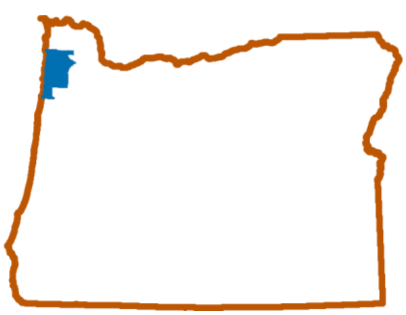
Tillamook County

MULTI-JURISDICTIONAL NATURAL HAZARDS MITIGATION PLAN
2023 UPDATE

- Tillamook County
- Bay City
- Garibaldi
- Manzanita
- Nehalem
- Rockaway Beach
- Tillamook
- Wheeler



- Nehalem Bay Fire and Rescue District
- Nestucca Valley School District
- Port of Garibaldi
- Port of Tillamook Bay
- Tillamook People's Utility District

FEMA

Effective [month][day], 2023 through [month][day], 2028

Acknowledgments

Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan Update Steering Committee

Tillamook County

Sarah Absher, Community Development Planner
Ed Colson, Public Health Emergency Manager
Chris Laity, Public Works Director
Erin Skaar, County Commissioner
Randy Thorpe, Emergency Manager
Lynn Tone, Administrative Assistant

City of Bay CIty

Liane Welch, City Manager
David Mattison, Planner

City of Garibaldi

Juliet Hyams, City Manager
Scott Fregonese, Contract Planner
Jay Marugg, Fire Chief, Garibaldi FD
Blake Paulsen, Division Chief-Training, Garibaldi FD

City of Manzanita

Leila Aman, City Manager
Linda Kozlowski, City Council Member
Dan Weitzel, Public Works Director & Emergency Manager

City of Nehalem

Melissa Thompson-Kiefer, City Manager
Yuriy Ukhach, Deputy City Recorder
Brian Moore, Public Works Director

City of Rockaway Beach

Luke Shepard, City Manager
Dan Emerson, Public Works Superintendent

City of Tillamook

Tommy O'Donnell, Planner

City of Wheeler

Mary Johnson, City Manager pro tem/Recorder

Nehalem Fire and Rescue District

Chris Beswick, Fire Chief

Nestucca Valley School District

Chad Holloway, Administrator of Facilities and Alternative Education

Port of Garibaldi

Michael Saindon, General Manager

Port of Tillamook Bay

Michele Bradley, General Manager

Tillamook People's Utility District

KC Fagen, Engineering Manager

State and Federal Agencies

Federal Emergency Management Agency, Region X

Erin Cooper

Oregon Department of Land Conservation and Development

Brett Estes, Marian Lahav, Lisa Phipps, Meg Reed

Oregon Department of Geology and Mineral Industries

Matt Williams

Oregon Military Department, Office of Emergency Management

Jason Gately, Joseph Murray, Janine Mayer

Oregon State University, Oregon Climate Change Research Institute

Meghan Dalton, Dominique Bachelet, Erica Fleishman

Other Contributors

Interested Parties

Daron Bement, Tillamook RFPD;
Tilda Jones, Tillamook Bay Flood Improvement District;
Marge Jozsa, South Tillamook County Emergency Volunteer Corps;
Gordon McCraw, Retired Tillamook County Emergency Manager;
James Oeder, Nestucca RFPD;
Troy Trute, General Manager, Neskowin Regional Water District

Project Managers

Oregon Department of Land Conservation and Development

Katherine Daniel, Natural Hazards Mitigation Planner

Tillamook County

Sarah Absher, Community Development Director

Funding for the Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan Update was provided in part by grants PDMC-PL-10-OR-2019-003, from the Federal Emergency Management Agency. Cover photos courtesy of City of Tillamook, Tillamook County Public Works, Jarret Juarez for Tillamook County Pioneer.

Table of Contents

List of Figures

List of Tables

I. INTRODUCTION

The dramatic increase in the costs associated with natural disasters over the past decades fostered interest in identifying and implementing effective means of reducing vulnerability. On February 26, 2002, the Federal Emergency Management Agency (FEMA) published Interim Final Rule 44 CFR Part 201, which required all states and local governments to develop natural hazards mitigation plans to be eligible for certain hazard mitigation grant programs, and in the case of the states, to be eligible for certain categories of disaster assistance.

Disasters occur as a predictable interaction among three broad systems: natural systems (e.g., watersheds and continental plates), the built environment (e.g., cities and roads), and social systems (community organization infrastructure that relates to factors of demographics, business climate, and service provision). What is not predictable is exactly when natural hazards will occur or the extent to which they will affect communities within the state. However, with careful planning and collaboration it is possible to minimize the losses that can result from natural hazards.

Hazard mitigation is defined at 44 CFR 201.2 as *any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards*. Hazard mitigation is the responsibility of individuals, private businesses and industries, state and local governments, and the federal government. Engaging in mitigation actions provides the state, counties, cities, businesses, and citizens with a number of benefits: fewer injuries and deaths; less damage to buildings, critical facilities, and infrastructure; diminished interruption in essential services; reduced economic hardship; minimized environmental harm; and quicker, lower-cost recovery.

The 2017 Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan (MJNHMP, Plan) contains the most complete and up-to-date description of the natural hazards that impact each of the cities, ports, larger unincorporated communities, and unincorporated County. It assesses the probability of hazard occurrence and local vulnerabilities then helped the Steering Committee members to establish goals, objectives, and strategies for natural hazard mitigation. It identifies resources for implementing the mitigation strategies and also establishes processes, procedures, and responsibilities the Steering Committee intends to implement for periodically reviewing the plan, evaluating its effectiveness, and making adjustments throughout its five-year life. Every five years the plan must be reviewed in its entirety, updated as necessary, and re-approved by FEMA to maintain eligibility for FEMA's natural hazard mitigation grant programs.

Structure

Earlier editions of the Tillamook County Multi-Jurisdictional NHMP were approved by FEMA in 2006 and 2012. For the 2017 update, the entire plan was rewritten with new content and formatting, retaining only a few items from the 2012 Plan. The Steering Committee determined that the Plan would be stronger and better serve the County as a whole if it were integrated as much as possible. Therefore, the Plan is structured by content rather than by jurisdiction. The 2023 update relies on this same structure and brings the plan up to current conditions and priorities.

The Plan has three main components: Risk Assessment, Mitigation Strategy, and Planning Process.

Risk Assessment Structure

The purpose of the Risk Assessment is to evaluate the potential impact of the natural hazards that each community is subject to and to identify areas of vulnerability to the natural hazards addressed in this plan.

The Risk Assessment has three components in this Plan: Community Profile, Natural Hazards, and Community Risk Profiles.

The Community Profile discusses the unique geographic, demographic, economic, infrastructure, critical and essential facilities, built environment characteristics, and cultural and historic resources of the jurisdictions and larger unincorporated communities. This information is important for assessing local strengths and vulnerabilities with respect to natural hazard events and formulating mitigation strategies.

The Natural Hazards section introduces and characterizes each natural hazard that impacts the County. It documents historically significant natural hazard events, assesses probability of each hazard occurring, and provides exposure and loss estimates.

The Risk Profiles summarize statistics by jurisdiction that indicate the extent and intensity of natural hazards potentially impacting each community. These Risk Profiles also identify the critical or essential facilities located in each jurisdiction and, identify potential vulnerabilities or "Areas of Mitigation Interest".

Mitigation Strategy

The Mitigation Strategy establishes countywide goals and objectives for natural hazard mitigation. Each jurisdiction has identified and prioritized a set of mitigation actions with a strategy (leads, supporters, timeline, actual or potential funding sources as these elements are identified) for implementing them. They are presented in a series of tables for each jurisdiction or district. Those actions that were removed from the 2017 plan are identified. A discussion of the tools and assets available to each jurisdiction for implementing the NHMP is included with discussion of the importance of integrating natural hazard mitigation with other planning documents and initiatives.

Planning Process

This chapter details the process of updating the Tillamook County MJNHMP, reports public comments received and responses to them, and identifies plan format and content revisions. It frames processes for tracking implementation progress, and for monitoring, evaluating, and eventually updating this edition of the Plan. Documentation of the Planning Process is presented in the Appendices.

Participating Jurisdictions

Tillamook County and its seven incorporated cities (Bay City, Garibaldi, Manzanita, Nehalem, Rockaway Beach, Tillamook, and Wheeler) as well as two of the county's ports, the Port of Tillamook Bay, and the Port of Garibaldi, participated in the 2017 Tillamook County MJNHMP update. The Nehalem Bay Fire and Rescue District, the Nestucca Valley School District and the Tillamook People's Utility District joined the planning process and developed their first NHMPs during this 2023 update.

II. RISK ASSESSMENT

A. Introduction

Overview

The Risk Assessment identifies and characterizes Tillamook County's natural hazards and describes how each hazard can impact its communities. It reveals vulnerabilities and informs the mitigation strategy.

The Tillamook County MJNHMP assesses risk in unincorporated Tillamook County, the Cities of Bay City, Garibaldi, Manzanita, Nehalem, Rockaway Beach, Tillamook, Wheeler, and the Ports of Tillamook Bay and Garibaldi. Of the 13 unincorporated communities that also populate the County, Neskowin, Oceanside, Netarts, and Pacific City were mapped by DOGAMI. The community of Woods was no longer together with Pacific City. This may be due to an assessment as to whether the population size and density was large enough to allow valid assessment relative to the other jurisdictions.

Risk Assessment Structure

The Risk Assessment consists of three components: Community Profile, Natural Hazards, and Community Risk Profiles.

Community Profile

The Community Profile discusses the unique geographic, demographic, economic, infrastructure, critical and essential facilities, built environment characteristics, and cultural and historic resources of the communities. This information is important for assessing local strengths and vulnerabilities with respect to natural hazard events and formulating mitigation strategies. For the first time, the Plan includes an analysis of the location of new residential construction since the last update (2012–2016) relative to areas subject to natural hazards.

Natural Hazards

The Natural Hazards section presents an overview of each natural hazard to which the communities of Tillamook County are subject, along with the impacted jurisdictions, historically significant hazard events, probability, and vulnerability including exposure, loss estimates, and the local assessment of relative hazard risk.

Community Risk Profiles

The Community Risk Profiles summarize DOGAMI's analyses by jurisdiction, providing statistics and maps that indicate the geographic extent and intensity of natural hazards potentially impacting each community. These Profiles also identify the critical or essential facilities located in each jurisdiction, identify potential vulnerabilities ("Areas of Mitigation Interest") and suggest mitigation strategies.

Tillamook County's Natural Hazards

Each of Tillamook County's communities/jurisdictions are subject to some or all of 13 natural hazards.

Table 1. Tillamook County Jurisdictions Subject to Natural Hazards

			Floods					Severe Weather								
Jurisdiction	**Coastal Erosion**	**Earthquakes**	**Riverine**	**Coastal**	**Channel Migration**	**Dam Failure**	**Landslides**	**Drought**	**Windstorms**	**Winter Storms**	**Extreme Temperatures**	**Tsunamis**	**Volcanic Ashfall**	**Wildfires**	**Algal Blooms**	**Public Health Emergency**
Unincorporated Tillamook County (rural)	X	X	X	X	X	–	X	X	X	X	X	X	X	X		X
Bayside Gardens		X			–	X	X	X	X	X	X	X	X			X
Neskowin	X	X	X	X		–	X	X	X	X	X	X	X	X	X	X
Oceanside-Netarts		X		X		–	X	X	X	X	X	X	X	X	X	X
Pacific City–Woods	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X
Bay City		X	X	X		–	X	X	X	X	X	X	X	X	X	X
Garibaldi		X	X			–	X	X	X	X	X	X	X	X	X	X
Manzanita	X	X		X		–	X	X	X	X	X	X	X	X	X	X
Nehalem		X	X		X	–	X	X	X	X	X	X	X	X	X	X
Rockaway Beach	X	X	X	X		–	X	X	X	X	X	X	X	X	X	X
Tillamook		X	X		X	–		X	X	X	X	X	X	X	X	X
Wheeler		X	X		X	–	X	X	X	X	X	X	X	X	X	X
Nehalem Fire and Rescue District		X					X	X	X	X	X	X	X	X		X
Nestucca Valley School District		X					X	X	X	X	X	X	X	X		X
Port of Tillamook Bay	X	X	X	X		–	X	X	X	X	X	X	X	X		X
Port of Garibaldi	X	X	X			–	X	X	X	X	X	X	X	X	X	X
Tillamook People's Utility District		X	X			–	X	X	X	X	X	X	X	X		X

Note: None of the jurisdictions is subject to flooding from dam failure. Channel migration was analyzed by DOGAMI, but none of the jurisdictions or districts identified it as a natural hazard to address in this report.

Source: Derived from DOGAMI (2016) and personal communication D. Mattison, 2022.

Loss Estimation and Exposure Assessment

The Oregon Department of Geology and Mineral Industries (DOGAMI) produced a *Final Draft Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2016) that comprises much of this Risk Assessment. It includes a countywide building inventory developed from building footprint data, Tillamook County's tax assessor database, and a suite of datasets representing the best science for a variety of natural hazards. The full report may be found in Appendix A of this Plan.

Depending on the natural hazard, either losses were estimated, or exposure was assessed; both were performed for the flood hazard. Loss estimation was modeled using Hazus-MH (https://www.fema.gov/hazus-software), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Loss estimates identify buildings in hazard areas and apply damage functions based on the hazard severity and building characteristics. Loss estimation is reported as a percentage of estimated loss relative to the total replacement value of a building. Loss estimation was performed for a Cascadia Subduction Zone (CSZ) Magnitude 9.0 earthquake and several flood scenarios.

Exposure is a determination of the number of buildings, building value, and people within a hazard zone. Population was determined by associating 2010 census data with residential buildings. Exposure is reported as the total value of buildings within a hazard zone and the number of potentially displaced residents. Exposure was assessed for floods, five CSZ tsunami scenarios, coastal erosion, landslides, and wildfires.

Local Risk Assessment

Local assessment of relative hazard risk is accomplished using a methodology developed by the Federal Emergency Management Agency (FEMA) and refined by the Oregon Office of Emergency Management (OEM). It is called the “Local Risk Assessment Methodology” or “OEM Methodology” in this Plan. This methodology produces scores that range from 24 to 240. Vulnerability and probability are its two key components. Vulnerability examines both typical and maximum credible events, and probability endeavors to reflect how physical changes in the jurisdiction and scientific research modify the historical record for each hazard. Vulnerability accounts for approximately 60% of the total score, and probability approximately 40%.

Conducting this analysis as a group was a useful early step in soliciting ideas for improvements to the mitigation strategy for hazard mitigation, response, and recovery. Common themes of vulnerability and mitigation strategies undertaken since the 2017 update were discussed among the Steering Committee members during the ranking process.

The Steering Committee conducted the OEM Methodology ranking exercise with the use of an online polling tool (PollEverywhere) which allowed quick responses by all participants to each of the four factors (History, Probability, Vulnerability and Maximum Threat) for each of the thirteen identified natural hazards. At the first meeting focused on Risk Assessment, the DLCD project manager introduced the methodology to the steering committee and also introduced PollEverywhere as a tool for this exercise. At this introductory meeting one hazard was ranked using the online tool. At the following meeting the steering committee used PollEverywhere to rank most of the remaining hazards for the four factors that comprise the total Risk Score for the OEM Methodology. Each poll was followed by discussion to arrive at a consensus ranking score for as many hazards as could be completed in one meeting. The remaining hazards were ranked using a Google Docs based survey. The project manager compiled all the scores and calculated the average ranking for each of the hazards and each of the four factors.

The OEM Methodology does not predict the occurrence of a particular hazard, but it does "quantify" the relative risk of one hazard compared with another. The results of the OEM Methodology are also location dependent. During individual jurisdiction and district interviews with the DLCD project manager, the representatives of the participating jurisdictions and districts differentiated between the relative importance of these natural hazards in their localities as compared to the rankings for the county as a whole.

Table 3. Tillamook County 2022 Natural Hazard Vulnerability Assessment – OEM Methodology

Tillamook County 2022 Natural Hazard Vulnerability Assessment

Based on the OEM methodology combining factors of History, Probability, Vulnerability and Maximum Threat to assess risk. Further information upon request.

HAZARD	HISTORY WF = 2			PROBABILITY WF = 7			VULNERABILITY WF = 5			MAX THREAT WF = 10			RISK SCORE
Winter Storm	2 x	9.8	19.6	7 x	9.8	68.6	5 x	9.1	45.5	10 x	9.7	97.0	231
Flood (Riverine and Coastal)	2 x	9.4	18.8	7 x	9.6	67.2	5 x	9.3	46.5	10 x	9.5	95.0	228
Landslide	2 x	8.5	17.0	7 x	9.5	66.5	5 x	8.8	44.0	10 x	9.5	95.0	223
Public Health Emergency	2 x	7.3	14.6	7 x	9.1	63.7	5 x	8.3	41.5	10 x	9.7	97.0	217
Windstorm	2 x	8.8	17.6	7 x	8.8	61.6	5 x	9.0	45.0	10 x	9.0	90.0	214
Extreme Temperatures	2 x	7.3	14.6	7 x	7.6	53.2	5 x	8.6	43.0	10 x	8.4	84.0	195
Wildfire	2 x	7.2	14.4	7 x	7.9	55.3	5 x	8.8	44.0	10 x	8.1	81.0	195
Drought	2 x	5.4	10.8	7 x	7.5	52.5	5 x	7.5	37.5	10 x	9.1	91.0	192
Earthquake	2 x	4.7	9.4	7 x	7.0	49.0	5 x	8.8	44.0	10 x	8.8	88.0	190
Tsunami	2 x	5.4	10.8	7 x	7.0	49.0	5 x	8.1	40.5	10 x	8.5	85.0	185
Poor Air Quality	2 x	6.7	13.4	7 x	8.0	56.0	5 x	8.1	40.5	10 x	7.4	74.0	184
Coastal Erosion	2 x	7.0	14.0	7 x	8.0	56.0	5 x	7.4	37.0	10 x	6.6	66.0	173
Algal Blooms	2 x	5.1	10.2	7 x	6.2	43.4	5 x	5.6	28.0	10 x	6.0	60.0	142

Completed by the Tillamook County MJNHMP update Steering Committee during meetings held on March 15, 2022 and April 19, 2022.

Table 4. Relative Risks of Participating Jurisdictions and Districts

Relative Risks of Participating Jurisdictions and Districts

Based on the OEM methodology combining factors of History, Probability, Vulnerability and Maximum Threat to assess risk. Further information upon request.

	Tillamook County	City of Tillamook	Bay City	Garibaldi	Manzanita	Nehalem	Rockaway Beach	Wheeler	NBFRD	NVSD	POG	POTB	TPUD
Winter Storm	High	↓	same	same	same	same	same	same	same	Most concerning	same	same	Most concernin
Flood (Riverine and Coastal)	High	↑	↓	same	↓	↑	same	same	same	↓	same	same	↓
Landslide	High	↓	same	same	↓	same	same	↑	same	↓	↓	↓	same
Public Health Emergency	High	same	same	same	same	same	same	same	same	same	↑	same	↓
Windstorm	High	↓	↑	↑	↑	same	same	same	↑	Most concerning	Most concerning	same	2nd most concerning
Extreme Temperatures	Moderate	same	↓	same	↓	same	↓	same	↓	↓	same	same	same
Wildfire	Moderate	↓	same	same	↓	same	↓	same	same	same	same	same	3rd most concerning
Drought	Moderate	same	↓	same	↓	same	↓	same	same	↓	same	same	same
Earthquake	Moderate	same	same	same	↑	same	same	same	same	↓	same	same	↓
Tsunami	Moderate	same	↑	same	↑	same	↑	↓	same	↓	same	↓	same
Poor Air Quality	Moderate	same		same	↓	↓	↓	same	↑	↓	same	same	same
Coastal Erosion	Low	same	↓	same	↓	same	↑	↓	n/a	n/a	↑	↓	same
Algal Blooms	Low	same	same	same	same	same	same	same	n/a	n/a	↑	n/a	n/a

B. Community Profile

1. Political and Physical Geography

Tillamook County

Tillamook County, the twelfth county in Oregon to be organized, was established on December 15, 1853, when the Territorial Legislature approved an act to create the new county out of an area previously included in Clatsop, Yamhill and Polk Counties in the northwestern portion of Oregon. It is bordered by Clatsop and Columbia Counties on the north, Washington and Yamhill Counties on the east, Polk and Lincoln Counties on the south, and the Pacific Ocean on the west. Tillamook County has 75 miles of rocky and irregular coastline, four bays, nine rivers, estuaries, stretches of coastal lowlands, and a heavily forested mountainous interior that rises eastward comprising the main span and several spurs of the Coast Range.

The name Tillamook is derived from a tribe of Salish-speaking Indians who lived in villages south of Tillamook Head. For twelve thousand years or more, Tillamook people lived at the tidewaters of the Nehalem, Tillamook, Netarts, and Nestucca Bays and at the mouths of the present-day Miami, Kilchis, Wilson, Trask, Tillamook, Salmon, and Siletz Rivers, where they favored sites with good visibility, drainage, fresh water, and firewood. They lived in permanent cedar-plank lodges with "a gabled roof of overlapping planks," as described by anthropologists William Seaburg and Jay Miller. "Extra light," they continue, "was provided by torches or by burning fish heads or whale oil." They depended on marine and freshwater resources in the foothills of the Coast Range, including salmon, mussels, lampreys, berries, wild mustard, camas, grouse, beaver, deer, and elk. (The Oregon Encyclopedia, Tillamook (oregonencyclopedia.org)

Meriwether Lewis and William Clark estimated in their journals in early 1806 that twenty-four hundred Tillamooks lived in several villages, referring to the people as Kilamox, Killamuck, Cal-a-mex, and Callemex. Seaburg and Miller report that "epidemics of malaria and other diseases" killed many Tillamook people during the 1830s, and some Tillamooks were removed to the Grand Ronde and Siletz Reservations in the 1850s. Reportedly, only twenty-two lived in Tillamook County by 1930. (The Oregon Encyclopedia, Tillamook (oregonencyclopedia.org)

Most recent settlement has taken place along the coast and interior lowlands, with all the incorporated cities located in the northwest and west-central portion of the County. A number of unincorporated urban communities are located along the coast and inland in the southern to central portion of the County.

Neahkahnie is the northernmost unincorporated urban community, located on the coast north of Manzanita. Barview, Watseco, and Twin Rocks are also located along the coast, south of Rockaway Beach. Oceanside and Netarts are neighbors on the south side of a peninsula between Tillamook Bay on the north and Netarts Bay on the south. Oceanside lies on the Pacific Ocean; Netarts on Netarts Bay. Farther south, Pacific City lies on both the Pacific Ocean and the Nestucca River. Its neighbor Woods is an inland on the Nestucca River. Neskowin is the southernmost coastal community. East of Pacific City and Woods on US-101 heading north lie Cloverdale, Hebo, and Beaver. Siskeyville is located east of the City of Tillamook on Oregon 6, heading into the Coast Range.

The incorporated cities are all located between the center of the County and its northern bound. The northernmost triad — Manzanita, Nehalem, and Wheeler — clusters around Nehalem Bay with Manzanita on the coast and Nehalem and Wheeler inland on the Nehalem River. Rockaway Beach stretches between them and Tillamook Bay, where Garibaldi, the Port of Garibaldi, and Bay City are situated. The City of Tillamook is located inland, southeast of Tillamook Bay, between the Wilson and Trask Rivers. The Port of Tillamook Bay lies inland also, four miles south of the City of Tillamook. There are no incorporated cities south of the City of Tillamook.

Tillamook was the first city in the County, incorporated in 1891. Incorporation of the other cities came in pulses over a period of 55 years. The first pulse took place less than 10 years after the City of Tillamook incorporated; the second pulse came a little more than 10 years after that; and the third and final pulse occurred about 30 years later. No other cities have incorporated in Tillamook County in over 70 years. (Oregon Blue Book, State of Oregon: County Records Guide - Tillamook County History, accessed November 2022.)

Table 5. Incorporation or Establishment Dates

Date Incorporated or Established	Jurisdiction
December 15, 1853	Tillamook County
February 18, 1891	City of Tillamook
February 2, 1899	City of Nehalem
September 13, 1910	City of Bay City
1910	Port of Garibaldi
June 11, 1913	City of Wheeler
July 14, 1943	City of Rockaway Beach
April 8, 1946	City of Garibaldi
April 15, 1946	City of Manzanita
1911	Port of Tillamook Bay

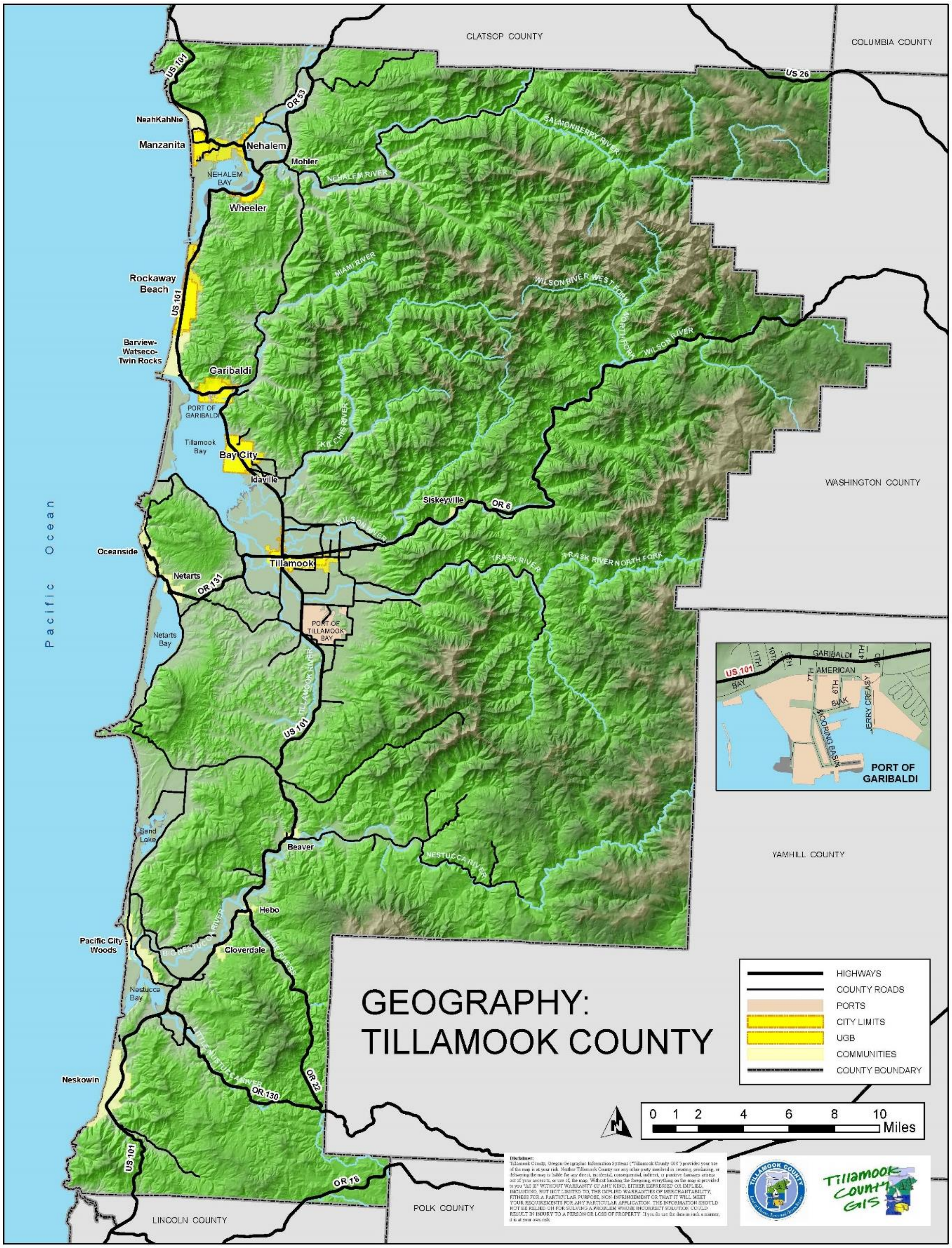
Source: Oregon Blue Book, State of Oregon: County Records Guide - Tillamook County History, accessed November 2022)

Table 6. Approximate Land Area and Elevation

Jurisdiction/Community/District	Area (Square Miles)	Elevation (Feet)
Tillamook County	1,125	0–3,706
City of Bay City	1.93	17
City of Garibaldi	1.45	22
City of Manzanita	0.72	78
City of Nehalem	0.27	11
City of Rockaway Beach	1.62	17
City of Tillamook	1.87	22
City of Wheeler	0.51	37
Neskowin	2.42	13
Netarts	0.73	66
Oceanside	0.85	148
Pacific City-Woods	1.41	13
Port of Garibaldi	0.23	0
Port of Tillamook Bay	2.50	36 (airport)

Sources: Oregon Blue Book, http://arcweb.sos.state.or.us/pages/records/local/county/tillamook/hist.html,; https://en.wikipedia.org/wiki/Pacific_City,_Oregon; https://en.wikipedia.org/wiki/Neskowin,_Oregon; https://en.wikipedia.org/wiki/Oceanside,_Oregon; https://en.wikipedia.org/wiki/Netarts,_Oregon; https://en.wikipedia.org/wiki/Tillamook_Airport; https://www.anyplaceamerica.com/directory/or/tillamook-county-41057/harbors/port-of-garibaldi-2668339/,

Figure 1. Political and Physical Geography: Tillamook County



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Unincorporated Communities

Of the 13 unincorporated communities, only Bayside Gardens, Oceanside, Netarts, Pacific City and Neskowin are addressed directly and separately from the rest of the unincorporated County. They were selected based on their population size and density, which allowed responsible characterization of exposure to and potential loss from natural hazards relative to the cities and county. The communities of Hebo, Beaver, Barview, Watseco, Twin Rocks, Siskeyville, and Cloverdale were not analyzed by DOGAMI separately, however the communities of Bayside Gardens and Cloverdale are highlighted in particular within this plan because there are special districts which serve or are located principally within those communities. The Neskowin Bay Fire & Rescue District's main station is located in Bayside Gardens and the Nestucca Valley School District is located in Cloverdale.

Bayside Gardens

Bayside Gardens is an unincorporated community in Tillamook County that lies along Route 101 between Manzanita and Nehalem and borders Nehalem Bay. The population of the community was 880 at the 2010 census.

Neskowin

Neskowin lies at the southern reach of Tillamook County near the mouth of Slab Creek on the Pacific Ocean. It is generally low-lying and flat west of US-101 and hilly east of the highway. Neskowin Creek runs along its southern end and Butte Creek along its southeastern edge. Neskowin is nestled up against the forested hills of the Coast Range and Cascade Head. Proposal Rock, at the mouth of Neskowin Creek, is perhaps the most treasured of Neskowin's natural features. A submerged forest of stumps on the beach south of Neskowin Creek is visible only when the sands have washed out and the tide is low. "Radiocarbon dating analysis in 1958 of samples of the stumps showed them to be 1730 years old, plus or minus 160 years" (Rubin & Alexander, 1958, p. 1477). Due to its geographical isolation, Neskowin has grown slowly from the time it was platted in 1910 until the new Highway 101 was cut over Cascade Head in the 1960s. It is primarily residential in nature with limited commercial development.

Oceanside-Netarts

Oceanside and Netarts are adjacent communities located on the southern portion of a peninsula bounded on the south by Netarts Bay; on the north by Tillamook Bay; and on the west by the Pacific Ocean. Oceanside is located on the Pacific Ocean while its neighbor Netarts is located at the mouth of Netarts Bay. Both communities rise quickly from the water into hilly terrain. While Oceanside is more consistently mountainous, Netarts is punctuated by hills and valleys. Rice Creek and O'Hare Creek drain through Netarts to Netarts Bay. Fall Creek drains to the mouth of Netarts Bay between Netarts and Oceanside. Baughman Creek is the main drainage through Oceanside but is a smaller stream than the creeks draining Netarts.

Oceanside and Netarts are bound together under the common administration of one sewer district. They are separated by a distance of about one and one-half miles and are about seven miles west of Tillamook City. Residential densities range from five to ten dwellings per acre. Services available include sewage disposal, public water, street lighting and fire protection as well as a range of countywide services. There is a fire hall and a post office in each community. There are a variety of commercial services in the communities, including grocery and general stores, laundromats, restaurants and taverns.

Oceanside

The Oceanside Community Growth Boundary is defined by the Pacific Ocean to the west; the southerly boundary of "The Capes" planned development to the south; Oregon 131 (Netarts-Oceanside Highway) and forest zoning to the east; and Radar Road to the north. Oceanside is predominantly a second home and retirement community.

Netarts

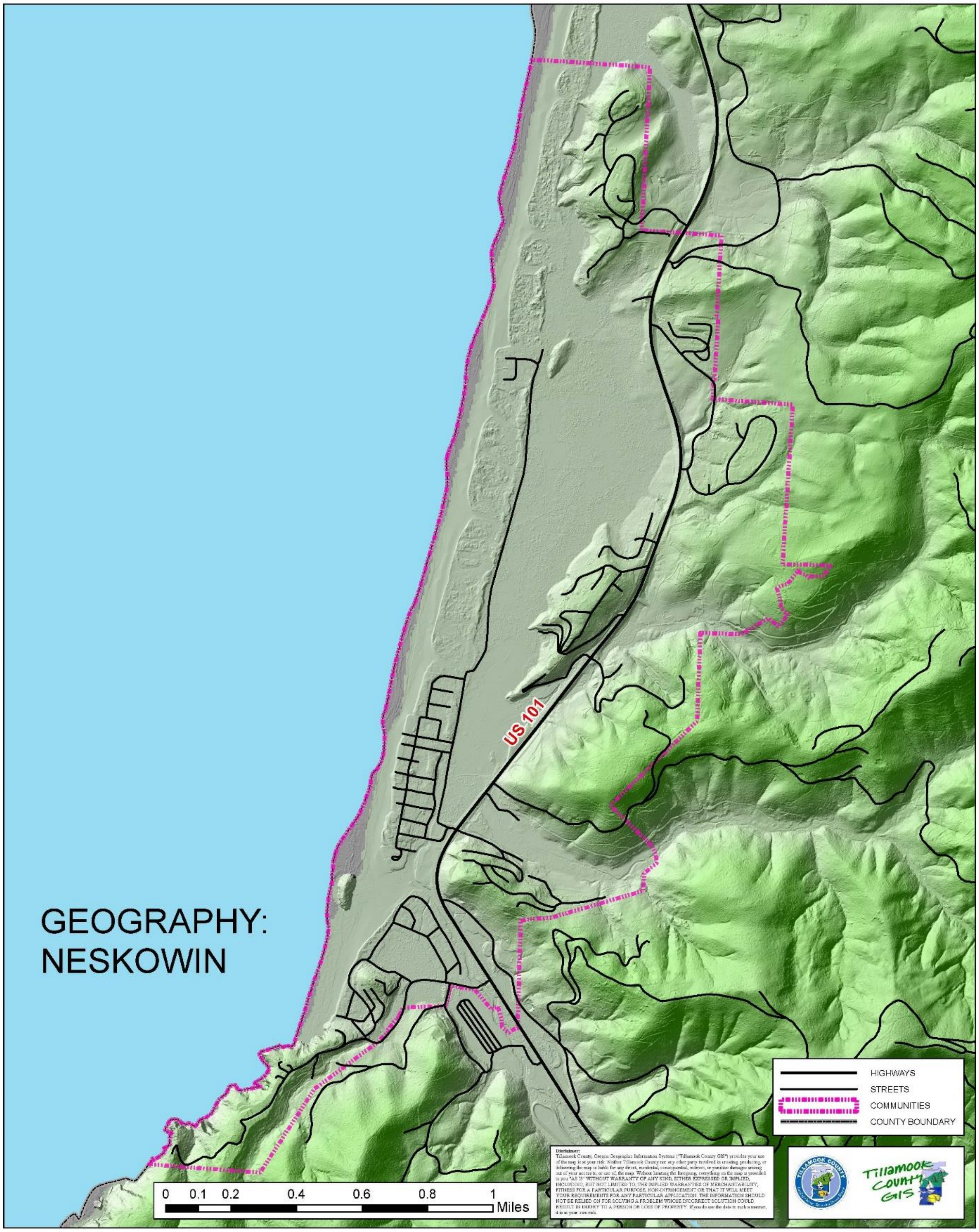
Netarts is a small community situated at the mouth of Netarts Bay, just south of Oceanside, along the Three Capes Scenic Route. Netarts Bay spans seven miles from north to south and is separated from the ocean by a long club-shaped stretch of forested sand known as the Netarts Spit. The Netarts Community Growth Boundary is defined by Netarts Bay to the west, the southerly boundary of "The Capes" planned development and forest lands to the north, forest lands to the east, and rural residential lands to the south. Netarts is also predominantly a second home and retirement community.

Pacific City–Woods

Pacific City–Woods is located along the Pacific Ocean adjacent to Bob Straub State Park. The Nestucca River bisects the community and, as the river meanders, forms an inland peninsula. The land by the river is flat, but the center of the peninsula is hilly. The area along the ocean is flat as well; the northern extent of the community is bounded by hills. Two small streams drain the hills to the north through the community. Other streams drain the hills on the peninsula emptying into the Nestucca River.

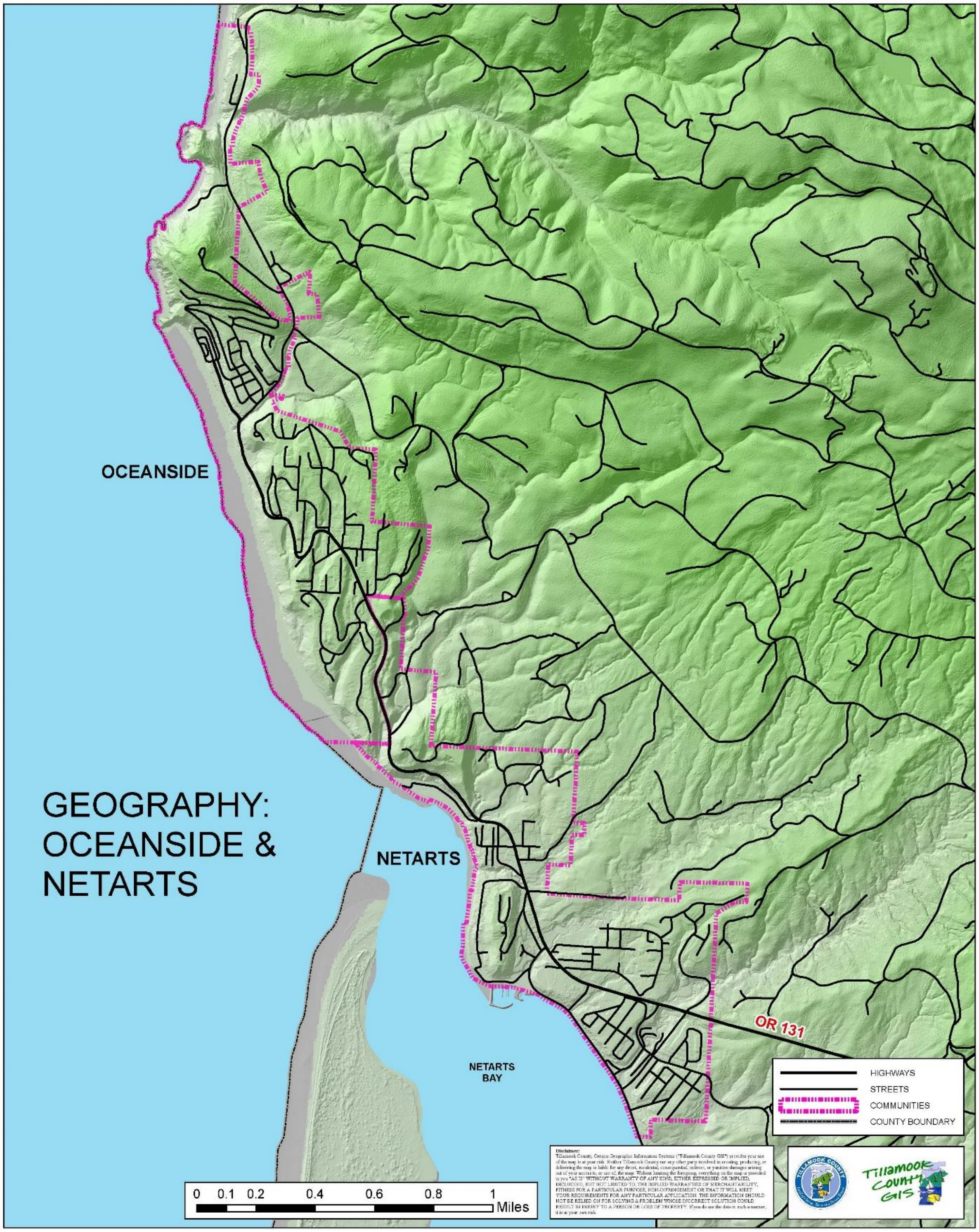
Woods developed before Pacific City. It offers a general store, drug store, sawmill, cabinet shop, photography gallery, postmaster, two weekly newspapers, and Rebecca Lodge. Thomas Malaney homesteaded and platted Pacific City (originally called “Ocean Park”) in 1883 along the south bank of the Nestucca River directly across from Woods. An 1894 flood caused the community to move to higher ground just downriver. The most distinctive natural features of this area are the Nestucca River and its estuary, tide pools, beaches, dunes, and Cape Kiwanda. The community of Woods is not detailed in this update to the NHMP as it is not currently a recognized place by the US Census.

Figure 2. Political and Physical Geography: Neskowin



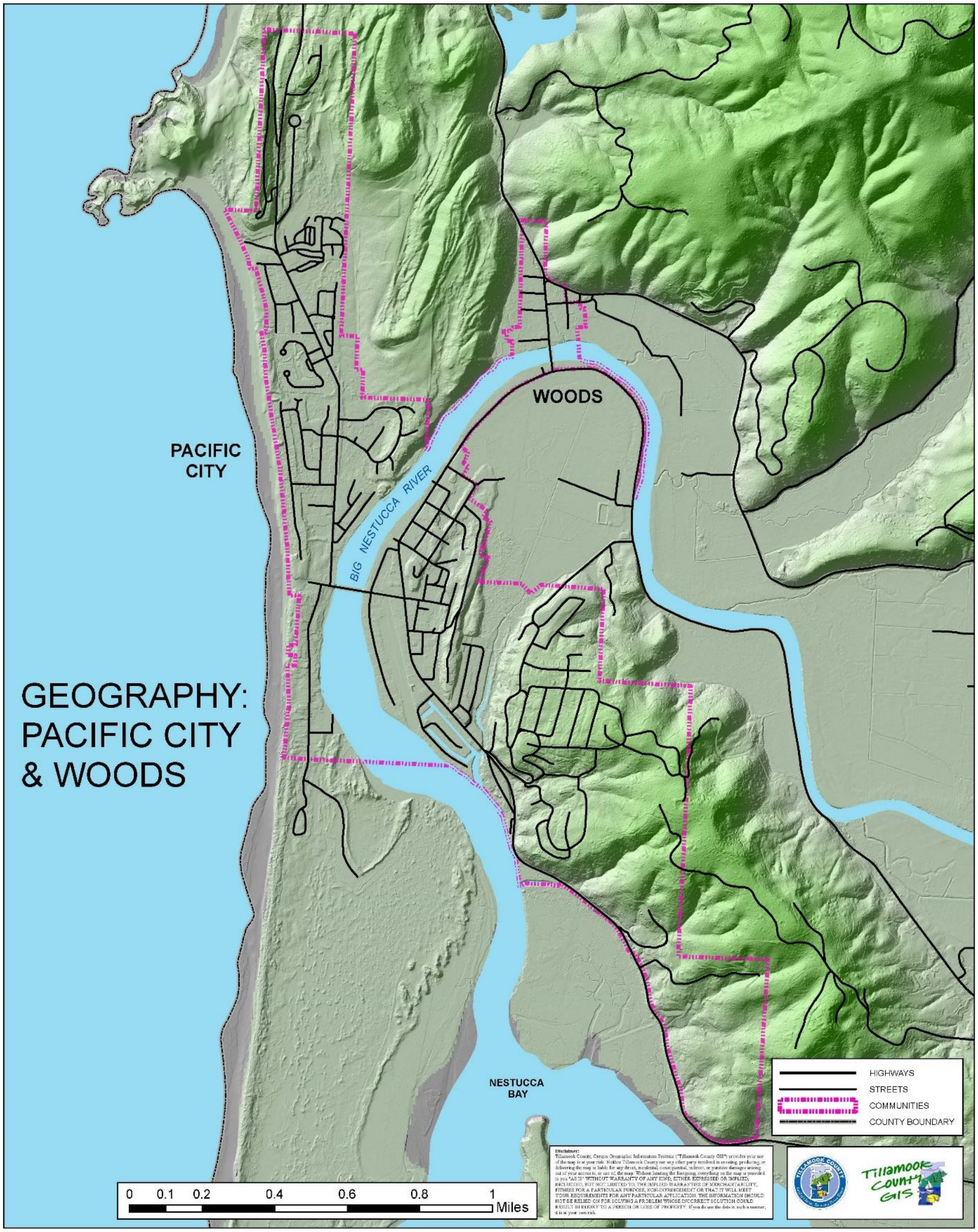
Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 3. Political and Physical Geography: Oceanside and Netarts



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 4. Political and Physical Geography: Pacific City-Woods



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Cities

City of Bay City

Bay City is a quiet coastal community that rests along the eastern shore of Tillamook Bay. Bay City has developed among low hills and valleys. US-101 hugs the shoreline as it rolls through Bay City, slicing a sliver of land on the west and the southwestern corner from the majority of the city located east of the highway. West of the highway the land is flat. East of the highway a single creek formed by the confluence of Jacoby and Patterson Creeks drains the area between two rises. Another stream drains the area southern lowland area (Ash Creek Associates, Inc., 2007).

Bay City is primarily residential in nature with some commercial development. Historically, two canneries and a mill were in operation through the turn of the 20th Century. Pacific Oyster is housed in the remaining cannery located within Bay City on Tillamook Bay. The Tillamook Smoker is located on the south side of Town on 101Recreational amenities include an, Bay City Art Center, crabbing & fishing, hiking and bird watching at Kilchis Point, children's play equipment, tennis courts, an RV park and a skateboard park at the Al Griffin Memorial Park, soccer fields at the Watt Family Park, and a boat launch to Tillamook Bay.

City of Garibaldi

The City of Garibaldi is a small village nestled against a hillside located at the north end of Tillamook Bay. It is mostly flat near the bay, ranges from near sea level to a few hundred feet as it rises gently northward into the hills.

The City of Garibaldi is known for fishing, crabbing, and clamming. It is home to the Oregon Coast Scenic Railroad depot and two history museums. While Garibaldi attracts many tourists in the fall, spring, and summer months, it has many full-time residents and recent residential development includes multi-family housing projects. Several streams draining the hillside traverse Garibaldi as they flow into Tillamook Bay. US-101 separates the city on the north from the Port of Garibaldi to the south as it meanders along the north shore of Tillamook Bay.

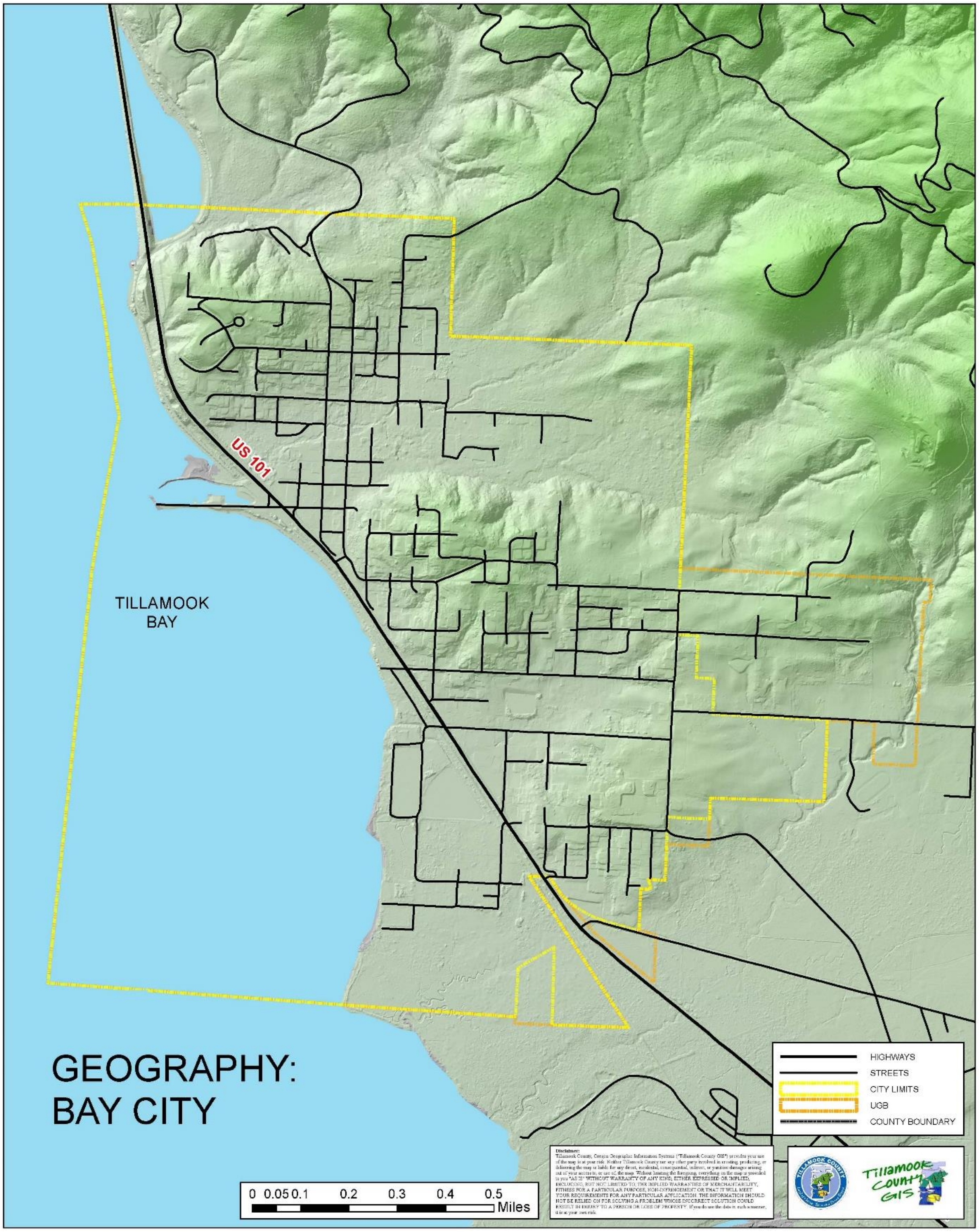
City of Manzanita

The City of Manzanita is the northernmost incorporated city in Tillamook County. Its sandy beaches give way to forested hills as the city rises from the Pacific Ocean south of Neakahnie Mountain. US-101 provides entry to the city where it touches its northeastern boundary as it skirts Neakahnie Lake. While there are no mapped streams in the city, there are a few wetlands.

City of Nehalem

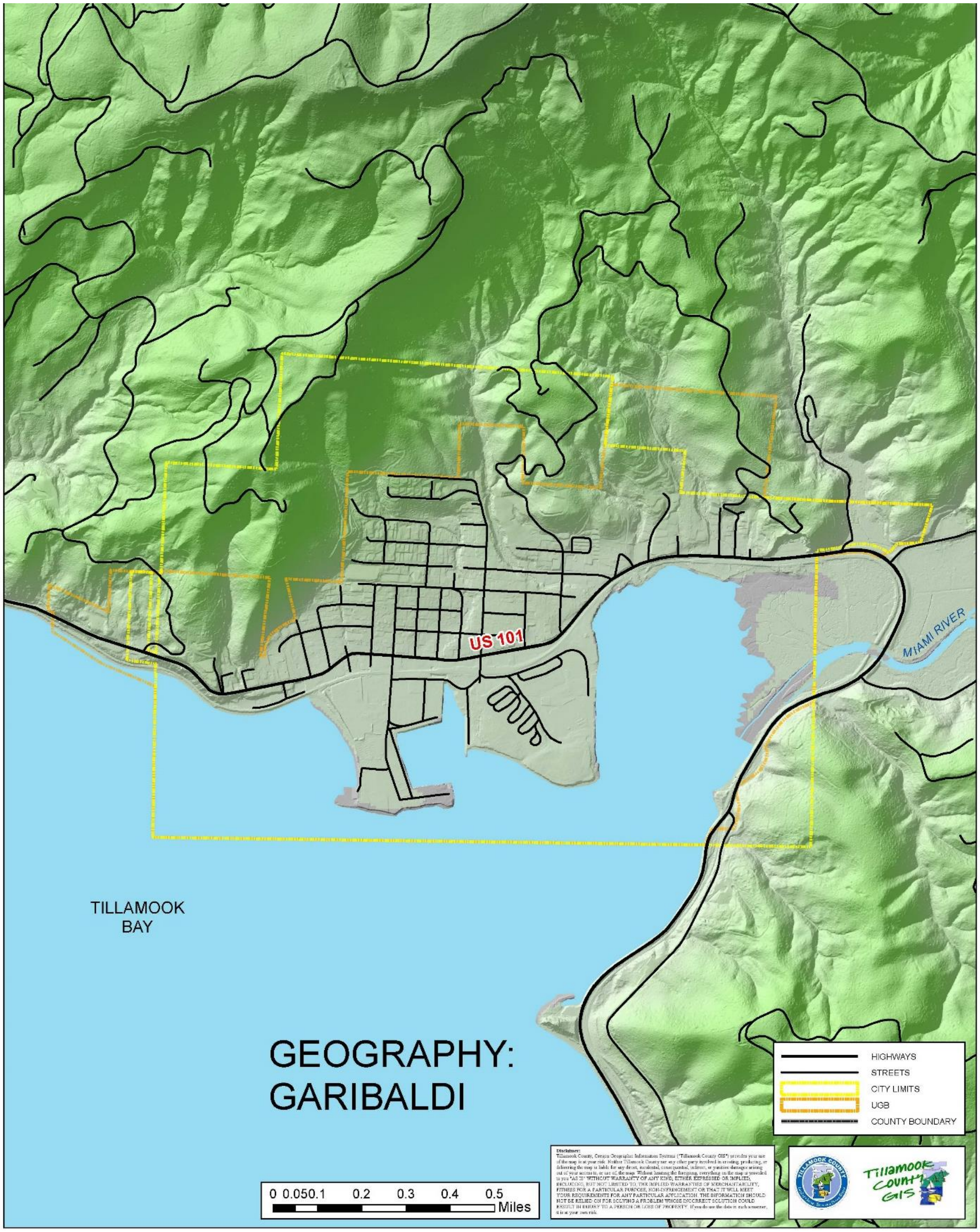
The City of Nehalem is situated on the Nehalem River, northeast of Nehalem Bay. It rises west from the river into hilly terrain. US-101 divides the majority of the city on its west from a sliver along the river. Several streams drain the city hills emptying into the Nehalem River.

Figure 5. Political and Physical Geography: City of Bay City



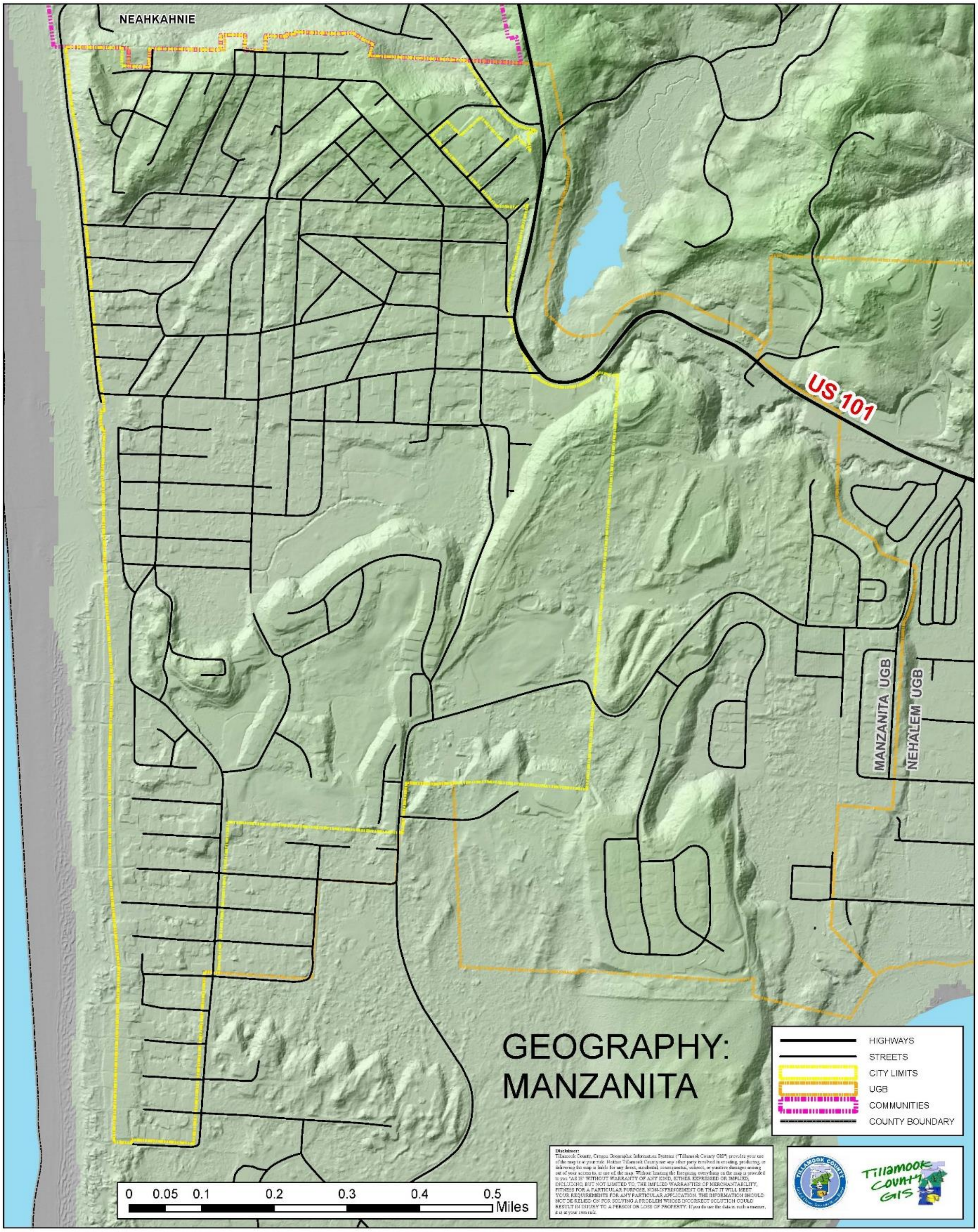
Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 6. Political and Physical Geography: City of Garibaldi



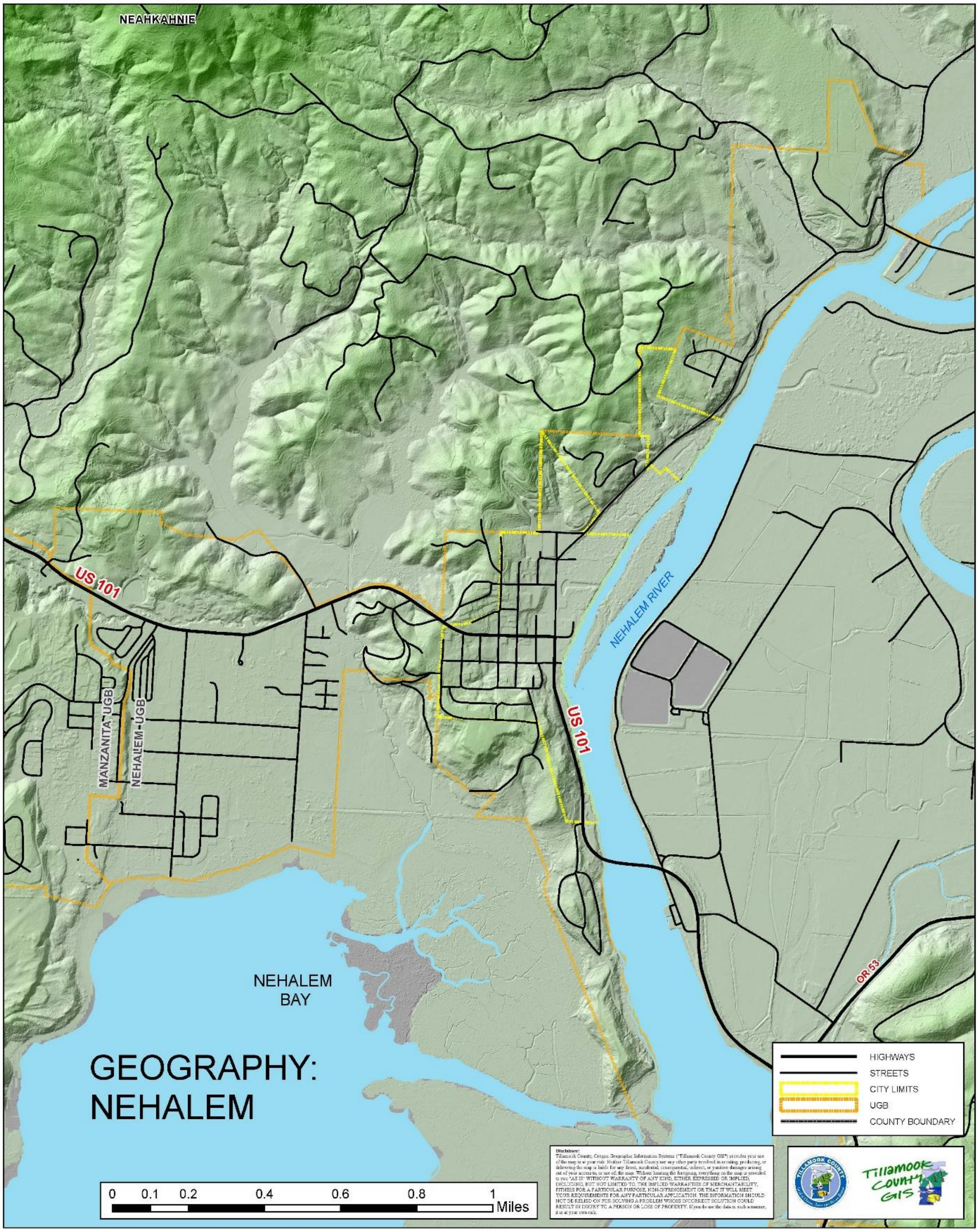
Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 7. Political and Physical Geography: City of Manzanita



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 8. Political and Physical Geography: City of Nehalem



Source: Tillamook County Geographic Information System (GIS) Team, 2017

City of Rockaway Beach

The City of Rockaway Beach is situated north of Tillamook Bay and South of Nehalem Bay, laid out linearly along the Pacific Ocean. It is bisected by US-101 and the Oregon Coast Scenic Railroad running north-south, parallel to the ocean. The low-lying city has developed between the Pacific Ocean and large forested hills to the east. Several streams draining the hills run through the city. The main waterway through the city is Spring Creek, which feeds Lake Lytle.

Rockaway Beach was established as a seaside resort in 1909 by the Rockaway Beach Company and named after Rockaway Beach on Long Island in New York. Popular with tourists, Rockaway Beach is also home to many full-time residents. Barview, Twin Rocks, and Watseco, are unincorporated communities that border Rockaway Beach on the south. Nedonna, a residential development, and Neah-Kah-Nie High School are located in the most northern region of Rockaway Beach's urban growth boundary.

