are crucial in making corrections to the data. A wide range of corrections might be required to produce a better outcome. For example, floating homes may need to have a first-floor height adjustment or a UDF point position might need to be moved due to issues with the depth grid. Incorrect basement or occupancy type attribution could be the cause of a problem. Commonly, inconsistencies between assessor data and tax lot geometry can be the source of an error. These are just a few of the many types of problems addressed in the quality control process.

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

CRS	Community Rating System
CSZ	Cascadia subduction zone
DLCD	Oregon Department of Land Conservation and Development
DOGAMI	Department of Geology and Mineral Industries (State of Oregon)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRI	Fire Risk Index
GIS	Geographic Information System
NFIP	National Flood Insurance Program
NHMP	Natural hazard mitigation plan
NOAA	National Oceanic and Atmospheric Administration
ODF	Oregon Department of Forestry
OEM	Oregon Emergency Management
OFR	Open-File Report
OPDR	Oregon Partnership for Disaster Resilience
PGA	Peak ground acceleration
PGD	Permanent ground deformation
PGV	Peak ground velocity
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
UDF	User-defined facilities
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WUI	Wildland-urban interface
WWA	West Wide Wildfire Risk Assessment

D.2 Definitions

1% annual chance flood – The flood elevation that has a 1-percent chance of being equaled or exceeded each year. Sometimes referred to as the 100-year flood.

0.2% annual chance flood – The flood elevation that has a 0.2-percent chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1-percent-annual-chance flood. This elevation is the basis of the insurance and floodplain management requirements of the NFIP.

Critical facilities – Facilities that, if damaged, would present an immediate threat to life, public health, and safety. As categorized in HAZUS-MH, critical facilities include hospitals, emergency operations centers, police stations, fire stations and schools.

Exposure – Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.

Flood Insurance Rate Map (FIRM) – An official map of a community, on which FEMA has delineated both the SFHAs and the risk premium zones applicable to the community.

Flood Insurance Study (FIS) – Contains an examination, evaluation, and determination of the flood hazards of a community and, if appropriate, the corresponding water-surface elevations.

Hazus-MH – A GIS-based risk assessment methodology and software application created by FEMA and the National Institute of Building Sciences for analyzing potential losses from floods, hurricane winds, and earthquakes.

Lidar – A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Lidar is popularly used as a technology to make high-resolution maps.

Liquefaction – Describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually an earthquake, causing it to behave like liquid.

Loss Ratio – The expression of loss as a fraction of the value of the local inventory (total value/loss).

Magnitude – A scale used by seismologists to measure the size of earthquakes in terms of energy released.

Risk – Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard. Sometimes referred to as vulnerability.

Risk MAP – The vision of this FEMA strategy is to work collaboratively with State, local, and tribal entities to deliver quality flood data that increases public awareness and leads to action that reduces risk to life and property.

Riverine – Of or produced by a river. Riverine floodplains have readily identifiable channels.

Susceptibility – Degree of proneness to natural hazards that is determined based on physical characteristics that are present.

Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

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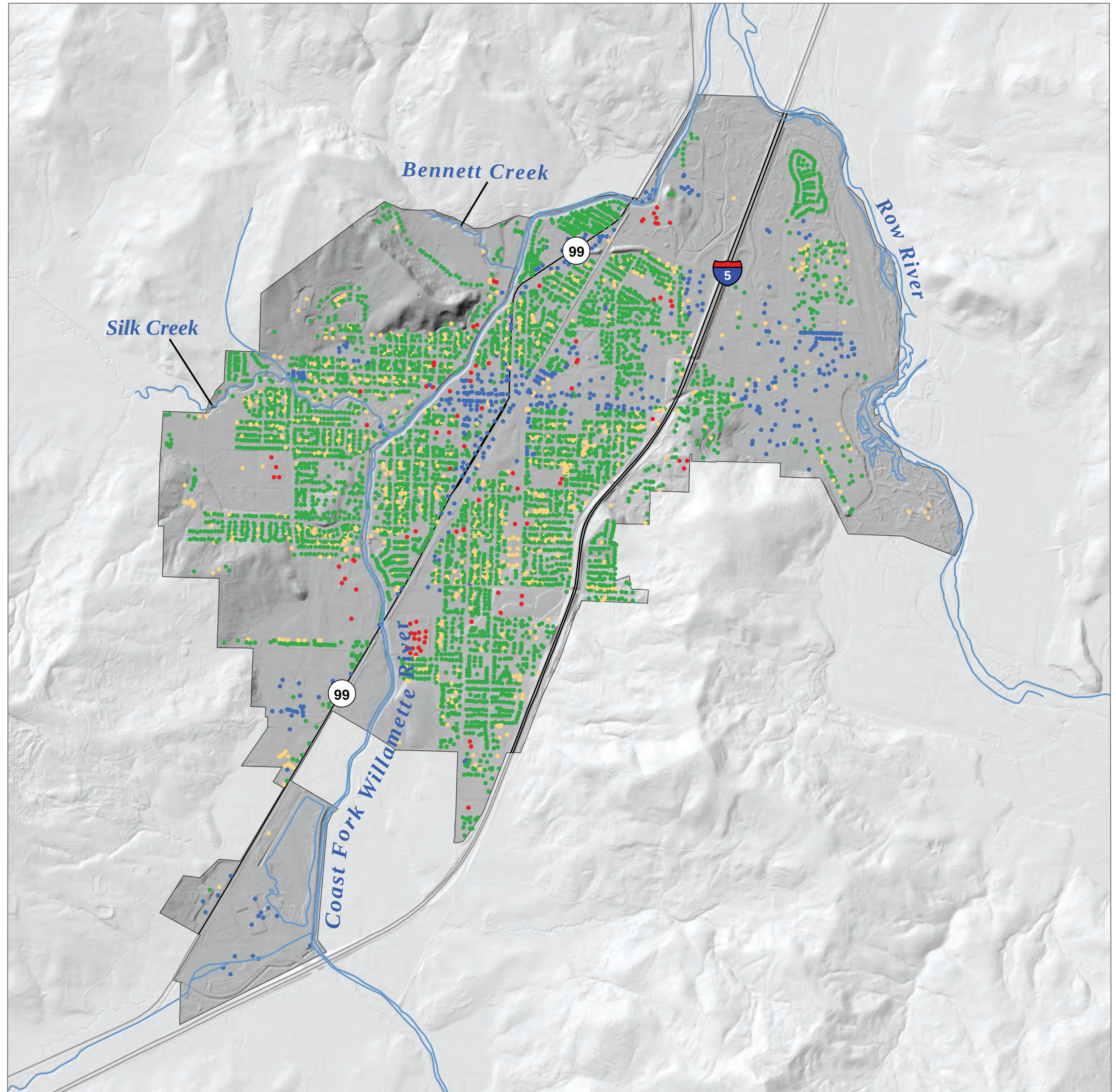
Building Distribution Map of Cottage Grove, Oregon

PLATE 1



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Building Occupancy

- Agricultural / Utility
- Commercial / Industrial
- Public / Nonprofit
- Residential

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

	Number of Buildings at Risk				
Community	Total Number of Buildings	CSZ Earthquake red or yellow-tagged	Flood Exposure	Landslide Exposure	Wildfire Exposure
Cottage Grove	5,776	318	700	44	0

Data Sources:
Building footprints: Statewide Building Footprints of Oregon (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Cottage Grove Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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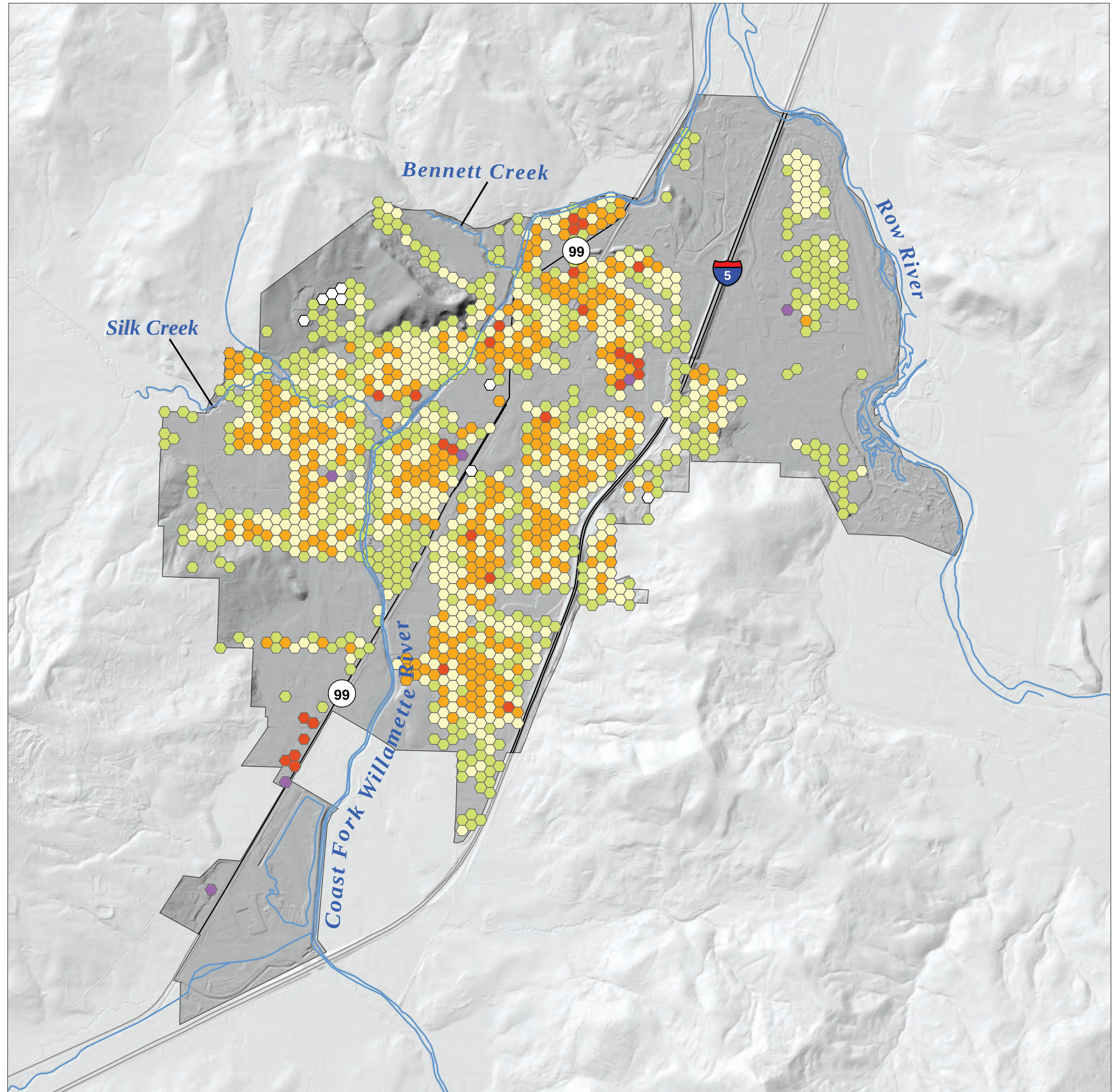
Population Density Map of Cottage Grove, Oregon

PLATE 2



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

People per 100 acres

- Building(s) present no permanent residents
- 1 - 5
- 6 - 10
- 11 - 20
- 21 - 30
- 31 +

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

Community	Number of Residents at Risk				
	Total Number of Residents	CSZ Earthquake displaced population	Flood Exposure	Landslide Exposure	Wildfire Exposure
Cottage Grove	10,373	37	1,188	79	0

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Data Sources:
Population data: U.S. Census (2010) & Portland State University (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Cascadia Subduction Earthquake Shaking Map of Cottage Grove, Oregon

PLATE 3

Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215 - 0.401
VIII	Severe	Mod./Heavy	0.401 - 0.747
IX	Violent	Heavy	0.747 - 1.39
X	Extreme	Very Heavy	> 1.39

Map Elements

Cottage Grove Urban Growth Boundary
Streams
Major Roads

Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

Peak Ground Acceleration (PGA) is the maximum acceleration in a given location or rather how hard the ground is shaking during an earthquake. It is one measurement of ground motion, which is closely associated with the level of damage that occurs from an earthquake.

0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

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Data Sources:
Earthquake peak ground acceleration: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Coseismic Landslide Map of Cottage Grove, Oregon

PLATE 4

Coseismic Landslide Susceptibility (Wet)

0 (None) — 9 (High)

Coseismic landslide is a type of ground deformation that occurs during an earthquake where slope failure creates a mass movement of rock and debris. Saturated ground increases the susceptibility of a landslide occuring from seismic shaking. Coseismic landslides are a significant factor in the risk from earthquake hazard.

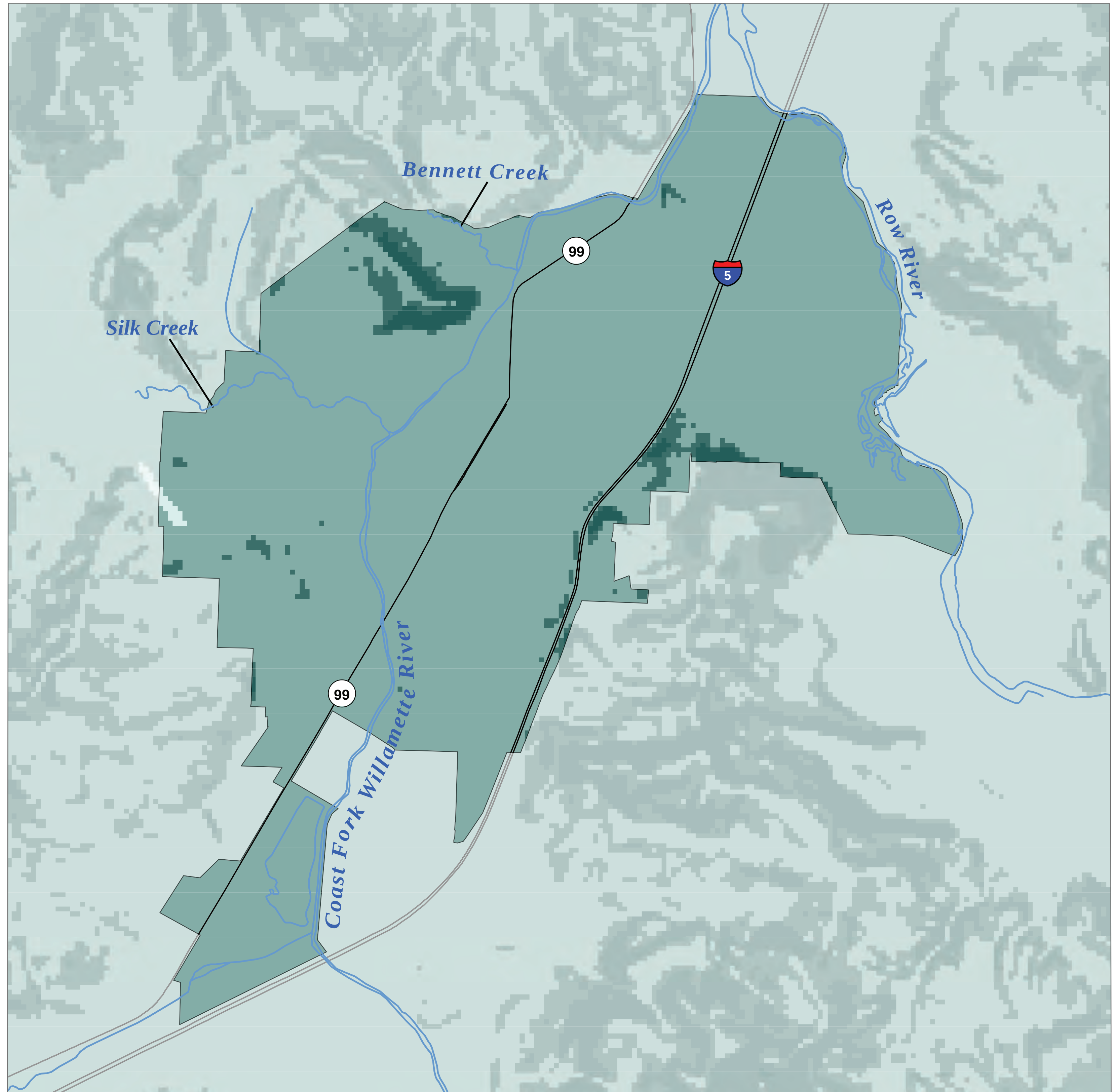
Map Elements

Cottage Grove Urban Growth

Boundary Streams

Major Roads

Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

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Data Sources:
Coseismic landslide: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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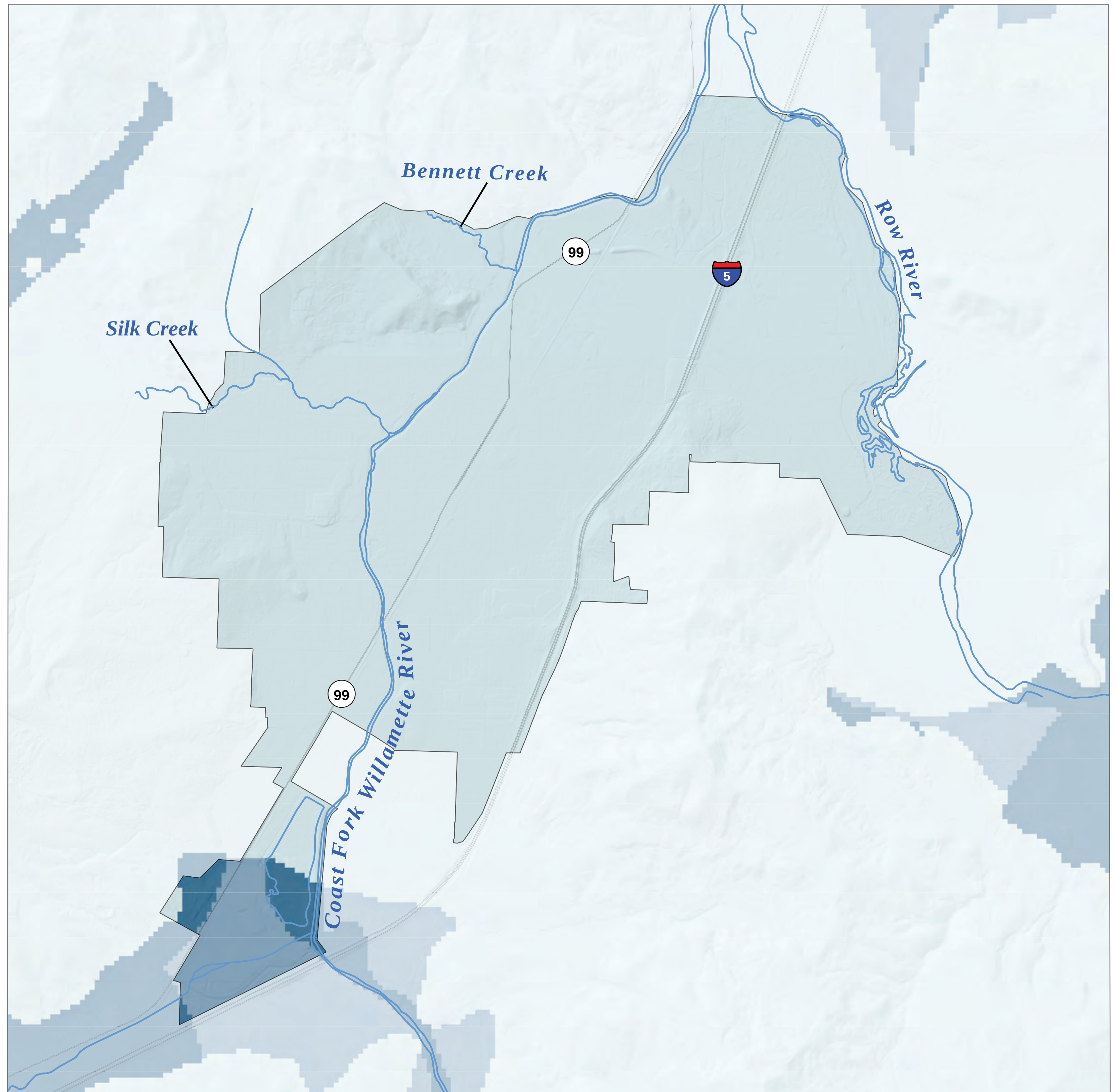
Liquefaction Map of Cottage Grove, Oregon

PLATE 5



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Liquefaction Susceptibility

- Low or None
- Moderate
- High
- Very High

Liquefaction is a type of ground deformation that occurs during an earthquake where saturated, non-cohesive soil contracts and liquefies. The ground that becomes liquefied can no longer support heavy structures that are built on top of it. Liquefaction is a significant factor in the risk from earthquake hazard.

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

	Earthquake Risk					
Community	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

Data Sources:
Liquefaction: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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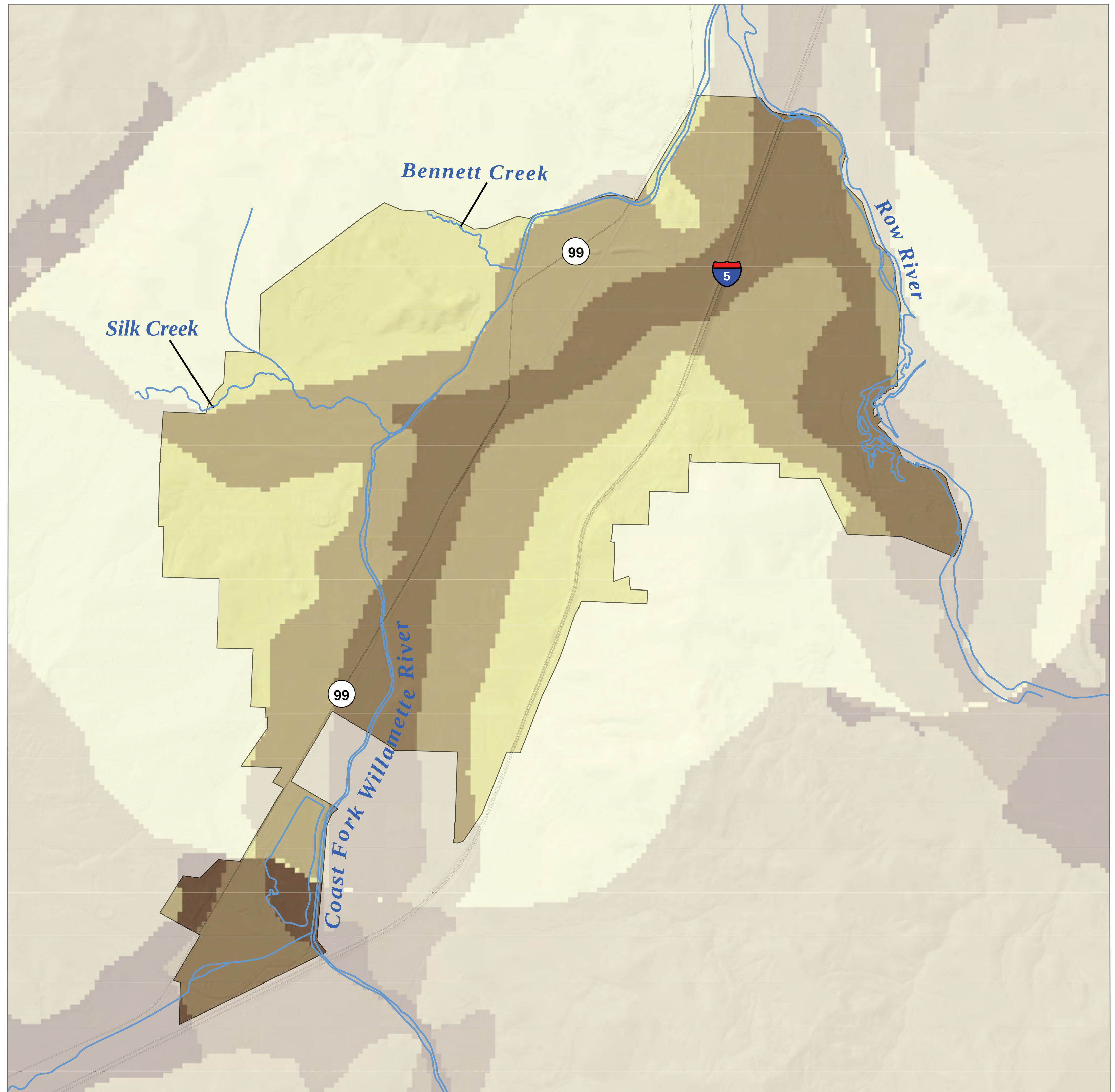
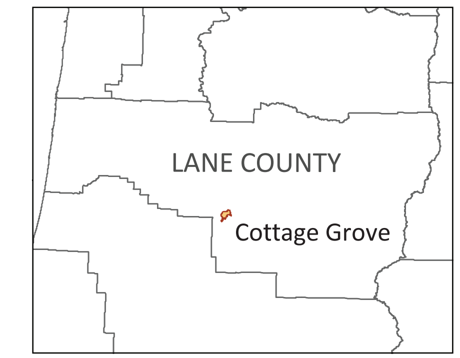
Site Amplification Class Map of Cottage Grove, Oregon

PLATE 6





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

NEHRP Class

- B
- C
- D
- E, F

Site Amplification is the degree to which soil types attenuate (weaken) or amplify (strengthen) seismic waves produced from an earthquake. The National Earthquake Hazards Reduc-tion Program (NEHRP) classifies these geologic units into soft rock (B), dense soil or soft rock (C), stiff soil (D), and soft clay or soil (E, F). NEHRP soils can significantly affect the level of shaking and amount of damage that occurs at a specifically location during an earthquake

Map Elements

- Cottage Grove Urban Growth
- Boundary Streams
- Major Roads

	Earthquake Risk					
Community	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

Data Sources:
Soil amplification: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
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Flood Hazard Map of Cottage Grove, Oregon

PLATE 7

Flood Hazard Zone

100-Year Flood (1% annual chance)

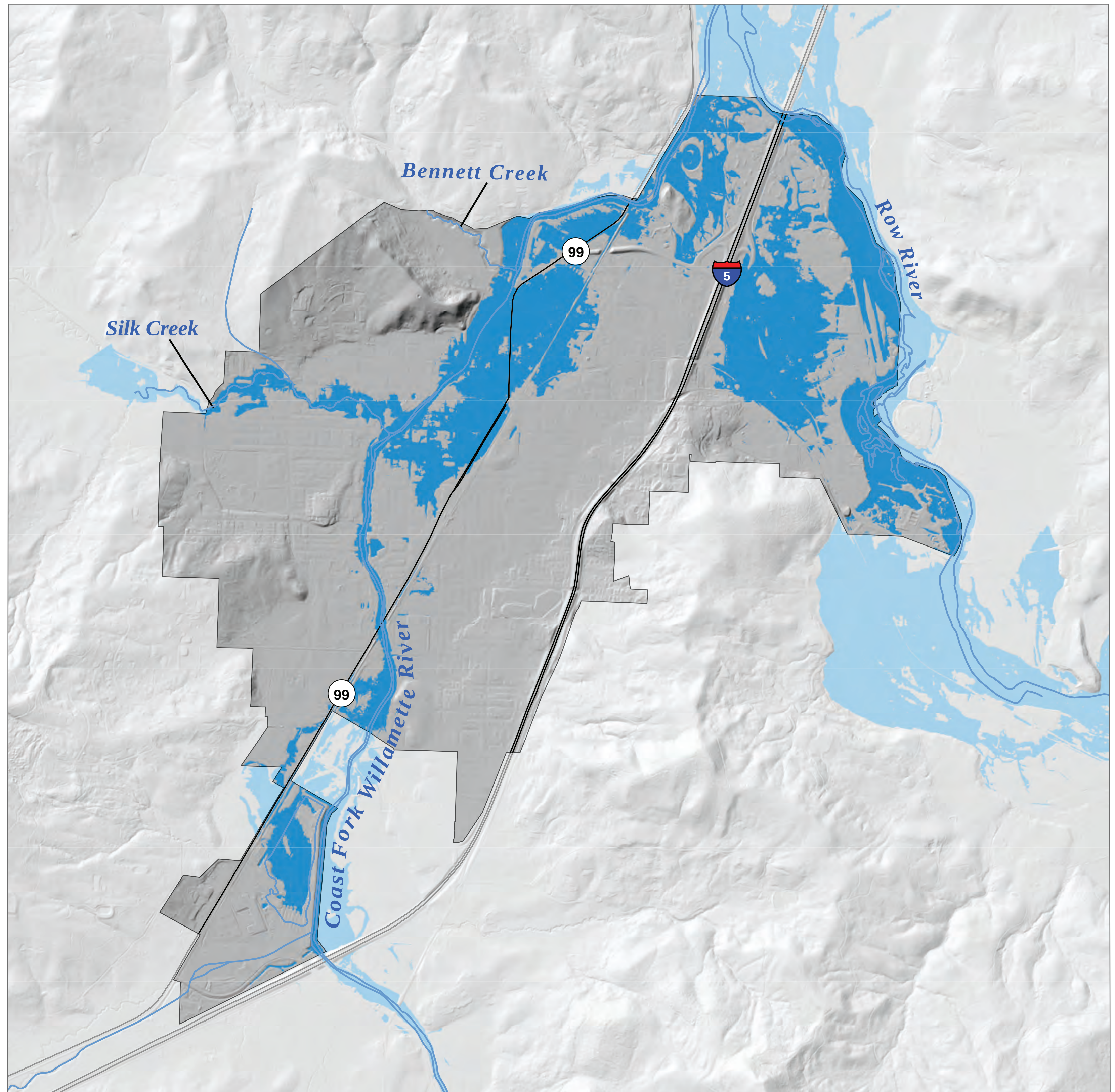
The flood hazard data show areas expected to be inundated during a 100-year flood event. Flooding sources include riverine. Areas are consistent with the regulatory flood zones depicted in Lane County's Digital Flood Insurance Rate Maps.

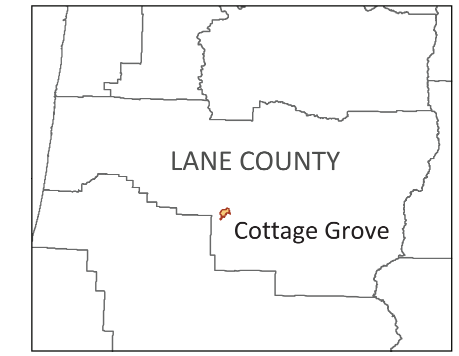
Map Elements

Cottage Grove Urban Growth Boundary

Streams

Major Roads





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Community	Flood Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilites	Loss Estimate ($)	Loss Ratio
Cottage Grove	1,188	11%	451	0	6,851,000	0.4%

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Data Sources:
Flood hazard zone (100-year): Lane County Flood Insurance Rate Map - Draft (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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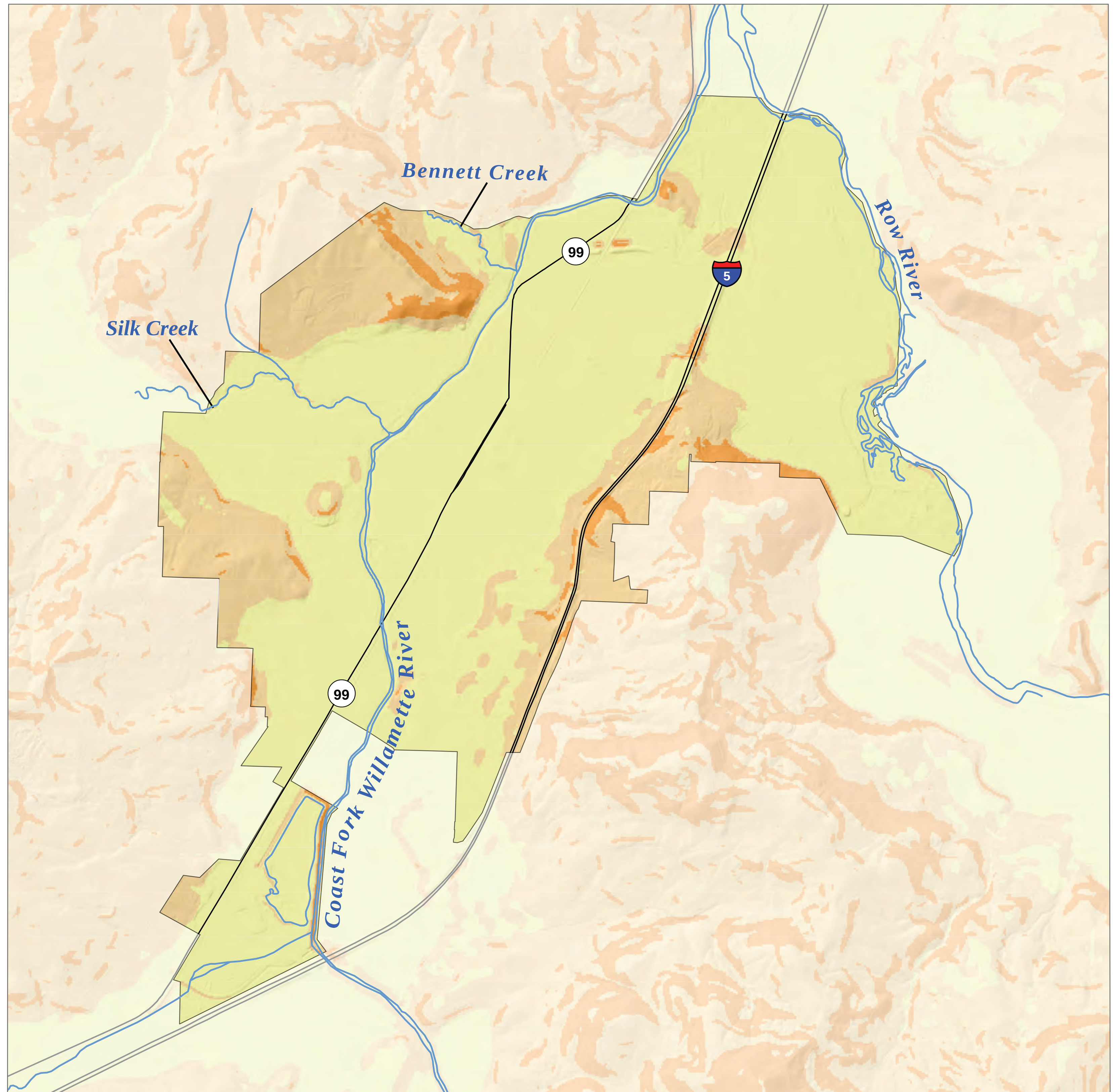
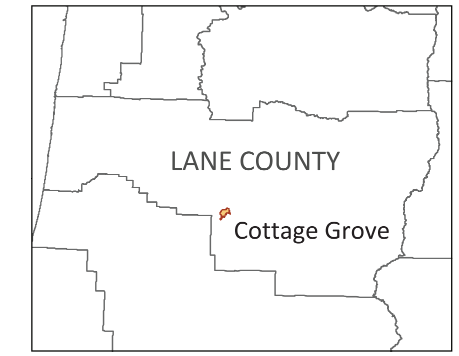
Landslide Susceptibility Map of Cottage Grove, Oregon

PLATE 8





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Landslide Susceptibility

- Low
- Moderate
- High
- Very High

Landslide susceptibility is categorized as Low, Moderate, High, and Very High which describes the general level of susceptibility to landslide hazard. The dataset is an aggregation of three primary sources: landslide inventory (SLIDO), generalized geology, and slope.

Map Elements

- Cottage Grove Urban Growth
- Boundary Streams
- Major Roads

Community	Landslide Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	79	0.8%	44	0	12,103,000	0.8%

Data Sources:
Landslide susceptibility: Oregon Department of Geology, Burns and others (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illstrator CC

Cartography by: Matt C. Williams, 2022

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitutefor site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Cottage Grove Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

Appendix D: OCCRI Future Climate Projections report

Future Climate Projections
Lane County, Oregon

July 2022

Oregon Climate Change Research Institute

Dexter Lake, Lane County, Oregon
Photograph by Rick Obst, CC BY 2.0, via flickr.com

OCCRI DLCD

Future Climate Projections: Lane County, Oregon

Report to the Oregon Department of Land Conservation and Development

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Executive Summary

Climate change is expected to increase the occurrence of many climate-related natural hazards. Confidence that the risk of heat waves will increase is very high (Table 1) given strong evidence in the peer-reviewed literature, consistency among the projections of different global climate models, and robust theoretical principles underlying increasing temperatures in response to ongoing emissions of greenhouse gases. Confidence that the risk of many other natural hazards will increase as climate changes is high or medium (Table 1), reflecting moderate to strong evidence and consistency among models, yet these risks are influenced by multiple secondary factors in addition to increasing temperatures. Confidence in changes in risks is indicated as low if projections suggest relatively few to no changes or evidence is limited.

Table 1. Projected direction and level of confidence in changes in the risks of climate-related natural hazards. Very high confidence means that the direction of change is consistent among nearly all global climate models and there is robust evidence in the peer-reviewed literature. High confidence means that the direction of change is consistent among more than half of models and there is moderate to robust evidence in the peer-reviewed literature. Medium confidence means that the direction of change is consistent among more than half of models and there is moderate evidence in the peer-reviewed literature. Low confidence means that the direction of change is small compared to the range of model responses or there is limited evidence in the peer-reviewed literature.

	Low Confidence	Medium Confidence	High Confidence	Very High Confidence
Risk Increasing ↑		Drought Expansion of Non-native Invasive Plants Reduced Air Quality Loss of Wetlands	Heavy Rains Flooding Wildfire Changes in Ocean Temperature and Chemistry Coastal Hazards	Heat Waves
Risk Unchanging =	Windstorms			
Risk Decreasing ↓				Cold Waves

This report presents future climate projections for Lane County relevant to specified natural hazards for the 2020s (2010–2039) and 2050s (2040–2069) relative to the 1971–2000 historical baseline. The projections are presented for a lower greenhouse gas emissions scenario (RCP 4.5) and a higher greenhouse gas emissions scenario (RCP 8.5), and are based on multiple global climate models. All projections in this executive summary refer to the 2050s, relative to the historical baseline, under the higher emissions scenario. Projections for both time periods and emissions scenarios are included in the main report.

Heat Waves

The number, duration, and intensity of extreme heat events will increase as temperatures continue to warm.

In Lane County, the number of extremely hot days (days on which the temperature is 90°F or higher) and the temperature on the hottest day of the year are projected to increase by the 2020s and 2050s under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios.

In Lane County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 18 days (range 5–30 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Lane County, the temperature on the hottest day of the year is projected to increase by an average of about 7°F (range 2–9°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Cold Waves

Cold extremes will become less frequent and intense as the climate warms.

In Lane County, the number of cold days (maximum temperature 32°F or lower) per year is projected to decrease by an average of 3 days (range -2– -5 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Lane County, the temperature on the coldest night of the year is projected to increase by an average of 6°F (range 2–10°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Heavy Rains

The intensity of extreme precipitation is expected to increase as the atmosphere warms and holds more water vapor.

In Lane County, the number of days per year with at least 0.75 inches of precipitation is not projected to change substantially. However, by the 2050s, the amount of precipitation on the wettest day and wettest consecutive five days per year is projected to increase by an average of 13% (range 0–30%) and 9% (range -1–21%), respectively, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Lane County, the number of days per year on which a threshold for landslide risk, which is based on prior 18-day precipitation accumulation, is exceeded is not projected to change substantially. However, landslide risk depends on multiple factors, and this metric does not reflect all aspects of the hazard.

River Flooding

Winter flood risk at mid- to low elevations in Lane County, where temperatures are near freezing during winter and precipitation is a mix of rain and snow, is projected to increase as winter temperatures increase. The temperature increase will lead to an increase in the percentage of precipitation falling as rain rather than snow.

Drought

Drought, as represented by low summer soil moisture, low spring snowpack, low summer runoff, and low summer precipitation, is projected to become more frequent in Lane County by the 2050s.

Wildfire

Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase in Lane County by 12 days (range -6–29) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

In Lane County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 27 days (range 9–43) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality

The risk of wildfire smoke in Lane County is projected to increase. The number of days per year on which the concentration of wildfire-derived fine particulate matter results in poor air quality is projected to decrease by 5%, but the concentration of fine particulate matter is projected to increase by 58%, from 2004–2009 to 2046–2051 under a medium emissions scenario.

Coastal Erosion and Flooding

The risk of coastal erosion and flooding on the Oregon coast is expected to increase as climate changes due to sea level rise and changing wave dynamics.

In Lane County, local sea level is projected to rise by 1.7 to 5.7 feet by 2100. This projection is based on the intermediate-low to intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment. Because these local sea level projections account for estimated trends in vertical land movement, they are relative to the future land position.

Given these levels of sea level rise, the multiple-year likelihood of a flood reaching four feet above mean high tide is 45–83% by the 2030s, 93–100% by the 2050s, and 100% by 2100.

At risk within the four-foot inundation zone in Lane County as of the 2010 census were 116 people, $23 million in property value, nearly 9 miles of highways, roads, and railways, and more than 100 buildings.

Changes in Ocean Temperature and Chemistry

The open-ocean surface temperature off the Northwest coast increased by 1.2 ± 0.5°F since the year 1900 and is projected to increase by about another 5.0 ± 1.1°F by the year 2080. These changes in temperature may affect many other drivers of ocean change. For example, increases in temperature accelerate the rate of reduction of dissolved oxygen and increase the toxicity of harmful algal blooms. Ocean acidity is projected to increase by roughly 100–150%, resulting in a drop in open-ocean pH from 8.1 to 7.8, by the year 2100. The change in pH is likely to affect shell formation in diverse species of commercial, recreational, and cultural value.

Loss of Wetlands

In the Willamette Valley, losses of wetlands in recent decades largely were caused by conversion to agriculture. Projected effects of climate change on wetlands in the Northwest include reductions in water levels and hydroperiod duration. If withdrawals of ground water do not increase, then wetlands that are fed by ground water rather than surface water may be more resilient to climate change.

The structure, composition, and function of coastal wetland ecosystems will be affected by rising sea levels and saltwater intrusion, coastal erosion and flooding, changes in temperature and precipitation, and ocean acidification.

Wetland area in the Siuslaw River estuary is projected to decrease with increasing sea levels. Under 4.7 feet of sea level rise, tidal wetland area in these estuaries is projected to decrease by about 54%.

Windstorms

Limited research suggests little if any change in the frequency and intensity of windstorms in the Northwest as a result of climate change.

Expansion of Non-native Invasive Plants

In general, non-native invasive plants in Lane County are likely to become more prevalent in response to projected increases in temperature and the frequency, duration, and severity of drought. However, many of these responses are uncertain, are likely to vary locally, and may change over time.

Introduction

Industrialization has increased the amount of greenhouse gases emitted worldwide, which is causing Earth's atmosphere, oceans, and lands to warm (IPCC, 2021). Climate change and its effects already are apparent in Oregon (Dalton *et al.*, 2017; Mote *et al.*, 2019; Dalton and Fleishman, 2021). Climate change is expected to increase the likelihood of natural hazards such as heavy rains, river flooding, drought, heat waves, wildfires, and episodes of poor air quality, and to decrease the likelihood of cold waves.

Oregon's Department of Land Conservation and Development (DLCD) contracted with the Oregon Climate Change Research Institute (OCCRI) to analyze the influence of climate change on natural hazards. The scope of the analysis that yielded this report is limited to the geographic area encompassed by Marion, Linn, Lane, and Tillamook Counties, Oregon, which are the focus of the Pre-Disaster Mitigation (PDM) 19 grants that DLCD received from the Federal Emergency Management Agency. Products of OCCRI's analysis include county-specific data, graphics, and narrative summaries of climate projections related to ten climate-related natural hazards (Table 2). This information will be integrated into the Natural Hazards Mitigation Plan (NHMP) updates for the four counties, and can be used in other county plans, policies, and programs. In addition to the county reports, OCCRI will share data and provide other technical assistance to the counties. This report covers climate change projections related to natural hazards relevant to Lane County.

Table 2. Selected natural hazards and related climate metrics.

Heat Waves Hottest Day, Warmest Night Hot Days, Warm Nights	**Cold Waves** Coldest Day, Coldest Night Cold Days, Cold Nights
Heavy Rains Wettest Day, Wettest Five Days Wet Days, Landslide Risk Days	**River Flooding** Annual Maximum Daily Flows Atmospheric Rivers Rain-on-Snow Events
Drought Summer Flow, Spring Snow Summer Soil Moisture Summer Precipitation	**Wildfire** Fire Danger Days Extremely Dry Air Days
Reduced Air Quality Days with Unhealthy Smoke Levels	**Coastal Erosion and Flooding** Sea Level Rise Waves
Changes in Ocean Temperature and Chemistry	**Loss of Wetlands**
Windstorms	**Expansion of Non-native Invasive Species**

Future Climate Projections Background

Introduction

The county-specific future climate projections presented here are derived from 10–20 global climate models and two scenarios of future global emissions of greenhouse gases. The spatial resolution of projections from global climate models has been refined to better represent local conditions. County-level summaries of changes in climate metrics (Table 2) are projected to the beginning and middle of the twenty-first century relative to a historical baseline. More information about the data sources is in the Appendix.

Global Climate Models

Global climate models (GCMs) are computer models of Earth's atmosphere, ocean, and land and their interactions over time and space. The models are grounded in the fundamental laws of physics. Over time the spatial resolution of the models has increased and more physical, chemical, and biological processes, such as wildfire emissions and dynamic vegetation, have been included (Figure 1). The latest GCMs from the sixth phase of the Coupled Model Intercomparison Project (CMIP6), the climate modeling foundation of the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report, generally have higher resolution, better represent Earth system processes, and improve simulation of recent mean values of climate change indicators relative to older GCMs or versions of GCMs (IPCC, 2021). However, some CMIP6 models overestimate temperatures in the twentieth century, likely due to the difficulty of accurately simulating cloud dynamics. Consequently, the IPCC ranked climate models on the basis of their ability to reproduce twentieth-century temperatures, and used only the most accurate models to produce its official warming projections given different fossil fuel emissions scenarios (Hausfather *et al.*, 2022).

Differences in simulations of Oregon's projected average temperature between the fifth phase of the Coupled Model Intercomparison Project (CMIP5) and CMIP6 were estimated in the Fifth Oregon Climate Assessment (Dalton and Fleishman, 2021). The CMIP6 models generally projected greater warming over Oregon than the CMIP5 models, largely because temperature in the CMIP6 models was more sensitive to a doubling of atmospheric carbon dioxide. The latter outcome reflected a larger amplification of temperature increases by clouds within the CMIP6 models (Dalton and Fleishman, 2021; IPCC, 2021), which may or may not be realistic (Hausfather *et al.*, 2022). In view of this uncertainty, and because downscaled data from CMIP6 are not yet widely available, this report presents the more conservative projections from CMIP5 GCMs.

GCMs are the most sophisticated tools for understanding Earth's climate, but they still simplify the climate system. Because there are several ways to implement such simplifications, different GCMs yield somewhat different projections. Accordingly, it is best practice to average and report the range of projections from at least ten GCMs that simulate the historical climate well (Mote *et al.*, 2011; Hausfather *et al.*, 2022). More information about GCMs and uncertainty is in the Appendix.

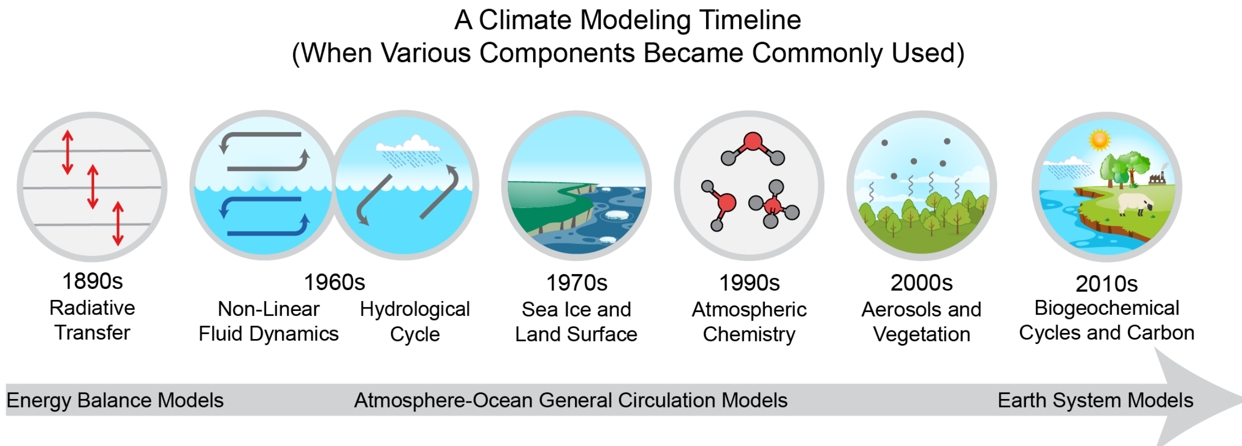


Figure 1. As scientific understanding of climate has evolved over the last 120 years, increasing amounts of physics, chemistry, and biology have been incorporated into global climate calculations, and over the second half of the twentieth century as computing resources became available, into global climate models. (Source: science2017.globalchange.gov)

Greenhouse Gas Emissions

When scientists use GCMs to project climate, they make assumptions about the quantity of future global emissions of greenhouse gases. The GCMs then simulate the effects of those emissions on the air, ocean, and land over the coming centuries. Because the precise amount of greenhouse gases that will be emitted in the future is unknown, scientists use multiple scenarios of greenhouse gas emissions that correspond to plausible societal trajectories. The CMIP5 models on which future climate projections in this report are based used Representative Concentration Pathways (RCPs) that describe different levels of radiative forcing. Radiative forcing is the total amount of energy retained in the atmosphere via changes in incoming solar radiation, reflectivity of the Earth's surface, and concentrations of heat-trapping greenhouse gases, and usually is estimated to the year 2100. A fixed greenhouse gas emissions trajectory was associated with each pathway. The higher the volume of global emissions, the greater the projected increase in global temperature (Figure 2). CMIP6 models used Shared Socio-economic Pathways (SSPs) that reflect sets of social and economic assumptions and can be associated with the different levels of emissions of CMIP5 RCPs (IPCC, 2021). Projections in this report assume a lower emissions pathway (RCP 4.5) and a higher emissions pathway (RCP 8.5). These are the most commonly used pathways, or scenarios, in the peer-reviewed literature, and downscaled data representing the effects of these scenarios on local climate are available. More information about emissions scenarios is in the Appendix.

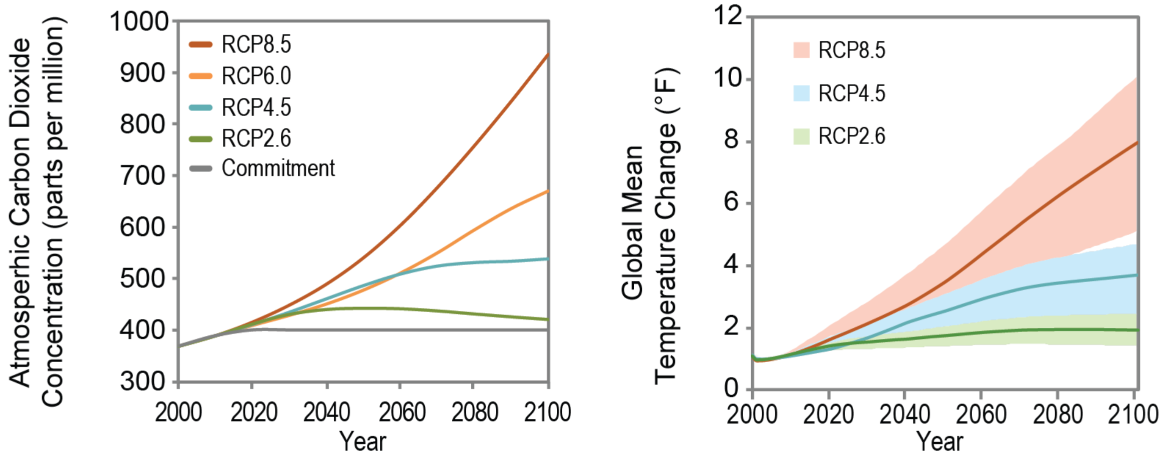


Figure 2. Future scenarios of atmospheric carbon dioxide concentrations (left) and projections of global temperature change (right) resulting from several different emissions scenarios, called Representative Concentration Pathways (RCPs), that were considered in the fourth National Climate Assessment. In the left plot, the gray line represents a scenario in which atmospheric carbon dioxide concentrations remain constant upon reaching 400 parts per million. In the right plot, the solid line and shading represent the mean and range of CMIP5 GCM simulations. (Source: science2017.globalchange.gov)

Downscaling

Global climate models simulate the climate across contiguous grid cells at coarse spatial resolutions, such that only one to three grid cells cover the state of Oregon. To make these coarse-resolution simulations more locally relevant, GCM outputs are combined statistically with historical observations, yielding higher-resolution projections. This process is called statistical downscaling. The future climate projections in this report were statistically downscaled to a resolution of about 2.5 by 2.5 miles (Abatzoglou and Brown, 2012). More information about downscaling is in the Appendix.

Future Time Periods

When analyzing GCM projections, it is best practice to compare the average of simulations across at least 30 future years to the average of simulations across at least 30 recent past years. The average over the 30 recent past simulated years is called the *historical baseline*. This report presents projections averaged over two future 30-year periods, 2010–2039 (2020s) and 2040–2069 (2050s), relative to the historical baseline from 1971–2000 (Table 3).

Because each of the 20 GCMs is based on slightly different assumptions, each yields a slightly different value for the historical baseline. Therefore, this report does not present the average and range of projected absolute values of variables. Instead, it presents the average and range of projected *changes* in values of climate variables relative to each model's historical baseline. The average of the 20 historical baselines, the *average historical baseline*, is also presented to aid in understanding the relative magnitude of projected changes. The 20-model average projected future change that appears in the tables can be added to the 20-model average historical baseline, which also appears in the tables, to infer the 20-model average projected future value of a given variable.

Table 3. Historical and future time periods over which projections were averaged.

Historical Baseline	2020s	2050s
1971–2000	2010–2039	2040–2069

How to Use the Information in this Report

Because the observational record may not include many values of climate variables nor the frequency of some extreme conditions that are projected to occur in the future, one cannot reliably anticipate future climate by considering only past climate. Future projections from GCMs enable exploration of a range of plausible outcomes given the climate system's complex response to increasing atmospheric concentrations of greenhouse gases. Projections from GCMs should not be interpreted as predictions of the weather on a given date, but rather as projections of climate, which is the long-term statistical aggregate of weather.[1]

The projected direction and magnitude of change in values of climate variables in this report are best interpreted relative to the historical climate conditions under which a particular asset or system was designed to operate. For this reason, considering the projected changes between the historical and future periods allows one to envision how natural and human systems will respond to future climate conditions that are different from past conditions. In some cases, the projected change may be small enough for the existing system to accommodate. In other cases, the projected change may be large enough to require adjustments, or adaptations, to the existing system. However, engineering or design projects would require an analysis that is more detailed than the analyses described in this report.

The information in this report can be used to

- Explore a range of plausible future outcomes that take into consideration the climate system's complex response to increasing concentrations of greenhouse gases
- Envision how current systems may respond under climate conditions different from those under which the systems were designed to operate
- Inform evaluation of potential mitigation actions within hazard mitigation plans to accommodate future conditions
- Inform a risk assessment in terms of the likelihood of occurrence of a particular climate-related hazard

[1] Read more: https://nca2014.globalchange.gov/report/appendices/faqs#narrative-page-38784

Average Temperature

Oregon's average temperature warmed at a rate of 2.2°F per century from 1895 through 2019 (Dalton and Fleishman, 2021). Average temperature is expected to continue increasing during the twenty-first century if global emissions of greenhouse gases continue; the rate of warming depends on the level of emissions (IPCC, 2021). By the 2050s (2040–2069), relative to the 1970–1999 historical baseline, Oregon's average temperature is projected to increase by 3.6°F (range of 1.8–5.4°F) under a lower emissions scenario (RCP 4.5) and by 5.0°F (range of 2.9–6.9°F) under a higher emissions scenario (RCP 8.5) (Dalton *et al.*, 2017; Dalton and Fleishman, 2021). Furthermore, summers are projected to warm more than other seasons (Dalton *et al.*, 2017; Dalton and Fleishman, 2021).

During the twenty-first century, average temperature in Lane County is projected to warm at a rate similar to that of Oregon as a whole (Figure 3). Projected increases in average temperature in Lane County relative to the 1971–2000 historical baseline in each global climate model (GCM), range from 1.0–3.4°F by the 2020s (2010–2039) and 1.5–6.4°F by the 2050s (2040–2069), depending on emissions scenario and GCM (Table 4).

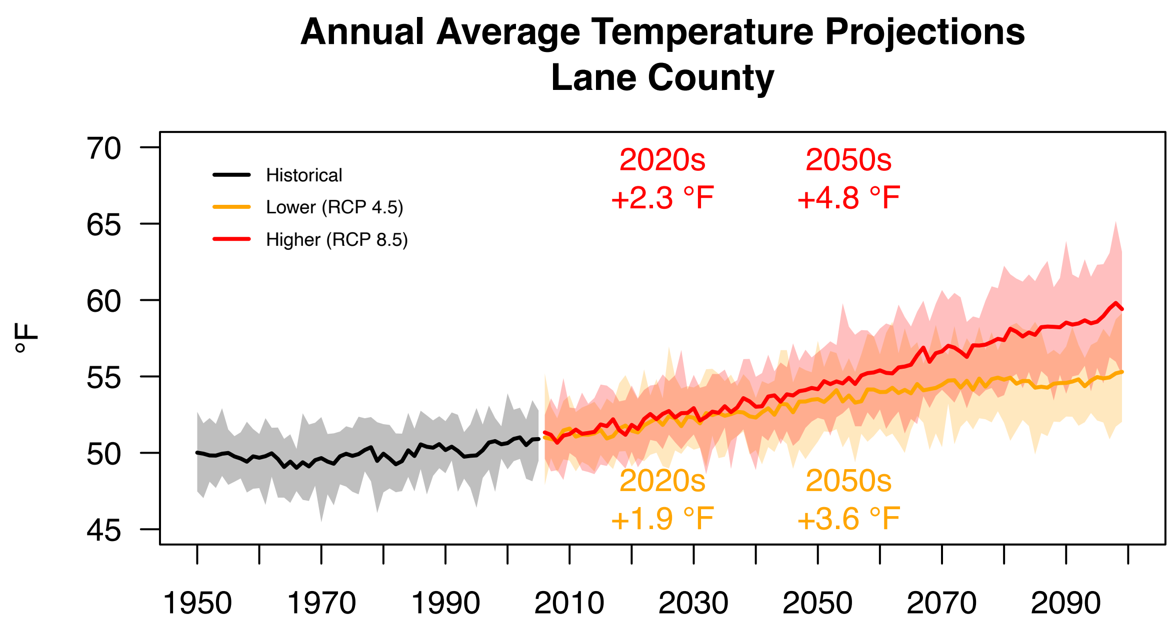


Figure 3. Projected annual average temperature in Lane County as simulated by 20 downscaled global climate models under a lower (RCP 4.5) and a higher (RCP 8.5) greenhouse gas emissions scenario. Solid lines and shading represent the 20-model mean and range, respectively. The figure shows the multiple-model mean differences between the average historical baseline (1971–2000 average) and the 2020s (2010–2039 average) and the 2050s (2040–2069 average).

Table 4. Projected future changes between the 1971–2000 baseline annual temperature in Lane County and annual temperature projected by each of 20 global climate models. Values are changes averaged across the 20 models (range in parentheses) for two emissions scenarios and two future time periods.

Emissions Scenario	2020s (2010–2039 average)	2050s (2040–2069 average)
Higher (RCP 8.5)	+2.3°F (1.3–3.4)	+4.8°F (2.8–6.4)
Lower (RCP 4.5)	+1.9°F (1.0–3.1)	+3.6°F (1.5–5.0)

Heat Waves

Extreme heat has become more frequent and intense worldwide since the 1950s, largely due to human-caused climate change (IPCC, 2021). The number, duration, and intensity of extreme heat events in Oregon is projected to increase due to continued warming temperatures. In fact, the temperature on the hottest days in summer is projected to increase even more than the mean summer temperature in the Northwest (Dalton *et al.*, 2017). Heat waves occur periodically as a result of natural variability in temperature, but human-caused climate change is increasing their severity (Vose *et al.*, 2017). In addition, evidence of increases in the number of summer extreme heat events that are defined by nighttime minimum temperatures is stronger than evidence of increases in the number of extreme heat events that are defined by maximum temperatures (Dalton and Fleishman, 2021).

Extreme heat can refer to days on which maximum or minimum temperatures are above a threshold, seasons in which temperatures are well above average, and heat waves, or multiple days on which temperature are above a threshold. This report presents projected changes in three metrics of extremes daytime heat (maximum temperature) and nighttime heat (minimum temperature) (Table 5).

Table 5. Metrics and definitions of heat extremes.

Metric	Definition
Hot Days	Number of days per year on which maximum temperature is 90°F or higher
Warm Nights	Number of days per year on which minimum temperature is 65°F or higher
Hottest Day	Highest value of maximum temperature per year
Warmest Night	Highest value of minimum temperature per year
Daytime Heat Waves	Number of events per year in which the maximum temperature on at least three consecutive days is 90°F or higher
Nighttime Heat Waves	Number of events per year in which the minimum temperature on at least three consecutive days is 65°F or higher

In Lane County, the number of hot days and warm nights, and the temperature on the hottest day and warmest night, are projected to increase by the 2020s (2010–2039) and 2050s (2040–2069) under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios (Table 6, Figure 4, Figure 5). For example, by the 2050s under the higher emissions scenario, the number of hot days, relative to each GCM's 1971–2000 historical baseline, is projected to increase by 5–30. The average number of hot days per year is projected to be 18 more than the average historical baseline of 4 days. The average number of warm nights per year is projected to be 4 more than the average historical baseline of virtually zero.

Similarly, under the higher emissions scenario, the temperature on the hottest day of the year is projected to increase by 2.0–9.2°F by the 2050s relative to the GCMs' historical baselines. The average projected increase in temperature on the hottest day is 6.5°F above the average historical baseline of 91.4°F. The average projected increase in temperature on the warmest night is 5.7°F above the average historical baseline of 61.2°F.

Under the higher emissions scenario, the numbers of daytime and nighttime heat waves are projected to increase by 0.9–3.5 and 0.0–1.2, respectively, by the 2050s relative to the GCMs' historical baselines. The average number of daytime and nighttime heat waves is projected to increase by 2.5 and 0.5, respectively, above the average historical baselines of 0.7 and zero (Table 6, Figure 6).

Table 6. Projected future changes in extreme heat metrics in Lane County. Changes from the 1971–2000 baseline were calculated for each of 20 global climate models and averaged across the 20 models (range in parentheses) for a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario and for the 2020s (2010–2039 average) and 2050s (2040–2069 average). The 20-model average projected future change can be added to the 20-model average historical baseline to infer the average projected future value of a given variable.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Hot Days	4.4 days	4.6 days (1.5-8.5)	6.2 days (2.5-8.4)	11.3 days (4.8-17.9)	18.2 days (5.2-29.7)
Warm Nights	0.3 days	0.4 days (0-1.2)	0.7 days (0-1.5)	1.7 days (0.2-4.3)	3.7 days (0.8-10.1)
Hottest Day	91.4°F	2.4°F (0.7-3.8)	3.1°F (1.2-4.8)	4.9°F (2.1-7.4)	6.5°F (2-9.2)
Warmest Night	61.2°F	1.9°F (0.2-3.6)	2.5°F (0.9-3.6)	4°F (1.9-6.7)	5.7°F (2.4-8.8)
Daytime Heat Waves	0.7 events	0.8 events (0.2-1.4)	1 events (0.4-1.6)	1.7 events (0.8-2.6)	2.5 events (0.9-3.4)
Nighttime Heat Waves	0 events	0 events (0-0.2)	0.1 events (0-0.2)	0.2 events (0-0.5)	0.5 events (0-1.2)

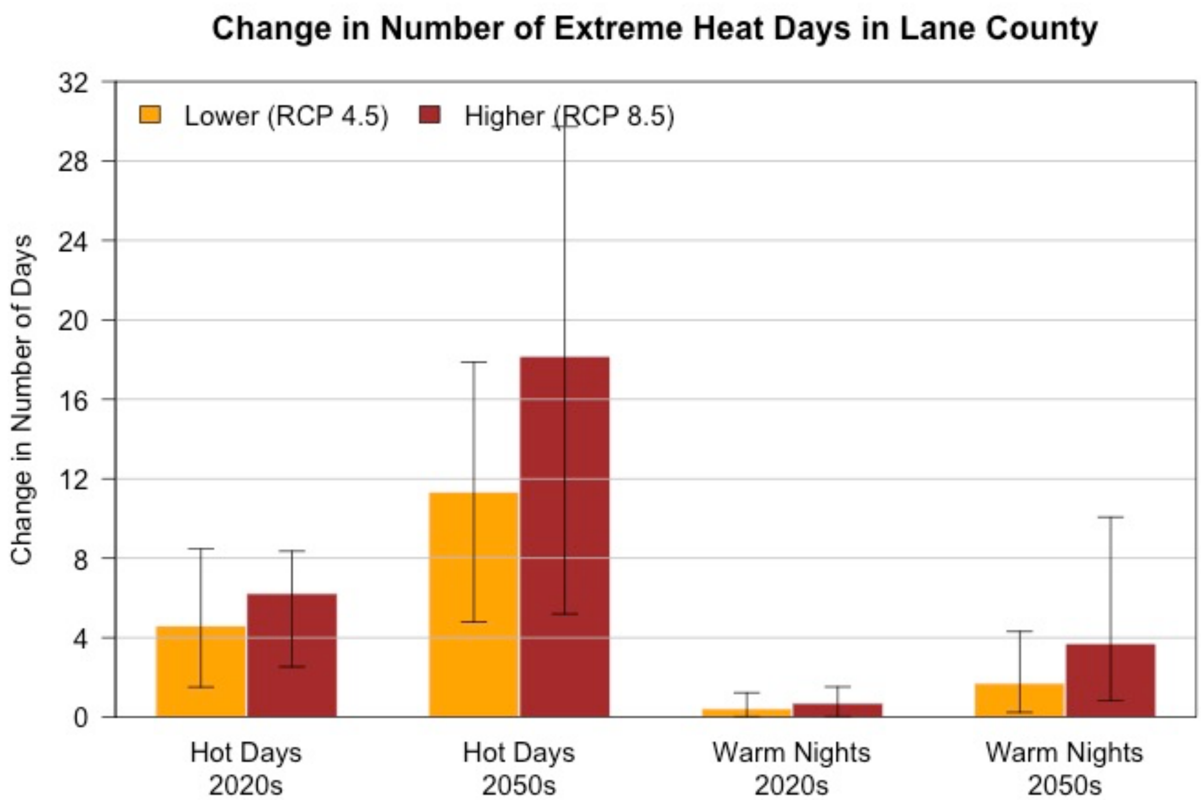


Figure 4. Projected changes in the number of hot days (left two sets of bars) and warm nights (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models. Hot days are those on which the maximum temperature is 90°F or higher; warm nights are those on which the minimum temperature is 65°F or higher.

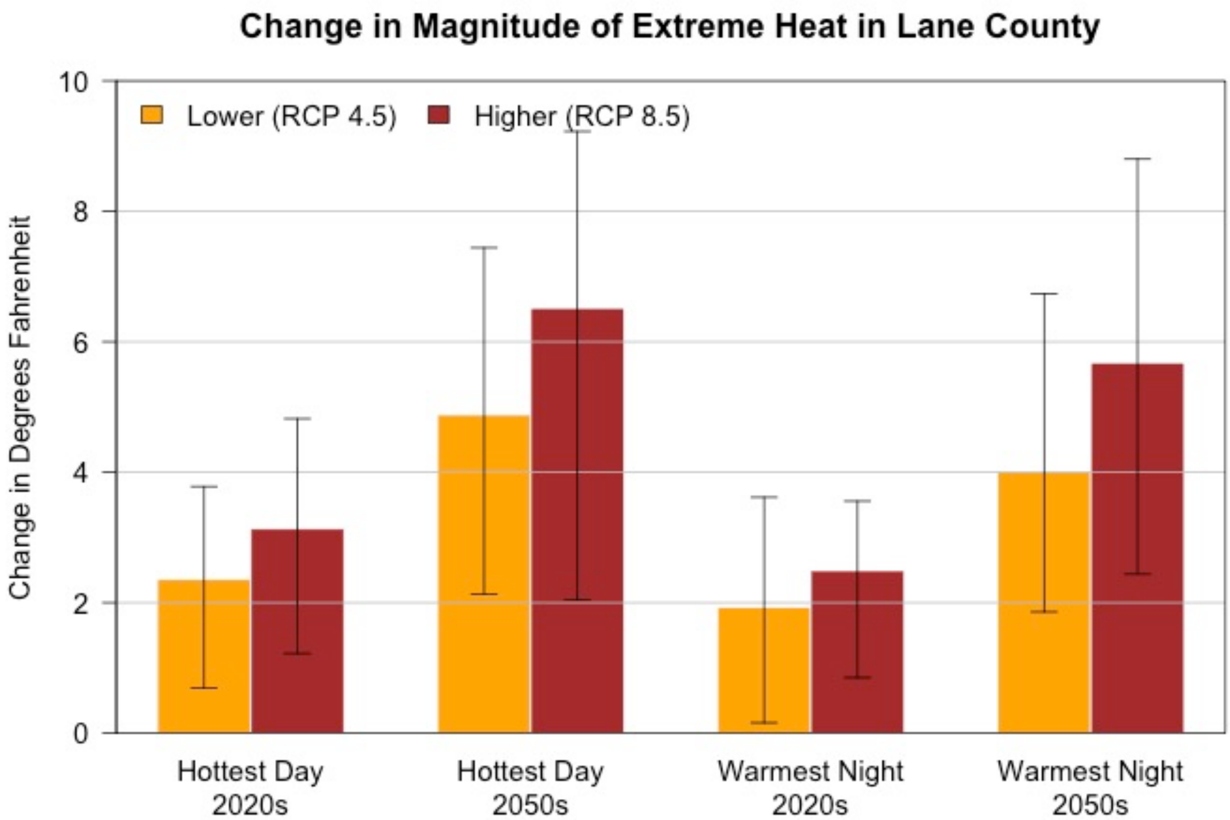


Figure 5. Projected changes in the temperature on the hottest day of the year (left two sets of bars) and warmest night of the year (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models.