City of Tillamook

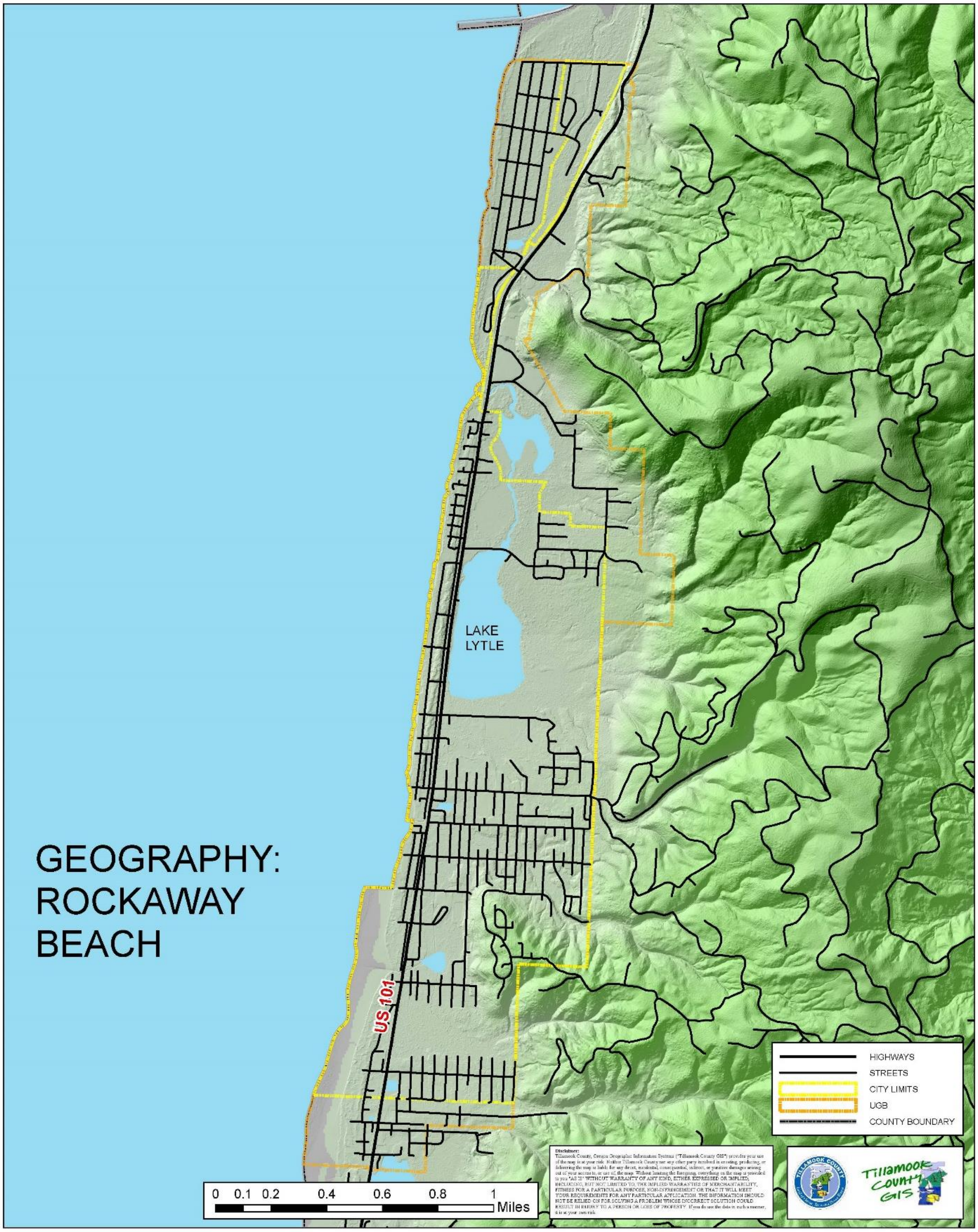
The City of Tillamook is located inland from the Pacific Ocean, southeast of Tillamook Bay. It runs mainly east-west south of OR-6, with an extension north along US-101. It is roughly bounded by the Trask River and a tributary to it on the south and southwest, and Hoquarton Slough on the north. Dougherty Slough and Hall Slough pass under US-101 and through commercial and residential districts. The Wilson River forms the northern boundary of the city’s extension along US-101. The city is flat on a natural peninsula that elevates most of it above the floodplain. It is surrounded primarily by farmland.

The City of Tillamook is named for the Tillamook people, a Native American tribe speaking a Salishan language who lived in this area until the early 19th century, when the remaining members of the tribe were forcibly moved to the Siletz Reservation.. The City of Tillamook is the County seat and the largest incorporated city in Tillamook County. The city is known for its dairy industry and the Tillamook County Creamery Association. With primarily a full-time resident population, the City of Tillamook supports several commercial districts. Efforts are underway for improvements to city infrastructure as well as renovations to commercial structures in the downtown core.

City of Wheeler

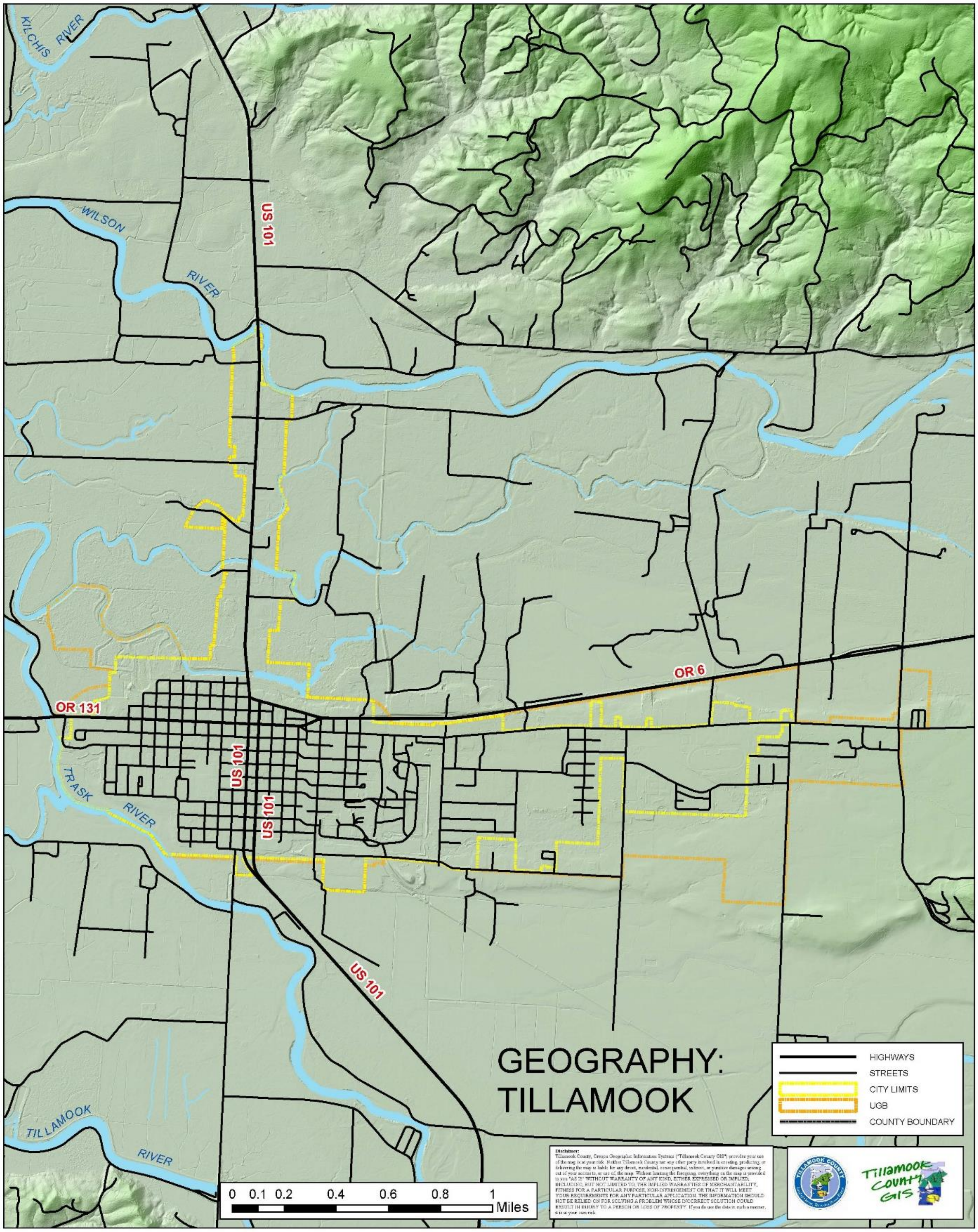
The City of Wheeler is located on the Nehalem River’s southeast bend at the bottom of mountainous area. US-101 runs along the riverbank and most of the city is located to its east, rising quickly up the steep terrain. While US-101 provides access, the city’s geography isolates it from its nearest neighbors. Four stream systems drain through the city, dividing it into discrete sections. These sections are in large measure isolated from one another.

Figure 9. Political and Physical Geography: City of Rockaway Beach



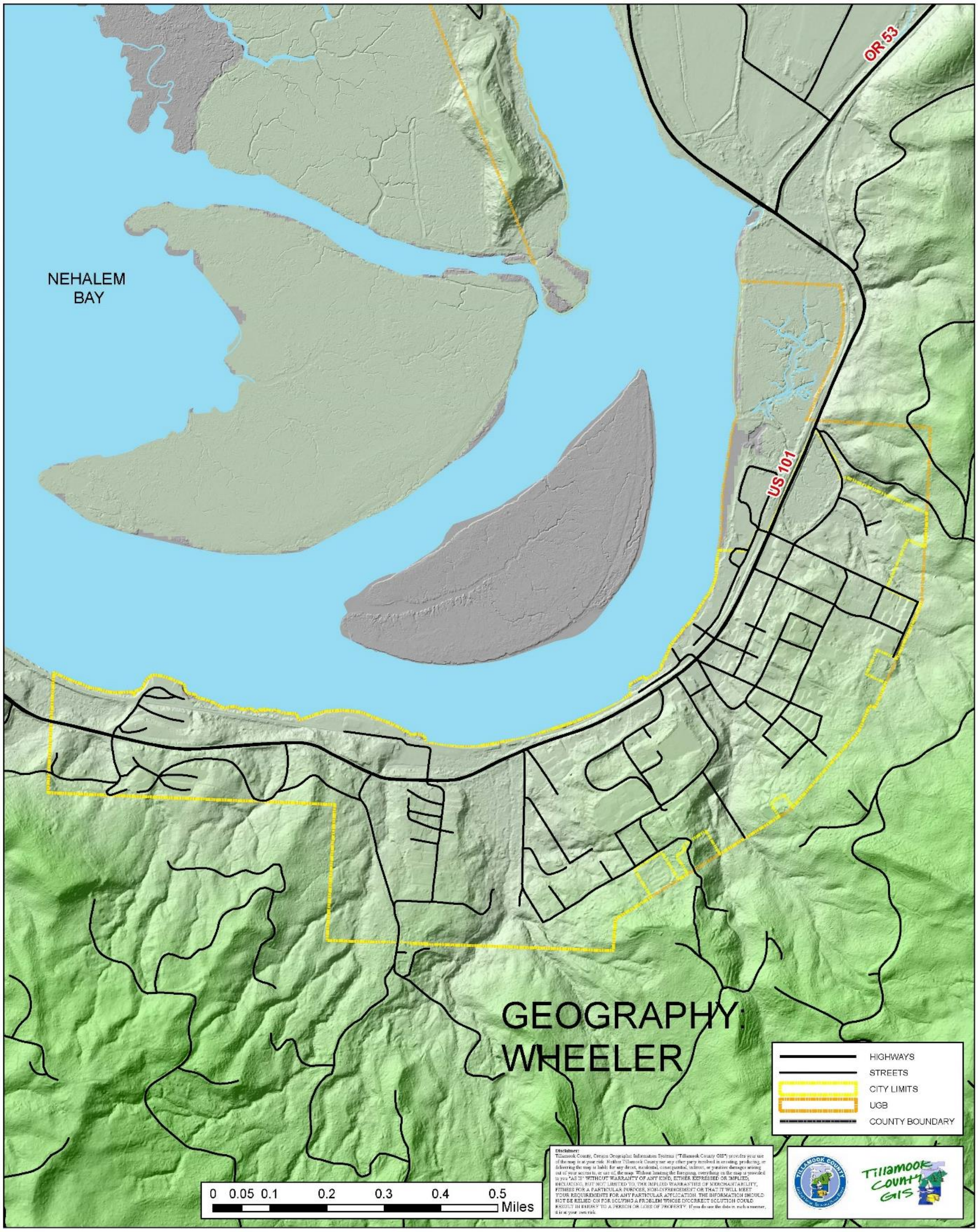
Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 10. Political and Physical Geography: City of Tillamook



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Figure 11. Political and Physical Geography: City of Wheeler



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Ports

A port's primary purpose is to support and facilitate commerce. Among other authorities, ports may own and lease property, provide services, and levy taxes within their District boundaries. Residents and residences, as well as businesses, public facilities, or other concerns not located on Port property fall within the primary jurisdiction of their respective cities or Tillamook County. Similarly, the Ports of Tillamook Bay and Garibaldi are located in Tillamook County and the City of Garibaldi, respectively, and fall under those jurisdictions for many purposes, including emergency response.

The Ports identify their primary areas of activity and development, land, and submerged land ownership as "the Port" or being within the "Port Boundary." The maps in this Plan depict the most current tax lot information provided by the Tillamook County Departments of Assessment and Taxation and Geographic Information Systems as comprising the areas within the Ports' boundaries.

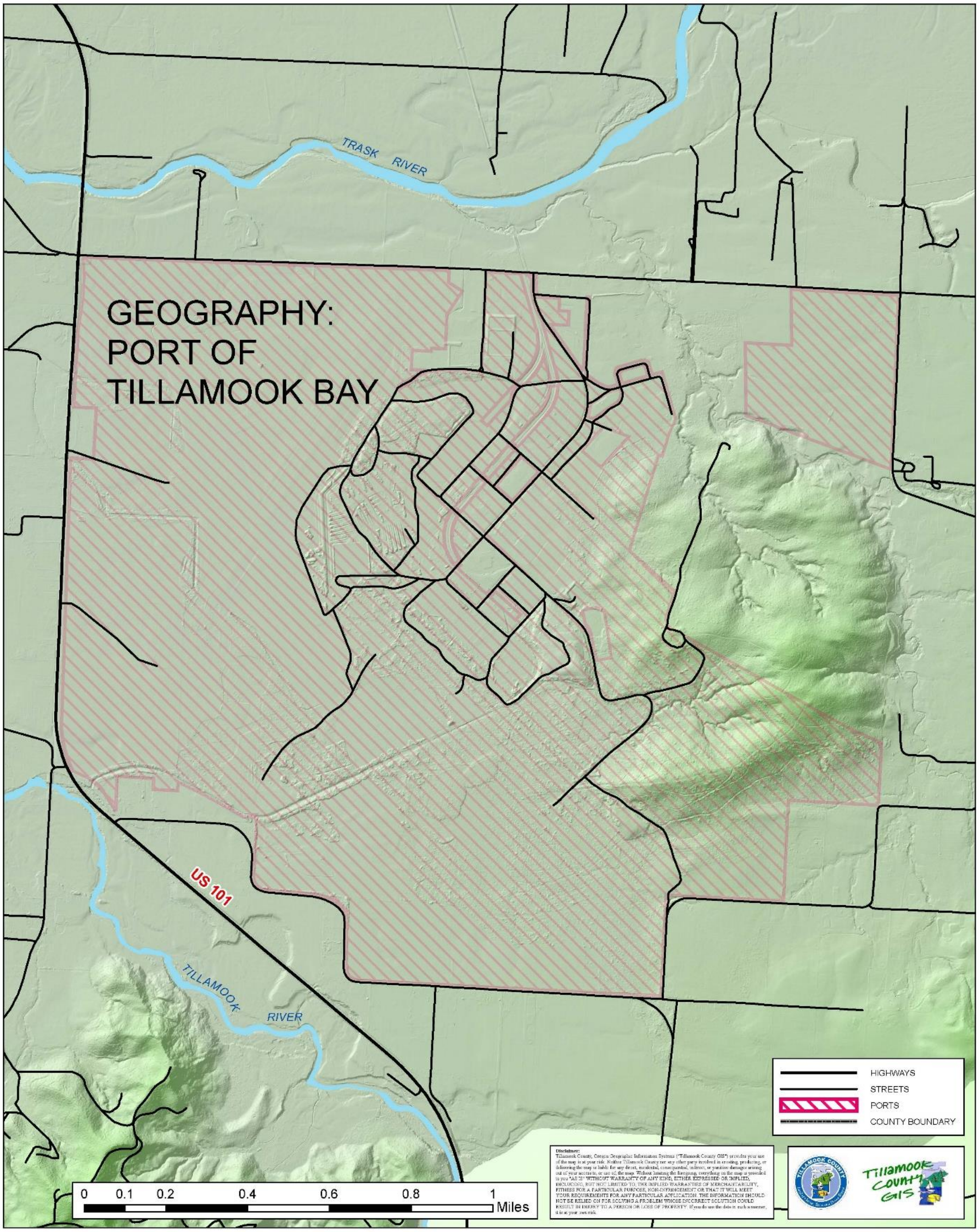
Port of Tillamook Bay

The Port of Tillamook Bay property comprises roughly 1,600 acres of land and is located approximately four miles south of downtown Tillamook, Oregon, along US Highway 101. Port property is accessed by Blimp Boulevard, which is approximately one mile east along Long Prairie Road from Highway 101. It is bounded roughly on the east by Brickyard Road; on the south by South Prairie Loop Road; on the west by Highway 101; and on the north by Long Prairie Road. Most of the Port's property lies upon flat ground, with one hill rising on its eastern edge. The hill is drained by a small stream running fairly parallel to Mill Creek through the Port proper.

The Port of Tillamook Bay's service and taxing district encompasses a much larger area: the entire width of the county from Cape Lookout on the south running north along the Pacific Ocean and enveloping the south side of the Tillamook Bay jetty system, then southeast through the center of Tillamook Bay and on east to Siskeyville and the county line. Discussions are underway to adjust the boundary between the Port of Tillamook Bay and the Port of Garibaldi, moving the south jetty into the Port of Garibaldi District. The boundary realignment would enable unified management of the north/south jetty system.

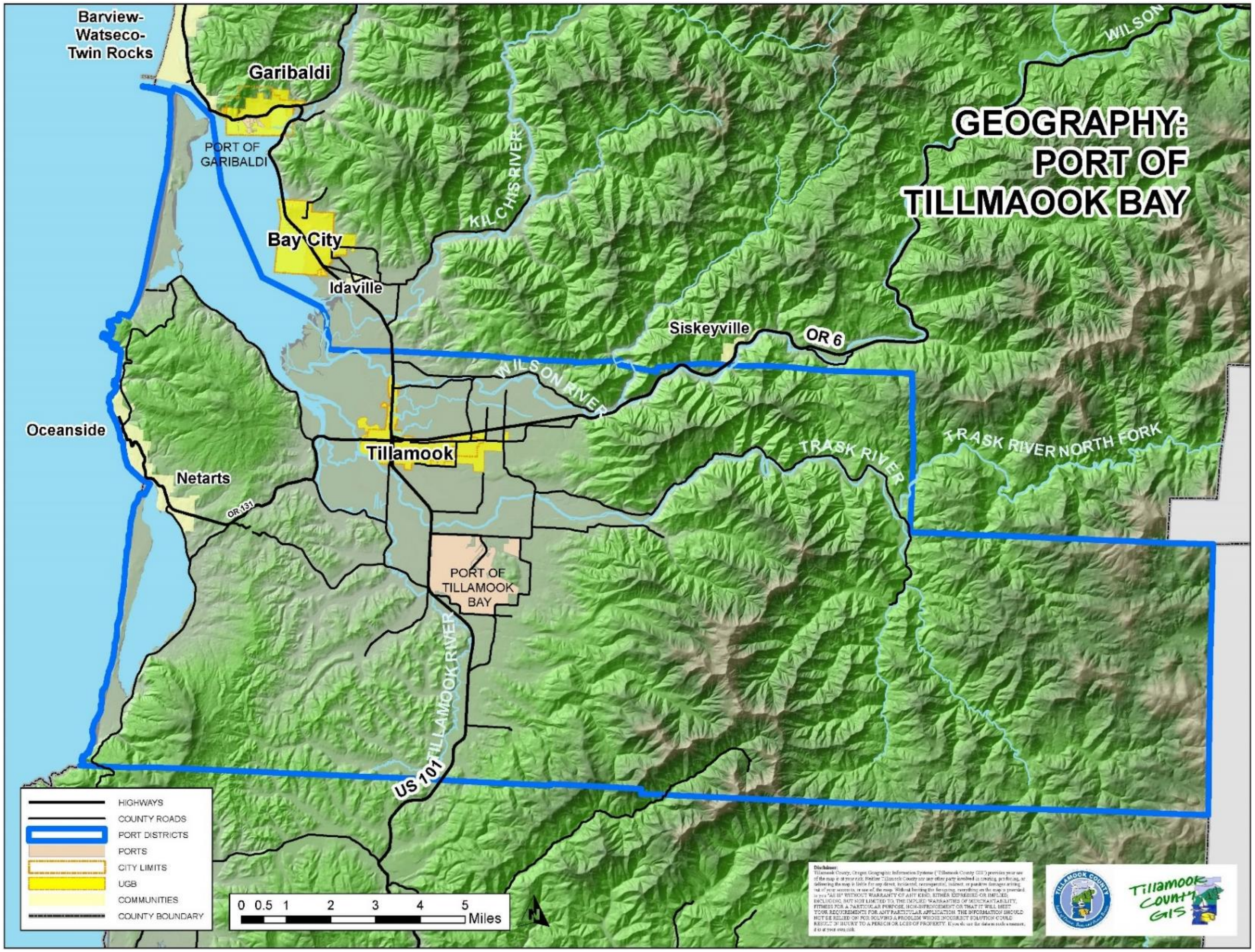
The Port of Tillamook Bay (originally formed as the Port of Bay Ocean in 1911) incorporated an approximate 1,600-acre parcel of land formerly known as the Naval Air Station Tillamook (1942–1948) into its district in 1953. Subsequent to that time, this area has evolved into the core of Tillamook County's industrial sector through Port's operation of a railroad system, the Tillamook Municipal Airport, and an approximate 200-acre industrial park complex serving multiple lease tenants engaged in varying levels of industrial manufacturing and development. After the storms of December 2007 that resulted in major damages to the rail line, the Port placed the railroad under a Discontinuance of Service with the Surface Transportation Board and has partnered with the Salmonberry Trail Intergovernmental Agency to explore the creation of a trail system along the rail corridor.

Figure 12. Political and Physical Geography: Port of Tillamook Bay



Source: Tillamook County Geographic Information System (GIS) Team , 2017

Figure 13. Political and Physical Geography: Port of Tillamook Bay – Port District



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Port of Garibaldi

The Port of Garibaldi owns approximately 150 acres of land and submerged lands in the Cities of Garibaldi and Bay City. It is located primarily within the City of Garibaldi on a peninsula constructed of fill in Tillamook Bay at about sea level. It is flat and paved with access to US-101 at its north end. Piers have been constructed at the south end of the peninsula. A marina, the primary mooring facility with 277 slips is located in the center of the peninsula. About 400 linear feet of transient tie-ups are located opposite the marina in the boat basin. Two piers are located in Bay City. There is a mix of publicly and privately owned buildings and facilities on Port-owned land; however, there are no permanent residents on any Port property.

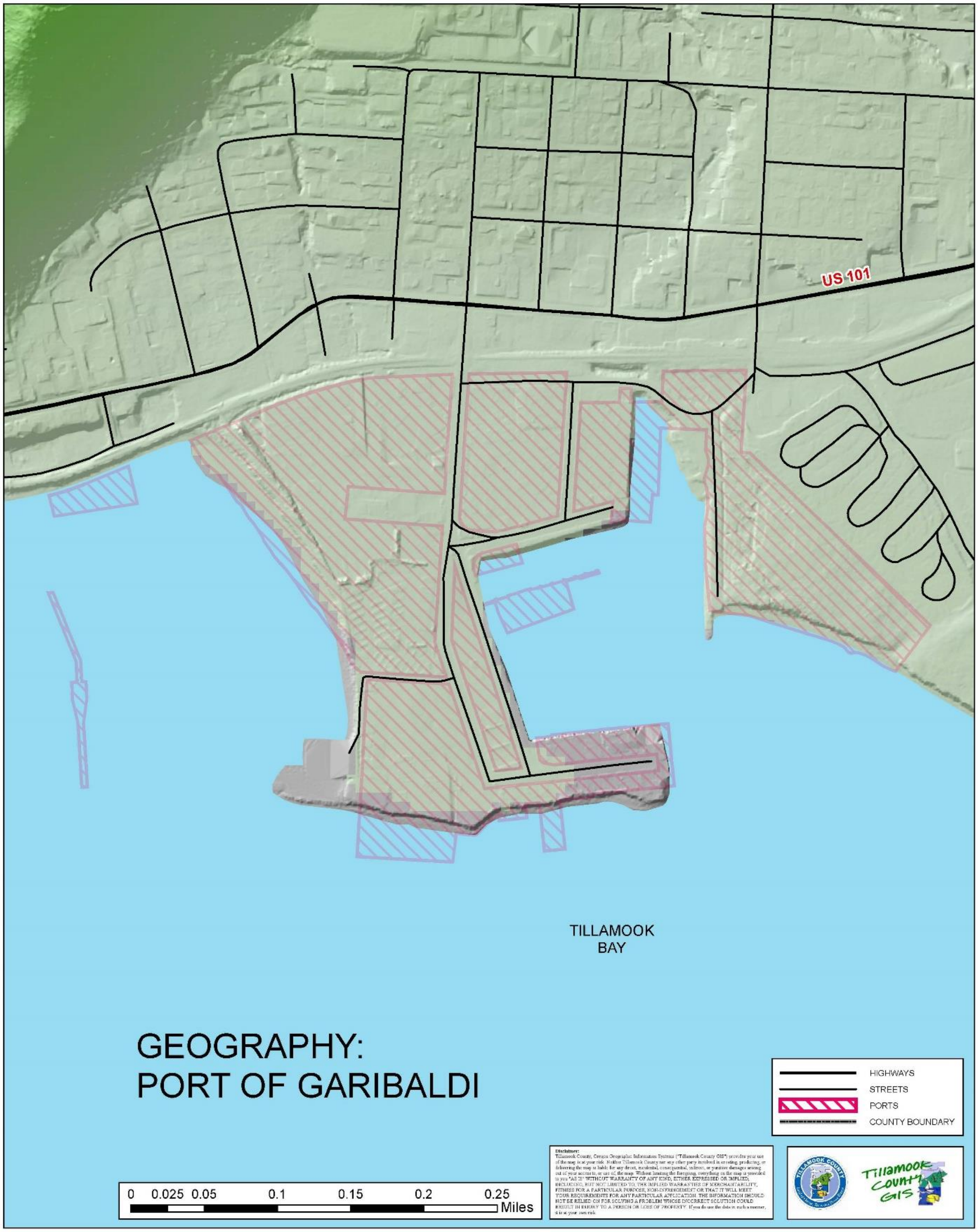
The Port of Garibaldi Special District encompasses approximately 350 square miles of Tillamook County. The District's boundaries extend from the Tillamook Cheese Factory north to Neah-Kah-Nie High School and east up Oregon 6 to Lee's Camp. Discussions are underway to adjust the boundary between the Port of Garibaldi and the Port of Tillamook Bay, moving the south jetty into the Port of Garibaldi District. The boundary realignment would enable unified management of the north/south jetty system. The District is characterized by coastal lowlands as well as forested mountains. Three of the primary rivers in the County — the Wilson, Kilchis, and Miami — drain the District.

The Port of Garibaldi was initially established as the Port of Bay City in 1910 to facilitate construction of the Tillamook Bay north jetty. Historically it has focused on job creation through development of its resources, support for business opportunities, collaboration and partnerships, and community relations. Its infrastructure includes commercial piers, docks, a boat ramp, a boat basin, sea walls, hoists, utility services, various buildings, a recreational vehicle park, playground, and other infrastructure associated with the operation of a sea port. Recent federal, state, and local government investments of $10,000,000.00 in the port's infrastructure have spurred a resurgence of the local fishing and seafood processing industry.

The Port of Garibaldi is also working on diversification into new venues and business activities supportive of its authentic fishing harbor character. The Port's boat basin has moorage for 277 vessels and serves as the base of operations for several commercial fishermen and charter operations. The harbor also has a public boat launch for people wishing to fish, crab or get to the Pacific Ocean. Other businesses located in the Port include additional recreational vehicle parks, a hotel, restaurants, fishing charters, and a variety of other recreational businesses; shrimp, crab, and fish processing facilities; and a lumber mill. Significantly, the Port of Garibaldi is home to the US Coast Guard Station Tillamook Bay.

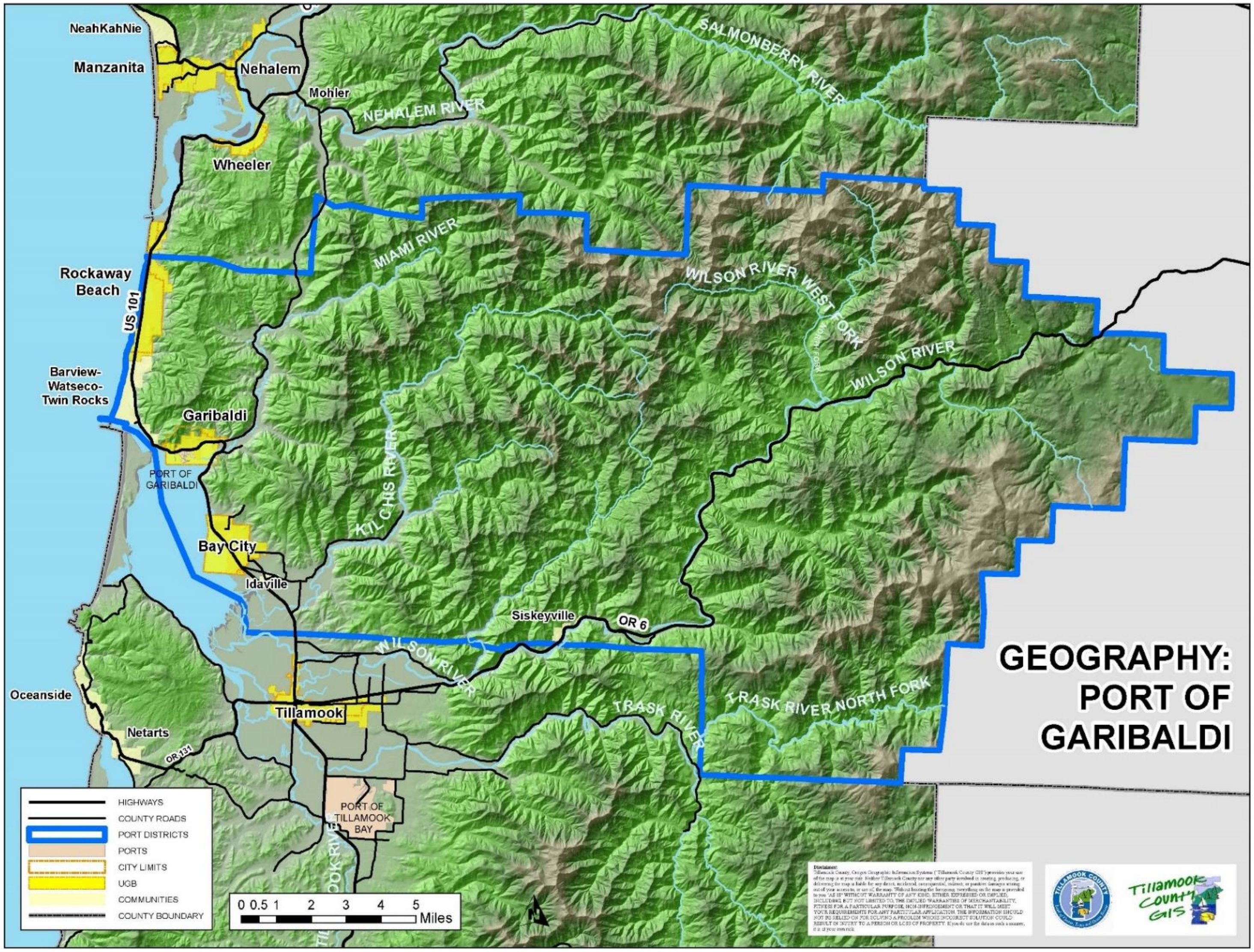
The Port's primary focus for natural hazards mitigation is on the protection of the navigable channels, boat basin, and infrastructure as they are important assets and critical infrastructure for and of Tillamook County.

Figure 14. Political and Physical Geography: Port of Garibaldi



Source: Tillamook County Geographic Information System (GIS) Team , 2017

Figure 15. Political and Physical Geography: Port of Garibaldi – Port District



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Ecoregion

The US EPA uses “ecoregions” to describe areas of ecosystem similarity. Tillamook County is located in the US EPA ecoregion, “Coast Range.” Mountains in the Coast Range are low in elevation and high in precipitation, creating lush evergreen forests. Naturally diverse forests have given way to monocrop plantings for timber harvest. The Oregon Coast Range is volcanic in origin and is drained by hundreds of creeks, streams, rivers, and lakes. Sedimentary soils are more prone to slope failure following clear cuts and road building than are areas with volcanic soils, which may be of concern as commercial Douglas fir forests are highly productive commercial logging areas. Landslides can impact the safety of nearby infrastructure and health of the region’s waterways. Sedimentary soils create more concerns for stream sedimentation than areas with volcanic soils. Low lands include beaches, dunes, forests, lakes, marshes, and streams. Many wetlands in the ecoregion have been converted to dairy pastures (Thorson et al., 2003).

Climate

The Oregon Coast has a predominantly mild climate with localized variation in precipitation levels. Precipitation occurs predominantly in the winter months, mostly in the form of rain due to the region’s low elevation. Wet winters and dry summers impact risk of drought, floods, landslides, and wildfires. Winter storms are often accompanied by high winds. Because there are a number of microclimates in the County, temperature and precipitation vary widely from one locale to another. NOAA National Centers for Environmental Information, Climate at a Glance: County and Divisional Time Series, published August 2019 reports the following climate data for Tillamook County.

Table 7. Average Precipitation and Temperature in Tillamook County

Sub-Region	Annual Precipitation Mean & Range (1981–2010)	January & July Mean Precipitation (1981–2010)	Annual Mean Temperature (1981–2010)	January & July Average Min/Max Temperature (1981–2010)
Tillamook County	100.29” (70.77”–145.93”)	Jan: 15.22” Jul: 1.29”	49.5°F	Jan: 35.4/45.6 Jul: 50.4/70.9

Source: Oregon NHMP: Oregon Department of Land Conservation and Development, 2020: NOAA National Centers for Environmental Information, Climate at a Glance: County & Divisional Time Series, published August 2019, retrieved on August 8, 2019 from https://www.ncdc.noaa.gov/cag/

Climate Change

The Oregon Climate Change Research Institute (OCCRI) developed projections of the potential impact of warming climate on the natural hazards identified by the Tillamook County NHMP Steering Committee. The information below is a summary of that work. The full report is available as an appendix to this 2023 Tillamook County Multi-Jurisdictional NHMP.

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 that explain why temperature increases 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 evidence is limited or projections suggest relatively few to no changes.

Table 8. 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 Species 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

The OCCRI report presents future climate projections for Tillamook 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. Projections in this executive summary refer to the 2030s, the 2050s, and the 2100s, 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 Tillamook 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 Tillamook County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 3 days (range 0–6 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario. In Tillamook County, the temperature on the hottest day of the year is projected to increase by an average of about 6°F (range 1–9°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 less intense as the climate warms. In Tillamook County, the number of cold days (maximum temperature 32°F or lower) per year is projected to decrease by an average of 1 day (range 0–2 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario. In Tillamook County, the temperature on the coldest night of the year is projected to increase by an average of 5°F (range 0–10°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 Tillamook 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 15% (range 2–29%) and 11% (range 1–25%), respectively, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Tillamook 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 in coastal rain-dominated watersheds in Tillamook County 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 Tillamook 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 Tillamook County by 11 days (range 5–28) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

In Tillamook County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 27 days (range 6–52) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality
The risk of wildfire smoke in Tillamook 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 increase by 17%, and the concentration of fine particulate matter is projected to increase by 84%, 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. Local sea level at Astoria is projected to rise by 0.8 to 4.8 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 likelihoods of a flood reaching four feet above mean high tide at some point before 2030, 2050, and 2100 are 4–38%, 19–100%, and 98–100%, respectively. At risk within the four-foot inundation zone in Tillamook County as of the 2010 census are 485 people, $58 million in property value, nearly 17 miles of highways, roads, and railways, 1 airport, 12 potential contaminant sources, and around 300 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
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 five estuaries in Tillamook County is projected to increase with lower sea level rise but decrease with increasing sea levels. Under 4.7 feet of sea level rise, tidal wetland area is projected to decrease the most, about 24%, in Tillamook Bay. In Netarts Bay, wetland area is projected to increase by about 39% under 4.7 feet of sea level rise, but by 54% under 2.5 feet of sea level rise.

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 Species
In general, non-native invasive plants in Tillamook 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.

2. Demographics

Statistics are reported from the US Census of 2020 (Census Bureau Data) and the 5-year American Community Survey (ACS) of 2020. The American Community Survey is an estimate, rather than an actual count. Therefore, some of the estimates and calculations, particularly for the smaller cities, are within the margin of error and should be understood in that context. In some cases, data has not been reported or calculated for that reason.

We have included data where possible for the unincorporated communities of Bayside Gardens, Neskowin, Oceanside-Netarts, and Pacific City and the remainder of the unincorporated area of the County (“Unincorporated County”) to be consistent with the Multi-Hazard Risk Report (DOGAMI, 2022). The Port of Garibaldi has no residents. The Port of Tillamook Bay has one single-family residence located within its boundary, but not on Port property. Within each district boundaries that extend throughout the county jurisdiction there are some residences.

Resident Population

Understanding the population and certain of its characteristics helps identify actions that can be taken to reduce the impacts of a disaster before it occurs.

The population of Tillamook County is located largely in low-lying areas along its coast, bays, and rivers, with the greatest population in the north and central regions.

As a whole, Tillamook County’s population remained essentially unchanged between 2010 and 2015, but grew by 7.71 between 2015 and 2020, a 1.54% annual growth rate, faster than the average across the State of Oregon. Because the ACS is an estimate and the communities are so small, the changes in their population and average annual growth rates would not be very accurate or meaningful and are not calculated. However, the data does estimate that all the cities and unincorporated urban areas have grown a bit except for Garibaldi and Pacific City, which are estimated to have lost some population. The Unincorporated County is also estimated to have lost population.

In general, the jurisdictions agree with this assessment. The City of Garibaldi reports a loss of residents due to closing of a mobile home park. However, demand for housing is increasing. Primary and secondary single-family homes and apartments are being developed. The city anticipates the population to increase in the next few years. The City of Wheeler indicates that its steady population may be due to very little potential for new development or redevelopment in the city.

One privately owned property inside the Port of Tillamook Bay industrial park boundaries is developed with one single-family home with a population of two.

The Port of Garibaldi has no permanent residents.

Table 9. Tillamook County Population change 2015 - 2020

	2015		2020		Population Change 2015/2020		Average Annual Growth Rate
	Population	% of County	Population	% of County	Population Change	Percent Change	
Oregon	3,939,233		4,237,256		298,023	7.57%	1.51%
Tillamook County	25,430	100	27,390	100.0%	1960	7.71%	1.54%
Incorporated							
Bay City	1,466	5.7	1,389	5.1%	-77	-5.3%	–
Garibaldi	782	3	830	3.0%	48	6.1%	–
Manzanita	426	1.7	603	2.2%	177	41.5%	–
Nehalem	254	1	270	1.0%	16	6.3%	–
Rockaway Beach	1,227	4.8	1,441	5.3%	214	17.4%	–
Tillamook	4,958	19.5	5,204	19.0%	246	5.0%	–
Wheeler	397	1.6	422	1.5%	25	6.3%	–
Total Incorporated	9,510	37.3	10,159		649	6.8%	
Unincorporated							
Total Uninc. County	15,920	62.6%	17,231	62.9%	1311	8.2%	–
Bayside Gardens			1,214	4.4%			
Neskowin	156	0.6%	205	0.7%	49	31.4%	–
Oceanside-Netarts	1,296	5.1%	1,260	4.6%	-36	-2.8%	–
Pacific City–Woods	963	3.8%	1109*	4.6%			–

Source: 2015 and 2020 US Census American Community Survey 5-year estimates, Table DP05, Census Bureau Data.
*Pacific City only

Longer term data reflect a less extreme range in percentage population change in Tillamook's cities.

Table 10. Tillamook Cities population change 2010 to 2020

Population by City, 2010, and 2020

	2010	2020	2010-2020 Change Number	*Percent*
Bay City	1,286	1,389	103	*8.0%*
Garibaldi	779	830	51	*6.5%*
Manzanita	598	603	5	*0.8%*
Nehalem	271	270	-1	*-0.4%*
Rockaway Beach	1,312	1,441	129	*9.8%*
Tillamook	4,935	5,204	269	*5.5%*
Wheeler	414	422	8	*1.9%*

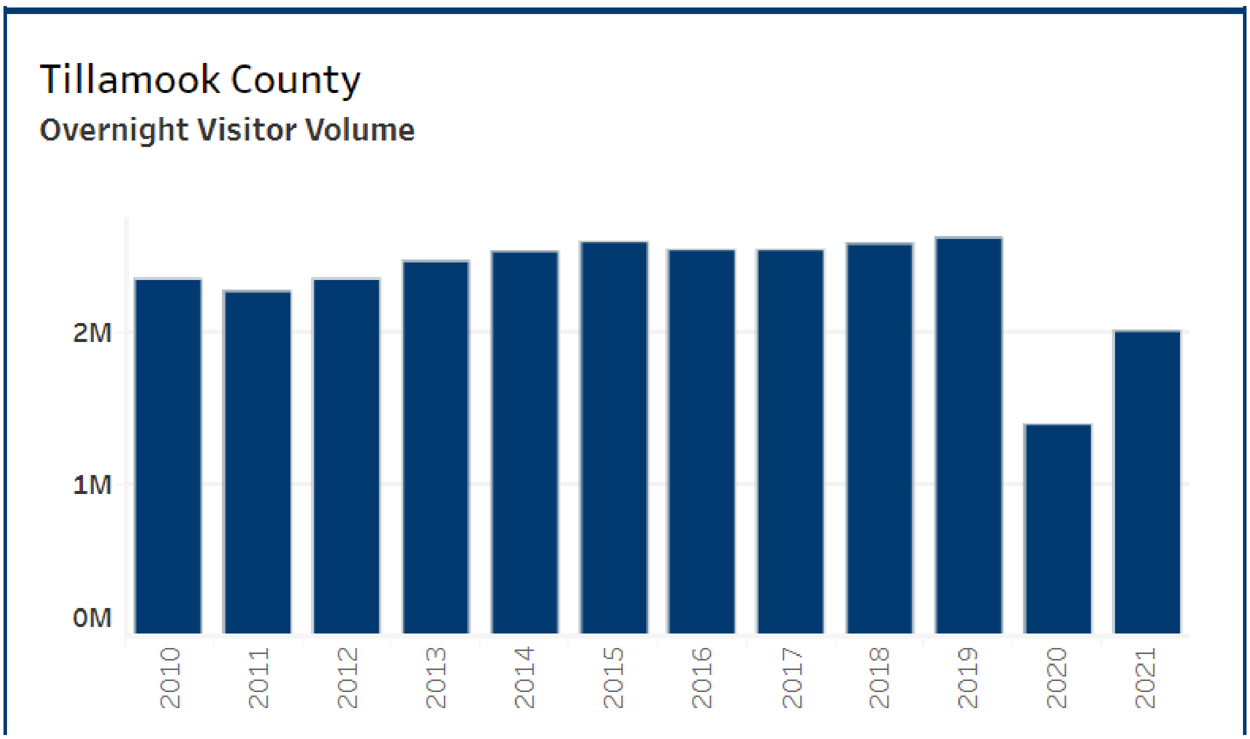
U.S. Census Bureau, PL94-171 redistricting data files.
Compiled by PSU Population Research Center, www.pdx.edu/prc

Tourists

In addition to year-round residents, Tillamook County attracts many tourists. The Steering Committee members confirm that the County's population increases dramatically during the summer tourist season, especially on holidays and for special events. In addition to individuals and groups, many families arrive, significantly boosting the number of children throughout the County.

Dean Runyan Associates reports tourist industry data for Tillamook County. There was a significant dip in number of visitors to Tillamook County in 2020 due to the COVID-19 pandemic. Since that time the number of nights spent by visitors to Tillamook County has rebounded and the amount of money spent per night has increased.

Figure 16. Tillamook County Overnight Visitor Volume 2010 - 2021



Source:

Figure 17. Tillamook County Average Overnight Spending 2010-2021

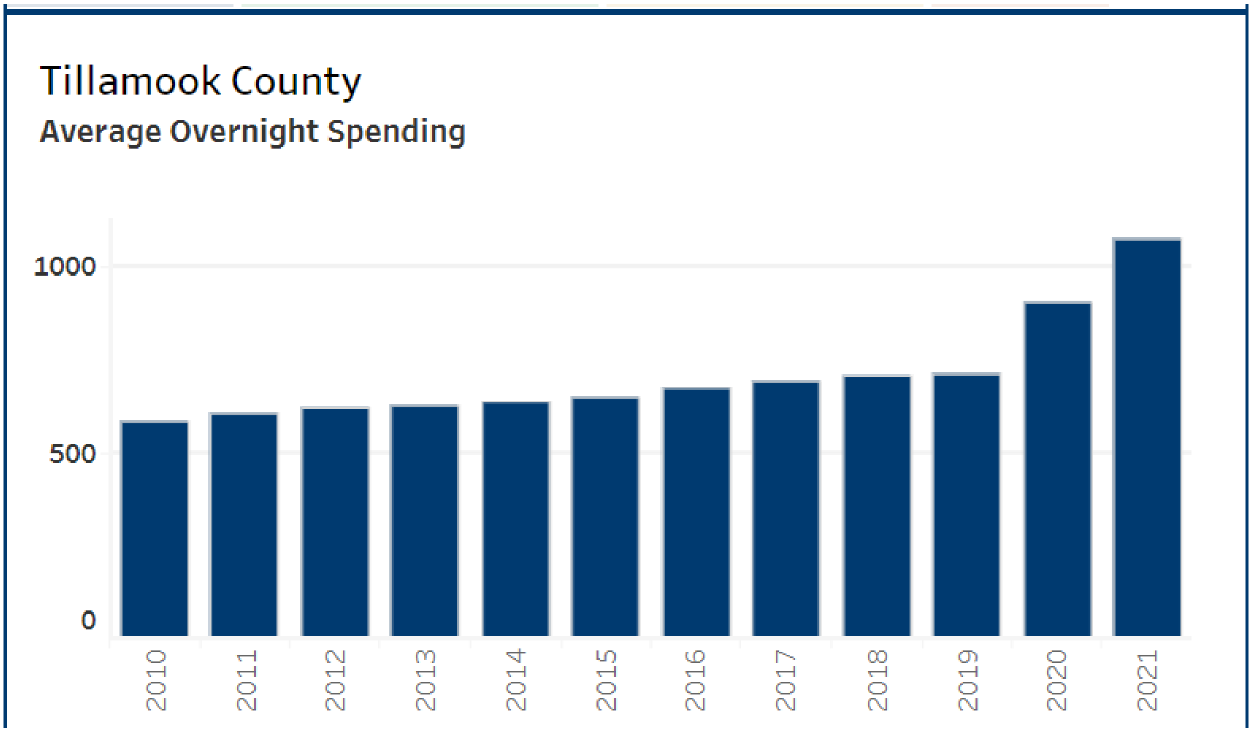
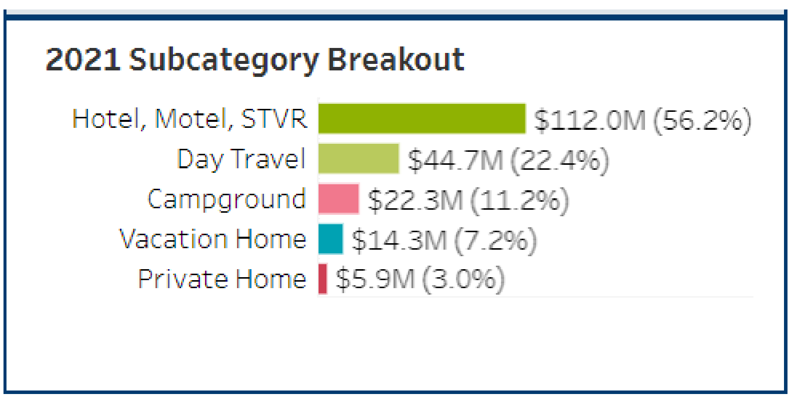


Figure 18. Accommodation Breakdown for Overnight Visits in Tillamook County 2021



In July 2022 the county instituted a moratorium on Short Term Rental permits for a year to allow an advisory committee to study the impacts to livability, health, safety, and quality of life of issues presented by Short Term Rentals.

No similar official statistics exist for the individual jurisdictions. In the 2016 Tillamook County NHMP, Bay City and Nehalem reported hosting few visitors. These cities each have a recreational vehicle park and a few vacation rental homes, but no hotels. Wheeler reports hosting few overnight tourists but many day-trippers who take advantage of its transient boat ramp and dock for sport fishing. Garibaldi has two hotels, three recreational vehicle parks, and a few vacation home rentals. The Port of Garibaldi is home to one hotel, two recreational vehicle parks, a marina, and a public boat launch. Together the City of

Garibaldi and the Port support sport fishing and other tourist activities as well as the year-round commercial fishing industry. The Port of Tillamook Bay owns and operates the Tillamook Air Museum, which receives approximately 65,000 visitors per year, and also operates a year-round recreational vehicle park just off US-101 approximately four miles south of downtown Tillamook. Rockaway Beach, Manzanita, Tillamook, and the unincorporated communities also report having many tourist accommodations and hosting many overnight tourists. The Tillamook Creamery, just north of the City of Tillamook, is one of the largest tourist attractions in the state, receiving more than 1.3 million visitors per year. These visitors stay in accommodations throughout the region and support many other tourism-related businesses.

Difficulty locating or accounting for travelers increases their vulnerability in the event of a natural disaster. Further, tourists are often unfamiliar with evacuation routes, communication outlets, or even the type of hazard that may occur. Targeting natural hazard mitigation outreach efforts to places where tourists lodge can help increase awareness and minimize the vulnerability of this population. Tillamook County has recently required the posting of tsunami evacuation route maps in all vacation rentals. Rockaway Beach rental property owners are required to post information in the dwelling unit to assist renters in dealing with natural disasters, power outages and other emergencies. The City provides a list of emergency contacts to be provided in each rental dwelling unit.

Age

Age is an indicator of vulnerability. Both children and the elderly are more vulnerable than others are to impacts of disasters.

Many seniors are sensitive to heat and cold, reliant upon public transportation or other people to transport them to obtain medication and access medical facilities and have comparatively more difficulty in making home modifications that reduce risk to hazards. In addition, seniors may be reluctant to leave home in a disaster event. This implies the need for targeted preparatory programming that includes evacuation procedures and shelter locations accessible to seniors (Morrow, 1999; Oregon NHMP: Oregon Department of Land Conservation and Development, 2015). Seniors living alone may have more challenges knowing about and responding to a disaster than those living with other people.

Young children are also more vulnerable to heat and cold, have fewer transportation options, and require assistance to obtain medication and access medical facilities. In addition, parents may lose time and money when childcare facilities and schools are impacted by disasters. Therefore, special consideration should also be afforded young children, schools, and parents during the natural hazards mitigation process (Oregon NHMP: Oregon Department of Land Conservation and Development, 2015).

In general, Tillamook County has a high percentage of seniors (more than 25% are at or over the age of 65) and a low percentage of children (4.5% are 5 years old or younger). The following table was generated using the American Community Survey for the 5-year period prior to 2020. The data are estimates and the populations estimated are sometimes small. Thus, the error in the estimates may result in the data appearing skewed or incorrect. Notably, Neskowin is estimated to have no children under the age of 18. Pacific City, Tillamook and Nehalem are estimated to have at least 6% of their populations being under 5 years old.

Table 11. Percent of Total Population - Children and Seniors

Community	Children		Seniors	
	% > 5 years	% 5 to 17	% ≥ Age 65	% ≥ Age 65 Living Alone
Oregon	5.5%	15.3%	17.6%	4.6%
Tillamook County	4.5%	14.4%	25.5%	5.7%
Incorporated				
Bay City	6.1%	16.5%	17.0%	4.5%
Garibaldi	0.6%	9.4%	39.6%	12.6%
Manzanita	0.0%	2.9%	46.9%	12.3%
Nehalem	6.6%	12.6%	19.1%	5.7%
Rockaway Beach	2.3%	17.5%	21.4%	6.7%
Tillamook	6.8%	18.2%	16.8%	28.8%
Wheeler	1.6%	14.1%	38.2%	7.9%
Total Incorporated	5.2%	16.2%	21.0%	17.8%
Unincorporated				
Total Uninc. County	4.6%	14.7%	19.2%	4.9%
Bayside Gardens	2.9%	22.3%	18.6%	5.3%
Neskowin	0.0%	0.0%	24.1%	67.1%
Oceanside	0.0%	6.0%	48.0%	22.5%
Netarts	1.6%	24.4%	32.0%	7.5%
Pacific City	6.2%	16.0%	44.9%	6.2%

Source: Source: US Census, American Community Survey 5-year estimates, 2020, Tables S0101 (Age and Sex) and B09020 (Relationship by Household Type (Including Living Alone) for the Population 65 Years and Over

Disability

People with disabilities (physical, cognitive, or sensory) are disproportionately affected during disasters (Cutter, Boruff, & Shirley, 2003). The resources or assistance they need may not be available. Outreach targeted to disabled residents could help them, and the local governments, and non-government organizations that serve them to prepare for and recover after a disaster.

In Tillamook County, slightly more than 20% of the non-institutionalized population has a disability. In a county whose population is just over 25% seniors aged 65 and older, this is not surprising. What is surprising is that the proportion of the general population in Tillamook County that lives with a disability is significantly higher than that population in Oregon as a whole. This represents a vulnerability for the people living in the county when a natural hazard event occurs.

Table 12. Non-institutionalized People with a Disability

Community	% With a Disability	% ≥ Age 65 with a Disability
Oregon	14.3%	26.0%
Tillamook County	20.2%	21.1%
Incorporated		
Bay City	20.6%	24.8%
Garibaldi	25.8%	29.9%
Manzanita	22.5%	24.0%
Nehalem	19.9%	17.8%
Rockaway Beach	32.5%	36.5%
Tillamook	23.5%	53.7%
Wheeler	22.2%	15.6%
Unincorporated		
Unincorp. County		
Bayside Gardens	24.6%	21.3%
Neskowin	12.5%	9.5%
Oceanside	8.6%	0.0%
Netarts	26.8%	25.0%
Pacific City	12.7%	3,9%

Source: US Census, American Community Survey 5-year estimates, 2020, Table S1810: Disability Characteristics

Language

For people who are not native English speakers, communication about hazards before, during, and after a disaster may be daunting, increasing their vulnerability. Culturally appropriate outreach and informative materials in the languages spoken in the County would reduce that vulnerability. Almost 10% of Tillamook County's people speak a language other than English at home as compared to more than 15% of the people in the state of Oregon who speak a language other than English at home. Of those, most speak Spanish or Spanish Creole, and most live in the unincorporated areas of the County. The City of Tillamook is home to the next greatest concentration with a very small number living in the other cities and unincorporated urban areas. (US Census, American Community Survey, 5-year Estimates, 2020, Table S1601)

Education

Studies (e.g., Cutter et al., 2003) show that education and socioeconomic status are deeply intertwined with higher educational attainment correlating to increased lifetime earnings. Education can also influence a person's and community's ability to access disaster information and resources. The tables provided below divide the county communities into the cities and the unincorporated communities. There are communities in both categories where a portion of the people over 25 years old have not graduated from High School, but there are no communities where less than 82% of the people have not graduated from High School. Some communities are home to a higher percentage of people who have attained a bachelor's degree or greater. Notably Neskowin and Oceanside residents have high levels of higher educational achievement both exceeding 60% of the population with a Bachelor's degree or higher.

Table 13. Educational Attainment in Tillamook County and Incorporated Cities

	Tillamook County	Bay City	Garibaldi	Manzanita	Nehalem	Rockaway Beach	Tillamook	Wheeler
Population 25 years and over	20,090	1,596	562	441	251	995	3,593	322
% Not a High School Graduate	9.7%	10.7%	6.9%	1.4%	15.1%	17.9%	15.1%	5.9%
% High school graduate or higher	90.3%	89.3%	93.1%	98.6%	84.9%	82.1%	84.9%	94.1%
% Bachelor's degree or higher	21.4%	21.5%	17.3%	49.0%	17.9%	20.8%	12.0%	41.0%

Source: US Census Data, American Community Survey 5-year Estimates, 2020, Table S1501: Educational Attainment

Table 14. Educational Attainment in Unincorporated Communities within Tillamook County

	Bayside Gardens	Beaver	Cloverdale	Hebo	Neskowin	Netarts	Oceanside	Pacific City
Population 25 years and over	826	121	146	107	79	550	437	961
% Not a High School Graduate	5.9%	0.0%	6.8%	0.0%	0.0%	4.4%	3.2%	3.7%
% High school graduate or higher	94.1%	100.0%	93.2%	100.0%	100.0%	95.6%	96.8%	96.3%
% Bachelor's degree or higher	18.4%	44.6%	25.3%	0.0%	68.4%	30.9%	64.5%	25.0%

Source: US Census Data, American Community Survey 5-year Estimates, 2020, Table S1501: Educational Attainment

Housing Occupancy and Tenure

Housing tenure is often linked to household income, and household income to the ability to recover from a natural disaster. Renters are less likely to have the financial resources to recover from a natural disaster. In general, they do not make improvements or repairs to the rented structure and may lack sufficient shelter options when lodging becomes uninhabitable or unaffordable after a disaster. They are less likely to return after a disaster.

The population in Tillamook County who live in homes they own is slightly more than this statistic for the State of Oregon. The US Census statistics for owner occupied housing and renter occupied housing has changed since the data provided in the 2016 plan. The US Census now reports the population living in owned or rented housing as opposed to reporting the number of housing units that are owner-occupied or renter occupied. The data provided comes from the American Community Survey 5-year estimates for 2018. Nonetheless, the trends remain mostly consistent with the data provided in the prior plan. People living in Neskowin and Oceanside occupy homes that are owned rather than rented. People in Bay City, Garibaldi, Manzanita, Nehalem and Bayside Gardens also living in homes that are owned at higher rates than in Oregon or Tillamook County as a whole. People in Rockaway Beach, Tillamook, Wheeler, Netarts and Pacific City live in homes that are owned at a lower rate than Oregon or Tillamook County as a whole.

A countywide housing analysis, Creating a Healthy Housing Market for Tillamook County: Findings and Recommendations for the Tillamook County Housing Task Force (czb, March 2017), is based on 2014 data and was a resource for the 2016 plan update. It supported the data relating to owner or renter occupied housing.

Table 15. Population living in owned or rented homes

Community	Owner-Occupied		Renter-Occupied	
	Estimated population	Percent	Estimated population	Percent
Oregon	2,545,176	64%	1,448,791	36%
Tillamook County	16,817	66%	8,537	34%
Incorporated				
Bay City	1,024	68%	490	32%
Garibaldi	584	68%	273	32%
Manzanita	274	82%	59	18%
Nehalem	343	71%	138	29%
Rockaway Beach	665	55%	543	45%
Tillamook	2,135	42%	2,997	58%
Wheeler	136	49%	142	51%
Unincorporated				
Total Unincorp. County	4,273	59%	858	12%
Bayside Gardens	665	85%	120	15%
Neskowin	187	100%	0	0%
Oceanside	352	100%	0	0%
Netarts	384	48%	408	52%
Pacific City	601	58%	436	42%

Source: 2018 American Community Survey 5-year estimates, Table B25008

In the previous plan update, representatives from Manzanita and Rockaway Beach in particular indicated that about two thirds to three fourths of homes were owned by people who are not permanent residents, so much of the housing stock sits empty for long periods during the off-season. This plan update provides data regarding vacant housing. The data presented below from the 2020 American Community Survey 5-year estimates for vacancy due to Seasonal, Recreational or Occasional Use reflects the high proportion of housing that is occupied for only part of the year.

The Port of Tillamook Bay and the Port of Garibaldi have no housing.

Table 16. Vacant Housing Units due to Seasonal, Recreational or Occasional Use

Community	Total Estimated Housing units	Estimated vacant units*	Estimated units vacant for seasonal, recreational, or occasional use*	Percent of vacant units for seasonal, recreation or occasional use[1]
Oregon	**1,813,747**	**160,545**	**61,382**	**38.2%**
Tillamook County	**18,919**	**8,082**	**6,985**	**86.4%**
Incorporated				
Bay City	686	121	88	72.7%
Garibaldi	532	123	112	91.1%
Manzanita	1,340	999	953	95.4%
Nehalem	179	32	28	87.5%
Rockaway Beach	1,980	1,515	1,319	87.1%
Tillamook	2,295	173	27	15.6%
Wheeler	275	75	71	94.7%
Unincorporated				
Total Unincorp. County	11,632	5,044	4,387	87.0%
Bayside Gardens	745	305	241	79.0%
Neskowin	490	561	529	94.3%
Oceanside	653	537	478	89.0%
Netarts	757	429	398	92.8%
Pacific City	1,363	1,077	1,012	94.0%

Source: 2020 American Community Survey 5-year estimates, Tables H-1 and B25004

1. Percentages are based on units that are vacant for seasonal, recreational, or occasional use compared to total vacant units.

* Note: These data are estimates and may not reflect the actual number of vacant units or those vacant for seasonal, recreational, or occasional use.

3. Economics

Income and Poverty

People living in poverty suffer a disproportionate burden from disasters. They are more likely to be isolated and less likely to have the assets to withstand economic setbacks. When a disaster interrupts work, the ability to provide housing, food, and basic necessities becomes increasingly difficult. In addition, low-income populations are hit especially hard as public transportation, public food assistance, public housing, and other public programs upon which they rely for day-to-day activities are often impacted in the aftermath of the disaster.

Overall, during the period from 2015 to 2020 Tillamook County's median income increased by more than 27%, but slightly less than the increase seen across the state of Oregon at more than 28% over the five-year period. The percentage of Tillamook County families experiencing poverty is lower than in the state of Oregon as a whole.