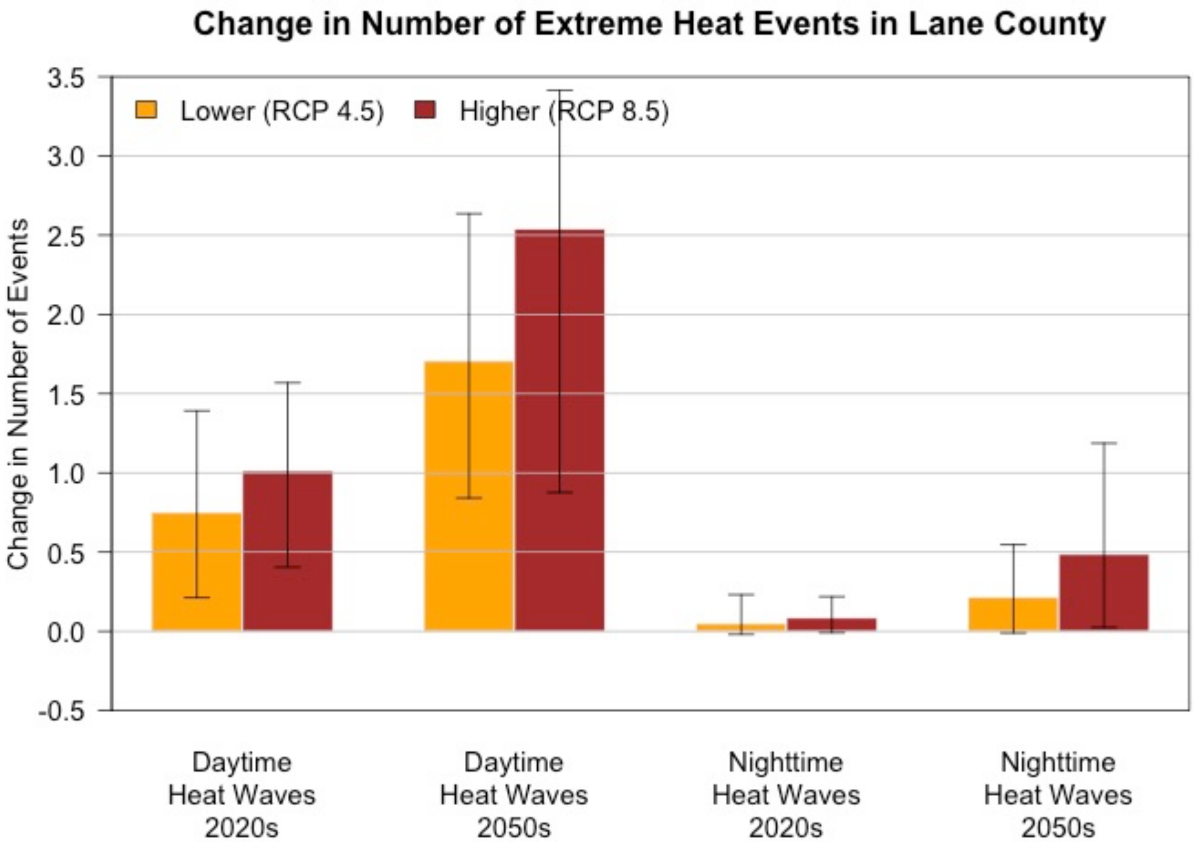


Figure 6. Projected changes in the number of daytime heat waves (left two sets of bars) and nighttime heat waves (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models. Daytime heat waves are defined as three or more consecutive days on which the maximum temperature is 90°F or higher; nighttime heat waves are three or more consecutive days on which the minimum temperature is 65°F or higher.

Key Messages

⇒ The number, duration, and intensity of extreme heat events will increase as temperatures continue to warm.

⇒ In Lane County, the number of extremely hot days (days on which the temperature is 90°F or higher) and the temperature on the hottest day of the year are projected to increase by the 2020s and 2050s under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios.

⇒ In Lane County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 18 days (range 5–30 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

⇒ In Lane County, the temperature on the hottest day of the year is projected to increase by an average of about 7°F (range 2–9°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Cold Waves

Over the past century, cold extremes have become less frequent and severe in the Northwest and worldwide. This trend is driven by human-caused climate change and is expected to continue (Vose *et al.*, 2017; IPCC, 2021). This report presents projected changes in three metrics of extreme daytime cold (maximum temperature) and nighttime cold (minimum temperature) (Table 7).

Table 7. Metrics and definitions of cold extremes.

Metric	Definition
Cold Days	Number of days per year on which the maximum temperature is 32°F or lower
Cold Nights	Number of days per year on which the minimum temperature is 0°F or lower
Coldest Day	Lowest value of maximum temperature per year
Coldest Night	Lowest value of minimum temperature per year
Daytime Cold Waves	Number of events per year in which maximum temperature on at least three consecutive days is 32°F or lower
Nighttime Cold Waves	Number of events per year in which minimum temperature on at least three consecutive days is 0°F or lower

In Lane County, the number of cold days and nights is projected to decrease by the 2020s (2010–2039) and 2050s (2040–2069) under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios (Table 8, Figure 7). For example, climate models projected that by the 2050s under the higher emissions scenario, the number of cold days will decrease by 2–5 relative to each GCM's 1971–2000 historical baseline. The average projected number of cold days per year is 3 less than the average historical baseline of 5 days. Nighttime temperatures rarely are lower than 0°F in Lane County.

Similarly, the temperatures on the coldest day and night are projected to increase by the 2020s and 2050s under both emissions scenarios (Table 8, Figure 8). For example, by the 2050s under the higher emissions scenario, the temperature on the coldest night of the year is projected to increase by 1.6–9.9°F relative to the GCMs' historical baselines. The average projected increase in the temperature on the coldest night is 5.6°F above the average historical baseline of 15.1°F. The average projected increase in the temperature on the coldest day is 4.7°F above the average historical baseline of 31.0°F. However, daytime and nighttime cold waves are rare in Lane County (Table 8, Figure 7, Figure 9).

Table 8. Projected future changes in extreme cold metrics in Lane County. Changes from the 1971–2000 baseline were calculated for each of 20 global climate models and averaged across the 20 models (range in parentheses) for a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario and for the 2020s (2010–2039 average) and 2050s (2040–2069 average). The 20-model average projected future change can be added to the 20-model average historical baseline to infer the average projected future value of a given variable.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Cold Days	4.8 days	-1.4 days (-2.8 - 0.1)	-1.9 days (-3.1 - -0.8)	-2.7 days (-3.7 - -1.2)	-3.2 days (-4.5 - -1.6)
Cold Nights	0.1 days	0 days (-0.1 - 0.2)	0 days (-0.1 - 0.2)	-0.1 days (-0.1 - 0)	-0.1 days (-0.1 - 0)
Coldest Day	31°F	1.1°F (-2.7 - 3.1)	2.2°F (-1.4 - 4.3)	3.6°F (0.1 - 6.2)	4.7°F (1.4 - 7.6)
Coldest Night	15.1°F	1.5°F (-1.8 - 5.1)	2.9°F (-0.1 - 6.1)	4.5°F (1.4 - 8)	5.6°F (1.6 - 9.9)
Daytime Cold Waves	0.6 events	-0.2 events (-0.3 - 0.1)	-0.2 events (-0.4 - -0.1)	-0.3 events (-0.5 - -0.1)	-0.4 events (-0.6 - -0.2)
Nighttime Cold Waves	0 events	0 events (0 - 0)	0 events (0 - 0)	0 events (0 - 0)	0 events (0 - 0)

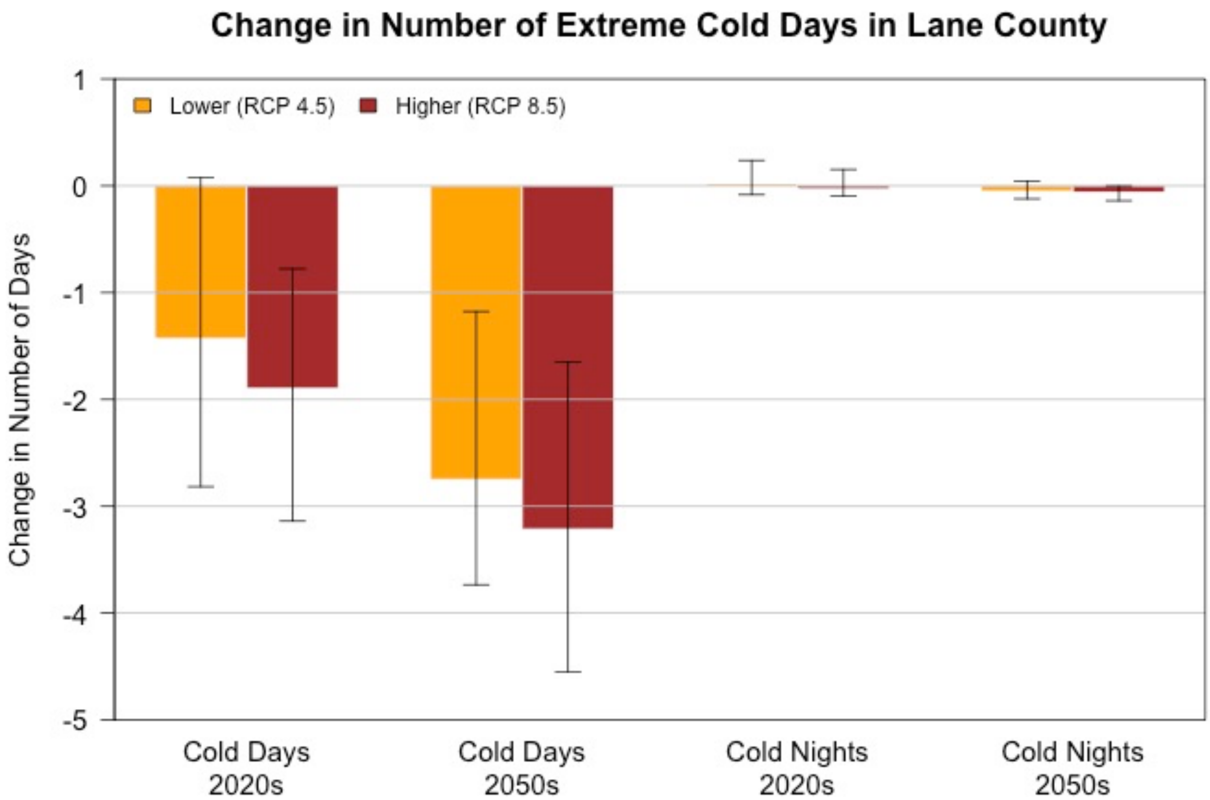


Figure 7. Projected changes in the number of cold days (left two sets of bars) and cold nights (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models. Cold days are those on which the maximum temperature is 32°F or lower; cold nights are those on which the minimum temperature is 0°F or lower.

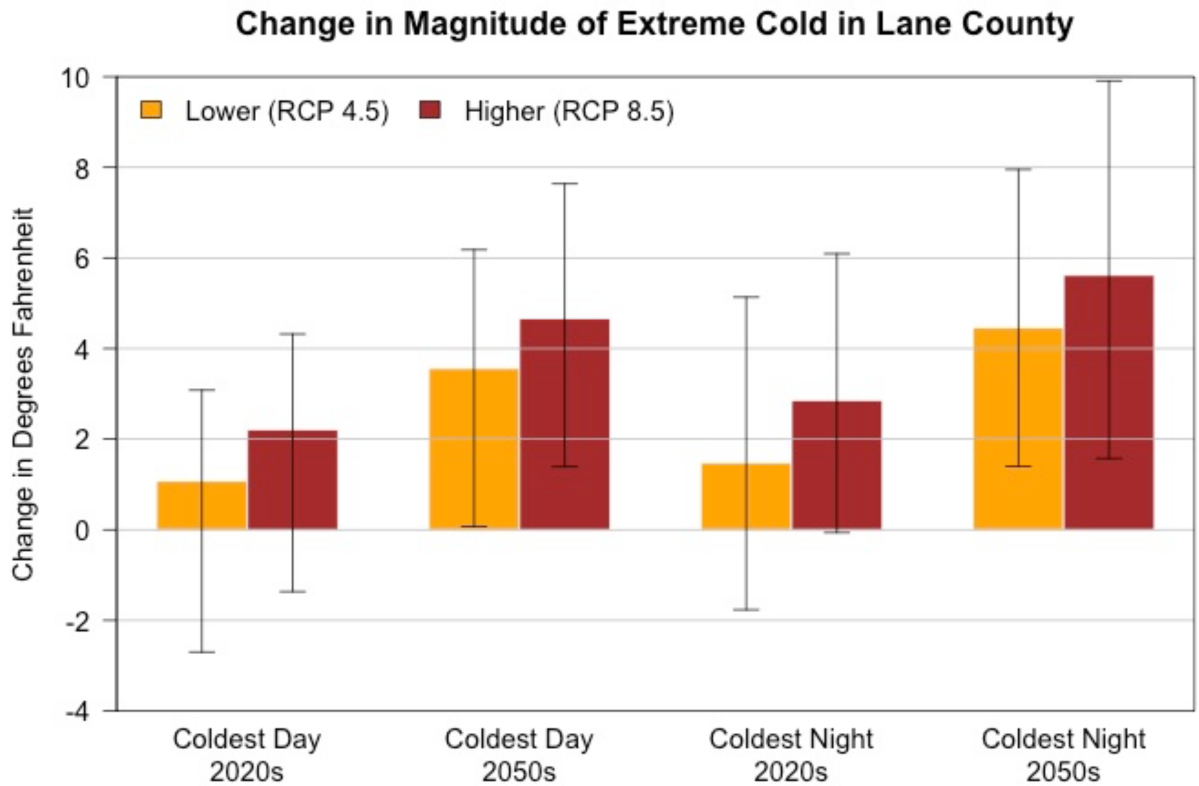


Figure 8. Projected changes in the temperature on the coldest day of the year (left two sets of bars) and coldest night of the year (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models.

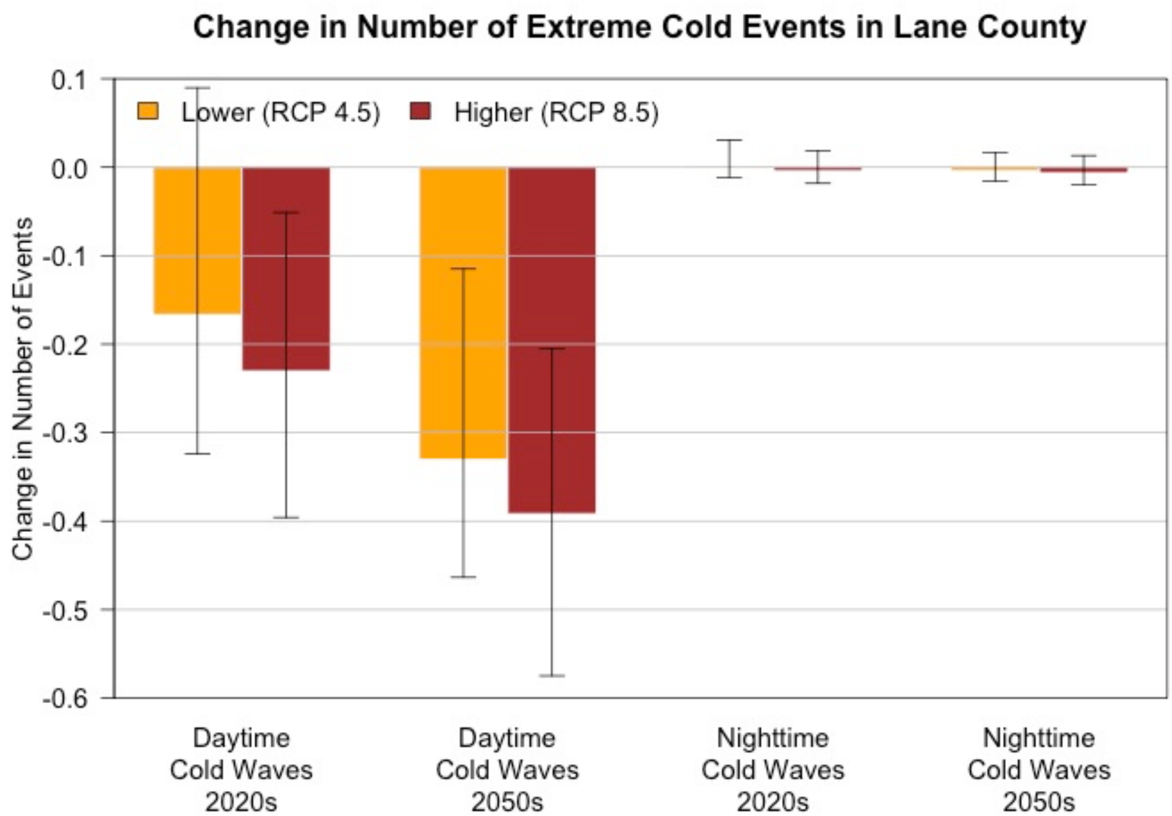


Figure 9. Projected changes in the number of daytime cold waves (left two sets of bars) and nighttime cold waves (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across 20 models. Daytime cold waves are defined as three or more consecutive days on which the maximum temperature is 32°F or lower; nighttime cold waves are three or more consecutive days on which the minimum temperature is 0°F or lower.

Key Messages

⇒ Cold extremes will become less frequent and intense as the climate warms.

⇒ In Lane County, the number of cold days (maximum temperature 32°F or lower) per year is projected to decrease by an average of 3 days (range -2– -5 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

⇒ In Lane County, the temperature on the coldest night of the year is projected to increase by an average of 6°F (range 2–10°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Heavy Rains

There is greater uncertainty in projections of future precipitation than projections of future temperature. Precipitation has high natural variability, and the atmospheric patterns that influence precipitation are represented differently among GCMs. Globally, mean precipitation is likely to decrease in many dry regions in the subtropics and mid-latitudes and to increase in many mid-latitude wet regions (IPCC, 2013; Stevenson *et al.*, 2022). Because the location of the mid-latitude boundary between increases and decreases in precipitation varies among GCMs, some models project increases and others decreases in precipitation in Oregon (Mote *et al.*, 2013).

Observed annual precipitation in Oregon has high year-to-year variability and has not changed significantly over the period of record; future trends in annual precipitation are expected to be dominated by natural variability (Dalton *et al.*, 2017; Dalton and Fleishman, 2021). On average, summers in Oregon are projected to become drier and other seasons to become wetter, resulting in a slight increase in annual precipitation by the 2050s. However, some models project increases and others decreases in each season (Dalton *et al.*, 2017). In addition, regional climate models project larger increases in winter precipitation east of the Cascade Range than west of the Cascade Range, which suggests a weakened rain shadow effect in winter (Mote *et al.*, 2019).

Extreme precipitation events in the Northwest are governed by atmospheric circulation and its interaction with complex topography (Parker and Abatzoglou, 2016). Atmospheric rivers—long, narrow swaths of warm, moist air that carry large amounts of water vapor from the tropics to mid-latitudes—generally result in extreme precipitation events across large areas west of the Cascade Range, and are associated with the majority of fall and winter extreme precipitation events in Oregon. By contrast, low pressure systems that are not driven by westerly flows from offshore often lead to locally extreme precipitation east of the Cascade Range (Parker and Abatzoglou, 2016).

The frequency and intensity of heavy precipitation has increased across most land areas worldwide since the 1950s (IPCC, 2021). Observed trends in the frequency of extreme precipitation events across Oregon vary among locations, time periods, and metrics, but overall, the frequency has not changed substantially. As the atmosphere warms, it holds more water vapor. As a result, the frequency and intensity of extreme precipitation, including atmospheric rivers, is expected to increase (Dalton *et al.*, 2017; Kossin *et al.*, 2017; Dalton and Fleishman, 2021). Regional climate models project a larger increase in precipitation extremes east of the Cascade Range than west of the Cascade Range (Mote *et al.*, 2019). Climate models project an increase in the number of days on which an atmospheric river is present, and that atmospheric rivers will account for an increasing proportion of total annual precipitation across the Northwest (Dalton and Fleishman, 2021). This report presents projected changes in four metrics of precipitation extremes (Table 9).

Table 9. Metrics and definitions of precipitation extremes.

Metric	Definition
Wettest Day	Highest one-day precipitation total per water year (1 October–30 September)
Wettest Five Days	Highest consecutive five-day precipitation total per water year
Wet Days	Number of days per water year on which precipitation exceeds 0.75 inches
Landslide Risk Days	Number of days per water year that exceed the landslide threshold developed by the US Geological Survey for Seattle, Washington (see https://pubs.er.usgs.gov/publication/ofr20061064). P3/(3.5-.67*P15)>1, where P3 = Precipitation accumulation on prior days 1–3 ▪ P15 = Precipitation accumulation on prior days 4–18

In Lane County, the amount of precipitation on the wettest day and wettest consecutive five days is projected to increase on average by the 2020s (2010–2039) and 2050s (2040–2069), relative to the 1971–2000 historical baseline, under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios (Table 10, Figure 10). However, some models project decreases in these metrics for certain time periods and scenarios.

Climate models project that by the 2050s under the higher emissions scenario, the amount of precipitation on the wettest day of the year, relative to each GCM's 1971–2000 historical baseline, will increase by 0.4–29.8% (Figure 10). The average projected amount of precipitation on the wettest day of the year is 12.9% greater than the average historical baseline of 2.6 inches.

Climate models project that by the 2050s under the higher emissions scenario, the amount of precipitation on the wettest consecutive five days of the year will change by -0.9–20.6% (Figure 10). The average projected amount of precipitation on the wettest consecutive five days is 9.2% above the average historical baseline of 6.5 inches.

The average number of days per year on which precipitation exceeds 0.75 inches is not projected to change substantially (Figure 11). For example, by the 2050s under the higher emissions scenario, the number of wet days per year is projected to increase by 0.3 (range -4.1–3.4). The historical baseline is an average of 24 days per year.

Landslides are often triggered by rainfall when the soil becomes saturated. As a surrogate measure of landslide risk, this report presents a threshold based on recent rainfall (cumulative precipitation over the previous 3 days) and antecedent precipitation (cumulative precipitation on the 15 days prior to the previous 3 days). By the 2050s under the higher emissions scenario, the average number of days per year in Lane County on which the landslide risk threshold is exceeded is projected to remain about the same, with a change of -0.2 days (range -4.0–4.3 days) (Figure 11). The historical baseline is an average of 30 days per year. Landslide risk depends on multiple site-specific factors, and this metric does not reflect all aspects of the hazard. The landslide risk threshold was developed for Seattle, Washington, and may be less applicable to other locations.

Landslide risk also can become high when heavy precipitation falls on an area that burned within approximately the past five to ten years. The probability that an extreme rainfall event will occur within one year after an extreme fire-weather event in Oregon or Washington was projected to increase by 700% from 1980–2005 to 2100 under the higher emissions scenario (Touma *et al.*, 2022). Similarly, projections suggest that by 2100, 90% of extreme fire-weather events across Oregon and Washington are likely to be succeeded within five years by three or more extreme rainfall events (Touma *et al.*, 2022). Although fire weather is not synonymous with wildfire, these results highlight the increasing likelihood of compounded climate extremes that elevate the risk of natural hazards.

Table 10. Projected future changes in extreme precipitation metrics in Lane County. Changes from the 1971–2000 baseline were calculated for each of 20 global climate models and averaged across the 20 models (range in parentheses) for a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario and for the 2020s (2010–2039 average) and 2050s (2040–2069 average). The 20-model average projected future change can be added to the 20-model average historical baseline to infer the average projected future value of a given variable.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Wettest Day	2.6 inches	7.6% (-0.3-25.5)	5.2% (-5.8-21.7)	10.7% (0.9-20)	12.9% (0.4-29.8)
Wettest Five-Days	6.5 inches	4.7% (-5.8-16.7)	3.3% (-5.2-17.3)	7.6% (-1.2-24.4)	9.2% (-0.9-20.6)
Wet Days	24.2 days	0.3 days (-2.2-2.9)	-0.3 days (-3.2-1.9)	0.5 days (-3-3.1)	0.3 days (-4.1-3.4)
Landslide Risk Days	29.6 days	-0.3 days (-3-3.1)	-0.5 days (-3.3-2.9)	-0.9 days (-3.9-1.7)	-0.2 days (-4-4.3)

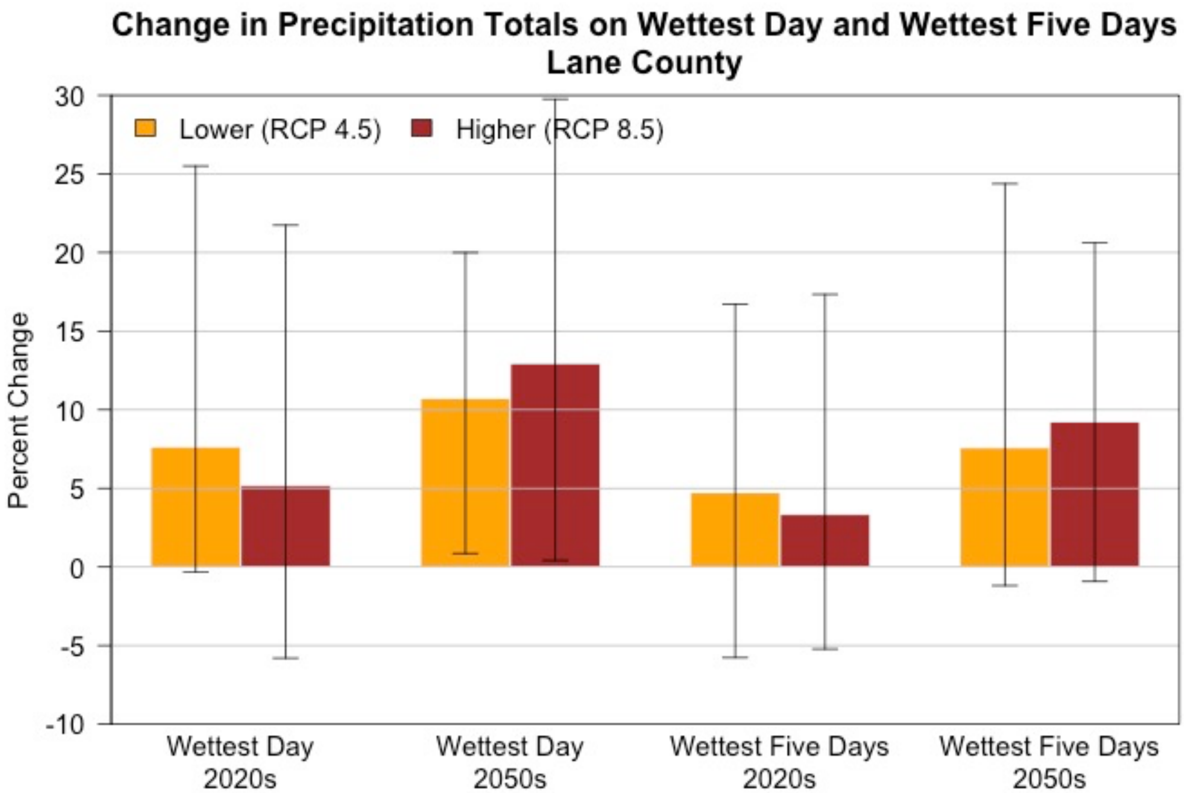


Figure 10. Projected percent changes in the amount of precipitation on the wettest day of the year (left two sets of bars) and wettest consecutive five days of the year (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models.

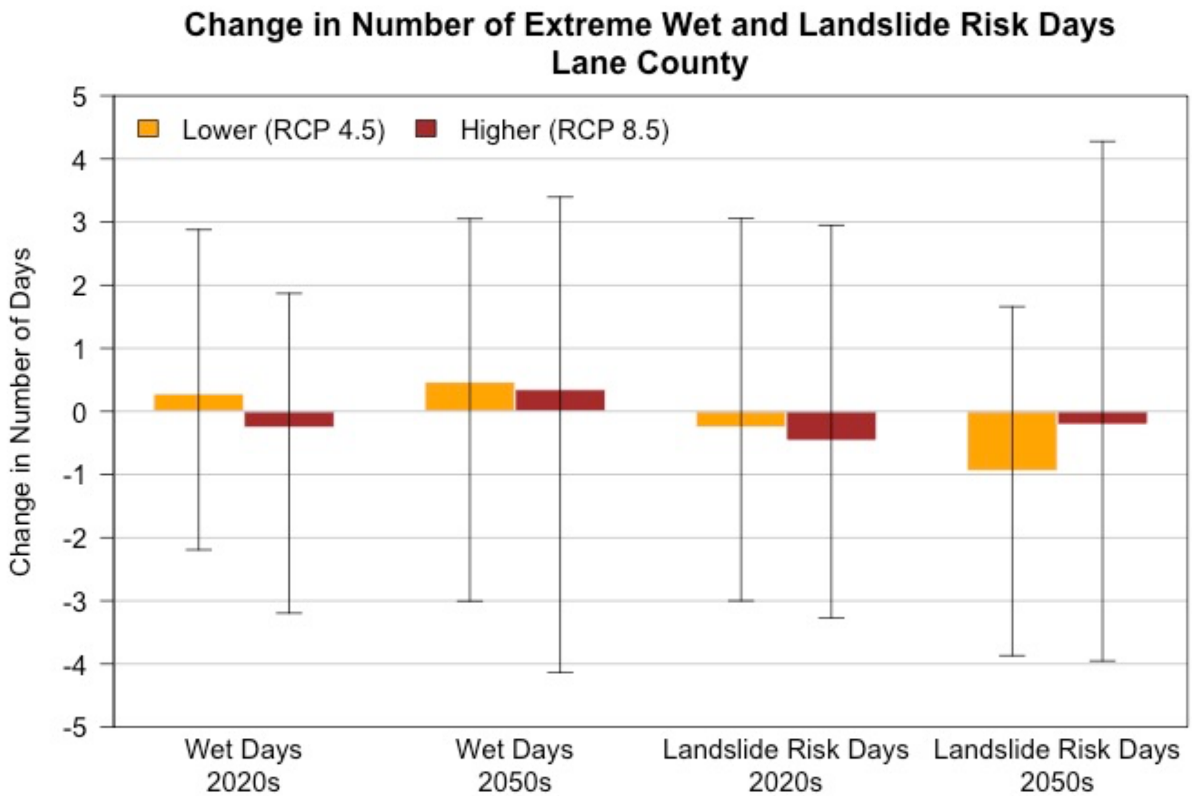


Figure 11. Projected changes in the number of wet days (left two sets of bars) and landslide risk days (right two sets of bars) in Lane County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models.

Key Messages

⇒ The intensity of extreme precipitation is expected to increase as the atmosphere warms and holds more water vapor.

⇒ In Lane County, the number of days per year with at least 0.75 inches of precipitation is not projected to change substantially. However, by the 2050s, the amount of precipitation on the wettest day and wettest consecutive five days per year is projected to increase by an average of 13% (range 0–30%) and 9% (range -1–21%), respectively, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

⇒ In Lane County, the number of days per year on which a threshold for landslide risk, which is based on prior 18-day precipitation accumulation, is exceeded is not projected to change substantially. However, landslide risk depends on multiple factors, and this metric does not reflect all aspects of the hazard.

River Flooding

Streams in the Northwest are projected to shift toward higher winter runoff, lower summer and fall runoff, and earlier peak runoff, particularly in snow-dominated regions (Raymondi *et al.*, 2013; Naz *et al.*, 2016). These changes are expected to result from increases in the intensity of heavy precipitation; warmer temperatures that cause more precipitation to fall as rain and less as snow, in turn causing snow to melt earlier in spring; and increasing winter precipitation and decreasing summer precipitation (Dalton *et al.*, 2017; Mote *et al.*, 2019; Dalton and Fleishman, 2021).

Warming temperatures and increasing winter precipitation are expected to increase flood risk in many basins in the Northwest, particularly mid- to low-elevation mixed rain-and-snow basins in which winter temperatures are near freezing (Tohver *et al.*, 2014). The greatest projected changes in peak streamflow magnitudes are at intermediate elevations in the Cascade Range and Blue Mountains (Safeeq *et al.*, 2015). Recent regional hydroclimate models project increases in extreme high flows throughout most of the Northwest, especially west of the Cascade crest (Salathé *et al.*, 2014; Najafi and Moradkhani, 2015; Naz *et al.*, 2016). One study, which used a single climate model, projected an increase in flood risk in fall due to earlier, more extreme storms, including atmospheric rivers; and an increase in the proportion of precipitation falling as rain rather than snow (Salathé *et al.*, 2014). Rainfall-driven floods are more sensitive to increases in precipitation than snowmelt-driven floods. Therefore, the projected increases in total precipitation, and in rain relative to snow, likely will increase flood magnitudes in the region (Chegwidden *et al.*, 2020).

This report presents monthly hydrographs of the McKenzie River at Leaburg (Figure 12) and the Middle Fork Willamette River at Dexter Reservoir (Figure 13). Both locations are within mixed rain-and-snow basins in which flow peaks during winter and, to a lesser degree, during spring snowmelt. By the 2050s (2040–2069), under both emissions scenarios, the monthly hydrographs are projected to shift as the basins become rain-dominated. Winter streamflow is projected to increase due to increased winter precipitation and the snowpack will melt earlier as temperatures increase and a greater percentage of precipitation falls as rain rather than snow. Other locations within Lane County, such as McKenzie River at Walterville, McKenzie River at Trail Bridge, South Fork McKenzie River at Cougar Reservoir, and Middle Fork Willamette River at Hills Creek Dam, have a similar hydrograph, and projections of future change at these locations also are similar. Mean monthly flows do not translate directly to flood risk because floods occur over shorter periods of time. However, increases in monthly flow may imply increases in flood likelihood, particularly if increases are projected to occur during months in which flood occurrence historically has been high.

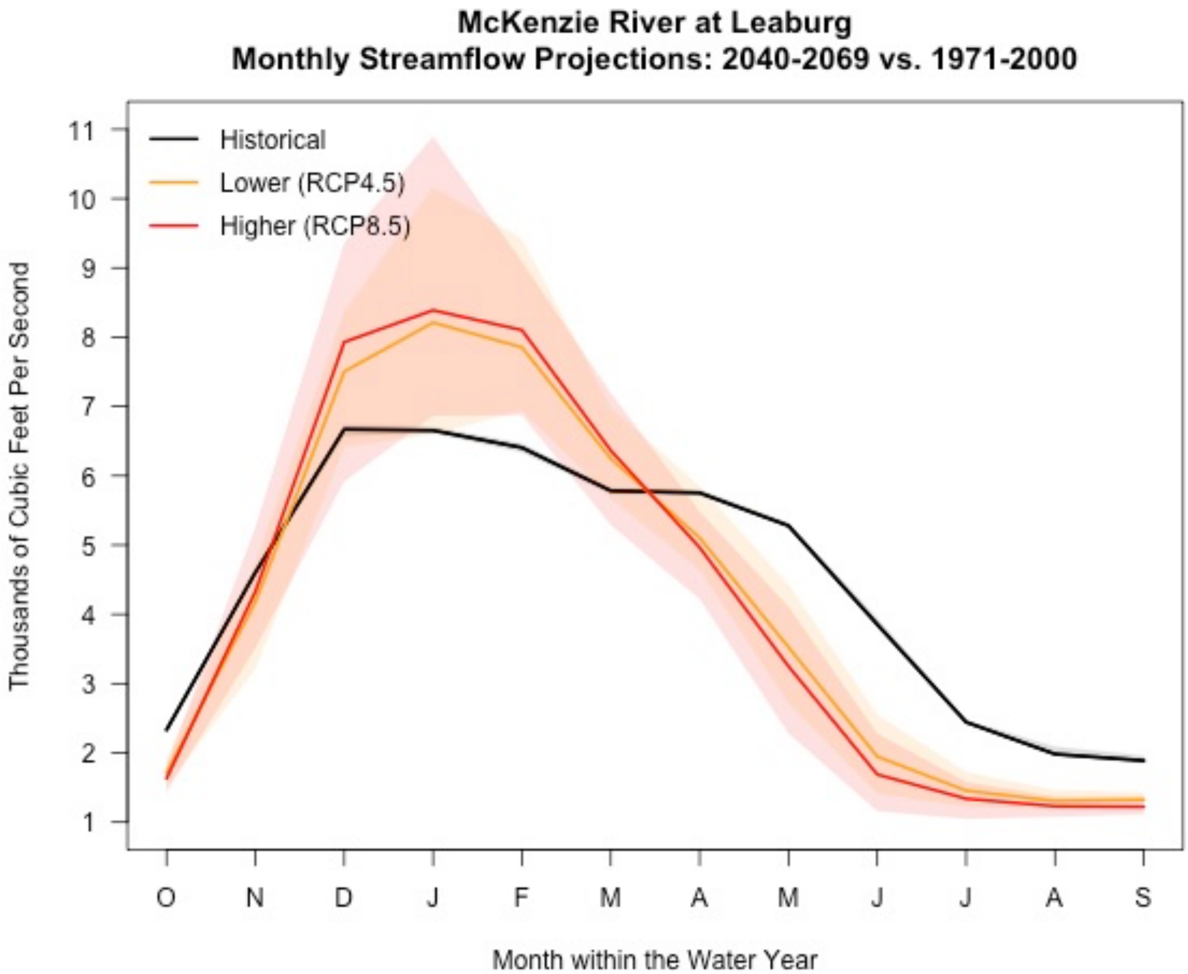


Figure 12. Simulated monthly, bias-corrected, non-regulated streamflow at the McKenzie River at Leaburg in 2040–2069 compared to 1971–2000. Solid lines and shading represent the mean and range across ten global climate models. (Data source: Integrated Scenarios of the Future Northwest Environment, https://climatetoolbox.org/tool/future-streamflows)

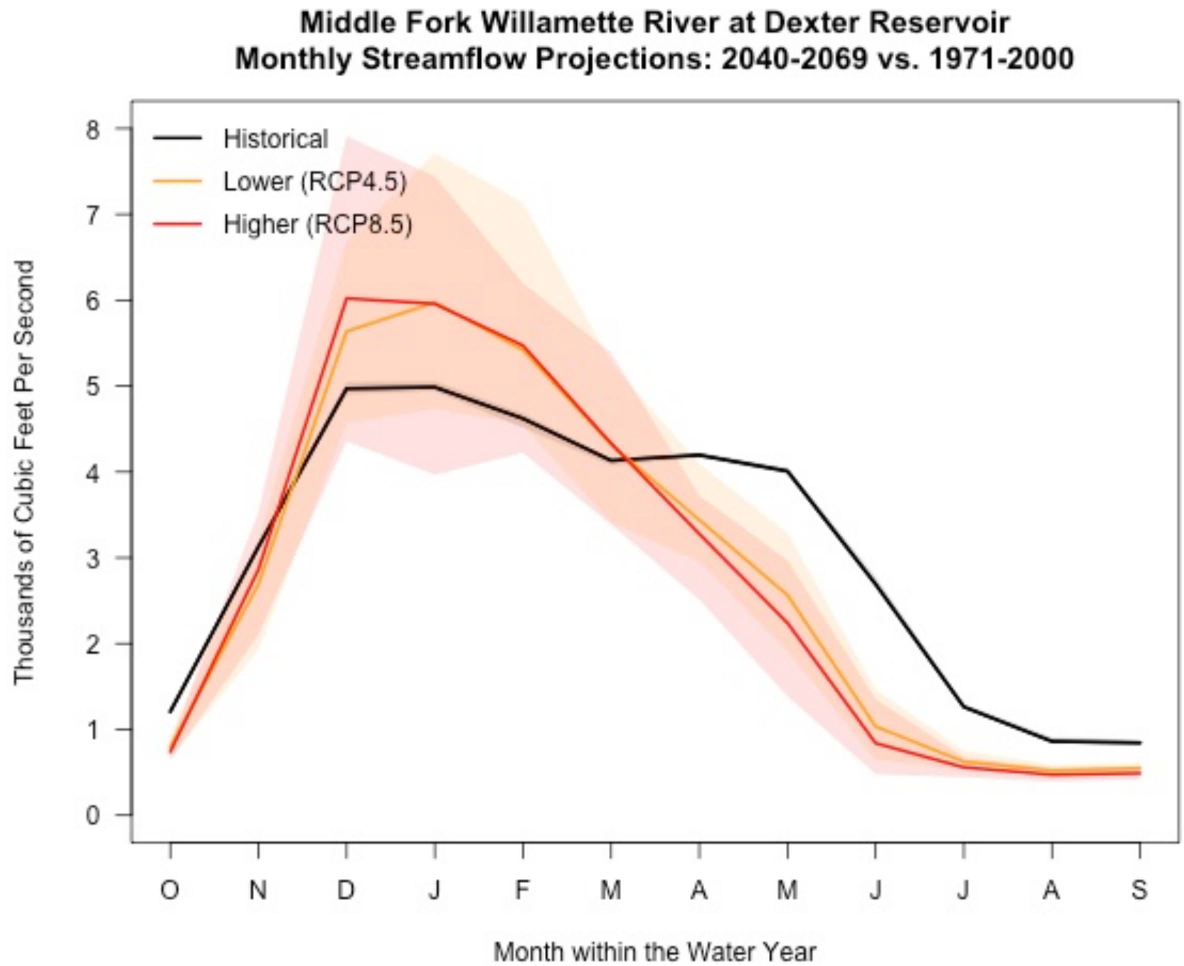


Figure 13. Simulated monthly, bias-corrected, non-regulated streamflow at the Middle Fork Willamette River at Dexter Reservoir in 2040–2069 compared to 1971–2000. Solid lines and shading represent the mean and range across ten global climate models. (Data source: Integrated Scenarios of the Future Northwest Environment, https://climatetoolbox.org/tool/future-streamflows)

Averaged across the western United States, major floods are projected to increase by 14–19% by the 2020s, 21–30% by 2040–2069, and 31–43% by 2070–2099, compared to the 1971–2000 historical baseline, under the higher emissions scenario (Maurer *et al.*, 2018). Major floods are defined as daily peak flow magnitudes that are associated with 100-year to 10-year return periods (1–10% probability that this daily flow magnitude will be exceeded in a given year). This report describes projected changes in single-day flood levels for six locations in Lane County in terms of the magnitude of water-year maximum daily flows with 2-year, 10-year, 25-year, and 100-year return periods (50%, 10%, 4%, and 1% probability, respectively, that this daily flow magnitude will be exceeded in a given year) (Table 11). Flood magnitudes are compared between a historical baseline period (1961–2010 or 1950–1999) and the 2050s (2031–2080) or the late twenty-first century (2050–2099). The results of the flood analysis can be interpreted as either an increase in flood magnitude given a flood frequency, or an increase in flood frequency given a flood magnitude. These analyses are exploratory and should not be applied to engineering or design.

On the McKenzie River at Leaburg, flood levels with 10-year and 100-year return periods (10% and 1% probability that this flood level would be exceeded in a given year) were projected to increase by 56% from 1950-1999 to 2050-2099 under the higher emissions scenario (Queen *et al.*, 2021) (Table 11). From 1961–2010 to 2031–2080, the average magnitudes of single-day floods with 2-year, 10-year, and 25-year return periods were projected to increase by 20%, 11%, and 9%, respectively, under the higher emissions scenario (RCP 8.5) (Table 11, Figure 14).

On the Middle Fork Willamette River at Dexter Reservoir, flood levels with 10-year and 100-year return periods (10% and 1% probability that this flood level would be exceeded in a given year) were projected to increase by 55% and 61%, respectively, from 1950-1999 to 2050-2099 under the higher emissions scenario (Queen *et al.*, 2021) (Table 11). From 1961–2010 to 2031–2080, the average magnitudes of single-day floods with 2-year, 10-year, and 25-year return periods were projected to increase by 15%, 18%, and 27%, respectively, under the higher emissions scenario (RCP 8.5) (Table 11, Figure 15). However, a few models projected no change or decreases in the magnitude of maximum daily flows for each return period and location.

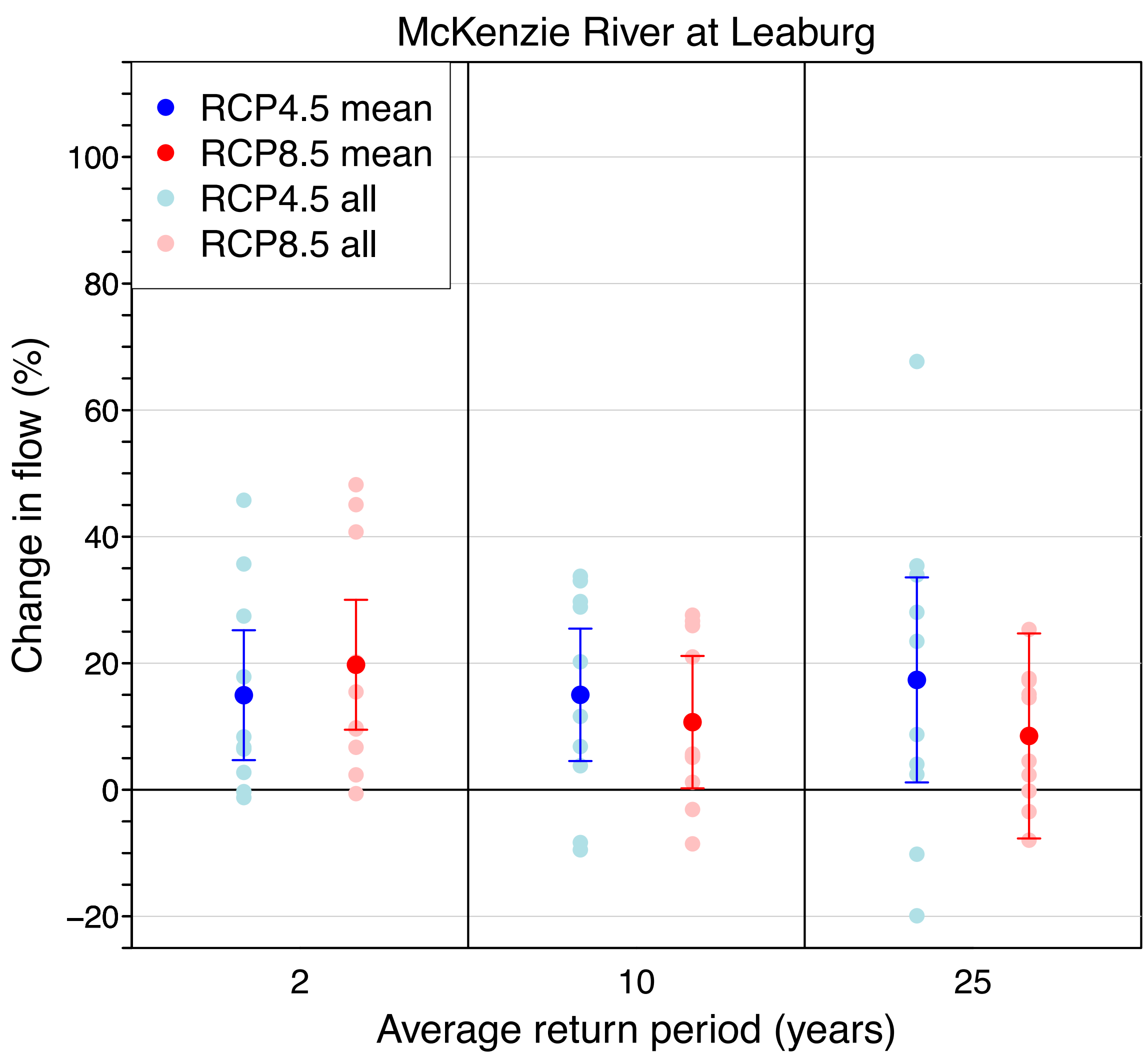


Figure 14. Projected change in water-year maximum daily, non-regulated streamflows with 2-year, 10-year, and 25-year return periods along the McKenzie River at Leaburg from 1961–2010 to 2031–2080 under lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios. Larger blue and red dots and bars represent the mean and two standard errors across ten global climate models. Only ten models simulated future hydrology out of the full set of 20 models that were used to project temperature and precipitation (see Appendix). Smaller light blue and light red dots represent projections from individual models. (Data source: Integrated Scenarios of the Future Northwest Environment, https://climate.northwestknowledge.net/IntegratedScenarios/; Figure source: David Rupp, OCCRI)

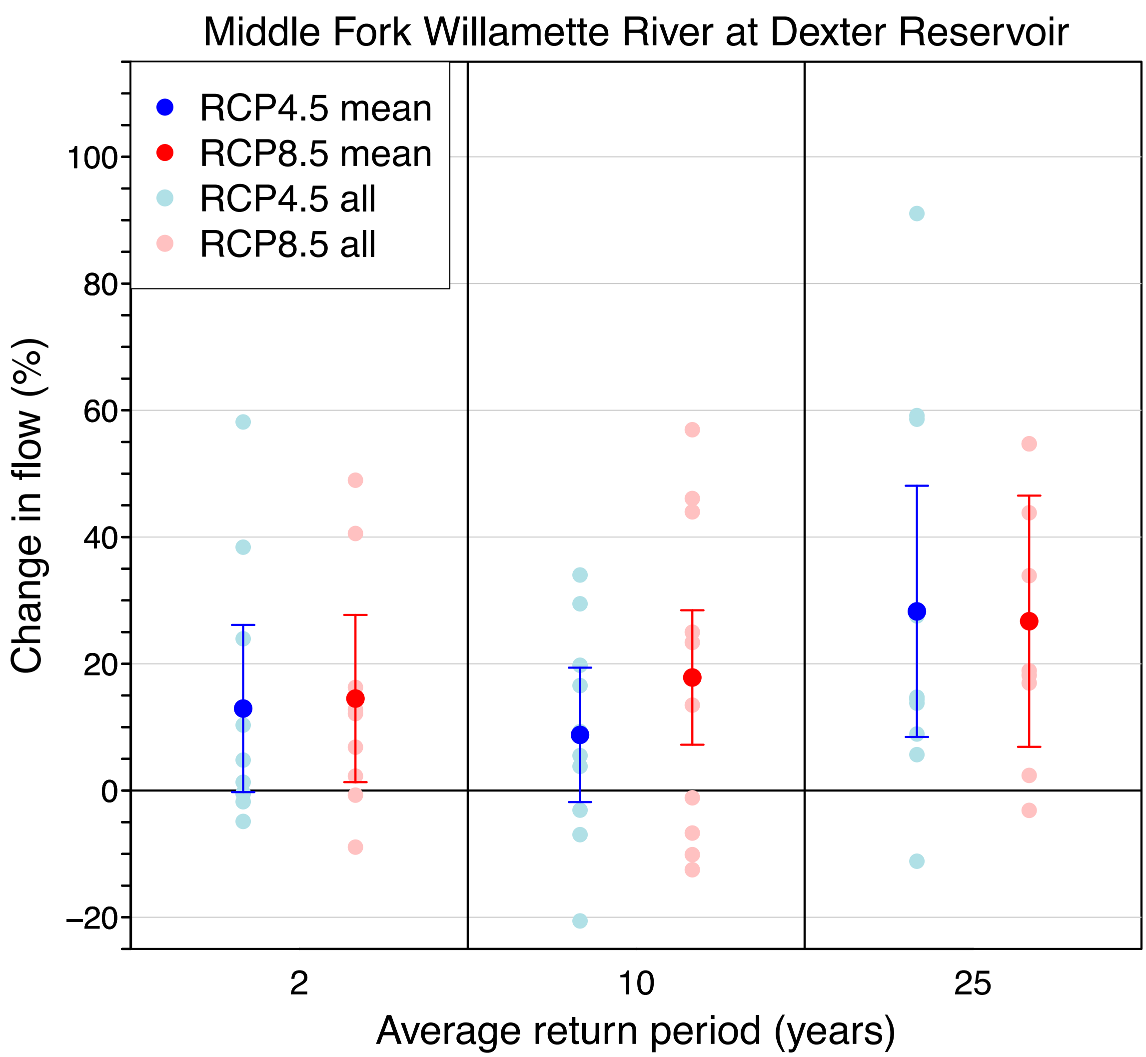


Figure 15. Projected change in water-year maximum daily, non-regulated streamflows with 2-year, 10-year, and 25-year return periods along the Middle Fork Willamette River at Dexter Reservoir from 1961–2010 to 2031–2080 under lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios. Larger blue and red dots and bars represent the mean and two standard errors across ten global climate models. Only ten models simulated future hydrology out of the full set of 20 models that were used to project temperature and precipitation (see Appendix). Smaller light blue and light red dots represent projections from individual models. (Data source: Integrated Scenarios of the Future Northwest Environment, https://climate.northwestknowledge.net/IntegratedScenarios/; Figure source: David Rupp, OCCRI)

Table 11. Average percent change in peak flow associated with multiple return periods for six locations in Lane County under the higher emissions scenario. The time period of analysis varies among sources.

Location	Time Period (Source)	Return Period (Probability that this level will be exceeded in a given year)			
		2-year (50%)	10-year (10%)	25-Year (4%)	100-Year (1%)
McKenzie River at Leaburg	2031–2080 vs. 1961–2010 (David Rupp)	19.8	10.7	8.5	--
	2050–2099 vs. 1950–1999 (Queen et al. 2021)	--	56	--	56
Middle Fork Willamette River at Dexter Reservoir	2031–2080 vs. 1961–2010 (David Rupp)	14.5	17.8	26.7	--
	2050–2099 vs. 1950–1999 (Queen et al. 2021)	--	55	--	61
McKenzie River at Walterville	2031–2080 vs. 1961–2010 (David Rupp)	19.3	15.9	10.4	--
	2050–2099 vs. 1950–1999 (Queen et al. 2021)	--	54	--	55
McKenzie River at Trail Bridge	2031–2080 vs. 1961–2010 (David Rupp)	22.1	22.8	42.7	--
South Fork McKenzie River at Cougar Reservoir	2031–2080 vs. 1961–2010 (David Rupp)	27.2	8.8	10.3	--
Middle Fork Willamette River at Hills Creek Dam	2031–2080 vs. 1961–2010 (David Rupp)	23.7	19.2	25.9	--
	2050–2099 vs. 1950–1999 (Queen et al. 2021)	--	57	--	60

Some of the Northwest's highest floods occur when large volumes of warm rain from atmospheric rivers fall on a deep snowpack, resulting in rain-on-snow floods (Safeeq *et al.*, 2015). The frequency and amount of moisture transported by atmospheric rivers is projected to increase along the West Coast in response to increases in air temperature (Kossin *et al.*, 2017), which in turn increase the likelihood of flooding (Konrad and Dettinger, 2017).

Future changes in the frequency of rain-on-snow events likely will vary along an elevational gradient. At lower elevations, the frequency is projected to decrease due to decreasing snowpack, whereas at higher elevations the frequency is projected to increase due to the shift from snow to rain (Surfleet and Tullos, 2013; Safeeq *et al.*, 2015; Musselman *et al.*, 2018). How such changes in frequency of rain-on-snow events are likely to affect streamflow varies. For example, projections for the Santiam River, Oregon, indicate an increase in annual peak daily flows at return intervals less than 10 years, but a decrease in annual peak daily flows at return intervals greater than or equal to 10 years (Surfleet and Tullos, 2013). Average runoff from rain-on-snow events in watersheds in northern coastal Oregon is projected to decline due to depletion of the snowpack (Musselman *et al.*, 2018), which may imply that the driver of floods in these areas shifts from rain-on-snow events to extreme rainfall that exceeds soil capacity (Berghuijs *et al.*, 2016; Musselman *et al.*, 2018). Shifts in vegetation and wildfire occurrences that affect soil properties also will likely affect water transport, but hydrological models generally have not accounted for these processes (Bai *et al.*, 2018; Wang *et al.*, 2020; Williams *et al.*, 2022).

Key Messages

⇒ Winter flood risk at mid- to low elevations in Lane County, where temperatures are near freezing during winter and precipitation is a mix of rain and snow, is projected to increase as winter temperatures increase. The temperature increase will lead to an increase in the percentage of precipitation falling as rain rather than snow.

Drought

Drought is common in the Northwest. The incidence, extent, and severity of drought has increased over the last 20 years relative to the twentieth century, and this trend is expected to continue under future climate change (Dalton and Fleishman, 2021). Drought can be defined in many ways (Table 12), but most fundamentally is insufficient water to meet needs (Redmond, 2002; Dalton and Fleishman, 2021).

Table 12. Definitions and characteristics of various drought classes. (Source: Dalton and Fleishman, 2021; Fleishman *et al.*, unpublished)

Drought Class	Definition and Characteristics
Meteorological	• lack of precipitation • evaporative demand that exceeds precipitation • minimum period of time for consideration operationally is 90 days
Hydrological	• prolonged meteorological drought affects surface or subsurface water supply, such as streamflow, reservoir and lake levels, or groundwater levels • tends to evolve more slowly than meteorological drought, with extents longer than six months
Agricultural	• occurs when meteorological and hydrological drought impacts agricultural production • reflects precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced availability of irrigation water
Socioeconomic	• occurs when meteorological, hydrological, or agricultural drought reduces the supply of some economic or social good or service • often affects state and federal drought declarations
Ecological	• undesirable changes in ecological state caused by deficits in water availability • usually caused by meteorological or hydrological drought • sensitivity to water limitation varies among species and life stages
Flash	• relatively short periods of warm surface temperatures, low relative humidities and precipitation deficits, and rapidly declining soil moisture • tends to develop and intensify rapidly within a few weeks, and may be generated or magnified by prolonged heat waves
Snow	• snowpack—or snow water equivalent (SWE)—is below average for a given point in the water year, traditionally 1 April • often followed by summers with low river and stream flows • warm snow drought—low snowpack with above average precipitation and temperature • dry snow drought—low snowpack and low precipitation

Summers in Oregon are expected to become warmer and drier, and mountain snowpack is projected to decline due to warmer winter temperatures (Dalton and Fleishman, 2021). Across the western United States, the decline in mountain snowpack is projected to reduce summer soil moisture in the mountains (Gergel *et al.*, 2017). Climate change is expected to result in lower summer streamflows in snow-dominated and mixed rain-and-snow basins across the Northwest as snowpack melts earlier due to warmer temperatures and decreases in summer precipitation (Dalton *et al.*, 2017; Mote *et al.*, 2019). For example, summer flow is projected to decrease in the McKenzie River at Leaburg (Figure 12) and in the Middle Fork Willamette River at Dexter Reservoir (Figure 13) by the 2050s (2040–2069). As mountain snowpack declines, seasonal drought will become less predictable and snow droughts will increase the likelihood of meteorological and hydrological drought in subsequent seasons (Dalton and Fleishman, 2021).

This report presents projected changes in four variables indicative of drought: low spring snowpack (snow drought), low summer soil moisture from the surface to 55 inches below the surface (agricultural drought), low summer runoff (hydrological drought), and low summer precipitation (meteorological drought). Drought is presented in terms of a change in the probability of exceeding the magnitude of seasonal drought conditions for which the historical annual probability of exceedance was 20% (5-year return period) (Figure 16).

In Lane County, summer (June–August) soil moisture, spring (April 1) snowpack, summer runoff, and summer precipitation are projected to decline by the 2050s under both lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios. Therefore, seasonal drought conditions will occur more frequently by the 2050s (Figure 16). By the 2050s under the higher emissions scenario, the annual probability of low summer soil moisture is projected to be about 53% (1.9-year return period). The annual probabilities of low spring snowpack, low summer runoff, and low summer precipitation are projected to be about 70% (1.4-year return period), 68% (1.5-year return period), and 30% (3.4-year return interval), respectively. Drought projections for the 2020s were not evaluated due to data limitations, but drought magnitudes in the 2020s likely will be smaller than those in the 2050s.

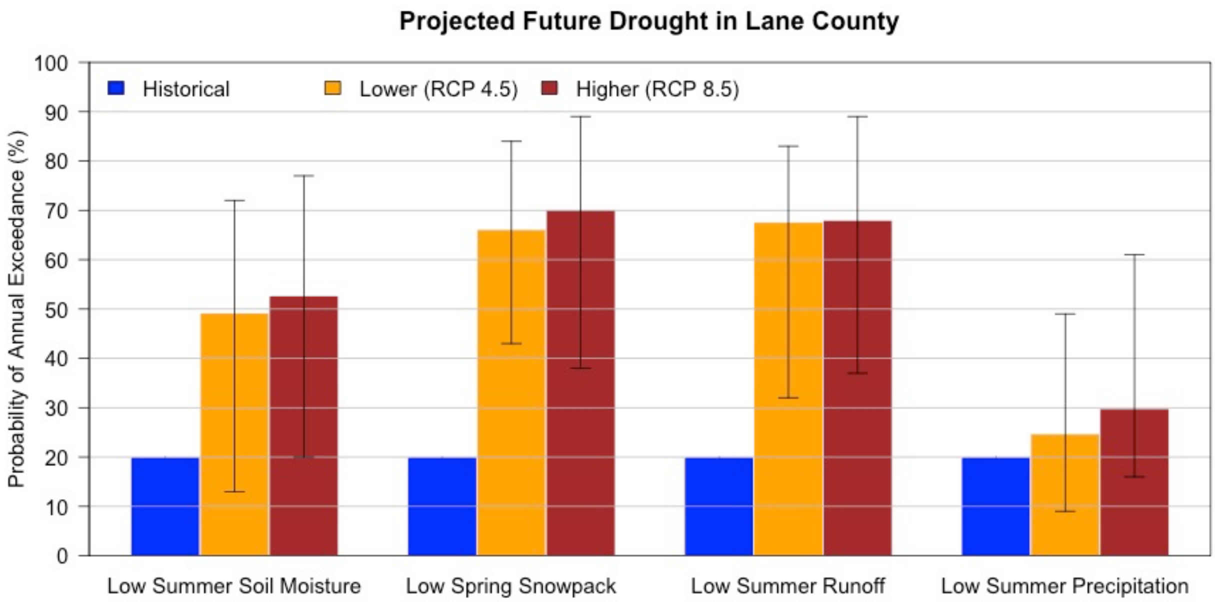


Figure 16. Projected probability of exceeding the magnitude of seasonal drought conditions for which the historical annual probability of exceedance was 20%. Projections are for the 2050s (2040–2069), relative to the historical baseline (1971–2000), under two emissions scenarios. Seasonal drought conditions include low summer soil moisture (average from June through August), low spring snowpack (April 1 snow water equivalent), low summer runoff (total from June through August), and low summer precipitation (total from June through August). The bars and whiskers represent the mean and range across ten global climate models. (Data Source: Integrated Scenarios of the Future Northwest Environment, https://climate.northwestknowledge.net/IntegratedScenarios/)

Key Messages

⇒ Drought, as represented by low summer soil moisture, low spring snowpack, low summer runoff, and low summer precipitation, is projected to become more frequent in Lane County by the 2050s.

Wildfire

Human activities have modified fire dynamics in the western United States through clearance of native vegetation for agriculture and urbanization, fragmentation and exploitation of forests and other natural land-cover types, human population growth and increased recreational activities, introduction of highly flammable, non-native annual grasses, and replacement of indigenous or natural fires by extensive fire suppression and vegetation management. From 1985 through 2017, the annual area burned by high-severity fires across forests in the western United States increased eightfold (Parks and Abatzoglou, 2020). However, area burned did not increase in naturally cool rainforests on the west side of the Cascade Range. Historically, wildfires in these rainforests occurred every few centuries due to the lack of ignitions and moist vegetation.

Over the last several decades, warmer and drier summers across the western United States have contributed to an increase in vegetation dryness and outbreaks of native insect herbivores, which contribute to increases in the volume of dead vegetation. Concurrently, the duration of the wildfire season has increased across the region (Dennison *et al.*, 2014; Jolly *et al.*, 2015; Westerling, 2016; Williams and Abatzoglou, 2016), largely due to warmer springs that cause earlier snowmelt and to an overall decline in mountain snowpack, mostly in response to warmer winters (Westerling, 2016).

Vegetation dryness is often caused by dry air. Vapor pressure deficit (VPD) corresponds to the difference in atmospheric pressure between water vapor in the air and the air's saturation point, which is the maximum amount of water the air can carry at a given temperature (dew point). This pressure difference drives transpiration by the plants' stomata. VPD and other measures of atmospheric dryness, such as evaporative demand, are more strongly associated with forest area burned than precipitation, drought indices, or temperature (Sedano and Randerson, 2014; Williams *et al.*, 2014; Seager *et al.*, 2015; Rao *et al.*, 2022). The area of forest burned annually is expected to increase exponentially with projected increases in VPD across the western United States (Zhuang *et al.*, 2021; Juang *et al.*, 2022).

CMIP6 climate model results suggest that human emissions of greenhouse gases can explain a large percentage of the observed VPD increase (Zhuang *et al.*, 2021). In the western United States from 1984 through 2015, about half of the observed increase in vegetation dryness—driven mainly by the dryness of the air—and 4.2 million hectares (16,000 square miles) of burned area were attributable to human-caused climate change (Abatzoglou and Williams, 2016).

Fire danger is generally evaluated on the basis of daytime conditions that may cause wildfires to spread. Historically, wildfires were less active overnight. However, nights have become hotter and drier, and the temperature and duration of wildfires is expected to increase as a result (Balch *et al.*, 2022). In the western United States, the number of nights during which atmospheric conditions are conducive to burning has increased by 45% since 1979 (Balch *et al.*, 2022).

Vegetation can also amplify or dampen the effect of aridity on wildfires. The geographic co-occurrence of plants with high water sensitivity (e.g., plants that do not close their stomata, shallow-rooted plants on porous soils) and high VPD suggests that the distribution of vegetation in the western United States has amplified the effect of climate change on wildfire hazard (Rao *et al.*, 2022).

High temperatures contribute to the drying of dead vegetation, and high VPD reduces moisture in live vegetation (e.g., the tree canopy), increasing the likelihood that any source of ignition will create a wildfire. The interaction between continued development in areas with flammable vegetation and increases in VPD suggests that projections of changing wildfire risk in the western United States may be conservative (Rao *et al.*, 2022), especially given that over 80% of all ignitions in the United States are now human-caused (Balch *et al.*, 2017) and that human activities have extended both the temporal and geographic extent of the fire season (Balch *et al.*, 2017; Bowman *et al.*, 2020). Furthermore, extreme wildfires may correspond to concurrent weather extremes, including high temperatures, aridity, and wind speeds. Coincidence among these extremes is becoming more common (Abatzoglou *et al.*, 2021a).

In 2020, the Santiam Fire became an exemplar of such a combination of extreme fire danger conditions that were unprecedented in the contemporary data record—a late summer that was warm and dry, extremely dry live and dead vegetation, and strong and dry east winds. These fires causes widespread loss of structures and the loss of five human lives (Abatzoglou *et al.*, 2021b). Management practices also likely affected the severity of the fire (Reilly *et al.*, 2017). For example, uniform canopy structure, which is common in forest plantations, can lead to subcanopy winds that transport moisture out of the watershed (Drake *et al.*, 2022). These wind patterns are relevant to forest water use and climate change over large areas of the montane, forested Pacific Northwest.

Projecting wildfire risk across the western United States in response to changes in climate and land use requires understanding the interactions among biology, climate, and human activity. The probability of wildfire occurrence in the Cascade Range of Oregon as a function of temperature and precipitation is projected to increase by 63% under the lower emissions scenario (RCP 4.5) and 122% under the higher emissions scenario (RCP 8.5) (Gao *et al.*, 2021). Multiple modeling approaches indicate future increases in forest area burned in the western United States (Abatzoglou *et al.*, 2021a). Similarly, model simulations of a common fire index based on precipitation and temperature, the Keetch–Byram Drought Index, and a proxy for fuel availability suggest that the number of days on which fire risk is extremely high will increase through the end of the twenty-first century (Brown *et al.*, 2021). Overall, wildfire frequency, intensity, and area burned are projected to continue increasing in the Northwest, even in climatologically wet areas in western Oregon (Dalton *et al.*, 2017; Mote *et al.*, 2019; Dalton and Fleishman, 2021)

This report considers the number of days with extreme values of 100-hour fuel moisture (FM100) and VPD as a proxy for wildfire risk. FM100 is a measure of the percentage of moisture in the dry weight of dead vegetation with 1–3 inch diameter, and commonly is used by the Northwest Interagency Coordination Center (https://gacc.nifc.gov/nwcc/) to predict fire danger. A majority of climate models project that 100-hour fuel moisture will decline across Oregon by the 2050s (2040–2069) under the higher emissions scenario (Gergel *et al.*, 2017). As explained above, drying of vegetation leads to greater wildfire risk, especially when coupled with decreases in summer soil moisture and increases in evaporative demand. CMIP6 model simulations given a higher emissions scenario projected that warm season VPD over the next 30 years will increase at a rate similar to that observed across the western United States from 1980 through 2020 (Zhuang *et al.*, 2021). Increases in VPD also were projected by CMIP5 models to contribute substantially to wildfire risk in Oregon (Ficklin and Novick, 2017; Chiodi *et al.*, 2021). Furthermore, observed increases in nighttime temperatures (Balch *et al.*, 2022) and nighttime VPD (Chiodi *et al.*, 2021) have been linked to fires burning longer into the night and increasing in intensity much earlier in the morning, which reduces the window of opportunity for suppression.