Table 17. Household Median Income and Families Living Below the Poverty Line

Community	Median Household Income 2015	Median Household Income 2020	% Change in Median Household Income	Families below poverty line (%)
Oregon	$51,243	$65,667	28.1%	14.1%
Tillamook County	$42,581	$54,268	27.4%	11.8%
Incorporated				
Bay City	$46,726	$62,629	34.0%	12.4%
Garibaldi	$36,429	$48,750	33.8%	13.0%
Manzanita	$51,429	$57,054	10.9%	5.1%
Nehalem	$43,500	$62,875	44.5%	12.3%
Rockaway Beach	$37,227	$47,857	28.6%	8.1%
Tillamook	$29,889	$45,737	53.0%	12.0%
Wheeler	$34,896	$42,625	22.1%	12.9%
Unincorporated				
Bayside Gardens	$62,163	$65,109	4.7%	4.5%
Neskowin	$39,559	$91,200	130.5%	0.0%
Oceanside	$59792	$86,830	45.2%	0.0%
Netarts	$62,045	$48,631	-21.6%	14.4%
Pacific City	$25,230	$59,583	136.2%	18.3%

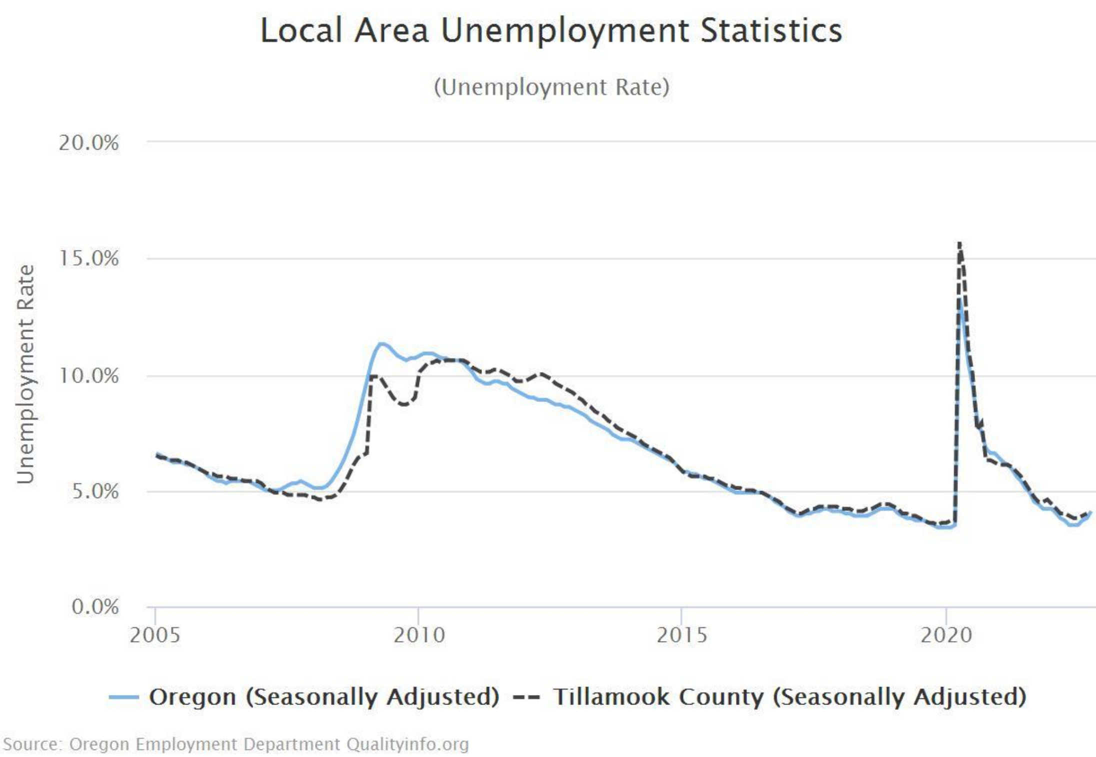
Source: 2020 American Community Survey 5-year estimates, Table S1901 and S170

The data indicates that change in median household income has increased in Neskowin and in Pacific City over the five-year period, whereas families living below the poverty line are among the highest in the county in Pacific City at 18.3%, higher than the state of Oregon's 14.1% as a whole. Most of the cities and unincorporated communities in the county saw increases in household median income over the period. In Netarts, household median income appears to have decreased and families living below the poverty line is at about the level of the state of Oregon as a whole. These data have a high margin of error especially in smaller communities.

Unemployment

Unemployment is an indicator of vulnerability, in much the same way that household income and poverty are. Unemployment in Tillamook County has generally followed unemployment trends statewide including the steep increase in unemployment during the COVID-19 pandemic and returning to essentially pre-pandemic levels in 2022. Employment on the Oregon Coast tends to increase with tourism in the summer and decrease in the winter. The data shown below is seasonally adjusted to remove this variability.

Figure 19. Tillamook County Unemployment Rates 2005–2022



Source: Oregon Employment Department, https://www.qualityinfo.org/ed-uesti/?at=1&t1=4101000000,4104000057~unemprate~y~2005~2022, accessed November 2022

Employment

"The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster" (Cutter et al., 2003). Spring and summer months bring more jobs to Tillamook County, as tourism, retail trade, and construction increase. The economy is more vulnerable during the winter months when tourism decreases and in turn the employment opportunities that support it.

In Tillamook County, employment is heaviest in the Government, Leisure/Hospitality, Accommodation/Food Services, Manufacturing, and Trade/Transportation/Utilities sectors. The Leisure/Hospitality and Accommodation/Food Services sectors support the tourism industry. Retail trade supports visitors as well as year-round residents. Manufacturers are not as dependent on local markets. However, these sectors are all dependent on the transportation system to transport goods and people into and out of the County. Disaster-caused disruption in the transportation system could have significant impacts on the local economy, jobs, and income from decreased tourism and impaired ability to transport goods into and out of the County.

Port Districts have a legal mandate to be a conduit for economic activity and commerce within their district boundaries. The Port of Tillamook Bay and the Port of Garibaldi nurture different economic sectors, together providing a wide range of opportunities and stoking the economic engine of Tillamook County. Adverse impacts to the Ports from natural hazards have far-reaching implications for the County's economy and employment outlook.

With 1,600 acres of industrial-zoned land, much of it accessible via US-101 and 500 acres available for development, the Port of Tillamook Bay is the driving economic force in Tillamook County. The Port operates the Tillamook Municipal Airport, an Airport Business Park, and Air Museum; a 200-acre industrial park with an assortment manufacturing and development operations; and a recreational vehicle park. A diverse assemblage of manufacturing and development operations including Stimson Lumber Mill, CHS Feed Mill, and Hallco Industries provides opportunities to earn a full spectrum of wages from entry-level on up. Near Space Corporation, a commercial provider of high-altitude, near-space platforms and flight services for government, academic, and commercial customers delivers high-end family-wage jobs.

The Port of Tillamook Bay is planning to grow three types of employment uses on its property:

(1) A mixture of retail and commercial uses on its land along Highway 101. These would potentially include both small-scale and large-format retail; facilities for visitors (e.g., a new museum); and a variety of businesses.

(2) Additional manufacturing in its Industrial Park. In 2012, the Port completed construction of three 18,000 square foot warehouses that can support small- to mid-scale manufacturing. Its 500 acres of vacant land could accommodate larger-scale manufacturers.

(3) Aviation and aerospace-related businesses. Firms in this sector will find opportunities for development in the Port's Airport Business Park.

The Port of Garibaldi supports timber, fishing, seafood processing and distribution, and recreation industries. Seafood is brought into the Port by commercial fishermen, processed on site, then distributed nationally and internationally. Hardwood harvested locally and throughout the Pacific Northwest is brought to the Port of Garibaldi for processing then distributed nationally. Each seafood and timber processing job at the Port of Garibaldi is linked with several jobs in harvesting and distribution. Distribution generates jobs not only locally, but also throughout the Pacific Northwest and the entire country.

The US Coast Guard Station Tillamook Bay is located in the Port of Garibaldi. Its area of operation stretches from Cape Kiwanda north to Cannon Beach and 15 nautical miles into the Pacific Ocean. Thirty people are employed here.

Table 18. Employment and Wages by Industry in Tillamook County, September 2022

	Tillamook County		
Industry	**Units or Employers**	**Employment**	**Wages**
Total all employers or ownerships	***1,089***	***9,914***	***$ 121,508,531***
Total private employment or coverage	**982**	**7,948**	**$ 91,088,006**
Natural resources and mining	82	670	$ 7,274,577
Construction	99	443	$ 7,544,441
Manufacturing	33	1,533	$ 23,637,258
Trade, transportation, and utilities	157	1,490	$ 13,374,880
Information	16	54	$ 593,541
Financial activities	54	179	$ 2,404,984
Professional and business services	98	426	$ 6,725,463
Education and health services	168	1,276	$ 16,237,217
Leisure and hospitality	146	1,497	$ 10,382,291
Other services	83	340	$ 2,424,084
Unclassified	46	39	$ 489,270
Total all government	**107**	**1,966**	**$ 30,420,525**
Total federal government	16	111	$ 1,950,837
Total state government	21	323	$ 5,452,527
Total local government	70	1,532	$ 23,017,161

This data excludes self-employment, agricultural labor, domestic service in a home, casual labor and several other sources of income. The data is reported for *particular time periods as described in the data sources and limitations notes at the link below.

Source: Oregon Employment Department, Employment and Wages by Industry (QCEW) - QualityInfo

4. Infrastructure

Roads

US-101 is the only continuous passage for automobiles and trucks traveling north-south along the Oregon Coast. Secondary roads provide other north-south connections between population centers. State Routes connect Tillamook County to the interior. SR-53 connects with US-101 between Wheeler and Nehalem, heading northeast to US-26 in Clatsop County. From there, one can head east directly to Portland. Alternatively, at the junction of SR-53 and US-26, one can head west to connect with US-101 and then north to Astoria and east to Portland. SR-6 runs east-west from the City of Tillamook, crossing the Coast Range to connect with US-26 farther inland, making it the shorter route to Portland. SR-22 meets US-101 at Hebo and runs east-west to Salem.

Portions of all these roadways are susceptible to damage and closure from earthquakes and landslides. Portions of US-101 and other lowland roadways are also susceptible to damage and closure from flooding and tsunamis. A Cascadia Subduction Zone event would have a devastating impact on automobile and truck travel in the County. Both north-south and east-west roads would be damaged or impassible hindering evacuation and emergency operations and hampering or severing ground connections with Portland and the Willamette Valley.

Travel along US-101 and other Tillamook County roads is disrupted or obstructed almost every year due to floods and landslides from winter storms. The roadbed itself may sustain damage and require costly repairs. Bay City indicates that its roads have not been subject to damage or closure from flooding but are at risk from landslides and earthquakes. Manzanita indicates that its roads are subject to damage from flooding, tsunamis, and earthquakes, but not from landslides. In addition to flooding, tsunamis and earthquakes, Rockaway Beach's roads are also at risk of debris flows from landslides in the hills to the city's east. Wheeler's location on the lower elevations of a steep mountain and on a riverbank make its roads particularly subject to damage and closure from earthquakes, tsunamis, landslides, and flooding, potentially isolating the city.

Port infrastructure at the Port of Tillamook Bay, an inland port, and the Port of Garibaldi, a marina, are as follows. The Port of Tillamook Bay owns the approximate 4.5 miles of roads within its property. Between 2012 and 2014, the Port of Tillamook Bay spent over $4 million of its FEMA Alternate Project funds on a complete road rehabilitation project. Currently, the Port of Tillamook Bay is working to develop a road maintenance fund to provide monies for ongoing maintenance and future project needs. The Port of Garibaldi functions as a marina. The primary mooring facility with 277 slips is located in the center of the peninsula that forms the Port of Garibaldi. About 6000 linear feet of transient tie-ups are located opposite the marina in the boat basin. Two piers are located in Bay City. There is a mix of publicly and privately owned buildings and facilities on Port-owned land. Currently, the Port of Garibaldi is focused on completing the reinforcement of the North Jetty to provide safe passage into the Tillamook Bay and improvements to the piers to provide resilience to natural hazards such as coastal erosion and flooding.

Bridges

Every primary or secondary roadway in the County has at least one bridge, and bridges are also highly vulnerable to seismic activity. Non-functional bridges disrupt local and freight traffic, emergency operations, and sever lifelines. These disruptions may exacerbate local economic losses if industries are unable to transport goods. The region's bridges are part of the state and interstate highway system that is maintained by the Oregon Department of Transportation (ODOT) or that are part of regional and local systems maintained by the region's counties and cities.

Data previously included in this plan provided data from ODOT on the structural condition of the County's bridges. The table below represents data from 2012 and 2013.

A distressed bridge (Di) is a condition rating used by ODOT indicating that a bridge has been identified as having a structural or other deficiency, while a deficient bridge (De) is a federal performance measure used for non-ODOT bridges. The ratings do not imply that a bridge is unsafe (ODOT, 2012, 2013).

Table 19. 2012-2013 Bridge Inventory

	State Owned			County Owned			City Owned			Other Owned			Area Total			Historic Covered
	Di	ST	%D*	De	ST	%D	De	ST	%D	De	ST	%D	D	T	%D	
Oregon	610	2,718	22%	633	3,420	19%	160	614	26%	40	115	35%	1,443	6,769	21%	334
Tillamook	45	76	48%	19	81	23%	0	1	0%	4	15	27%	68	190	36%	15

Note: Di = ODOT bridges Identified as distressed with structural or other deficiencies; De = Non-ODOT bridge Identified with a structural deficiency or as functionally obsolete; D = Total of Di and De bridges; ST = Jurisdictional Subtotal; %D = Percent distressed (ODOT) and/or deficient bridges; * = ODOT bridge classifications overlap and total (ST) is not used to calculate percent distressed, calculation for ODOT distressed bridges accounts for this overlap.

Source: ODOT (2012, 2013)

The ODOT's *Oregon Highways Seismic Plus Report* (2014) identifies only US-101 as a seismic lifeline in Tillamook County. Bridges along US-101 are designated for strengthening, rehabilitation, retrofitting, or replacement as mitigation to landslides and rockfalls. The Report recommends that this seismic resiliency work be undertaken in five phases across the state. Because the Redmond Airport will serve as Oregon's hub for moving goods and medical supplies into and across the state after a Cascadia event, Phase 1 is recommended to focus on the corridors that connect it with the most populated areas in the Willamette Valley. Coastal communities are recommended as the next areas on which to focus. Portions of US-101 in Tillamook County are identified for seismic resiliency work in Phases 2, 3, and 4.

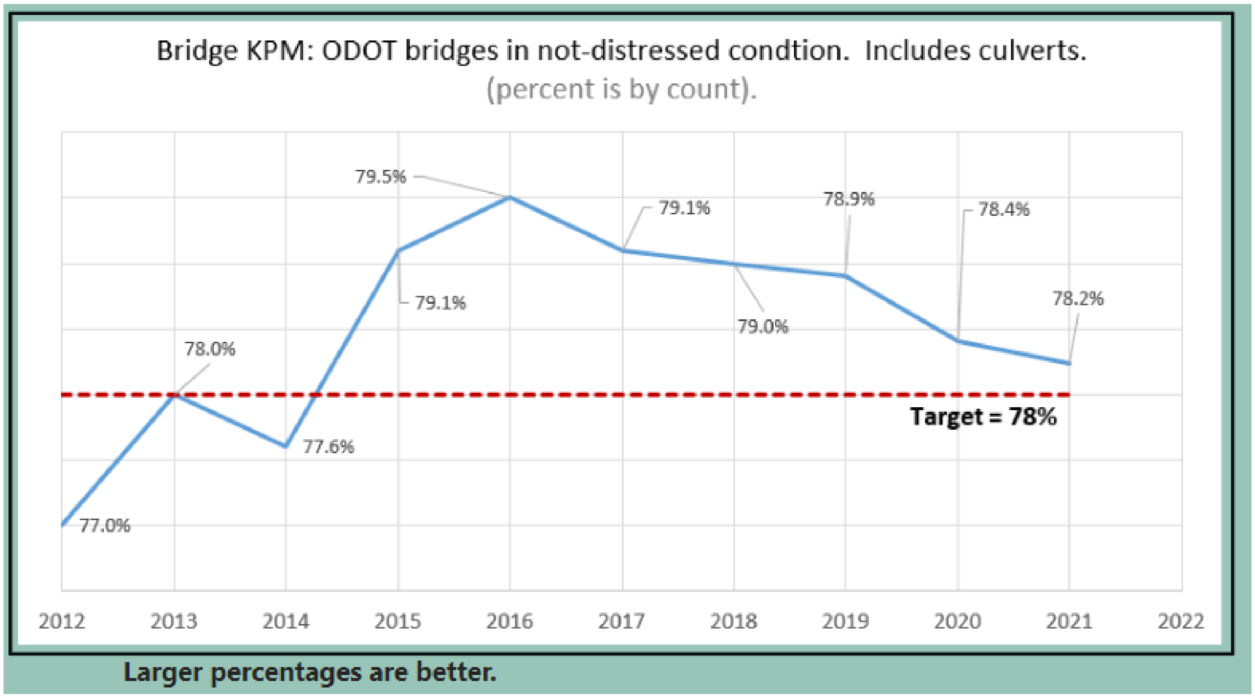
The status of the Department's work is represented in the following figures taken from the 2021 Dashboard Interactive Report, *2021 Bridge Condition Information.* [1] The region's bridges are predominantly in Fair condition, and one is in Poor condition near the junction of Hwy 130 and Hwy 22.[2] The Department target for non-distressed bridges, which is 78%, has been met, but there has been a decline in the Key Performance Measures used by ODOT to establish this data. The HB 2017 transportation package at about $10M/year provides funding to allow the seismic retrofitting program

[1] Oregon Department of Transportation : Bridge Condition Report : Bridge : State of Oregon

[2] Louie Creek bridge on Hwy 32 at MP 10.49 as show in the above footnote referenced report

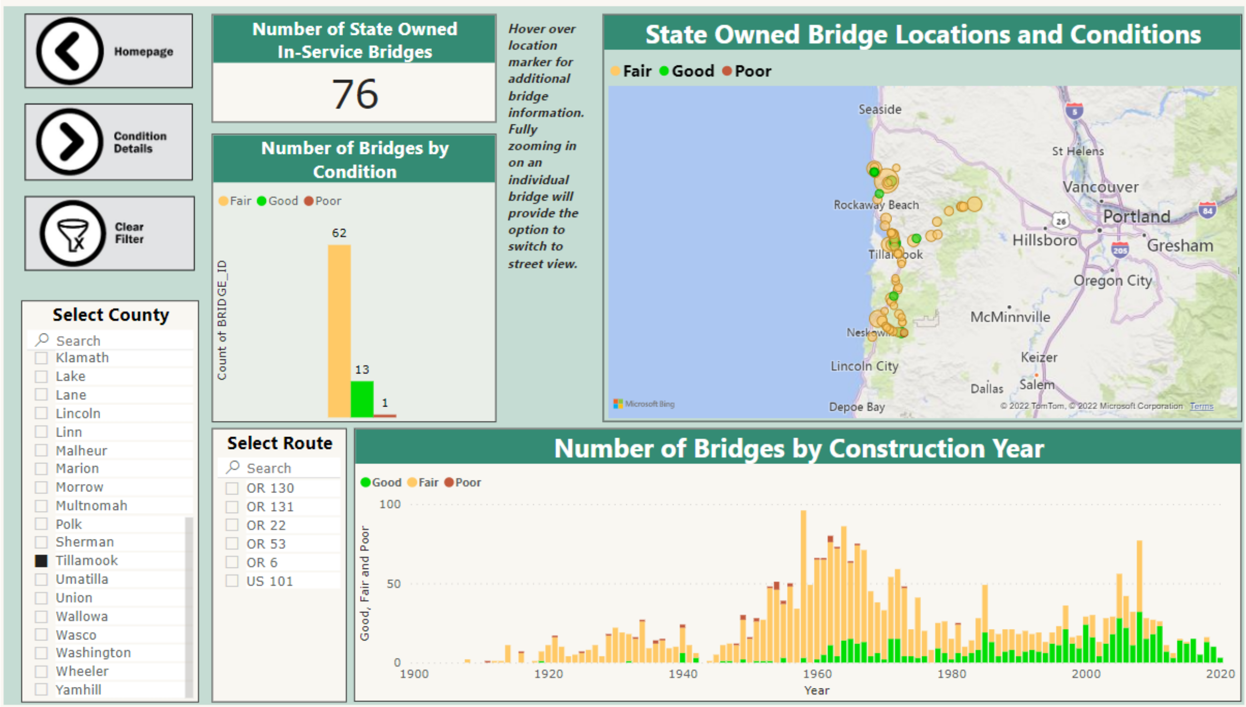
to improve Phase 1 bridges moving from Eugene, north on I-5 and finishing up on I-84 moving from east to west in 20 to 30 years. The report also provides detailed information on current and planned ODOT projects in ODOT Region 2, an area spanning the northwestern section of the state from Lane County to Clatsop and east to Washington, Marion and Linn counties.

Figure 20. Annual percentages of bridges in non-distressed condition 2012-2022



Source: Oregon Department of Transportation 2021 Bridge Condition Report

Figure 21. Tillamook County Bridge Location and Condition

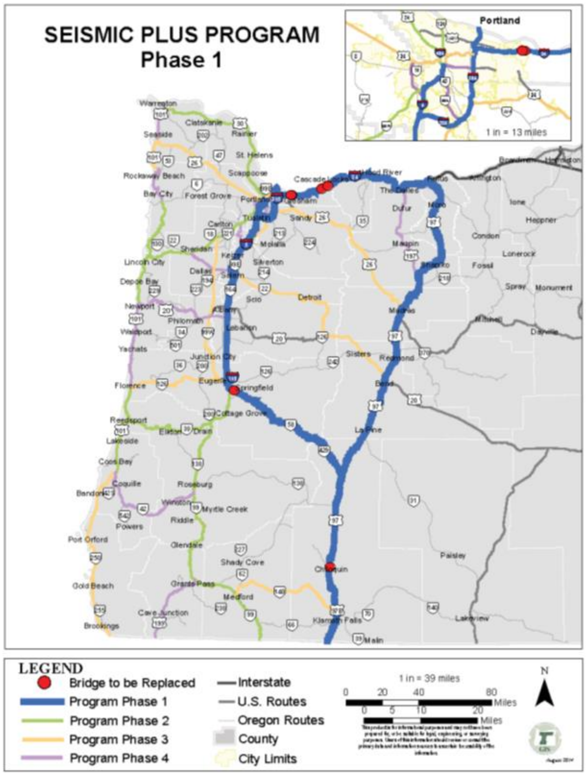


Source: [Oregon Department of Transportation 2021 Bridge Condition Report]

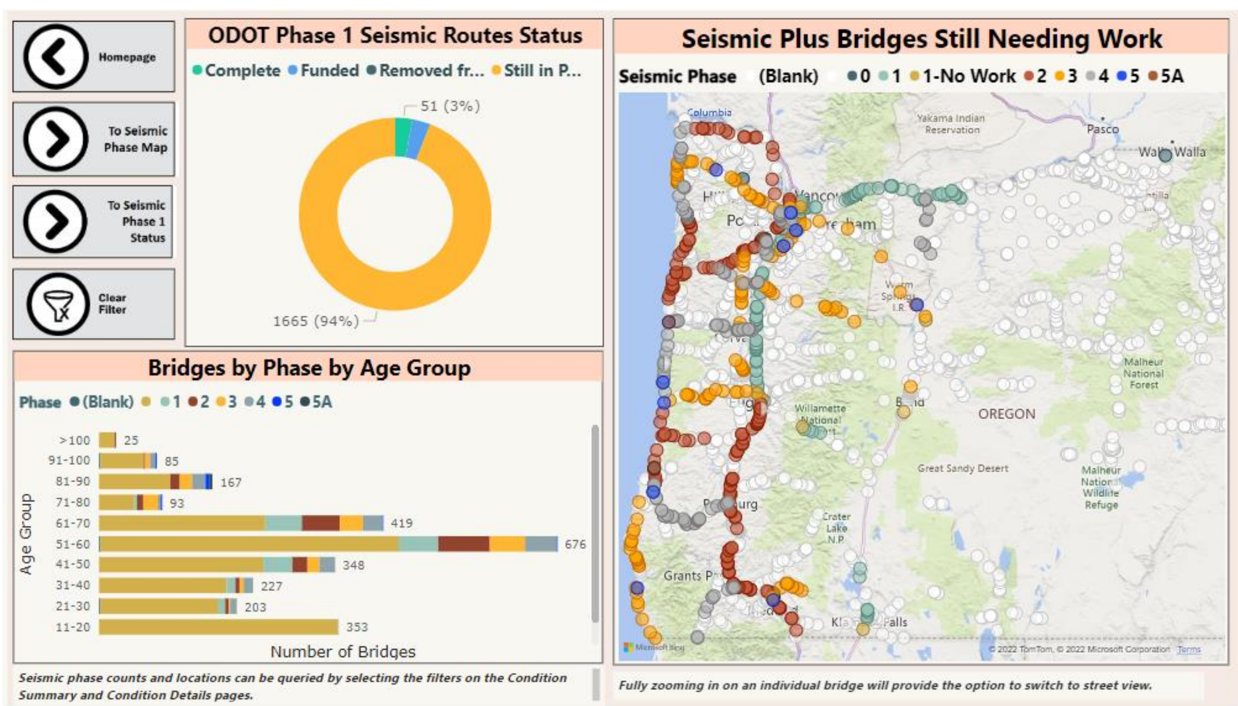
Figure 22. Poor Condition Bridge in Tillamook County

Source: [Oregon Department of Transportation 2021 Bridge Condition Report]

Figure 23. Phase 1 of the Oregon Seismic Plus Program



Source: [Oregon Department of Transportation 2021 Bridge Condition Report]

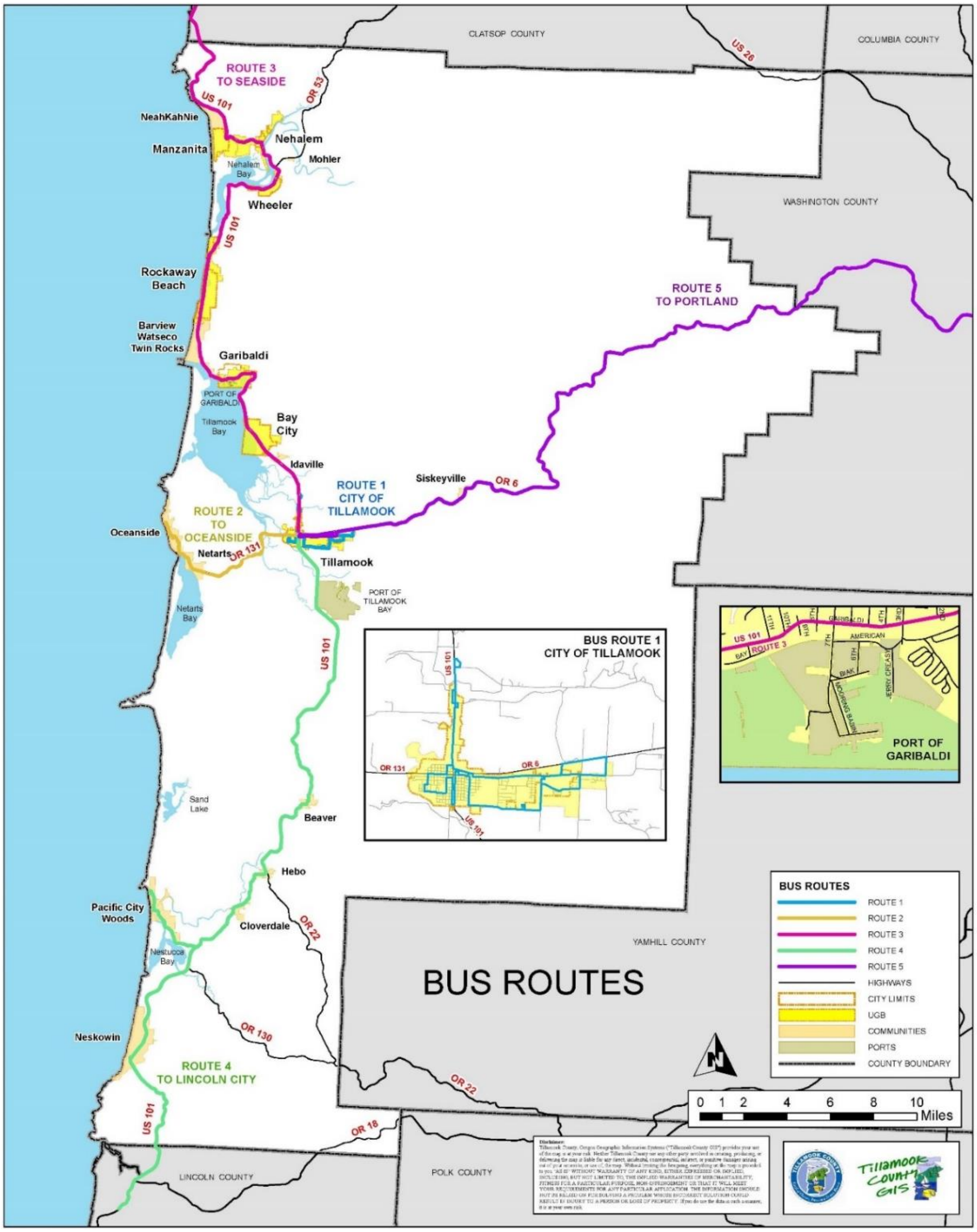


Source: [Oregon Department of Transportation 2021 Bridge Condition Report]

Public Transportation

The Tillamook County Transportation District provides local passenger and dial-a-ride service north to Cannon Beach, south to Lincoln City, and west to Pacific City. It also provides intercity connecting service to Portland daily that connects riders to Amtrak, Greyhound, Tri-Met, and Airport MAX. As a member of the Northwest Oregon Connector Alliance, the District has been able to offer regular connecting service Salem as well, including stops at casinos along the way.

Figure 24. Tillamook County Bus Routes



Source: Tillamook County Geographic Information System (GIS) Team, 2017

Railroads

A single freight rail line previously ran north from the Port of Tillamook Bay to the confluence of the Nehalem and Salmonberry Rivers, then east along the Salmonberry River into Washington County. In December of 2007, flooding from a major winter storm destroyed large sections of the rail line in the mountainous area of the Salmonberry River Canyon. Rather than rebuild, the Port decided to invest in its industrial park and airport facilities. A large coalition of stakeholders and interested parties is working to turn this damaged portion of railway into a multi-use, non-motorized trail. The project is known as the *Salmonberry Trail*. The Oregon Coast Scenic Railroad operates on an undamaged portion of the rail line between Garibaldi and the confluence of the Nehalem and Salmonberry Rivers. Approximately 40 railroad bridges and trestles along the line are managed by the Oregon Coast Scenic Railroad. They are all subject to damage from various natural hazards including winter storms, flooding, earthquakes, landslides, and wildfires (Walker Macy, 2015).

Airports

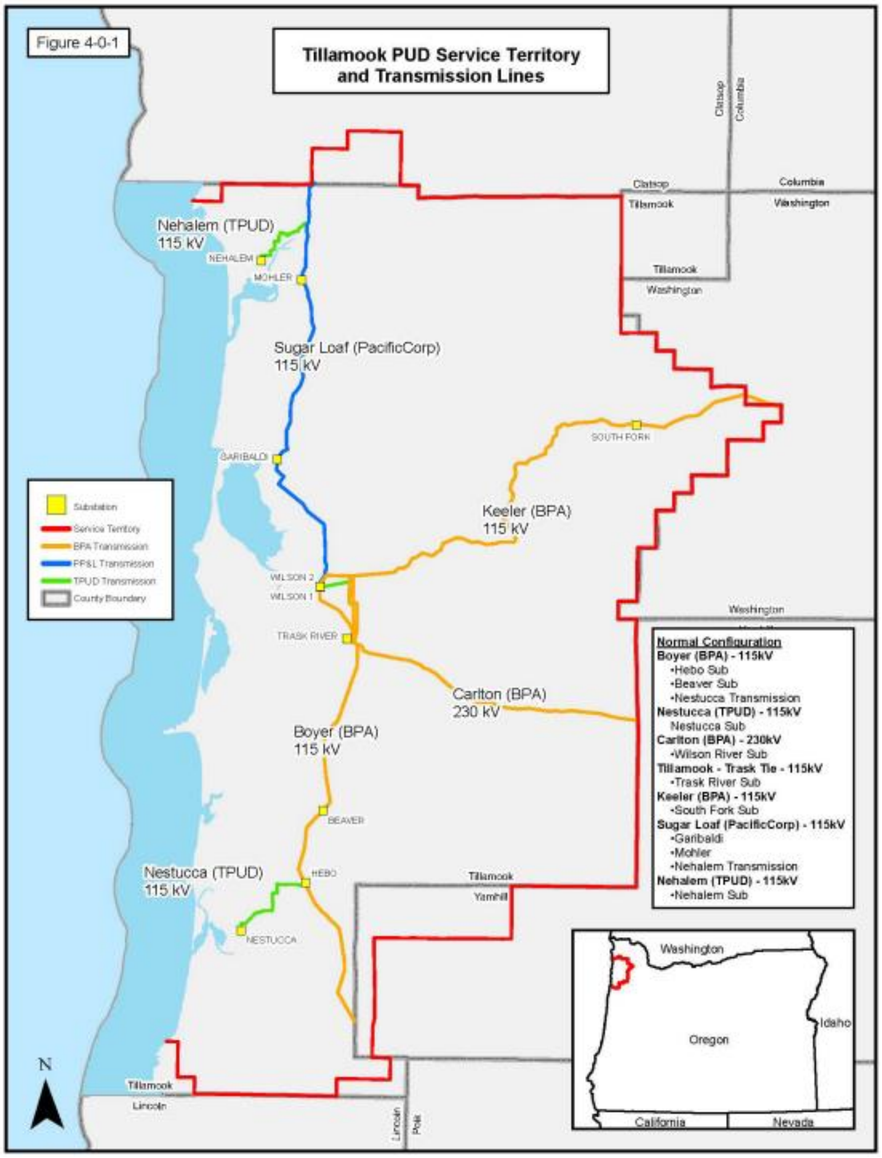
There are three publicly owned general aviation airports in Tillamook County and a fourth, privately owned medical helipad at Tillamook Regional Medical Center. Tillamook Municipal Airport is owned by the Port of Tillamook Bay located four miles south of the City of Tillamook. It has two runways and serves light passenger and cargo planes, military aircraft on training missions, vintage military aircraft, experimental aircraft, airships, helicopters, private jets and NASA weather balloons. Tillamook Municipal Airport (TMK) | Port of Tillamook Bay (potb.org) The State of Oregon owns the Nehalem Bay and Pacific City State Airports. Each has a single runway and serves light passenger aircraft. Oregon Department of Aviation : Oregon Airports : Oregon Airports : State of Oregon All of these facilities, especially the Tillamook Municipal Airport due to its sophistication and inland location, could play an important role in a post-disaster situation where other modes of transportation are inoperable.

Electricity

Tillamook People's Utility District (TPUD) is the primary electricity provider in Tillamook County. TPUD purchases and receives power from the Bonneville Power Administration (BPA) and delivers it to approximately 23,000 customers throughout Tillamook County and in portions of Clatsop and Yamhill Counties over an area of 1,333 square miles, an area that extends 53 miles north and south and 31 miles east to west. The Tillamook People's Utility District is a new participant and plan holder in the 2022 update of the Tillamook County Multi-Jurisdictional Natural Hazard Mitigation Plan.

The TPUD's facilities are included in the critical facilities in Tillamook County with the main office located in the City of Tillamook, and remote warehouses in Nehalem and Hebo. Substations are located at Nestucca, Hebo, Beaver, Trask River, Wilson River, South Fork, Garibaldi, Nehalem and Mohler (Tillamook County People's Utility District, http://www.tpud.org/aboutus/service-area/, accessed November 2022). The BPA also has an easement running through the Port of Tillamook Bay.

Figure 25. Tillamook PUD Service Territory



Source: Tillamook PUD Wildfire Mitigation Plan and website

Within the service territory, Tillamook PUD provides electric service using both overhead and underground facilities. Tillamook PUD receives electric service from Bonneville Power Administration at their Tillamook 230kV/115kV substation and owns 12.1 miles of 115kV overhead transmission lines to connect six of nine substations in the central and south sections of Tillamook County. Three substations are connected to the Pacific Power 115kV transmission line located in the north part of the county. Thirty-two 26kV feeders distribute the electricity from the nine power substations through the community to customers. Tillamook PUD owns and operates 778 miles of primary distribution lines (high voltage at 24.9kV and 20.8kV) and 440 miles of secondary (low voltage less than 600 volts) lines. These facilities are distributed throughout the service territory through 21,083 Tillamook PUD poles and 7,360 underground surface structures. Tillamook PUD has 236 miles of three-phase overhead primary lines and 345 miles of two and single-phase overhead primary lines. Tillamook PUD has 40 miles of three-phase and 157 miles of two and single-phase underground primary lines.

Overhead electric lines are vulnerable to damage from winter storms with wind, snow, and ice, earthquakes, and landslides. Underground lines are vulnerable to flooding and earthquakes. The system is also vulnerable to damage by wildfire and has the potential to spark wildfire. The TPUD Wildfire Mitigation Plan identifies the following information regarding system inspection and maintenance. Annual ground patrols are conducted and provide a visual inspection of the electric facilities. In addition, crews are patrolling facilities every day during the normal course of business. Infrared scans are conducted of the main Transmission and Distribution primary overhead and underground lines and all substations each year. The TPUD operates a drone program to support facility access inspections with a primary focus on inspecting transmission structures on a five-year rotating cycle. Where practical, lines are located in open areas and away from vegetation. Sufficient ground clearance is considered in the design as well as assessing easy access for ongoing operations and maintenance. Additional information on wildfire mitigation is provided in the Natural Hazard – Wildfire section.

Marinas

The Port of Garibaldi's marina has 277 slips and about 6000 linear feet of tie-ups, as well as a public boat launch and several piers. It provides direct access to the Pacific Ocean. In the event of an earthquake, tsunami, winter storm, windstorm, or landslide isolating the Cities of Garibaldi and Bay City, the marina could play an important role in transporting people and goods into and out of the area.

The Port of Nehalem, a special district established in 1909, serves users of the lower Nehalem River Valley to maintain and enhance the navigability of the Nehalem River, provides channel markers seasonally and removal of debris that causes navigation hazards. The Port of Nehalem is mentioned here for completeness although this port district has not opted to participate as a potential plan holder in this Multi-Jurisdictional NHMP.

Telecommunications

Television, radio, traditional landline telephone, cell phone broadband, and internet services are available in the County. Nehalem Telecom, Spectrum, and Lumen (CenturyLink) all provide services in Tillamook County. They are sources of a wide range of information and can play vital roles in emergency communications. Wireless providers sometimes offer free emergency mobile phones to those impacted by disasters, which can aid in communication when landlines and broadband services are unavailable. Residents in rural areas where cellular reception is low quality or unavailable rely upon landline service.

The Port of Tillamook Bay, the Tillamook People's Utility District, and Tillamook County are parties to an intergovernmental agreement creating the Tillamook Lightwave Intergovernmental Agency (Lightwave https://tillamook-lightwave.com) that was formed to design, construct, own, operate, and maintain a high-speed, low-cost broadband telecommunications network for the benefit of both private sector and government entities in Tillamook County. In 2005 Lightwave constructed a fiber network that runs from the North Tillamook County Cable Landing Station at Nedonna Beach, south along the railroad tracks to Tillamook where the cable runs on overhead lines to the Tillamook PUD office. From the PUD office, the fiber extends southward past the high school and out to the Port's industrial park south of Tillamook. Some fiber services are available in the Pacific City and Tierra Del Mar communities. The plan is to extend fiber further into South County when funds become available.

Radio

Tillamook County owns a VHF radio system that is used by 911 service, the County Sheriff's Office and the Tillamook People's Utility District (TPUD).

Ham radio is a service provided by licensed amateur radio operators (hams) and is considered to be an alternate means of communicating when normal systems are down or at capacity. Emergency communication is a priority for the Amateur Radio Relay League (ARRL). Tillamook County is served by Amateur Radio Emergency Service (ARES) District 5. Radio Amateur Civil Emergency Services (RACES) is a special phase of amateur radio recognized by FEMA that provides radio communications for civil preparedness purposes including natural disasters (http://www.usraces.org/). The official ham emergency station call for Tillamook County is KF7ARK (American Relay Radio League Oregon Chapter, www.arrloregon.org) (Oregon NHMP: Oregon Department of Land Conservation and Development, 2015).

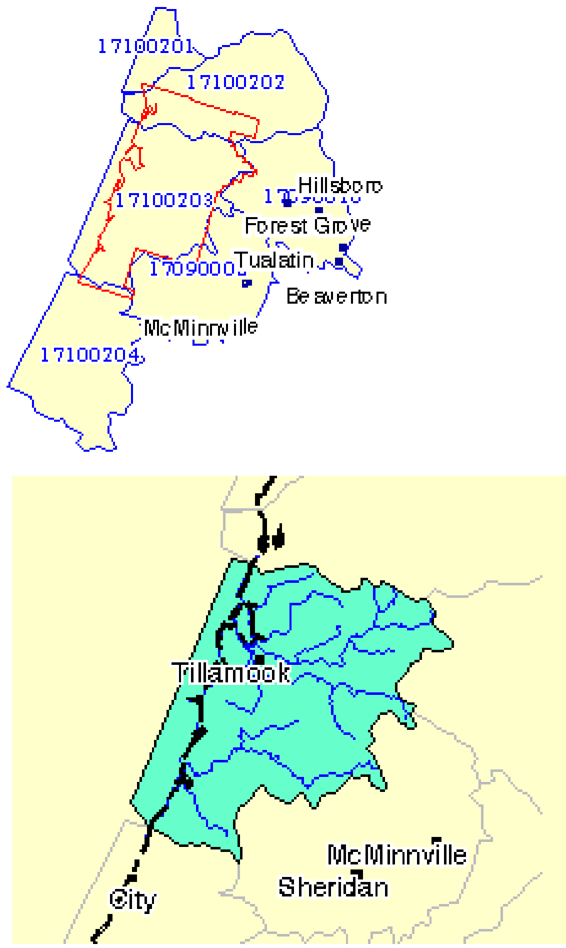
GMRS radios (General Mobile Radio Service), sometimes also called "Yellow Radios", are in use and promoted as a key two-way method of communication between individuals in Tillamook County in the event of a natural hazard event that knocks out cell phone service. Both GMRS and FRS (Family Radio Service) radios are less restrictive and easier to use than Ham radios. GMRS operates on a 12.5 kHz or 25kHz (20kHz authorized) bandwidth while FRS uses 12.5kHz. This means that more radio signals are available with GMRS. GMRS radios require a license to operate but provide more range than an FRS (Family Radio Service) radios. GMRS handheld radios are usually about 5 watts but can be up to 50 watts with modifications. You can expect a range of about 5-25 miles depending on terrain and weather conditions. This type of range is more efficient if you are trying to communicate with other survivors who might be farther away. FRS radios generally have quite a bit less power at just half a watt. This means that their range, though often stated at around 5 miles, is probably closer to ½ to 2 miles. This is still sufficient for traveling caravans or families that may have gotten separated during a quick evacuation.

Water

The Tillamook lowlands are a very productive water supply. Shallow groundwater can be obtained throughout the lower floodplains of the Nehalem and Nestucca Rivers. The Kilchis River provides groundwater for the Bay City regional water system. Some groundwater supplies are available under more localized conditions because they are perched above relatively impermeable materials. Limited yields of groundwater supplies are available in the marine sedimentary and volcanic rocks that underlie much of the County because they are largely impermeable. Also, coastal marine terrace deposits consisting of relatively permeable, unconsolidated sand, silt and gravel could provide groundwater in some areas because they receive large quantities of water during the rainy season. The six Tillamook County watersheds mainly rely upon the watershed identified by the USGS as HUC 17100203 to serve the population (Tillamook County MJNHMP: VLG Consulting & Pearson, 2012).

With respect to water rights, the Port of Tillamook Bay receives its water from the City of Tillamook which possess water rights from and re-sells this water to its lease tenants. The Port has multiple municipal water rights of its own within its property and has discussed developing its own water system in the future to better serve users of the Port.

Figure 26. HUC 17100203



Source: Tillamook County MJNHMP (VLG Consulting & Pearson, 2012)

Drinking water for Bay City, Garibaldi, Manzanita, and Wheeler is sourced from groundwater. Bay City supplies water to the Tillamook Cheese Factory and is intertied with the City of Tillamook. The City of Tillamook also sources drinking water from surface water. Garibaldi and Manzanita both use surface water as a backup. Nehalem sources its drinking water from surface water. Rockaway Beach's primary source of drinking water is surface water; it is supplemented by groundwater. There are a number of water districts that operate throughout the county to provide water to residents. Among these are the Cloverdale Water District, Hebo Water and Sanitary District, the Neskowin Water District, the Oceanside Water District, the Pacific City Water and Sewer District, and the Watseco Water District.

5. Critical or Essential Facilities

Critical or essential facilities play a crucial role in response and recovery efforts. Mitigation actions that ensure these facilities remain operational during and after a disaster are of paramount importance to protecting people, property, and the environment and advancing community resilience.

DOGAMI initially identified hospitals, schools, fire stations, police stations, emergency operations and military facilities as essential facilities (also referred to in this Plan as *critical facilities*). The jurisdictions identified others, primarily airports, clinics, materiel distribution points ("CPODs"), water and wastewater facilities, and correctional facilities as critical facilities. After the jurisdictions identified the additional critical facilities, DOGAMI was able to include clinics, water and wastewater facilities, public works buildings, schools and city halls not also functioning as other essential facilities (e.g., fire or police stations), and correctional facilities in its analysis. The essential facilities DOGAMI identified are shown on each jurisdiction's Multi-Hazard Community Map Set (see **Risk Profiles** section).

Table 20 shows DOGAMI-identified essential facilities by community. The Risk Profiles list each jurisdiction's critical or essential facilities. The Tillamook Municipal Airport and a Community Point of Distribution (CPOD) are located within the Port of Tillamook Bay. Just outside its boundaries are two schools, the County Sheriff's office, emergency management center, and an adult correctional facility. A youth correctional facility is also located just off Port property but can only be accessed from within the Port boundary. These essential facilities are included in Tillamook County's inventory. A US Coast Guard Station is located just within the Port of Garibaldi boundary, but not on Port property. It is included in the City of Garibaldi's essential facilities inventory. In addition, there are three ambulance quarters throughout the County: one at the Port of Garibaldi serving north Tillamook County; one at the Tillamook Regional Medical Center serving central Tillamook County; and one in Cloverdale serving south Tillamook County.

Table 20. Tillamook County Essential 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)							
Unincorp. County (rural)	1	2,114	8	63,118	9	13,009	1	8,848	0	0	23	47,063	42	134,152
Bayside Gardens	1	1,328	0	0	1	3,094	0	0	0	0	2	1,177	4	5,599
Neskowin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oceanside & Netarts	0	0	0	0	2	1,686	0	0	0	0	0	0	2	1,686
Pacific City	1	718	0	0	1	827	0	0	0	0	2	1,618	4	3,162
Total Unincorp. County	**3**	**4,160**	**8**	**63,118**	**13**	**18,616**	**1**	**8,848**	**0**	**0**	**27**	**49,858**	**52**	**144,600**
Bay City	0	0	0	0	1	1,258	0	0	0	0	2	2,222	3	3,480
Garibaldi	0	0	1	6,376	1	1,928	1	243	2	3,633	1	459	6	12,639
Manzanita	0	0	0	0	1	1,266	2	1,826	0	0	1	735	4	3,827
Nehalem	0	0	1	6,276	0	0	1	373	0	0	4	4,462	6	11,112
Rockaway Beach	0	0	1	3,714	2	2,419	0	0	0	0	2	2,402	5	8,535
Tillamook	2	18,102	5	78,255	3	6,566	1	137	0	0	7	32,534	12	141,186
Wheeler	2	14,259	0	0	0	0	0	0	0	0	1	621	3	14,880
Total Tillamook County	**7**	**36,522**	**16**	**157,739**	**21**	**32,053**	**6**	**11,427**	**2**	**3,633**	**45**	**93,293**	**91**	**340,259**

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).

6. Built Environment

Settlement Patterns

Balancing growth with hazard mitigation is key to planning resilient communities. Therefore, understanding where development occurs, and the vulnerabilities of the region's building stock is integral to developing mitigation efforts that move people and property out of harm's way. Eliminating or limiting development in hazard prone areas can reduce exposure to hazards, and potential losses and damages.

Since 1973, Oregon has maintained a strong statewide program for land use planning. The foundation of Oregon's program is the 19 land use goals that "help communities and citizens plan for, protect and improve the built and natural systems." These goals are achieved through local comprehensive planning. The intent of Goal 7, Areas Subject to Natural Hazards, is to protect people and property from natural hazards (Department of Land Conservation and Development, Department of Land Conservation and Development : Oregon's Statewide Land Use Planning Goals : Oregon Planning : State of Oregon.

Tillamook County and each of its seven cities has an acknowledged comprehensive plan and implementing ordinances.

Each of the unincorporated communities has a Community Plan identifying specific land use ordinances applicable to the housing, economy, water, stormwater, sewer, and geographic characteristics of the area.

Each city in the county also has identified an urban growth boundary intended to identify lands needed to accommodate population and employment growth for a 20-year period. Tillamook County and the cities jointly manage the urban growth areas through urban growth management agreements.

Most development has taken place along the coast and interior lowlands, with all the incorporated cities located in the northwest and west-central portion of the County. Slightly more than half the population is located in very low-density settlements along transportation routes throughout the unincorporated area. Densities increase in the unincorporated communities, and peak in the cities.

General descriptions of the coastal unincorporated communities, cities and districts participating in this NHMP update follows moving from south to north.

Neskowin, an unincorporated community, is almost entirely a residential community along the ocean with a few commercial establishments on the west side of the bend in US-101. The east side of the bend is hilly, and residences dot the hillside. An isolated residential development is sited along the west side of US-101 south of Lake Neskowin on another hill, and the southwest corner of the community is also developed on a hill. These three areas are susceptible to landslides, but due to their elevations, less susceptible than the rest of the community to tsunamis and not at all to flooding. Development along the shoreline is susceptible to coastal erosion, flooding, and tsunamis, and only the most northern, southern, and eastern parts of the community escape moderate risk of wildfires. The entire community is susceptible to earthquakes.

Pacific City, an unincorporated community, is primarily a residential community bounded by the Pacific Ocean on the west and bisected by the Nestucca River. A commercial district is developed on the inland bank of the river. Development along the shore is subject to coastal erosion, flooding, and tsunamis; development on the river is subject to flooding and tsunamis. Except for one small section, the entire community is at moderate risk of wildfires. Only the southwest portion of the community is highly susceptible to landslides. The entire community is susceptible to earthquakes.

Oceanside and Netarts, both unincorporated communities, are adjacent, primarily residential communities developed in the hills above the Pacific Ocean (Oceanside) and the mouth of Netarts Bay (Netarts). OR-131 connects the communities to each other and to the City of Tillamook, approximately 6 miles east of Netarts. Due to their elevation and steep rise from the water, these communities are not subject to coastal erosion or flooding, and minimally subject to tsunamis. Also due to their situation in the hills, they are highly susceptible to earthquakes and landslides, and at moderate risk of wildfires.

The Port of Tillamook Bay is located inland, 4 miles south of the City of Tillamook on US-101. The Port of Tillamook Bay is primarily zoned General Industrial and residential construction beyond a caretaker dwelling for an existing industrial use is not allowed. It contains public and non-profit offices, commercial and industrial development. Its northwest corner is subject to flooding and tsunamis. Most of the Port is at moderate risk of wildfires. One hill on the east side is highly susceptible to landslides and earthquakes.

Development in the City of Tillamook is located primarily south of OR-6 and along US-101. Residential development is clustered in three areas south of OR-6. Commercial development is located along the highways and between the areas of residential development. The Tillamook People's Utility District office and main warehouse is located in the City of Tillamook, but its infrastructure extends throughout the county. Because most of the city (east-west) is built on a natural peninsula and is mostly flat, it is not very susceptible to landslides, wildfires, or flooding. However, the western edges of the city and the area along US-101 north of OR-6 are subject to flooding and susceptible to tsunamis. Flooding along US-101 often obstructs the roadway, isolating the city from areas to the north and occasionally to the south. The entire city is subject to earthquakes.

Most development in the City of Bay City has taken place on or at the bottom of hills where it is subject to earthquakes, tsunamis, landslides, and wildfires. Development located in the southwest corner of the city, on the west side of US-101 is also subject to flooding.

The City of Garibaldi's business district is located in the lowlands along US-101 and at the waterfront. The Port of Garibaldi is within the city limits, built right on Tillamook Bay. Owing to its low-elevation location on Tillamook Bay, it is primarily susceptible to earthquakes, tsunamis, and flooding. Most residential development in the city is located upslope, making it more susceptible to landslides and wildfires, but less so to tsunamis. The businesses in the lowlands and the Port of Garibaldi are highly susceptible to tsunamis. The entire city, including the Port, is susceptible to earthquakes.

Residential development in the City of Rockaway Beach is concentrated all along the coast, in the southern two-thirds of the city, and at its northern reaches. The Oregon Coast Scenic Railway runs parallel to the coast and US-101. A great deal of residential development including motels, is located between the rails and the shore. More residential development stretches east from the railway into toward the hills. Commercial development is clustered around the railroad and US-101 in the central portion of the city. Development along the water is susceptible to coastal erosion and flooding. With the exception of a small area in the central-southeast portion of the city that is up on a hill, the entire city is subject to tsunamis.

The hill area in the central-southeast part of the city and the far northern portion of the city are both developed with housing and highly susceptible to landslides. The hills to the east contain many streams and springs, and are highly susceptible to landslide, raising concern of risk from landslide runout and debris flows even in areas shown as low susceptibility on the hazard maps. Scattered areas of residential development are moderately susceptible to wildfire. The entire city is susceptible to earthquakes.

Development in the City of Wheeler is divided into sections by mountain drainages. Most development is in the northernmost section with commercial development at the bottom of the mountain along US-101 and the Nehalem River. Residential development stretches a few blocks up the steep sides of the mountain in each section. Most of the city is highly susceptible to earthquakes and landslides, and moderately so to wildfires. Flooding and tsunami susceptibility is low and centered on the drainages.

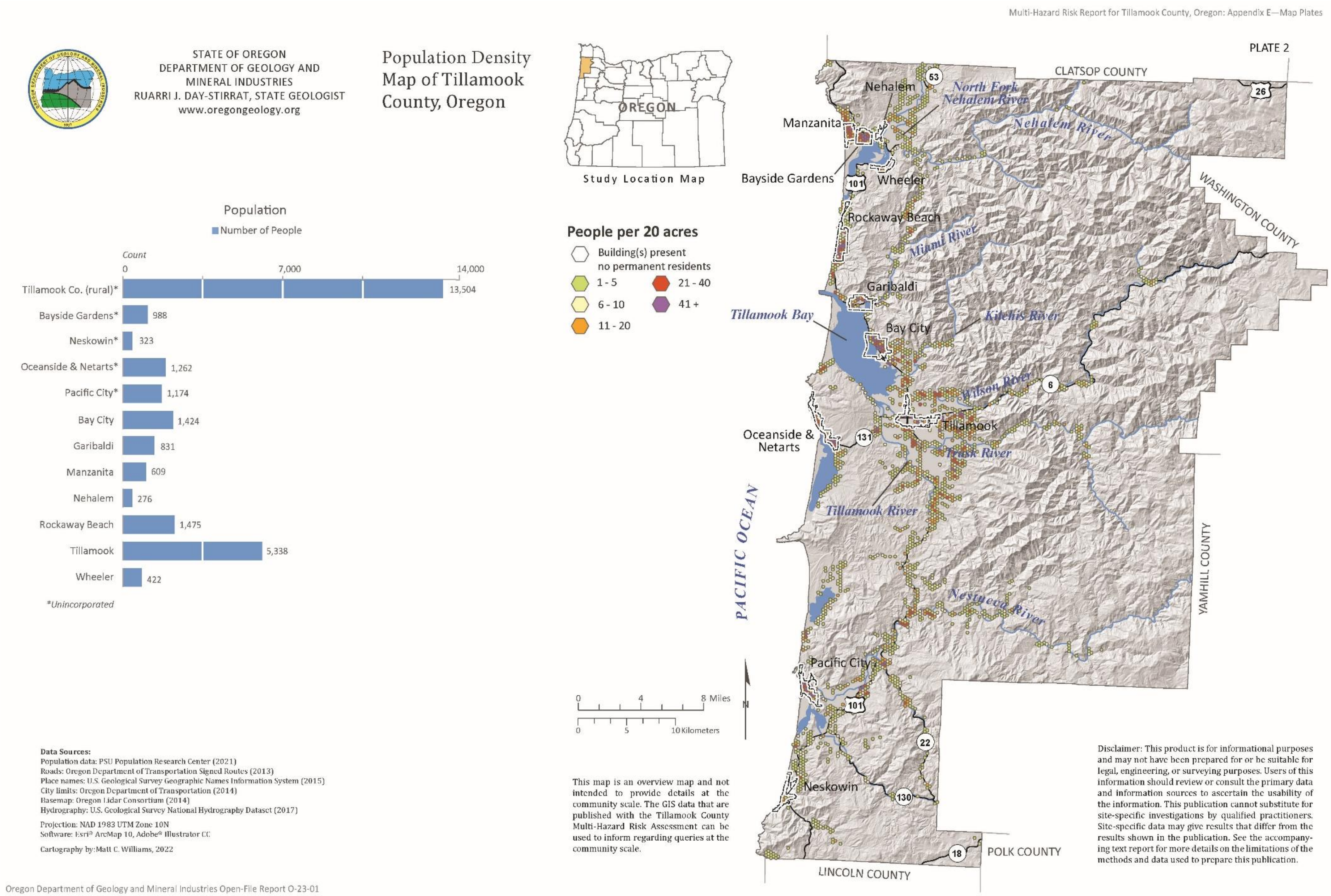
The City of Nehalem is developed along the Nehalem River and US-101 which takes a ninety-degree turn west in the middle of the city and heads up into the hills toward Manzanita. Commercial development hugs US-101 along the river and the first few blocks heading west up the hill. Residential development is concentrated to the south and west of US-101 and in the hills to its north. The developed areas are highly susceptible to earthquakes and landslides and the lower portions to flooding and tsunamis. The Nestucca Valley Fire and Rescue District Station 13 and offices are located between Manzanita and Nehalem.

The City of Manzanita is developed along the coast, up the northern mountainous half of the city, and along a ridge overlooking a wetland area. The southeastern portion of the city is not developed. The business district is located along US-101 and Laneda Road, an east-west route from the uplands to the shore. Development along the shore is subject to coastal erosion, flooding, and tsunamis. While much of the city’s development is too high to be subject to coastal flooding, it is still subject to tsunamis. All development in the city is highly susceptible to earthquakes and moderately so to wildfire. A small amount of residential development in the northwest corner and residential and commercial development in the northeast corner are subject to landslides. The entire city is moderately susceptible to earthquakes.

The inland communities of Cloverdale, Hebo and Beaver are located in the southern third of the county. The community of Cloverdale is home to the Nestucca Valley School District and the Nestucca Rural Fire Protection District is based in Hebo.

The distribution of building stock reflects the difference between the urban and rural populations as well. Most agriculture and utility buildings are found along transportation routes throughout the unincorporated area where people are living at very low densities. The bulk of residential, commercial, industrial, public, and non-profit buildings are clustered in the cities and unincorporated communities.

Figure 27. Population Density in Tillamook County, Oregon



Source: Multi-Hazard Risk Report, Tillamook County, Oregon, DOGAMI, 2022

Building Inventory

The countywide building inventory is key to assessing risk. This inventory consists of all buildings larger than 500 square feet, as determined from building footprints or tax assessor data.

shows the distribution of building count and value within the UDF database for Tillamook County.
Source: Multi-Hazard Risk Report for Tillamook County, Oregon, DOGAMI, 2022

Table 22 detail the occupancy class distribution by community. illustrates the variation of building value and occupancy across the communities of Tillamook County. maps building distribution by occupancy class countywide.

The Port of Tillamook Bay's inventory is included in the inventory for Unincorporated Tillamook County; the Port of Garibaldi's inventory is included in the inventory for the City of Garibaldi.

Table 21. Tillamook County Building Inventory

Community	Total Number of Buildings	Percentage of Buildings of Tillamook County	Total Estimated Building Value ($)	Percentage of Building Value of Tillamook County
Unincorporated County (rural)	14,107	52%	3,607,581,000	53%
Bayside Gardens	945	3.5%	186,325,000	2.7%
Neskowin	652	2.4%	141,094,000	2.1%
Oceanside & Netarts	1,628	6.0%	302,588,000	4.4%
Pacific City	1,721	6.4%	361,114,000	5.3%
Total Unincorporated County	19,053	70.3%	4,598,702,000	67.1%
Bay City	880	3.2%	229,175,000	3.3%
Garibaldi	755	2.8%	179,063,000	2.6%
Manzanita	1,517	5.6%	274,658,000	4.0%
Nehalem	234	0.9%	54,360,000	0.8%
Rockaway Beach	2,095	7.7%	454,733,000	6.6%
Tillamook	2,194	8%	982,931,000	14%
Wheeler	362	1%	81,137,000	1%
Total Tillamook County	27,090	100%	6,854,459,000	100%

Source: Multi-Hazard Risk Report for Tillamook County, Oregon, DOGAMI, 2022

Table 22. Port of Tillamook Bay and Port of Garibaldi Building Inventories by Occupancy Class

	(all dollar amounts in thousands)															
	Residential		**Commercial & Industrial**					**Agricultural**			**Public & Non-Profit**			**All Buildings**		
Community	**# of Bldgs**	**Bldg Value ($)**	**Bldg Value Ratio**	**# of Bldgs**	**Bldg Value ($)**	**Bldg Value Ratio**	**# of Bldgs**	**Bldg Value ($)**	**Bldg Value Ratio**	**# of Bldgs**	**Bldg Value ($)**	**Bldg Value Ratio**	**# of Bldgs**	**Bldg Value ($)**	**Bldg Value Ratio**
Port of Tillamook Bay[1]	1	58	0.1%	52	26,111	50.4%	0	0	0	34	25,639	49.5%	87	51,779	100%
Port of Garibaldi[1]	0	0	0	22	3,148	66.1%	0	0	0	13	1,614	33.9%	35	4,762	100%

[1]Port of Tillamook Bay buildings are counted in Tillamook County's inventory in . The Port of Garibaldi buildings are counted in the City of Garibaldi's inventory in .
Source: Personal communications, Aaron Palter, Port of Tillamook Bay, May 2017 and Michael Saindon, Port of Garibaldi, March 2017

The data in **Table** 22 were generated by the Port of Tillamook Bay and the Port of Garibaldi. Because the Ports' and DOGAMI's inventory methodologies differed, there are slight differences (see Hazard Profile tables and Multi-Hazard Community Map Set figures in the **Risk Profiles** section) in the total number of buildings and more significant differences, especially for the Port of Garibaldi, in the building values. Nevertheless, it is clear that the Commercial & Industrial and Public & Non-Profit occupancy classes dominate both Ports.

It is also important to note that Ports own properties that are used for their own public purposes, and also lease to other public or private entities for a variety of other uses. Privately owned buildings may also be located on Port property. Individual buildings may house more than one occupancy type. Ownership and occupancy are often not the same. In some cases, buildings are leased to more than one tenant and therefore house more than one occupancy class. Those have been enumerated as the occupancy class of the majority use of the building.

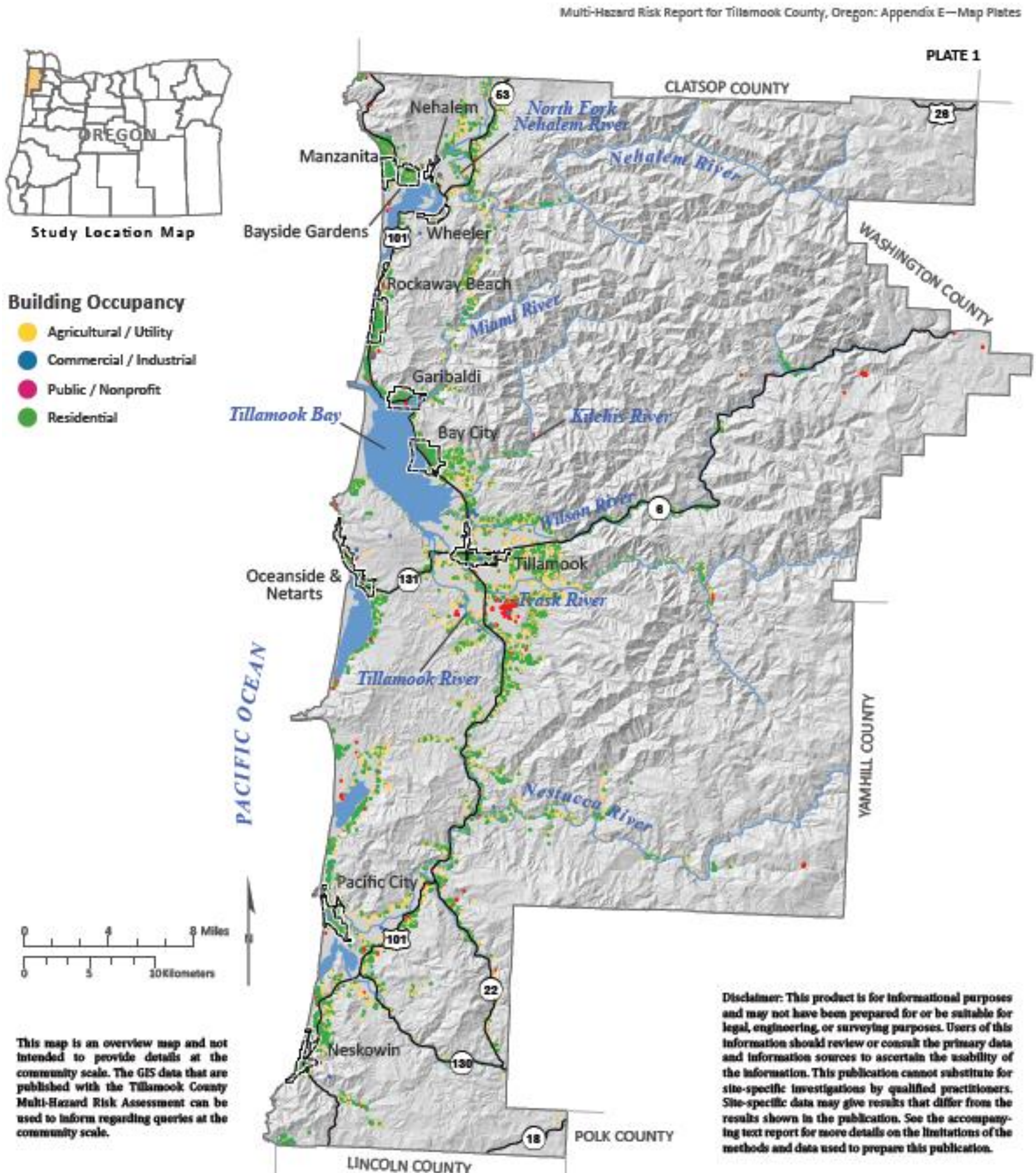
Port of Tillamook Bay:

- Of the 87 buildings within the Port of Tillamook Bay industrial park boundary, 52 are Port-owned and 35 are not.
- Of the 52 Port-owned buildings, 17 are occupied by Public & Non-Profit uses and 35 are occupied by Commercial & Industrial uses.
- Of the 35 buildings owned by other entities, 17 are occupied by Public & Non-Profit uses, 17 are occupied by Commercial & Industrial uses, and 1 is in residential use.

Port of Garibaldi:

- Of the 35 buildings within the Port of Garibaldi, 16 are Port-owned and 19 are not.
- All of the 19 buildings not owned by the Port are in Commercial & Industrial uses.
- Of the 16 Port-owned buildings, 3 are occupied by Commercial & Industrial uses.

Figure 28. Building Distribution, portion of Plate 1



Source: Multi-Hazard Risk Report for Tillamook County, Oregon, DOGAMI, 2022

Housing Stock

In addition to location, the character of its housing stock can also affect the level of risk a community faces from natural hazards. A study of the 1994 earthquake in Northridge, California found that persons living in multi-family structures were more likely to have been injured than those in single-family homes (Centers for Disease Control and Agency for Toxic Substances and Disease Registry, n.d.). In natural hazard events such as earthquakes and floods, mobile homes are more likely to shift on their foundations and create hazardous conditions for occupants and their neighbors (California Governor's Office of Emergency Services (OES), 1997).

Single-family homes comprise the vast majority of housing units in Tillamook County. The City of Tillamook has the most multi-family housing units, just over 825, trailed by Rockaway Beach with 185 and Netarts with 40. Pacific City has none.

Rockaway Beach and Pacific City each have over 200 mobile homes ranging from 10.6% to nearly 15% of the housing stock. Netarts, Bayside Gardens and Bay City each have 120-150 mobile homes ranging from 17% to 21.6% of the housing stock. Other cities and communities range from zero (in Neskowin and Oceanside) to 8% of the housing stock with a dozen to several dozen mobile homes.

Aside from location and type of housing, the year structures were built has implications for level of vulnerability to natural hazards. Seismic building standards were codified in Oregon building code starting in 1974. More rigorous building code standards passed in 1993 accounted for a Cascadia Subduction Zone (CSZ) catastrophic earthquake event (Judson, 2012). Therefore, homes built before 1994 within an earthquake hazard zone are more vulnerable to damage and loss caused by seismic events.

In Bay City, Garibaldi, Nehalem, Tillamook, Wheeler, and Neskowin about 60-80% of the housing stock was built before 1990 and the codification of seismic building standards. Manzanita and Rockaway Beach, Netarts, Oceanside, and Pacific City are in a slightly better position, with between 45% and 67% of their housing stock built before 1990. Bayside Gardens has the newest average construction with 76.8% of its housing stock constructed after 1990.

Table 23. Housing Type

Community	Total Housing Units	1 or 2 units		3 or more units		Mobile Homes*		Boats, RV, Vans	
		Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Oregon	1,750,539	1,237,7658	70.8%	366,782	20.9%	141,071	8.1%	4,921	0.3%
Tillamook	18,892	15,472	81.9%	1,356	7.2%	2,013	10.7%	51	0.3%
Incorporated									
Bay City	716	573	79.9%	22	3.0%	122	17.0%	0	0%
Garibaldi	511	451	88.3%	17	3.4%	41	8.0%	2	0.4%

Manzanita	1,266	1,221	96.5%	24	1.9%	21	1.7%	0	0%
Nehalem	182	166	91.2%	4	2.2%	12	6.6%	0	0%
Rockaway Beach	2,171	1,771	81.5%	158	7.3%	231	10.6%	11	0.5%
Tillamook	2,448	1,582	64.6%	829	33.9%	37	1.5%	0	0%
Wheeler	230	1902	83.5%	26	11.3%	12	5.2%	0	0%
Unincorporated									
Bayside Gardens	689	513	74.5%	27	3.9%	149	21.6%	0	0%
Neskowin	408	374	91.7%	34	8.3%	0	0%	0	0%

Netarts	634	473	74.7%	40	6.3%	121	19.1%	0	0%
Oceanside	783	755	96.4%	28	3.6%	0	0%	0	0%
Pacific City	1,530	1,252	81.8	26	1.7%	225	14.7%	27	1.8%

Source: US Census Bureau, Census 2018 American Community Survey 5-Year Estimates, Table DP04

Also in the 1970s, FEMA began assisting communities with floodplain mapping as part of administering the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. Upon receipt of floodplain maps, communities started to develop floodplain management ordinances to protect people and property from flood loss and damage. At least 50% to about 60% of the housing stock in Garibaldi, Nehalem, and Tillamook was built before the implementation of floodplain management ordinances. Between 35% and 40% of the homes in Bay City, Wheeler, and Neskowin and fewer in Manzanita, Netarts, Oceanside, Pacific City and Bayside Gardens were built before the implementation of floodplain management ordinances.

Table 24. Housing Age

		Pre 1970		1970 to 1989		1990 or Later	
Community	**Total Housing Units**	**Number**	**% of Total**	**Number**	**% of Total**	**Number**	**% of Total**
Oregon	**1,750,539**	**597,654**	**34.1%**	**531420**	**30.3%**	**621465**	**35.6%**
Tillamook County	**18,892**	**6,565**	**34.8%**	**5,426**	**28.7%**	**6,901**	**36.6%**
Incorporated							
Bay City	716	245	34.2%	247	34.5%	224	31.4%
Garibaldi	511	282	55.1%	111	21.8%	118	23.1%
Manzanita	1,266	282	22.2%	426	33.6%	558	44.1%
Nehalem	182	91	50.0%	52	28.5%	39	21.4%
Rockaway Beach	2,171	669	30.8%	536	24.7%	966	44.5%
Tillamook	2,448	1,514	61.9%	440	18.0%	494	20.2%
Wheeler	230	80	34.7%	60	26.1%	90	39.2%
Unincorporated							
Bayside Gardens	689	29	4.2%	131	19.0%	529	76.8%
Neskowin	408	164	40.2%	93	22.8%	151	37.0%
Netarts	634	142	22.4%	235	37.1%	257	40.5%
Oceanside-	783	166	21.2%	250	31.9%	367	46.9%
Pacific City	1,530	413	27.1%	326	21.3%	791	51.7%

Source: US Census Bureau, Census 2018 estimates, American Community Survey 5-Year Estimates, Table DP04

Changes in Development

To begin to understand changes in development, in the 2016 MJ NHMP update Tillamook County analyzed development with respect to natural hazards. Because analyzing all new development was beyond the resources available, the analysis was limited to new residential construction permits issued in the unincorporated County and each of the cities during the period January 1, 2012 through December 31, 2016. This detailed analysis of new residential construction permits was not replicated in the 2023 update, however, changes in development during the period from January 1, 2017 through December 31, 2022 was evaluated by staff whose experience is the basis for this evaluation.

Developable land is scarce in Tillamook County, and almost every location in the County is subject to at least one natural hazard. This was the conclusion drawn by the above mentioned analysis performed in 2016. That analysis concluded that it is very difficult to avoid developing in a hazard area in Tillamook County. This analysis demonstrated that adjusting city and urban growth boundaries to minimize exposure would not be a generally effective strategy because (a) development would remain subject to the same hazards; (b) development would become subject to other hazards; or (c) opportunities for urban development outside city and urban growth boundaries are limited by farm and forest zoning.

Neskowin

Neskowin is an unincorporated community located in south Tillamook County. Neskowin experienced some residential development between 2012 and 2016 within various regions of the community as depicted on the New Residential Construction Permits Issued 2012–2016 map.

Development within Neskowin is susceptible to almost all of the hazards identified in the County including earthquakes, tsunamis, landslides, and both riverine and coastal flooding. Coastal erosion and coastal flooding are the greatest hazards in this area. Neskowin has experienced severe coastal erosion and coastal flooding for the past two decades. The recently adopted Neskowin Coastal Hazards Overlay Zone addresses how development occurs within the regulated area. This overlay zone encompasses the DOGAMI Medium to XX-Large tsunami inundation boundaries and requires not only stricter development standards for construction but also limits or prohibits increased density or land division opportunities. There is moderate risk of wildfires, and the lower-lying areas of this community are at low risk of landslides. Development has occurred in areas zoned for residential development, on built and committed lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development outside of Neskowin's existing unincorporated community boundary. The area outside Neskowin's boundaries is susceptible to landslides, earthquakes, and wildfire. Therefore, moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. Development potential in adjacent areas is also limited by protected wetlands and lands zoned Forest and Farm that are committed to resource uses.

Oceanside and Netarts

The adjacent unincorporated communities of Oceanside and Netarts both experienced some residential development within their respective community boundaries.

Hazards identified in these two unincorporated communities include susceptibility to earthquakes, landslides, and wildfires. Due to the elevation of these communities, the risk of coastal flooding and tsunami inundation is limited to lower-lying areas. Specifically, the area in Netarts identified as "Happy Camp" is located in the Velocity Zone within an Area of Special Flood Hazard. Lower elevation bay-front properties or those properties adjacent to streams in the Netarts community are within the tsunami inundation boundary. Development has occurred in areas zoned for residential development, on built and committed lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development outside Oceanside's and Netart's existing unincorporated community boundaries. The area outside of their boundaries is susceptible to landslides, earthquakes, and wildfire. Moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. Development potential in adjacent areas is also limited by Forest-zoned lands committed to resource uses.

Pacific City

Pacific City is an unincorporated community located in south Tillamook County. The community experienced some residential development between 2012 and 2016 within its various regions as depicted on the New Residential Construction Permits Issued 2012–2016 map.

Development within Pacific City–Woods is susceptible to most of the hazards in the County including earthquakes, tsunamis, landslides, both riverine and coastal flooding, and coastal erosion. The Nestucca River Floodway traverses this community. There is moderate risk of wildfires, and the lower-lying areas of this community are at low risk of landslides. Development has occurred in areas zoned for residential development, on built and committed lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development outside of Pacific City-Woods' existing unincorporated community boundary. The area outside its boundary is susceptible to riverine flooding, landslides, earthquakes, and tsunami inundation. Moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. Development potential in adjacent areas is also limited by government-owned land and lands zoned Forest and Farm that are committed to resource uses.

Unincorporated Tillamook County

Residential development is primarily concentrated within incorporated cities and unincorporated communities. Risks identified within unincorporated areas not included in the communities already discussed, and not included in the cities are primarily on properties zoned Rural Residential 2-Acre. Some farm- and forest-zoned properties have also experienced residential development through approved land use review processes.

Hazards identified in areas within the unincorporated areas of Tillamook County that have experienced residential development between 2017 and 2022 include earthquakes, landslides, flooding (mostly riverine), and wildfire. Development within these areas occurs on existing lots of record or on properties zoned Farm or Forest that qualify for a dwelling. The Tillamook County Land Use Ordinance provides for development of unincorporated properties and includes standards for development within Areas of Special Flood Hazard (AO, A numbered or V zones); within Geologic Hazard or Beach and Dune Hazard areas; and within Forest (F) zones (fire siting standards for structures).

Development patterns in the past five years within the cities of Tillamook County listed alphabetically are described below. There is no residential development within any of the special districts that have participated in this plan therefore they are not discussed here.

City of Bay City

The City of Bay City has experienced a large residential development surge between 2017 and 2022, when the number of new single-family units increased exponentially each year. A majority of this development occurred within the city's upland areas, with the exception of the development known as "Sheltered Nook", and some other single-family homes developed in a low-lying area west of Highway 101.

The City of Bay City and its urban growth area are primarily susceptible to earthquakes, landslides, and tsunamis (on the lower-elevation properties). Additionally, a portion of the area of the City west of 101 is susceptible to flooding.

Risk of wildfire, landslides, earthquakes and tsunamis is moderate to low, and risk of flooding of creeks and streams appears to be primarily located on those properties west of Highway 101. Development has occurred in areas zoned for residential development, on built and committed lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development within the existing city limits and urban growth boundary.

The area outside these boundaries is also susceptible to landslides, earthquakes, and wildfires. Therefore, moving development to an alternative location would not completely alleviate the need to continue to address natural hazard risks. Development potential in adjacent areas is also limited by Farm- and Forest-zoned lands committed to resource uses.

City of Garibaldi

The City of Garibaldi is highly susceptible to earthquakes, landslides, wildfires, and to a lesser extent, tsunamis, and flooding. There was some residential development within the upland areas of the city, which appears to be located outside of the tsunami inundation zone and Areas of Special Flood Hazard (flooding of creeks and streams during heavy rain events), but remains susceptible to earthquakes, landslides, and wildfires. Development has occurred in areas zoned for residential development, on built and committed lots of record.

Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development outside of the existing city limits, and urban growth area. Areas outside these boundaries are susceptible to landslides, earthquakes, and wildfires. Therefore, moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. Development potential in adjacent areas is also limited by Farm- and Forest-zoned lands committed to resource uses as well as Areas of Special Flood Hazard.

City of Manzanita

The City of Manzanita experienced a substantial amount of residential lot development between 2012 and 2016. This development occurred in residentially zoned areas of the City of Manzanita and within Manzanita's urban growth area.

These areas are primarily susceptible to earthquakes, tsunamis, and coastal erosion. With the exception of oceanfront properties, the majority of the City of Manzanita and its urban growth area are outside of the Special Flood Hazard Area (mostly coastal flooding, not riverine). These areas of Manzanita are built and committed areas, and development has occurred on lots of record. The city as a whole is located on a dune, at the base of Neahkahnie Mountain. Due to the location of existing development, as well as topographical and geographical constraints there are few alternatives for relocating development outside of the existing city limits and urban growth area. The area outside these boundaries is susceptible to landslides, flooding, and wildfires. Moving development to an alternative location would result in the need to address different natural hazard risks.

City of Nehalem

The City of Nehalem experienced most of its residential construction within its urban growth area, specifically within the area known as “Bayside Gardens” west of the city limits and abutting the City of Manzanita’s urban growth boundary.

The City of Nehalem and its urban growth area are susceptible to earthquakes and tsunamis due to minimal elevation change from Nehalem Bay as well as the close proximity of the Nehalem River. Most of the City of Nehalem is located within the regulatory floodway and Area of Special Flood Hazard. This area is also susceptible to landslides. Wildfire is a moderate risk. Development has occurred in areas zoned for residential development and on lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocating development outside of the existing city limits and urban growth area. Lands outside these boundaries are susceptible to landslides and flooding on Farm-zoned lands committed to agricultural uses. Relocating development from these portions of the City of Nehalem is not possible due to the Nehalem River, Nehalem Bay, Nehalem River Floodway, and outer lying areas currently zoned Farm and Forest.

City of Rockaway Beach

Hazards identified for areas within the City of Rockaway Beach and its urban growth boundary include earthquakes, tsunamis, coastal flooding (with some riverine flooding attributable to creeks and streams during heavy rain events), landslides, coastal erosion, and wildfires. Review of the hazard maps confirms that development within any portion of the City of Rockaway or its urban growth area is susceptible to all or most of these hazards. These areas of Rockaway Beach are built and committed, and development has occurred on lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocation of development outside of the existing city limits and urban growth area. Hazards outside these boundaries include landslides and wildfires. Moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. The City of Rockaway Beach is purchasing a 10-acre lot located just east of North 3rd Avenue and Palisades Street. The city has expanded the urban growth boundary to include this 10-acre lot. The lot will primarily be for relocation of the city’s critical facilities.

City of Tillamook

The City of Tillamook has experienced some recent residential development, both within its city limits and in the urban growth area. The City of Tillamook and its urban growth area are susceptible to earthquakes, riverine flooding, and tsunamis. The northern, lower lying areas of the city along with the southwesterly region of its upland area appear to be the most susceptible to riverine flooding (including river floodway) and tsunami hazards. The City of Tillamook as a whole is susceptible to earthquakes. Most recent residential development that has occurred within the city appears to be located outside of areas at risk of flooding and tsunamis, but many older residential developments are still at risk from these hazards. Development has occurred in residentially zoned areas on built and committed lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocating development within the existing city limits and urban growth area. Outside the city limits, hazards include flooding, landslides, earthquakes, and wildfires. Therefore, moving development to an alternative location would not alleviate the need to continue to address natural hazard risks. Adjacent lands, including Farm- and Forest-zoned lands committed to resource uses are limited for development.

City of Wheeler

The City of Wheeler has experienced little residential construction from 2012 to 2016.

While identified hazards within the City of Wheeler and its urban growth area include earthquakes, landslides, wildfires and tsunamis, development has occurred in the upland portion of the city where the aforementioned risks are minimal. Flooding as a result of heavy rain events that increase streamflow and runoff has also been identified as a hazard. Development has occurred in built and committed areas, on lots of record. Due to the location of existing development, as well as topographical and geographical constraints, there are few alternatives for relocating development outside of the city limits and urban growth area. Hazards outside of these boundaries include earthquakes and landslides, as well as wildfires. Areas north, south, and east of the City of Wheeler are primarily zoned Forest and devoted to resource uses.

7. Cultural and Historic Resources

The first ancestors of the Tillamook settled in and near present day Tillamook County in the 15th century, living in an area ranging from Cape Lookout to Cape Meares. Meriwether Lewis and William Clark estimated in their journals in early 1806 that twenty-four hundred Tillamooks lived in several villages. The first documented western encounter with the Tillamook was in 1788 by Robert Haswell, second mate on Robert Gray's ship. A second encounter was in late 1805 by the Lewis and Clark Expedition while wintering at Fort Clatsop. Lewis and Clark described a village of around 1000 people living in about 50 houses. [3] [4]

Like the other Indian nations of the Northwest Coast, the Tillamook had permanent villages which consisted of several houses, a women's house, sweathouses, and a graveyard containing raised canoe burials. Tillamook houses were rectangular and constructed from horizontal cedar planks. Each house was occupied by more than one family and would have several hearth fires down the center. Two families would usually share a single fire. The side walls were lined with platforms for resting and sleeping. Mat partitions separated the sleeping areas of the different families.[5]

1824 and 1829 saw a pair of smallpox epidemics and combined with the arrival of Oregon Trail settlers in 1841 and the resulting conflicts led to the 1845 estimate by Wilkes showing only 400 Tillamook remaining. This was further reduced, with an 1849 estimate by Lane of only 200. In 1856 the Tillamook and more than 20 other tribes were placed on the Siletz Reservation, meaning that further population estimates are impossible since they are not separately enumerated. In 1898 the Tillamook became the

[3] Tillamook (oregonencyclopedia.org)
[4] Tillamook people - Wikipedia
[5] Ibid.

first tribe to sue the US government for compensation for the lands they had taken, along with the Clatsop. In 1907, along with two other tribes, they were awarded $23,500.[6]

The Tillamook were skilled basket-weavers and had a detailed mythology with links to existing events; the Story of the Thunderbird and Whale, for example, reflects the large earthquake in that region in 1700 which resulted in a tsunami.[7]

Figure 29. Tribal communities within Oregon

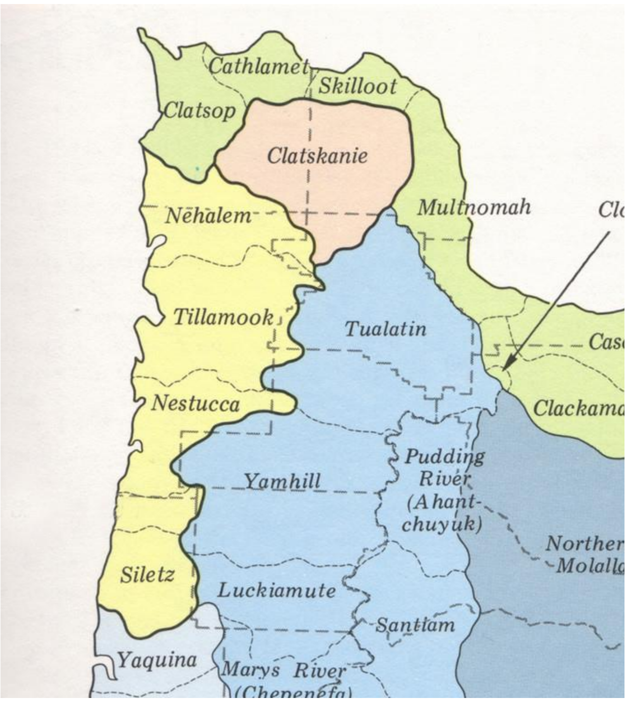


Figure 30. Traditional Tillamook house

Cultural and historic resources provide information about our past, insight into our present, and frame our local character and identity. It is important to protect them from natural hazard events. There are over 300 historic and pre-historic resources in Tillamook County listed on the Oregon Historic Sites Database (http://heritagedata.prd.state.or.us/historic/, accessed February 25, 2017). At least two or three are located in or near each city; there are none at the Port of Garibaldi. Some are listed or eligible for listing on the National Register of Historic Places (https://www.nps.gov/Nr/index.htm), the official list of historic resources that have met criteria establishing their importance in our nation's history. The list contains seven references to archeological sites near Netarts.

The Port of Tillamook Bay sits on land formerly designated as Naval Air Station Tillamook (1942–1948). Hangar B, currently operated as the Tillamook Air Museum, has been listed on the National Register of Historic Places since 1989. A cultural resource survey was performed in December 2010 as part of the Port's implementation of FEMA Alternate Projects within the industrial park and airport. The survey

[6] Ibid.

[7] Ibid.

identified multiple historic buildings and artifacts and also an area eligible for listing on the National Register of Historic Places as a historic district. The Port has not pursued creation of the historic district.

C. Natural Hazards

[8]

[8] Public Health Emergency: The COVID-19 Pandemic (DR-4499) occurred January 20, 2020 and was the first pandemic declared a natural disaster in Oregon. Although the Steering Committee identified Public Health Emergency as a natural hazard for the purposes of this plan, a detailed section was not prepared for it. The topic is well covered by others and could not be accommodated in this NHMP. The location and extent of the hazard was felt throughout the county.

Algal blooms were treated similarly in this plan. The impact of algal blooms on water quality was identified in the early work with the Steering Committee, however, this hazard was ranked the lowest concern of the Steering Committee members. The wider concern about water quality may arise in future updates to this plan at which point a full section may be developed. This hazard is located within the estuaries of Tillamook County and impacts the fishing and shellfish industries as well as water service districts the most. As no water service districts participated for the purposes of becoming NHMP plan holders, it was determined that a full section on this hazard was not warranted.

Poor Air Quality is described in the Wildfire section as an update to this plan.

1. Coastal Erosion

Introduction

The Pacific Northwest (PNW) coast of Oregon is without doubt one of the most dynamic coastal landscapes in North America, evident by its long sandy beaches, sheer coastal cliffs, dramatic headlands, and vistas, and ultimately the power of the Pacific Ocean that serves to erode and change the shape of the coast. Beaches and coastal bluffs are some of the most dynamic landforms, changing in response to waves, nearshore currents, tides, rain, and wind.

The most important natural variables that influence changes to the shape and width of the beach and ultimately its stability are the beach sand budget (balance of sand entering and leaving the system) and the processes (waves, currents, tides, and wind) that drive the changes.

Human influences associated with jetty construction, dredging practices, coastal engineering, and the introduction of non-native dune grasses have all affected the shape and configuration of the beach, including the volume of sand on a number of Oregon's beaches, ultimately influencing the stability or instability of these beaches.

Figure 31. Erosion at "The Capes" Condominiums, Oceanside, Oregon

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

Photo source: Jon Allan, DOGAMI

Table 25. Jurisdictions Subject to Coastal Erosion

Jurisdiction	Coastal Erosion
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	
Pacific City–Woods	X
Bay City	
Garibaldi	
Manzanita	X
Nehalem	
Rockaway Beach	X
Tillamook	
Wheeler	
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

Geology and Geomorphology

Tillamook County's geomorphic features include almost all those found along the Oregon Coast: plunging cliffs, rocky shorelines and shore platforms, wide and narrow beaches backed by dunes, gravel and cobble beaches backed by cliffs, barrier spits, and estuaries. Geomorphologically, the coast can be broken up into a series of "pocket beach" littoral cells that reflect resistant headlands (chiefly basalt) interspersed with short to long stretches of beaches backed by less resistant cliffs and dune. The headlands effectively prevent the exchange of sand between adjacent littoral cells. Some beaches form barrier spits, creating estuaries or bays behind them (e.g., Netarts and Nestucca spits).

Sand Budget

The beach sand budget is the rate at which sand is brought into the coastal system versus the rate at which sand leaves the system. Potential sources of sand include rivers, bluffs, dunes, and the inner shelf. Potential sand sinks include bays (estuaries), dunes, dredging around the mouths of estuaries, and mining of sand. Sand volume is a factor in susceptibility of a bluff to failure from wave action causing erosion at its toe. Conversely, in some areas such as Pacific City and Manzanita excess sand build-up is a concern.

Human Influences

Population pressure on the Oregon coast is relatively low and is largely confined to small coastal cities separated by large tracts of coast with little to no development. Tillamook County is home to some of these small cities. Although the processes driving coastal erosion on bluff-backed shores are entirely a function of the delicate balance between the assailing forces (waves, tides, and currents) and properties of the rock (rock type, bedding, strength, etc.), human influences along with extensive erosion caused by major storms have contributed to the perceived need for coastal engineering (such as riprap) to protect individual properties. The magnitude and extent of these erosion events have now left some properties entirely dependent on the integrity of the engineered structures. Oregon Land Use Planning Goal 18 precludes most new beachfront protective structures, engineered or otherwise.

Classifying Coastal Erosion

Chronic or catastrophic? Beach, dune, and bluff erosion are chronic hazards. They usually cause gradual and cumulative damage. However, storms that produce large winter waves, heavy rainfall, and/or high winds may result in very rapid erosion that can affect properties and infrastructure over a matter of hours. Damage from chronic hazards is generally less severe than that from catastrophic hazards. However, the wide distribution and frequent occurrence of chronic hazards makes them a more immediate concern.

Causes of Coastal Erosion

Most coastal hazards, coastal erosion among them, are the product of the annual barrage of rain, wind, and waves that batter the Oregon coast, causing ever-increasing property damage and losses. Coastal erosion may be further exacerbated by climate cycles such as the El Niño Southern Oscillation, or longer-term climate cycles associated with the Pacific Decadal Oscillation.

Waves

Along dune- and bluff-backed shorelines, waves are the major factor affecting the shape and composition of beaches. Short-term beach and shoreline variability is directly dependent on the size of the waves that break along the coast, along with high ocean water levels, and cell circulation patterns associated with rip currents. In contrast, long-term shoreline change is dependent on the balance of the beach sediment budget, changes in sea level over time, and patterns of storminess.

Figure 32. Bluff Failure Due to Toe Erosion by Ocean Waves

Note: The top of the bluff eroded landward by about 30 ft over a 48-hour period in November 2006.
Photo source: Oregon Partnership for Disaster Resilience

The Oregon coast is exposed to one of the most extreme ocean wave climates in the world, due to its long fetches and the strength of the extratropical storms that develop and track across the North Pacific. These storms exhibit a pronounced seasonal cycle producing the highest waves in the winter. Summer months are dominated by considerably smaller waves, enabling beaches to rebuild and gain sand eroded by the preceding winter. When large waves are superimposed on high tides, they can reach much higher elevations at the back of the beach, contributing to significantly higher rates of coastal erosion and flood hazards. It is the combined effect of these processes that leads to the erosion of coastal dunes and bluffs, causing them to retreat landward.

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

Ocean Water Levels

The elevation of the sea is controlled in part by astronomical tide. High ocean water levels at the shoreline may be the product of combinations of high tides, storm surges, strong onshore-directed winds, El Niños, and wave runup. Tides tend to be highest in the winter and lowest in the summer. The typical seasonal variability in water levels enables waves to break closer to dunes or along the base of coastal bluffs.

Shoreline Changes

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

Recently, studies undertaken by the USGS provide additional insights into the spatial extent of erosion patterns on the Oregon coast. Long-term erosion rates (albeit low rates) dominate the bulk of Tillamook County (i.e., Bayocean Spit, Netarts, Sand Lake, and Neskowin littoral cells), while accretion prevailed in the north along Rockaway Beach and on Nehalem Spit. The significant rates of accretion identified adjacent to the mouth of Tillamook Bay are entirely due to construction of the Tillamook jetties, with the north jetty completed in 1917 and the south jetty in 1974. Short-term shoreline change patterns indicate that erosion has continued to dominate the bulk of the shoreline responses observed along the Tillamook County coast. Erosion is especially acute in the Neskowin, Sand Lake and Netarts littoral cells, and especially along Rockaway Beach. In many of these areas, the degree of erosion remains so significant, that if Tillamook County were to experience a major storm(s) in the ensuing winters, the risk of considerable damage to property and infrastructure in these areas would likely be high.

The processes of wave attack significantly affect shorelines characterized by indentations, known as inlets. Waves interact with ocean tides and river forces to control patterns of inlet migration. This is especially the case during El Niños. During an El Niño, large storm waves tend to arrive out of the south, which causes the mouth of the estuary to migrate to the north, where it may abut against the shoreline, allowing large winter waves to break much closer to the shore. This can result in significant "hotspot" erosion north of the estuary mouth. A recent example of the importance of inlet dynamics during an El Niño is Netarts Spit near Oceanside.

Similar processes occurred nearby during the 1972-73 winter, which led to one home having to be pulled off its foundation. Both examples provide a stark reminder of the danger of building too close to the beach and that these types of changes do occur relatively frequently.

Climate Change and Sea Level Rise

On the central to northern Oregon coast, sea level is rising faster than tectonic uplift of the land creating conditions supporting widespread erosion.

In 2012, the National Research Council completed a major synthesis of the relative risks of sea level rise on the US West Coast. Based on that report, erosion and flood hazards on the northern Oregon Coast will almost certainly accelerate over time, increasing the risk to property.

Human Activities

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

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

While site-specific coastal engineering efforts such as the construction of riprap revetments is less likely to cause direct adverse impacts to the beach, the cumulative effect of constructing many of these structures along a particular shore (e.g., as has occurred along the communities of Neskowin, Pacific City, and Rockaway) will almost certainly decrease the volume of sediment being supplied to the beach system, potentially affecting the beach sediment budget and hence the stability of beaches within those littoral cells.

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

Historic Coastal Hazard Events

Table 26. Historic Coastal Erosion Events in Tillamook County

Date	Location	Description
1931	Rockaway	coastal damage from December storm
Oct–Dec. 1934	Rockaway	coastal damage (Rockaway Beach)
Dec. 1935	Rockaway Beach	coastal damage
Jan. 1939	coastwide	severe gale; damage: coastwide
multiple spit breaches (southern portion of Netarts Spit)		
Jan. 1953	Rockaway	70-ft dune retreat; one home removed
Dec. 1967	Netarts Spit	damage: coastwide
State constructed wood bulkhead to protect foredune along 600 ft section (Cape Lookout State Park campground)		
1997–98	Tillamook Counties	El Niño winter (second strongest on record); erosion: considerable
1999	coastwide	five storms between January and March; coastal erosion: extensive, including causing significant erosion (Neskowin, Netarts Spit, Oceanside, Rockaway beach)

Sources: Allan and Priest (2001); Allan and Komar (2002); Allan, Komar and Priest (2003); Allan, Hart, & Tranquilli (2006); Allan and Hart (2007, 2008); Allan, Witter, Ruggiero, & Hawkes (2009); Allan, Ruggiero, & Roberts, 2012); Allan and Stimely (2013); Komar (1986); Jackson (1987); Komar and Rea (1976); McKinney (1977); Komar (1997; Komar and Allan (2010); Peterson, Jackson, O'Neil, Rosenfeld, & Kimerling (1990); Priest (1999); Revell, Komar, & Sallenger (2002); Schlicker, Deacon, Olcott, & Beaulieu (1973); Stembridge (1975); and Terich and Komar (1974)

Probability

The erosion of the Oregon coast is exceedingly complex, reflecting processes operating over both short and long time scales, and over large spatial scales. However, the most significant erosion effects are largely controlled by high-magnitude (relatively infrequent) events that occur over the winter when wave heights and ocean water levels tend to be at their highest.

Previous analyses of extreme waves for the Oregon coast estimated the “100-year” (1%) storm wave to be around 33 ft. In response to a series of large wave events that occurred during the latter half of the 1990s, the wave climate was subsequently re-examined and an updated projection of the 1% storm wave height was determined, which is now estimated to reach approximately 47–52 ft (**Table 27**), depending on which buoy is used. These estimates are of considerable importance to the design of coastal engineering structures and in terms of defining future coastal erosion hazard zones.

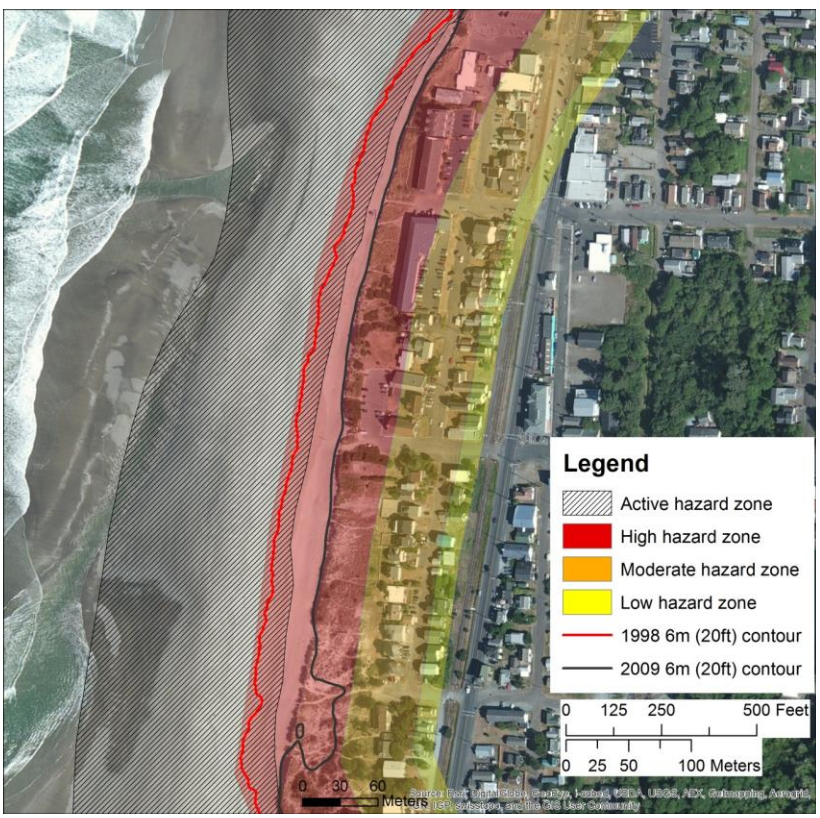
Table 27. Projection of Extreme Wave Heights for Various Recurrence Intervals: Each Wave Height Is Expected to Occur on Average Once during the Recurrence Interval

Recurrence Interval (Years)	Extreme Wave Heights (Feet)	
	NDBC Buoy #46002*(Oregon)	NDBC Buoy #46005+(Washington)
10	42.5	41.7
25	46.2	44.0
50	48.8	–
75	50.1	45.7
100	51.2	47.1

Sources: *Analyses by Jon Allan, DOGAMI; +Ruggiero, Komar and Allan (2010)

In order to understand the potential extent of erosion for different communities, DOGAMI has completed coastal erosion hazard maps for Tillamook County. The maps depict erosion hazard zones that fall into four categories: Active, High, Medium, and Low (). The High and Medium hazard zones reflect erosion associated with a 2% and 1% storm, respectively. The Low hazard zone includes a 1% storm coupled with a Cascadia subduction zone earthquake and has a much lower probability of occurrence. The erosion scenarios were defined using a combination of probabilistic (waves) and deterministic (water levels) approaches.

Figure 33. Example Map Product Showing Erosion Hazard Zones Developed for Rockaway Beach in Tillamook County



Note the erosion that has taken place since 1998 (red line) up through 2009 (black line).
Photo source: DOGAMI

In July 2014, DOGAMI completed updated maps for the dune-backed beaches in Tillamook County using a fully probabilistic approach of the waves and water levels to map the erosion hazard zones. The revised modeling used three total water level scenarios (10%, 2%, and 1% events) produced by the combined effect of extreme wave runup (R) plus the measured tidal elevation (T), and erosion due to sea level rise (low/mean/maximum estimates) in 2030, 2050, and 2100. In total, 81 scenarios of coastal erosion were modeled; an additional two scenarios were also modeled that considered the effects of a Cascadia subduction zone earthquake, and the effects of a single (1%) storm, where the storm's duration was considered. The completed study ultimately recommended five hazard zones for consideration. A sixth hazard zone was also proposed. This latter zone was defined using a more sophisticated dune erosion model that accounted for the effect of the duration of a storm. Table 28 provides the calculated erosion associated with an extreme (1%) storm for Tillamook County, after accounting for the storms duration. The results indicate that the storm induced erosion ranges from about 47 to 73 ft. When the duration of the storm is removed from consideration the amount of beach and dune erosion increases substantially to about 70 to 260 ft. Finally, modeling coastal change by nature is fraught with large uncertainty that is a function of variations in the morphology of the beach and the beach sediment budget.

Table 28. Storm-Induced Erosion Defined for Selected Sites in Tillamook County after Having Accounted for the Duration of the Event

	Maximum 1% Erosion Distance	
	(Meters)	(Feet)
Neskowin	20.6	67.6
Nestucca Spit	14.5	47.6
Sand Lake	18.7	61.4
Netarts Spit	22.2	72.8
Bayocean Spit	17.6	57.7
Rockaway	19.9	65.3
Nehalem Spit	19.3	63.3

Modeled erosion is for a 1% storm.

Climate Change and Sea Level Rise

Recent research indicates that sea levels along Oregon's coast are rising as are wave heights off the Oregon coast. These conditions are expected to increase coastal erosion.

One of the climate risks discussed in the Oregon Climate Adaptation Framework (Department of Land Conservation and Development : Oregon's Climate Change Adaptation Framework : Climate Change : State of Oregon) is "Increased coastal erosion and risk of inundation from increasing wave heights and storm surges." The executive summary of the Adaptation Framework provides a summary of various challenges associated with increased coastal erosion:

> *Increased wave heights, storm surges, and sea levels can lead to loss of natural buffering functions of beaches, tidal wetlands, and dunes. Accelerating shoreline erosion has been documented and is resulting in increased applications for shore protective structures. Shoreline alterations typically reduce the ability of beaches, tidal wetlands, and dunes to adjust to new conditions.*
>
> *Increasing sea levels, wave heights, and storm surges will increase coastal erosion and likely increase damage to private property and infrastructure situated on coastal shorelands. Coastal erosion and the common response to reduce shoreland erosion can lead to long-term loss of natural buffering functions of beaches and dunes. Applications for shoreline alteration permits to protect property and infrastructure are increasing, but in the long term they reduce the ability of shore systems to adjust to new conditions.*

Vulnerability

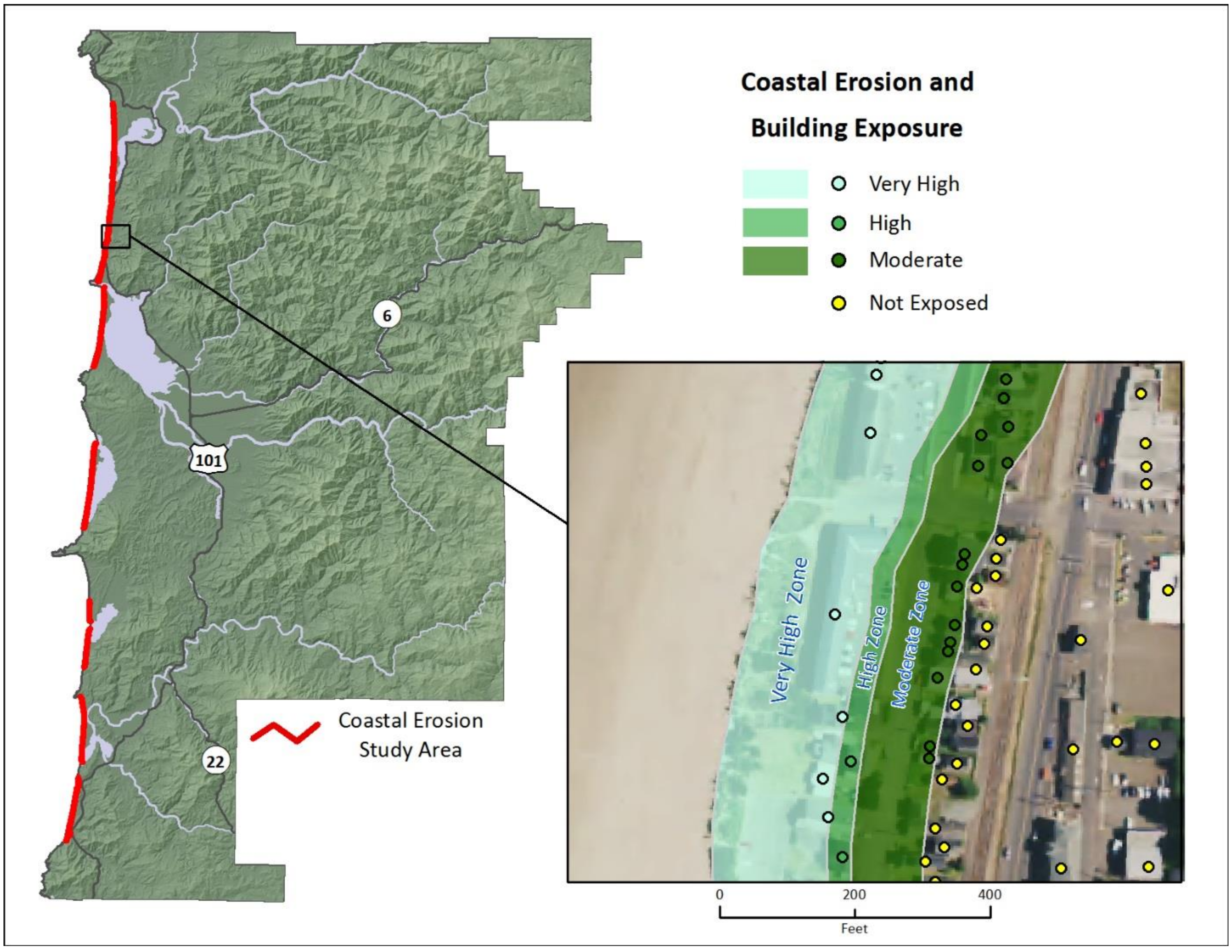
Oregon does not have one standard method to assess risk across all hazards statewide. Experts from DOGAMI compiled and analyzed data and determined the best method or combination of methods to identify vulnerability and potential impacts of coastal erosion for the following state assessment from the 2015 Oregon NHMP (Oregon Department of Land Conservation and Development, 2015).

Vulnerability expresses the impacts to people and the built environment anticipated from coastal erosion. Based on review of the available data, DOGAMI ranks Tillamook County first among counties vulnerable to coastal erosion in Oregon. Most coastal communities and unincorporated areas of Tillamook County have a marginal level of exposure to coastal erosion; the exceptions are Neskowin and Rockaway Beach. These two communities have approximately 15% to 25% of their overall building value exposed to moderate coastal erosion hazard.[9]

The *Final Draft Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2022) provides a coastal erosion exposure analysis for Tillamook County. **Figure 34** provides an example of the building exposure analysis. Exposure analysis results are shown in **Table 29** and **Table 30**, and **Figure 35** illustrates those results.

[9] Multi-hazard Risk Report for Tillamook County, Oregon; DOGAMI; 2022

Figure 34. Coastal Erosion Zones and Building Exposure Example



Source: DOGAMI (2022)

Table 29. Coastal Erosion Exposure: Tillamook County and Cities

Community*	Total Number of Buildings	Total Estimated Building Value ($)	Very High Hazard[1] Number of Buildings	Very High Hazard[1] Building Value ($)	Very High Hazard[1] Ratio of Exposure Value	High Hazard[1] Number of Buildings	High Hazard[1] Building Value ($)	High Hazard[1] Ratio of Exposure Value	Moderate Hazard[1] Number of Buildings	Moderate Hazard[1] Building Value ($)	Moderate Hazard[1] Ratio of Exposure Value
	(all dollar amounts in thousands)										
Unincorp. County (rural)	15,015	1,282,436	109	13,418	1.0%	161	18,928	1.5%	309	33,885	2.6%
Neskowin	653	118,463	95	32,205	27.2%	110	34,149	28.8%	156	40,374	34.1%
Pacific City–Woods	1,707	212,062	3	5,991	2.8%	25	8,909	4.2%	88	19,740	9.3%
Total Unincorp. County	**17,375**	**1,612,961**	**207**	**51,614**	**3.2%**	**296**	**61,986**	**3.8%**	**553**	**93,999**	**5.8%**
Manzanita	1,523	259,780	10	2,225	0.9%	25	4,389	1.7%	103	18,410	7.1%
Rockaway Beach	2,240	211,809	241	44,795	21.1%	288	50,675	23.9%	534	79,618	37.6%
Total Tillamook County*	**21,138**	**2,084,550**	**458**	**98,634**	**4.7%**	**609**	**117,050**	**5.6%**	**1,190**	**192,027**	**9.2%**

*Does not include non-coastal communities (these communities do not factor in to total amounts and percentages)

[1]Very High, High, and Moderate hazard correspond to the coastal erosion zones of High, Moderate, and Low 1 determined by Stimely and Allan (2014).

Source: DOGAMI (2016)

Community*	Total Number of Buildings	Total Estimated Building Value ($)	High Hazard Number of Buildings	High Hazard Building Value ($)	High Hazard Percent of Building Value Exposed	Moderate Hazard Number of Buildings	Moderate Hazard Building Value ($)	Moderate Hazard Percent of Building Value Exposed	Low Hazard Number of Buildings	Low Hazard Building Value ($)	Low Hazard Percent of Building Value Exposed
	(all dollar amounts in thousands)										
Unincorp. County (rural)	14,104	3,607,281	170	28,111	0.5%	513	105,734	2.1%	1,317	265,019	5.2%
Neskowin	652	141,094	99	28,343	0.6%	116	32,475	0.6%	379	83,556	59.2%
Oceanside & Netarts	1,628	302,588	84	16,082	0.3%	306	58,766	1.1%	455	83,718	1.6%
Pacific City	1,721	361,114	5	2,585	0.1%	31	9,631	0.2%	330	74,854	1.5%

Total Unincorp. County	19,050	4,598,402	358	75,121	1.5%	966	206,607	4.0%	2,481	507,146	9.9%
Manzanita	1,517	274,658	25	5,105	0.1%	69	14,699	0.3%	477	85,199	1.7%
Rockaway Beach	2,095	454,733	146	47,790	0.9%	192	58,196	1.1%	805	185,974	3.6%
Total Tillamoo k County	21,717	5,141,468	529	128,016	2.5%	1,227	279,502	5.4%	3,763	778,318	15.1%

DRAFT

Table 30. Coastal Erosion Exposure: Port of Tillamook Bay and Port of Garibaldi

	Total Number of Buildings	Total Estimated Building Value ($)	Very High Hazard[1]			High Hazard[1]			Moderate Hazard[1]		
			Number of Buildings	Building Value ($)	Ratio of Exposure Value	Number of Buildings	Building Value ($)	Ratio of Exposure Value	Number of Buildings	Building Value ($)	Ratio of Exposure Value
Port of Garibaldi	36	8,035,760	0	0	0.00%	0	0	0.00%	0	0	0.00%
Port of Tillamook	83	61,545,144	0	0	0.00%	0	0	0.00%	0	0	0.00%

*Does not include non-coastal communities (these communities do not factor in to total amounts and percentages)

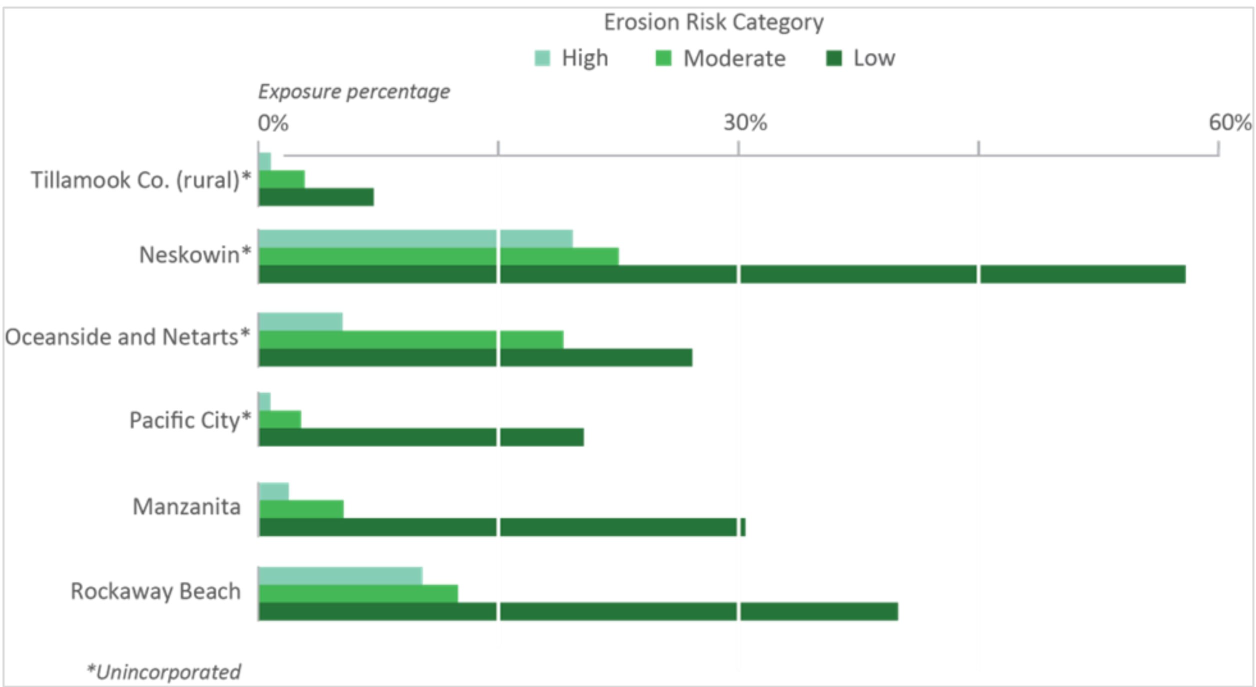
[1]Very High, High, and Moderate hazard correspond to the coastal erosion zones of High, Moderate, and Low 1 determined by Stimely and Allan (2014).

Source: DOGAMI (2016)

Neskowin and Rockaway Beach have by far the greatest ratio of exposure value across all three hazard risk categories. Neskowin drafted *Adapting to Coastal Erosion Hazards in Tillamook County: Framework Plan* in 2011 (Woolley et al., 2011) and subsequently adopted a coastal erosion overlay zone to mitigate the effects of coastal erosion.

Coastal erosion is constantly impacting the north-south jetty system of Tillamook Bay. The tumultuous Pacific Ocean environment has caused recession of both the north and south jetties. The revetment has also experienced some damage caused by wave overtopping that over time destabilizes the stones and causes erosion within the structure. A 2010 rehabilitation project capped the north jetty at its current length of 5,214 feet and made necessary repairs to the revetment. The south jetty remains in need of attention. Funding is being pursued for south jetty repairs. The north jetty lies within the southwestern portion of the Port of Garibaldi District boundary, the south jetty within the northwestern portion of the Port of Tillamook Bay District boundary.

Figure 35. Coastal Erosion Exposure by Tillamook County Community



*Unincorporated communities

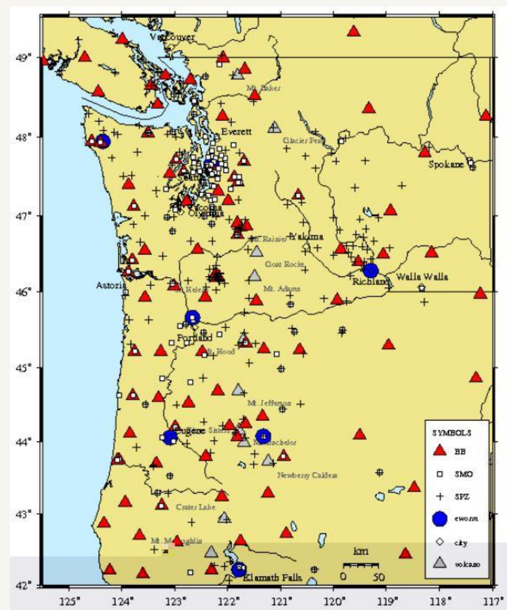
Note: Beyond the designated communities, in unincorporated Tillamook County, building values total $28 million in areas of high coastal erosion hazard, $106 million in areas of moderate hazard, and $265 million in areas of low hazard.
Source: Multi-hazard Risk Report for Tillamook County, Oregon; DOGAMI; 2022

2. Earthquakes

Introduction

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

Figure 36. Earthquake Monitoring Stations in the Pacific Northwest



Note: The earthquake monitoring network system is operated out of the University of Washington by the Pacific Northwest Seismic Network.

Source: Pacific Northwest Seismic Network (http://www.pnsn.org/)

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

Seismic networks can detect very small earthquakes, locate them to within a few miles, and determine their magnitude accurately. Seismographs have only existed for about a century, and in Oregon, the instrumental record is really only complete and modern from about 1990 on.

Historical felt location data come from verbal and written reports of earthquake effects. The felt record extends back to the mid-1800s for Oregon, but only locates moderate to large earthquakes, and those only with an accuracy of tens or even hundreds of miles.

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

In Oregon, the combined earthquake history derived from these three sources clearly outlines two major types of earthquake hazard and two less significant sources. By far the greatest is the hazard posed by infrequent **megathrust earthquakes** on the Cascadia Subduction Zone. The second major hazard comes from smaller **crustal earthquakes** on faults in or near populated areas, which includes all of Oregon's damaging historic earthquakes. **Intraplate earthquakes**, which have been historically damaging in the Puget Sound area, are possible in Oregon but no damaging prehistoric or historic events are known.

Location

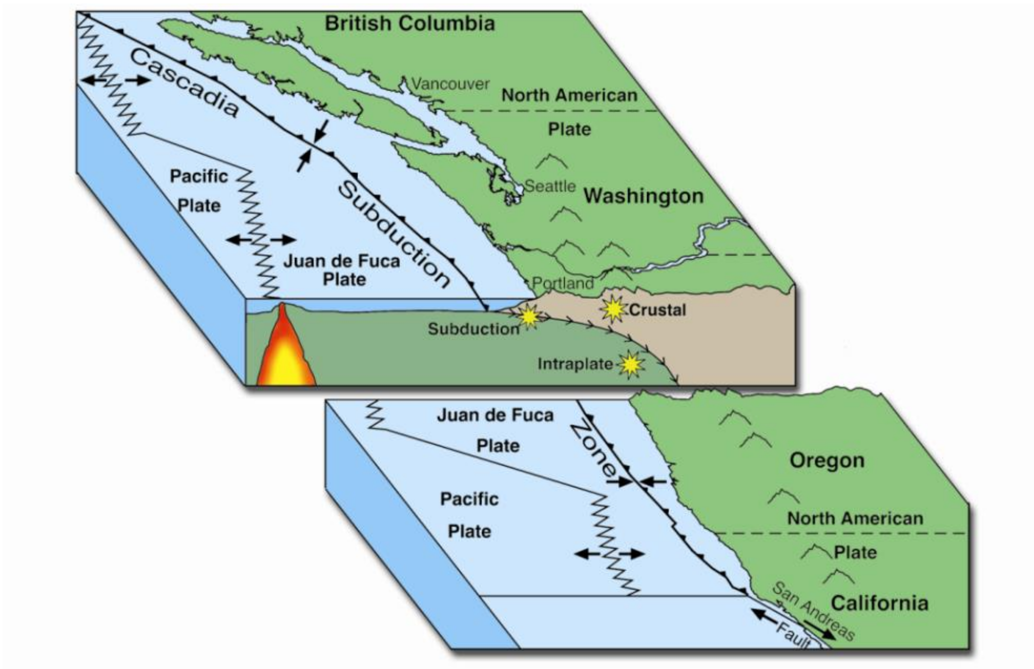
All the communities in Tillamook County will be impacted by a Cascadia Subduction Zone earthquake. A crustal earthquake is unlikely to occur in the County, but a crustal earthquake that occurs elsewhere may impact the County.

Hazard Characterization

The Cascadia Subduction Zone is the boundary between two of the earth's crustal plates. These continent-sized plates are in constant slow motion, and the boundaries between plates are the site of most earthquake activity around the globe. At the Cascadia Subduction Zone, the Juan De Fuca plate, located offshore of Oregon and Washington, slides to the northeast and under the North American plate, which extends from the Oregon coast to the middle of the Atlantic Ocean. The Juan de Fuca plate slides beneath the continent (subducts) at about 1.5 inches per year, a speed that has been directly measured using high-accuracy GPS. The fault that separates the plates extends from Cape Mendocino in Northern California to Vancouver Island in British Columbia, and slopes down to the east from the sea floor. The fault is usually locked, so that rather than sliding slowly and continuously, the 1.5 inches per year of subduction motion builds tremendous stress along the fault. This stress is periodically released in a megathrust earthquake, which can have a magnitude anywhere from 8.3 to 9.3.

Figure 37 is a schematic three-dimensional diagram with the generalized locations of the three types of earthquake sources found in Oregon: subduction zone, crustal, and intraplate.

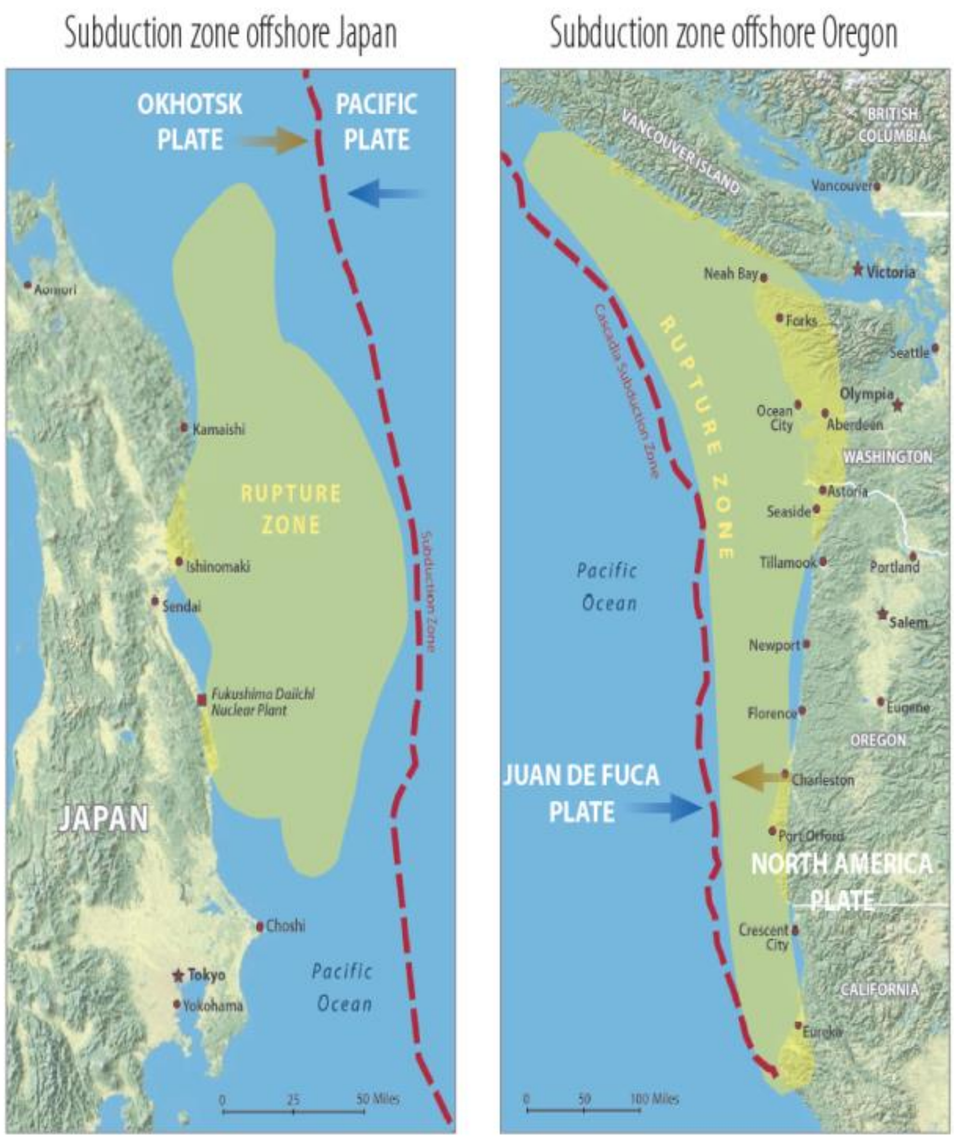
Figure 37. General Source Areas for Subduction Zone, Crustal Earthquakes, and Intraplate Earthquakes



Source: Cascadia Region Earthquake Workgroup, Roddey, and Clark (2005)

The Cascadia Subduction Zone closely mirrors the subduction zone in northern Japan that produced the 2011 Tohoku earthquake (**Figure 38**). This magnitude 9 megathrust event and its associated tsunami captured the world's attention with unforgettable images of destruction on a massive scale. Oregon should regard this as a window into our future, as this is the very type of earthquake that our best science tells us is likely on the Cascadia Subduction Zone. Particular attention must be paid to the incredibly destructive tsunami that accompanied the Tohoku earthquake, and we must plan for a similar tsunami in Oregon. (See the **Tsunamis** section of this Plan for more information about tsunamis in Oregon.)