In this report, the future change in wildfire risk is expressed as the increase in the average annual number of days on which fire danger is very high and VPD is extreme. Projections are presented for two future periods under two emissions scenarios compared to the historical baseline. A day on which fire danger is very high is defined as a day on which FM100 is lower (i.e., vegetation is drier) than the historical 10th percentile value. Historically, fire danger in Lane County was very high on 36.5 days per year. A day on which VPD is extreme is defined as a day on which VPD exceeds the historical warm season (March–November) 90th percentile value.

In Lane County, the average number of days per year on which fire danger is very high is projected to increase by 12 days (range -6–29) by the 2050s, compared to the historical baseline, under the higher emissions scenario (Figure 17). The average number of days per year on which VPD is extreme is projected to increase by 27 days (range 9–43) by the 2050s, compared to the historical baseline, under the higher emissions scenario (Figure 18). The impacts of wildfire on air quality are discussed in the following section, Reduced Air Quality.

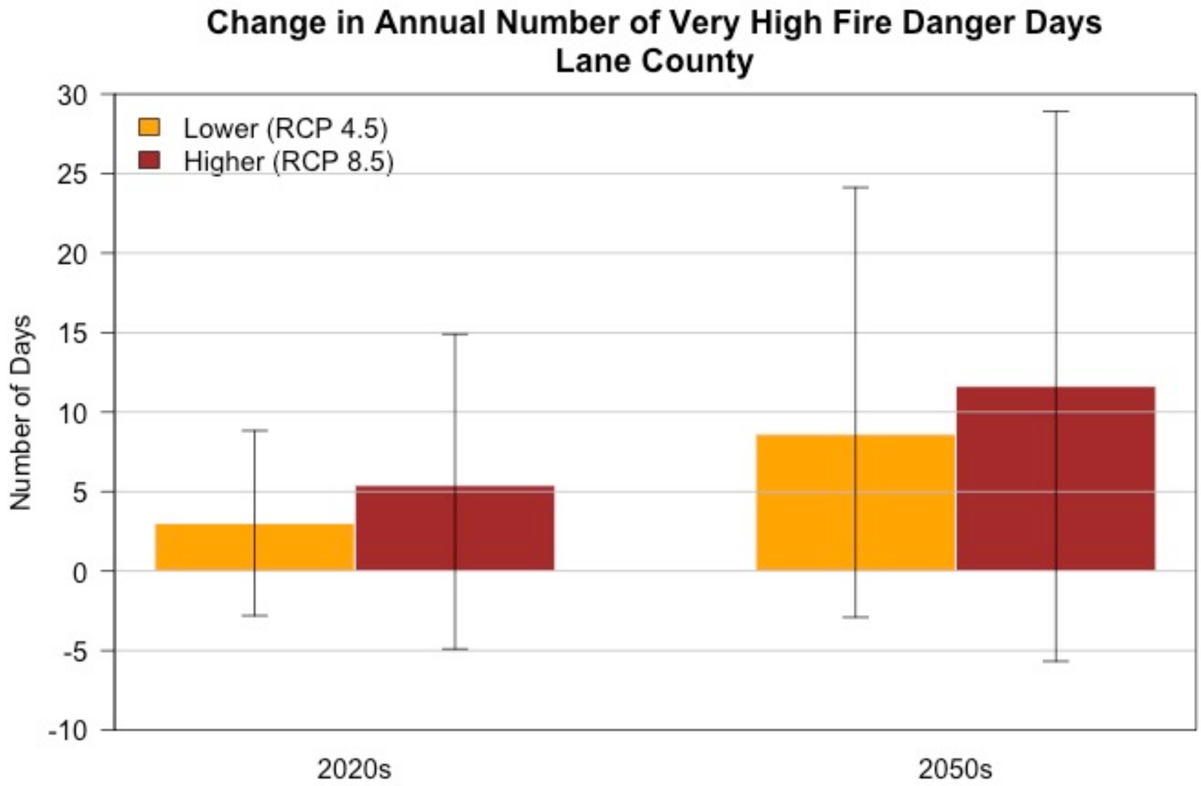


Figure 17. Projected changes by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the 1971–2000 historical baseline and under two emissions scenarios, in the number of days on which fire danger in Lane County is very high. Changes were calculated for each of 18 global climate models relative to each model's historical baseline, then averaged across the 18 models. Whiskers represent the range of changes across the 18 models. Only 18 models included the data necessary to estimate fire danger out of the full set of 20 models that were used to project temperature and precipitation. (Data Source: Climate Toolbox, climatetoolbox.org/tool/Climate-Mapper)

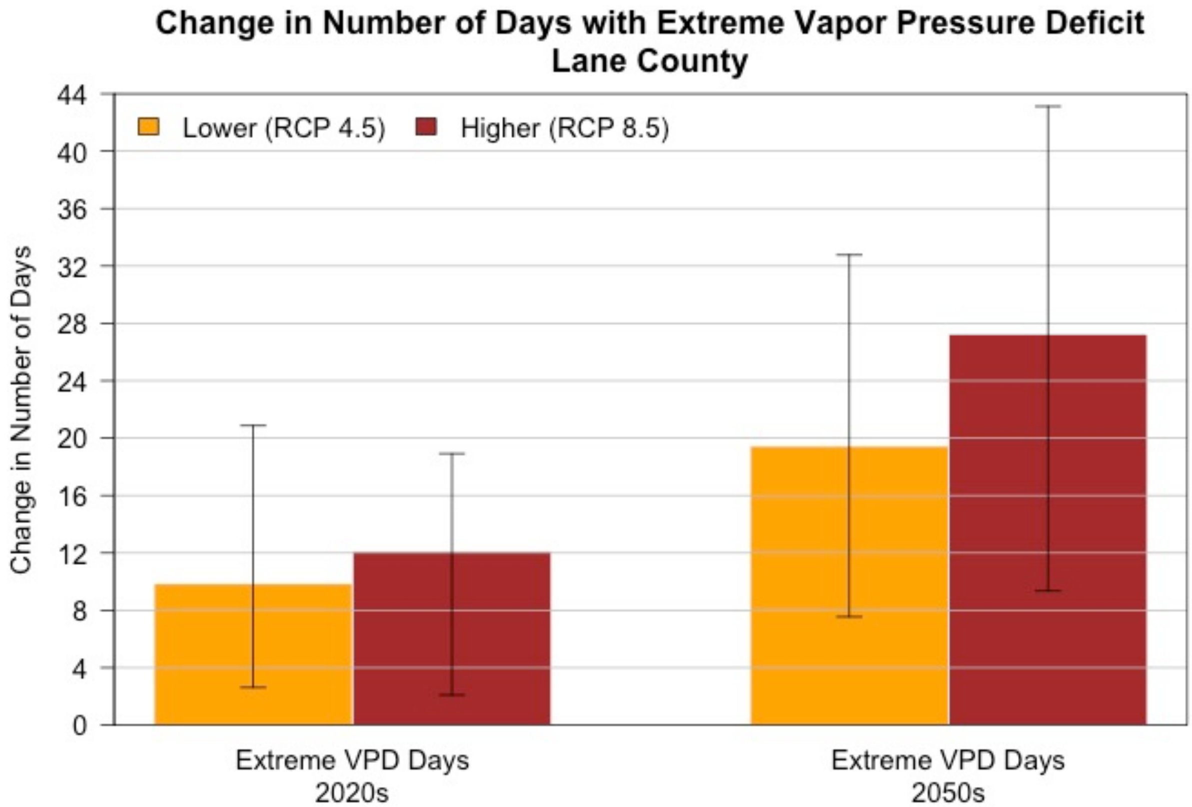


Figure 18. Projected changes by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the 1971–2000 historical baseline and under two emissions scenarios, in the number of days on which vapor pressure deficit in Lane County is extreme. Changes were calculated for each of 20 global climate models relative to each model's historical baseline, then averaged across the 20 models. Whiskers represent the range of changes across the 20 models. (Data Source: Climate Toolbox, climatetoolbox.org/tool/Climate-Mapper)

Key Messages

⇒ Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase in Lane County by 12 days (range -6–29) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

⇒ In Lane County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 27 days (range 9–43) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality

Climate change is expected to reduce outdoor air quality. Warmer temperatures may increase ground-level ozone concentrations, increases in the number and size of wildfires may increase concentrations of smoke and fine particulate matter, and increases in pollen abundance and the duration of pollen seasons may increase aeroallergens. Such poor air quality is expected to exacerbate allergy and asthma conditions and increase the incidence of respiratory and cardiovascular illnesses and death (Fann *et al.*, 2016).

Over the past several decades, fire seasons have increased in length, and the intensity and severity of wildfires have increased. This trend is expected to continue as a result of complex factors including traditional forest management practices, increasing population density in fire risk zones, and climate change (Sheehan *et al.*, 2015). Large wildfires in the western United States can create extensive smoke plumes that travel at high altitudes over long distances and affect air quality not only near to but far from those wildfires. Hazardous levels of air pollution are most common near wildfires. Fires emit fine particulate matter (less than 2.5 micrometers in diameter [$PM_{2.5}$]), which exacerbate chronic cardiovascular and respiratory illnesses (Cascio, 2018). In addition, because exposure to $PM_{2.5}$ increases susceptibility to viral respiratory infections, exposure to wildfire smoke is likely to increase susceptibility to and the severity of reactions from Covid-19 (Henderson, 2020). Wildfire smoke also impairs visibility and can disrupt outdoor recreational and social activities, in turn affecting physical and mental health (Nolte *et al.*, 2018).

From 2000 through 2020, the frequency, duration, and area of co-occurrence of two air pollutants related to wildfire smoke, $PM_{2.5}$ and ozone, increased in the western United States (Kalashnikov *et al.*, 2022) and in the Pacific Northwest in particular (Buchholz *et al.*, 2022). Wildfires emit ozone precursors that in hot and sunny conditions react with other pollutants to increase the concentration of ozone. The area in which $PM_{2.5}$ and ozone co-occurred more than doubled during the past 20 years.

Wildfires are the primary cause of exceedances of air quality standards for $PM_{2.5}$ in western Oregon and parts of eastern Oregon (Liu *et al.*, 2016), although woodstove smoke and diesel emissions also contribute (Oregon DEQ, 2016). Fine particulate matter from vehicles, woodstoves, and power plants can be regulated, but it is much more difficult to control wildfires. Therefore, the incidence of chronic smoke exposure that has potentially severe health consequences is increasing (Liu *et al.*, 2016). Across the western United States, $PM_{2.5}$ concentrations from wildfires are projected to increase 160% by 2046–2051, relative to 2004–2009, under a medium emissions scenario (SRES A1B) (Liu *et al.*, 2016). The SRES A1B scenario, which is from an earlier generation of emissions scenarios, is most similar to RCP 6.0 (Figure 2). CMIP6 models integrated with an empirical statistical model projected that $PM_{2.5}$ concentrations in August and September in the Northwest will double to triple by 2080–2100 under lower (SSP5-4.5) and higher (SSP5-8.5) emissions scenarios (Xie *et al.*, 2022).

This report presents projections of future air quality that are based on $PM_{2.5}$ from wildfire smoke. Smoke wave days are defined as two or more consecutive days on which simulated, county-averaged, wildfire-derived $PM_{2.5}$ values are in the highest 2% of simulated daily values from 2004 through 2009 (Liu *et al.*, 2016). Smoke wave intensity is defined as the concentration of $PM_{2.5}$ on smoke wave days. Mean number of smoke wave days and mean smoke wave intensity are projected for two six-year periods, 2004–2009 and 2046–2051, under a medium emissions scenario. More information about these methods of projecting future air quality is in the Appendix. In Lane County, the number of smoke wave days is projected to decrease by 5%, but the intensity of smoke wave days is projected to increase by 58% (Figure 19).

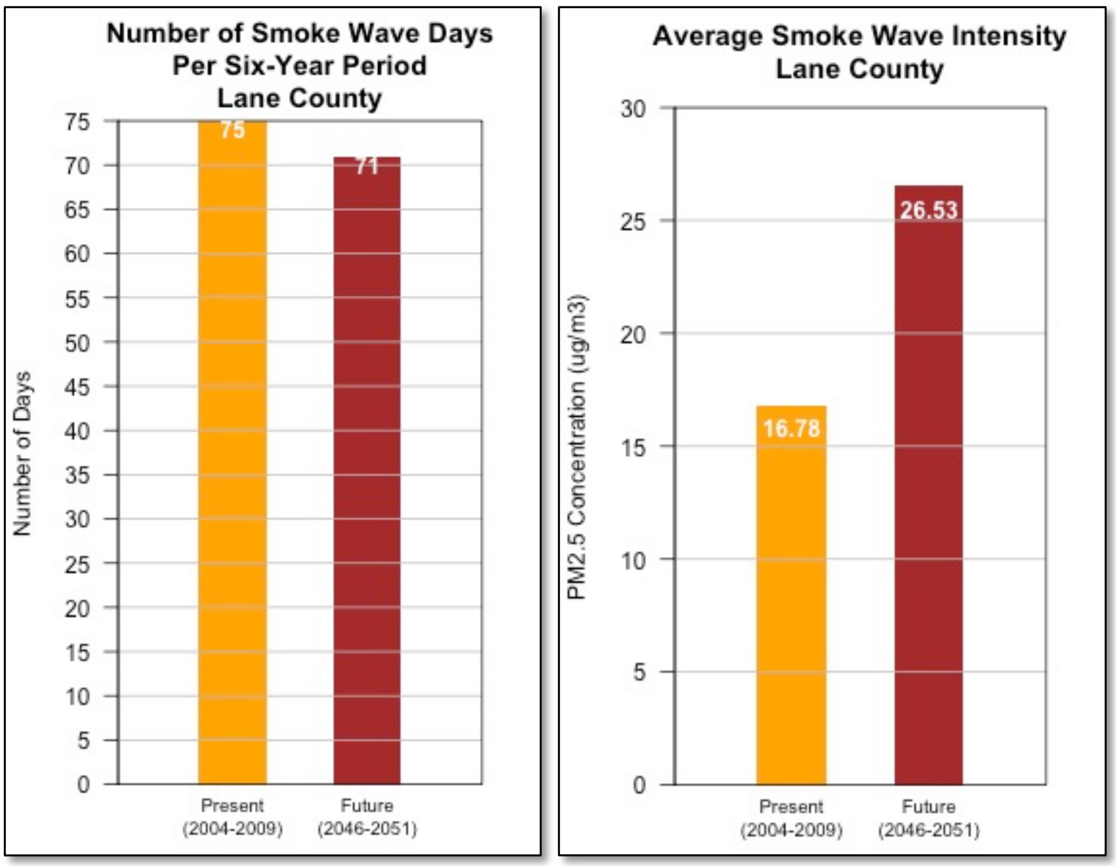


Figure 19. Simulated present (2004–2009) and future (2046–2051) number (left) and intensity (right) of smoke wave days in Lane County under a medium emissions scenario. Values represent the mean among 15 global climate models. (Data source: Liu et al. 2016, https://khanotations.github.io/smoke-map/)

Plants also are responding to changes in climate and atmospheric concentrations of carbon dioxide by producing more pollen, and by producing pollen earlier in spring and for longer periods of time (Ziska *et al.*, 2009). From 1990 through 2018, pollen seasons increased by about 20 days and pollen concentration increased by 21% in the conterminous United States (Anderegg *et al.*, 2021), including northern California (Paudel *et al.*, 2021).

Fungal spores also could become more abundant following extreme floods or droughts, which are expected to become more common with climate change. The period during which outdoor airborne mold spores are detectable increased in the last 20 years as a result of increasing concentrations of carbon dioxide and changes in climate and land use (Paudel *et al.*, 2021). Furthermore, because both ozone and fine particulates affect the sensitivity of respiratory systems to airborne allergens, the combined effects of climate change, air pollution, and changes in vegetation phenology will likely increase the severity of respiratory diseases and allergies (D'Amato *et al.*, 2020).

Key Messages

⇒ The risk of wildfire smoke in Lane County is projected to increase. The number of days per year on which the concentration of wildfire-derived fine particulate matter results in poor air quality is projected to decrease by 5%, but the concentration of fine particulate matter is projected to increase by 58%, from 2004–2009 to 2046–2051 under a medium emissions scenario.

Coastal Erosion and Flooding

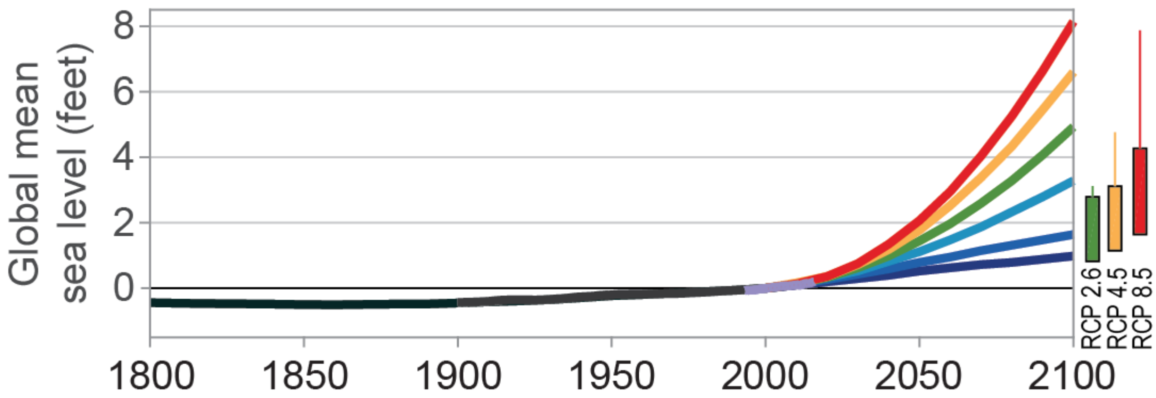
Variability in water levels associated with the El Niño–Southern Oscillation, tides, storm surges, and waves, especially in conjunction with relative sea level rise, can result in flooding and erosion along the Oregon coast. Projected changes in these processes and phenomena may increase their risks to coastal communities and, in some cases, ecosystems. Relative refers to the fact that sea level rise is calculated with respect to land elevations. Differences in the rate and direction of vertical land motions along the Oregon coast can affect relative sea level rise strongly.

Observed and Projected Trends in Sea Level

Global mean sea level has risen by about 7–8 inches since 1900, and recent observations suggest that rates of sea level rise have accelerated since 1993 (Nerem *et al.*, 2018). Global mean sea level is very likely to continue to rise by another 1–4 feet, relative to the year 2000, by the year 2100 (Sweet *et al.*, 2017a; Hayhoe *et al.*, 2018). Instabilities in Antarctic ice sheets that are plausible, but have low probability, could result in much higher (~8 feet) global sea level rise (Hayhoe *et al.*, 2018) (Figure 20).

Recent advances in sea level observations and modeling increased understanding of the processes that contribute to global and regional changes in sea level. These processes include changes in ice sheets and glaciers; changes in water storage on land; thermal expansion of sea water; changes in freshwater input; changes in vertical land motion; and changes in tides, storm surges, and waves (Hamlington *et al.*, 2020). Projected sea level rise varies along the Oregon coast, primarily due to variations in vertical land motions.

Local sea level at the National Oceanic and Atmospheric Administration (NOAA) water-level station at South Beach in Newport, Oregon, rose about four inches from 1967–2013. Climate change is expected to accelerate sea level rise along the Oregon coast during the twenty-first century. Local sea level is projected to rise by 1.7–5.7 feet by 2100 (Climate Central, 2022) given the intermediate-low and intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment (Sweet *et al.*, 2017a) (Table 13). This range of sea level rise scenarios is similar to the *very likely* range projected under the higher emissions scenario (RCP 8.5) by 2100 (Figure 20). Additionally, median local sea level rise at South Beach in Newport, Oregon, was projected for each decade from 2030–2100, relative to the 1992 mean high tide line, given six scenarios of global sea level rise. These projections incorporated estimates of trends in vertical land movement derived from global positioning system (GPS) measurements and tide gauge platforms (Sweet *et al.*, 2017b) (Table 13). Accordingly, the projections are relative to the future land position as opposed to the existing land position.



Scenario	RCP 2.6	RCP 4.5	RCP 8.5
Low (1 ft)	94%	98%	100%
Intermediate-Low (1.6 ft)	49%	73%	96%
Intermediate (3.3 ft)	2%	3%	17%
Intermediate-High (4.9 ft)	0.4%	0.5%	1.3%
High (6.6 ft)	0.1%	0.1%	0.3%
Extreme (8.2 ft)	0.05%	0.05%	0.1%

Figure 20. (Top) Global mean sea level rise from 1800 to 2100, based on tide gauge-based reconstruction (black), satellite-based reconstruction (purple), and six future scenarios (navy blue, royal blue, cyan, green, orange, red) used in the 2018 U.S. National Climate Assessment (NCA4). Colored boxes indicate the *very likely* ranges in 2100 given different Representative Concentration Pathways (RCPs). Lines augmenting the very likely ranges account for estimates of accelerated Antarctic ice-sheet melt. (Bottom) Probability of exceeding each NCA4 global mean sea level scenario in 2100 under three RCPs. (Source: Sweet et al., 2017a, https://science2017.globalchange.gov/chapter/12/)

Table 11. Median decadal, local sea level rise projections at the NOAA water level station at South Beach in Newport, Oregon, based on scenarios used in the 2018 U.S. National Climate Assessment. Sea level rise is feet above the 1992 baseline. Each scenario also has an associated likely range of sea level rise (not shown). Projections account for estimated trends in vertical land movement. (Source: Climate Central Surging Seas Risk Finder, https://riskfinder.climatecentral.org/county/lane-county.or.us?comparisonType=county&forecastType=NOAA2017_int_p50&level=4&unit=ft&zillowPlaceType=postal-code)

Scenario	2030	2040	2050	2060	2070	2080	2090	2100
Low	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2
Intermediate-Low	0.5	0.6	0.8	1.0	1.2	1.3	1.5	1.7
Intermediate	0.6	0.9	1.2	1.6	2.0	2.4	2.9	3.5
Intermediate-High	0.9	1.3	1.8	2.4	3.0	3.8	4.7	5.7
High	1.1	1.7	2.5	3.4	4.3	5.5	6.8	8.4
Extreme	1.3	2.0	2.9	4.1	5.3	6.8	8.4	10.3

Anticipated Effects of Climate Change on Ocean Wave Climate

Wave climate refers to attributes of waves that are averaged over a given period of time in a given location. Wind waves can be dominant contributors to total water levels at the coastline via their influence on wave setup and swash (the movement of water that washes up on the beach after a wave breaks) (Melet *et al.*, 2020). Although substantial uncertainties remain, along the mainland west coast of the United States, mean wave height is projected to decrease by approximately 2–20% (Hemer *et al.*, 2013; Wang *et al.*, 2014; Erikson *et al.*, 2015; Morim *et al.*, 2019), and mean wave period is projected to increase by approximately 2–5% (Hemer *et al.*, 2013; Erikson *et al.*, 2015; Morim *et al.*, 2019), by 2100. Mean wave direction is projected to shift anticlockwise (more waves from the south) by approximately 2–5% by 2100 (Hemer *et al.*, 2013; Erikson *et al.*, 2015; Morim *et al.*, 2019), likely due to a northward shift in storm tracks along the west coast of the United States. Projection of future deep-water wave conditions has progressed considerably. However, deep-water wave conditions must be downscaled to the nearshore to understand the local effects of these changes. Such local downscaling can be computationally demanding and time intensive. Because wave transformation across the shelf determines which storm events affect the coastline, the nearshore effects of a change in the deep-water wave climate may vary in space, even at nearby locations (Serafin *et al.*, 2019).

A simultaneous increase in wave period and decrease in wave height may have contrasting effects on a location's wave energy flux. Global wave power, which is the transport of wave energy, increased since 1948, most likely due to increases in temperatures of the upper ocean (Reguero *et al.*, 2019). However, average and extreme conditions may be modified by the future global climate in different ways. For example, although the annual average wave height may decrease across the west coast of the United States, annual maximum and winter wave heights may increase (Wang *et al.*, 2014). Ongoing research will continue to advance understanding of the impacts of alterations to the wave climate and will examine extreme and average conditions separately.

Coastal Erosion

Over the past 100 years (late 1800s through 2002), trends in beach erosion were statistically significant in only three of Oregon's 18 littoral cells (coastal compartments within which sediment movement is self-contained), Humbug, Heceta, and Netarts (Ruggiero *et al.*, 2013). However, in the shorter term (1967–2002), 10 of Oregon's littoral cells eroded at a statistically significant rate of 1–3.6 feet per year (Ruggiero *et al.*, 2013). This increase in rates of erosion along much of Oregon's coastline may be related to the effects of sea level rise and changes in storm patterns (Ruggiero *et al.*, 2013). In the Heceta littoral cell, which is along the coastline in Lane County between Cape Perpetua and Heceta Head, the long-term average annual rate of erosion across the shoreline was a statistically significant 1.3 feet, with some parts of the shoreline eroding at annual rates greater than 3.3 feet (Ruggiero *et al.*, 2013). However, in the shorter term, the annual erosion rate in the Heceta littoral cell was not significant. The Coos littoral cell to the south between Heceta Head and Cape Arago, in which the shoreline has the largest dune accumulation in the United States, has been accreting over the long term, likely due to the effects of jetties constructed at the mouths of the Coos Bay, Umpqua River, and Siuslaw River. The average annual rate of accretion across the shoreline is a statistically significant 1.6 feet, although 26% of the shoreline is eroding (Ruggiero *et al.*, 2013). The average annual accretion rate in the Coos littoral cell is smaller and not significant in the short term, and 54% of the shoreline is eroding (Ruggiero *et al.*, 2013).

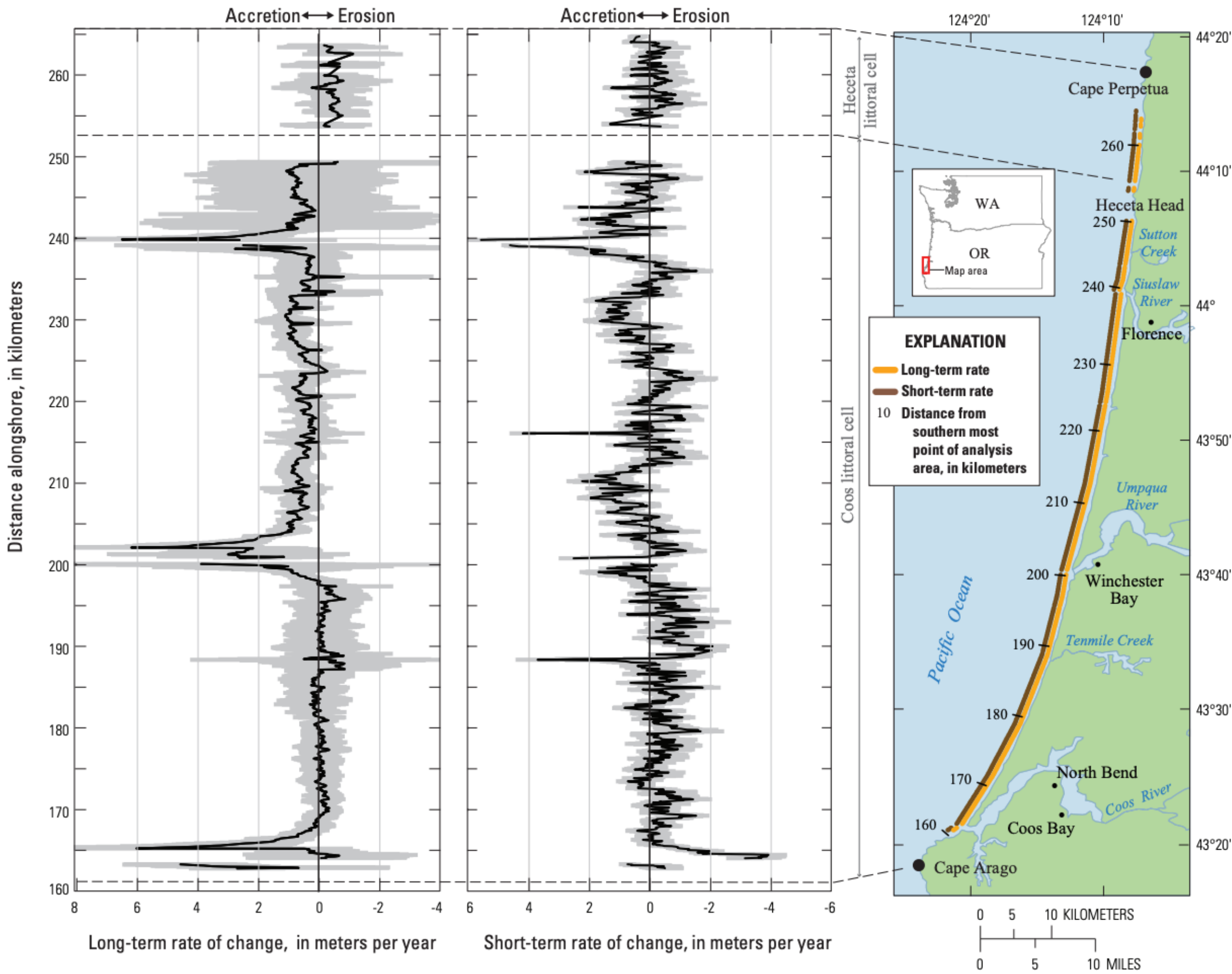


Figure 21. Long-term (1800s through 2002) and short-term (1960s through 2002) shoreline change rates (black lines on plots) in the Coos and Heceta littoral cells along the coastline of Lane and Douglas County, Oregon. Shaded gray area behind long- and short-term rate lines represents uncertainty associated with rate calculation. (Source: Ruggiero et al., 2013)

Coastal Flooding

The projected increase in relative sea levels along the Oregon coast raises the starting point (still water level) for waves, storm surges, and high tides that can impinge on beaches and backshore areas. Possible changes to waves, storm surges, and tides have the potential to make coastal flooding in Oregon (which is associated with total water levels) more severe and more frequent in the future. A simple estimate of coastal flood risk combined projections of relative sea level rise and historic flood frequencies to estimate the multiple-year risk of flooding above a certain threshold (Climate Central, 2022). For example, one can project the likelihood that at least one coastal flood will exceed four feet above mean high tide by a given year (Table 14).

Assuming the intermediate-low to intermediate-high sea level scenarios for South Beach at Newport, Oregon (Table 13), the projected likelihood that at least one flood will exceed four feet above mean high tide was 45–83% by 2030, 93–100% by 2050, and 100% by 2100 (Climate Central, 2022) (Table 14). For historical perspective, the highest observed flood in the area from 1967 through 2015 was 3.91 feet above mean high tide in 1969, and the statistical 1-in-100 year flood height is 3.9 feet (Climate Central, 2022). As of 2010, 116 people, 82 buildings, and $23 million in property value in Lane County were within zero to four feet above mean high tide and were not protected by levees or other features (Climate Central, 2022). These flood risk projections did not incorporate changes to wave dynamics or storm surges, which could result in a given coastal flood level occurring sooner.

Table 12. Percent likelihood that at least one flood will exceed four feet above mean high tide from 2016 through each year. Likelihoods are based on median projections of local sea level rise at South Beach in Newport, Oregon (Table 13). (Source: Climate Central Surging Seas Risk Finder, https://riskfinder.climatecentral.org/county/lane-county.or.us?comparisonType=county&forecastName=Basic&forecastType=NOAA2017_lo_p50&impact=Roads&impactGroup=Infrastructure&level=4&unit=ft&zillowPlaceType=postal-code)

Scenario	2030	2040	2050	2060	2070	2080	2090	2100
Low	35	59	80	94	99	100	100	100
Intermediate-Low	45	74	93	99	100	100	100	100
Intermediate	60	91	100	100	100	100	100	100
Intermediate-High	83	100	100	100	100	100	100	100
High	96	100	100	100	100	100	100	100
Extreme	99	100	100	100	100	100	100	100

Relative sea level rise narrows the gap in elevations between commonly occurring high tides and the thresholds above which flooding begins. Coastal communities were developed with an understanding of this gap and the flooding that could occur under extreme conditions. When considering only long-term sea level trends (still water levels), the gap between high tide and flooding may be filled on the order of decades. When considering sea-level variability associated with waves (total water levels), flooding and its effects on the built and natural environment may become frequent much sooner, on the order of years (Mills *et al.*, 2018; Hamlington *et al.*, 2020). Incremental increases in relative sea level rise can produce exponential increases in coastal flood frequency (Taherkhani *et al.*, 2020). For example, on the west coast of the United States, approximately 2.1 inches of sea level rise doubles the odds of exceeding the present-day, 50-year water-level event (a flood level with a 2% annual probability of exceedance) (Taherkhani *et al.*, 2020). The odds of such extreme flooding double about every five years (Taherkhani *et al.*, 2020).

The Oregon Coastal Management Program (OCMP) estimated the exposure to sea level rise of Oregon's estuaries, including the Siuslaw River in Lane County (Sepanik *et al.*, 2017). The OCMP sea level rise scenarios are taken from the upper range of projections for Newport, Oregon in *Sea-Level Rise for Coasts of California, Oregon, and Washington* (National Research Council, 2012). In this report for Lane County, OCCRI summarized the sea level rise and flooding scenarios considered by OCMP for Lane County and compared them to the sea level rise and flooding scenarios from the 2018 U.S. National Climate Assessment (2018 NCA) and Climate Central (Table 15) to place the OCMP analysis in the context of more-recent sea level rise scenarios (Table 13).

OCMP's scenarios for the 2030s and 2050s most closely align with the upper end of the likely range of the 2018 NCA's intermediate scenario. OCMP's sea level rise scenario for 2100 most closely aligns with the lower end of the likely range of the 2018 NCA's intermediate-high scenario (Table 15). The OCMP estimated that the mean flood levels coinciding with a 1% and 50% probability of exceedance in a given year were 3.9 feet and 2.56 feet, respectively, for the Siuslaw River estuary in Lane County (Sepanik *et al.*, 2017). These levels are similar to Climate Central's estimates for South Beach at Newport, Oregon's mild flood level (2.6 feet) and major flood level (3.9 feet) (Table 15).

Climate Central's projections of water levels resulting from combined effects of sea level rise and flooding, and associated likelihoods of flood risk, can be compared to OCMP's water-level scenarios (Table 15, Table 16). For example, the likelihood that flood levels will exceed four feet above mean high tide in any single year by 2050, similar to OCMP's 2050 + 50% scenario, is 64%, but the likelihood that four feet will be exceeded at some point between 2016 and 2050 is 100% (Table 16). The likelihood that flood levels will exceed eight feet above mean high tide in any single year by 2100, similar to OCMP's extreme scenario, 2100 + 1%, is 9%, whereas the likelihood that seven feet will be exceeded at some point between 2016 and 2100 is 31% (Table 16). The likelihood of exceeding eight feet by the year 2120 is 100% (Climate Central, 2022).