Figure 38. Comparison of the Northern Japan Subduction Zone in and the Cascadia Subduction Zone



Note: Yellow patches are the measured earthquake rupture zone in Japan, modeled earthquake rupture zone in Oregon.
Source: DOGAMI (2012)

Crustal earthquakes occur for the most part on shore on much smaller faults located in the North American plate. These are the more familiar "California-style" earthquakes with magnitudes in the 5 to 7 range. Although much smaller than megathrust earthquakes, crustal earthquakes may occur much closer to population centers, and are capable of producing severe shaking and damage in localized areas. These are not a significant threat on the northern Oregon Coast.

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

2011 Tohoku Earthquake Numbers

- about 16,000 dead
- 92% of deaths due to tsunami (drowning)
- Fatality rate within the tsunami inundation zone about 16%
- about 4,000 missing (as of 10/2/2011)
- about 6,000 injuries
- Population within 40 km of coastline about 3,000,000
- about 300,000 homes destroyed
- about 600,000 homes damaged

Source: https://earthquake-report.com/2011/10/02/japan-tohoku-earthquake-and-tsunami-catdat-41-report-october-2-2011/

Earthquake Effects

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

Two measurement scales are used to describe the magnitude and intensity of earthquakes. To measure the magnitude, the "moment magnitude" (M_w, or M) scale uses the Arabic numbering scale. It provides clues to the physical size of an earthquake (http://www.actforlibraries.org/understanding-the-richter-scale-and-moment-magnitude-scale/) and is more accurate than the previously used Richter scale for larger earthquakes. The second scale, the "modified Mercalli," measures shaking intensity and is based on felt observations; it is therefore more subjective than the mathematically derived moment magnitude. It uses Roman numerals to indicate the severity of shaking. It is important to understand the relationship between the intensity of shaking and the amount of damage expected from a given earthquake scenario.

Table 31 gives an abbreviated description of the 12 levels of Modified Mercalli intensity.

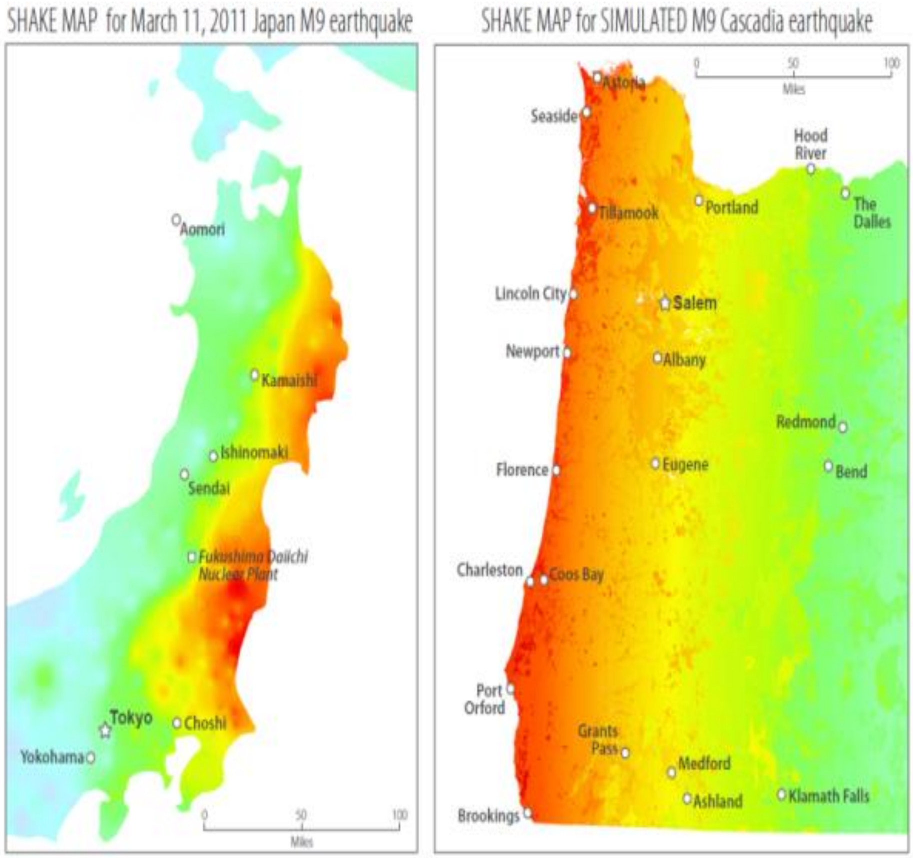
Table 31. Levels of Modified Mercalli Intensity

Level	Intensity
I	not felt except by a very few under especially favorable conditions
II	felt only by a few persons at rest, especially on upper floors of buildings
III	felt quite noticeably by persons indoors, especially on upper floors of buildings; many people do not recognize it as an earthquake; standing motor cars may rock slightly; vibrations similar to the passing of a truck; duration estimated
IV	felt indoors by many, outdoors by few during the day; at night, some awakened; dishes, windows, doors disturbed; walls make cracking sound; sensation like heavy truck striking building; standing motor cars rocked noticeably
V	felt by nearly everyone; many awakened; some dishes, windows broken; unstable objects overturned; pendulum clocks may stop
VI	felt by all, many frightened; some heavy furniture moved; a few instances of fallen plaster; damage slight
VII	damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII	damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse; damage great in poorly built structures; fall of chimneys, factory stacks, columns, monuments, walls; heavy furniture overturned
IX	damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse; buildings shifted off foundations
X	some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; rails bent
XI	few, if any (masonry) structures remain standing; bridges destroyed; rails bent greatly
XII	damage total; lines of sight and level are distorted; objects thrown into the air

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

Future megathrust earthquakes on the Cascadia Subduction Zone (CSZ) will occur off the coast, and the strength of shaking will decrease inland. Oregon coastal communities will experience severe shaking. The other unique characteristic of megathrust earthquakes is that the strong shaking will last for several minutes, in contrast to a large crustal earthquake, which might shake for only 30 seconds. The long duration of shaking contributes greatly to damage, as structures go through repeated cycles of shaking. Figure 39 shows a side-by-side comparison of shake maps for (a) the 2011 M9 earthquake in Japan, and (b) a simulated M9 CSZ event in Oregon.

Figure 39. Comparison of Measured Shaking from Tohoku Earthquake and Simulated Shaking from M9 Cascadia Megathrust Earthquake

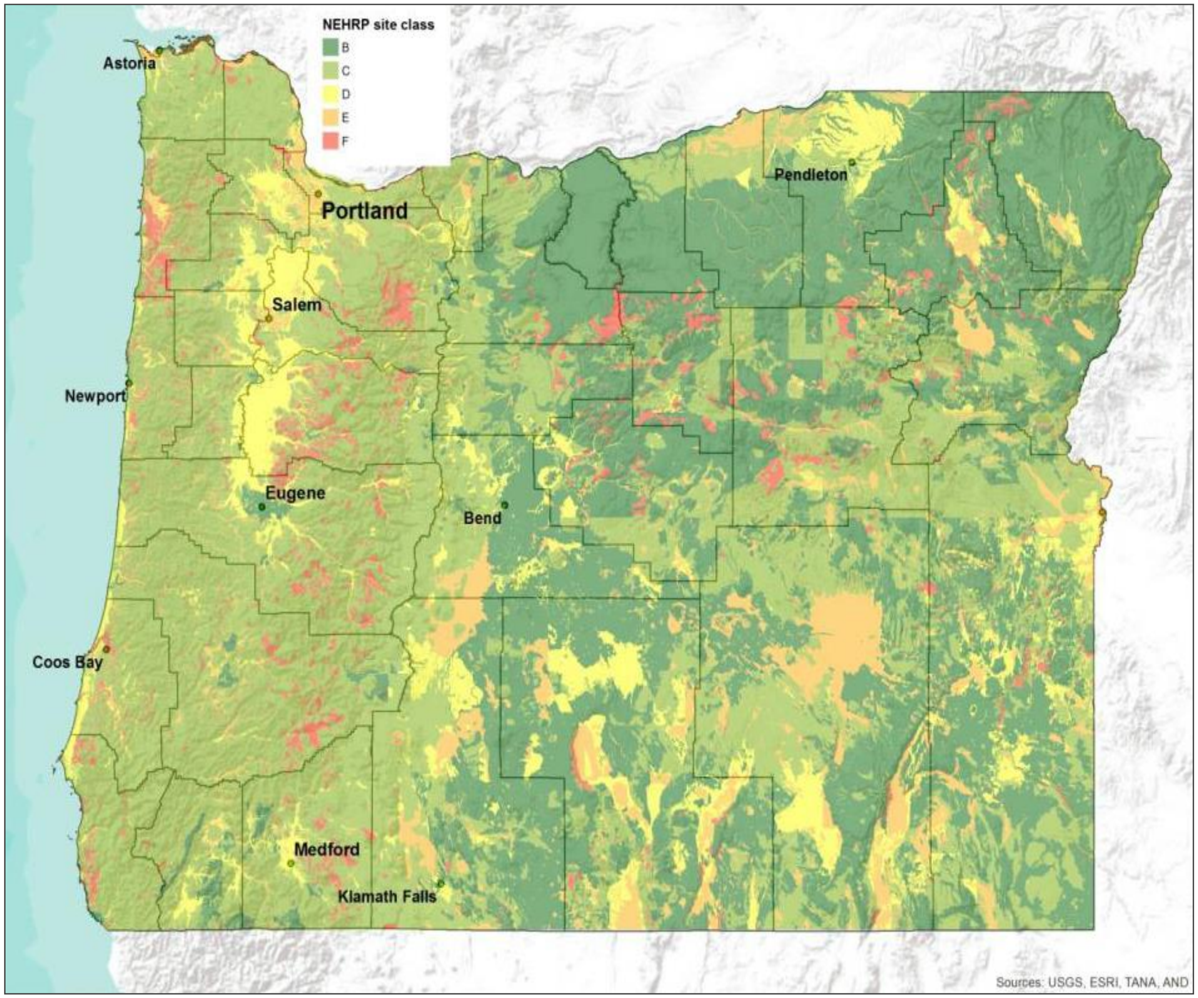


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

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

The other important factor in controlling earthquake damage is the contribution of local geology. Soft soils can strongly amplify shaking (**Figure 40**). Loose saturated sand or silt can liquefy, causing dramatic damage, and new landslides can occur on steep slopes while existing landslide deposits may start to move again. These effects can occur regardless of earthquake source, and the geologic factors that cause them can be identified in advance by geologic and geotechnical studies. Liquefaction- and earthquake-induced landslides are both more likely to occur during the several minutes of shaking produced by a megathrust earthquake, and these effects are expected to be widespread during the next event (**Figure 41** through **Figure 44**). In 2013, DOGAMI published a suite of statewide earthquake hazard maps with GIS files in Open-File Report O-13-06, *Ground motion, ground deformation, tsunami inundation, coseismic subsidence, and damage potential maps for the 2012 Oregon Resilience Plan for Cascadia Subduction Zone earthquakes* (Madin and Burns, 2013).

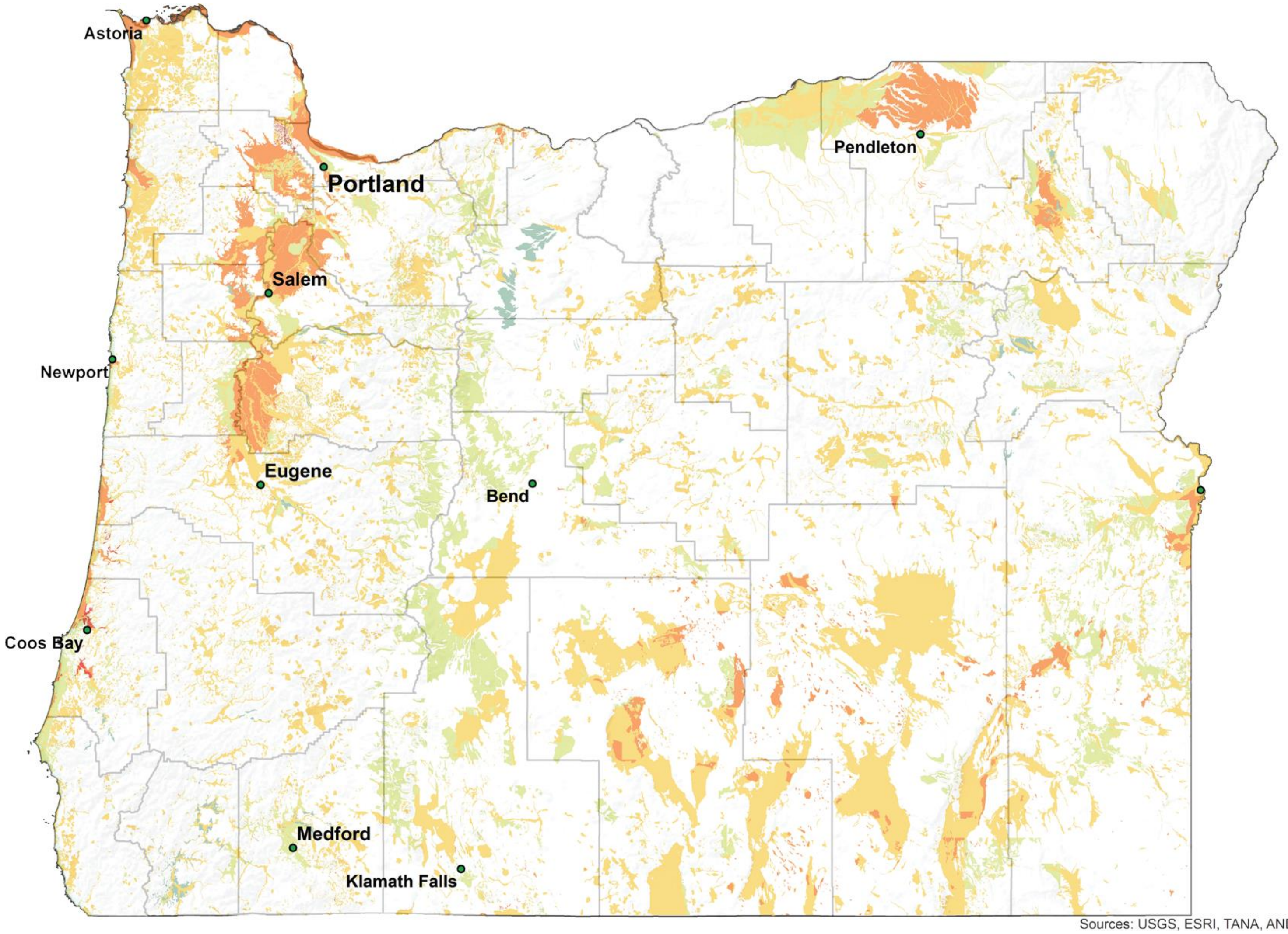
Figure 40. Soils Map Showing Where Soils Can Amplify Earthquake Ground Shaking



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

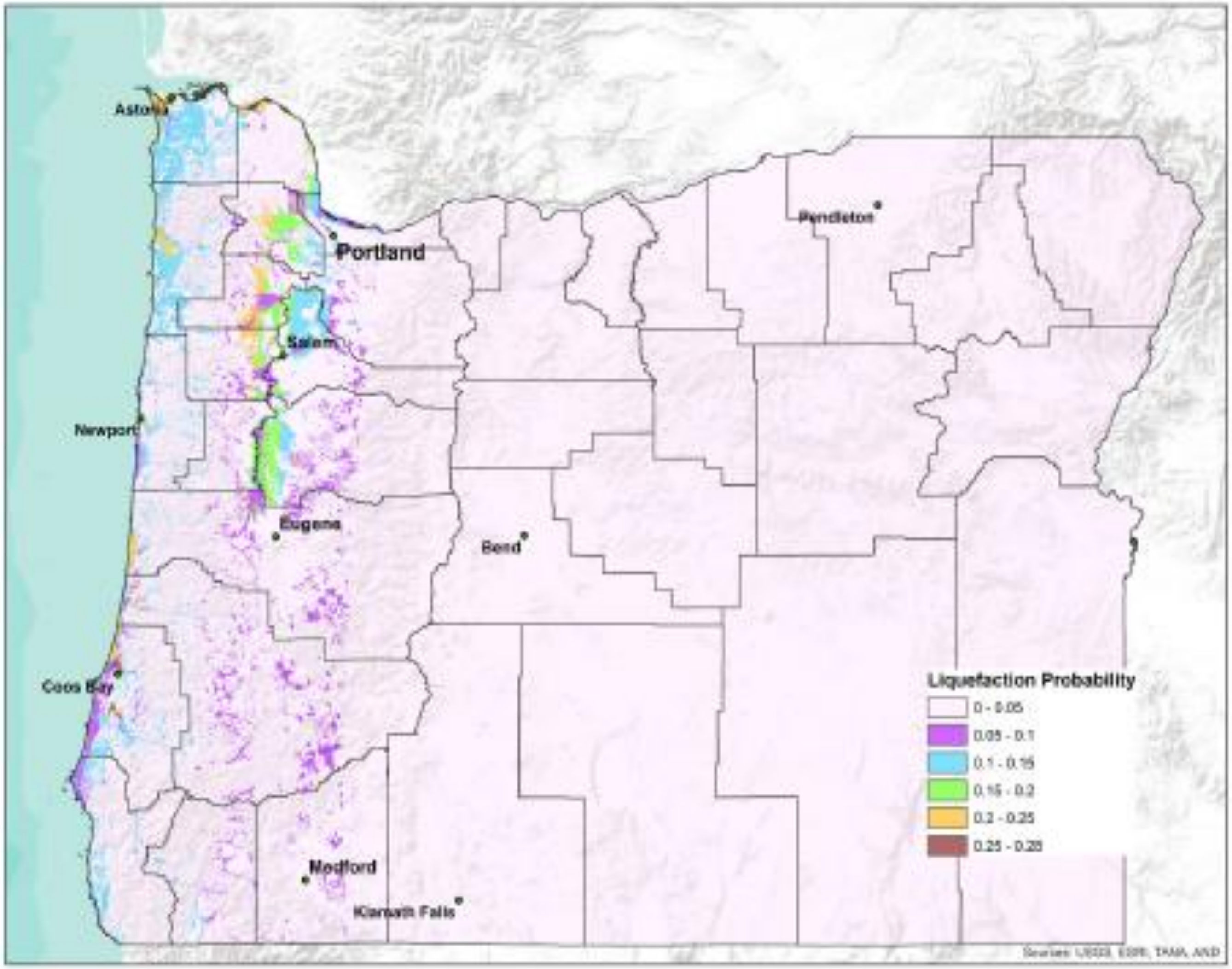
Source: Madin and Burns (2013)

Figure 41. Liquefaction Susceptibility Map



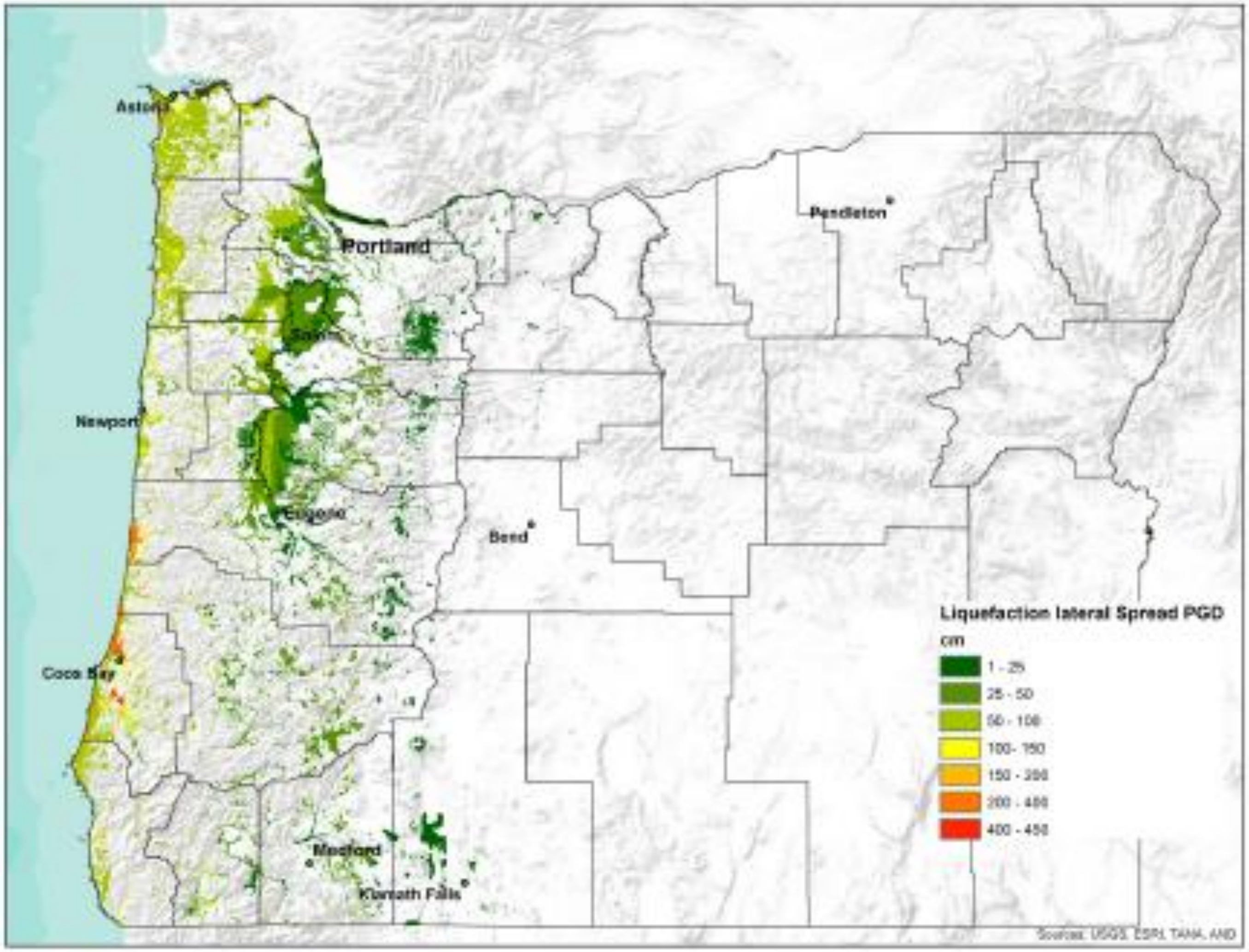
Note: This liquefaction susceptibility map shows areas where soils can liquefy due to the earthquake ground shaking. Areas in red are most prone to liquefy.
Source: Madin and Burns (2013)

Figure 42. Liquefaction Probability Map



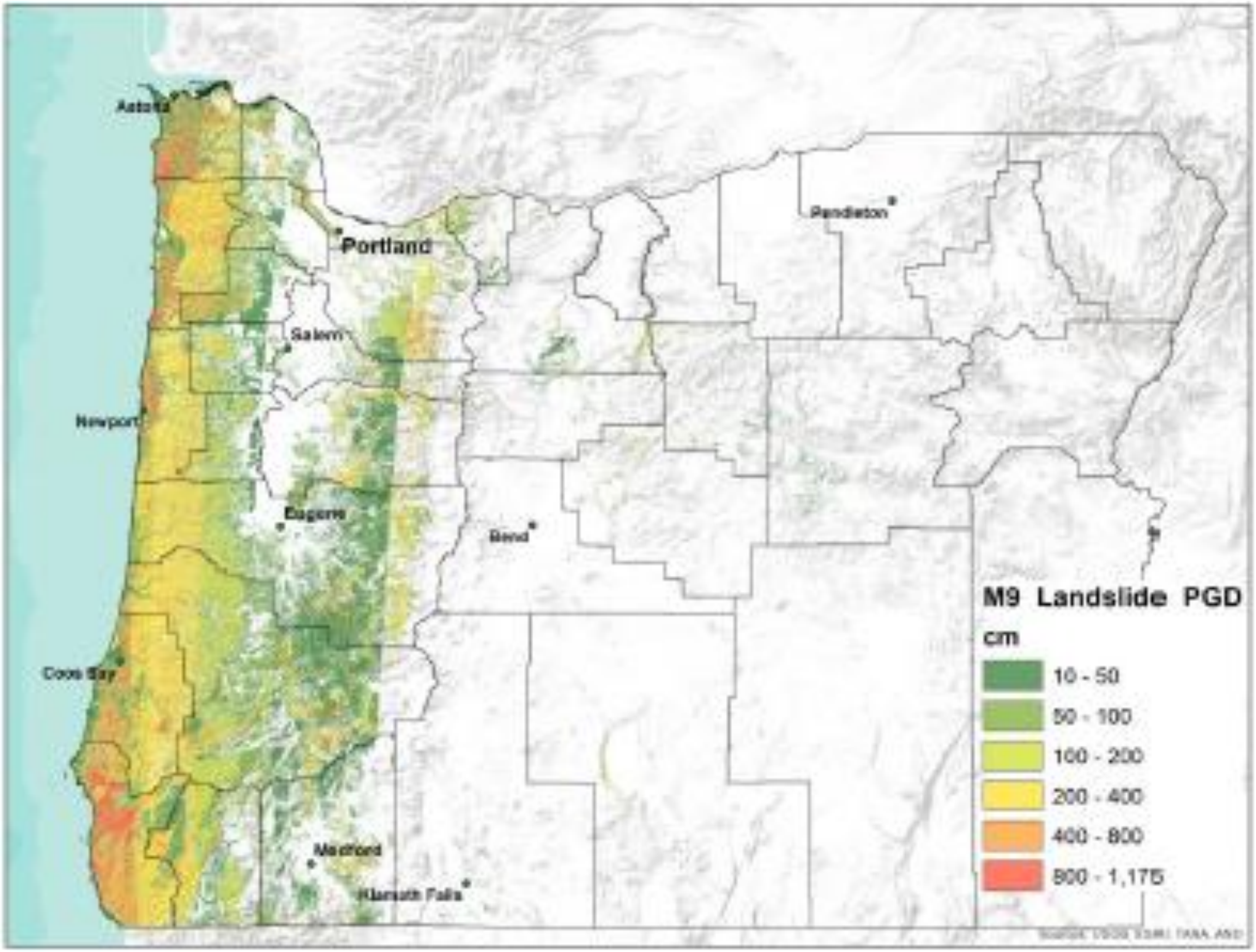
Note: This liquefaction probability map shows the probability of soil liquefaction due to a magnitude 9 Cascadia earthquake. Areas in dark red have the highest probability.
Source: Madin and Burns (2013)

Figure 43. Lateral Spreading Map



Note: This lateral spreading map shows areas of lateral spreading hazard due to a magnitude 9 Cascadia earthquake. Areas in red have the highest displacement.
Source: Madin and Burns (2013)

Figure 44. Expected Displacement Map



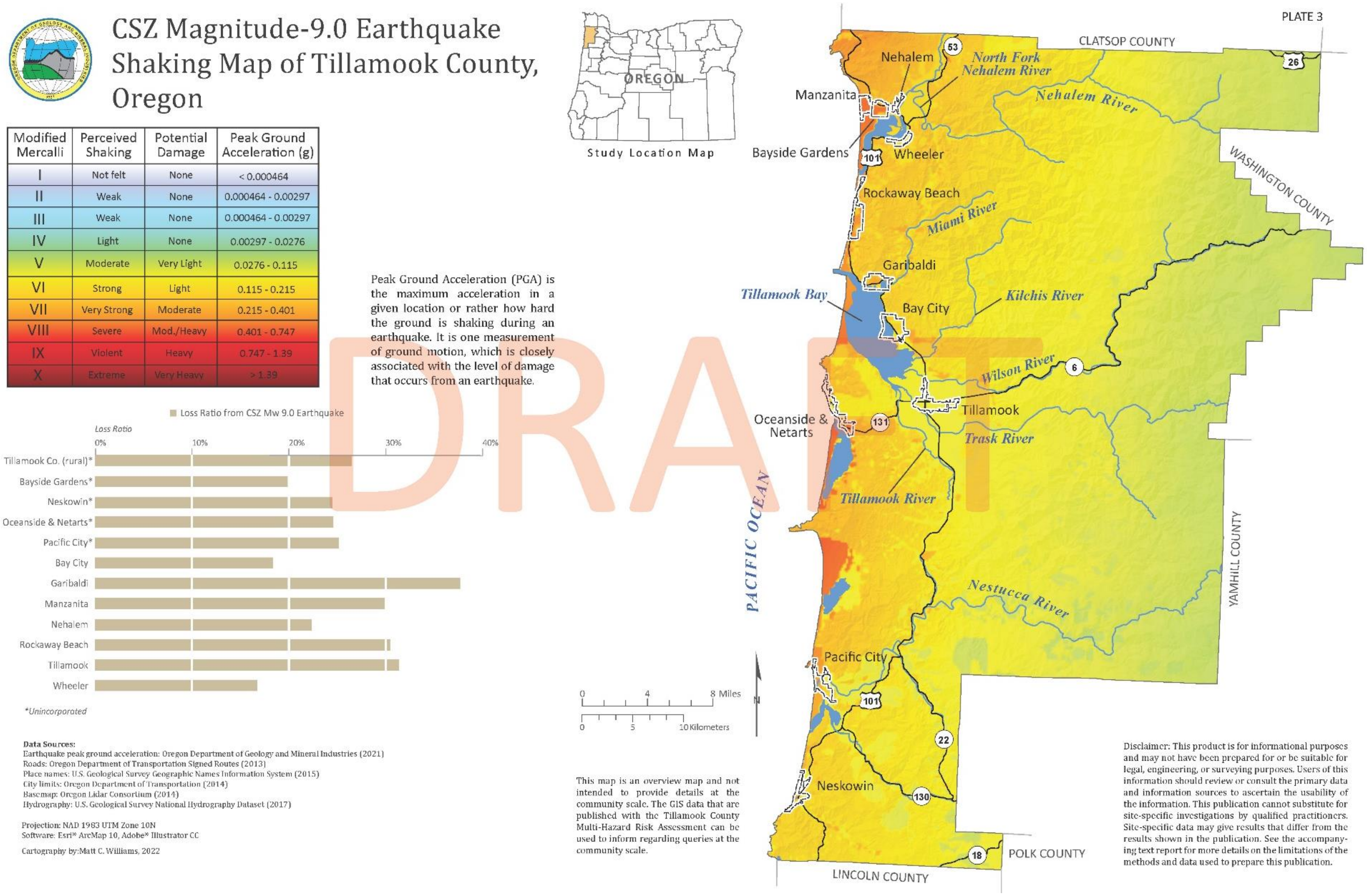
Note: This landslide hazard map shows areas and amount of expected displacement due to a magnitude 9 Cascadia earthquake. Areas in red have the highest displacement.
Source: Madin and Burns (2013)

The 2022 DOGAMI Multi-hazard Risk Assessment analyzed two earthquake scenarios under which they modeled loss and damage estimates. These are the Cascadia Subduction Zone and Happy Camp fault earthquakes. The figures below are from that report and show peak acceleration for both scenarios.

The crustal earthquake scenario examined for DOGAMI's MHRA report is the Happy Camp fault, located a few miles south of Tillamook Bay and oriented east to west. This fault is a Quaternary fault and is about 1.8 miles (3 km) long, approximately 5.6 miles (9 km) deep, and experiences slip of 0.2mm/yr (0.008 in/yr). The estimated maximum fault displacement could produce relatively large (Mw-6.6) crustal earthquakes, enough to pose a significant hazard (see MHRA for Personius, 2002). Although the damage produced from this fault would be far more localized than a CSZ event, it poses a possible seismic threat to the communities in the vicinity of Tillamook Bay. Using the U.S. Geological Survey (USGS) "Unified Hazard Tool" from the National Seismic Hazard Model, the likelihood or probability of risk from a Happy Camp fault generated earthquake versus any other earthquake scenario, is about 2%. The remaining 98% likelihood is from CSZ generated earthquakes.

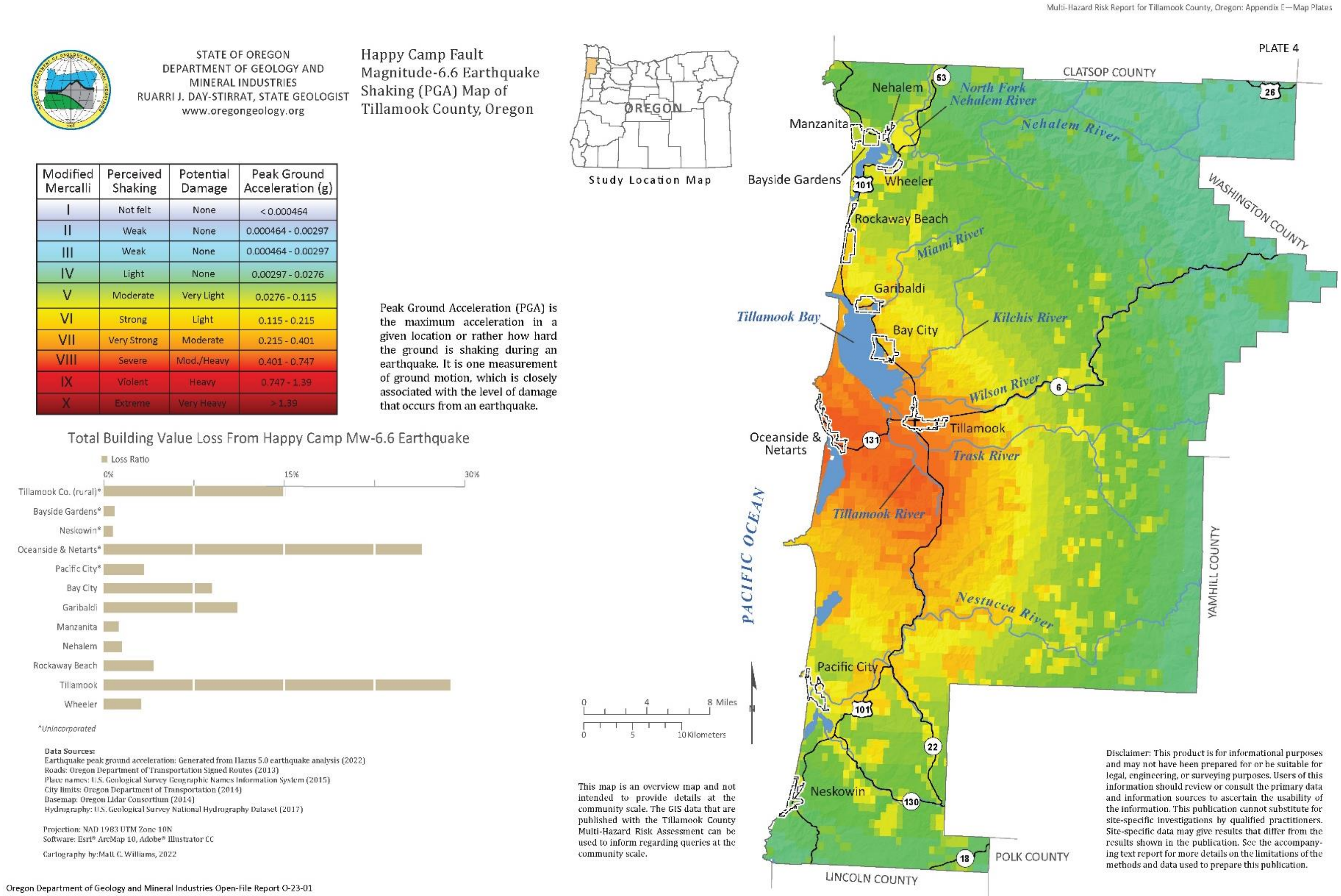
The Happy Camp Fault is considered "undifferentiated Quaternary" in age, meaning major seismic activity is likely to have occurred sometime in the last 1.6 million years (U.S. Quaternary faults), but no further constraint on the timing is known. There is higher uncertainty with this fault's activity level, and when it last was active, than the CSZ, which is considered "Latest Quaternary," or having had major seismic activity in the last 15,000 years. In fact, we have several well-defined records of when the CSZ last experienced a large earthquake, which was in 1700 CE, as well as several earlier, well-constrained rupture dates. Also, preparation for a CSZ earthquake would be similarly useful for a local crustal earthquake, so we consider CSZ results to be the most useful for understanding the totality of the earthquake and coseismic hazard events, such as tsunami and liquefaction. We have included the Happy Camp analysis as a means to better understand the overall earthquake risk in Tillamook County.

Figure 45. Earthquake Peak Ground Acceleration – CSZ M9.0 scenario



DOGAMI (2022)

Figure 46. Earthquake Peak Acceleration – Happy Camp scenario



Source: DOGAMI (2022)

Historic Earthquake Events

Table 32 lists historic earthquakes that impacted or may have impacted Tillamook County from both CSZ events and combined crustal events.

Table 32. Historic Earthquakes that May Have Impacted Tillamook County

Date	Location	Description
Approximate Years: 1400 BCE*, 1050 BCE, 600 BCE, 400, 750, 900	offshore, Cascadia Subduction Zone	probably 8-9 *these are the mid-points of the age ranges for these six events*
Jan. 1700	offshore, Cascadia Subduction Zone	about 9.0 generated a tsunami that struck Oregon, Washington, and Japan; destroyed Native American villages along the coast
1892[1]	Portland, Oregon	intensity VI; affected area: 26,000 square kilometers; buildings swayed, people terrified and rushed into the street; felt in Astoria and Salem
Apr. 13, 1941[1]	Olympia, Wash.	magnitude 7.0; at Olympia, Washington, and a broad area around the capital city; fatalities: 8; damage: $25 million; affected area: 388,000 sq km; damage: widespread (Oregon); injuries: several (Astoria and Portland); maximum intensity: VIII (Clatskanie and Rainier); chimneys twisted and fell; damage to brick and masonry
Dec. 15, 1953[1]	Portland, Oregon	intensity: VI; minor damage (Portland area); affected area: 7,700 sq km; one cracked chimney and slight damage to fireplace tile; plaster cracking (Portland and Roy, Oregon, and Vancouver, Washington)
Nov. 6, 1961[1]	Portland, Oregon	intensity VI; affected area: 23,000 sq km (northwestern Oregon and southwestern Washington); principle damage: plaster cracking; part of a chimney fell, and windows and lights broke
1993[2]	Scott's Mills, Oregon	5.7 M_w; largest earthquake since 1981; felt from Puget Sound to Roseburg, Oregon4
February 28, 2001[2]	Nisqually, Wash.	6.8 M_w at a depth of 57 km ; an interplate earthquake with a Mercalli intensity of VIII (Severe) felt as far south as central Oregon

*BCE: Before Common Era.

Sources: (1) USGS. Oregon Earthquake History. Retrieved October 28, 2013, http://earthquake.usgs.gov/earthquakes/states/oregon/history.php; (2) USGS. Earthquake Archive. Retrieved October 28, 2013, http://earthquake.usgs.gov/earthquakes/search/; (3) Sherrod (1993); (4) Thomas, Crosson, Carver & Yelin (1996); (5) Dewey (1993); (6) Bott and Wong (1993)

During the 2000-2022 timeframe, the USGS recorded four earthquakes that occurred on land in or near Tillamook County (2001, 2015, 2021, 2022) and exceeded M 2.5 and one earthquake that occurred in the ocean 29 kilometers west of Neskowin that registered magnitude 3.1. Neither caused damage in Tillamook County or elsewhere.

Table 33. Recent Earthquakes in Tillamook County 2017-2022 > M 2.5.

Date	Location	Magnitude
May 6, 2001	17 km N of Willimina	M 2.9, depth 51.5 km
June 25, 2015	24 km WNW of Gaston	M 3.1, depth 51.6 km
November 27, 2021	11 km WNW of Beaver	M 2.5, depth 15.3 km
September 24, 2022	1 km S of Tillamook	M 2.5, 17.9 km depth

Source: USGS. Earthquake Archive. Retrieved April 22, 2023, http://earthquake.usgs.gov/earthquakes/search/

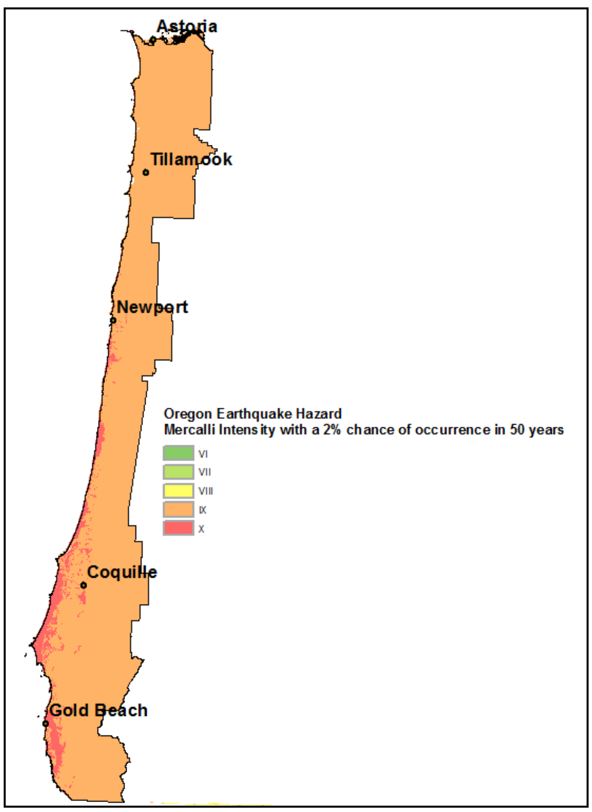
Probability

In coastal Oregon, the probability of damaging earthquakes is dominated by Cascadia subduction earthquakes originating from a single fault with a well-understood recurrence history.

Error! Reference source not found. shows the probabilistic hazard for the Oregon Coast. This map shows the expected level of earthquake damage that has a 2% chance of occurring in the next 50 years. The map is based on the 2008 USGS National Seismic Hazard Map and has been adjusted to account for the effects of soils following the methods of Madin and Burns (2013). In this case, the strength of shaking calculated as peak ground acceleration and peak ground velocity is expressed as Mercalli intensity, which describes the effects of shaking on people and structures. This map incorporates all that is known about the probabilities of earthquake on all faults, including the Cascadia Subduction Zone.

For the Oregon Coast, the Cascadia subduction zone is responsible for most of the hazard. The paleoseismic record includes 18 magnitude 8.8–9.1 megathrust earthquakes in the last 10,000 years that affected the entire subduction zone. The return period for the largest earthquakes is 530 years, and the probability of the next such event occurring in the next 50 years ranges from 7 to 12%

Figure 17. Probabilistic Earthquake Hazard for the Oregon Coast



Color zones show the maximum level of earthquake shaking and damage (Mercalli Intensity Scale) expected with a 2% chance of occurrence in the next 50 years. A simplified explanation of the Mercalli levels is:

- VI Felt by all, weak buildings cracked;
- VII Chimneys break, weak buildings damaged, better buildings cracked;
- VIII Partial collapse of weak buildings, unsecured wood frame houses move;
- IX Collapse and severe damage to weak buildings, damage to wood-frame structures; and
- X Poorly built structures destroyed, heavy damage in well-built structures.

Source: Madin and Burns (2013)

Vulnerability

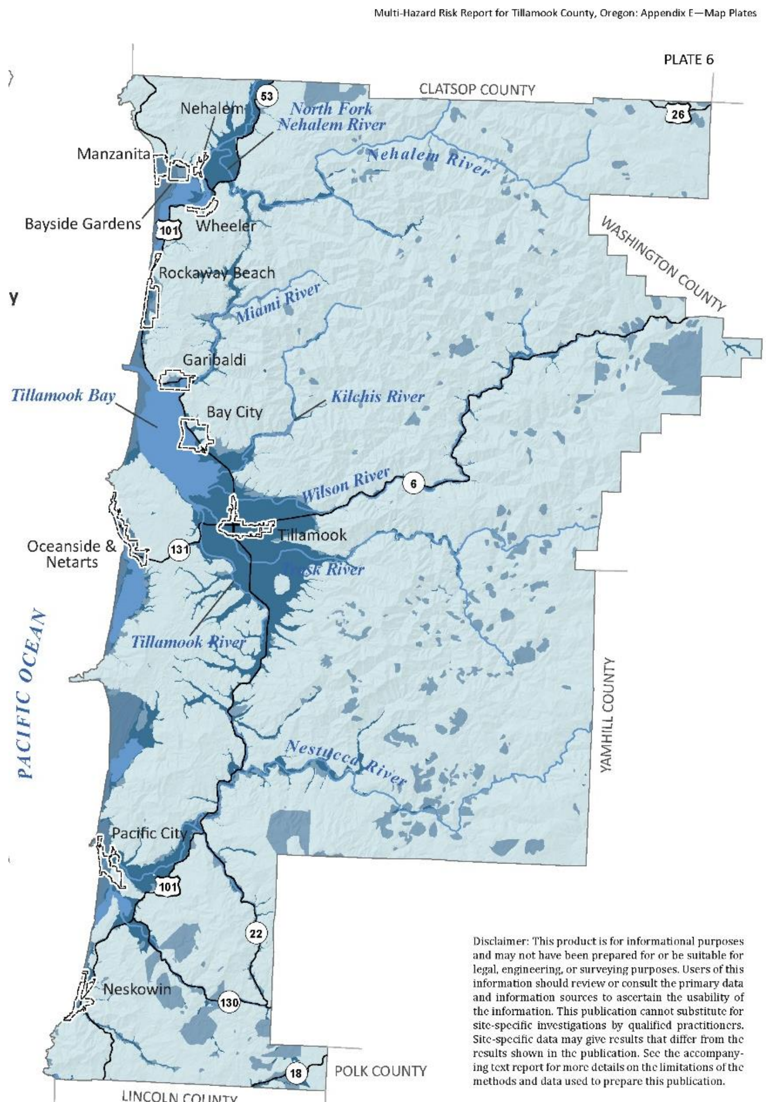
Vulnerability expresses the impacts to people and the built environment anticipated from an earthquake.

A major Cascadia earthquake (>M_W 8.5) would be devastating. Most of the state's major critical infrastructure such as energy sector lifelines, transportation hubs, and medical facilities are particularly vulnerable to damage from liquefaction and long periods of shaking. The long-term effects from a major earthquake would be felt for years.

Tillamook County is especially vulnerable to earthquake hazards. This is because of the built environment's proximity to the CSZ, regional seismicity, topography, bedrock geology, and local soil profiles. For example, a large number of buildings are constructed of unreinforced masonry (URM) or are constructed on soils that are subject to liquefaction during severe ground shaking. Also, some principal roads and highways are susceptible to earthquake-induced landslides. Bridges and tunnels need to be retrofitted to withstand ground shaking.

The results indicate that Tillamook County will incur losses of approximately $1.5 billion or 22% of their total building assets due to a CSZ Mw-9.0 earthquake. These results are strongly influenced by the ground deformation from liquefaction. Moderate to high liquefaction susceptibility exists throughout the county, which increases the risk from an earthquake. Most developed areas in Tillamook County are in proximity to estuaries and within floodplains which tend to be composed of highly liquefiable soil.

Figure-47. Liquefaction Susceptibility in Tillamook County



Source: DOGAMI (2022)

Seismic Lifelines

"Seismic lifelines" are the state highways ODOT has identified as most able to serve response and rescue operations, reaching the most people and best supporting economic recovery. According to ODOT's report, *Statewide Loss Estimates: Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification* (CH2M Hill, 2012), seismic lifelines on the Oregon Coast have the following vulnerabilities.

The Oregon Coast has the most seismically vulnerable highway system of all the geographic zones and is the most difficult to access due to multiple geographic constraints. While it could be argued that the region's critical post-earthquake needs should dictate that all coastal area routes be Tier 1 (first priority roadways), the reality is that — to make the entire lifeline system resilient — the vulnerabilities on the Coast are so extensive that the majority of the cost would be incurred for repairs done within this region. Furthermore, because of the high vulnerability of the region, it is paramount that emergency services and recovery resources are able to reach this region from other regions. Consequently, all needs are best served with a conservative Tier 1 backbone system, selected according to the criteria described in the report.

The Tier 1 (first roadway priority) system on the Oregon Coast consists of three access corridors:

- OR-30 from Portland to Astoria,
- OR-18 from the Willamette Valley to US-101 and north and south on US-101 between Tillamook and Newport, and
- OR-38 from I-5 to US-101, and north and south on US-101 from Florence to Coos Bay.

The Tier 2 (second roadway priority) system on the Oregon Coast consists of three access corridors:

- US-26 from OR-217 in Portland to US-101 and north and south on US-101 from Seaside to Nehalem,
- OR-126 from the Valley to US-101 at Florence, and
- US-101 from Coos Bay to the California border.

The Tier 3 (third roadway priority) system on the Oregon Coast would complete an integrated coastal lifeline system and consists of the following corridors:

- US-101 from Astoria to Seaside,
- US-101 from Nehalem to Tillamook,
- OR-22 from its junction with OR-18 to the Valley,
- OR-20 from Corvallis to Newport,
- OR-42 from I-5 to US-101, and
- US-199 from I-5 to the California border.

Regional Impact

Coastal highways, most importantly US-101, will be fragmented in many areas. In some areas there are possible detours inland from US-101, but many of those routes are also vulnerable to ground shaking, landslides, and other hazards.

- Ground shaking: On the Oregon Coast ground shaking will be intense and prolonged. Most unreinforced structures and many unreinforced roadbeds and bridges will be damaged to varying extents, and it is likely that many damaged areas will become impassable without major repairs.
- Landslides and Rockfall: Many areas along the coast highway, US-101, are cut into or along landslide prone features. Removal of slide and rockfall material is an ongoing responsibility of ODOT Maintenance crews on long stretches of the highway. A major seismic event will increase landslide and rockfall activities and may reactivate ancient slides that are currently inactive.

- Tsunami: Some reaches of US-101 and connecting and parallel routes will be inundated by tsunami. Tsunami debris may block large areas of the street and highway network.
- Liquefaction: Structures in wetland, estuarine, alluvial and other saturated areas will be subject to liquefaction damage; the total area of such impacts will vary with the extent of saturated soils at the time of the event.

Regional Loss Estimates

Highway-related losses include disconnection from supplies and replacement inventory, and the loss of tourists and other customers who must travel to do business with affected businesses.

Most Vulnerable Jurisdictions

The vulnerabilities studied in the Oregon Seismic Lifeline Report project are geographic rather than jurisdictional. Other research suggests that the risks of a subduction zone seismic event are somewhat higher along the Southern Oregon Coast, but the risks assessed in this study pertain to the vulnerability of highway facilities in the case of a CSZ event and the higher vulnerabilities are generally low-lying areas, active and ancient landslide and rock fall areas, and where critical bridges may not be easily repaired or circumvented. Vulnerability also relates to a current conditions context — high groundwater and saturated soils, high tides, and time of day as it relates to where people are relative to the highway system and other vulnerable facilities. The Port of Garibaldi is built on fill in Tillamook Bay and is therefore subject to liquefaction of the entire facility in the event of an earthquake. Tillamook County is highly vulnerable to a CSZ event.

Loss Estimation

The *Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2022) provides an explanation and supporting statistics illustrating the effect of iterative advancements in seismic building codes on structural losses due to earthquakes. It also provides an earthquake loss estimate for Tillamook County based on data created for the *Oregon Resilience Plan for Cascadia Subduction Zone Earthqua*kes (Madin & Burns, 2013) and a 9.0 magnitude CSZ earthquake.

Table 34. CSZ Earthquake Loss Estimates: Tillamook County and Cities

			(all dollar amounts in thousands)									
			Total Earthquake Damage*		**Earthquake Damage outside of Medium Tsunami Zone**							
									Building Design Level Upgraded to at Least Moderate Code			
	Total Number of Buildings	**Total Estimated Building Value ($)**	**Buildings Damaged**		**Buildings Damaged**							
Community			**Sum of Economic Loss**	**Loss Ratio**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss**	**Loss Ratio**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss**	**Loss Ratio**
Unincorp. County (rural)	14,107	3,610,281	961,387	27%	2,873	1,189	846,758	23%	2,607	647	527,099	15%
Bayside Gardens	945	186,325	37,614	20%	265	77	35,747	19%	232	62	31,144	17%
Neskowin	652	141,094	34,753	25%	32	8	5,780	4%	24	6	4,640	3%
Oceanside & Netarts	1,628	302,588	74,865	25%	493	159	71,051	23%	400	109	56,721	19%
Pacific City	1,721	361,114	91,384	25%	273	74	44,443	12%	224	54	37,548	10%
Total Unincorp. County	**19,050**	**4,598,402**	**1,200,003**	**26%**	**3,936**	**1,507**	**1,003,779**	**22%**	**3,487**	**878**	**657,152**	**14%**
Bay City	880	229,175	42,388	18%	145	44	37,779	16%	116	28	28,059	12%
Garibaldi	755	179,063	67,965	38%	241	97	54,416	30%	148	41	30,627	17%
Manzanita	1,517	274,658	82,840	30%	434	133	64,332	23%	354	83	51,280	19%
Nehalem	234	54,360	12,232	23%	31	8	8,199	15%	22	5	4,520	8%
Rockaway Beach	2,095	454,733	139,386	31%	173	51	30,077	7%	142	35	25,277	6%
Tillamook	2,194	982,931	309,985	32%	521	263	309,757	32%	519	139	161,461	16%
Wheeler	362	81,137	13,654	17%	60	20	11,215	14%	55	13	8,374	10%
Total Tillamook County	**27,090**	**6,854,759**	**1,868,454**	**27%**	**5,541**	**2,123**	**1,519,554**	**22%**	**4,843**	**1,219**	**966,751**	**14%**

*Yellow-tagged buildings are considered extensively damaged.

**Red-tagged buildings are considered a total loss.

All losses calculated from earthquake inside or outside of Medium tsunami zone.

Source: DOGAMI (2022)

Table 35. CSZ Earthquake Loss Estimates: Port of Tillamook Bay and Port of Garibaldi

			Total Earthquake Damage (Includes Medium Tsunami Zone)		Excludes Medium Tsunami Zone							
			Buildings Damaged		Buildings Damaged				All Buildings Changed to at Least Moderate Code			
Community	Total Number of Buildings	Total Estimated Building Value ($)	Sum of Economic Loss ($)	Loss Ratio	Yellow*-Tagged Buildings	Red**-Tagged Buildings	Sum of Economic Loss ($)	Loss Ratio	Yellow*-Tagged Buildings	Red**-Tagged Buildings	Sum of Economic Loss ($)	Loss Ratio
Port of Garibaldi	36	8,035,760	6,476,037	81%	0	4	544,725	7%	ND	ND	ND	ND
Port of Tillamook	83	61,545,144	29,138,980	47%	18	39	29,138,980	47%	ND	ND	ND	ND

*Yellow-tagged buildings are considered extensively damaged.

**Red-tagged buildings are considered a total loss.

ND = not done

Source: Derived from DOGAMI (2016)

The Port of Garibaldi would be 100% damaged in the event of a tsunami. It would also potentially suffer 100% damage from liquefaction in the event of an earthquake not associated with a tsunami.

Table 36. Happy Camp Mw 6.6 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
Unincorp. County (rural)	14,107	3,610,281	2,071	636	548,865	15%	1,857	497	437,021	12%
Bayside Gardens	945	186,325	15	3	2,673	1.4%	14	3	2,486	1.3%
Neskowin	652	141,094	7	1	1,605	1.1%	6	1	1,249	0.9%
Oceanside & Netarts	1,628	302,588	482	174	74,538	25%	426	127	62,696	21%
Pacific City	1,721	361,114	92	22	13,452	3.7%	87	21	12,452	3.4%
Total Unincorp. County	**19,050**	**4,598,402**	**2,668**	**836**	**641,134**	**14%**	**2,390**	**650**	**515,904**	**11%**
Bay City	880	229,175	76	19	18,948	8.3%	64	16	15,694	6.8%
Garibaldi	755	179,063	70	17	17,543	9.8%	54	13	12,865	7.2%
Manzanita	1,517	274,658	29	7	4,826	1.8%	26	6	4,237	1.5%
Nehalem	234	54,360	5	1	1,135	2.1%	4	1	929	1.7%
Rockaway Beach	2,095	454,733	125	29	21,934	4.8%	114	28	19,740	4.3%
Tillamook	2,194	982,931	658	224	283,930	29%	571	153	204,161	21%
Wheeler	362	81,137	17	4	2,509	3.1%	16	4	2,186	2.7%
Total Study Area	**27,090**	**6,854,759**	**3,648**	**1,136**	**991,959**	**15%**	**3,239**	**870**	**775,715**	**11%**

Source: DOGAMI (2022)

Seismic Building Codes

The years that seismic building codes are enforced within a community, called "benchmark" years, have a great effect on the results produced from the Hazus-MH earthquake model. Oregon initially adopted seismic building codes in the mid-1970s. 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 earthquake model to determine what damage functions are applied to a given building. 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 Tillamook County. The information in the **Table 37** outlines the various benchmark years that apply to buildings within Tillamook County.

Table 37. Tillamook County Seismic Design Level Benchmark Years

Building Type	Year Built	Design Level	Basis
Single Family Dwelling (includes Duplexes)	Prior to 1976	Pre Code	Interpretation of Judson (2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–Present	High Code	
Manufactured Housing	Prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured Dwelling Special Codes http://www.oregon.gov/bcd/codes-stand/Documents/md-2002-mdparks-code.pdf
	2003–2010	Low Code	
	2011–Present	Moderate Code	Interpretation of OR BCD 2010 Manufactured Dwelling Special Codes Update http://www.oregon.gov/bcd/codes-stand/Documents/md-2010omdisc-codebook.pdf
All other buildings	Prior to 1976	Pre Code	Business Oregon (BO) 2014-0311 Oregon Benefit-Cost Analysis Tool (Business Oregon, 2015, p. 24)
	1976–1990	Low Code	
	1991–Present	Moderate Code	

Source: DOGAMI (2016)

Table 38 and **Table 39** and corresponding **Figure 48** and **Figure 49** illustrate the current state of seismic building codes for the county. A comparison of the data from the DOGAMI 2016 report and the DOGAMI 2022 report shows a reduction in the percentage of buildings in the Pre-Code category and an increase in the percentage of buildings in the High Code category. Note that the table for the ports have not been updated using 2022 data, although that analysis can be performed using the geodatabase provided by DOGAMI. Analysis of the ports was not separately performed for the 2022 report.

Table 38. Seismic Design Level: Tillamook County and Cities

		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**
Unincorp. County (rural)	14,107	4,941	35%	2,287	16%	4,816	34%	2,063	14.6%
Bayside Gardens	945	117	12%	136	14.4%	391	41.4%	301	31.9%
Neskowin	652	286	44%	102	16%	147	23%	117	17.9%
Oceanside & Netarts	1,628	424	26%	244	15%	520	32%	440	27.0%
Pacific City	1,721	487	28%	252	14.6%	577	33.5%	405	23.5%
Total Unincorp. County	**19,050**	**6,255**	**33%**	**3,021**	**16%**	**6,451**	**34%**	**3,326**	**17.5%**
Bay City	880	341	39%	122	13.9%	166	18.9%	251	28.5%
Garibaldi	755	378	50%	88	12%	160	21%	129	17.1%
Manzanita	1,517	325	21%	368	24%	495	33%	329	21.7%
Nehalem	234	112	48%	23	9.8%	63	27%	36	15%
Rockaway Beach	2,095	649	31%	202	9.6%	536	25.6%	708	33.8%
Tillamook	2,194	1,240	57%	182	8.3%	517	23.6%	255	11.6%
Wheeler	362	153	42%	34	9.4%	113	31%	62	17.1%
Total Tillamook County	**27,090**	**9,453**	**35%**	**4,040**	**15%**	**8,501**	**31%**	**5,096**	**19%**

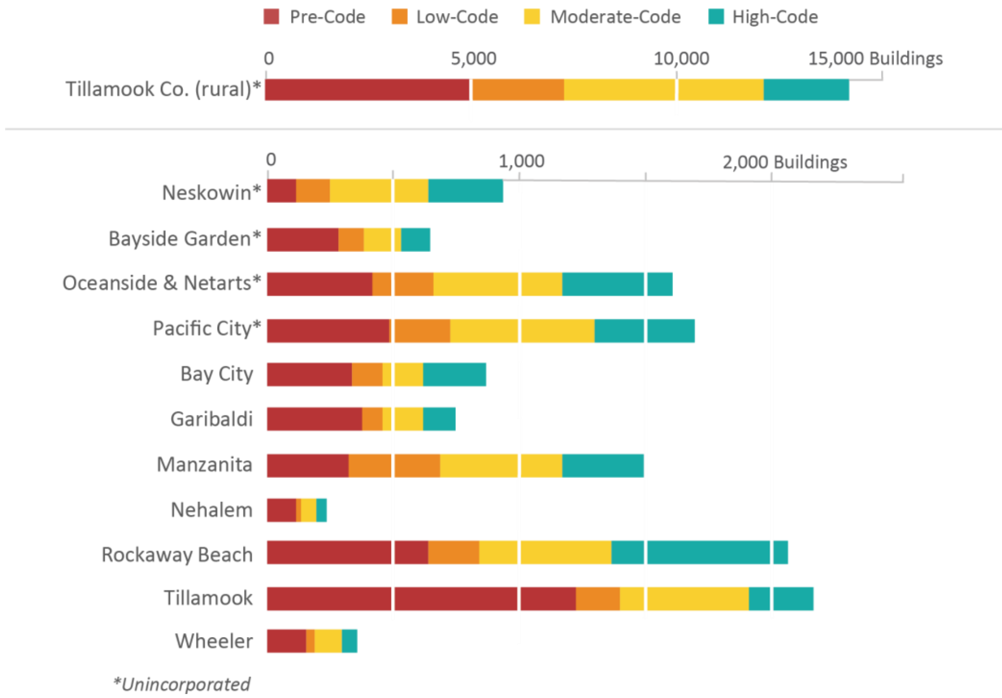
Source: DOGAMI (2022)

Table 39. Seismic Design Level: Port of Tillamook Bay and Port of Garibaldi

		Pre-Code		Low-Code		Moderate-Code		High-Code	
Community	**Total Number of Buildings**	**Number of Buildings**	**% of Buildings**	**Number of Buildings**	**% of Buildings**	**Number of Buildings**	**% of Buildings**	**Number of Buildings**	**% of Buildings**
Port of Tillamook Bay	87	20	23%	14	16%	53	61%	0	0%
Port of Garibaldi	35	11	31%	13	37%	11	31%	0	0%

Source: Derived from DOGAMI (2016)

Figure 48. Seismic Design Level by Community

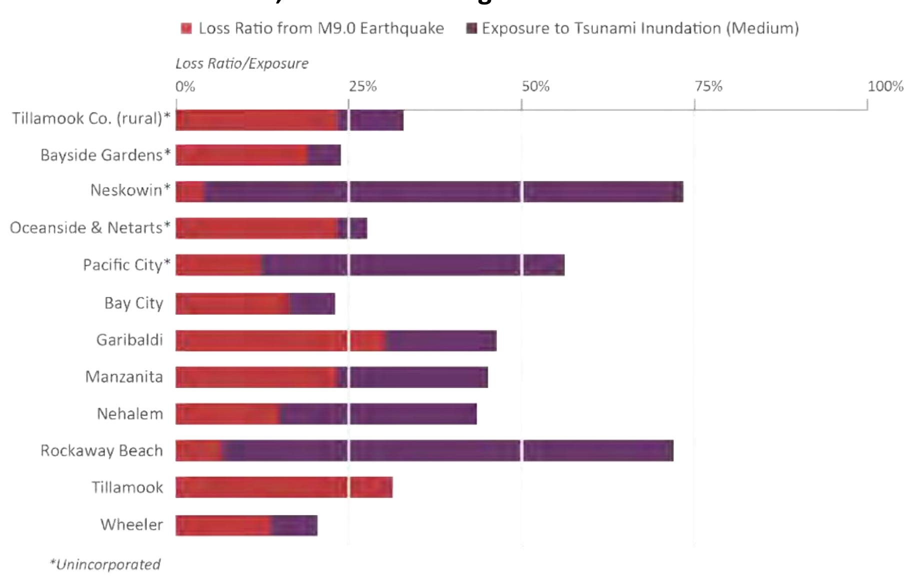


*Unincorporated communities. Note that "Tillamook Co. (rural)" excludes incorporated communities, Pacific City, Oceanside-Netarts, and Neskowin.