Table 13. Sea level rise (SLR) and flooding scenarios for a given year that were generated by the Oregon Coastal Management Program (OCMP), Climate Central, and 2018 U.S. National Climate Assessment (NCA). (Source: Sepanik et al., 2017; Climate Central Surging Seas Risk Finder for Lane County, Oregon, https://riskfinder.climatecentral.org)

OCMP SLR Scenario[2]	2018 NCA SLR Scenario[3]
2030: 0.75 feet	2030: 0.8 feet
2050: 1.57 feet	2050: 1.5 feet
2100: 4.66 feet	2100: 4.6 feet
OCMP Flood Scenario[4]	Climate Central Flood Scenario[5]
1% probability: 3.9 feet	major flood: 3.9 feet
50% probability: 2.56 feet	mild flood: 2.6 feet

Table 14. Scenarios of the combined effects of sea level rise (SLR) and flooding developed by the Oregon Coastal Management Program (OCMP) and Climate Central. Climate Central estimated the likelihood that water levels will exceed the given floor (the integer before the decimal; the floor of a flood of 4.4 feet is 4 feet) in any single year and at some point during the given time period. The OCMP water levels are for the Siuslaw River in Lane County. Water levels were derived from the applicable sea level rise and flood scenarios in Table 15. (Source: Sepanik et al., 2017; Climate Central Surging Seas Risk Finder for Lane County, Oregon, https://riskfinder.climatecentral.org)

OCMP SLR + Flood Scenarios	OCMP SLR + Flood Water Level (feet)	Climate Central Equivalent SLR + Flood Water Level (feet)	Climate Central Estimated Single Year Flood Risk (%)	Climate Central Estimated Multiple-Year Flood Risk (%)
2030 + 50%	3.3	3.4	87	100
2030 + 1%	4.7	4.7	14	76
2050 + 50%	4.1	4.1	64	100
2050 + 1%	5.5	5.4	5	33
2100 + 50%	7.2	7.2	79	100
2100 + 1%	8.6	8.5	9	31

2 The OCMP analysis used the upper end of the range of sea level rise projections for Newport, Oregon (NRC, 2012).

3 The 2018 NCA sea level rise scenario for South Beach at Newport, Oregon, that most closely aligns with the OCMP 2030 and 2050 sea level rise scenarios is the 83rd percentile, or upper end of the likely range, of the intermediate scenario. The NCA 2018 sea level scenario that most closely aligns with the OCMP 2100 scenario is the 17th percentile, or lower end of the likely range, of the intermediate-high scenario.

4 The OCMP analysis used NOAA's estimates of extreme water levels to calculate the 1% and 50% probability of exceedance in a given year. Values are for the Siuslaw River estuary in Lane County.

5 Extreme water levels at the NOAA water level station at South Beach at Newport, Oregon.

Under the 2050 + 50% scenario, which is virtually certain to occur at least once by 2050, exposed assets in the Siuslaw River estuary in Lane County include 1.5 miles of state highways, 6.5 miles of state, county and local roads, 0.6 miles of railways, and 106 buildings (Table 17). Under the 2100 + 1% scenario, which has an 31% likelihood of occurring at least once by 2100 and is virtually certain to occur at least once by 2120, exposed assets include 5.3 miles of state highways, 19.4 miles of state, county and local roads, 1.9 miles of railways, and 366 buildings (Table 17). No airports, critical facilities, municipal drinking water facilities, wastewater treatment plants, electrical substations, or potential contaminant sources are exposed under either scenario.

Table 17. Assets exposed under OCMP's 2050 + 50% and 2100 + 1% sea level and flooding scenarios for the Siuslaw River estuary in Lane County. The exposure of the built infrastructure within the footprint of the Siuslaw River estuary to future flooding, relative to all estuaries along the Oregon coast, is low. (Source: Sepanik et al., 2017)

Assets	2050 SLR + 50% Probability Flood (4.1 feet)	2100 SLR + 1% Probability Flood (8.6 feet)
State Highways (miles)	1.5	5.3
State, County, and Local Roads (miles)	6.5	19.4
Railways (miles)	0.6	1.9
Buildings (number)	106	366

Key Messages

⇒ The risk of coastal erosion and flooding on the Oregon coast is expected to increase as climate changes due to sea level rise and changing wave dynamics.

⇒ In Lane County, local sea level is projected to rise by 1.7 to 5.7 feet by 2100. This projection is based on the intermediate-low to intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment. Because these local sea level projections account for estimated trends in vertical land movement, they are relative to the future land position.

⇒ Given these levels of sea level rise, the multiple-year likelihood of a flood reaching four feet above mean high tide is 45–83% by the 2030s, 93–100% by the 2050s, and 100% by 2100.

⇒ At risk within the four-foot inundation zone in Lane County as of the 2010 census were 116 people, $23 million in property value, nearly 9 miles of highways, roads, and railways, and more than 100 buildings.

Changes in Ocean Temperature and Chemistry

As a result of increasing human-caused emissions of carbon dioxide (CO_2) into the atmosphere, the world's oceans are warming, acidifying, and deoxygenating. These changes are leading to alterations in marine ecosystems that affect the economies and livelihoods of coastal communities worldwide (Pershing *et al.*, 2018).

The most direct and well-documented effect of climate change on the oceans is warming (Pershing *et al.*, 2018). More than 90% of the extra heat associated with carbon emissions has been captured by the oceans. The temperature of global ocean surface waters increased on average by 1.3 ± 0.1°F per century from 1900 through 2016 (Pershing *et al.*, 2018). Open-ocean, surface waters in the eastern North Pacific, offshore of the northwestern United States, warmed at a rate of 1.15 ± 0.54°F per century during the same period, and are projected to warm by 5.0 ± 1.1°F by 2080, relative to 1976–2005, under a higher emissions scenario (RCP 8.5) (Jewett and Romanou, 2017).

In addition to gradual ocean warming as a result of climate change, episodic severe heat events, known as marine heat waves, increasingly are being documented. One such event occurred from 2013 through 2017 in the waters of the eastern North Pacific (Harvey *et al.*, 2020). A warm water anomaly first appeared in the upper ocean during the winter of 2013–2014 (Bond *et al.*, 2015), then spread across the eastern North Pacific onto the Oregon shelf (Peterson *et al.*, 2017). By mid-September 2014, sea surface temperatures off central Oregon had risen by 8.1°F above regional averages, and the anomalously high temperature persisted within the region until early 2016 (Peterson *et al.*, 2017). The temperature continued to be anomalously high to depths of ~492 feet until at least late 2017 (Barth *et al.*, 2018; Fisher *et al.*, 2020). This event triggered a coast-wide harmful algal bloom that affected commercial, recreation, and tribal subsistence fisheries off the Northwest coast (May *et al.*, 2018). It is likely that marine heat waves will occur regularly as atmospheric and oceanic temperatures become more variable over the coming decades. Warming ocean temperatures affect marine ecosystems in a variety of ways, including but not limited to changing the metabolic rates of organisms, increasing the toxicity of harmful algal blooms, and causing species' ranges to shift (Somero *et al.*, 2016; Harvey *et al.*, 2020; Trainer *et al.*, 2020).

Warming ocean temperatures have profound effects on other aspects of ocean physics, particularly water density and stratification in the upper part of the water column, which in turn reduces transfer of oxygen among surface and deeper layers (Pershing *et al.*, 2018). Additionally, warm water holds less oxygen than cool water, so increasing water temperature directly decreases the concentration of dissolved oxygen. Trends in dissolved oxygen are difficult to detect given that oxygen concentration varies considerably due to periodic circulation patterns and interdecadal oscillations (e.g., seasonal coastal upwelling, seasonal coastal storm mixing, El Niño-Southern Oscillation, Pacific Decadal Oscillation) (Pierce *et al.*, 2012). Local coastal processes of decomposition further can lead to temporally and spatially variable low-oxygen or hypoxia events (oxygen concentration less than 1400 ppm). On the shelf and adjacent slope, changes are already noticeable; oxygen levels off Newport, Oregon, decreased by 40% at 197–230 feet below the surface from 1960–1971 to 1998–2009 (Pierce *et al.*, 2012). These changes have led to an increasingly recognizable and severe late-summer hypoxia season in Oregon and throughout the Pacific Northwest (Chan *et al.*, 2008, 2019) that can cause extensive mortality and changes in the distribution of marine species (Chan *et al.*, 2019). The risk of an increasing number of hypoxia events is high given that average oxygen levels were projected to decline by 17% throughout the north Pacific Ocean by 2100, assuming RCP 8.5 (Jewett and Romanou, 2017; Pershing *et al.*, 2018).

Globally, over the last 150 years, surface ocean waters absorbed large amounts of anthropogenic CO_2 from the atmosphere and became 30% more acidic than prior to the Industrial Revolution (Jewett and Romanou, 2017; Osborne *et al.*, 2020). This process of ocean acidification is caused by the chemical reactions that result from CO_2 entering the ocean, reacting with seawater to release hydrogen (H+) ions, and altering the carbonate chemistry of the ocean. Multiple parameters are used to document and describe ocean acidification, including dissolved CO_2, pH, total alkalinity, and calcium carbonate (aragonite, Ω) concentrations (Doney *et al.*, 2020). Over the twenty-first century, the surface ocean waters are projected to acidify by 100 to 150% (assuming RCP 8.5), resulting in a decrease of open ocean pH from 8.1 (current average) to as low as 7.8 by 2100 (Jewett and Romanou, 2017). Negative effects of ocean acidification, including increased toxicity of harmful algal blooms, reduced olfaction in fishes, and thinner shells in shellfish, are already evident in marine ecosystems worldwide (Doney *et al.*, 2020).

Along the West Coast, ocean acidification, and to some extent hypoxia, are correlated with seasonal and decadal changes in coastal upwelling (Chan *et al.*, 2008, 2019; Osborne *et al.*, 2020), which brings nutrient-rich, low-oxygen, and acidified deep waters up onto Oregon's coastal shelf (Jewett and Romanou, 2017). By 2100, coastal upwelling along Oregon's coast is projected to intensify in spring but weaken in summer, and about 23–40% fewer strong upwelling events are expected (Jewett and Romanou, 2017). Seasonal upwelling not only drives ocean circulation but affects species that rely on upwelling for nutrition, larval migration, and other ecological functions.

On the West Coast, ocean acidification and hypoxia tend to co-occur, and the aggregated effects of ocean acidification and hypoxia can be greater than the independent effects of either (Chan *et al.*, 2016). The West Coast of North America was one of the first places in the world in which the ecological, and economic consequences of ocean acidification and hypoxia were severe. The magnitude of regional ocean acidification and hypoxia in part reflects natural upwelling of CO_2-enriched, low-oxygen water along the continental shelf of the West Coast (Chan *et al.*, 2016). Ocean acidification is occurring globally, and reducing global levels of CO_2 emissions will be the most effective means of decreasing the effects of ocean acidification (Chan *et al.*, 2016). However, reducing local inputs of nutrients and organic matter to the coastal environment also may decrease the magnitude of ocean acidification and hypoxia (Chan *et al.*, 2016).

Changes in ocean temperature and chemistry are already transforming ocean ecosystems and the economies, coastal communities, cultures, and businesses that depend on them (Pershing *et al.*, 2018). Research is examining the differences in responses among taxa and the capacity of different taxa to adapt to changing ocean conditions (Menge *et al.*, 2022). Sessile species (e.g., macroalgae, eelgrasses, and some invertebrates, such as bivalves, barnacles, and sea anemones) and species with relatively low mobility (e.g., small phytoplankton and zooplankton, non-migratory fishes, and some invertebrates, such as crabs, shrimp, and sea stars) are the most affected by local or regional changes in ocean temperature and chemistry (Grantham *et al.*, 2004; Bednaršek *et al.*, 2020; Harvey *et al.*, 2020). In contrast, mobile species, such as migratory fishes, seabirds, and marine mammals, often can move away from localized stressors, and are more affected by extensive shifts in marine food webs (Cheung *et al.*, 2015; Cheung and Frölicher, 2020; Harvey *et al.*, 2020). Regardless of mobility, many species' reproductive cycles are tied to oceanographic and other environmental drivers (e.g., light, temperature, seasonality of spring and autumn ocean upwelling, freshwater inputs, and food or nutrients) (Chavez *et al.*, 2017; Harvey *et al.*, 2020). Ocean change is likely to affect foraging during species' migrations, including the location and timing of feeding and the types of prey available or selected, potentially reducing growth and population viability. Changes in oceanographic patterns may exceed species tolerances and disrupt reproductive cycles (Bakun *et al.*, 2015; Chavez *et al.*, 2017).

Key Messages

⇒ The open-ocean surface temperature off the Northwest coast increased by 1.2 ± 0.5°F since the year 1900 and is projected to increase by about another 5.0 ± 1.1°F by the year 2080. These changes in temperature may affect many other drivers of ocean change. For example, increases in temperature accelerate the rate of reduction of dissolved oxygen and increase the toxicity of harmful algal blooms. Ocean acidity is projected to increase by roughly 100–150%, resulting in a drop in open-ocean pH from 8.1 to 7.8 by the year 2100. The change in pH is likely to affect shell formation in diverse species of commercial, recreational, and cultural value.

Loss of Wetlands

In the United States, wetlands are defined under the Clean Water Act as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Wetlands also may be associated with the edges of lakes and with streams and rivers (Halofsky *et al.*, 2019).

The extent of historic wetlands in the Willamette Valley has been reduced by an estimated 57–95% by agriculture, urbanization, timber harvest, and channelization of the Willamette River (Baker *et al.*, 2004; Christy and Alverson, 2011; Fickas *et al.*, 2016). About 4.3% of emergent, lacustrine, riparian, and riverine wetland area within the two-year floodplain inundation zone along the main stem Willamette River changed (became larger or smaller or changed among the latter four classes) from 1972 through 2012 (Fickas *et al.*, 2016). The majority of losses resulted from conversion to agriculture (Daggett *et al.*, 1998; Bernert *et al.*, 1999; Fickas *et al.*, 2016), and the greatest proportion of change reflected conversion of riparian to riverine wetland (Fickas *et al.*, 2016). Some of the gains and losses in area related to agriculture may have been prompted by drought—creation of ponds in the former case, and farming of newly dry lands in the latter—and may not be permanent (Bernert *et al.*, 1999).

Wetlands and their associated plants and animals are likely to be affected by increases in air temperature, which generally are correlated with increases in freshwater temperature; decreases in snowpack and summer stream flows; and increases in evapotranspiration (Lee *et al.*, 2015). Projected effects in the Northwest include reductions in water levels and hydroperiod duration, and may be most pronounced in wetlands that become temporary in dry years (Lee *et al.*, 2015). Wetlands along low-gradient, wide valley bottoms that are dominated by riparian trees and understory species may be most susceptible to decreases in flow and water volume, in part because recruitment of some riparian species depends on seasonal flooding (Dwire *et al.*, 2018). Systems that are fed primarily by ground water may have more consistent temperature, water chemistry, and water levels than wetlands that are fed primarily by surface water (Halofsky *et al.*, 2019). However, effects of climate change on ground water aquifers that are recharged by snowpack are uncertain (Dwire *et al.*, 2018). Moreover, where increasing aridity leads to greater demand for ground water, decreases in ground water availability may affect wetlands. Additionally, changes in vegetation at the perimeter of wetlands that result from land use or changes in climate, such as replacement of riparian hardwoods to conifers and shrubs (Dwire *et al.*, 2018), may affect water temperatures (Halofsky *et al.*, 2019), chemistry, and nutrient cycles. If increases in temperature or decreases in water availability increase use of wetlands by domestic livestock, habitat quality for native species likely will decrease.

Among the major wetland management efforts in Lane County is the West Eugene Wetlands Program (https://www.eugene-or.gov/644/Wetlands), which for the past 30 years has worked to conserve and restore about 3000 acres west of the city's downtown. Most of the wetland area is remnant wet prairie, some of which provides habitat for Fender's blue butterfly (*Icaricia icarioides fenderi*), a subspecies listed as endangered under the U.S. Endangered Species Act. Vernal pools, emergent wetlands, and dry grasslands and woodlands also are present. The West Eugene Wetlands are managed for their benefits to native species, stormwater treatment, and food control (City of Eugene and Lane County, 2004). Seventeen federal, state, and county agencies or other entities; watershed councils; and other nonprofit organizations collaborate on oversight of the program. In May 2022, the U.S. Bureau of Land Management received $95,000 for control of invasive plants in wetlands west of Eugene (Shumway, 2022).

Climate change affects Oregon's coastal estuaries and tidal wetlands through rising sea levels and saltwater intrusion, increases in wave height and the intensity of coastal storms, increases in air and water temperatures, changes in precipitation patterns and freshwater runoff, and ocean acidification. These changes in climate interact with the direct and indirect effects of changes in land use, from construction of housing and infrastructure to increases in the distribution and abundance of non-native invasive species (ODFW, n.d.).

As the climate changes, biological, chemical, and physical processes in coastal wetlands may change, and some species may move or become less viable (ODFW, n.d.). In addition, sea level rise is likely to alter the location and spatial extent of tidal wetlands. The locations of some tidal wetlands may not change if the rates of accretion and sea level rise are similar. If sea level rise exceeds accretion, wetlands may form further upslope if the landscape and lack of coastal development allow this migration (Brophy *et al.*, 2017).

Under scenarios of sea level rise of up to 2.5 feet, wetland area in 23 estuaries in Oregon is projected to increase somewhat as tides inundate slightly higher land surfaces (Brophy *et al.*, 2017). However, projected tidal wetland area begins to decline sharply as sea level continues to rise, with a 21% reduction in area at 4.7 feet of sea level rise, 45% reduction at 8.2 feet, and 60% reduction at 11.5 feet (Brophy *et al.*, 2017). The 2.5 and 4.7 feet of sea level rise correspond to the upper end of the range of sea level rise projected by 2050 and 2100, respectively, at Newport, Oregon (National Research Council, 2012). The 2.5 feet sea level rise scenario corresponds to the level expected by the 2090s, 2070s, and 2050s under the 2018 NCA's intermediate, intermediate-high, and high sea level rise scenarios, respectively (Table 13). The 4.7 feet sea level rise scenario is similar to that projected by the 2090s under the 2018 NCA's intermediate-high sea level rise scenario and by the 2070s to 2080s under the high sea level rise scenario (Table 13).

The projected change in tidal wetland area of the Siuslaw River estuary in Lane County was inconsistent with the general pattern of increases in potential tidal wetland area with relatively low levels of sea level rise, followed by decreases with high levels of sea level rise. Potential tidal wetland area in the Siuslaw River estuary is projected to decrease early and continuously under all sea level rise scenarios. Assuming 4.7 feet of sea level rise, tidal wetland area in the Siuslaw River estuary (Figure 22) is projected to decrease by about 54% (Brophy *et al.*, 2017) (Table 18).

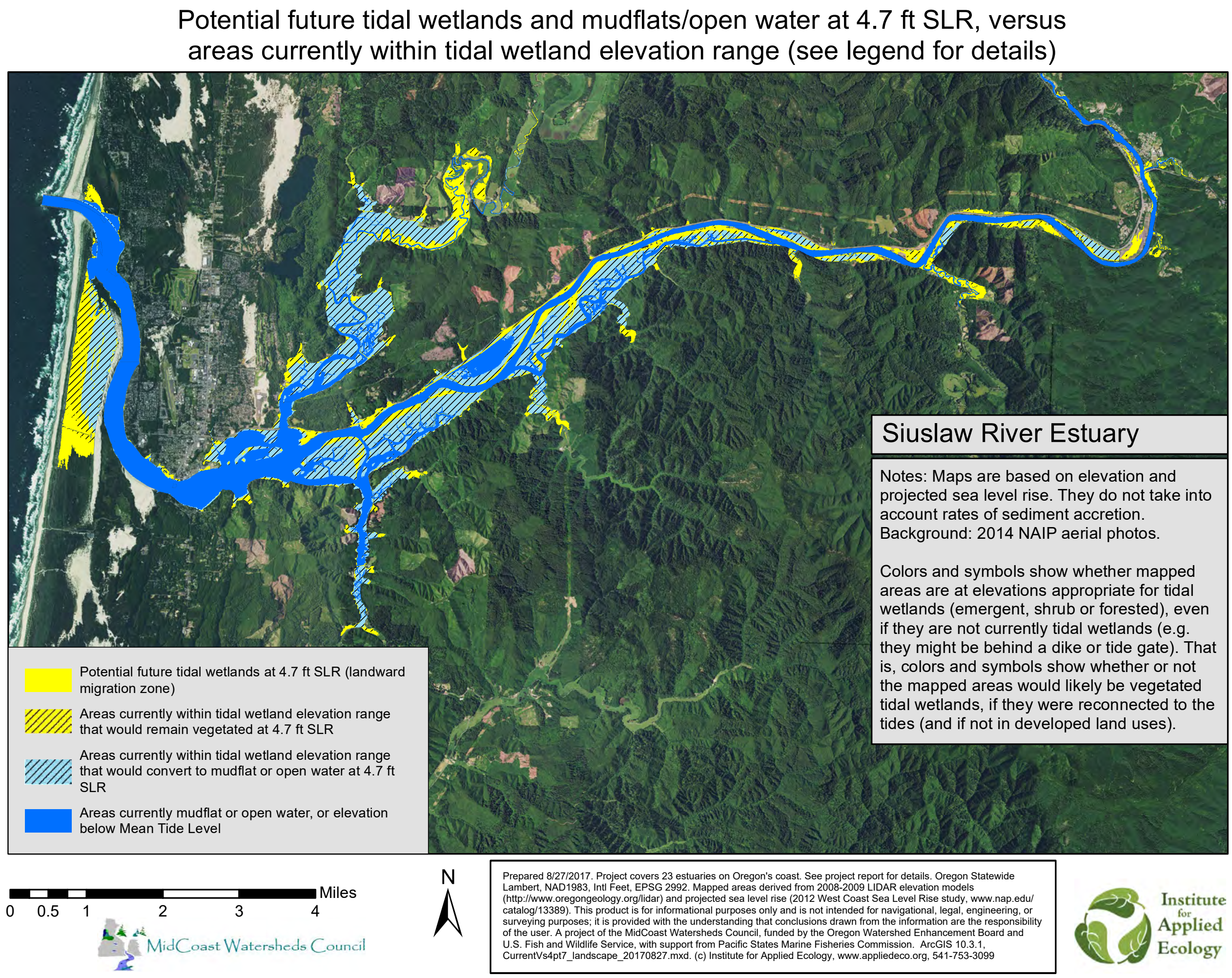


Figure 22. Potential tidal wetlands, mudflats, and open water at 4.7 feet sea level rise, versus areas currently within the elevation range of tidal wetlands, within the Siuslaw River estuary. (Source: Brophy et al., 2017)

Table 18. Present-day baseline and potential future tidal wetland area of the Siuslaw River estuary in Lane County, and projected changes in area under two sea level rise (SLR) scenarios. (Source: Brophy et al. 2017).

Present-Day Tidal Wetland Area (acres)	Future Tidal Wetland Area with 2.5 feet of SLR (acres)	Future Tidal Wetland Area with 4.7 feet of SLR (acres)	Change in Tidal Wetland Area with 2.5 feet of SLR (%)	Change in Tidal Wetland Area with 4.7 feet of SLR (%)
2996	2435	1365	-19	-54

Key Messages

- ⇒ In the Willamette Valley, losses of wetlands in recent decades largely were caused by conversion to agriculture. Projected effects of climate change on wetlands in the Northwest include reductions in water levels and hydroperiod duration. If withdrawals of ground water do not increase, then wetlands that are fed by ground water rather than surface water may be more resilient to climate change.
- ⇒ The structure, composition, and function of coastal wetland ecosystems will be affected by rising sea levels and saltwater intrusion, coastal erosion and flooding, changes in temperature and precipitation, and ocean acidification.
- ⇒ Wetland area in the Siuslaw River estuary is projected to decrease with increasing sea levels. Under 4.7 feet of sea level rise, tidal wetland area in these estuaries is projected to decrease by about 54%.

Windstorms

Climate change has the potential to alter surface winds through changes in the global free atmospheric circulation and storm systems, and through changes in the connection between the free atmosphere and Earth's surface. West of the Cascade Range, changes in surface wind speeds tend to follow changes in upper atmosphere winds associated with extratropical cyclones (Salathé *et al.*, 2015). The trend in winter extratropical storm frequency in the northeast Pacific since 1950 was positive, although not statistically significant (Vose *et al.*, 2014). However, uncertainty in projections of future extratropical cyclone frequency is high (IPCC, 2013).

Future projections indicate a slight northward shift in the jet stream and extratropical cyclone activity in the North Pacific. Over the northern hemisphere, the frequency of the most intense extratropical cyclones generally is projected to decrease, although in the northern North Pacific the frequency is projected to increase (IPCC, 2021) Therefore, there is no consensus on whether extratropical storms (Vose *et al.*, 2014; Seiler and Zwiers, 2016; Chang, 2018) and associated extreme winds (Kumar *et al.*, 2015) will intensify or become more frequent in the Northwest under a warmer climate.

Key Messages

⇒ Limited research suggests little if any change in the frequency and intensity of windstorms in the Northwest as a result of climate change.

Expansion of Non-native Invasive Plants

Changes in climate and atmospheric concentrations of carbon dioxide can affect the distribution and population dynamics of native and non-native species of animals and plants that are considered to be invasive or pests in natural and agricultural systems. Species-environment relations are not static (MacDonald, 2010; Walsworth *et al.*, 2019). Therefore, even when the current ecology of a species is well understood, it often is difficult to predict with confidence how the species will respond to projected changes in climate, especially when climate change interacts with land-use change or other environmental changes. Species adapt not to changes in climate but to all types of environmental change, including management actions (Thomas *et al.*, 1979; Skelly *et al.*, 2007; Winter *et al.*, 2016). These responses may be rapid, on the order of years or decades, especially when organisms have short generation times (Boughton, 1999; MacDonald *et al.*, 2008; Willis and MacDonald, 2011; Singer, 2017). Adaptive capacity also is affected by whether individuals can move freely or whether habitat fragmentation and other barriers impede movement (Thorne *et al.*, 2008; Willis and MacDonald, 2011; Fleishman and Murphy, 2012). Monocultures, dense populations, and even-aged populations of animals or plants generally are more susceptible to pests and pathogens than individuals in areas with higher species richness or populations with greater demographic diversity.

Lane County Public Works recognizes 43 species of plants as noxious or invasive weeds that it aims to reduce, control, or eradicate (Table 19). Although little is known about how many of these species may to respond to climate change, some evidence suggests how others may be affected. In general, non-native invasive plants in Lane County are likely to become more prevalent in response to projected changes in climate. However, many of these responses are uncertain, are likely to vary locally, and may change over time. Moreover, the density and distribution of weedy plants tends to increase in response to ground disturbance, whether from wildfire, livestock grazing, recreational activities, or removal of overstory trees and shrubs.

Table 19. Lane County Public Work's noxious and invasive weed management list.

Species	Growth form
Armenian blackberry (*Rubus armeniacus*)	Perennial vine
Black locust (*Robinia pseudoacacia*)	Tree
Bull thistle (*Cirsium vulgare*)	Biennial forb
Butterfly bush (*Buddleja davidii*)	Perennial shrub
Canada thistle (*Cirsium arvense*)	Perennial forb
Dalmatian toadflax (*Linaria dalmatica*)	Perennial forb
Diffuse knapweed (*Centaurea diffusa*)	Biennial forb
English ivy (*Hedera helix*)	Perennial vine
English hawthorn (*Crataegus monogyna*)	Shrub or small tree
English holly (*Ilex aquifolium*)	Shrub
Evergreen blackberry (*Rubus laciniatus*)	Shrub
False brome (*Brachypodium sylvaticum)*	Perennial grass
French broom (*Cytisus monspessulanas*)	Shrub

Garlic mustard (*Alliaria petiolata)*	Perennial forb
Giant hogweed (*Heracleum mantegazzianum*)	Biennial or perennial forb
Giant knotweed (*Fallopia sachalinensis*)	Shrub
Gorse (*Ulex europaeus*)	Shrub
Himalayan knotweed (*Polygnonum polystachyum)*	Annual forb
Houndstongue (*Cynoglossum officinale*)	Biennial or short-lived perennial forb
Hybrid knotweed (*Polygonum cuspidatum* var. *sachalinense*)	Shrub
Iberian starthistle (*Centaurea iberica*)	Annual forb
Italian thistle (*Carduus pycnocephalus)*	*Annual or biennial forb*
Japanese knotweed (*Fallopia japonica*)	Shrub
Kudzu (*Pueraria lobata*)	Perennial aquatic vine
Meadow knapweed (*Centaurea pratensis*)	Perennial forb
Orange hawkweed (*Aegilops ovata*)	Perennial forb
Policeman's helmet (*Impatiens glandulifera*)	Annual forb
Portuguese broom (*Cytisus striatus)*	Shrub
Puncturevine (*Tribulus terrestris*)	Annual forb
Purple loosestrife (*Lythrum salicaria*)	Perennial forb
Purple starthistle (*Centaurea calcitrapa*)	Annual, biennial, or perennial forb
Reed canary grass (*Phalaris arundinacea*)	Perennial grass
Russian knapweed (*Acroptilon repens*)	Perennial forb
Scotch broom (*Cytisus scoparius*)	Shrub
Scotch thistle (*Onopordum acanthium*)	Annual or biennial forb
Spanish broom (*Spartium junceum*)	Shrub
Spotted knapweed (*Centaurea stoebe*)	Short-lived perennial forb
Squarrose knapweed (*Centaurea virgata*)	Perennial forb
Tree of heaven (*Ailantus altissima*)	Tree
Sulfur cinquefoil (*Potentilla recta*)	Perennial forb
Yellow flag iris (*Iris pseudocorus*)	Perennial aquatic
Yellow starthistle (*Centaurea solstitalis*)	Annual forb
Yellow toadflax (*Linaria vulgaris*)	Perennial forb

Increasing concentrations of carbon dioxide not only lead to increases in global temperature, but affect many plants' primary productivity, water-use efficiency, and nutrient content. Increases in photosynthesis in response to increases in carbon dioxide are more common in plants with C3 metabolism than in plants with C4 metabolism. C4 metabolism has evolved multiple times, usually as an adaptation to hot, dry climate. Plants with C4 metabolism lose considerably less water per unit of carbon dioxide absorbed, and tend to photosynthesize more efficiently, than plants with C3 metabolism. By contrast, tolerance of the herbicide glyphosate, the active ingredient in Roundup, tends to increase more in C4 than in C3 plants as carbon dioxide increases (Chen *et al.*, 2020).

English ivy can benefit from increases in carbon dioxide concentrations, especially when temperatures are relatively warm (Manzanedo *et al.*, 2018), as can black locust (Nadal-Sala *et al.*, 2019). Similarly, in a greenhouse experiment, the water-use efficiency and aboveground and belowground biomass of reed canary grass increased as carbon dioxide concentrations increased (Ge *et al.*, 2012), and biomass of yellow starthistle increased markedly in response to experimentally increased concentrations of carbon dioxide (Dukes *et al.*, 2011). Experiments suggested that the photosynthetic rate and biomass of Canada thistle, and the number and length of the species' spines, are likely to increase as ambient concentrations of carbon dioxide increase throughout the twenty-first century, and may have increased during the previous century (Ziska, 2002). However, whether the root biomass of Canada thistle responds positively to increases in carbon dioxide concentrations, especially independent of increases in temperature, is unclear (Ziska *et al.*, 2004; Tørresen *et al.*, 2020). Furthermore, both bull thistle and Canada thistle can establish readily in soils that have been disturbed by high-severity wildfires, which may become more common as climate changes, or by logging (Reilly *et al.*, 2020). Warming increased seed mass of diffuse knapweed independent of increases in carbon dioxide (Li *et al.*, 2018).

Changes in climate, ongoing human additions of nitrogen to the environment, and their interactions also affect the growth and competitive relations among plant and animal species (Greaver *et al.*, 2016). The competitive advantage of non-native forbs and grasses over native species of plants may be strongest in relatively warm and dry areas, which often coincide with lower elevations (Dodson and Root, 2015). Additionally, non-native invasive plants generally gain a competitive advantage from nitrogen deposition. For example, the size of yellow starthistle plants increased substantially in response to experimentally increased nitrogen deposition, whereas co-occurring native plants responded less strongly (Dukes *et al.*, 2011). Japanese knotweed, too, may gain a competitive advantage over native species when nitrogen availability is variable or episodic (Parepa *et al.*, 2013). Nevertheless, how field experiments with supplemental nitrogen relate to changes in nitrogen deposition or availability as a result of climate change is uncertain. Japanese knotweed also is fairly tolerant of high temperatures, drought, saturated soils, and fire (Clements and DiTommaso, 2012).

Responses of non-native invasive plants to increases in temperature are diverse, even within the same species. For example, although it appears that photosynthesis in Japanese knotweed is constrained by temperatures below freezing (Baxendale and Tessier, 2015), the range of the species is expanding northward, perhaps reflecting evolution of frost tolerance (Clements and DiTommaso, 2012). Therefore, Japanese knotweed may become more widespread or abundant as minimum temperatures increase. Butterfly bush, Scotch broom, and English ivy usually are not highly tolerant of frost in autumn, although populations can become more frost-tolerant over time (Ebeling *et al.*, 2008; Strelau *et al.*, 2018; Winde *et al.*, 2020). In England, giant hogweed germinated earlier as the number of heat degree days >41˚F increased, and the species' overwinter survival decreased as frost incidence increased, but overwinter survival of seeds was not related to winter temperature or the number of days with frost from November through March (Willis and Hulme, 2002).

A 6.3°F increase in temperature was associated with an increase in aboveground biomass of reed canary grass early in the growing season, but with earlier senescence and lower biomass later in the growing season, especially when water availability was limited (Ge *et* *al.*, 2012). Increases in mean monthly temperature and maximum daily temperature, and reduction in the number of spring days with minimum temperatures below 32˚F, may lead to earlier seedling emergence and increase reproduction and recruitment of garlic mustard (Blossey *et al.*, 2017; Anderson *et al.*, 2021). Garlic mustard also may flower earlier as temperature increases (Fox and Jönsson, 2019). Yet germination of garlic mustard seeds currently requires winter chilling, and increases in winter temperature may limit the species' expansion until it evolves tolerance of higher winter temperatures (Footitt *et al.*, 2018). By contrast, reproduction of false brome along a latitudinal gradient in Europe was independent of temperature (growing degree hours above 41°F after 1 January) (De Frenne *et al.*, 2009). In at least some experimental contexts, growth of kudzu appears to be more sensitive to photoperiod than to temperature (Way *et al.*, 2017). Increases in temperature also can present opportunities for controlling non-native invasive plants. For instance, there is some evidence that heat stress impairs photosynthesis and therefore growth of English ivy (Strelau *et al.*, 2018). The life span of flowers of policeman's helmet (which is associated with duration of pollination) and the amount and sugar concentration of nectar produced responded negatively to temperatures above 80.6˚F (Descamps *et al.*, 2021).

The flowering phenology of purple loosestrife, which readily colonizes wetlands, is adapted to the duration of the growing season. At northern latitudes, including Oregon, purple loosestrife flowers early, at a small size; at southern latitudes, it flowers later, at a larger size (Colautti and Barrett, 2013). Early flowering limits reproductive growth of purple loosestrife, and northern plants generally produce fewer seeds and have less population-level genetic variation than southern plants (Colautti *et al.*, 2010). Climate change is expected to prolong the growing season, and therefore to increase the long-term viability of purple loosestrife, although local adaptation may be relatively slow due to genetic constraints of flowering time (Colautti *et al.*, 2010, 2017).