Source: DOGAMI (2022)

Because a CSZ earthquake is likely to produce a tsunami and the impacts of the two are closely related, DOGAMI assumed for this estimate that any structure in the medium tsunami zone would be a total loss, and so are analyzed as exposure only. Earthquake damage estimates are reported for structures outside the medium tsunami zone.

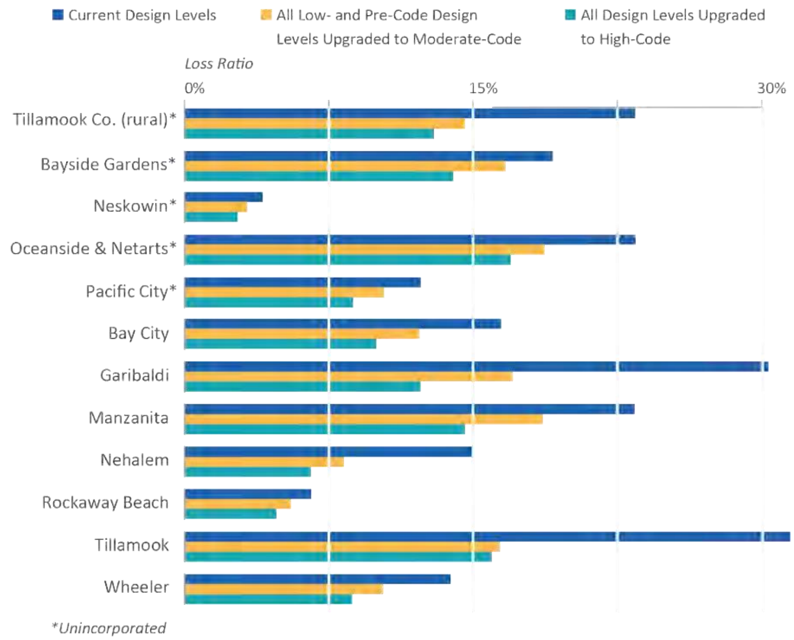
Figure 49. CSZ M9.0 Event Loss Ratio, for Both Shaking and Tsunami Inundation



Source: DOGAMI (2022)

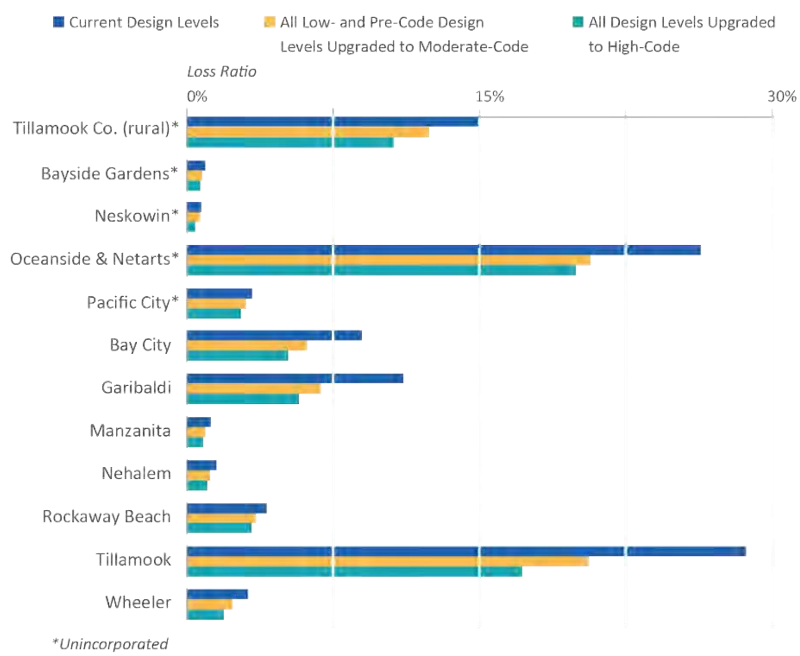
So many buildings were constructed before the advent of seismic codes and with less stringent codes than we have today that we expect a great deal of earthquake damage. DOGAMI analyzed the potential for reducing such damage if buildings were retrofitted to higher seismic building code standards. These results are also reported in Table 38 and Table 39 and illustrated in Figure 50. The results demonstrate that damage could indeed be greatly reduced by upgrading buildings to high code standards , except in areas where landslides, liquefaction or other factors would come into play.

Figure 50. CSZ M9.0 Earthquake Loss Ratio, with Alternate Seismic Design Level Results



Source: DOGAMI (2022)

Figure 51. Happy Camp Mw-6.6 earthquake Loss Ratio, with Alternate Seismic Design Level Results



3. Floods

Introduction

In its most basic form, a flood is an accumulation of water over a normally dry area. When floods inundate areas where people live, work, and play, loss of life and property may result.

Tillamook County has an extensive history of flooding that is typically caused by large-scale weather systems generating prolonged rainfall or rain-on-snow events generating large amounts of runoff. The County also is subject to coastal flooding from high tides and wind-driven waves. While less common, potential also exists for flooding from tsunamis and channel migration. Flooding from tsunamis is discussed in the **Tsunamis** section.

The El Niño Southern Oscillation (ENSO) Cycle influences flooding. El Niño and La Niña are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific. La Niña is sometimes referred to as the cold phase of ENSO and El Niño as the warm phase of ENSO. These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate. El Niño and La Niña episodes typically last nine to 12 months, but some prolonged events may last for years. They often begin to form between June and August, reach peak strength between December and April, and then decay between May and July of the following year. While their periodicity can be quite irregular, El Niño and La Niña events occur about every 3 to 5 years. Typically, El Niño occurs more frequently than La Niña. (Source: NOAA, “What are El Niño and La Niña?”, http://oceanservice.noaa.gov/facts/ninonina.html)

A measure of this cycle is the Southern Oscillation Index (SOI), which is “calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin, Australia.” The earliest systematic study of ENSO in the Northwest was Redmond and Koch (1991). The results were sufficiently strong that the authors suggested a cause-effect relationship between the SOI and Oregon weather. SOI values less than zero represent El Niño conditions, near zero values are average, and positive values represent La Niña conditions.

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

What Oregonians should especially plan for and monitor, however, is La Niña. During La Niña events, heavy rain arrives in Oregon from the western tropical Pacific, where ocean temperatures are well above normal, causing greater evaporation, more extensive clouds, and a greater push of clouds across the Pacific toward Oregon.

Types of Flooding

Riverine and coastal flooding are the most common types of flooding in Tillamook County.

Riverine

Riverine flooding is caused by the passage of a larger quantity of water than can be contained within the normal stream channel. The increased stream flow is usually caused by heavy rainfall over a period of several days.

The most severe flooding conditions occur, however, when heavy rainfall is augmented by rapid snowmelt. These rain-on-snow events occur on mountain slopes within the low elevation snow zones of the Pacific Northwest. These events make more water available for runoff than does precipitation alone by melting the snowpack and by adding a small amount of condensate to the snowpack (van Heeswijk, Kimball, and Marks, 1996). If the ground is frozen, stream flow can be increased even more by the inability of the soil to absorb additional runoff.

There are two distinct periods of riverine flooding in Tillamook County — winter and late spring — with the most serious occurring December through February. The situation is especially severe when riverine flooding, caused by prolonged rain and melting snow, coincides with high tides and coastal storm surges. In short, the rivers back up and flood the lowlands. This type of flooding is especially troublesome in the Tillamook Bay area where homes and livestock can be isolated for several days. Several northern coastal rivers carry heavy silt loads that originated in areas burned during the "Tillamook Burn" fires (1933 to 1951) or from areas covered with volcanic ash during the Mount St. Helens eruption (1980). Consequently, some rivers actually may be elevated above local floodplains, which increases flood hazards. The costs and long-term benefits of dredging these rivers have not been determined.

Coastal

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

Flooding from wind-driven waves is common during the winter, during El Niño events, and when spring and perigean tides occur. The Federal Emergency Management Agency has identified and mapped coastal areas subject to direct wave action (V zones) and sand dune over-topping (AH and AO zones). Direct wave action was especially severe during the winter storm event of 1978 (Nestucca Spit), and the El Niño event of 1997-98. Significant beach and cliff erosion occurred during this period and a number of homes were destroyed. The following lessons were learned:

- Oregon coastal processes are complex and dynamic, sometimes eroding, sometimes accreting.
- Some sections of the Oregon coast are rising in relation to ocean levels, others remain fairly constant or are becoming lower (Komar, 1992);
- Primary frontal dunes provide protection from ocean storms.
- Sand spits are not permanent features; and

- Erosion rates vary and are dependent on several factors including storm duration and intensity, composition of sea cliff, time of year, and impact of human activities (e.g., altering the base of sea cliffs, interfering with the natural movement of beach sand).

Channel Migration

Channel migration is the process by which streams move laterally over time. It is typically a gradual phenomenon that takes place over many years due to natural processes of erosion and deposition. In some cases, usually associated with flood events, significant channel migration can happen rapidly. In high flood flow events stream channels can “avulse” and shift to occupy a completely new channel.

Areas most susceptible to channel migration are transitional zones where steep channels flow from foothills into broad, flat floodplains. The most common physiographic characteristics of a landscape prone to channel migration include moderate channel steepness, moderate to low channel confinement (i.e., valley broadness), and erodible geology.

Dam Failure

Dam failures and accidents, though rare, can result in extreme flooding downstream of the dam. Catastrophic dam failures have occurred in other parts of the country and around the world. The South Fork Dam failure (1889 Johnstown flood) resulted in over 2,000 fatalities in western Pennsylvania. The Saint Francis Dam in southern California failed in 1928 with a loss of an estimated 600 people. Oregon’s dam safety statutes (ORS 540.350 through 400) came into effect shortly after the Saint Francis disaster. Many historical dam failures were triggered by flood events, others by poor dam construction, and some have been triggered by earthquakes.

Location

Table 40. Types of Flooding Hazards Potentially Impacting Each Jurisdiction

Jurisdiction	Riverine Flooding	Coastal Flooding	Channel Migration	Dam Failure
Unincorporated Tillamook County	X	X	X	–
Neskowin	X	X		–
Oceanside-Netarts		X		–
Pacific City	X	X	X	–
Bay City	X			–
Garibaldi	X			–
Manzanita		X		–
Nehalem	X		X	–
Rockaway Beach	X	X		–
Tillamook	X		X	–
Wheeler	X		X	–
Port of Tillamook Bay	X	X		–
Port of Garibaldi	X			–

Source: Derived from DOGAMI (2016)

Hazard Characterization

The principal flood sources in Tillamook County are its rivers, sloughs, and the Pacific Ocean. The Kilchis, Miami, Nehalem, Nestucca, Tillamook, Trask, and Wilson Rivers, Three Rivers, and the Dogherty and Hoquarten Sloughs all drain westward, eventually flowing into the Pacific Ocean. The Pacific Ocean is the source of coastal flooding.

Riverine

Floods are the most common and widely recognized of the hazards within Tillamook County. Flooding generally occurs quickly due to heavy concentrated rainfall. It can be confined to one river system or affect all 7 river systems within the County. Tidal changes coupled with high winds and/or snow accumulation at higher elevations has influence on the severity as well. Flood season is in effect from November 1 through March 31.

Many of the buildings built along the streams and the coast of unincorporated Tillamook County are exposed to the 100-year flood. In Neskowin, developed areas along Neskowin Creek, Kiwanda Creek, and the Pacific Ocean are exposed to the 100-year flood. The primary flood hazard in Pacific City is from the Nestucca River, though coastal flooding may occur. Several buildings inside the 1% flood zone are elevated above the estimated flood level. Central Pacific City is most affected by Nestucca River flooding.

Although some buildings in flood-prone areas have been elevated, greatly reducing overall flood risk, many buildings still can be impacted by floods. Nearly half of the buildings exposed to the 100-year flood in unincorporated Tillamook County and Neskowin, and nearly a quarter in Pacific City are estimated to be elevated above the predicted flood level. While the buildings themselves would not be damaged from flood, access to these buildings could be an issue.

The Cities of Nehalem, Rockaway Beach, and Tillamook are also subject to riverine flooding. Nehalem River flooding presents a particular hazard to structures in the City’s low-lying business area. Floods from Rock Creek and other minor creeks cause damage to structures in low-lying areas of Rockaway Beach. The City of Tillamook lies between two major floodplains created by the Trask, Wilson, and Tillamook Rivers as well as many adjoining tributaries. Numerous buildings in the low-lying areas of the City of Tillamook are exposed to the 100-year flood. Rockaway Beach and the City of Tillamook have sustained significant damage from many floods, most recently during the December 2015 winter storms.

Although many buildings in these cities’ flood-prone areas have been elevated, greatly reducing overall flood risk, many can still be impacted by floods. Nearly half of the buildings exposed to the 100-year flood in unincorporated Rockaway Beach and nearly a third in the City of Tillamook are estimated to be elevated above the predicted flood level. While the buildings themselves would not be damaged from flood, access to these buildings could be an issue. The Port of Garibaldi suffers impacts from flooding of rivers that empty into Tillamook Bay. Flooding causes increased sediment deposits in the Bay and boat basin hindering safe navigation of vessels and creating a need for frequent dredging.

Coastal

Coastal flooding regularly hammers low-lying areas of Neskowin and Rockaway Beach in particular, and to a lesser extent Pacific City. Rockaway Beach was particularly hard-hit during the December 2015 winter storms.

Channel Migration

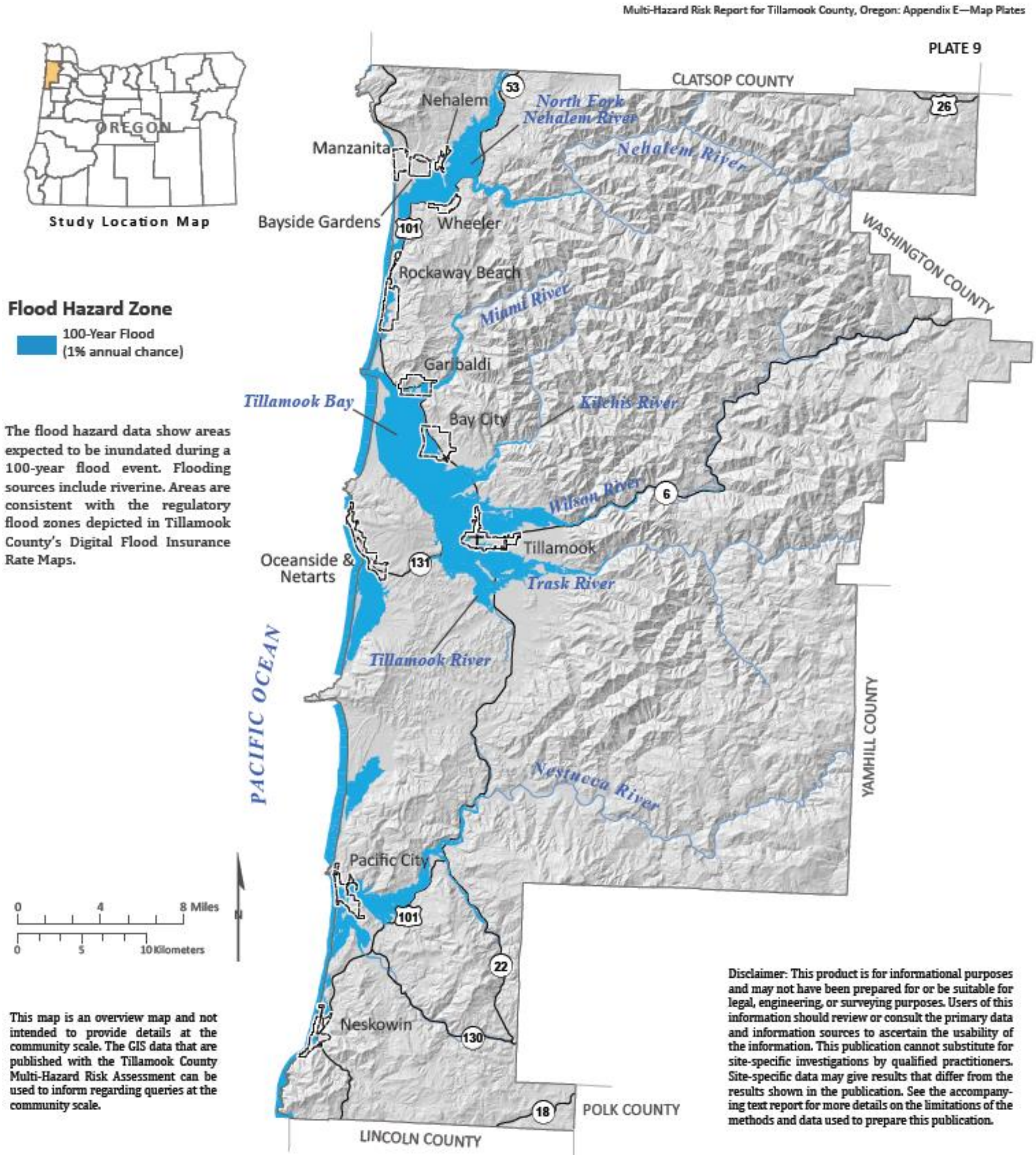
In 2015, DOGAMI produced *Statewide Subbasin-Level Channel Migration Screening for Oregon*, a statewide study of susceptibility to channel migration (Roberts and Anthony, 2015). The Nehalem, Wilson, Trask, and Nestucca Rivers were studied. In general, where these rivers flow through lower elevations, their susceptibility for channel migration is greatest. More study is necessary to accurately determine the area within which their channels are likely to migrate over time and evaluate potential losses.

Exposure to flooding of any type is minimal in Oceanside-Netarts and the Cities of Bay City, Garibaldi, Manzanita, and Wheeler.

Dam Failure

Only two dams exist today that could potentially pose a threat to Tillamook County — the Barney Reservoir and the McGuire Reservoir dams. However, both are among the most resistant to earthquakes in the Oregon, and are not likely to fail in a Cascadia event. (Keith Mills, Oregon Water Resources Department, personal communication, September 2016) Therefore, flooding from dam failure is not considered a hazard of concern in Tillamook County.

Figure 52. Flood Hazard



DOGAMI (2022)

Historically Significant Flood Events

Table 41. Historic Floods in Tillamook County

Date	Location	Description	Type of Flood
1813	NW Oregon	said to exceed "Great Flood" of 1861 (source: Native Americans)	unknown
Feb. 1890	coastal rivers	widespread flooding	rain on snow
Mar. 1931	western Oregon	extremely wet and mild; saturated ground	rain on snow
Dec. 1933	northern Oregon	intense warm rains; Clatskanie River set record	rain on snow
Dec. 1937	western Oregon	heavy coastal rain; large number of debris flows	rain on snow
Dec. 1953	western Oregon	heavy rain accompanied major windstorm; serious log hazards on Columbia	rain on snow
Dec. 1955	Columbia and coastal streams	series of storms; heavy, wet snow; many homes and roads damaged	rain on snow
Mar. 1964	coast and Columbia River estuary	ocean flooding	tsunami
Dec. 1964	entire state	two storms; intense rain on frozen ground	rain on snow
Jan. 1972	northern coast	severe flooding and mudslides; 104 evacuated from Tillamook	rain on snow
Jan. 1974	western Oregon	series of storms with mild temperatures; large snowmelt; rapid runoff	rain on snow
Dec. 1978	coastal streams	intense warm rain; widespread flooding	rain on snow
Feb. 1986	entire state	warm rain and melting snow; numerous homes evacuated	rain on snow
Feb. 1987	western Oregon	heavy rain; mudslides; flooded highways; damaged homes	rain on snow
Dec. 1989	Clatsop, Tillamook and Lincoln	warm Pacific storm system; high winds; fatalities; mudslides	rain on snow
Jan. 1990	W. Oregon	significant damage in Tillamook County; many streams had all-time records	rain on snow
Apr. 1991	Tillamook County	48-hour rainstorm. Wilson River 5 ft. above flood stage; businesses closed	rain on snow
Feb. 1996	NW Oregon	deep snow pack; warm temperatures; record-breaking rains	rain on snow
Nov. 1996	W. Oregon	record-breaking precipitation; flooding; landslides (FEMA-1149-DR-Oregon)	rain on snow
Nov. 2006	Tillamook County	heavy rains caused major flooding in Nehalem and Tillamook, causing $1 million in damage in Nehalem and $15 million in Tillamook	riverine
Dec. 2007	Tillamook County	heavy rains led to flooding in Tillamook along the Wilson River damaging businesses, homes, the railroad to the Port; county-wide damages total 26 million	riverine
Dec. 2008	Tillamook County	heavy rainfall caused flooding in downtown Tillamook; estimate of $3.8 million in damages throughout Tillamook County	riverine
Jan. 2012	Coos, Curry, Lincoln, and Tillamook Counties	a severe winter storm including flooding, landslides, and mudslides affected mostly the southern Oregon coastal counties	riverine
Sep. 2013	Tillamook County	heavy rain caused flooding at the Wilson River	riverine
Dec. 2015	W. Oregon	severe winter storm; Rockaway Beach flooded on the east side of Hwy 101 due to a combination of sand blocking outlets and high tides meeting large volumes of runoff from higher ground; the Hwy 101 corridor north of the City of Tillamook flooded causing a number of long-duration road closures; previous mitigation projects minimized losses	riverine
2/9/2017	Nehalem River near Foss	A series of fronts brought moderate to heavy rainfall across Northwest Oregon, resulting flooding on many rivers across the area over the next several days. Event Narrative Heavy rain caused the Nehalem River near Foss to flood. The river crested at 18.36 feet, which is 3.36 feet above flood stage.	Riverine Flooding

10/21-10/22/2017	Wilson River near Tillamook, Trask River near Tillamook, Nehalem River near Foss	Episode Narrative: A very potent atmospheric river brought strong winds to the north Oregon Coast and Coast Range on October 21st. What followed was a tremendous amount of rain for some locations along the north Oregon Coast and in the Coast Range, with Lees Camp receiving upwards of 9 inches of rain. All this heavy rain brought the earliest significant Wilson River Flood on record, as well as flooding on several other rivers around the area. 10/21 Event Narrative: Heavy rain, with amounts up to 10.7 inches in the Coast Range led to flooding on the Wilson River near Tillamook. The river crested at 17.05 feet, which is 5.05 feet above flood stage. 35K in property damage for the event. 10/22 Event: Heavy rain caused the Trask River near Tillamook to flood. The river crested at 17.56 feet, which is 1.06 feet flood stage. And at 2S Batterson: Heavy rain caused the Nehalem River near Foss to flood. The river crested at 15.02 feet, which is 0.02 foot above flood stage.	
1/18/2018	Seaside, Cannon Beach, and Neskowin in Tillamook County	A strong stationary low-pressure system off the British Columbia coast brought impressively high seas into the Oregon Coast. Wave heights up to 37 feet were recorded at buoys off the coast, with top one-tenth wave heights up to 45 feet. Tillamook Emergency manager reported Seaside and Cannon Beach had water in streets. Logs and other debris washed up on closed roads. In Neskowin, a hotel prepared ahead of time and had minimal loss from flooding of bottom floor.	Coastal Flooding
12/18-12/20/2018	Wilson River near Tillamook	A strong low-pressure system over the Gulf of Alaska brought a strong cold front through. This generated strong winds across northwest Oregon, and also brought heavy rain which caused flooding on the Tillamook River. Large seas also caused damage in spots along beaches. The Wilson River near Tillamook crested at 12.5 feet around 10 AM, which is 0.5 foot above flood stage. No damage was reported. 12/20: A series of strong Pacific fronts moved across the region bringing high winds to the coast with heavy rain across much of the area. The heavy rains resulted in flooding of some coastal rivers as well as small stream flooding and a debris flow. The gage on the Wilson River near Tillamook (TLMO3) crested at 12.4 feet. Flood stage is 12.0 feet. No damage was reported.	Riverine Flooding
12/13/2020	Northern Oregon Coast	A very active storm system in the north Pacific generated large swell directed at the Washington and Oregon coasts that lasted for several days. Additionally, the combination of high surf and high astronomical tides contributed to tidal overflow.	Coastal Flooding
11/15/2020	Frasier Rd area, county	Strong south winds, large surf, and high astronomical tides resulted in tidal overflow. Water over Frasier Road in Tillamook County.	Coastal Flooding
11/17/2020	Northern Oregon Coast	A deep low-pressure system off the Washington coast brought strong southerly winds and large waves resulting in tidal overflow.	Coastal Flooding

1/3/2021	Wilson River and Trask River near Tillamook	A strong westerly upper-level jet over the northern Pacific was directed at the Washington and Oregon coast, driving a plume of deep moisture toward western Washington and northwest Oregon. The Wilson River near Tillamook (TLMO3) reached flood stage at 0000PST, crested at 13.4 feet, then dropped below flood stage at 0930PST. Flood stage is 12 feet.	Riverine Flooding
1/10 – 1/13/2021	Rockaway Beach, Garibaldi, Seaside, Trask River near Tillamook	A series of slow-moving fronts brought periods of heavy rain along with strong winds. This resulted in high surf; coastal, river and urban flooding; landslides; and debris flows. At Rockaway Beach in Tillamook County, logs were pushed into the parking lot of the Rockaway Beach City Center and Park. Buoy 46029 reported wave heights of 22 feet at 16 seconds near the time of high tide at the Garibaldi tide gage where the water level reached 10.12 feet at 0942PST. The calculated surge height was 0.46 feet. Flooding on Highway 101 south of Seaside, Oregon during the period of high river levels and higher than normal tidal influence. The Trask River near Tillamook (TRAO3) rose above flood stage at 0115PST, crested at 17.10 feet, then fell below flood stage at 0745PST. Flood stage is 16.5 feet.	Coastal Flooding

Source: Taylor and Hannan (1999), Hazards and Vulnerability Research Institute (2007); Julie Slevin, OEM, personal communication, September 16, 2016; Chris Shirley, DLCD, personal communication, September 16, 2016; National Climatic Data Center, Storm Events, Storm Events Database - Search Page | National Centers for Environmental Information (noaa.gov) ; FEMA https://www.fema.gov/disaster/4258 accessed September 2021;;

Probability

Flood risk or probability is generally expressed by frequency of occurrence and measured as the average recurrence interval of a flood of a given size and place. It is stated as the percent chance that a flood of a certain magnitude or greater will occur at a particular location in any given year.

FEMA's Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) are the most widely used indicators of the probability of flooding. FIRMs depict the inundation area of a flood with a 1% chance of occurring in any year (also known as "base flood" or "100-year flood") as well as inundation area of a flood with a 0.2% chance ("500-year flood), areas where the probability of flooding is unknown, and base flood elevations (BFEs) where they have been calculated. BFE is the projected depth of floodwater at the peak of a base flood, generally measured as feet above sea level. It is important to recognize that floods occur more frequently near the flooding source. Information regarding the probability of flooding at a given location in the regulated flood zones is provided by Flood Insurance Studies (FIS) for large watersheds. FEMA does not provide information about floods emanating from small watersheds (less than one square mile), or for floods caused by local drainage issues. Probabilities for these types of flood are, as a result, difficult to obtain.

Ocean storms can be expected every year. El Niño effects, which tend to raise ocean levels, occur about every 3 to 5 years (Taylor & Hannan, 1999). V (wave velocity) zones, depicted on FEMA's Flood Insurance Rate Maps, are areas subject to 100-year flood events. The Flood Insurance Rate Maps show areas vulnerable to wave action (V zones), as well as ponding and sheet-flow from waves over-topping dunes (AO and AH zones). Currently, DOGAMI is working with FEMA to update and remap FEMA coastal flood zones established for Oregon's coastal communities.

Communities participating in the NFIP are required to regulate development in Areas of Special Flood Hazard (1% chance), also known as the 100-year flood zone. The FIRMs are also used to rate required flood insurance policies on homes and businesses with federally backed mortgages.

FEMA initially developed Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) to administer the National Flood Insurance Program (NFIP) in Tillamook County in 1977 and 1978. The FIRMs for the Cities of Bay City, Garibaldi, and Wheeler have not been updated. The others have been updated, with the most recent update completed 12 years ago. FEMA is currently in the process of updating the FIS and FIRMs countywide. The Draft FIS and Draft FIRMs dated 2016, while currently unofficial, are the best available data and were used for this NHMP update. The Area of Special Flood Hazard (1% chance or 100-year flood zone) is basis of the flood exposure and loss analyses.

Table 42. Initial and Effective FIS and FIRM Dates

Jurisdiction	Initial FIRM	Effective FIS & FIRM	Preliminary FIS & FIRM
Unincorporated Tillamook County (includes the Port of Tillamook Bay)	Aug. 1, 1978	Aug. 20, 2002	Dec. 12, 2016
Bay City	Aug. 1, 1978	Aug. 1, 1978	Dec. 12, 2016
Garibaldi (includes the Port of Garibaldi)	Aug. 1, 1978	Aug. 1, 1978	Dec. 12, 2016
Manzanita	May 1, 1978	Jan. 12, 1982	Dec. 12, 2016
Nehalem	Apr. 3, 1978	Dec. 7, 1982	Dec. 12, 2016
Rockaway Beach	Sep. 29, 1978	Oct. 12, 1982	Dec. 12, 2016
Tillamook	May 1, 1978	Apr. 16, 2004	Dec. 12, 2016
Wheeler	Nov. 16, 1977	Nov. 16, 1977	Dec. 12, 2016

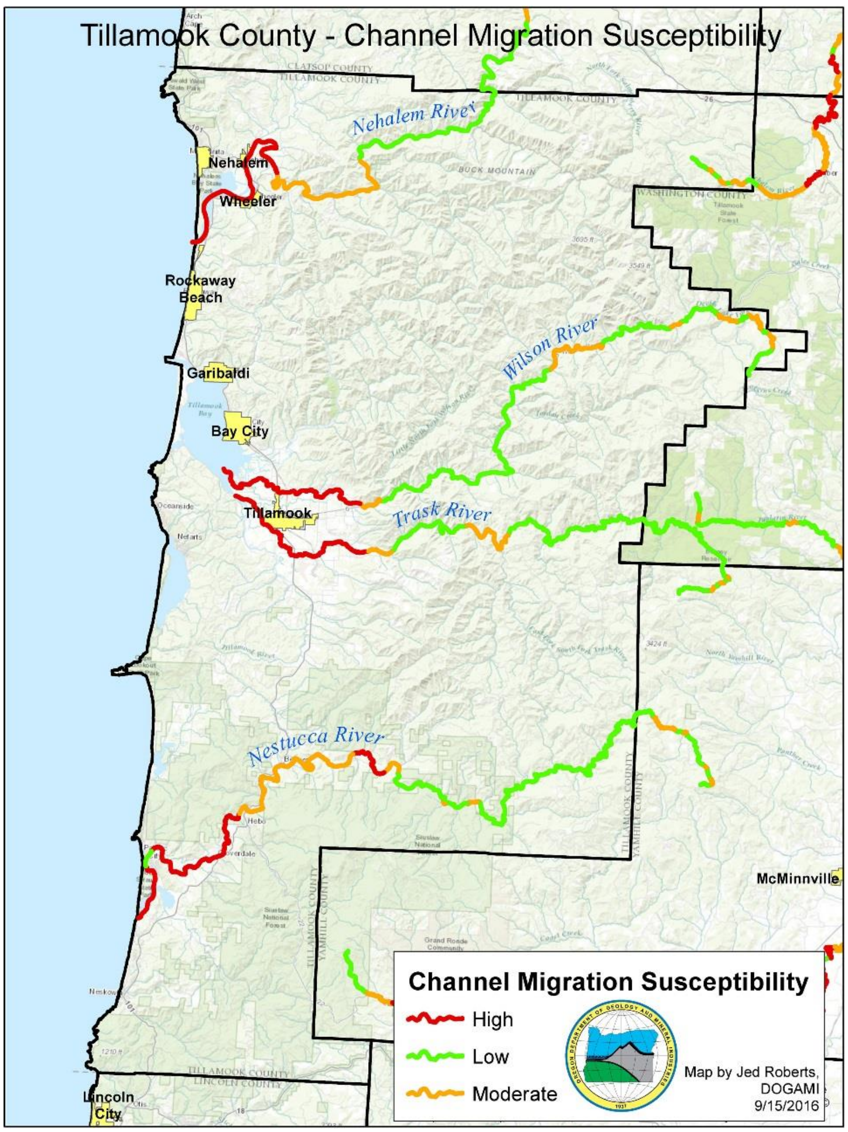
Source: FEMA Community Information System [online database https://isource.fema.gov/cis/], accessed September 2021

Channel Migration

Channel migration associated with flooding also can be identified with respect to a probability of migration over a period of 100 years. Historic aerial photos are catalogued to calculate past rates of migration that are then projected out to define a channel migration zone. Avulsion (i.e., channel shifting) zones, which are a component of the larger channel migration zone, are an exception to the migration rate approach. Areas of likely avulsion are identified by professional judgment of a fluvial geomorphologist, using high-resolution topographic data, aerial photos, and field observation.

Identification of channel migration susceptibility at the regional level is described in terms of low, moderate, and high relative probabilities. Probability is determined by assessing physiographic parameters of channel gradient, confinement, and pattern.

Figure 53. Channel Migration Susceptibility in Tillamook County



Source: Jed Roberts, personal communication, September 15, 2016

Southern Flow Corridor Project

Five major rivers drain into Tillamook Bay. The lower valleys of the Wilson, Trask, and Tillamook rivers merge to form a broad floodplain at the head of the bay on which the City of Tillamook is located. The Wilson River flows through a steep canyon out of the mountains and does not have any significant floodplain until around six miles above the bay.

The river channel is perched, meaning it runs in a channel with natural banks that are higher than the floodplains around it. Consequently, flood flows that leave the Wilson River, especially to the much larger southern floodplain, never return to the channel but flow south to the lowest part of the valley and west to meet the Trask and Tillamook Rivers. Highway 101 crosses the Wilson River floodplain at grade and so suffers frequent deep inundation across its lowest portions between Hoquarton and Dougherty Sloughs.

Recent decades have seen a number of damaging floods occur in Tillamook County. The 1996 flood in particular was noted for its long duration and extensive damage. Since then, large floods have occurred in 1998 and most recently in 2006 and 2007, causing further damage.

Listed as “threatened” under the federal Endangered Species Act, Oregon coastal coho populations have been severely impacted by the loss of off-channel and tidal wetland habitats. In few places is this impact more pronounced than in Oregon’s Tillamook Bay, where almost 90% of the estuary’s tidal wetlands have been lost to agricultural and urban/residential development.

The resulting lack of available tidal wetland habitats has been a primary contributor to the decline of Tillamook Bay coho, and today’s runs (just over 2,000 fish in 2012) represent a fraction of estimated historic abundance (~200,000). Likewise, the lack of available tidal wetland habitats has been identified as a key impediment to species recovery. These tidal habitat losses have impacted the Bay’s four other anadromous species, as well, particularly Chinook, which use tidal wetlands extensively for rearing.

The primary intent of Southern Flow Corridor-Landowner Preferred Alternative Project (SFC-LPA) is to remove manmade impediments to flood flows to the maximum extent possible in the lower Wilson River floodplain. The project accomplishes this by extensive removal of existing levees and fill and the new construction of setback tidal dikes to protect adjacent private lands from inundation from daily tides.

Areas outside the setback levees will be restored to tidal marsh. Working with a diverse set of partners, Tillamook County is restoring the 522 acres of tidal marsh habitats at the confluence of the Bay’s two most productive salmon systems, the Wilson and Trask Rivers. Representing 10% of the watershed’s historic tidal acreage and a far greater percentage of the “restorable” tidal lands, the project site contains an expansive mosaic of tidal wetlands, disconnected freshwater wetlands, and drained pasture lands. As the site restores to a tidal regime, the resulting range of habitats (including mud flats, aquatic beds, emergent marsh, scrub-shrub wetlands, forested wetlands and sloughs) will provide substantial habitat benefits to not only Threatened coho, but also chum and Chinook salmon, and cutthroat trout. A conservation easement permanently protects over 506 acres of County owned lands in the project area.

Long-term ecological and socio-economic outcomes include:

- reduced flooding in the Highway 101 business corridor and adjacent residential/agricultural lands, including measureable reductions in flood elevation and duration;
- improved freshwater and estuarine water quality, including reductions in temperature, dissolved oxygen, and turbidity.
- increased habitat complexity and availability across the range of tidal wetland habitats; and
- enhanced ecological function benefiting other aquatic, terrestrial, and avian species.

The project was completed by the end of 2017 and the monitoring phase of the project began. Validation of the expected flood level reduction started in October 2017 as part of a post-project monitoring effort. Model results for the 2017 flood showed the SFC project resulted in widespread reduction in flood levels. The results were consistent with prior modeling of the similarly sized 1999 flood event during the design phase. A flood event in January 2021 provided a second opportunity to validate the projected flood level reductions. A second monitoring report was produced in 2021 and it documents monitoring and flood modeling of the January 2021 event. [10]

Peak flows during the 2021 event were similar to the 2017 event on both the Trask and Wilson rivers (about a 5-year event on the Wilson River and a 3-year event on the Trask River), but the January 2021 event had significantly more volume than in 2017. Tides during the 2021 event were 1-2 feet higher than levels recorded in 2017. Boundary conditions in the 2021 SFC hydraulic model were updated to reflect characteristics of the January flood event. A new high-water mark (HWM) dataset was used to validate the model. Simulation results closely matched the observed dataset without requiring re-calibration. The model was then run with pre-project conditions in place. The difference in simulated maximum water surface elevation between pre- and post-project conditions was calculated. The 2021 predicted peak flood level reductions were also compared with results from prior modeling of the 2017 and 1999 floods.[11]

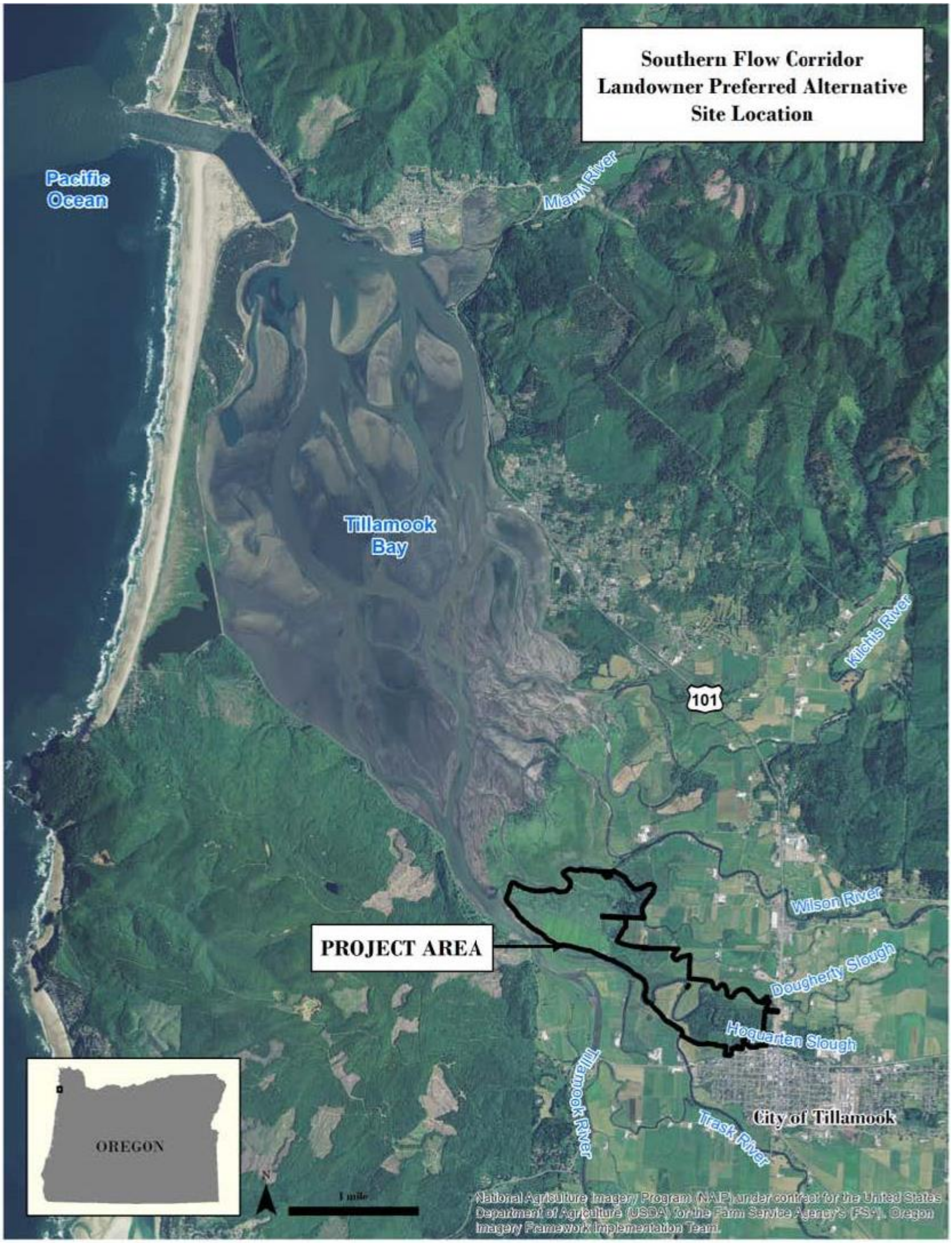
Model results for the January 2021 flood show similar results to the 2017 flood modeling with the SFC project resulting in widespread reduction in flood levels, including decreases of up to 0.7 feet along the Highway 101 corridor in North Tillamook. The duration of flooding on Highway 101 was reduced by 3-4 hours. Increases in flood level were negligible ((<0.03 feet) and limited in area. In all, about 4,800 acres showed some reduction in peak flood level, similar to the 2017 results. The results were also consistent with prior modeling of the similarly sized 1999 flood event, conducted during the design phase.[12]

The conclusion is that the SFC project continues to meet the desired project objectives for flood level reduction during floods of around a 5-year return interval under a range of flood volumes and tides. The consistency in results also gives additional confidence in projecting that the SFC project will provide significant flood level reduction over the full range of flood events as was predicted during the design phase modeling.[13]

[10] (https://tillamookoregonsolutions.com/ accessed April 2022.
Microsoft Word - SFC_Jan2021_Monitoring_Report_R1.docx (wordpress.com)

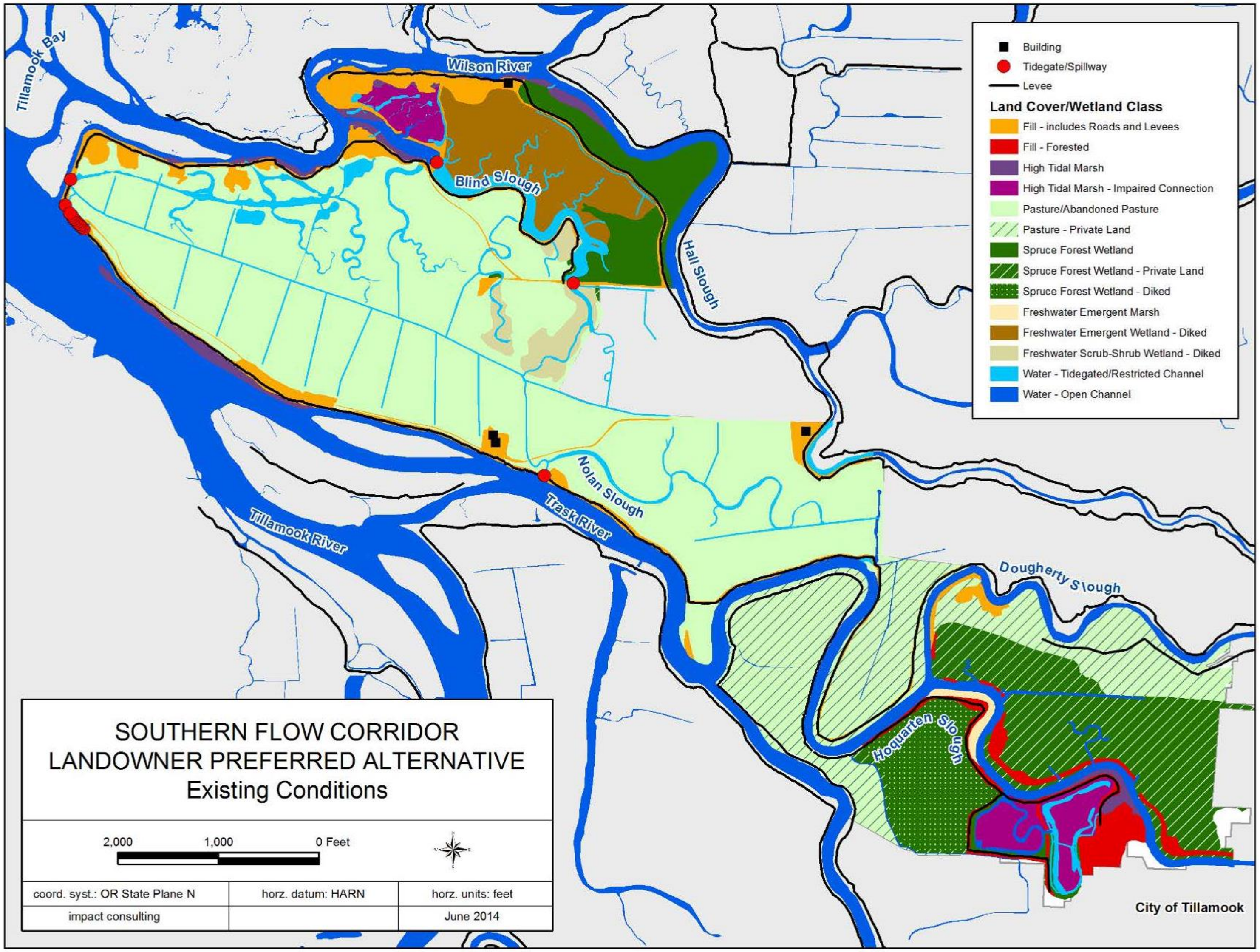
[11] Ibid.
[12] Ibid.
[13] Ibid.

Figure 54. Southern Flow Corridor Landowner Preferred Alternative Site Location



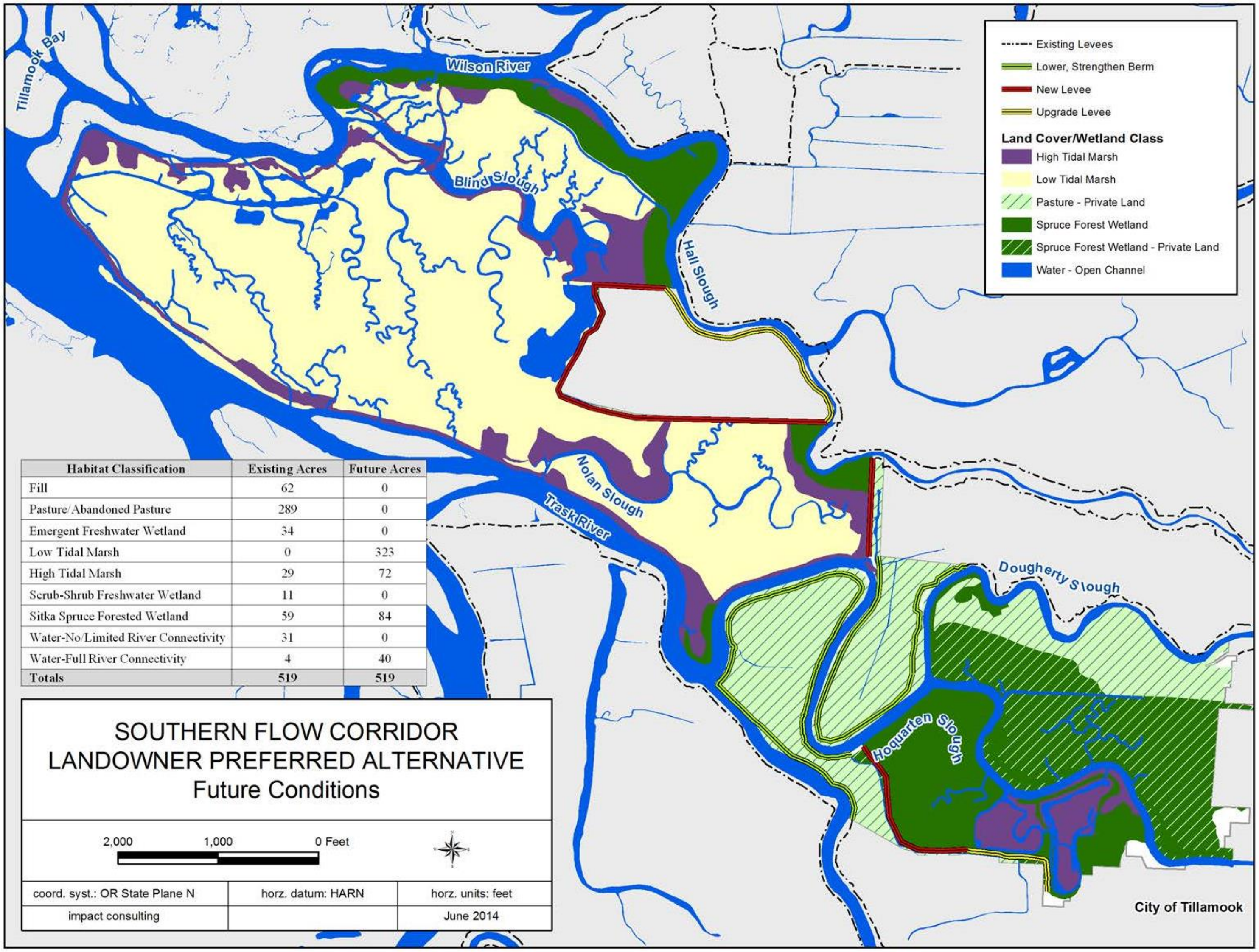
Source: https://ossfc.files.wordpress.com/2013/12/g-sfc_vicinity1.pdf, accessed January 21, 2017

Figure 55. Southern Flow Corridor Landowner Existing Conditions



Source: https://ossfc.files.wordpress.com/2014/01/g-sfc_pre1.pdf, accessed January 21, 2017

Figure 56. Southern Flow Corridor Landowner Future Conditions



Habitat Classification	Existing Acres	Future Acres
Fill	62	0
Pasture/Abandoned Pasture	289	0
Emergent Freshwater Wetland	34	0
Low Tidal Marsh	0	323
High Tidal Marsh	29	72
Scrub-Shrub Freshwater Wetland	11	0
Sitka Spruce Forested Wetland	59	84
Water-No/Limited River Connectivity	31	0
Water-Full River Connectivity	4	40
Totals	519	519

Source: https://ossfc.files.wordpress.com/2014/01/g-sfc_post.pdf, accessed January 21, 2017

Climate Change and Sea Level Rise

Recent studies make it clear that global ocean water levels are rising. Because Oregon's western edge is rising, the rates of sea level rise in Oregon are not as high as rates seen in other west coast locations, but they are rising. Flooding on the estuarine fringe is affected by ocean water levels — including tides and storm surges — in addition to freshwater inflow from the estuarine watershed.

Recent research also indicates that significant wave heights off Oregon are increasing. Increasing significant wave heights may be a factor in the observed increase of coastal flooding events in Oregon. During El Niño events, sea levels can rise up to about 1.5 feet (0.5 meters) higher over extended periods (seasons). Rising sea levels and increasing wave heights are both expected to increase coastal erosion and coastal flooding.

Extreme precipitation events have the potential to cause localized flooding due partly to inadequate capacity of storm drain systems. Flood events are expected to increase in number and magnitude. Areas thought to be outside the floodplain may begin to experience flooding.

The Future Climate Projections Tillamook County report prepared by the Oregon Climate Change Research Institute (2022) presents future climate projections for Tillamook 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. The complete report can be found in the Appendices to this plan.

The intensity of extreme precipitation is expected to increase as the atmosphere warms and holds more water vapor. In Tillamook 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 15% (range 2–29%) and 11% (range -1–25%), respectively, relative to the1971–2000 historical baselines, under the higher emissions scenario.

In Tillamook 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.

Vulnerability

Vulnerability expresses the impacts to people and the built environment anticipated from flooding.

Properties near the rivers that feed Tillamook Bay have experienced significant flood losses. In fact, the meaning of the term "100-year flood" was lost when repetitive flood events impacting the City of Tillamook and adjacent portions of Tillamook County exceeded the base flood elevation numerous times, including major flood events in 1996, 1998 and 1999, 2007, 2011 and, most recently, 2015. Many buildings — including those built before and after FIRMs were first developed — experienced repetitive flood losses along US-101 north of the City of Tillamook, many of which have been mitigated using FEMA post-disaster mitigation (HMGP) grants.

In general, the north coast is more vulnerable to riverine flood damage than the south coast because it is more densely populated and consequently contains much of the region's infrastructure. Physical location also makes a difference. For example, five rivers empty into Tillamook Bay, increasing risk from riverine flooding on the relatively flat valley floor.

Fortunately, unlike the East and Gulf coasts, only a few of Oregon's coastal developments are within FEMA-designated Velocity (V) zones. Information from the National Flood Insurance Program (NFIP) indicates that Lincoln and Tillamook Counties and their coastal cities account for nearly all of the V-zone flood policies and losses on the Oregon coast.

Coastal highways have always been problematic. Much of the problem is linked to local geology; some sections are more susceptible to wave action than others and require continuous maintenance. There is no practical solution outside of relocation of the highway.

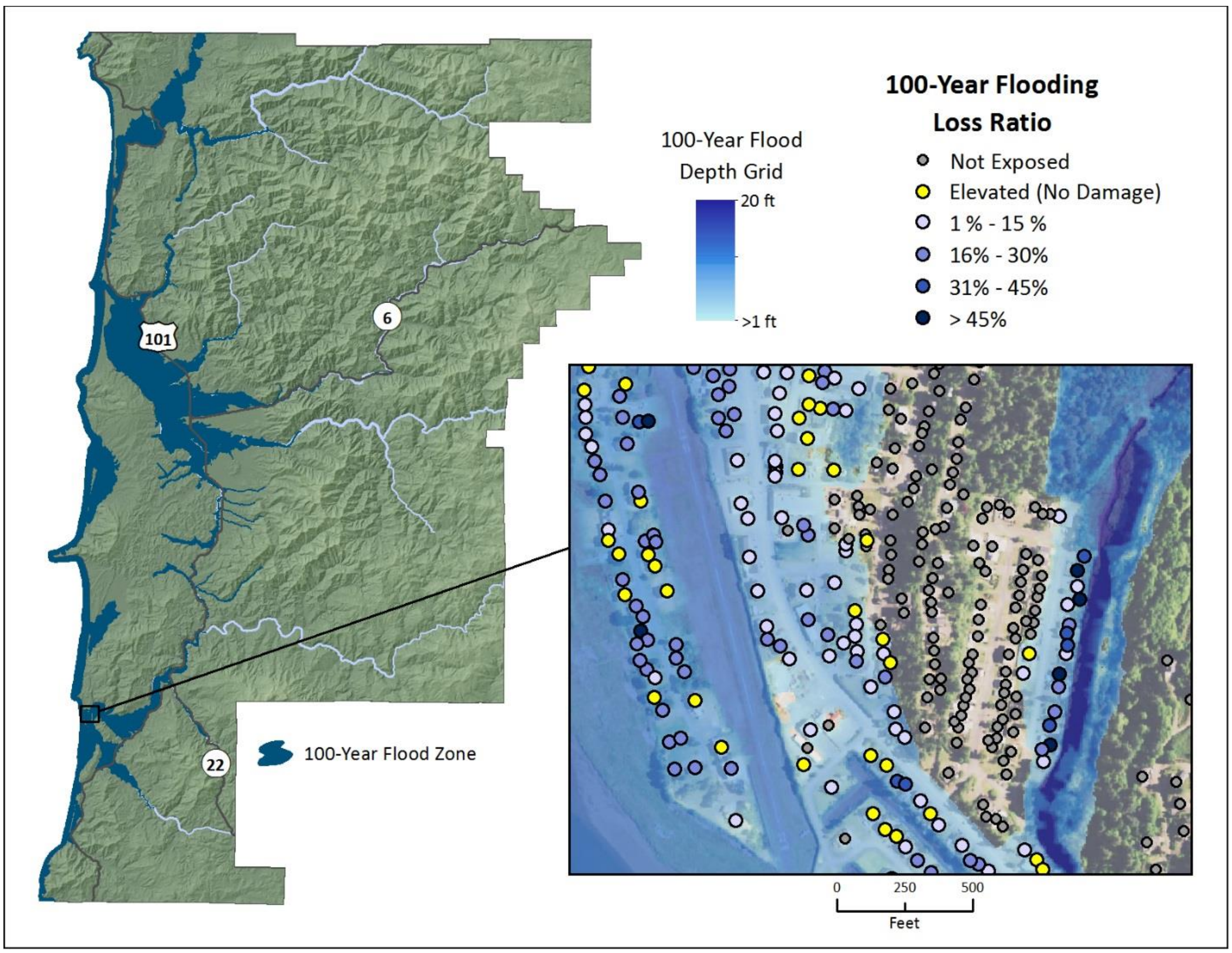
Loss Estimation and Exposure

The *Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2022) provides flood loss estimation and exposure analyses for Tillamook County. **Figure 57** provides an example of the building exposure analysis. **Figure 58** provides an example of the depth grids used for loss estimation, and Error! Reference source not found. illustrates the estimated loss ratio. Exposure results are shown **Table 43** and **Table 45**; loss estimation results in **Table 44**.

Most buildings exposed to flood throughout the County are expected to be subject to flood damage.

While the potentially displaced populations are significant by percentage, the actual numbers of potentially displaced people in Neskowin, Nehalem, and Rockaway Beach are relatively low because they are small communities. Conversely, the percentages of potentially displaced people are lower in the rural parts of Tillamook County and Tillamook City, but the actual numbers of potentially displaced people are significant.

Figure 57. 100-year Flood Zone and Building Exposure Example



Source: DOGAMI (2016)

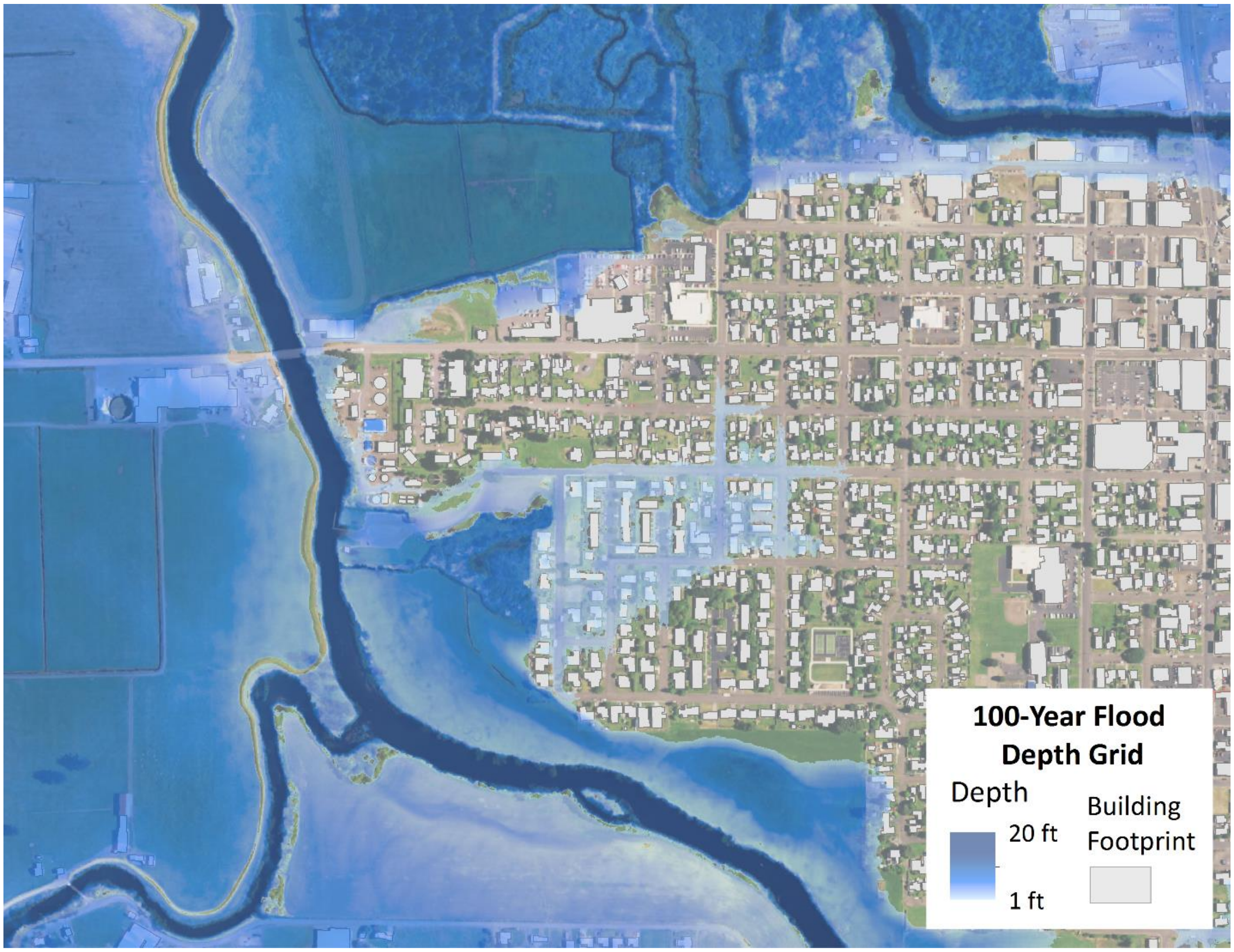
Table 43. Flood Exposure: Tillamook County and Cities

					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**
Unincorp. County (rural)	14,107	13,540	1,161	8.6%	1,295	9.2%	282
Bayside Gardens	945	988	0	0.0%	3	0.3%	2
Neskowin	652	323	50	15.4%	127	19.5%	54
Oceanside & Netarts	1,628	1,262	11	0.9%	37	2.3%	17
Pacific City	1,721	1,174	325	27.7%	462	26.8%	93
Total Unincorp. County	**19,050**	**17,288**	**1,547**	**8.9%**	**1,924**	**10.1%**	**448**
Bay City	880	1,424	4	0.3%	5	0.6%	5
Garibaldi	755	831	12	1.4%	29	3.8%	11
Manzanita	1,517	609	0	0%	4	0%	3
Nehalem	234	271	46	17%	44	19%	15
Rockaway Beach	2,095	1,465	163	11%	302	14%	148
Tillamook	2,194	5,317	499	9%	256	12%	64
Wheeler	362	422	0	0%	10	3%	0
Total Tillamook County	**27,090**	**27,627**	**2,272**	**8%**	**2,574**	**10%**	**694**

*1% results include coastal flooding source.

Source: DOGAMI (2022, Table B-6)

Figure 58. Flood Depth Grid Example, City of Tillamook



Source: DOGAMI (2016)

Table 44. Flood Loss Estimates: Tillamook County and Cities

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	10% (10-yr)			2% (50-yr)			1% (100-yr)			0.2% (500-yr)		
			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
Unincorp. County (rural)	14,107	3,610,281	479	24,192	0.7%	794	46,550	1.3%	1,013	60,068	1.7%	1,267	87,395	2.4%
Bayside Gardens	945	186,325	0	0	0.0%	1	5	0.0%	1	7	0.0%	1	12	0.0%
Neskowin	652	141,094	3	43	0.0%	16	188	0.1%	73	2,837	2.0%	61	997	0.7%
Oceanside & Netarts	1,628	302,588	0	0	0.0%	0	0	0.0%	20	214	0.1%	6	54	0.0%
Pacific City	1,721	361,114	125	1,847	0.5%	293	7,733	2.1%	369	11,593	3.2%	495	20,552	5.7%
Total Unincorp. County	**19,050**	**4,598,402**	**607**	**26,083**	**0.6%**	**1,104**	**54,476**	**1.2%**	**1,476**	**74,720**	**1.6%**	**1,830**	**109,009**	**2.4%**
Bay City	880	229,175	0	0	0.0%	0	0	0.0%	0	0	0.0%	1	5	0.0%
Garibaldi	755	179,063	11	855	0.5%	16	980	0.5%	18	1,070	0.6%	34	1,599	0.9%
Manzanita	1,517	274,658	0	0	0.0%	0	0	0.0%	1	10	0.0%	0	0	0.0%
Nehalem	234	54,360	5	219	0.4%	13	478	0.9%	29	806	1.5%	49	1,458	2.7%
Rockaway Beach	2,095	454,733	83	748	0.2%	101	1,062	0.2%	154	2,546	0.6%	280	5,347	1.2%
Tillamook	2,194	982,931	56	3,365	0.3%	127	7,439	0.8%	192	11,938	1.2%	297	25,257	2.6%
Wheeler	362	81,137	4	128	0.2%	4	186	0.2%	10	254	0.3%	13	441	0.5%
Total Tillamook County	**27,090**	**6,854,759**	**766**	**31,398**	**0.5%**	**1,365**	**64,621**	**0.9%**	**1,880**	**91,345**	**1.3%**	**2,504**	**143,116**	**2.1%**

*1% results include coastal flooding source.