Changes in the amount and timing of precipitation may contribute to expansion or contraction of different non-native invasive plants. Some species that occur in Lane County tend to have high drought tolerance. For example, following experimental drought treatment in a seasonally flooded area, percent cover of bull thistle increased five to 13 times (Hogenbirk and Wein, 1991). Black locust also may be able to adapt to chronic drought (Mantovani *et al.*, 2014), although this capacity appears to have high spatial variability (Klisz *et al.*, 2021). In forests in western Oregon, cover of English ivy was associated negatively with summer precipitation, and occurrence of bull thistle and Canada thistle was associated negatively with annual precipitation (Gray, 2005).

By contrast, drought reduced the number of leaves, growth, and reproductive output of policeman's helmet (Descamps *et al.*, 2021), and drought in conjunction with shade may constrain the distribution of English holly (Aranda *et al.*, 2008). Yellow starthistle is somewhat sensitive to drought, and can be outcompeted by natives that are more tolerant of dry conditions (Dlugosch *et al.*, 2015; Young *et al.*, 2017). Spotted knapweed also may be outcompeted by some native grasses (e.g., bluebunch wheatgrass [*Pseudoroegneria spicata*]) during drought, but may have a competitive advantage when precipitation is closer to average (Pearson *et al.*, 2017). Monocultures of spotted knapweed appear to be less affected by drought (Pearson *et al.*, 2017). Evidence of drought tolerance in Scotch broom is equivocal, especially in the field rather than in greenhouse experiments (Potter *et al.*, 2009; Hogg and Moran, 2020). The growth and survival of Scotch broom in relatively open woodlands and forests may increase as snow depths decrease, especially during the winter after germination (Stevens and Latimer, 2015).

Normal to high precipitation can decrease the viability of certain non-native invasive plants, at least in some contexts. For example, gorse can spread after wildfire and generally is highly flammable. However, extreme precipitation following wildfire directly or indirectly may reduce seedling survival via movement of soil and litter, which can either expose or bury the small plants (Luís *et al.*, 2005). By contrast, increases in annual precipitation may facilitate expansion of French broom (García *et al.*, 2014) and diffuse knapweed (Blumenthal *et al.*, 2008). Whether drought limits vegetative growth of purple loosestrife is unclear. Increased spring temperatures and decreased precipitation associated with the El Niño–Southern Oscillation in some parts of the species' range were associated with early flowering and aboveground biomass accumulation, but not with total aboveground biomass, inflorescence lengths (an indicator of reproductive output), timing of senescence (Dech and Nosko, 2004).

Key Messages

⇒ In general, non-native invasive plants in Lane County are likely to become more prevalent in response to projected increases in temperature and the frequency, duration, and severity of drought. However, many of these responses are uncertain, are likely to vary locally, and may change over time.

Appendix

Future Climate Projections Background

Read more about global climate models, emissions scenarios, and uncertainty in the Climate Science Special Report—Volume 1 of the Fourth National Climate Assessment (https://science2017.globalchange.gov).

Global climate models (GCMs) and downscaling: https://science2017.globalchange.gov/chapter/4#section-3

Emissions scenarios: https://science2017.globalchange.gov/chapter/4#section-2

Uncertainty: https://science2017.globalchange.gov/chapter/4#section-4

Coupled Model Intercomparison Project phase 6 (CMIP6) climate models and emissions scenarios: see section B. Possible Climate Futures, https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

Climate and Hydrological Data

Statistically downscaled GCM outputs from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) were the basis for projections of future temperature, precipitation, and hydrology in this report. The coarse resolution of the GCMs outputs (100–300 km) was downscaled to a resolution of about 6 km with the Multivariate Adaptive Constructed Analogs (MACA) statistical downscaling method, which is skillful in complex terrain (Abatzoglou and Brown, 2012). The MACA approach uses gridded observational data to train the downscaling. It applies bias corrections and matches the spatial patterns of observed coarse-resolution to fine-resolution statistical relations. For a detailed description of the MACA method see https://climate.northwestknowledge.net/MACA/MACAmethod.php.

MACA data are the inputs to integrated models of climate, hydrology, and vegetation run by the Integrated Scenarios of the Future Northwest Environment project (https://climate.northwestknowledge.net/IntegratedScenarios/). Snow dynamics were simulated by the Integrated Scenarios project, which applied the Variable Infiltration Capacity (VIC) hydrological model (VIC version 4.1.2.l; Liang *et al.*, 1994 and updates) to a 1/16 x 1/16 degree (6 km) grid.

Simulations of daily maximum temperature, minimum temperature, and precipitation from 1950 through 2099 for 20 GCMs (Table 20) and two emissions scenarios (Representative Concentration Pathway [RCP] 4.5 and RCP 8.5) are available. Hydrological simulations of snow water equivalent (SWE) are available for the 10 GCMs used as input to VIC. All available modeled outputs were obtained from the Integrated Scenarios data archives and included in this report to represent the mean and range of projections among the largest possible ensemble of GCMs.

Table 20. The 20 global climate models (GCMs) from the firth phase of the Coupled Model Intercomparison Project (CMIP5) represented in this report. Asterisks indicate the ten GCMs used as inputs to the Variable Infiltration Capacity hydrological model.

Model Name	Modeling Center
BCC-CSM1-1 BCC-CSM1-1-M*	Beijing Climate Center, China Meteorological Administration
BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University, China
CanESM2*	Canadian Centre for Climate Modeling and Analysis
CCSM4*	National Center for Atmospheric Research, USA
CNRM-CM5*	National Centre of Meteorological Research, France
CSIRO-Mk3-6-0*	Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia
GFDL-ESM2G GFDL-ESM2M	NOAA Geophysical Fluid Dynamics Laboratory, USA
HadGEM2-CC* HadGEM2-ES*	Met Office Hadley Center, UK
INMCM4	Institute for Numerical Mathematics, Russia
IPSL-CM5A-LR IPSL-CM5A-MR* IPSL-CM5B-LR	Institut Pierre Simon Laplace, France
MIROC5* MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan
MRI-CGCM3	Meteorological Research Institute, Japan
NorESM1-M*	Norwegian Climate Center, Norway

All simulated climate data and the streamflow data, with the exception of snow water equivalent, were bias-corrected with quantile mapping by the Integrated Scenarios project. Quantile mapping adjusts simulated values by comparing the cumulative probability distributions of simulated and observed values. In practice, the simulated and observed values of a variable (e.g., daily streamflow) over the historical time period are sorted and ranked, and each value is assigned a probability of exceedance. The bias-corrected value of a given simulated value is assigned the observed value that has the same probability of exceedance as the simulated value. The historical bias in the simulations is assumed to be constant. Therefore, the relations between simulated and observed values in the historical period were applied to the future scenarios. Climate data in the MACA data reflect quantile mapping relations for each non-overlapping 15-day window in the calendar year. Streamflow data reflect quantile mapping relations for each calendar month.

The Integrated Scenarios project simulated hydrology with VIC (Liang *et al.*, 1994) run on a 1/16 x 1/16 degree (6 km) grid. To generate daily streamflow estimates, daily runoff from VIC grid cells was routed to selected locations along the stream network. Where records of naturalized flow were available, the daily streamflow estimates were bias-corrected so their statistical distributions matched those of the naturalized streamflows.

Vapor pressure deficit and 100-hour fuel moisture were computed by the Integrated Scenarios project with the same MACA climate variables according to the equations in the National Fire Danger Rating System (NWCG, 2019).

Smoke Wave Data

Data from Liu et al. (2016) are available at https://khanotations.github.io/smoke-map/. Variables used in this report included "Total # of SW days in 6 yrs" and "Average SW Intensity". The former is the number of days within each time period on which the concentration of fine particulate matter ($PM_{2.5}$), averaged within each county, exceeded the 98th quantile of the distribution of daily, wildfire-specific $PM_{2.5}$ values from 2004 through 2009 (smoke wave days). The latter is the average concentration of $PM_{2.5}$ across smoke wave days within each time period. Liu et al. (2016) used 15 GCMs from the third phase of the Coupled Model Intercomparison Project under a medium emissions scenario (SRES-A1B) as inputs to a fire prediction model and the GEOS-Chem three-dimensional global chemical transport model. The available data include only the multiple-model mean value (not the range), which should be interpreted as the direction of projected change rather than the actual expected value.

Sea Level Rise and Coastal Flooding Data

In this report, we used the sea level rise projections for the United States (Sweet *et al.*, 2017b) that were developed for the 2018 U.S. National Climate Assessment (Sweet *et al.*, 2017a). We accessed the projections from the Climate Central Surging Seas Risk Finder (riskfinder.climatecentral.org). The magnitude of global mean sea level rise by 2100 (GMSL) defines each scenario. The Risk Finder provides the corresponding local projections from NOAA, which vary due to local factors such as rising or sinking land. Low, middle, and high sub-scenarios yield a range of possible local sea level rise outcomes (17th, 50th and 83rd percentiles) given each main scenario. The low scenario assumes that sea level rise rates during the last 30 years remains stable, whereas the extreme scenario assumes accelerated loss of the Antarctic ice sheet. Flood likelihoods and assets at risk were based on these sea level change scenarios and accessed directly from the Climate

Central Surging Seas Risk Finder’s data visualization tools (riskfinder.climatecentral.org).

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Appendix E: Evaluation of Mitigation Strategies

Economic Analysis of Natural Hazard Mitigation Projects

This appendix was developed by the University of Oregon's Oregon Natural Hazards Workgroup and it outlines three approaches for conducting economic analysis of natural hazard mitigation projects. It describes the importance of implementing mitigation activities, different approaches to economic analysis of mitigation strategies, and methods to calculate costs and benefits associated with mitigation strategies. Information in this section is derived in part from: The Interagency Hazards Mitigation Team, *State Hazard Mitigation Plan,* (Oregon State Police – Office of Emergency Management, 2000), and Federal Emergency Management Agency Publication 331, *Report on Costs and Benefits of Natural Hazard Mitigatio*n. This section is not intended to provide a comprehensive description of benefit/cost analysis, nor is it intended to provide the details of economic analysis methods that can be used to evaluate local projects. It is intended to (1) raise benefit/cost analysis as an important issue, and (2) provide some background on how economic analysis can be used to evaluate mitigation projects.

Why Evaluate Mitigation Strategies?

Mitigation activities reduce the cost of disasters by minimizing property damage, injuries, and the potential for loss of life, and by reducing emergency response costs, which would otherwise be incurred. Evaluating possible natural hazard mitigation activities provides decision-makers with an understanding of the potential benefits and costs of an activity, as well as a basis upon which to compare alternative projects.

Evaluating mitigation projects is a complex and difficult undertaking, which is influenced by many variables. First, natural disasters affect all segments of the communities they strike, including individuals, businesses, and public services such as fire, police, utilities, and schools. Second, while some of the direct and indirect costs of disaster damages are measurable, some of the costs are non-financial and difficult to quantify in dollars. Third, many of the impacts of such events produce "ripple-effects" throughout the community, greatly increasing the disaster's social and economic consequences.

While not easily accomplished, there is value, from a public policy perspective, in assessing the positive and negative impacts from mitigation activities, and obtaining an instructive benefit/cost comparison. Otherwise, the decision to pursue or not pursue various mitigation options would not be based on an objective understanding of the net benefit or loss associated with these actions.

What are Some Economic Analysis Approaches for Evaluating Mitigation Strategies?

The approaches used to identify the costs and benefits associated with natural hazard mitigation strategies, measures, or projects fall into three general categories: benefit/cost analysis, cost-effectiveness analysis and the STAPLE/E approach. The distinction between the methods is outlined below:

Benefit/cost Analysis

Benefit/cost analysis is a key mechanism used by the state Office of Emergency Management (OEM), the Federal Emergency Management Agency, and other state and federal agencies in evaluating hazard mitigation projects..

Benefit/cost analysis is used in natural hazards mitigation to show if the benefits to life and property protected through mitigation efforts exceed the cost of the mitigation activity. Conducting benefit/cost analysis for a mitigation activity can assist communities in determining whether a project is worth undertaking now, in order to avoid disaster-related damages later. Benefit/cost analysis is based on calculating the frequency and severity of a hazard, avoided future damages, and risk. In benefit/cost analysis, all costs and benefits are evaluated in terms of dollars, and a net benefit/cost ratio is computed to determine whether a project should be implemented. A project worth pursuing will have a benefit/cost ratio greater than 1 (i.e., the net benefits will the exceed net costs).

Cost-Effectiveness Analysis

Cost-effectiveness analysis evaluates how best to spend a given amount of money to achieve a specific goal. This type of analysis, however, does not necessarily measure costs and benefits in terms of dollars. Determining the economic feasibility of mitigating natural hazards can also be organized according to the perspective of those with an economic interest in the outcome. Hence, economic analysis approaches are covered for both public and private sectors as follows.

Investing in public sector mitigation activities

Evaluating mitigation strategies in the public sector is complicated because it involves estimating all of the economic benefits and costs regardless of who realizes them, and potentially to a large number of people and economic entities. Some benefits cannot be evaluated monetarily, but still affect the public in profound ways. Economists have developed methods to evaluate the economic feasibility of public decisions which involve a diverse set of beneficiaries and non-market benefits.

Investing in private sector mitigation activities

Private sector mitigation projects may occur on the basis of one of two approaches: it may be mandated by a regulation or standard, or it may be economically justified on its own merits.

A building or landowner, whether a private entity or a public agency, required to conform to a mandated standard may consider the following options:

- Request cost sharing from public agencies;
- Dispose of the building or land either by sale or demolition;
- Change the designated use of the building or land and change the hazard mitigation compliance requirement; or
- Evaluate the most feasible alternatives and initiate the most cost effective hazard mitigation alternative.

The sale of a building or land triggers another set of concerns. For example, real estate disclosure laws can be developed which require sellers of real property to disclose known defects and deficiencies in the property, including earthquake weaknesses and hazards to prospective purchasers. Correcting deficiencies can be expensive and time consuming, but their existence can prevent the sale of the building. Conditions of a sale regarding the deficiencies and the price of the building can be negotiated between a buyer and seller.

STAPLE/E Approach

Conducting detailed benefit/cost or cost-effectiveness analysis for every possible mitigation activity could be very time consuming and may not be practical. There are some alternate approaches for conducting a quick evaluation of the proposed mitigation activities which could be used to identify those mitigation activities that merit more detailed assessment. One of these methods is the STAPLE/E Approach.

Using STAPLE/E criteria, mitigation activities can be evaluated quickly by steering committees in a systematic fashion. This criteria requires the committee to assess the mitigation activities based on the Social, Technical, Administrative, Political, Legal, Economic, and Environmental (STAPLE/E) constraints and opportunities of implementing the particular mitigation item in your community. The second chapter in FEMA's April How-To Guide "Developing the Mitigation Plan – Identifying Mitigation Actions and Implementation Strategies" as well as the "State of Oregon's Local Natural Hazard Mitigation Plan: An Evaluation Process" outline some specific considerations in analyzing each aspect. The following are suggestions for how to examine each aspect of the STAPLE/E Approach from the "State of Oregon's Local Natural Hazard Mitigation Plan: An Evaluation Process".

Social: Community development staff, local non-profit organizations, or a local planning board can help answer these questions:

- Is the proposed action socially acceptable to the community?
- Are there equity issues involved that would mean that one segment of the community is treated unfairly?
- Will the action cause social disruption?

Technical: The city or county public works staff, and building department staff can help answer these questions.

- Will the proposed action work?
- Will it create more problems than it solves?
- Does it solve a problem or only a symptom?
- Is it the most useful action in light of other community goals?

Administrative: Elected officials or the city or county administrator, can help answer these questions.

- Can the community implement the action?
- Is there someone to coordinate and lead the effort?
- Is there sufficient funding, staff, and technical support available?
- Are there ongoing administrative requirements that need to be met?

Political: Consult the mayor, city council or county planning commission, city or county administrator, and local planning commissions to help answer these questions.

- Is the action politically acceptable?
- Is there public support both to implement and to maintain the project?

Legal: Include legal counsel, land use planners, risk managers, and city council or county planning commission members, among others, in this discussion.

- Is the community authorized to implement the proposed action? Is there a clear legal basis or precedent for this activity?
- Are there legal side effects? Could the activity be construed as a taking?
- Is the proposed action allowed by the comprehensive plan, or must the comprehensive plan be amended to allow the proposed action?
- Will the community be liable for action or lack of action?
- Will the activity be challenged?

Economic: Community economic development staff, civil engineers, building department staff, and the assessor's office can help answer these questions.

- What are the costs and benefits of this action?
- Do the benefits exceed the costs?
- Are initial, maintenance, and administrative costs taken into account?
- Has funding been secured for the proposed action? If not, what are the potential funding sources (public, non-profit, and private)?
- How will this action affect the fiscal capability of the community?
- What burden will this action place on the tax base or local economy?
- What are the budget and revenue effects of this activity?
- Does the action contribute to other community goals, such as capital improvements or economic development?
- What benefits will the action provide? (This can include dollar amount of damages prevented, number of homes protected, credit under the CRS, potential for funding under the HMGP or the FMA program, etc.)

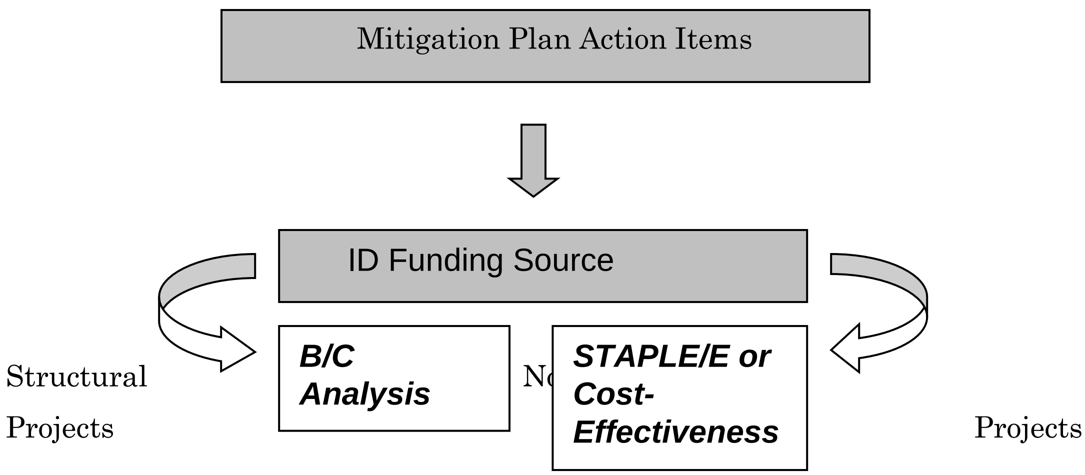
Environmental: Watershed councils, environmental groups, land use planners and natural resource managers can help answer these questions.

- How will the action impact the environment?
- Will the action need environmental regulatory approvals?
- Will it meet local and state regulatory requirements?
- Are endangered or threatened species likely to be affected?

The STAPLE/E approach is helpful for doing a quick analysis of mitigation projects. Most projects that seek federal funding and others often require more detailed Benefit/Cost Analyses.

When to use the Various Approaches

It is important to realize that various funding sources require different types of economic analyses. The following figure is to serve as a guideline for when to use the various approaches.



Implementing the Approaches

Benefit/cost analysis, cost-effectiveness analysis, and the STAPLE/E are important tools in evaluating whether or not to implement a mitigation activity. A framework for evaluating mitigation activities is outlined below. This framework should be used in further analyzing the feasibility of prioritized mitigation activities.

<u>1. Identify the Activities</u>

Activities for reducing risk from natural hazards can include structural projects to enhance disaster resistance, education and outreach, and acquisition or demolition of exposed properties, among others. Different mitigation project can assist in minimizing risk to natural hazards, but do so at varying economic costs.

2. Calculate the Costs and Benefits

Choosing economic criteria is essential to systematically calculating costs and benefits of mitigation projects and selecting the most appropriate activities. Potential economic criteria to evaluate alternatives include:

Determine the project cost. This may include initial project development costs, and repair and operating costs of maintaining projects over time.

Estimate the benefits. Projecting the benefits, or cash flow resulting from a project can be difficult. Expected future returns from the mitigation effort depend on the correct specification of the risk and the effectiveness of the project, which may not be well known. Expected future costs depend on the physical durability and potential economic obsolescence of the investment. This is difficult to project. These considerations will also provide guidance in selecting an appropriate salvage value. Future tax structures and rates must be projected. Financing alternatives must be researched, and they may include retained earnings, bond and stock issues, and commercial loans.

Consider costs and benefits to society and the environment. These are not easily measured, but can be assessed through a variety of economic tools including existence value or contingent value theories. These theories provide quantitative data on the value people attribute to physical or social environments. Even without hard data, however, impacts of structural projects to the physical environment or to society should be considered when implementing mitigation projects.

Determine the correct discount rate. Determination of the discount rate can just be the risk-free cost of capital, but it may include the decision maker's time preference and also a risk premium. Including inflation should also be considered.

3. Analyze and Rank the Activities

Once costs and benefits have been quantified, economic analysis tools can rank the possible mitigation activities. Two methods for determining the best activities given varying costs and benefits include net present value and internal rate of return.

- ***Net present value***. Net present value is the value of the expected future returns of an investment minus the value of expected future cost expressed in today's dollars. If the net present value is greater than the project costs, the project may be determined feasible for implementation. Selecting the discount rate, and identifying the present and future costs and benefits of the project calculates the net present value of projects.
- ***Internal Rate of Return***. Using the *internal rate of return* method to evaluate mitigation projects provides the interest rate equivalent to the dollar returns expected from the project. Once the rate has been calculated, it can be compared to rates earned by investing in alternative projects. Projects may be feasible to implement when the internal rate of return is greater than the total costs of the project. Once the mitigation projects are ranked on the basis of economic criteria, decision-makers can consider other factors, such as risk, project effectiveness, and economic, environmental, and social returns in choosing the appropriate project for implementation.

Economic Returns of Natural Hazard Mitigation

The estimation of economic returns, which accrue to building or landowner as a result of natural hazard mitigation, is difficult. Owners evaluating the economic feasibility of mitigation should consider reductions in physical damages and financial losses. A partial list follows:

- Building damages avoided
- Content damages avoided
- Inventory damages avoided
- Rental income losses avoided
- Relocation and disruption expenses avoided
- Proprietor's income losses avoided

These parameters can be estimated using observed prices, costs, and engineering data. The difficult part is to correctly determine the effectiveness of the hazard mitigation project and the resulting reduction in damages and losses. Equally as difficult is assessing the probability that an event will occur. The damages and losses should only include those that will be borne by the owner. The salvage value of the investment can be important in determining economic feasibility. Salvage value becomes more important as the time horizon of the owner declines. This is important because most businesses depreciate assets over a period of time.

Additional Costs from Natural Hazards

Property owners should also assess changes in a broader set of factors that can change as a result of a large natural disaster. These are usually termed "indirect" effects, but they can have a very direct effect on the economic value of the owner's building or land. They can be positive or negative, and include changes in the following:

- Commodity and resource prices
- Availability of resource supplies
- Commodity and resource demand changes
- Building and land values
- Capital availability and interest rates
- Availability of labor
- Economic structure
- Infrastructure
- Regional exports and imports
- Local, state, and national regulations and policies
- Insurance availability and rates

Changes in the resources and industries listed above are more difficult to estimate and require models that are structured to estimate total economic impacts. Total economic impacts are the sum of direct and indirect economic impacts. Total economic impact models are usually not combined with economic feasibility models.

Many models exist to estimate total economic impacts of changes in an economy. Decision makers should understand the total economic impacts of natural disasters in order to calculate the benefits of a mitigation activity. This suggests that understanding the local economy is an important first step in being able to understand the potential impacts of a disaster, and the benefits of mitigation activities.

Additional Considerations

Conducting an economic analysis for potential mitigation activities can assist decision-makers in choosing the most appropriate strategy for their community to reduce risk and prevent loss from natural hazards. Economic analysis can also save time and resources from being spent on inappropriate or unfeasible projects. Several resources and models are listed on the following page that can assist in conducting an economic analysis for natural hazard mitigation activities.

Benefit/cost analysis is complicated, and the numbers may divert attention from other important issues. It is important to consider the qualitative factors of a project associated with mitigation that cannot be evaluated economically. There are alternative approaches to implementing mitigation projects. Many communities are looking towards developing multi-objective projects. With this in mind, opportunity rises to develop strategies that integrate natural hazard mitigation with projects related to watersheds, environmental planning, community economic development, and small business development, among others. Incorporating natural hazard mitigation with other community projects can increase the viability of project implementation.

Resources

CUREe Kajima Project, *Methodologies For Evaluating The Socio-Economic Consequences Of Large Earthquakes*, Task 7.2 Economic Impact Analysis, Prepared by University of California, Berkeley Team, Robert A. Olson, VSP Associates, Team Leader; John M. Eidinger, G&E Engineering Systems; Kenneth A. Goettel, Goettel and Associates Inc.; and Gerald L. Horner, Hazard Mitigation Economics Inc., 1997.

Federal Emergency Management Agency, *Benefit/Cost Analysis of Hazard Mitigation Projects*, Riverine Flood, Version 1.05, Hazard Mitigation Economics Inc., 1996.

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Appendix F: Plan Development Timeline

2005

General: The City of Cottage Grove developed the 2005 Hazards Mitigation Plan as an addendum to the Lane County All-Hazard Mitigation Plan in an effort to take a more regional approach to planning for natural hazard scenarios. The Natural Hazards Mitigation Plan Team was formed in February of 2003, and served to provide guidance and direction in the Natural Hazards Mitigation Plan by the City Council in 2005.

Activities: Community Development Department engaged in several community-wide planning activities that implemented elements of the 2005 Natural Hazards Mitigation Plan, including a 2050 Visioning project, Total Maximum Daily Load (TMDL) Implementation Planning process and plan adoption, extended work with the Coast Fork Watershed Council on floodplain and riparian protections, work with the 2006-2007 Development Code Advisory Committee on the adoption of new sensitive lands standards in 2008, and ongoing work with the Lane County Countywide Preparedness Group.

The original Natural Hazards Mitigation Plan Advisory Committee was used as an Advisory Committee for the TMDL Implementation Plan; information from this on-going planning process was used to inform changes made in the Update done in 2010.

Table 2. 2005 NHMP Action Items

Flood #1: Investigate FEMA's Community Rating System requirements to potentially lower flood insurance rates.
Flood #2: Improve upon localized flood hazard knowledge.
Flood #3: Inventory structures and infrastructure in the FEMA mapped floodway and explore mitigation options.
Flood #4: Address concerns associated with development in areas with high water tables.
Flood #5: Increase channel maintenance and debris removal from rivers and streams.
Flood #6: Update Storm Drainage Master Plan, determine and implement appropriate mitigation measures.

Flood #7: Improve public notification system in case of a dam break.
Landslide #1: Evaluate risk level for buildings identified in the landslide hazard area.
Landslide #2: Limit future development in high landslide potential areas.
Landslide #3: Adopt erosion control regulations for all development, especially in high landslide hazard areas. Wildland Fire #1: Encourage fire-safe construction practices for existing and new construction in high-risk areas.
Winter Storm #1: Decrease risk of power and utility outages by moving lines underground.
Winter Storm #2: Periodically survey trees on city property and trim as necessary.
Winter Storm #3: Ensure that critical facilities have backup power and emergency operations plans to deal with power outages.
Earthquake #1: Complete inventory of residential, commercial, and public buildings in Cottage Grove that may be particularly vulnerable to earthquake damage, including (but not limited to) unreinforced masonry buildings and wood frame buildings with cripple wall foundations and with sill plates not bolted to the foundation.
Earthquake #2: Complete seismic vulnerability assessments and develop mitigation strategies of seismic retrofit of critical public buildings identified as being particularly vulnerable.
Earthquake #3: Study and make necessary improvements to the water transmission line from Layng Creek.
Multi-Hazard #1: Complete inventories of buildings and infrastructure at risk from each hazard and prioritize mitigation projects to reduce the level of risk.
Multi-Hazard #2: Identify and pursue funding opportunities to develop and implement specific mitigation projects in Cottage Grove.
Multi-Hazard #3: Strengthen emergency preparedness and response capabilities.
Multi-Hazard #4: Integrate the information, objectives, mitigation strategies and action items into existing regulatory documents and programs.
Multi-Hazard #5: Update the Comprehensive Plan to meet State Land Use Planning Goal 7.
Multi-Hazard #6: Enhance awareness of natural hazards.
Multi-Hazard #7: Increase the medical resources capable of handling large-scale medical needs.
Multi-Hazard #8: Ensure that there are adequate shelter facilities in hazard-free zones to serve Cottage Grove residents.

2010

General: The 2005 Plan was due for an update by April 2010. In December 2009, a steering committee was formed to update the 2005 Plan.

This committee reviewed and updated the mission, goals and objectives of the 2005 Plan. They also reviewed and updated the plan's risk assessment, the mitigation actions, and the plan implementation and maintenance process. The planning process was designed to: (1) result in an updated plan that is Disaster Mitigation Act 2000 compliant; (2) coordinate with the State's plan and Lane County's plan; (3) build a network of local organizations that can play an active role in plan implementation; and (4) reflect any changes or new information that occurred since the plan's initial adoption in 2005.

This planning process was influenced by the work done by the Oregon Partnership for Disaster Resilience on the 2009 Eugene/Springfield Multi-Jurisdictional Natural Hazards Mitigation Plan, funded through a FEMA awarded Pre-Disaster Mitigation grant.

Table 3. 2010 NHMP Action Items

Flood Hazard 1: Improve upon localized flood hazard knowledge.
Flood Hazard 2: Inventory structures and infrastructure in the FEMA mapped floodway and explore mitigation options.
Flood Hazard 3: Coordinate with other local, state and federal agencies on floodplain improvements
Flood Hazard 4: Increase channel maintenance and debris removal from rivers and streams.
Flood Hazard 5: Adopt Storm Drainage Master Plan, and determine and implement appropriate mitigation measures.
Flood Hazard 6: Improve public notification system in case of a dam break.
Flood Hazard 7: Improve Riparian area health.
Landslide Hazard 1: Evaluate risk level for buildings identified in the Landslide hazard area.
Landslide Hazard 2: Limit future development in high landslide potential areas.
Landslide Hazard 3: Adopt erosion control regulations for all development, especially in high landslide hazard areas.
Landslide Hazard 4: Evaluate landslide hazard risk for Knox Hill Reservoir and mitigate as necessary.

Landslide Hazard 5: Improve knowledge of landslide hazard through better mapping.
Wildfire 1: Encourage fire-safe construction practices for existing and new construction in high-risk areas.
Winterstorm 1: Decrease risk of power and utility outages by moving lines underground.
Winterstorm 2: Periodically survey trees on city property and trim as necessary.
Winterstorm 3: Ensure that critical facilities have backup power and emergency operations plans to deal with power outages.
Winterstorm 4: Develop plans for snow emergency and roof clearance.
Earthquake 1: Complete and maintain inventory of critical infrastructure in Cottage Grove that may be particularly vulnerable to earthquake damage, including (but not limited to) unreinforced masonry buildings and infrastructure.
Earthquake 2: Complete seismic vulnerability assessments and develop mitigation strategies of seismic retrofit of critical public buildings and facilities identified as being particularly vulnerable.
Earthquake 3: Complete and maintain inventory of commercial and multi-family residential buildings in Cottage Grove that may be particularly vulnerable to earthquake damage, including (but not limited to) unreinforced masonry buildings and wood frame buildings with cripple wall foundations and with sill plates not bolted to the foundation.
Earthquake 4: Complete necessary improvements to the Row River Water Treatment Plant.
Earthquake 5: Participate in ODOT Bridge review program.
Multi Hazard 1: Complete inventory of buildings and infrastructure at risk from each hazard and prioritize mitigation projects to reduce the level of risk.
Multi Hazard 2: Identify and pursue funding opportunities to develop and implement specific mitigation projects in Cottage Grove.
Multi Hazard 3: Strengthen emergency preparedness and response capabilities.
Multi Hazard 4: Integrate the information. Objectives, mitigation strategies and action items into existing regulatory documents and programs.
Multi Hazard 5: Update the Comprehensive Plan and Development Code to meet State Land Use Planning Goal 7.
Multi Hazard 6: Enhance awareness of natural hazards.

<u>Multi Hazard 7:</u> Increase the medical resources capable of handling large-scale medical needs.
<u>Multi Hazard 8:</u> Ensure that there are adequate shelter facilities in hazard-free zones to serve Cottage Grove residents.

<u>Activities</u>:

<u>Steering Committee Meeting (February, 2010)</u>

The committee met to review and update as necessary plan goals and objectives; (2) develop a stakeholder list and approve a public involvement plan; and (3) develop a project timeline.

<u>Steering Committee Meeting (March, 2010)</u>

The committee met again in early March to (1) review and update the city's hazard profile and vulnerability estimates; (2) review and make recommendations on mitigation strategies; and (3) discuss stakeholder survey content.

Agendas from those meeting were included as part of the City's Appendix to the Lane County Natural Hazards Mitigation Plan Update. Once defined, the public involvement schedule and project goals were uploaded to the City's website and a notice of the upcoming planning process was sent to all City water service customers.

<u>Stakeholder Identification</u>

As part of the public involvement plan, the Steering Committee identified a group of stakeholders that may be impacted by or have some control over the impacts of natural hazards in Cottage Grove. Representatives from the following organizations were contacted via mail and email to inform them on the ongoing project and request comment on revised mitigation strategies:

- The Building Department
- Cottage Grove Historical Society
- Cottage Grove Area Chamber of Commerce
- Coast Fork Willamette Watershed Council
- City of Cottage Grove Public Works, Engineering
- City of Cottage Grove, Maintenance
- City of Cottage Grove, Sewer & Water
- South Lane County Fire and Rescue District
- Lane County Transportation Planning
- Oregon Department of Forestry
- U.S. Forest Service
- Department of State Lands
- Lane County Waste Management

- Lane County Land Management
- ODOT Region 5
- Pacific Power & Light
- NW Natural
- Emerald People's Utility District
- Peace Health
- South Lane School District
- Cottage Grove Economic & Business Improvement District
- Visioning Committee
- U.S. Army Corps of Engineers
- Department of Land Conservation & Development

Public Open House & Steering Committee meeting (June 2010)

The Steering Committee met to review final draft mitigation strategies as prepared by Community Development Department staff at a meeting in June at City Hall in an Open House format. The drafts were made available on-line for public comment two weeks before the open house.

All stakeholders had received email and written invitations to attend the Open House. Additionally, all water-bill customers within Cottage Grove received a public notice of the meeting. The public open house was also published in the Sentinel and advertised on-line and at various public locations throughout Cottage Grove. Comments taken at the meeting were incorporated into the final draft of the document. (See Appendix for copies of public notice, meeting materials and meeting attendance.)

Final Draft

Staff created a draft 2011 Natural Hazards Mitigation Plan Update integrating comments received during the open house. This draft was sent to the State Hazard Mitigation Office and to FEMA Region 5 for review and comment to verify that the City was on the right track. Comments were incorporated into the draft prior to release to the public.

State Hazard Mitigation Officer Review (November 2011)

The final approved draft of the 2011 Update was sent to the State Hazard Mitigation Officer and to FEMA for review. Upon receipt of approval pending adoption, City staff began the process for local adoption.

Final adoption (April 2012)

The Cottage Grove City Council is responsible for adopting the City of Cottage Grove Natural Hazards Mitigation Plan as well as the Lane County All-Hazard Mitigation Plan as an addendum to the Cottage Grove Plan.

The City Council adopted the final draft of the document through Resolution No. 1802 on April 23, 2012.

2015-16 Update

In June of 2015, the decision was made to update the City's current NHMP as Lane County was also in the process of updating its NHMP in order to incorporate changes made in state level planning guidelines. The Cottage Grove NHMP Update is being undertaken early in the 5 year planning cycle in order to make it adaptable to new FEMA mitigation planning standards released in 2013, and in coordination with efforts undertaken by Lane County Emergency Management.

The process began with a review of the current plan as it was adopted in April of 2012. The changes to the 2016 plan update include a significant change in the format of the document, and a very thorough review of existing Mitigation Actions. Mitigation Actions are now listed in a concise table format, and separate tables outlining Critical Infrastructure and Key Resources (CIKR), and the Natural Hazards to which they are vulnerable. Below is the timeline of development:

2015-16 NHMP Update Timeline	
October	• Form Advisory Committee • Invitees: ○ South Lane County Fire and Rescue – Justin Baird ○ Cottage Grove Police Department – Dan White ○ Planning Commission – Alan Widener ○ City Council - Garland Burbank ○ Community Development Department - Howard Schesser ○ City Planner - Amanda Ferguson ○ Public Works – Jan Wellman ○ Water Treatment – Jan Wellman ○ Finance Department – Bert Olson • Contact Stakeholders with Initial Information
December	• Advisory Committee • Review Proposed Mitigation Actions
March 2016	• Public Forum on survey results, proposed mitigation measures
April	• Advisory Committee: Review Second Draft Plan • Public Meeting on Draft Plan
May	• Final Draft of plan to stakeholders (written notice, plan on-line) • Advisory Committee: final Draft Review • Planning Commission – Draft Review • Revise as necessary based on comments
June	• Final Draft of Plan made available to City Council for comment
September	• Final Draft of Plan open for public comment on website
October	• Final Draft of Plan to OEM

2022-23 Plan Update

The process of updating the NHMP was initiated in 2020 with an application by the (then) Office of Emergency Management to FEMA's Pre-Disaster Mitigation program. The Department of Land Conservation and Development was the sub-applicant and the agency to carry out the update project. The initial work (Community Profile, Risk Assessment and Public Engagement) was coordinated by Pam Reber, and she prepared a 75% draft of the plan update. Due to Pam's departure from the agency, a second Natural Hazard Mitigation Planner (Katherine Daniel) worked with the steering committee to complete the analysis of the Mitigation Strategy.

The city has had a structure and practice in place to maintain and make progress on the Cottage Grove Natural Hazard Mitigation Plan since the 2017 update. The Hazard Mitigation AC solicited participation from county, state, federal and tribal government, the Coast Fork Willamette Watershed Council, the city-owned airport, the water district, the education service district and school facilities managers and superintendents, private insurance and power company representatives, Lane Community College, historical and health organizations. The steering committee met five times beginning in January 2022 and finishing in April 2023. Meeting minutes and agendas are provided in Appendix G.

The activities conducted to complete the plan update included publicly noticed meetings as well as public engagement through the city's website and a survey. The Central Lane County Flood Risk meetings were occurring during the same time frame as the plan update (October 2022). This was another opportunity to engage members of the public in free events open to the public. The city also received notification in October 2022 that it had retained its CRS rating of 6.

Public input was included in the plan to confirm the risk assessment conducted by the Steering Committee using the OEM Hazard Assessment Methodology as a group exercise. The survey received eighteen responses. Although the data were not analyzed or graphed, a review of the responses to the question "How would you like local government agencies to prepare for the earthquake hazard?" commonly included the following:

- Retrofit or rebuild critical facilities to ensure they have the structural integrity to withstand an earthquake event.
- Ensure that Cottage Grove's water supply can withstand a major earthquake event.;
- Install automatic shut off valves for fuel to prevent spills, explosions, and fires after an earthquake event.
- Install automatic shut off valves for water supply to prevent loss, leakage, or flooding.
- Educate the community about seismic retrofits for private homes.
- Educate the community about how to be 3-weeks ready with emergency food and supplies.

The survey contained the following questions:

Cottage Grove Community Hazard Survey

Cottage Grove Public Works & Development Department is leading the five-year update of the City's Natural Hazard Mitigation Plan. We want to hear from the community about your concerns regarding risks from natural hazards! Please answer the following survey questions and return the survey to the location where you received it or mail it to 400 E. Main St., Cottage Grove, OR 97424

1. Where do you live in Cottage Grove? Please choose the direction or landmark closest to your primary residence. *Select one:*

   - ☐ *Northwest (Mt. David)*
   - ☐ *Southwest (CGHS & Bohemia School)*
   - ☐ *Northeast (Middlefield)*
   - ☐ *Southeast (Lincoln Middle School)*
   - ☐ *Central/Downtown West (west of Hwy 99, east of the river)*
   - ☐ *Central/ Downtown East (east of Hwy 99, west of I-5)*

2. Are you concerned about **Flooding** affecting your home, family, or livelihood? *Select one:*

   - ☐ *Yes*
   - ☐ *No*
   - ☐ *Unsure*

3. Are you concerned about a **Landslide** affecting your home, family, or livelihood? *Select one:*

   - ☐ *Yes*
   - ☐ *No*
   - ☐ *Unsure*

4. Are you concerned about a **Wildfire** affecting your home, family, or livelihood? *Select one:*

   - ☐ *Yes*
   - ☐ *No*
   - ☐ *Unsure*

5. Is your home address well-signed and clearly visible from the street? (For example, reflective numbers visible at night, without vegetation impeding visibility, etc.)

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

6. *What actions have you taken to reduce wildfire* risk for your home? Please select all that apply:

- ☐ *Purchased insurance: homeowners, renters, and/or flood insurance.*
- ☐ *Retrofit home for fire or earthquake—such as installing fire-resistant siding, securing water tanks, etc.*
- ☐ *Created a firebreak around your home by removing or reducing fuels—such as dead trees, overgrown vegetation, or cleaning debris from gutters and roof.*
- ☐ *Installed smoke detectors, carbon monoxide detectors, and/or fire extinguishers.*

7. Are you concerned about a **Winter Storm** affecting your home, family, or livelihood?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

8. Are you concerned about an **Earthquake** affecting your home, family, or livelihood?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

9. Seismic standards were put into place in 1994. Have you considered seismic retrofits?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

10. How would you like local government agencies to prepare for the earthquake hazard? *Select all that apply*:

- ☐ *Retrofit or rebuild critical facilities to ensure they have the structural integrity to withstand an earthquake event.*
- ☐ *Ensure that Cottage Grove's water supply can withstand a major earthquake event.*

- ☐ *Install automatic shut off valves for fuel to prevent spills, explosions, and fires after an earthquake event.*
- ☐ *Install automatic shut off valves for water supply to prevent loss, leakage, or flooding.*
- ☐ *Educate the community about seismic retrofits for private homes.*
- ☐ *Educate the community about how to be 3-weeks ready with emergency food and supplies.*

11. Are you concerned about a **Drought** affecting your home, family, or livelihood?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

12. Are you concerned about a **Volcanic Event** affecting your home, family, or livelihood?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

13. Are you concerned about **Climate Change** affecting your home, family, or livelihood?

Select one:

- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*

14. Do you have any additional concerns or comments about hazards in your community? Please share them in the space below (200-word limit).

15. Provide your name if you would like it to appear with your comment.

16. Please provide your email if you would like to learn about future opportunities regarding hazards in Cottage Grove.

Thank you for completing this survey! Please return completed surveys to the location where you received it or mail it to: 400 E. Main Street, Cottage Grove, OR 97424.

The data from the 28 responses were provided in graphical form to the final plan writier, however, the open-ended responses were as follows:

Public Comment Matrix

The following comments were provided by the community as a part of the City of Cottage Grove Community Hazards Survey available July 2022.

Open-Ended Response Comments Do you have any additional concerns or comments about hazards in your community?			
#	Commenter	Comment	Response
1	Emad Al-Nasian, Northwest (Mt. David)	No concerns aside from the power outages.	Thank you. Power outages are addressed by backup power and are considered under the Winter Storm and All-Hazards mitigation actions and hazard chapters.
2	Chelsy, Southeast (Lincoln Middle School)	More housing	Housing production is outside of the scope of this plan. However, the location and density of residential development is considered.
3	Anonymous, Northwest (Mt. David)	Crime and homeless	Crime is not specifically addressed in a plan of this type. Addressing the needs of the whole community in a disaster is a consideration in natural hazards planning.
4	James, Northwest (Mt. David)	Homeless people	Addressing the needs of the whole community in a disaster is a consideration in natural hazards planning.
5	Anonymous, Southwest (CGHS & Bohemia School)	People driving too fast	Natural hazard mitigation planning does not address this concern.
6	Keri, Southwest (CGHS & Bohemia School)	No	Thank you for participating in this survey.
7	Pam Gothberg, Southwest (CGHS & Bohemia School)	No	Thank you for participating in this survey.
8	Erika, Southeast (Lincoln Middle School)	No	Thank you for participating in this survey.

Appendix G: Public Meeting Documentation

44 CFR Requirement 201.6(b)
An open public involvement process is essential to the development of an effective plan. In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include: (2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process. (3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.

Outlined below are the highlights of Cottage Grove Natural Hazards Mitigation Plan Advisory Committee meetings and general mitigation activities undertaken during this planning cycle. These activities demonstrate the committed and diverse involvement of community members, local government, regional agencies, the public, and various stakeholders.

The 2023 Natural Hazards Mitigation Plan Advisory Committee began meeting in late January 2022. Committee members included staff from Public Works, Community Development, the city Building Official, Water Production Superintendent, City Engineer, and the City Manager, South Lane Fire & Rescue District, Cottage Grove City Council. Representatives from other community organizations participated as partners. These included the Coast Fork Willamette Watershed Council, Community Sharing, and the Cottage Grove Museum. Lane County Emergency Management acted as an ex-officio member of the committee, receiving agenda packets prior to each meeting.

Public notice for all meetings was provided and meetings were held in City Council Chambers at City Hall, 400 E. Main Street. All Steering Committee meetings were held as public meetings and time was provided at each meeting for public comment. Information was sent out to the community about the meetings through press releases and website updates at least 2 weeks before each meeting, and current drafts of the document were available to review as it was being developed on the City's website, www.cottagegrove.org. The final document was made available for review by City Council and stakeholders in December 2023. The final draft was placed on the City's website for public comment for 30 days. No additional comments were received during this public comment period. The final draft was concurrently forwarded to the Oregon Department of Emergency Management (OEM) for their review in December 2023.

Figure 11. January 26, 2022 Steering Committee meeting agenda.

City of Cottage Grove
Natural Hazard Mitigation Plan (NHMP)
2022 Update
Organizational Meeting
January 26, 2022 09:30– 11:00AM
Hybrid Meeting
in City Council Chambers, 400 E. Main St., and Online via
https://www.gotomeet.me/RichardMeyers/natural-hazard-mitigation-plan-update-meeting

You can also dial in using your phone.
United States (Toll Free): 1 877 309 2073
United States: +1 (571) 317-3129

Access Code: **417-087-397**

AGENDA	
Welcome/Introductions • During introductions, please share your name, title, and organization.	**Faye Stewart, City** **Eric Mongan, City**
Project Overview • Plan update components • Update priorities	**Pam Reber, DLCD**
Floodplain Management Planning • NHMP Update to align with floodplain planning activity.	**Eric Mongan, City**
Public Involvement/ Cost Share • Steering Committee roster & process. • Public engagement discussion. • Providing filled out cost share forms helps the process.	**Pam Reber, DLCD**
Public comment • **Please provide name and address/email address for future notices.**	**Eric Mongan, City**
Next Steps • Meeting schedule: Let's choose next HMAC dates in March, May. • Information requests	**Pam Reber, DLCD**

City of Cottage Grove NHMP Website
https://www.cottagegroveor.gov/cd/page/natural-hazards-mitigation

Figure 12. January 26, 2022 Steering Committee meeting notes.

City of Cottage Grove
Natural Hazard Mitigation Advisory
Committee Organizational Meeting
January 26, 2022 at 9:30 AM
City Hall Council Chambers

Members Present in Person: DLCD- Pam Reber, City Planner –Eric Mongan, Public Works Director- Faye Stewart, Assistant Planner – Matt Laird, Assistant to City Manager- Jake Boone, Community Sharing Director- Mike Fleck, City Engineer- Ron Bradsby, SLC Fire Marshall-Danny Solesbee, Administrative Assistant-Angela Keppler

Members Present Online: Coast Fork Watershed Council-Amanda Gilbert, Waste Water Superintendent- Erich Schroeder

Pam presented a power point for the City of Cottage Grove Natural Hazard Mitigation Plan Update. Agenda and Power Point are attached.

The topics of discussion were:

1. Disaster Risk Management Cycle
2. Project Components
    - Planning Process
    - Hazard Identification and Risk Assessment
    - Mitigation Strategy
    - Plan Review, Evaluation, and Implementation
    - Plan Adoption
3. When is a Hazard a Risk?
4. Local Risk Assessment
5. State Risk Assessment
6. Update Priorities
    - Plan Integration
    - Updated Hazard Information
    - Wildfire, Landslides, and Floodplain Management
7. Public Outreach
8. Community Engagement
9. Plan Update Overview

10. HMAC Membership Outcomes
11. HMAC Membership Responsibilities
    - Attending and Actively Participating, Cost Share
    - Providing Data and Information
    - Engaging

Members discussed outreach to groups, or organizations that would benefit from inviting to our team, and ways to reach the public. They include:

- Local Churches
- Community Members in higher risk areas
- Red Cross
- Police
- Hospitals, Life Flight
- School District
- National Guard
- Lane County Emergency Manager
- The State's Emergency Manager's Office
- SIM Program (Mass Notification System)
- Corps of Engineers
- Department of Forestry
- Volunteer Fire Department
- HAM Radio Group
- Friends of Mt. David
- Local Papers, City's Website and Friday updates

Faye Stewart talked about an upcoming Preparing for Emergency Fair scheduled for August 6, 2022, and the possibility of getting a booth there for outreach.

Pam explained that we will be using a file sharing tool called "Box" as our File Transfer Protocol (FTP) site. This will be where all the materials for the project will be kept. She will send an invite to all the members to sign up for "Box" and get access to the files.

Eric said he is working to create a link on the City's website where all the information regarding the Natural Hazard Mitigation Plan can be found and easily accessed and updated.

Next Meeting will be on February 23, 2022 at 9:30 AM at City Hall Council Chambers. March's meeting is scheduled for March 16, 2022 at 9:30 AM at City Hall Council Chambers.

Pam recommended the group read ***Chapter Three*** of the current Natural Hazard Mitigation Plan Projects. We will discuss this at the next meeting.

Danny mentioned some possible grant funding from the state to state fire marshal's office to fund projects to mitigate fire danger in areas of high risk around the state. He thinks we could potentially use these funds to print out brochures or pamphlets to get the word out about risks of wildfires. He will look into it further and get back to us.

Adjournment
Meeting was adjourned at 10:44 AM

Figure 13. February 23, 2022 Steering Committee meeting agenda

City of Cottage Grove
Natural Hazard Mitigation Plan (NHMP)
2022 Update
Meeting #2
February 23, 2022 09:30– 11:00AM
Hybrid Meeting
in City Council Chambers, 400 E. Main St., and Online via WebEx Meeting:

Please join from your computer, tablet or smartphone.
https://meet.goto.com/RichardMeyers/natual-hazard-mitigation-plan-update---february-23
You can also dial in using your phone.
United States (Toll Free): 1 877 309 2073
United States: +1 (571) 317-3129
Access Code: 803-643-469
Get the app now and be ready when your first meeting starts: https://meet.goto.com/install

AGENDA	
Welcome/Introductions	**Faye Stewart, City** **Eric Mongan, City**
• During introductions, please share your name, title, and organization.	
January 26th Meeting Minutes	**All**
• Please review and approve the minutes from the last meeting.	
Lane County Updates	**Patence Winningham, Lane County EM**
• Standing agenda item for county and countywide topics.	
Review Plan Goals & Mission	**Patence Winningham, Lane County EM**
• Retain Plan Mission? • Review five Goals with their Objectives; Preliminary review, no decision needed.	
Review Mitigation Action Status and Timeline	**Eric Mongan, City**
• Flood • Landslide • Wildfire	

Figure 14. February 23, 2022 Steering Committee meeting notes

City of Cottage Grove
Natural Hazard Mitigation Advisory
Committee Organizational Meeting
February 23, 2022 at 9:30 AM
City Hall Council Chambers

Members Present in Person: DLCD- Pam Reber, City Planner –Eric Mongan, Public Works Director- Faye Stewart, Assistant Planner – Matt Laird, Assistant to City Manager- Jake Boone, Community Sharing Director- Mike Fleck, City Engineer- Ron Bradsby, Coordinator of CG Museum- Tara Sue Hughart, Public Works Supervisor -Greg Griswell

Members Present Online: Coast Fork Watershed Council-Amanda Gilbert, Waste Water Superintendent- Erich Schroeder, SLC Fire Marshall-Danny Solesbee, Administrative Assistant-Angela Keppler, Lane County Emergency Manager- Patence Winningham-Melcher, SLSD-Matt Allen, Water Treatment Supervisor- Ryan Kimball

Pam presented a power point for the City of Cottage Grove Natural Hazard Mitigation Plan Action Update 2023. Agenda and Power Point are attached.

It was moved by Ron Bradsby and seconded by Tara Sue Hughart to approve January 26th, 2022 meeting minutes. Minutes have been approved with all members in favor.

Patence Winningham from Lane County discussed updates on:

- Hazard Mitigation Grants
- Funding that will cover projects
- Covid HMGP dollars close on February 28, 2022
- Working with fire district regarding wildfire planning
- The community fire risk reduction specialist- Kyle Reed

Faye Stewart said the City of Cottage Grove had its own Hazard Mitigation Plan since 2014. The primary reason for having our own plan is to help our Community Rating System for lowing our insurance rates to our citizens in floodplains.

Pam said the mission of the City of Cottage Grove Natural Hazard Mitigation Plan is to promote sound public policy designed to protect citizens, critical facilities, infrastructure, and property from natural hazards.

She discussed Section 3: Mission, Goals, and Action items.

- Protect life and property
- Public Awareness
- Emergency Services
- Partnerships and Implementation
- State/National Guidelines

Pam pointed out that there are a lot of items in the goal section, and she would like the committee to help her and Eric with the use of verbs in our goal list to make them more specific. She discussed emergency services goals, and suggested rephrasing it, and taking policy out of the goal statement.

Greg said ICS training would be nice. Eric said the ICS one hundred and two hundred are online courses. They would be helpful for staff to understand how things are supposed to work in an emergency.

Faye said that there are a lot of new employees in the public works department, he would like to get the employees incident command training.

Pam talked about coordinating and integrating natural hazard mitigation activities with emergency operations plans to make priorities clear.

Danny said that the fire station did retrofit station #2 in Cottage Grove for earthquake. The Creswell station has not been retrofitted and needs a new station built, and the Saginaw station meets the earthquake standards. He said that fire chief Wooten is part of Lane County's plan.

Patence said that the fire districts sign off on the CWPP Plan.

Pam discussed action item development. She said developing a problem statement helps hone mitigation actions to be clear and specific for FEMA funding.

Questions that Oregon Emergency Management would ask are:

- What hazard is being mitigated
- How does this proposal mitigate the hazard
- Who does it impact
- What authority do you have
- Do you have capacity to do it

Ron said that Holly Street could be damaged in a landslide and may damage utilities.

Eric said that maybe this action item is missing specific definitions, such as if a known potential slide area or steep slope it must be engineered before development is allowed. He also mentioned adding a mitigation item about natural gas not being allowed in steep slope areas.

Faye said DOGAMI has a program to renew steep areas in our community, and will look into this more. He said shut off valves on utilities may help isolate the problem if there is a failure.

The committee discussed landslide prevention and awareness in the community, ways the public could be notified of potential dangers in the area and alternative routes to take if a landslide was to block off roads. GIS system may help the public awareness of slopes.

Wildfire

Danny said he had talked to Kyle Reed and he was told that there is some funding available for community risk reduction. This may be used for things like training, brochures, and handouts for public awareness.

Pam discussed prioritizing at risk areas. She said the housing needs analysis has interesting maps to review, along with the urban wildfire interface maps. These can be used to help create defensible space.

Patence spoke about action items that Lane County is working on. They include:

- 762 Funds
- Wildfire risk reduction
- Coordinating approach in high hazard areas
- Wildfire evacuation planning

Pam talked about hazard history and impacts on the community.

- Characteristics
- Extent
- Duration
- Magnitude
- Severity
- Frequency
- Locally-specific vulnerabilities

There was discussion on the impacts of Snowmageddon back in February 2019.

- Power outages
- Roof collapses
- Tree limbs falling

Next step:
Turn in cost share.

Next meeting will be on March 16, 2022 at 9:30 AM at City Hall Council Chambers.

Adjournment
Meeting was adjourned at 11:05 AM

Figure 15. March 16, 2022 Steering Committee meeting agenda

City of Cottage Grove
Natural Hazard Mitigation Plan (NHMP)
2022 Update
Meeting #3
March 16, 2022 9:30AM– 11:00AM
Hybrid Meeting

in City Council Chambers, 400 E. Main St., and Online via WebEx Meeting:
Please join from your computer, tablet or smartphone.
https://meet.goto.com/RichardMeyers/natural-hazard-mitigation-plan-update---march-16-2
Call in 1 877 309 2073 or +1 1(646) 749-3129/ Access Code: 451-301-973
Get the app now and be ready when your first meeting starts: https://meet.goto.com/install

AGENDA	
Welcome/Introductions	Faye Stewart, City Eric Mongan, City
• During introductions, please share your name, title, and organization.	
February 23rd Meeting Minutes	All
• Please review and approve the minutes from the last meeting.	
Lane County Updates	Patence Winningham, Lane County EM
• Standing agenda item for county and countywide topics.	
Review Heritage Resources Plan for Mitigation Actions	Pam Reber, DLCD Eric Mongan, City
• Review and discuss some potential action items and content from the Disaster Resilience Plan for Heritage Resources in Cottage Grove	
Review Mitigation Action Status	Eric Mongan, City Pam Reber, DLCD
• Continue to review the status of action items by hazard • Please review the previous list for status and timeline (if continued).	
Public comment	Eric Mongan, City
• Please provide name and address/email address for future notices.	

Next Steps	Pam Reber, DLCD
• Next meeting: mid to late May? May 11th, 18th, or 25th? • Please submit your cost share report for the first quarter of 2022.	

City of Cottage Grove NHMP Websites

https://www.cottagegroveor.gov/cd/page/natural-hazard-mitigation-plan-update

2022 Cottage Grove Natural Hazard Mitigation Plan Update Contacts:

Eric Mongan, AICP CFM
City Planner
planner@cottagegrove.org
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541-942-3340

Faye Stewart
Public Works
& Development Director
pwdirector@cottagegrove.org
City of Cottage Grove
541-942-3340

Pamela Reber
Natural Hazard Planner
OR Dept. of Land Conservation
and Development (DLCD)
pamela.reber@dlcd.oregon.gov
971-304-5505

Figure 16. March 16, 2022 Steering Committee meeting notes

City of Cottage Grove
Natural Hazard Mitigation Advisory
Committee Organizational Meeting
March 16, 2022 at 9:35 AM
City Hall Council Chambers

Members Present in Person:	City Planner –Eric Mongan, Public Works Director- Faye Stewart, Assistant Planner – Matt Laird, Community Sharing Director- Mike Fleck, Administrative Assistant-Angela Keppler, SLC Fire Marshal-Danny Solesbee
Members Present Online:	DLCD- Pam Reber, Assistant to City Manager- Jake Boone, Waste Water Superintendent- Erich Schroeder, SLSD Facility Supervisor -Matt Allen

Pam presented a power point for the City of Cottage Grove Natural Hazard Mitigation Plan Action Update 2023. Agenda and Power Point are attached.

Pam said she has been working with the Oregon Climate Change Research Institute to set up their introduction meeting for the report that will be coming out for Lane County. She will be sending out links to example plans for us to go over and discuss how to integrate the information into the Cottage Grove plan.

It was moved by Mike Fleck, and seconded by Eric Mongan to approve February 23, 2022 meeting minutes. Minutes have been approved with all members in favor.

Pam went over the Disaster Resilience Plan for Heritage Resources in Cottage Grove. They included:

- Heritage Organizations
- Volunteers & Staff
- Buildings
- Sites of Historic Significance
- Structure of Historical Significance

The specific structures that are mentioned in the plan are:

- Cottage Grove Museum
- Cottage Grove Historical Society
- Bohemia Gold Mining Museum

Danny pointed out that the property owners are responsible for seismic upgrades. The City and organization can help business and property owners acquire grant funding. Still, ultimately it's the owners who are responsible for the upkeep of the buildings.

Eric said the Comprehensive Plan does require the City to support the historic downtown economy. However, we cannot make private owners do upgrades. If there are major seismic events, we will need a plan to open and make the street functional if the buildings fall.

Faye said FEMA has seismic resiliency funds available for public buildings. If there is money available, we can apply for these funds to put a plan together to help our city be nimble and react when needed. We would prioritize based on the importance of the facilities, such as the Water Reservoir. The City can assist and share with property owners the information about possible grant funding. Still, the City will not take on seismic upgrades of private buildings.

The Committee reviewed existing mitigation actions and potential revisions.

Earthquake Mitigation Action:

Address Community vulnerability to seismic threats:

1. Develop an inventory of public, commercial, and historically significant buildings.
2. Inventory of buildings within Downtown Historic District

Eric said there is an existing historic inventory. Status is ongoing, we have raw data, but it needs refinement.

3. *Nothing was listed for 3??*
4. Identify most at rick structures
5. Create an earthquake scenario to estimate potential loss

Potential Revisions:

- Revise by combining # 2 and # 4

The Committee discussed Emergency Operations Plans (EOP), ICS training, having unified command exercises, creating a list of heavy equipment available, and community emergency response teams (CERT).

Potential Revisions:

- Coordinate across emergency response organizations to conduct annual training and exercises. -City, County EM, Fire, Police, Sheriff, ODF, Corps, USFS, BLM, etc.

- Conduct an annual meeting about ICS priorities to develop trainings, exercises, resources, and volunteers.
- Conduct a tabletop exercise with a major disaster.

6. Establish a school survey procedures

Matt Allen said they have DOGAMI survey for collapse potential of all their facilities.

Danny mentioned that the State Senate Bill 762 may have possible funding opportunity for schools and hospitals to get fire mitigation grants.

Potential Revisions:

- Build community support by conducting educational efforts for bond funds to conduct seismic and wildfire mitigation.

7. Assist with and/or develop program to fund seismic retrofit designs for historic buildings.

Drought Mitigation Action:

The Committee discussed the following**:**

Assess vulnerability to drought risk:

1. Gather and analyze water and climate data
2. Identify factors that affect the severity of a drought
3. Identify alternative available water solutions
   - Non-potable water available for emergency fire use
   - Develop backup well head for city water
   - Develop agreement with EWEB for emergency water supply

Monitor drought conditions:

1. Identify local drought indicators
2. Establish a regular scheduled to monitor and record conditions

Faye said the city has a certified weather station at the Water Treatment Plant. The data is sent to the State, and they use the information to determine if we are on course for normal rainfall or going into a drought.

Monitor water supply:

1. Regularly check for leaks
2. Improve water supply monitoring
3. Develop a long range water conservation plan

There was discussion about the City's automated water meters, which has immensely helped catch unusual water uses and possible leaks.

Next step:
Turn in cost share.

Next meeting date was not determined.

Adjournment
Meeting was adjourned at 11:10 AM

Figure 17. October 5, 2022 Steering Committee meeting agenda

City of Cottage Grove
Natural Hazard Mitigation Plan (NHMP)
2022 Update
Meeting #4
October 5, 2022 9:30AM– 11:00AM
Hybrid Meeting AGENDA
in City Council Chambers, 400 E. Main St., and Online via WebEx Meeting:
Please join from your computer, tablet or smartphone.
https://meet.goto.com/CottageGrove/natural-hazard-mitigation-plan-update
Call in 1 866 899 4679 or +1 (571) 317-3116/ Access Code: 348-287-685
Get the app now and be ready when your first meeting starts: https://meet.goto.com/install

AGENDA	
Welcome/Introductions	Faye Stewart, City Eric Mongan, City
• During introductions, please share your name, title, and organization.	
March 16th Meeting Minutes	All
• Please review and approve the minutes from the last meeting.	
Lane County Updates	Patence Winningham, Lane County EM
• Standing agenda item for county and countywide topics.	
DOGAMI Risk Report Presentation	Matt Williams, DOGAMI
• The draft DOGAMI Risk Report is available for HMAC members to review in the online folder at this link	
Review Hazard Vulnerability Analysis and Rank Hazards	Eric Mongan, City Pam Reber, DLCD
• Use Oregon Emergency Management methodology to rank the city's hazards. See materials on Box here.	
Public comment	Eric Mongan, City
• Please provide name and address/email address for future notices.	

Next Steps	Pam Reber, DLCD
• Next meeting: • Please submit your cost share report for the third quarter of 2022.	

City of Cottage Grove NHMP Websites
https://www.cottagegroveor.gov/cd/page/natural-hazard-mitigation-plan-update

2022 Cottage Grove Natural Hazard Mitigation Plan Update Contacts:

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Pamela Reber
Natural Hazard Planner
OR Dept. of Land Conservation
and Development (DLCD)
pamela.reber@dlcd.oregon.gov
971-304-5505

Figure 18. October 5, 2022 Steering Committee meeting notes

Public Works and Development

400 E. Main Street
Cottage Grove, Oregon

(541) 942-3340
www.cottagegroveor.gov

October 5, 2022

RE: **Natural Hazard Mitigation Plan Update**
Advisory Committee Meeting No. 4 Meeting Notes; October 5, 2022 @ 9:30 AM to 11AM

Attendance: Councilor Fleck and Amanda Gilbert. [Consultant(s)]: Pam Reber; DLCD, Matt Williams; DOGAMI. [Staff]: Faye Stewart, Eric Mongan, Matt Laird, Ron Bradsby, and Greg Griswell. Amy Merryday [Public]

Location: The meeting was held in a hybrid style allowing attendance in-person (Cottage Grove Council Chambers) and via remote link with audio and video.

Meeting/Discussion:

After brief re-introductions by those in attendance the minutes from the March 16th, 2022 meeting were reviewed and approved by the Committee.

Brendan Irsfeld, Lane County Hazard & Recovery Analyst introduced himself on behalf of Lane County at the new Analyst.

The Committee then discussed the Plan format. Pam suggested that the updated Plan will presented a bit differently due to additional information and data. There was a discussion on how the Plan benefits Public Works, Engineering, and Planning. Those benefits being Capital Improvement Planning, Infrastructure Design, and Growth Modeling.

Pam asked the Committee how the Hazards should be organized in the report, alphabetical or by ranking. This conversation then went into the ranking of the hazards via the HVA and a decision on whether to go with alphabetical or ranking was not made.

The Committee discussed the ranking that staff and Pam had been doing regarding the hazards and Ron brought up that there had been chemical spills in town and therefore the numbers should be adjusted. Following that there was a discussion on dam failure. The Committee felt that the dam failure numbers should have been higher. Faye interjected and stated the two dams were considered to be a "medium hazard" per recent ACE analysis. The Committee asked that staff and Pam revise the hazmat and dam failure rankings.

Matt Williams from DOGAMI presented the Draft Cottage Grove Risk Report. He explained the data and how it is analyzed (HAZUS). There was a Power Point Presentation showing the background, methods, and results for the study area (full Urban Growth Boundary).

Amy Merryday (public) shared her concerns about wildfire risk, climate change, and the lack of information on climate risks in the current draft plan available for public review. In referencing the wildfire risk maps she noted, "low risk is not no risk." Amy also suggested that a post-fire debris flow study could be used to protect the City's water system and noted that the City's water reservoir is a vulnerable asset. Faye noted that there was a wildfire in 2021 in the Bohemia Mining District and following that, the CG water plant experienced plugging of the membrane at the water plant. By calling this out, he also noted that Dorena Reservoir also functions as a City water reservoir.

Pam thanked Amy for her comment and shared the exact locations of the climate change information in each relevant hazard chapter, noting that ideas for improving how it is presented are welcome. She also encouraged Amy and other members of the public to offer specific local information about how the community may be at risk in unique ways. Amy also articulated that climate change is a serious concern that poses a grave risk to the community, so it needs to be taken seriously and acted on soon. Faye shared some of the ways that the City is working to ensure that infrastructure is made more resilient as it is upgraded.

Greg Griswell shared his experience with earthquake impacts on water and sewer lines and noted the risk of pipes connecting the City to these water reservoirs could break in an earthquake event if they were not retrofitted to use flexible pipe connectors and other best practices.

At the conclusion of the meeting the next meeting date was discussed with the Committee and the tentative date for that meeting is December 7, 2022 at 9:30 AM.

Figure 19. April 18, 2023 Steering Committee meeting agenda

City of Cottage Grove NHMP 2022 Update
Meeting #5
April 18, 2023 1:00 PM– 2:30 PM
Hybrid Meeting
in City Council Chambers, 400 E. Main St., and Online

Join the meeting from remotely
https://meet.goto.com/CottageGrove/april182023naturalhazardmitigationplanadvisorycomm
You can also dial in using your phone.
Access Code: 200-600-861
United States (Toll Free): 1 866 899 4679
United States: +1 (571) 317-3116

AGENDA

1. **Welcome/Introductions** Eric Mongan, Cottage Grove	Faye Stewart, Cottage Grove
2. **October 10, 2022 Meeting Minutes**	All
3. **Lane County Updates** - Standing agenda item for county and countywide topics	Patence Winningham, Lane County EM
4. **Review Plan Draft status**	Katherine Daniel, DLCD Eric Mongan
5. **Review Mitigation Action Status** Particular attention to Ongoing Mitigation Strategy actions	Eric Mongan Katherine Daniel
6. **Discuss Public Engagement Open House**	All
7. **Next Steps** Next meeting: 3rd week in May (5/22-5/26)	Katherine Daniel
8. **Public Comment** Please provide name and address/email address for future notices.	Eric Mongan

City of Cottage Grove NHMP Websites
https://www.cottagegroveor.gov/cd/page/natural-hazard-mitigation-plan-update

2022 Cottage Grove Natural Hazard Mitigation Plan Update Contacts:

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Appendix H: FEMA Approval and Local Adoption Documentation