Source: DOGAMI (2022, TableB-5)

Table 45. Flood Loss Estimates: Port of Tillamook Bay and Port of Garibaldi

Community	Total Number of Buildings	Total Estimated Building Value ($)	10% (10-yr)			2% (50-yr)			1% (100-yr)*			0.2% (500-yr)		
			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
Port of Garibaldi	35	8,035,760	4	1,211	0.02%	4	19,764	0.25%	6	20,080	0.25%	6	21,026	0.26%
Port of Tillamook	83	61,545,144	2	30,473	0.05%	5	70,289	0.11%	5	72,863	0.12%	5	76,786	0.12%

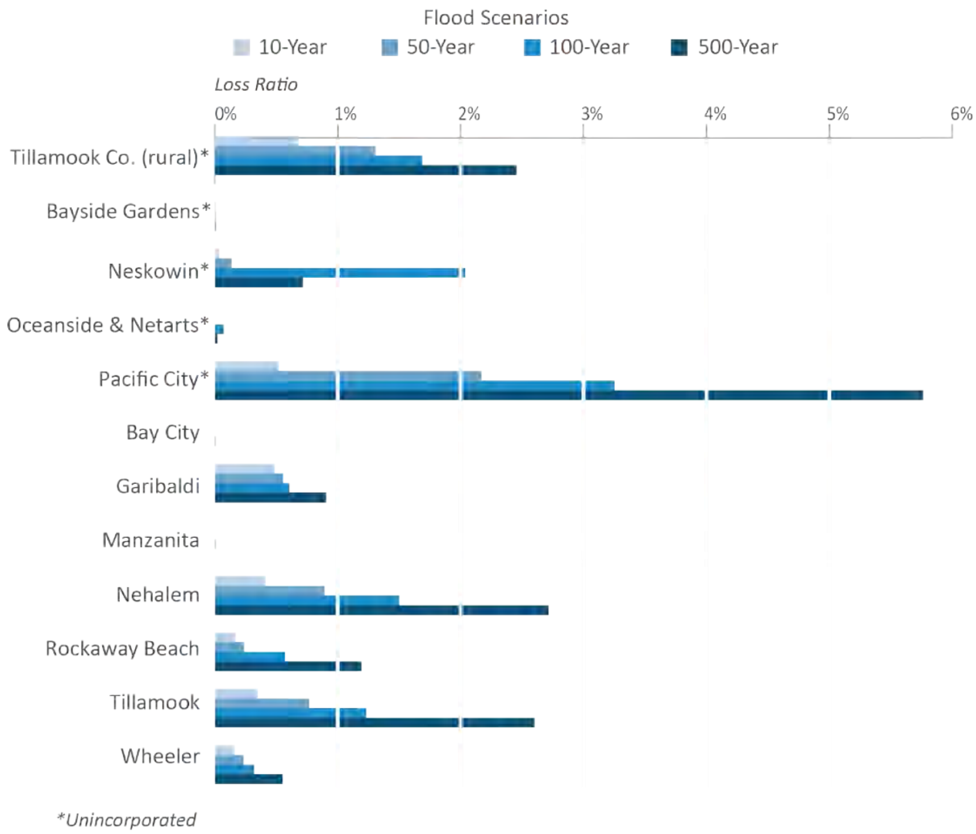
Source: Derived from DOGAMI (2016, Table A-2)

The loss estimate countywide for a 1% probability flood is about $91 million with about 1.900 buildings damaged. Pacific City has a significantly greater number of properties where value is at risk from flood damage (the loss ratio, the percentage of loss relative to replacement cost) than any of the other communities or the rural areas of the County.

The Port of Tillamook Bay Railroad runs from the Port's industrial park complex through the eastern portion of the City of Tillamook and north to Wheeler before turning east through the Salmonberry Canyon. Previous Salmonberry River flooding seriously damaged the rail line. In the Tillamook area, the elevated portion of the rail line has served as a pedestrian pathway during floods. Flooding of this portion would hamper mobility even further. The Port is a partner in the Southern Flow Corridor Project, which seeks to reduce the durational impact of recurrent floodwaters in the Highway 101 Business Corridor of Tillamook. Trask River floods block traffic along Long Prairie Road impacting the continuous flow of commerce into the Port's Airport and Industrial Park complex; however, these periods of interruption are far less in duration than a flood event within the City of Tillamook area.

The Port of Garibaldi suffers impacts from flooding of rivers that empty into Tillamook Bay. Flooding causes increased sediment deposits in the Bay and boat basin hindering safe navigation of vessels and creating a need for frequent dredging. The expense of and operational disruptions caused by frequent dredging are considered economic losses from flooding.

Figure 59. Flood Loss Estimates by Community



*Unincorporated communities. Note that "Tillamook Co. (rural)" excludes incorporated communities, Pacific City, Oceanside/Netarts, and Neskowin. Coastal flooding information only available for the 100-year flood (non-cumulative results can occur, as seen in the community of Neskowin).
Source: DOGAMI (2016)

National Flood Insurance Program (NFIP)

All of the jurisdictions in Tillamook County participate in the NFIP and their floodplain management ordinances are in compliance. They will all be reviewed again after the Letter of Final Determination is issued for the FIS and FIRMs that are currently being updated.

Structures built prior to issuance of the initial NFIP FIS and FIRMs are known as "pre-FIRM" structures. Their lowest floors are often below the BFE making them particularly susceptible to flooding. Those with lowest floors at least one foot below the BFE are called "minus rated" and are more vulnerable to flood damage. Table 46 indicates a large number of flood insurance policies for pre-FIRM buildings in the County. Two thirds of the structures are located in unincorporated Tillamook County and one fifth are in Rockaway Beach, two of the places most susceptible to both riverine and coastal flooding in the County.

Table 46. NFIP Flood Insurance Policies

Jurisdiction	Number of Policies		Number of Policies by Building Type					
	Total Policies	Pre-FIRM Policies	Single-Family	2-4 Family	Other Residential	Non-Residential	Minus-Rated A Zone	Minus-Rated V-Zone
Unincorporated Tillamook County	999	434	784	21	150	44	38	1
Bay City	6	3	5	0	0	1	1	0
Garibaldi	15	7	10	0	0	5	0	0
Manzanita	160	43	150	8	0	2	0	0
Nehalem	15	7	9	1	0	5	1	0
Rockaway Beach	247	89	191	9	38	9	25	0
Tillamook	79	37	48	7	2	22	2	0
Wheeler	7	4	4	1	0	2	0	0
Total	**2,279**	**998**	**1,754**	**78**	**278**	**168**	**112**	**1**

Source: FEMA Community Information System [online database https://isource.fema.gov/cis/], accessed August 22, 2016

The total number of policies in the county decreased since 2016 from 1,537 to 999, however rural properties still hold the greatest number of policies in the county as a whole. In Rockaway Beach, the city with the next largest number of policies, the number has since 2016 declining from 415 policies in force in 2016 to 247 policies in 2022, with the decrease Pre-FIRM policies decreased by approximately half from 197 to 89. Also of note is that the minus rated policies in the V-zone in Rockaway Beach decreased from 7 to 0. Minus rated policies in the unincorporated portion of the county also decreased significantly. The City of Manzanita gained about 8 policies and the City of Wheeler gained 1, otherwise the trend of decreasing policies, greater claims predominantly for pre-firm policies was the trend between 2016 and 2023.

Table 47. NFIP Flood Insurance Claims

Jurisdiction	Insurance in Force ($)	Total # Paid Claims	# Pre-FIRM Paid Claims	# Post-FIRM Paid Claims	Total Paid ($)
Unincorporated Tillamook County	280,484,000	496	349	130	965,963.74
Bay City	2,327,000	2	1	1	4,145
Garibaldi	4,753,000	3	3	0	28,064
Manzanita	55,901,000	1	0	1	1,954
Nehalem	5,409,000	20	16	3	228,326
Rockaway Beach	67,587,000	65	45	19	826,707
Tillamook	24,519,000	202	135	64	8,229,286
Wheeler	2,066,000	0	0	0	0
Total	**572,361,500**	**623**	**440**	**183**	**14,556,830**

Source: FEMA Community Information System [online database https://isource.fema.gov/cis/], accessed August 22, 2016

Repetitive Loss Properties

FEMA has identified 61 buildings in Tillamook County as repetitive loss (RL) properties. The NFIP defines a RL property as any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period since 1978. At least two of the claims must be more than 10 days apart but within 10 years of each other. Or, the property must have incurred flood-related damage on 2 occasions, in which the cost of the repair, on average, equaled or exceeded 25% of the market

Jurisdiction	Totals			Building Type													
				Single-Family		2-4 Family		Other Residential		Commercial		Industrial		Agricultural		Other Non-Residential	
	RL	SRL	Total	RL	SRL	RL	SRL	RL	SRL	RL	SRL	RL	SRL	RL	SRL	RL	SRL
Unincorporated Tillamook County	41	2	43	27	2	1	0	1	0	4	0	0	0	5	0	3	0
Bay City	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Garibaldi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manzanita	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nehalem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rockaway Beach	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Tillamook	16	0	16	4	0	0	0	0	0	11	0	0	0	1	0	0	0
Wheeler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**59**	**2**	**61**	**33**	**2**	**1**	**0**	**1**	**0**	**15**	**0**	**0**	**0**	**6**	**0**	**3**	**0**

value of the structure at the time of each such flood event.

Beyond identifying vulnerable buildings, the RL list provided by FEMA has value for hazard mitigation planning because the location of these buildings may indicate areas of persistent flood or drainage problems. The City of Tillamook is the only city in the state with RL buildings numbering in the double digits.

Severe Repetitive Loss Properties

Severe repetitive loss (SRL) properties are a subset of RL properties. SRL properties:

1. Are covered under a contract for flood insurance made available under the NFIP; and
2. Have incurred flood related damage:
   a. For which four or more separate claims payments have been made under flood insurance coverage with the amount of each such claim exceeding $5,000, and with the cumulative amount of such claims payments exceeding $20,000; or
   b. For which at least two separate claims payments have been made under such coverage, with the cumulative amount of such claims exceeding the market value of the insured structure.

Table 48. NFIP Repetitive Loss and Severe Repetitive Loss Buildings by Type

Source: FEMA BureauNet, accessed August 7, 2017

Community Rating System (CRS)

Communities can reduce the likelihood of damaging floods by employing floodplain management practices that exceed NFIP minimum standards. DLCD encourages communities that adopt such standards to participate in FEMA's Community Rating System (CRS), which results in reduced flood insurance costs. The Cities of Nehalem and Tillamook participate in CRS. Tillamook County participated in the past and is in the process of rejoining the program.

4. Landslides

Introduction

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

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

Landslides in Oregon are typically triggered by periods of heavy rainfall and/or rapid snowmelt, such as those occurring during La Niña periods of the ENSO cycle. On the Oregon Coast, soft bluff soils can become saturated, increasing the likelihood of landslides. In addition, as waves remove sediment from the toe of a bluff its vulnerability to landslide increases. Earthquakes, volcanoes, and human activities also trigger landslides.

In general, the coast and Coast Range Mountains have a very high incidence of landslides. On occasion, major landslides occur on US or state highways and sever these major transportation routes (including rail lines), causing temporary but significant economic damage to the state. Less commonly, landslides and debris flows in this area cause loss of life.

Tillamook County has one of the highest landslide counts of the all Oregon counties (Oregon Department of Land Conservation and Development, 2015) on the basis of data in SLIDO-2 [Burns, Mickelson, & Saint-Pierre, 2011), and DOGAMI estimates that count to be potentially as little as 25% of those that actually exist. Although a statewide landslide susceptibility map was released in 2016 (Burns, Mickelson, & Madin, 2016), until landslides can be mapped using lidar and susceptibility modeled for Tillamook County, we will not fully understand the location and extent of its landslide hazards.

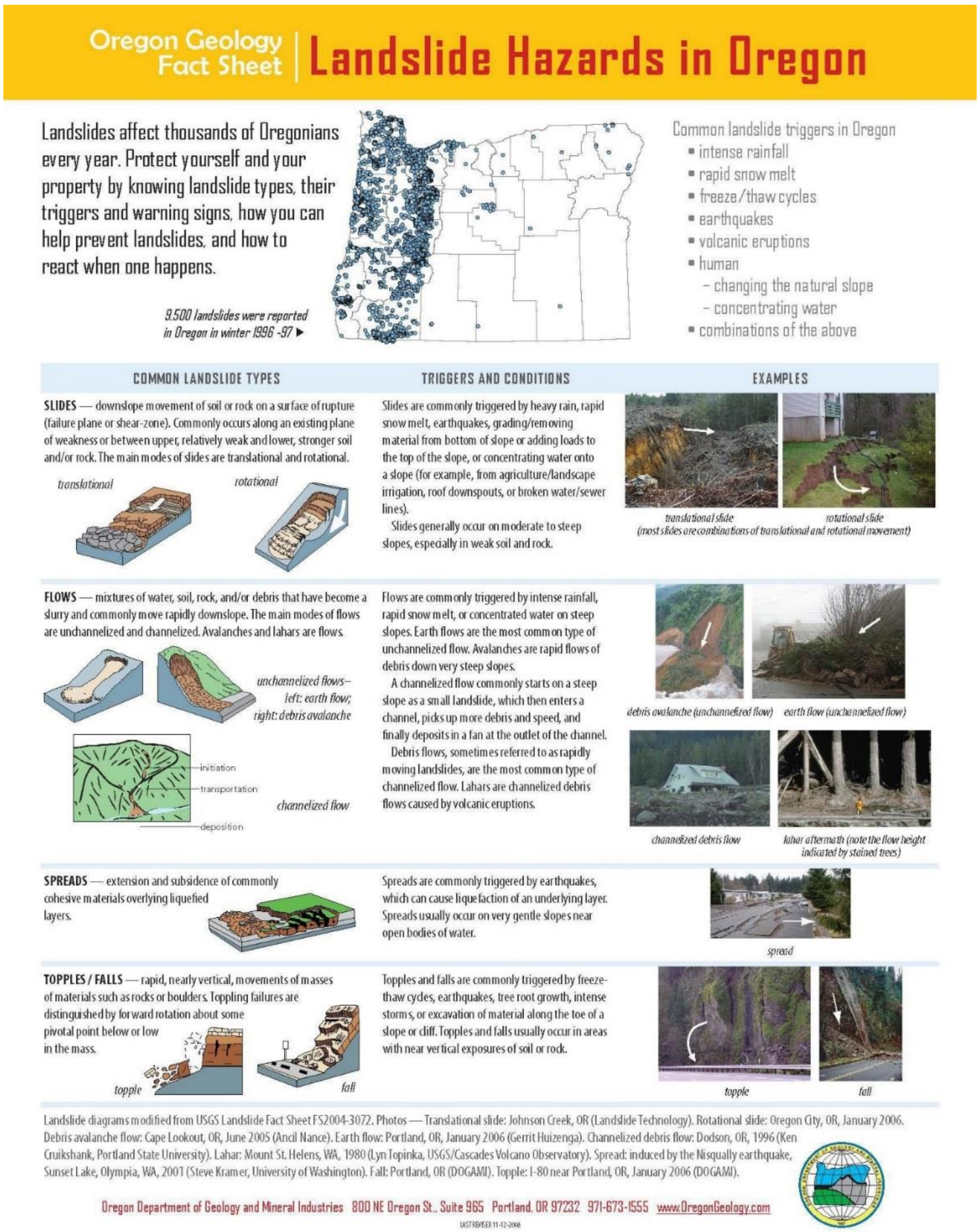
Types of Landslides

The general term “landslide” refers to a range of mass movement including rock falls, debris flows, earth slides, and other mass movements. All landslides have different frequencies of movements, triggering conditions, and very different resulting hazards.

All landslides can be classified into one the following six types of movements: (a) slides, (b) flows, (c) spreads, (c) topples, (d) falls, and (f) complex (). Most slope failures are complex combinations of these distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard associated with the landslide, the landslide characteristics, identification methods, and potential mitigation alternatives. These types of movements can be combined with other aspects of the landslide such as type of material, rate of movement, depth of failure, and water content for a better understanding of the type of landslide.

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

Figure 60. Common Types of Landslides in Oregon



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

Location

Table 49. Jurisdictions Subject to Landslides

Jurisdiction	Landslides
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

Areas that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. Other types of landslides tend to occur in the same locations.

The velocity of landslides varies from imperceptible to over 35 miles per hour. Some volcanic induced landslides have been known to travel between 50 to 150 miles per hour. Debris flows typically start on steep hillsides as shallow landslides, enter a channel, then liquefy and accelerate. Canyon bottoms, stream channels, and outlets of canyons can be particularly hazardous. Landslides can move long distances, sometimes as much as several miles. On less steep slopes, landslides tend to move slowly and cause damage gradually. Large, slow moving landslides frequently cause significant property damage, but are far less likely to result in serious injuries. One such landslide occurred in Tillamook County in 1997.

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

Because debris flows can be initiated at many sites over a watershed, in some cases recurrence intervals can be less than 10 years. Slope alterations can greatly affect recurrence intervals for all types of landslides, and also cause landslides in areas otherwise not susceptible. Most slopes in Western Oregon steeper than 30 degrees (about 60%) have a risk of rapidly moving landslide activity regardless of geologic unit. Areas directly below these slopes in the paths of potential landslides are at risk as well. Based on the Oregon Department of Forestry storm impacts study (Robison et al., 1999), the debris flow hazard is high in much of the Coast Range.

Deep landslides are generally defined as having a failure plane within the regional bedrock unit (generally greater than 15 feet deep), whereas the failure plane of shallow landslides is commonly between the thin soil mantle and the top of the bedrock. Deep landslide hazard is high in parts of the Coast Range. Deep landslides are fairly common in fine-grained sedimentary rock units of the Coast Range. Deep landslides also occur in semi-consolidated sedimentary rocks in Tillamook County.

The ODF storm impacts study (Robison et al., 1999) estimated that tens of thousands of landslides occurred on steep slopes in the forests of Western Oregon during 1996. The Oregon Department of Geology and Mineral Industries' *Slope Failures in Oregon* (Hofmeister, 2000) inventoried thousands of reports of landslides across the state resulting from the 1996-97 storms. The number of injuries and deaths in the future will be directly related to vulnerability: the more people in these areas, the greater the risk of injury or death.

The *Landslide Susceptibility Overview Map of Oregon* (Burns et al., 2016) identifies the general level of susceptibility of a given area to primarily shallow and deep-seated landslides. It was developed by aggregating three primary sources: landslide inventory, generalized geology, and slope. The landslide inventory was taken from DOGAMI's previous landslide mapping effort, the *Statewide Landslide Information Database for Oregon* (Burns et al., 2011). Together these documents indicate that thousands of landslides have occurred throughout Tillamook County and much of the County is susceptible to future landslides.

Figure 61. Landslide in Tillamook County

Source: DLCD

Recent landslide inventory mapping in Tillamook County (Calhoun and others, 2020) based on lidar using methods outlined in DOGAMI Special Paper Special Paper 42 (SP-42: Burns and Madin, 2009) was recently completed, but had not yet been incorporated into the Statewide Landslide Susceptibility Map. For this risk assessment, the 2022 Multi-Hazard Risk Assessment performed by DOGAMI's geohazard analyst took a conservative approach and overlaid this new landslide inventory (Calhoun and others, 2020), which are equivalent to Very High susceptibility, and replaced the susceptibility zones in the Statewide Landslide Susceptibility Map (Burns and others, 2016). Areas that were previously mapped as Very High but were outside of the new landslide mapping were changed to High zones.

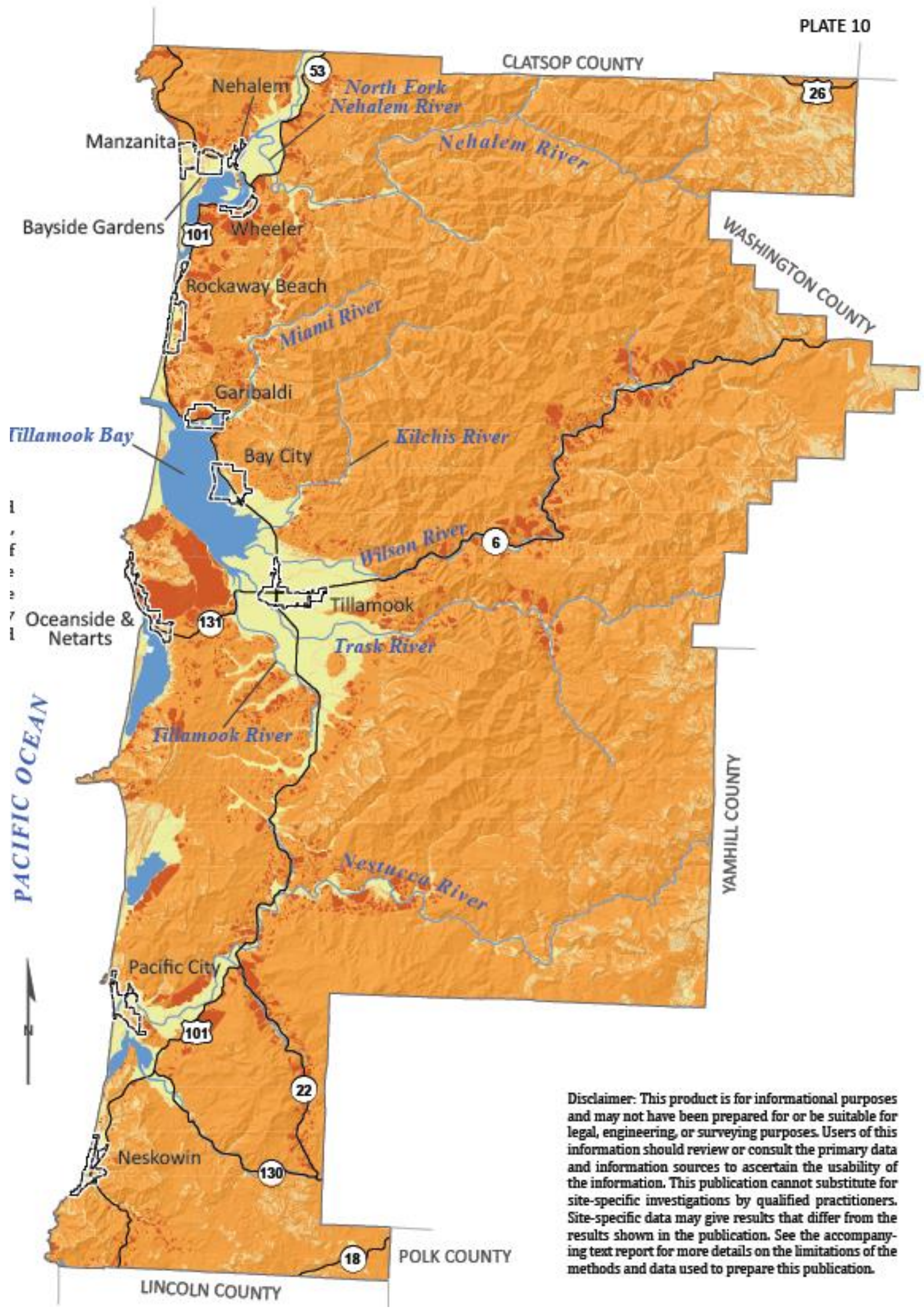
DOGAMI's analyst used the data from the combined Statewide Landslide Susceptibility Map (Burns and others, 2016) and new landslide mapping (Calhoun and others, 2020) in this report to identify the general level of susceptibility of given area to landslide hazards, primarily shallow and deep landslides. DOGAMI's analyst overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community. The total dollar value of exposed buildings was summed for the study area and is reported in this section. DOGAMI also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose real risk to communities were not examined for this report.

Figure 62. Landslide Susceptibility

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.



Source: DOGAMI (2022)

Historically Significant Landslides

Table 50. Historic Landslides in Tillamook County

Date	Location	Description
Feb. 1996	Statewide	FEMA-1099-DR-Oregon; heavy rains and rapidly melting snow contributed to hundreds of landslides and debris flows across the state, many on clear cuts that damaged logging roads
Dec. 2005–Jan. 2006	Western and Central Oregon including Tillamook County	FEMA-1632-DR; Oregon Severe Storms, Flooding, Landslides, and Mudslides
Nov. 2006	North Coast and Hood River County	FEMA-1672-DR; Oregon Severe Storms, Flooding, Landslides, and Mudslides
Dec. 2007	Clatsop and Tillamook	FEMA-1733-DR; Oregon Severe Storms, Flooding, Landslides, and Mudslides
Dec. 2008	Tillamook	FEMA-1824-DR; Severe Winter Storm, Record And Near Record Snow, Landslides, and Mudslides
Jan. 2011	Several counties from Western to Central Oregon including Tillamook County	FEMA-1956-DR; Severe Winter Storm, Flooding, Mudslides, Landslides and Debris Flows
Jan. 2012	Western Oregon including Tillamook County	FEMA-4055-DR; Oregon Severe Winter Storm, Flooding, Landslides, and Mudslides
Dec. 2015	Western Oregon including Tillamook County	FEMA-4258-DR: Oregon Severe Winter Storms, Straight-line Winds, Flooding, Landslides, and Mudslides

Sources: Taylor and Hatton (1999); EMA After-Action Report, 1996 events; interviews, Oregon Department of Transportation representatives; Hazards and Vulnerability Research Institute (2007); FEMA, Disaster Declarations for Oregon, https://www.fema.gov/disasters/grid/state-tribal-government/88?field_disaster_type_term_tid_1=All&order=field_disaster_declaration_date&sort=desc, accessed January 22, 2017

Probability

There is a 100% probability of landslides occurring in Tillamook County in the future. Although we do not know exactly where and when they will occur, they are more likely to happen in the general areas where landslides have occurred in the past. Also, they will likely occur during heavy rainfall events or during a future earthquake.

Climate Change

Flooding and landslides are projected to occur more frequently throughout western Oregon. Landslides in Oregon are strongly correlated with rainfall, so the likelihood of landslides may increase in areas where rainfall is projected to increase. Widespread damaging landslides that accompany intense rainstorms (such as “Pineapple Express” winter storms) and related floods occur during most winters. Particularly high consequence events occur about every decade; recent examples include those in February 1996, November 2006, and December 2007.

Vulnerability

Vulnerability expresses the impacts to people and the built environment anticipated from landslides.

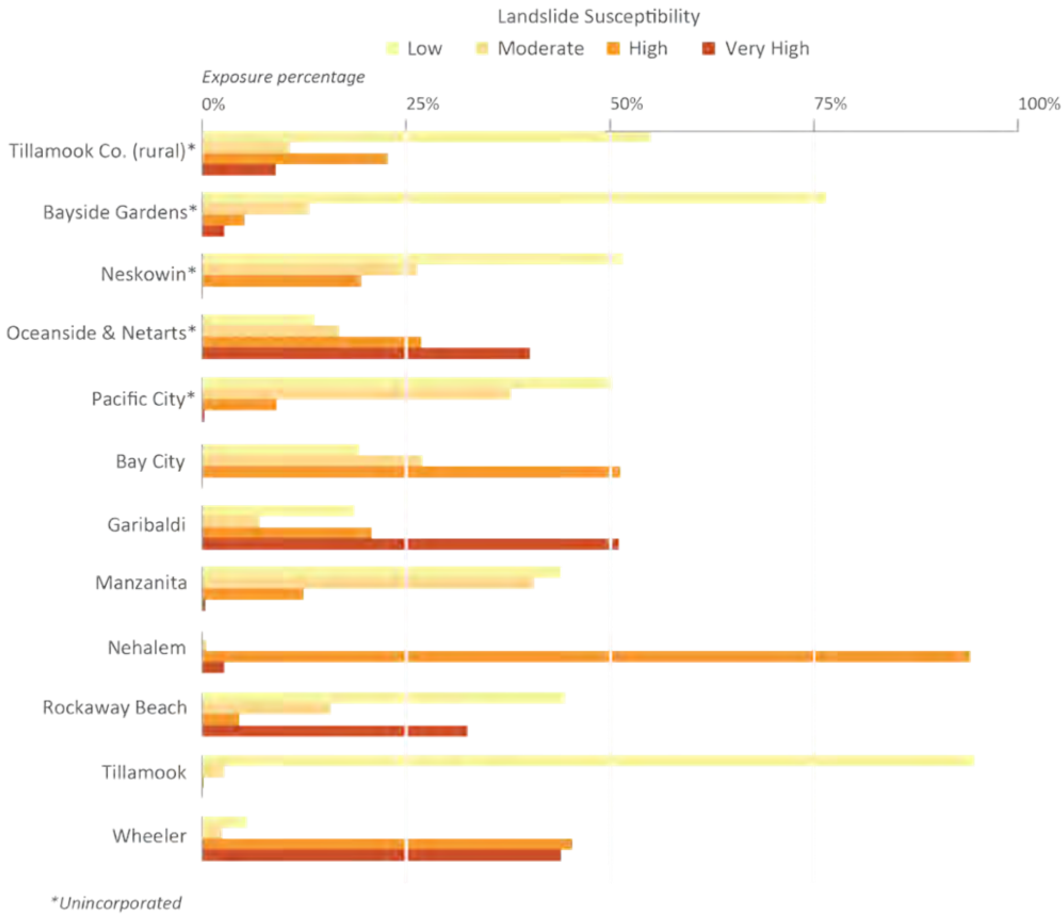
The new *Landslide Susceptibility Overview Map of Oregon* (Burns et al., 2016) indicates that many developed areas of Tillamook County are highly susceptible to damage and potentially loss of life from landslides.

Rain-induced landslides and debris flows can potentially occur during any winter in Tillamook County. Increased landslides due to climate change will cause more damage to property and infrastructure and will disrupt transportation and the distribution of water, food, and essential services. Some of the greatest exposure to damage from landslides in Tillamook County comes from the potential for injury and loss of life from rapidly moving landslides along the east-west roadways carrying traffic to and from the coast.

This area is also subject to future very large earthquakes, which will trigger landslides.

The *Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2022) provides a landslide exposure analysis for Tillamook County. **Figure 63** provides an example of the building exposure analysis. Exposure analysis results are shown in **Table 51** and **Table 52**, and Error! Reference source not found. illustrates those results.

Figure 63. Landslide Susceptibility and Building Exposure Example



Source: DOGAMI (2022)

All of the communities in Tillamook County are exposed to some level of landslide risk. Those with development in areas of moderate to steep slopes or at the base of steep slopes are at greater risk. Countywide, almost a third of the buildings located are in areas that are highly or very highly susceptible to landslides. Almost all the buildings in Nehalem, close to three quarters of the buildings in Wheeler and Garibaldi, and about half of the buildings in Bay City are located in areas of very high susceptibility to landslides. In Nehalem, 94% of the building value is in an area of very high landslide susceptibility. Should a landslide occur there, the community would suffer a tremendous loss in terms of both property damage and potentially loss of life, as 99% of the population would be displaced. Wheeler, Garibaldi, and Bay City would also be tremendously impacted. Ninety-three percent of Wheeler's population, 74% of Garibaldi's and 54% of Bay City's would be displaced.

The Port of Tillamook Bay is vulnerable to impacts from landslides due to the proximity of Anderson Hill to Port's eastern industrial park boundary. The Port's Truck Route runs through this area; a landslide here would likely result in the interruption of commerce throughout the industrial park and a fair amount of damage to buildings. The Bonneville Power Administration's electrical transmission lines that provide power to the greater Tillamook area run through the Anderson Hill area. An electrical substation belonging to the Tillamook People's Utility District lies adjacent to Anderson Hill. A landslide here could bring down power lines and damage the substation causing a major interruption of power impacting thousands of electrical customers.

Table 51. Landslide Exposure: Tillamook County and Cities

Source: DOGAMI 2022

			(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**
Unincorp. County (rural)	14,107	3,610,281	1,647	331,634	9.2%	3,880	841,297	23.3%	2,058	397,643	11%
Bayside Gardens	945	186,325	22	5,131	2.8%	48	9,805	5.3%	139	25,143	13%
Neskowin	652	141,094	0	0	0%	134	28,177	20.0%	199	38,211	27%
Oceanside & Netarts	1,628	302,588	578	124,757	41.2%	511	83,312	27.5%	321	51,993	17%
Pacific City	1,721	361,114	6	822	0.2%	178	33,587	9.3%	609	140,313	39%
Total Unincorp. County	**19,050**	**4,598,402**	**2,253**	**462,345**	**10%**	**4,751**	**996,178**	**21.7%**	**3,326**	**653,302**	**14%**
Bay City	880	229,175	0	0	0.0%	488	120,575	52.6%	258	63,469	28%
Garibaldi	755	179,063	465	93,873	52.4%	152	38,113	21.3%	41	12,892	7%
Manzanita	1,517	274,658	5	924	0.3%	199	34,792	12.7%	647	114,688	42%
Nehalem	234	54,360	12	1,517	3%	221	52,589	96.7%	1	254	0%
Rockaway Beach	2,095	454,733	695	151,990	33.4%	108	21,184	4.7%	349	73,581	16%
Tillamook	2,194	982,931	0	0	0.0%	1	1,108	0.1%	55	26,742	3%
Wheeler	362	81,137	220	36,668	45.2%	119	37,822	46.6%	7	2,040	3%
Total Tillamook County	**27,090**	**6,854,759**	**3,650**	**747,317**	**10.9%**	**6,039**	**1,302,360**	**19.0%**	**4,684**	**946,967**	**13.8%**

Table 52. Landslide Exposure: Port of Tillamook Bay and Port of Garibaldi

	Total Number of Buildings	Total Estimated Building Value ($)	Very High Susceptibility			High Susceptibility			Moderate Susceptibility		
			Number of Buildings	Building Value ($)	Ratio of Exposure Value	Number of Buildings	Building Value ($)	Ratio of Exposure Value	Number of Buildings	Building Value ($)	Ratio of Exposure Value
Port of Garibaldi	36	8,035,760	0	0	0%	2	78,810	0.98%	4	137,921	1.72%
Port of Tillamook	83	61,545,144	1	34,419	0.06%	1	22,425	0.04%	1	28,552	0.05%

Source: Derived from DOGAMI (2016, Table A-6)

5. Severe Weather

Severe weather encompasses droughts, windstorms, and winter storms.

Droughts

Introduction

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

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

Drought – The Nebulous Natural Hazard

- Drought is often associated with water scarcity, which usually is perceived as a "human-caused" hazard, rather than a "natural" hazard.
- Drought is frequently an "incremental" hazard, the onset and end are often difficult to determine. Also, its effects may accumulate slowly over a considerable period of time and may linger for years after the termination of the event.
- Quantifying impacts and provisions for disaster relief is a less clear task than it is for other natural hazards.
- The lack of a precise and universally accepted definition adds to the confusion about whether or not a drought actually exists.
- Droughts are often defined by growing seasons, the water year, and livestock impacts.

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

Types of Drought

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

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

Meteorological or Climatological Droughts

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

Agricultural Droughts

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

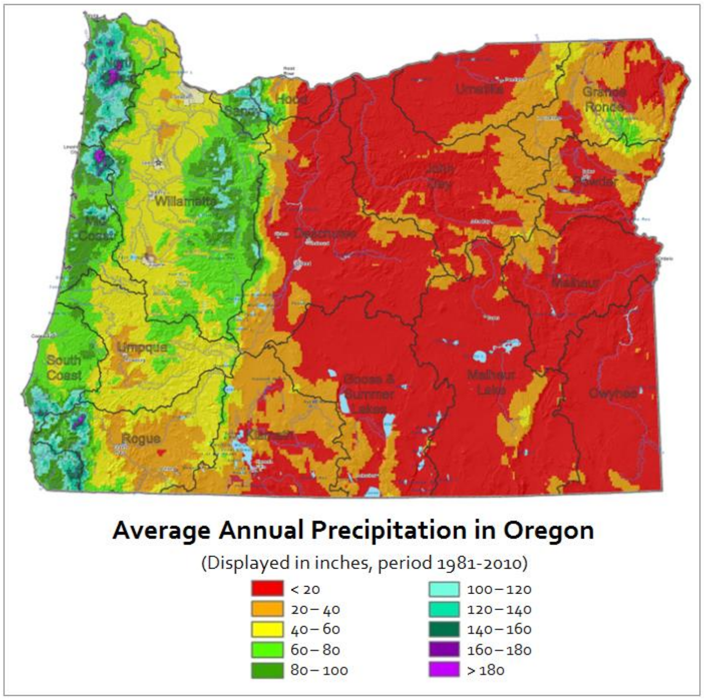
Hydrological Droughts

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

Socioeconomic Droughts

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

Figure 64. Oregon Average Annual Precipitation, 1981–2010



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

Location

Table 53. Jurisdictions Subject to Drought

Jurisdiction	Drought
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

Low streamflows prevailed in western Oregon during the period 1976–1981, but the worst year, by far, was 1976-77, the single driest year of the century. The Portland Airport received only 7.19 inches of precipitation between October 1976 and February 1977, only 31% of the average 23.16 inches for that period. This drought also impacted California and other parts of the West Coast. It is often acknowledged as one of the most significant droughts in Oregon's history.

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

In 2001 and 2002, Oregon experienced drought conditions, affecting most of the state including the coast. More recent droughts have not affected the coast.

Historic Drought Events

Table 54. Historic Droughts and Dry Periods in Tillamook County

Date	Location	Description
1924	statewide	prolonged statewide drought that caused major problems for agriculture
1928–41	statewide	the 1920s and 1930s, known more commonly as the Dust Bowl, were a period of prolonged drier than normal conditions across much of the state and country; moderate to severe drought affected much of the state; caused major problems for agriculture; the three Tillamook burns, in the normally wet coastal range, the first in 1933, were the most significant impacts of this very dry period
1939	statewide	Water Year 1939 was one of the more significant drought years for the Oregon Coast; the second of the three Tillamook Burns started in 1939
1976-77	western Oregon	the 1977 drought was one of the most significant on record in western Oregon
1985–94	statewide	generally dry period, capped by statewide droughts in 1992 and 1994; the Oregon Coast suffered a severe drought in 1992; the winter of 1991-92 was a moderate El Niño event, which can manifest itself in warmer and drier winters in Oregon; Governor declared a drought for all 36 counties in September 1992; 10 consecutive years of dry conditions caused problems throughout the state, such as fires and insect outbreaks
2001-02	statewide except Portland metro area and northern Willamette Valley	the second most intense drought in Oregon's history; 18 counties with state drought declaration (2001); 23 counties state-declared drought (2002); some of the 2001 and 2002 drought declarations were in effect through June or December 2003

Sources: Taylor and Hatton (1999); Governor-declared drought declarations obtained from the Oregon State Archives division (http://sos.oregon.gov/archives/); NOAA's Climate at a Glance (https://www.ncdc.noaa.gov/cag/); Western Regional Climate Center's Westwide Drought Tracker, (http://www.wrcc.dri.edu/wwdt); Kathie Dello, Oregon Climate Service, Oregon State University, personal communication.

Probability

Drought is a normal, recurrent feature of climate. Despite impressive achievements in the science of climatology, estimating drought probability and frequency continues to be difficult. This is because of the many variables that contribute to weather behavior, climate change, and the absence of historic information. Based on limited data, the probability of drought occurring in Tillamook County is low.

Climate Variability

The variability of Oregon's climate often can be attributed to long-term oscillations in the equatorial Pacific Ocean: El Niño and La Niña. Simply stated, these systems involve the movement of abnormally warm or cool water into the eastern Pacific, dramatically affecting the weather in the Pacific Northwest. El Niño tends to bring warm and dry winters; the inverse is true with La Niña. However, there have been wet years during an El Niño event, dry years in a La Niña, and both types of water years in neutral conditions. In other words, El Niño and La Niña do not explain all of the variability in every given winter. Also, climate change is reducing the robustness of the low-elevation snowpack, which will likely influence the frequency of drought conditions and associated impacts on Oregon communities.

An El Niño system moves heat, both in terms of water temperature and in atmospheric convection. The heat is transported toward North America, producing mild temperatures and dry conditions in Oregon. Its effects are most pronounced from December through March.

La Niña conditions are more or less opposite of those created by El Niño. It involves the movement of abnormally cool water into the eastern Pacific. This event produces cooler than normal temperatures in Oregon and increased precipitation. It also is most pronounced from December to March.

Predicting Droughts in Oregon

Predicting weather patterns is difficult at best; however, the 1997-98 El Niño event marked the first time in history that climate scientists were able to predict abnormal flooding and drought months in advance for various locations around the United States (http://www.nationalgeographic.com/elnino/mainpage2.html). The methodology consists of monitoring water temperatures, air temperatures, and relative humidity plus measuring sea-surface elevations. Once an El Niño or La Niña pattern is established, climatologists can project regional climatic behavior. Although the scientific community is optimistic about its recent forecasting achievements, not all droughts are associated with El Niño or La Niña events.

Climate Change

Climate models project warmer, drier summers for Oregon, with mean projected seasonal increases in summer temperatures of 2.6 °C to 3.6 °C by mid-century, and a decline in mean summer precipitation amounts of 5.6 to 7.5% by mid-century. These summer conditions will be coupled with projected decreases in mountain snowpack due to warmer winter temperatures. Models project a mean increase in winter temperatures of 2.5 °C to 3.2 °C by mid-century. This combination of factors exacerbates the likelihood of drought. These same conditions often lead to an increase in the likelihood of wildfires.

Vulnerability

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on the state's agricultural sector, particularly east of the Cascade Mountains. Below-average snowfall in Oregon's higher elevations has a far-reaching effect on the entire state, especially in terms of hydroelectric power generation, irrigation, recreation, and industrial uses.

There also are environmental consequences. A prolonged drought in Oregon's forests promotes an increase of insect pests, which in turn, damage trees already weakened by a lack of water. Water stress brought on by drought and other factors is the central cause in tree mortality events (Oregon Department of Forestry, 2008). A moisture-deficient forest constitutes a significant fire hazard. In addition, drought and water scarcity add another dimension of stress to imperiled species.

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

Population

Droughts can affect all segments of Oregon's population, particularly those employed in water-dependent activities (e.g., agriculture, hydroelectric generation, recreation, etc.). Also, domestic water-users may be subject to stringent conservation measures (e.g., rationing) during times of drought and could see increases in electricity consumption and associated costs.

Infrastructure

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

Critical/essential facilities

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

State-owned or -operated facilities

A variety of state-owned or -operated facilities could be affected by a prolonged drought. The most obvious include schools, universities, office buildings, health-care facilities, etc. Power outages are always a concern. Maintenance activities (e.g., grounds, parks, etc.) may be curtailed during periods of drought. The Oregon Parks and Recreation Department operates several campground and day-use facilities that could be impacted by a drought.

Economy

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

Environment

Oregon has several fish species listed as threatened or endangered under the Endangered Species Act (ESA). Some of these species have habitat requirements that are jeopardized by the needs or desires of humans. For example, in times of scarcity, the amount of water needed to maintain habitat for fish species may conflict with the needs of consumptive uses of water. The state of Oregon is committed to implementation of the ESA and the viability of a productive economic base. There are no easy solutions, only continuous work to resolve difficult drought situations.

Based on a review of Governor-declared drought declarations since 1992, Tillamook County is less vulnerable to drought impacts than most of Oregon. Nevertheless, even short-term droughts can be problematic. Potential impacts to community water supplies are the greatest threat. Tillamook County's dairy industry can suffer catastrophic losses due to lack of feed production and therefore milk production. The economic consequences would impact not only individual dairy farmers but also the local and state economies. Long-term drought periods of more than a year can impact forest conditions and set the stage for potentially devastating wildfires. Severe drought conditions resulted in the four disastrous Tillamook fires (1933, 1939, 1945, and 1951), collectively known as the Tillamook Burn.

The Port of Garibaldi could suffer secondary impacts from drought. Droughts both local and in Southern Oregon and Northern California can affect current year fish returns and impact quotas for upcoming years. These reduced numbers can have a drastic impact on the local economy for both the commercial fishing and seafood processing industries. Low fish stock returns can also drastically impact the local sport fishing industry having negative impacts on the many support services in and around the Port of Garibaldi such as charter business, restaurants, hotels, fuel sales, grocery sales, and others.

Local Risk Assessment Methodology

Tillamook County executed the "OEM Methodology" in October 2015 considering probability of and vulnerability to drought throughout the county. The County rated probability low and vulnerability moderate. The total score for drought trailed the scores for floods, winter storms, windstorms, landslides, earthquakes and volcanic ash fall.

Tillamook County and its cities executed the "OEM Methodology" again as an element of developing this risk assessment in September 2016. This time, Tillamook County considered only the rural areas of the county and the unincorporated urban communities of Neskowin, Oceanside-Netarts, and Pacific City. An assessment was also done by each city and the two ports. The assessment is based on the knowledge and experience of local officials and subject matter experts.

Most jurisdictions in Tillamook County assessed their risk of drought as low; one as moderate; and two as high. Both that were assessed as high were assessed in conjunction with windstorms and winter storms. Therefore it is not clear that risk of drought alone would have been assessed as high. The State assessment is that Tillamook County is susceptible to drought, but less so than other areas of the state. When drought does occur, the county as a whole can be quite vulnerable.

Table 55. Local Risk Assessment: Drought

Jurisdiction	History	Vulnerability	Maximum Threat	Probability	Total	Risk Level
Unincorporated Tillamook County, including Neskowin, Oceanside-Netarts, and Pacific City–Woods	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Bay City	2	20	90	28	140	Low
Garibaldi*	12	15	50	42	119	Low
Manzanita	0	20	40	0	60	Low
Nehalem*	16	30	90	56	192	High
Rockaway Beach*	20	45	100	56	221	High
Tillamook	0	15	30	0	45	Low
Wheeler	8	15	80	56	159	Moderate
Port of Tillamook Bay	0	5	10	7	22	Low
Port of Garibaldi	2	5	10	7	24	Low

*Assessed as part of "severe weather" together with windstorms and winter storms.

Source: Based on information presented at the Tillamook County Multi-Jurisdictional NHMP Update Steering Committee Meeting, September 23, 2016

Extreme Temperatures

Introduction

Extreme temperatures can refer to either extreme cold or extreme heat. Because only extreme heat was of concern in Tillamook County, it is the only aspect of extreme temperatures that is addressed in this section.

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. OCCRI's report presents projected changes in three metrics of extreme daytime heat (maximum temperature) and nighttime heat (minimum temperature).[14]

Table 56. 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

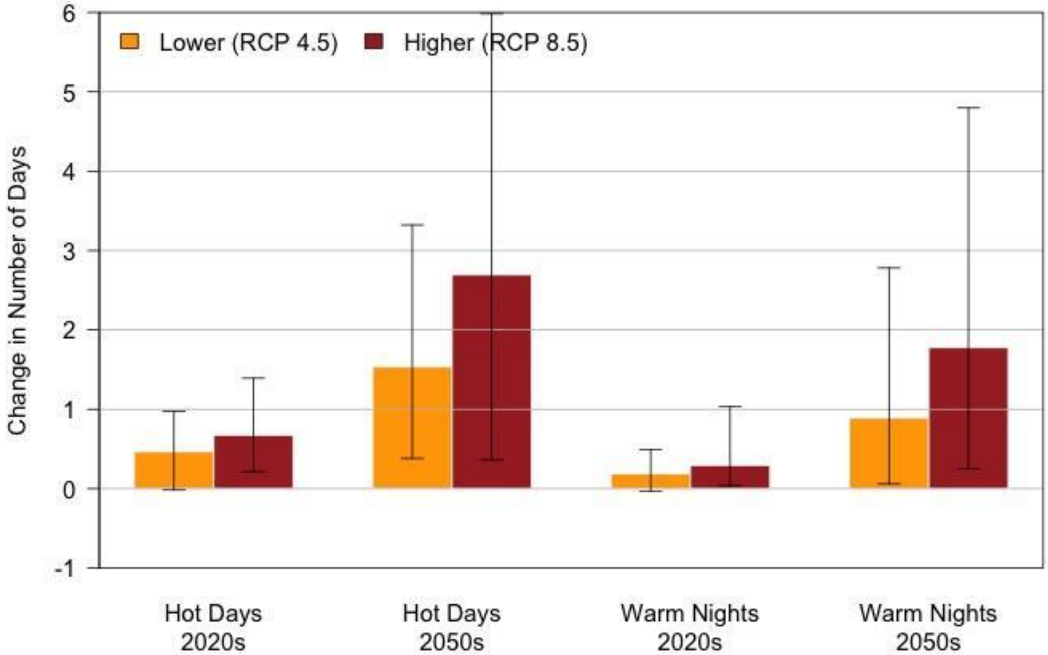
Source: Future Climate Projections Tillamook County, Oregon, OCCRI, 2022

Extreme Heat Events

Although many other locations in Oregon experienced extreme heat events during June and August of 2021, temperatures in Tillamook County did not reach this level. The hazard is raised as a new concern in this NHMP due to the probability that extreme heat may worsen with climate change.

[14] Future Climate Projections Linn County, Oregon, OCCRI, 2022

Figure 65. Change in Number of Extreme Heat Days in Tillamook County



Source: Future Climate Projections Tillamook County, Oregon, OCCRI, 2022

Probability

In Tillamook 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.

The number of days per year with temperatures 90°F or higher is projected to increase by an average of 3 days (range 0–6 days) by the 2050s in Tillamook County, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

The temperature on the hottest day of the year in Tillamook County is projected to increase by an average of about 6°F (range 1–9°F) by the 2050s, relative to the 1971–2000historical baselines, under the higher emissions scenario.

Vulnerability

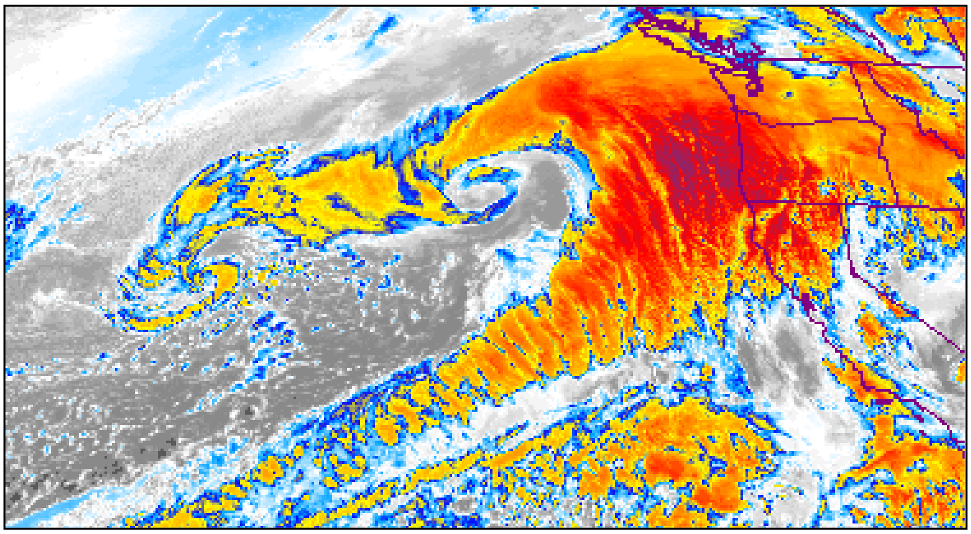
Extreme heat can result in death. During the June 2021 extreme heat event Multnomah County had the largest number of fatalities in the state of Oregon with 73 deaths directly related to the heat. Death can result as well when residents seek relief in bodies of water. During the August 11-12, 2021 extreme heat event, a 22-year-old woman drowned after being swept away while wading in the Willamette River near the pedestrian bridge between the University of Oregon campus and Autzen Stadium in Eugene. The high temperature at Eugene (KEUG) was 102 degrees on the 11th and 104 degrees on the 12th.

Windstorms

Introduction

This section covers most kinds of windstorm events in Oregon, including the wind aspects of Pacific storm events. The precipitation aspects of Pacific storm events are covered with floods. Winds specifically associated with blizzards and ice storms are covered with Winter Storms.

Figure 66. Satellite Image of the Type of Severe Pacific Storm that Can Bring High Winds to Western Oregon



Source: NOAA

Types of Windstorms

High winds can be among the most destructive weather events in Oregon; they are especially common in the exposed coastal regions and in the mountains of the Coast Range. Most official wind observations in Oregon are sparse, taken at low-elevation locations where both the surface friction and the blocking action of the mountain ranges substantially decrease the speed of surface winds. Furthermore, there are few long-term reliable records of wind available. Even the more exposed areas of the coast are lacking in any long-term set of wind records. From unofficial, but reliable observations, it is reasonable to assume that gusts well above 100 mph occur several times each year across the higher ridges of the Coast and Cascade Ranges. At the most exposed Coast Range ridges, it is estimated that wind gusts of up to 150 mph and sustained speeds of 110 mph will occur every 5–10 years.

Destructive wind storms are less frequent, and their pattern is fairly well known. They form over the North Pacific during the cool months (October through March), move along the coast, and swing inland in a northeasterly direction. Wind speeds vary with the storms. Gusts exceeding 100 miles per hour have been recorded at several coastal locations but lessen as storms move inland. These storms, such as the Columbus Day Storm of October 1962, can be very destructive. Less destructive storms can topple trees and power lines and cause building damage. Flooding can be an additional problem. A large percentage of Oregon's annual precipitation comes from these events (Taylor & Hatton, 1999; FEMA-1405-DR-OR, https://www.fema.gov/disaster/1405; Oregon Emergency Management and the Federal Emergency Management Agency, 2002).

Tornadoes, while generally not associated with the State of Oregon, do occur, and have occurred on the Oregon Coast and in Tillamook County. The first recorded tornado on the Oregon Coast occurred in 1897. They are characteristically brief and small, but also damaging.

Location

Table 57. Jurisdictions Subject to Windstorms

Jurisdiction	Windstorms
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City–Woods	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

Pacific storms can produce high winds and often are accompanied by significant precipitation and low barometric pressure. These storms usually produce the highest winds in Western Oregon, especially in the coastal zone. These storms are most common from October through March. The impacts of these storms on the state are influenced by storm location, intensity, and local terrain.

Additional wind hazards occur on a very localized level, due to several down-slope windstorms along mountainous terrain. These regional phenomena known as foehn-type winds, result in winds exceeding 100 mph, but they are of short duration and affect relatively small geographic areas.

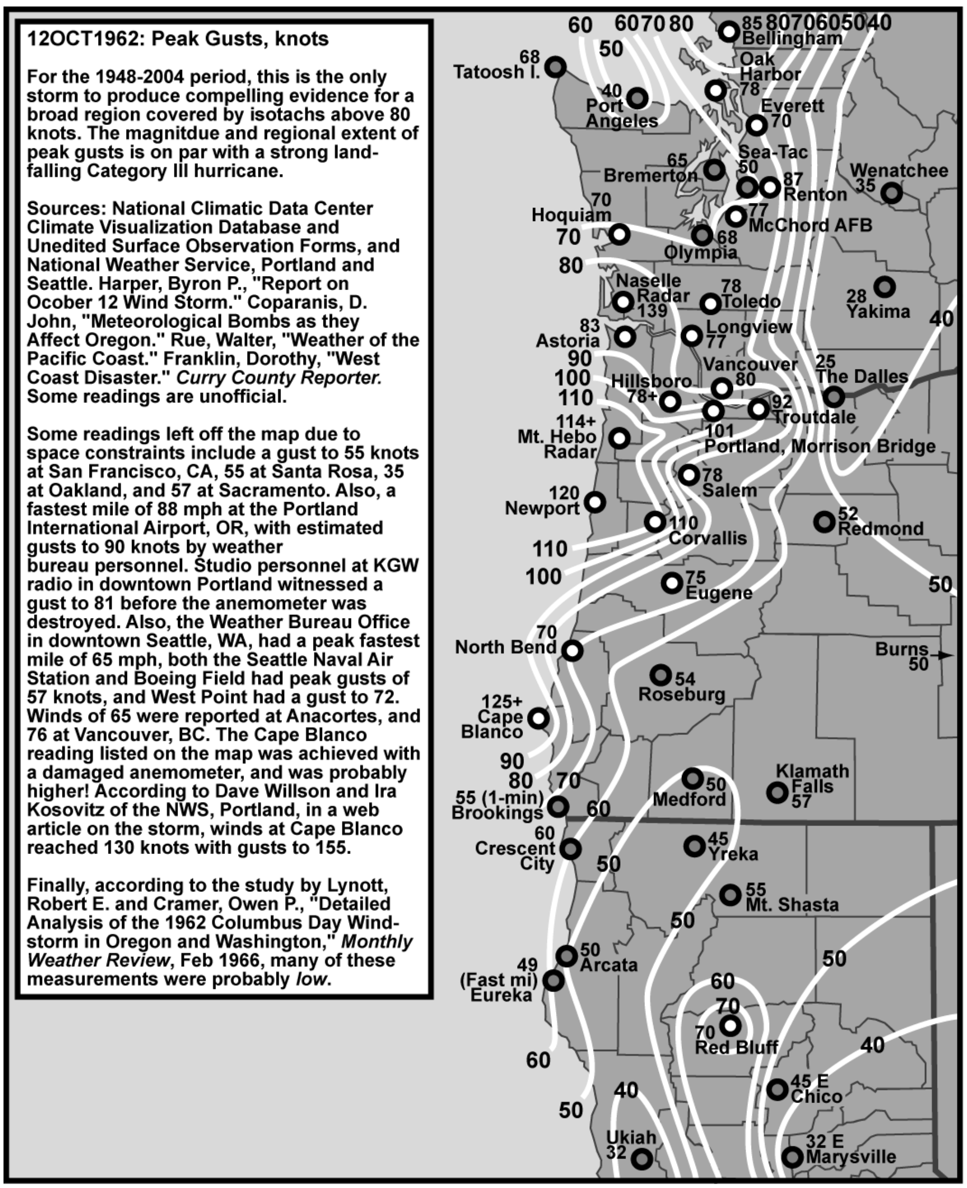
The historian Lancaster Pollard documented exceptional storms that occurred in 1880, 1888, 1920, 1931, and 1962. On January 29, 1920 a hurricane off the mouth of the Columbia River had winds estimated at 160 miles per hour (Pitzer, 1988).

One easterly windstorm that affected much of Oregon, particularly northern Oregon, was the northeasterly gale of April 21-22, 1931. This storm proved to be very destructive. Dust was reported by ships 600 miles out to sea. "While officially recorded wind speeds were not extreme, sustained wind speeds observed were 36 mph at Medford, 32 mph at Portland, 28 mph at Baker, and 27 mph at

Roseburg. Unofficial wind measuring equipment reported winds of up to 78 mph. Damage was heavy to standing timber and fruit orchards" (http://www.wrh.noaa.gov/Portland/windstorm.html).

The most destructive winds are those that blow from the south, parallel to the major mountain ranges. The Columbus Day Storm of 1962 was a classic example of a south windstorm. The storm developed from Typhoon Freda remnants in the Gulf of Alaska, deepened off the coast of California and moved from the southwest, then turned, coming into Oregon directly from the south. This was the most damaging windstorm in Oregon of the last century. Winds in the Willamette Valley topped 100 mph, while in the Coast Range they exceeded 140 mph. The Columbus Day Storm was the equivalent of a Category IV hurricane in terms of central pressure and wind speeds.

Figure 67. Peak Gusts for Windstorm on October 12, 1962



Source: Wolf Read, Climatologist, Oregon Climate Center, Oregon State University, http://www.climate.washington.edu/stormking/October1962.html

Historic Windstorm Events

Table 58. Historic Windstorms in, near, or Impacting Tillamook County

Date	Location	Description	Remarks
Jan. 1880	western Oregon	very high winds, 65-80 mph near Portland	flying debris; fallen trees
Jan. 1921	Oregon coast / Lower Columbia	winds 113 mph at mouth of Columbia; gusts at Astoria, 130 mph	widespread damage
Apr. 1931	western Oregon	unofficial reports of wind speeds up to 78 mph	widespread damage
Nov. 1951	most of Oregon	winds 40–60 mph with 75–80 mph gusts	widespread damage, especially to transmission lines
Dec. 1951	most of Oregon	winds, 60–100 mph, strongest along coast	many damaged buildings; telephone/power lines down
Jan. 1956	western Oregon	heavy rains, high winds, mud slides	estimated damage: $95,000 (1956 dollars)
Nov. 1958	most of Oregon	wind gusts to 75 mph at Astoria; gusts to 131 mph at Hebo	damage to buildings and utility lines
Oct.. 1962	statewide	wind speeds of 131 mph on the Oregon coast (Columbus Day Windstorm Event)	Oregon's most destructive storm: 23 fatalities; damage at $170 million
Mar. 1963	Coast and NW Oregon	100 mph gusts (unofficial)	widespread damage
Oct. 1967	western and N. Oregon	winds on Oregon Coast 100–115 mph	significant damage to buildings, agriculture, and timber
Mar. 1971	most of Oregon	notable damage in Newport	falling trees took out power lines; building damage
Nov. 1981	Oregon coast and N. Willamette Valley, Oregon	back-to-back storms on Nov. 13 and 15	
Jan. 1986	N and central Oregon coast	75 mph winds	damaged trees, buildings, power lines
Dec. 1987	Oregon coast / NW Oregon	winds on coast 60 mph	saturated ground enabled winds to uproot trees
Mar. 1988	N. and central coast	wind gusts 55–75 mph	one fatality near Ecola State Park; uprooted trees
Jan. 1990	statewide	100 mph winds in Netarts and Oceanside	one fatality; damaged buildings; falling trees (FEMA-853-DR-Oregon)
Feb. 1990	Oregon coast	wind gusts of 53 mph at Netarts	damage to docks, piers, boats
Jan. 1991	most of Oregon	winds of 63 mph at Netarts; 57 at Seaside	75-foot trawler sank NW of Astoria
Nov. 1991	Oregon coast	slow-moving storm; 25-foot waves off shore	buildings, boats, damaged; transmission lines down
Jan. 1993	Oregon coast / N. Oregon	Tillamook wind gusts at 98 mph	widespread damage, esp. Nehalem Valley
Dec. 1995	statewide	wind gusts over 100 mph; Sea Lion Caves: 119 mph; followed path of Columbus Day Storm (Dec. 1962)	four fatalities; many injuries; widespread damage (FEMA-1107-DR-Oregon)
Nov. 1997	western Oregon	winds of 89 mph at Florence; 80 mph at Netarts and Newport	severe beach erosion; trees toppled

Date	Location	Description	Remarks
Dec. 2004	Tillamook County		$6,250 in property damage (figure includes damages outside of Tillamook County)
Jan. 2006	Clatsop, Tillamook, Lincoln, Lane Counties	two storm events with high winds of 86 mph and 103 mph	$244,444 and $144,444 in estimated property damage among all four coastal counties; the storm also impacted 5 other counties outside Region 1; total damages equal $300,000 and $200,000, respectively
Feb. 2006	Clatsop, Tillamook, Lincoln, Lane Counties	wind storm event with winds measured at 77 mph	$150,000 and $91,600 in estimated property damage among all four coastal counties; the storm also impacted nine other counties outside of Region 1; total damages equal $300,000 and $275,000
Mar. 2006	Clatsop, Tillamook, Lincoln, Lane Counties	two wind storm events with winds measured at 60 mph and 75 mph	$75,000 and $211,000 in estimated property damage among all four coastal counties; the storms also impacted 10 other counties outside of Region 1; total damages equal $75,000 and $475,000
Dec. 2006	Clatsop, Tillamook Counties	storm with high winds	total of $10,000 in damages
Feb. 2007	NW and central coast and north central Oregon	severe winter storm with a wind component	FEMA-1683-DR-Oregon
Nov. 2007	Clatsop, Tillamook Counties	storm with high winds	total of $10,000 in damages
Dec. 2007	Clatsop, Tillamook Counties	series of powerful Pacific storms	resulted in Presidential Disaster Declaration; $180 million in damage in the state, power outages for several days, and five deaths attributed to the storm
Dec. 2008	Clatsop, Lane, Tillamook, Lincoln Counties	intense wind and rain events	resulted in nearly $8 million in estimated property and crop damages for Clatsop, Lane, Tillamook, and Lincoln Counties

Sources: Oregon Climate Service, http://www.ocs.oregonstate.edu/; Pitzer (1988)

Table 59. Tornadoes Recorded in Tillamook County

Date	Location	Remarks
June 1897	Bay City, Oregon	observed, but no damage recorded
Dec. 1975	Tillamook, Oregon	90 mph wind speed; damage to several buildings
Oct. 2016	Manzanita, Oregon	20 homes and several businesses damaged; no injuries
OCt. 2016	Oceanside, Oregon	no damage

Sources: National Weather Service, Portland; Taylor and Hatton (1999); Storm Events Database, http://www.ncdc.noaa.gov/stormevents/; Hazards and Vulnerability Research Institute (2007); US Tornado Climatology, http://www.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html

Probability

The Central and North Coast experience the highest wind speeds under the influence of winter low-pressure systems in the Gulf of Alaska and North Pacific Ocean, and the Columbia River Gorge, when cold air masses funnel down through the canyon in an easterly direction.

The much more frequent and widespread strong winds from the southwest are associated with storms moving onto the coast from the Pacific Ocean. If winds are from the west, they are often stronger on the coast than in interior valleys due to the north-south orientations of the Coast Range and Cascades. These mountain ranges obstruct and slow the westerly surface winds.

High winds are especially common in coastal regions and in the mountains of the Coast Range between October and March. From unofficial but reliable observations, it is reasonable to assume that gusts well above 100 mph occur several times each year across the higher ridges of the Coast and Cascades Ranges. At the most exposed Coast Range ridges, it is estimated that wind gusts of up to 150 mph and sustained speeds of 110 mph will occur every 5 to 10 years.

The probability of a severe wind event is expressed as a percentage annual probability or a specific return interval, similar to the probability of a flood. A 25-year event is a storm with one-minute average wind speed of 75 mph and a 4% chance of occurring each year. A 50-year event has a one-minute average wind speed of 80 mph and a 2% chance of occurring each year. A 100-year event has a one-minute wind speed of 90 mph and a 1% chance of occurring each year (Oregon Public Utilities Commission).

Climate Change

There is insufficient research on changes in the likelihood of wind storms in the Pacific Northwest as a result of climate change.

Vulnerability

The damaging effects of windstorms may extend for distances of 100 to 300 miles from the center of storm activity. Isolated wind phenomena in the mountainous regions have more localized effects. Near-surface winds and associated pressure effects exert loads on walls, doors, windows, and roofs, sometimes causing structural components to fail.

Positive wind pressure is a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Negative pressure also affects the sides and roof: passing currents create lift and suction forces that act to pull building components and surfaces outward. The effects of high-velocity winds are magnified in the upper levels of multi-story structures. As positive and negative forces impact and remove the building protective envelope (doors, windows, and walls), internal pressures rise and result in roof or leeward building component failures and considerable structural damage. Structures most vulnerable to high winds in Tillamook County include insufficiently anchored manufactured homes and older buildings in need of roof repair.

Debris carried along by extreme winds can directly contribute to loss of life and indirectly to the failure of protective building envelope components. Upon impact, wind-driven debris can rupture a building, allowing more significant positive and internal pressures. When severe windstorms strike a community, downed trees, power lines, and damaged property are major hindrances to response and recovery.

Many buildings, utilities, and transportation systems in Tillamook County are vulnerable to wind damage. This is especially true in open areas, natural grasslands, or farmland. It also is true in forested areas, along tree-lined roads and electrical transmission lines, and on residential parcels where trees have been planted or left for aesthetic purposes.

Fallen trees are especially troublesome. They can block roads and rails for long periods, which can affect emergency operations. In addition, uprooted or shattered trees can down power and/or utility lines, effectively bringing local economic activity and other essential activities to a standstill. Much of the problem may be attributed to a shallow or weakened root system in saturated ground. Many roofs have been destroyed by uprooted ancient trees growing next to a house.

Unstable trees near electric lines left after a logging operation near electric lines pose a serious threat of personal injury, forest fire, and outages should high winds develop. Forest owners and workers need to coordinate their "leave trees" with electric utilities to prevent dangerous conditions as depicted in Figure 34.

Figure 68. Unstable Trees near Electric Lines Remaining after a Logging Operation

Photo source: Randy Miller, PacifiCorp

Wind-driven waves are common along the Oregon coast and are responsible for road and highway wash-outs and the erosion of beaches and headlands.

Windstorms and winter storms pose the greatest threat to the Port of Garibaldi’s infrastructure due to their frequency and the Port’s exposure and vulnerability. At the Port, it is common for high winds to exceed 70 mph with gusts up to 100 mph and damage buildings and mooring facilities. Over the last 15 years, many roofs and structures have sustained damage during windstorms and winter storms.

High winds out of the south create rough water conditions on Tillamook Bay causing swells that impact Port property by eroding all exposed areas. These swells also cause a severe surge to enter the boat basin, which can damage docks and exposed vessels.

The Port of Tillamook Bay has suffered multiple losses from windstorms over many years. Hangar B, which houses the Tillamook Air Museum and other tenants is a prime example. High winds from the southwest wreak havoc on the southern portion of this building. Other Port buildings, most of which were constructed in the 1940s, are similarly vulnerable to these high-wind events.

In 1962 dollars, the Columbus Day Storm caused an estimated $230–280 million in damage to property in California, Oregon, Washington and British Columbia combined, with $170–200 million happening in Oregon alone. The Columbus Day Storm was declared the worst natural disaster of 1962 by the Metropolitan Life Insurance Company. In terms of timber loss, about 11.2 billion board feet was felled... in Oregon and Washington combined" (http://www.climate.washington.edu/stormking/). "The storm claimed 46 lives, injured hundreds more, and knocked power out for several million people" (http://www.wrh.noaa.gov/pqr/info/pdf/pacwindstorms.pdf).

Winter Storms

Introduction

Winter storms are among nature's most impressive spectacles. Their combination of heavy snow, ice accumulation, and extreme cold can totally disrupt modern civilization, closing down roads and airports, creating power outages, and downing telephone lines. Winter storms remind us how vulnerable we are to nature's awesome powers.

For the most part, the wind aspects of winter storms are covered with windstorms. Heavy precipitation aspects associated with winter storms in some parts of the state, which sometimes lead to flooding, are covered with floods. This section generally addresses snow and ice hazards and extreme cold.

Location

Table 60. Jurisdictions Subject to Winter Storms

Jurisdiction	Winter Storms
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City–Woods	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

According to the National Weather Service (2003) —

> *Most snowstorms need two ingredients: cold air and moisture. Rarely do the two ingredients occur at the same time over western Oregon, except in the higher elevations of the Coast Range and especially in the Cascades. But snowstorms do occur over eastern Oregon regularly during December through February. Cold arctic air sinks south along the Columbia River Basin, filling the valleys with cold air. Storms moving across the area drop precipitation, and if conditions are right, snow will occur.*
>
> *However, it is not that easy of a recipe for western Oregon. Cold air rarely moves west of the Cascade Range. The Cascades act as a natural barrier, damming cold air east of the range. The*

> *only spigot is the Columbia River Gorge, which funnels the cold air into the Portland area. Cold air then begins deepening in the Columbia River valley, eventually becoming deep enough to sink southward into the Willamette valley. If the cold air east of the Cascades is deep, it will spill through the gaps of the Cascades and flow into the western valleys via the many river drainage areas along the western slope. The cold air in western Oregon is now in place. The trick is to get a storm to move near or over the cold air, which will use the cold air and produce freezing rain, sleet, and/or snow. Sometimes, copious amounts of snow are produced. Nearly every year, minor snowfalls of up to six inches occur in the western interior valleys. However, it is a rare occurrence for snowfalls of over a foot in accumulations* [sic].

Snow is relatively rare on the Oregon Coast. Freezing rain, ice and snow are most common the Coast Range passes, making travel to the east treacherous. They also cause widespread power outages in Tillamook County. Ice storms and freezing rain can cause severe problems when they occur.

Freezing Rain

Also known as an ice storm, freezing rain is rain that falls onto a surface with a temperature below freezing. The cold surface causes the rain to freeze so the surfaces, such as trees, utilities, and roads, become glazed with ice. Even small accumulations of ice can cause a significant hazard to property, pedestrians, and motorists.

Sleet

Sleet is rain that freezes into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects; however, it can accumulate like snow and cause roads and walkways to become hazardous.

Black Ice

Black ice can fool drivers into thinking water is on the road. What they may not realize is that condensation, such as dew, freezes when temperatures reach 32 °F or below, forming a thin layer of ice. This shiny ice surface is one of the most dangerous road conditions. Black ice is likely to form under bridges and overpasses, in shady spots and at intersections.

Heavy Snow

Meteorologists define heavy snow as 6 inches or more falling in less than 12 hours, or snowfall of 8 inches or more in 24 hours.

Blizzard

A blizzard is a severe winter weather condition characterized by low temperatures and strong winds blowing a great deal of snow. The National Weather Service defines a blizzard as having wind speeds of 35 mph or more, with a visibility of less than a quarter mile. Sometimes a condition known as a whiteout can occur during a blizzard. This is when the visibility drops to zero because of the amount of blowing snow.

Wind Chill

Wind blowing across your body makes you feel colder. The wind chill factor is a measure of how cold the combination of temperature and wind makes you feel. Wind chill of 50 °F or lower can be very dangerous: exposed skin can develop frostbite in less than a minute, and a person or animal could freeze to death after just 30 minutes of exposure.

Historic Winter Storm Events

Table 61. Historic Winter Storms in Oregon

Date	Location	Description
Dec. 9–11, 1919	statewide	one of three heaviest snowfall-producing storms to hit Oregon on record; lowest statewide average temperature since record keeping began in 1890; the Columbia River froze over, closing the river to navigation from the confluence with the Willamette River upstream; nearly every part of the state affected; snow totals (inches): Albany, 25.5; Bend, 49.0; Cascade Locks, 21.5; Eugene, 8.5; Heppner, 16.0; Parkdale, 63.0; Pendleton, 15.0; Siskiyou Summit, 50.0
Feb. 10, 1933	statewide	cold outbreak across state; the city of Seneca, in northeast Oregon, recorded the state's all-time record low temperature of -54 °F; the next day high was nearly 100 degrees warmer at 45 °F
Mid Jan.–Feb, 1950	statewide	extremely low temperatures injured a large number of orchard and ornamental trees and shrubs, and harmed many power and telephone lines and outdoor structures; severe blizzard conditions and a heavy sleet and ice storm together caused several hundred thousand dollars damage and virtually halted traffic for two to three days; Columbia River Highway closed between Troutdale and The Dalles leaving large numbers of motorists stranded, removed to safety only by railway; damage to orchard crops, timber, and power services, costing thousands in damages.
Feb. 1–8, 1989	statewide	heavy snow across state; up to 6–12 inches of snow at the coast, 9 inches in Salem, more than a foot over the state; numerous record temperatures set; wind chill temperatures 30–60 degrees below 0 °F; power failures throughout state, with home and business damage resulting from frozen plumbing; several moored boats sank on the Columbia River because of ice accumulation; five weather-related deaths (three auto accidents caused by ice and snow, and two women froze to death); damage estimates exceeded one million dollars
Dec.28, 2003 – Jan. 9, 2004	statewide	Presidential disaster declaration for 30 of Oregon's 36 counties. Estimated the cost of damages to public property at $16 million; 2-6 inches of snow along the North Oregon Coast
Dec. 2007	Tillamook County	heavy winds, rain, flooding, power outages, and two deaths
Feb. 6–10, 2014	Lane, Benton, Polk, Yamhill, Columbia, Clackamas, Multnomah, Washington, Linn, Marion, Hood River, Lincoln, Tillamook and Clatsop Counties	a strong winter storm system affected the Pacific Northwest during the February 6–10, 2014 time period bringing a mixture of arctic air, strong east winds, significant snowfall and freezing rain to several counties in northwest Oregon; a much warmer and moisture-laden storm moved across northwest Oregon after the snow and ice storm (Feb. 11-14), which produced heavy rainfall and significant rises on area rivers from rain and snowmelt runoff; during the 5-day period Feb. 6–10, 5 to 16 inches of snow fell in many valley locations and 2 to10 inches in the coastal region of northwest Oregon; freezing rain accumulations generally were 0.25 to 0.75 inches; the snowfall combined with the freezing rain had a tremendous impact on the region
Feb. 11–14, 2014	Lane, Benton, Polk, Yamhill, Columbia, Clackamas, Multnomah, Washington, Linn, Marion, Hood River, Lincoln, Tillamook and Clatsop Counties	another weather system moved across northwest Oregon during the February 11–14 time frame; this storm was distinctly different from the storm that produced the snow and ice the week prior and brought abundant moisture and warm air from the sub-tropics into the region; as this storm moved across the area, 2 to 7 inches of rain fell across many counties in western Oregon; the heavy rainfall combined with warm temperatures led to snowmelt and rainfall runoff that produced rapid rises on several rivers, which included flooding on three rivers in northwest Oregon
December 6-23, 2015	Clatsop, Columbia, Coos, Curry, Lane, Lincoln, Linn, Multnomah, Polk, Tillamook, Washington, and Yamhill Counties	Presidential disaster declaration DR-4258: severe winter storms, straight-line winds, flooding, landslides, and mudslides

Source: The National Weather Service, https://www.fema.gov/disaster/4258 and https://www.fema.gov/news-release/2016/02/18/president-declares-disaster-state-oregon, accessed January 29, 2017.

Probability

Because there is not a statewide effort to track and gather data about winter storm impacts, either historical or for future planning, probability is difficult to quantify. There are only limited snowfall sensors distributed mainly through the mountain ranges of the state and there is not an annual tracking system in place for snowfall statewide.

Winter storms occur annually in Oregon bringing snow to Oregon's mountains and much of Eastern Oregon. In Tillamook County, most often winter storm hazards occur in the Coast Range, rather than in the low-lying areas of the County.

Climate Change

There is no current research available about changes in the incidence of winter storms in Oregon due to changing climate conditions.

Vulnerability

A major winter storm can last for days and can include high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. In Tillamook County, the major vulnerabilities are isolation from being unable to transport people and freight over the Coast Range and large-scale power outages.

Winter storms and windstorms pose the greatest threat to the Port of Garibaldi's infrastructure due to their frequency and the Port's exposure and vulnerability. At the Port, it is common for high winds to exceed 70 mph with gusts up to 100 mph and damage buildings and mooring facilities. Over the last 15 years, many roofs and structures have sustained damage during winter storms and windstorms.

High winds out of the south create rough water conditions on Tillamook Bay causing swells that impact Port of Garibaldi property by eroding all exposed areas. These swells also cause a severe surge to enter the boat basin, which can damage docks and exposed vessels.

The Port of Tillamook Bay's railroad has suffered repetitive losses during past winter storms, most notably in 1996 and 2007. The December 2007 storm damaged an approximately 15-mile portion of the rail line. Winter storms also damage building (e.g. roofs, siding, etc.) and depending on severity may cause other ancillary damages.

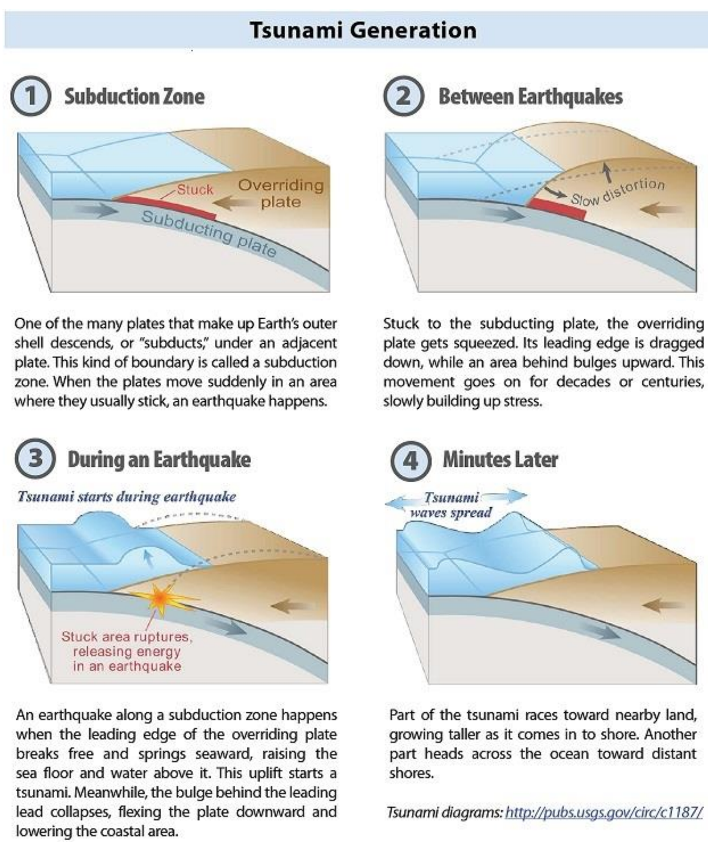
6. Tsunamis

Introduction

Tsunamis are a low frequency natural hazard in Oregon and are restricted almost exclusively to coastal areas. Tsunamis are most often caused by the abrupt change in the seafloor accompanying an earthquake (**Figure 69**). The most common sources of the largest tsunamis are earthquakes that occur at subduction zones like the Cascadia Subduction Zone (CSZ), where an oceanic plate descends beneath a continental plate (**Figure 70**). Other important processes that may trigger a tsunami include underwater volcanic eruptions and landslides (includes landslides that start below the water surface and landslides that enter a deep body of water from above the water surface). Tsunamis can travel thousands of miles across ocean basins, so that a particular coastal area may be susceptible to two different types of tsunami hazard caused by:

1. Distant sources across the ocean basin, and
2. Local sources that occur immediately adjacent to a coast.

Figure 69. Generation of a Tsunami by Subduction Zone Earthquakes



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

Figure 70. Cascadia Subduction Zone (CSZ) Active Fault Map

Note: The fault, indicated by the triangles, is the contact where the Juan de Fuca Plate plunges beneath the North American continental plate.

Source: DOGAMI

Distant tsunamis that may threaten the Oregon Coast are usually generated by a subduction zone earthquake elsewhere in the Pacific and would take at least 4 hours to reach the Oregon coastline from the closest source, the subduction zone in the Gulf of Alaska. For example, the 1964 Alaska tsunami reached the Oregon Coast in four to five hours after the magnitude 9.2 earthquake that generated it. In contrast, a local tsunami generated by a CSZ earthquake, would take about 15-20 minutes to reach most of the coast.

Most locally generated tsunamis will be higher and travel farther inland (overland and up river) than distant tsunamis. By the time the tsunami wave hits the coastline, it may be traveling at 30 mph and have heights of 20 to about 100 feet, depending on the local coastal bathymetry (water depths), shape of the shore, and the amount of fault movement on the subduction zone. The tsunami wave will break up into a series of waves that will continue to strike the coast for a day or more, with the most destructive waves arriving in the first 4-5 hours after the local earthquake. As was seen in the 2004 Sumatra tsunami, the first wave to strike the coast is not always the most destructive. This was again the case during the 2011 Japan tsunami.

Location

Table 62. Jurisdictions Subject to Tsunamis

Jurisdiction	Tsunamis
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City–Woods	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2022)

Hazard Characterization

The coasts of Washington, Oregon, and northern California are particularly vulnerable to tsunamis from magnitude 9+ earthquakes that occur about every 500 years on the CSZ. Additional, smaller tsunamis and earthquakes occur in the subduction zone south of Waldport. The combined recurrence for both types of Cascadia earthquake can be as low as about 230 years in Curry County.

The initial tsunami wave mimics the shape and size of the sea floor movement that causes it, but quickly evolves into a series of waves that travel away from the source of disturbance, reflect off of coastlines, and then return again and again over many hours. The tsunami is thus “trapped” owing to the processes of reflection and refraction. In the deep ocean, tsunami waves may be only a few feet high and can travel at wave speeds of 300–600 mph. As a tsunami approaches land where the water depth decreases, the forward speed of the wave will slow as wave height increases dramatically. When the wave makes landfall, the water is mobilized into a surging mass that floods inland until it runs out of mass and energy. The wave then retreats, carrying all sorts of debris. Successive waves then batter the coast with this debris. Swimming through such turbulent debris-laden water is next to impossible.

Tsunamis are potentially more destructive than the earthquake that caused them. Loss of lives from the tsunami can often be many times the loss from the earthquake ground shaking. This was highlighted by the December 26, 2004 tsunami, associated with a magnitude 9.3 earthquake, which occurred offshore from the Indonesian island of Sumatra. The tsunami impacted almost every county located around the Indian Ocean rim and claimed the lives of approximately 350,000 people. The greatest loss of life occurred along the coast of Sumatra, close to the earthquake epicenter. The event displaced some 2 to 3 million people and its economic impact continues to be felt to the present. The Sumatra event is a direct analogue for what can be expected to occur along the Oregon Coast due to its close proximity to the Cascadia Subduction Zone.

In addition, fires started by the preceding earthquake are often spread by the tsunami waves, if there is a gasoline or oil spill. As was seen in the Sumatra 2004 tsunami, flood inundation from a tsunami may be extensive, as tsunamis can travel up rivers and streams that lead to the ocean. Delineating the inland extent of flooding, or inundation, is the first step in preparing for tsunamis.

Distant tsunamis caused by earthquakes on Pacific Rim strike the Oregon coast frequently but only a few of them have caused significant damage or loss of life. Local tsunamis caused by earthquakes on the Cascadia Subduction Zone (CSZ) happen much less frequently but will cause catastrophic damage and, without effective mitigation actions, great loss of life.

On March 11, 2011, a magnitude (M_w) 9.0 earthquake struck off the east coast of Japan. This caused a massive tsunami that inundated much of the eastern coastline of Japan, and reached the west coast of the US many hours later. There was one death and millions of dollars of damage to ports and harbors in Oregon and California. Japan suffered many thousands of dead and missing as well as a nuclear catastrophe that will continue to be a hazard far into the future. Oregon received a Presidential Declaration of Disaster (DR-1964) that brought millions of dollars of financial aid to repair and mitigate future tsunami damage. Debris from tsunami-damaged buildings in Japan floated across the Pacific Ocean and began arriving on the Canadian and US West Coast in December 2011 and is expected to continue to arrive for years.

In March 1964, a tsunami struck southeastern Alaska following an earthquake beneath Prince William Sound and arrived along the Alaska coastline between 20 and 30 minutes after the quake, devastating villages. Damages were estimated to be over $100 million (1964 dollars). Approximately 120 people drowned. The tsunami spread across the Pacific Ocean and caused damage and fatalities in other coastal areas, including Oregon. The tsunami killed five people in Oregon and caused an estimated $750,000 to $1 million in damage. In Crescent City, California, there were 10 fatalities, while damage to property and infrastructure was estimated to range from $11 to 16 million.

Going still further back in time, there is scientific consensus that the Pacific Northwest experienced a subduction zone earthquake estimated at magnitude 9 on January 26, 1700. The earthquake generated a tsunami that caused death and damage as far away as Japan, where it was well-documented in the literature of the time. The earthquake and tsunami left behind geologic “footprints” in the form of (a) tsunami sand sheets in marshes, (b) layers of marsh vegetation covered by tide-borne mud when the coast abruptly subsided, and (c) submarine sand and silt slurries shaken off the continental shelf by the earthquake (turbidites). The widespread and large body of oral traditional history of the Thunderbird and Whale stories passed down by First Nations people depict both strong ground shaking and marine flooding that may have been inspired by this event. Although this earthquake undoubtedly produced tsunamis that reached about 30–40 ft at the coast, geologic evidence from study of 10,000 years of turbidite deposits suggests that the 1700 earthquake was just an average event. Some Cascadia earthquakes have been many times larger, so, while devastating, the earthquake and tsunami were far from the worst case.

The tsunami wave tends to arrive at the coast as a fast moving surge of rising water. As the tsunami enters coastal bays and rivers, it may move as a high-velocity current or a breaking wave that travels up an estuary as a bore (wall of turbulent water like the waves at the coast after they break). This inland wave of water can often cause most or all of the damage, and the current may be just as destructive when it is retreating from the land as when it is advancing. For example, in Seaside the damage from the

1964 Alaskan tsunami occurred along the Necanicum River and Neawanna Creek, well inland from the coast. In addition, storm waves and wind waves may ride on top of the tsunami waves, further compounding the level of destruction.

During Cascadia earthquakes there is also the added effect of coastal subsidence, or the downward movement of the land relative to the sea level, during the earthquake. This is due to the release of the accumulated strain that caused the western edge of the North American Plate to bend and bulge. The new earthquake models used for the local tsunami scenarios indicate that portions of the Oregon coast could drop by a few to several feet.

In 2010 the Oregon Department of Geology and Mineral Industries (DOGAMI) completed an analysis of the full range of Cascadia tsunamis and earthquakes, separating the results into five size classes with “T-shirt” names, S, M, L, XL, and XXL (Witter, 2011). The XL or XXL events probably only happened once or twice in the last 10,000 years, but estimated tsunami heights were comparable to those of the 2011 Japan and 2004 Sumatra tsunamis, the largest known.

Historic Tsunami Events

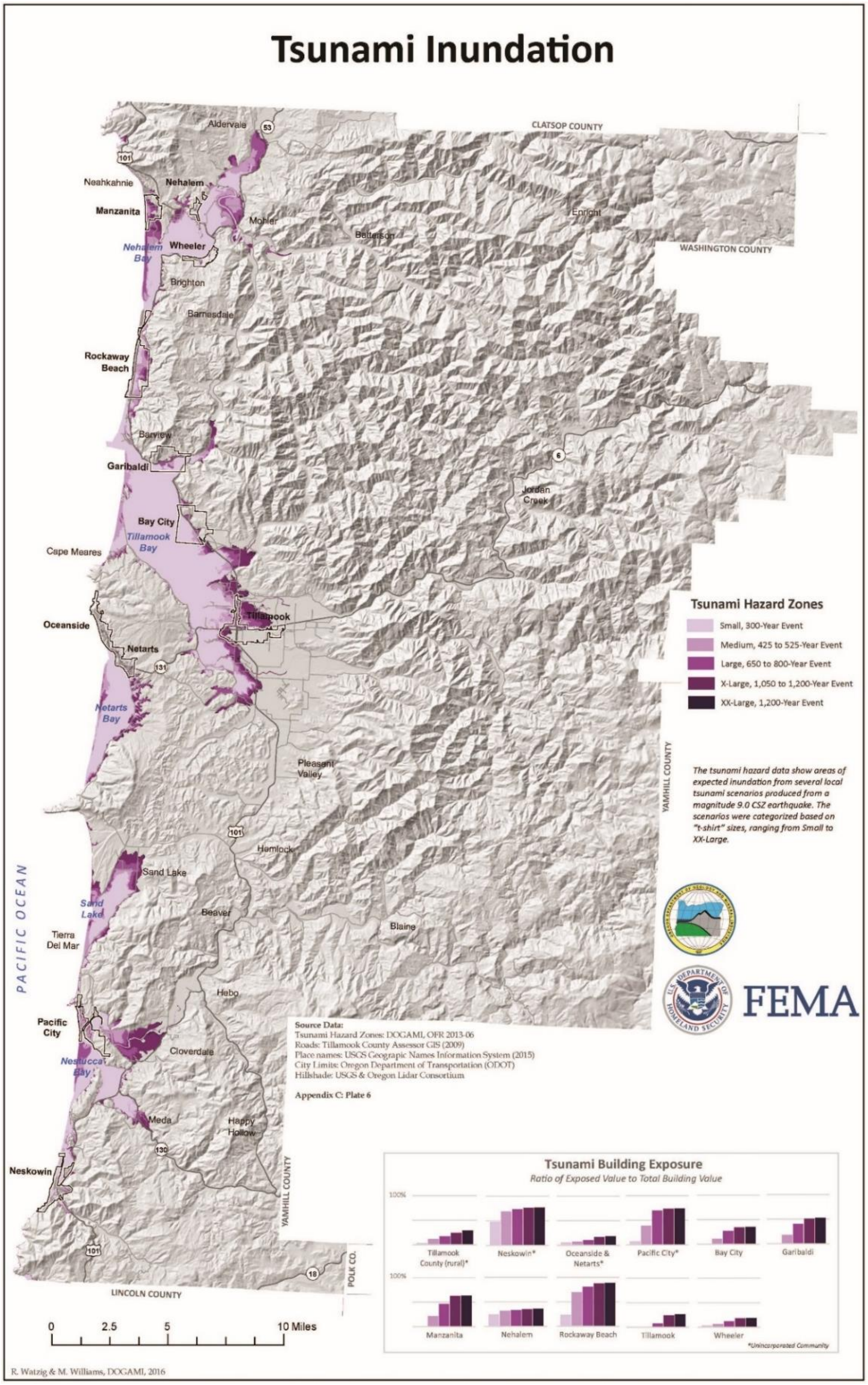
Table 63. Historic Tsunamis that Impacted the Northern Oregon Coast

Date	Origin of Event	Affected Oregon Community	Damage	Remarks
Apr. 1868	Hawaii	Astoria		observed
Aug. 1868	N. Chile	Astoria		observed
Aug. 1872	Aleutian Islands	Astoria		observed
Apr. 1946		Clatsop Spit		water 3.7 m above MLLW
Apr. 1946		Seaside		wall of water swept up Necanicum River
Nov. 1952	Kamchatka	Astoria		observed
May 1960	S. Cent. Chile	Astoria		observed
May 1960		Seaside	bore on Necanicum River damaged boat docks	
May 1960		Netarts	some damage observed	
Mar. 1964	Gulf of Alaska	Cannon Beach	bridge and motel unit moved inland; $230,000 damage	
Mar. 1964		Seaside	1 fatality (heart attack); damage to city: $41,000; private: $235,000; four trailers, 10–12 houses, two bridges damaged	
Oct. 1994	Japan	coast		tsunami warning issued, but no tsunami observed
Mar. 2011	Japan	coast	$6.7 million; extensive damage to the Port of Brookings	tsunami warning issued, observed ocean waves

Sources: Lander, Lockridge, & Kozuch, 1993; FEMA, 2011, Federal Disaster Declaration (https://www.fema.gov/disasters)

In addition to the historical distant tsunamis of **Table 63**, the last CSZ tsunami struck at 9 PM on January 26, 1700. This may be considered a historical event, because the tsunami was recorded in historical port records in Japan. The date and time of occurrence here in Oregon were inferred by Japanese and USGS researchers from a tsunami and earthquake model.

Figure 71. Tsunami Inundation Scenarios and Building Exposure Example

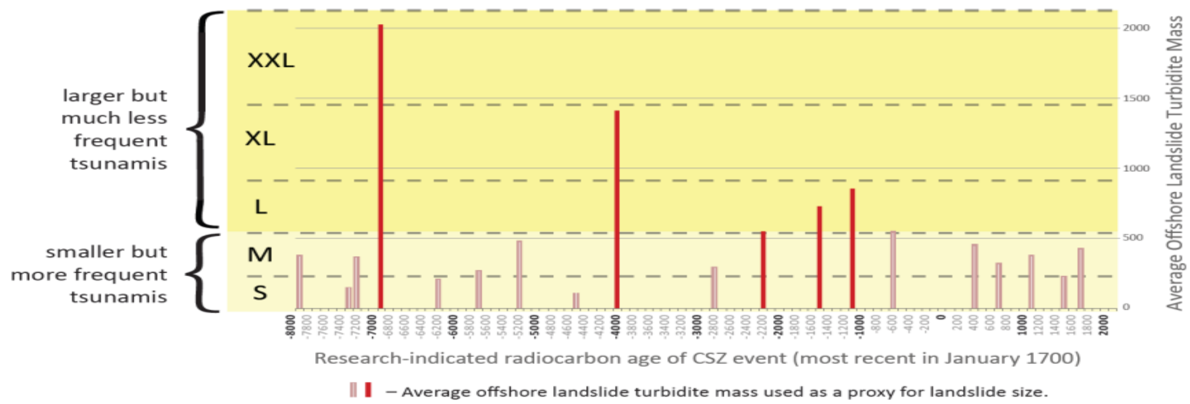


Source: DOGAMI (2022

Probability

While large (about magnitude 9) CSZ earthquakes and associated tsunamis have occurred on average every 500 years over the last 10,000 years, the time interval between events has been as short as decades and as long as 1,150 years. Smaller earthquakes on the southern part of the CSZ have occurred about as often as larger earthquakes, making CSZ events in southernmost Oregon about twice as likely as in northern Oregon. The size and frequency of the 19 large earthquakes on the CSZ are inferred from offshore turbidite deposits and are shown in **Figure 72**. All 19 of these large CSZ events were likely magnitude 8.7–9.2 earthquakes.

Figure 72. Occurrence and Relative Size of Cascadia Subduction Zone Megathrust Earthquakes



Source: Turbidite data from C. Goldfinger, Oregon State University; relative earthquake size comparison from Witter et al. (2011)

In April 2008 USGS workers indicated that for the next 30 years there is a 10% probability of a magnitude 8-9 earthquake somewhere along the 750-mile-long Cascadia Subduction Zone (Field, Milner & the 2007 Working Group on California Earthquake Probabilities: https://pubs.usgs.gov/fs/2008/3027/fs2008-3027.pdf). In 2012 Goldfinger et al. showed that the southern part of the CSZ also ruptures in segments, so probabilities some type of CSZ earthquake increase from north to south. Segment earthquakes and tsunamis will generally be smaller than full-margin events. Segment tsunamis, by the time they travel more than about 43 miles north of a segment, are similar in size to distant tsunamis with the largest waves striking 2 hours or more after the earthquake (Priest et al., 2014). New tsunami inundation maps from DOGAMI illustrate the range of inundation from all full-margin and significant segment ruptures on the CSZ.

Vulnerability

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

Because tsunamis in Oregon typically occur as a result of earthquakes, the unknown time and magnitude of such events adds to the difficulty in adequately preparing for such disasters. If a major earthquake occurs along the CSZ, a local tsunami could follow within 5 to 30 minutes. Although tsunami evacuation routes have been posted all along the Oregon Coast, damage to bridges and roadways from an earthquake could make evacuation quite difficult even if a tsunami warning were given. In addition, if a major earthquake and tsunami occur during the “tourist season,” causalities and fatalities from these disasters would be far greater than if the same events occurred during the winter months.

It is also important to consider where the impact of a tsunami would be the greatest. Owing to relatively large resident and visitor populations located at very low elevations, cities facing the Pacific Ocean on the northern Oregon Coast are more vulnerable to inundation and have the greater potential for loss of life than coastal cities in central and southern Oregon.

Distant tsunamis, except for the most extreme events, will not affect significant numbers of residents, since they flood principally beaches and immediate waterfront areas. Loss of life from distant tsunamis will also be far less than for local tsunamis, because there will be at least four hours to evacuate prior to wave arrival rather than 15–20 minutes.

That said, visitors are more vulnerable than are residents to both distant and locally generated tsunamis, because they are more likely to be at beaches and shoreline parks and are generally less aware of hazard response and preparedness. During the summer and holidays, visitors can greatly outnumber residents in the small coastal towns. While intensive education and outreach programs led by DOGAMI and OEM have greatly increased awareness and preparedness, residents are much more likely to have received this education than are visitors.

The Oregon Resilience Plan (ORP) uses the impact of a “Medium” or “M” CSZ earthquake and tsunami for planning purposes, because this was judged the most likely CSZ event (see DOGAMI Special Paper 43 [Witter et al., 2011] for explanation). The current regulatory tsunami inundation used by the Oregon Building Code to limit new construction of critical, essential, large occupancy, and hazardous facilities also uses a scenario similar to the “Medium” case. The ORP describes the “M” impact as follows:

> *Following the Cascadia event, the coastal communities will be cut off from the rest of the state and from each other. The coastal area’s transportation system, electrical power transmission and distribution grid, and natural gas service will be fragmented and offline, with long-term setbacks to water and wastewater services. Reliable communications will be similarly affected. Because so many of these connecting systems are single lines with little or no redundancy, any break or damage requiring repair or replacement will compromise the service capacity of the entire line.*

The loss of roads and bridges that run north and south will make travel up and down the coast and into the valley difficult, if not impossible, due to the lack of alternate routes in many areas. Reestablishing the roads and utility infrastructure will be a challenge, and the difficulties will be exacerbated in the tsunami inundation area by its more complete destruction. Even businesses outside of the tsunami inundation may not recover from the likely collapse of a tourist-based economy during the phased and complicated recovery and reconstruction period.

Based on the resilience targets provided by the Transportation, Energy, Communications, and Water/Wastewater task groups, current timelines for the restoration of services up to 90-percent operational levels will take a minimum of one to three years, and often over three years in the earthquake-only zone. Restoration in the tsunami zone will take even longer than that... The most critical infrastructure is the road and highway system. Without functioning road systems, none of the infrastructure can be accessed to begin repairs.

The tsunami will also create an enormous amount of debris that needs to be gathered, sorted, and managed. The recent experience of Japan, with a similar mountainous coastline, has shown that debris management competes with shelter and reconstruction needs for the same flat land that is often in the inundation zone.

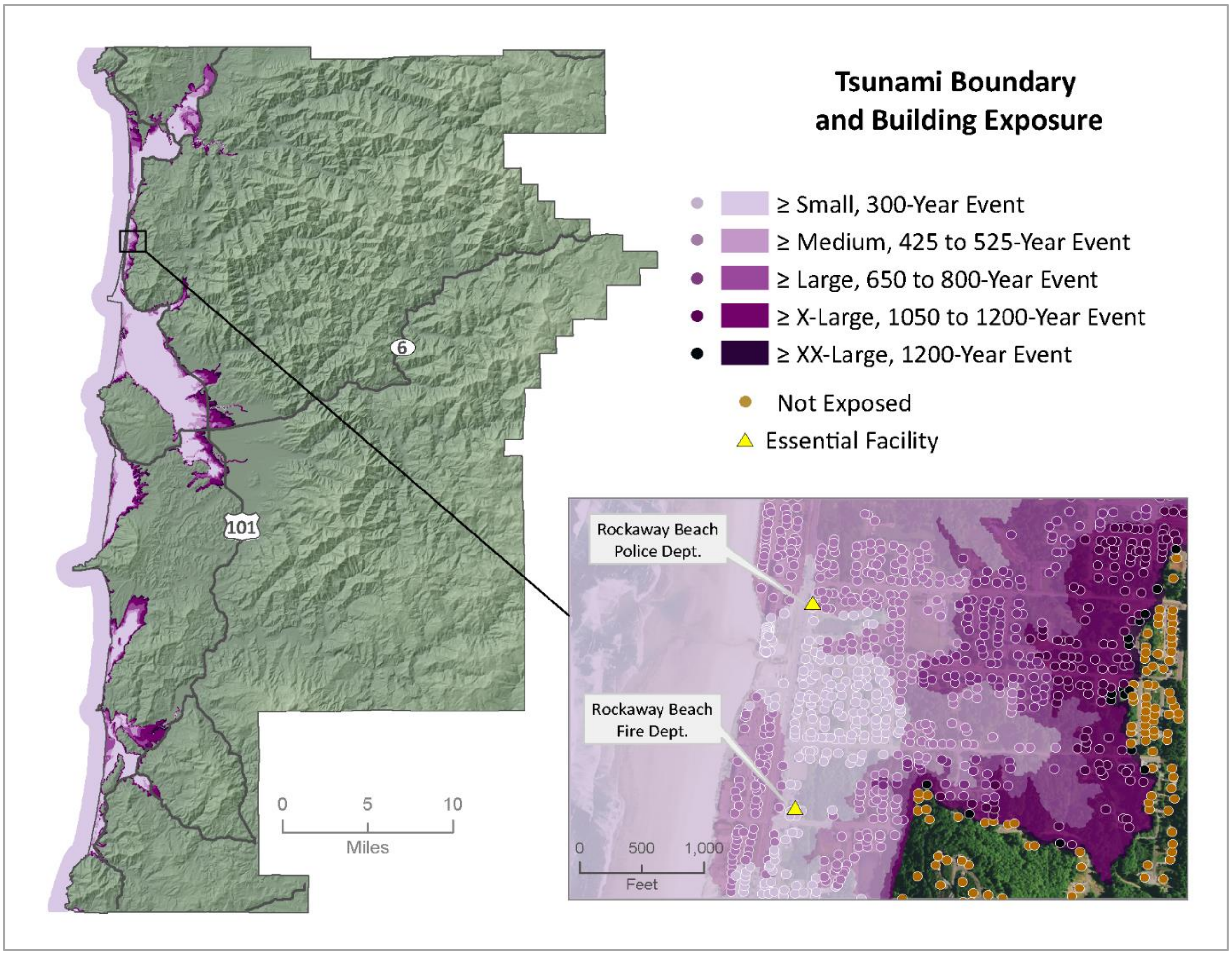
The ORP estimates that times for recovery of the coastal infrastructure for a Medium CSZ event will be as follows: electricity and natural gas, 3–6 months; drinking water and sewer systems, 1–3 years; and Healthcare facilities, 3 years. The ORP gives no estimate for times to recover police and fire stations or the coastal transportation system, but times for the latter would no doubt be measured in years. Economic recovery would also be many years, since much of the coast is dependent on tourism that is directly dependent on the transportation system. According to the ORP:

Even if a business had sufficient capital to relocate, it is unlikely that the tourist industry will recover rapidly enough to support business start-up. Local authorities may need to keep tourists out of the inundation zones, for safety reasons, for months or years after a tsunami.

Exposure Analysis

The *Final Draft Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2016) provides a tsunami exposure analysis for Tillamook County. **Figure 73** provides an example of the building exposure analysis. Exposure analysis results are shown in **Table 64** and **Table 65**, and **Figure 74** illustrates those results. For the Medium size tsunami scenario, thought to be the most likely, Rockaway Beach and Neskowin are most vulnerable, with 69% ratio of exposure value. Pacific City and Nehalem follow with 39% and 32%, respectively. Further, Rockaway Beach, Pacific City, and Neskowin are extremely difficult to evacuate owing to local geographic factors and significant percentages of retirees with limited mobility.

Figure 73. Tsunami Inundation Scenarios and Building Exposure Example



Source: DOGAMI (2022)

Table 64. Tsunami Exposure: Tillamook County and Cities

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	Small (Low Severity) Number of Buildings	Small (Low Severity) Building Value ($)	Small (Low Severity) Ratio of Exposure Value	Medium (Moderate Severity) Number of Buildings	Medium (Moderate Severity) Building Value ($)	Medium (Moderate Severity) Ratio of Exposure Value	Large (High Severity) Number of Buildings	Large (High Severity) Building Value ($)	Large (High Severity) Ratio of Exposure Value	XX Large (Very High Severity) Number of Buildings	XX Large (Very High Severity) Building Value ($)	XX Large (Very High Severity) Ratio of Exposure Value
Unincorp. County (rural)	15,015	1,282,436	520	46,924	3.7%	1,692	147,262	11%	2,548	223,814	18%	3,706	370,556	29%
Neskowin	653	118,463	268	56,198	47%	461	81,824	69%	485	86,960	73%	508	91,182	77%
Oceanside-Netarts	1,701	203,363	62	11,292	5.6%	88	15,432	7.6%	141	21,433	11%	326	36,738	18%
Pacific City–Woods	1,707	212,062	175	15,825	7.5%	806	83,301	39%	1,252	148,741	70%	1,355	156,498	74%
Total Unincorp. County	**19,076**	**1,816,324**	**1,025**	**130,239**	**7.2%**	**3,047**	**327,819**	**18%**	**4,426**	**480,948**	**26%**	**5,895**	**654,974**	**36%**
Bay City	884	74,770	4	370	0.5%	62	8,455	11%	136	20,515	27%	234	26,459	35%
Garibaldi	755	64,331	9	549	0.9%	91	11,870	18%	197	26,106	41%	336	33,894	53%
Manzanita	1,523	259,780	0	0	0.0%	354	56,238	22%	703	121,483	47%	966	163,906	63%
Nehalem	260	24,886	45	6,091	25%	61	7,856	32%	67	8,261	33%	77	8,872	36%
Rockaway Beach	2,240	211,809	591	49,215	23%	1,525	146,945	69%	1,888	170,195	80%	2,095	186,898	88%
Tillamook	2,270	322,398	0	0	0.0%	3	71	0.2%	84	24,651	7.6%	482	84,661	26%
Wheeler	363	30,556	14	1,047	3.4%	24	2,072	6.8%	33	3,798	12%	56	5,703	19%
Total Tillamook County	**27,371**	**2,804,854**	**1,688**	**187,511**	**6.7%**	**5,167**	**561,327**	**20%**	**7,534**	**855,957**	**31%**	**10,141**	**1,165,367**	**42%**

Source: DOGAMI (2016)

Table 65. Tsunami Exposure: Port of Tillamook Bay and Port of Garibaldi

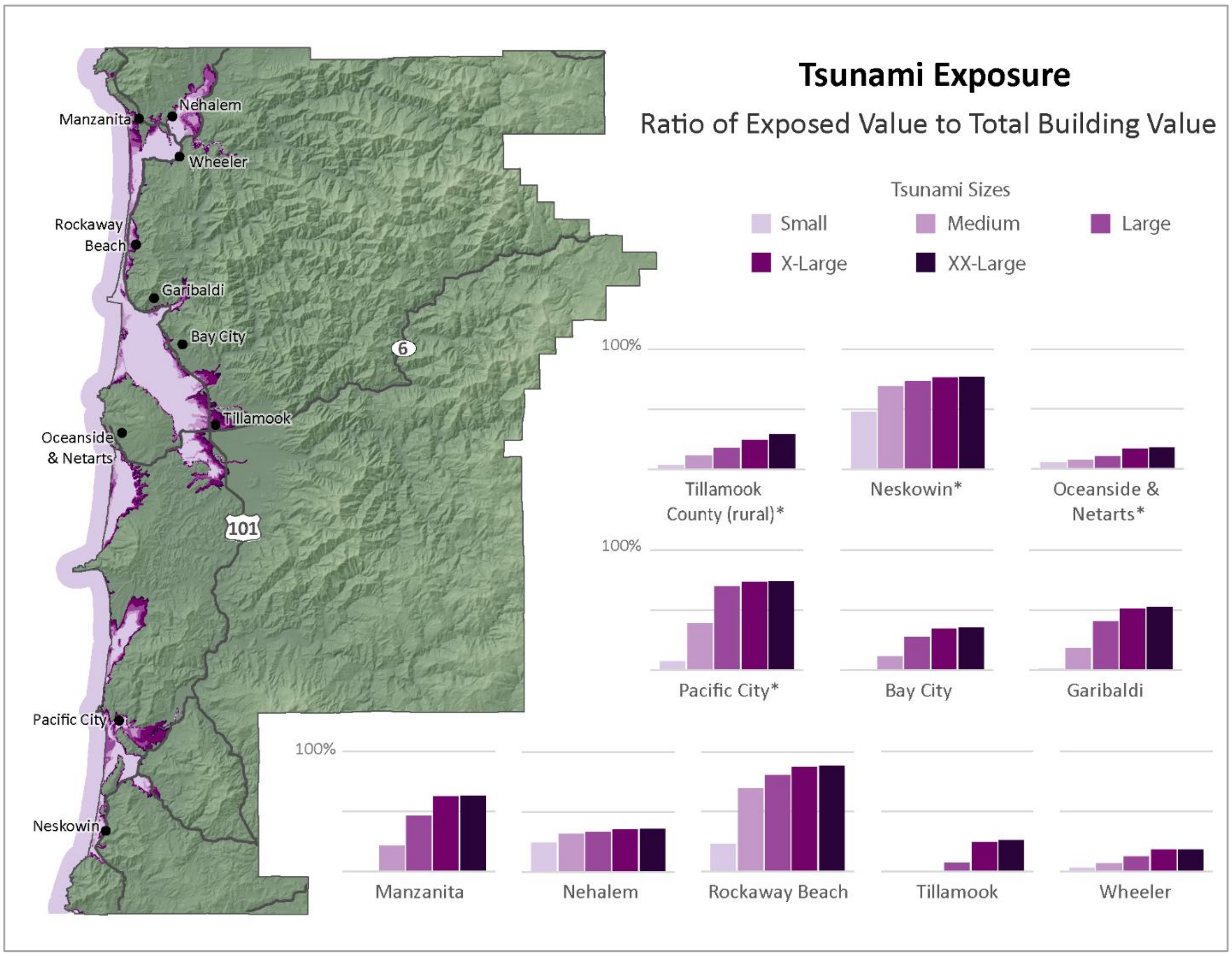
	Total Number of Buildings	Total Estimated Building Value ($)	Small (Low Severity) Number of Buildings	Small (Low Severity) Building Value ($)	Small (Low Severity) Ratio of Exposure Value	Medium (Moderate Severity) Number of Buildings	Medium (Moderate Severity) Building Value ($)	Medium (Moderate Severity) Ratio of Exposure Value	Large (High Severity) Number of Buildings	Large (High Severity) Building Value ($)	Large (High Severity) Ratio of Exposure Value	XX Large (Very High Severity) Number of Buildings	XX Large (Very High Severity) Building Value ($)	XX Large (Very High Severity) Ratio of Exposure Value
Port of Garibaldi	36	8,035,760	4	555,180	6.91%	26	3,427,250	43%	35	8,035,760	100%	35	8,035,760	100%
Port of Tillamook	83	61,545,144	0	0	0%	0	0	0%	0	0	0%	0	0	0%

Source: Derived from DOGAMI (2016)

The Port of Garibaldi is susceptible to infrastructure damage from tsunamis. The mooring basin, docks, and vessels are at risk from tsunamis of all scales as they cause surges and rapid changes in water levels. They may also cause excessive sediment deposits in the boat basin and navigational channels requiring additional dredging. Further, tsunamis may damage the Tillamook Bay Jetty system.

The Port of Tillamook Bay is less susceptible to tsunamis. Only the northwestern portion is expected be inundated by a larger tsunami event. Depending on the severity of the event, much of the western portion of the Port of Tillamook Bay, including the Tillamook Municipal Airport, may be inaccessible for quite some time.

Figure 74. Tsunami Inundation Exposure by Community



*Unincorporated communities. Note that "Tillamook Co. (rural)" excludes incorporated communities, Pacific City, Oceanside-Netarts, and Neskowin.

Source: DOGAMI (2016)

7. Volcanic Ashfall

Introduction

Volcanoes are potentially destructive natural phenomena, constructed as magma ascends and then erupts onto the earth's surface. Volcanic eruptions are typically focused around a single vent area, but vary widely in explosivity. Therefore volcanic hazards can have far reaching consequences. Volcanic hazards may occur during eruptive episodes or in the periods between eruptions. Eruptive events may include hazards such as, pyroclastic surges and flows, ashfall, lava flows, or slurries of muddy debris and water known as lahars. Eruptions may last days, weeks, or years, and have the potential to dramatically alter the landscape for decades. Unlike other geologic hazards (e.g., earthquakes, tsunamis), impending eruptions are often foreshadowed by a number of precursors including ground movements, earthquakes, and changes in heat output and volcanic gases. Scientists use these clues to recognize a restless volcano and to prepare for events that may follow. Hazards occurring between eruptive periods are typically related to earthquakes or natural erosion, which may trigger debris avalanches or debris flows on the flanks of the volcano. Such events often occur without warning.

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

Location

A number of hazards are associated with volcanoes (**Figure 75**). In general, volcanic hazards are commonly divided into those that occur in proximal (near the volcano) and distal (far from the volcano) hazard zones. In the distal hazard zone, volcanic activity includes lahars (volcanic mudflows or debris flows) and fallout of ash; in the proximal hazard zone, activity can be much more devastating and includes rapidly moving pyroclastic flows (glowing avalanches), lava flows, and landslides. Each eruption is a unique combination of hazards. Not all hazards will be present in all eruptions, and the degree of damage will vary. It is important to know that during an active period for a volcano many individual eruptions may occur and each eruption can vary in intensity and length. For example, while Mount St. Helens is best known for its catastrophic May 1980 eruption, periodic eruptions of steam and ash and the growth of a central lava dome have continued to pose a hazard since that time.

Table 66. Jurisdictions Subject to Volcanic Ashfall

Jurisdiction	Volcanic Ashfall
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City–Woods	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

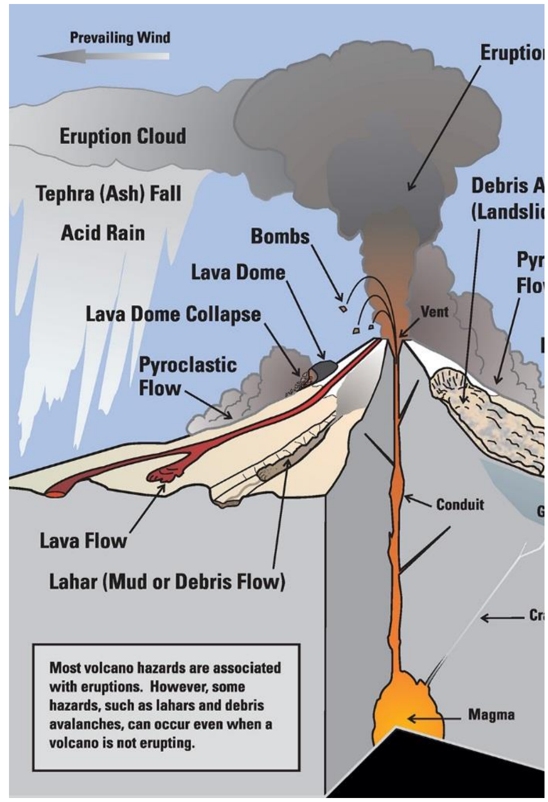
Source: Derived from DOGAMI (2016)

Hazard Characterization

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

Stratovolcanoes like Mount Hood, also called composite volcanoes, are generally tall, steep, conical shaped features, built up through layering of volcanic debris, lava, and ash. Eruptions tend be explosive, for example, the violent 1980 eruption of Mount St. Helens, and they produce volcanic mudflows (lahars) that can travel far from the mountain. Future eruptions are likely to be similar and present a severe hazard to the surrounding area. Volcanoes also pose other hazards because of their geology and resulting geomorphology. The relatively high elevation of volcanoes usually results in the meteorological effect called orographic lifting, which causes high precipitation and snow on the mountains that can result in flooding. The geologic material tends to be relatively weak and, when combined with the steep slopes, can cause frequent and hazardous landslides. Cascade Mountain Range volcanoes are also located near the active CSZ and nearby potentially active crustal faults, which contribute to moderate seismic hazard in the area.

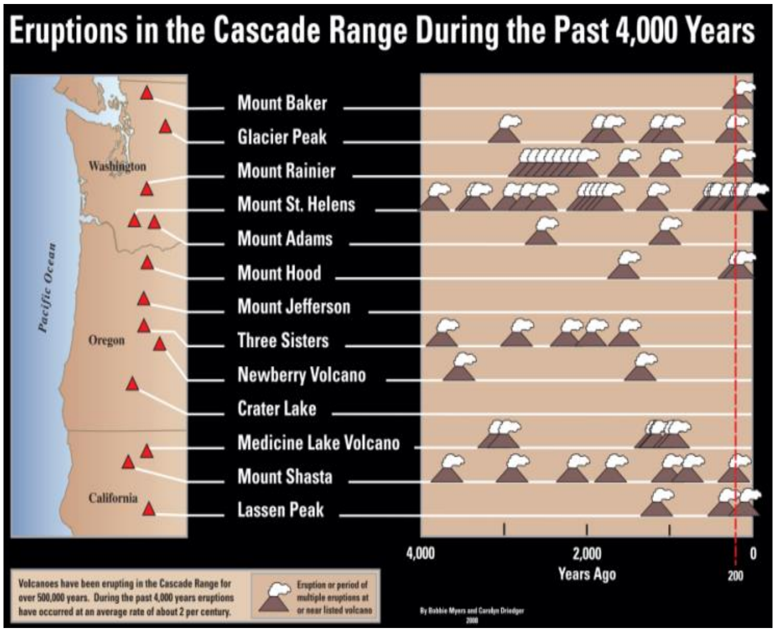
Figure 75. Potential Hazards at a Stratovolcano



Source: Myers and Dreidger (2008a)

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

Figure 76. Eruptions in the Cascade Range During the Past 4,000 Years



Source: Myers and Driedger (2008b)

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

Geological Survey has attempted to rank the relative hazard of volcanoes in North America. According to this study, Oregon has four Very High Threat Volcanoes: Crater Lake, Mount Hood, Newberry Volcano, and South Sister (Ewert, Guffanti, & Murray, 2005).

Ashfall

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

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

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

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

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

Historic Volcanic Events

Table 67. Historic Volcanic Events in Oregon over the Last 20,000 Years

Date	Location	Description
about 18,000 to 7,700 YBP	Mount Bachelor, central Cascades	cinder cones, lava flows
about 20,000 to 13,000 YBP	Polallie Eruptive episode, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
about 13,000 YBP	Lava Mountain, south-central Oregon	Lava Mountain field, lava flows
about 13,000 YBP	Devils Garden, south-central Oregon	Devils Garden field, lava flows
about 13,000 YBP	Four Craters, south-central Oregon	Four Craters field, lava flows
about 7,780 to 15,000 YBP	Cinnamon Butte, southern Cascades	basaltic scoria cone and lava flows
about 7,700 YBP	Crater Lake Caldera	formation of Crater Lake caldera, pyroclastic flows, widespread ashfall
about 7,700 YBP	Parkdale, north-central Oregon	eruption of Parkdale lava flow
<7,000 YBP	Diamond Craters, eastern Oregon	lava flows and tephra in Diamond Craters field
< 7,700 YBP; 5,300 to 5,600 YBP	Davis Lake, southern Cascades	lava flows and scoria cones in Davis Lake field
about 10,000 to <7,700 YBP	cones south of Mount Jefferson; Forked Butte and South Cinder Peak	lava flows
about 4,000 to 3,000 YBP	Sand Mountain, central Cascades	lava flows and cinder cones in Sand Mountain field
< 3,200 YBP	Jordan Craters, eastern Oregon	lava flows and tephra in Jordan Craters field
about 3,000 to 1,500 YBP	Belknap Volcano, central Cascades	lava flows, tephra
about 2,000 YBP	South Sister Volcano	rhyolite lava flow
about 1,500 YBP	Timberline eruptive period, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
about 1,300 YBP	Newberry Volcano, central Oregon	eruption of Big Obsidian flow
about 1,300 YBP	Blue Lake Crater, central Cascades	spatter cones and tephra
1760–1810	Crater Rock/Old Maid Flat on Mount Hood	pyroclastic flows in upper White River; lahars in Old Maid Flat; dome building at Crater Rock
1859/1865	Crater Rock on Mount Hood	steam explosions/tephra falls
1907 (?)	Crater Rock on Mount Hood	steam explosions
1980	Mount St. Helens (Washington)	debris avalanche, ashfall, flooding on Columbia River
1981–1986	Mount St. Helens (Washington)	lava dome growth, steam, lahars
1989–2001	Mount St. Helens (Washington)	hydrothermal explosions
2004–2008	Mount St. Helens (Washington)	lava dome growth, steam, ash

Note: YBP is years before present.

Sources: US Geological Survey, Cascades Volcano Observatory: http://volcanoes.usgs.gov/observatories/cvo/;
Wolfe and Pierson (1995); Sherrod, Mastin, Scott, and Schilling (1997); Scott et al. (1997); Scott, Iverson, Schilling, and Fisher (2001); Bacon, Mastin, Scott, and Nathenson (1997); Walder, Gardner, Conrey, Fisher, and Schilling (1999)

Tillamook County experienced ashfall from the Mount St. Helens eruption in May 1981.

Probability

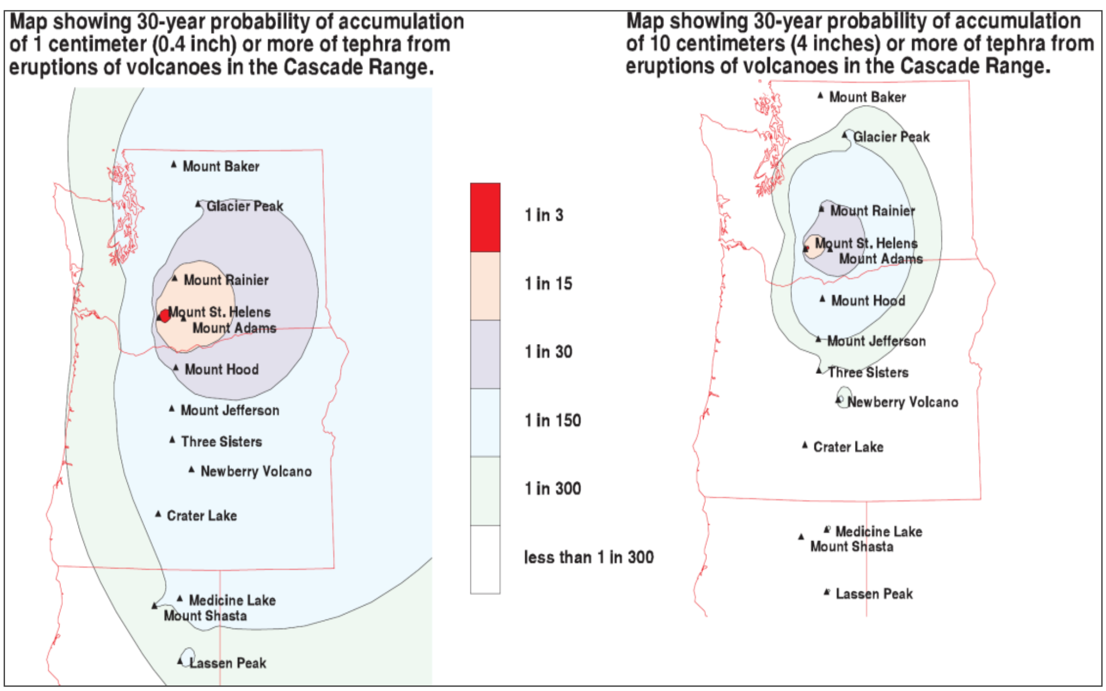
Geologists can make general forecasts of long-term volcanic activity from careful characterization of past activity, but they cannot supply a timeline. Several US Geological Survey open-file reports provide the odds of certain events taking place at particular volcanoes. However, the US Geological Survey stresses that government officials and the public must realize the limitations in forecasting eruptions and be prepared for such uncertainty.

Short-range forecasts, on the order of months or weeks, are often possible. There are usually several signs of impending volcanic activity that may lead up to eruptions. The upward movement of magma into a volcano prior to an eruption generally causes a significant increase in small, localized earthquakes and an increase in emission of carbon dioxide and compounds of sulfur and chlorine that can be measured in volcanic springs and the atmosphere above the volcano. Changes in the depth or location of magma beneath a volcano often cause changes in elevation. These changes can be detected through ground instrumentation or remote sensing. (This, in fact, was how the South Sister Bulge uplift was discovered.)

The Cascades Volcanic Observatory (CVO) employs scientists from a range of disciplines to continually assess and monitor volcanic activity in the Cascade Ranges. If anomalous patterns are detected (for example, an increase in earthquakes), CVO staff coordinate the resources necessary to study the volcano.

The probability of Tillamook County receiving ashfall is about 1 in 10,000. The probable geographic extent of volcanic ashfall from select volcanic eruptions in the Pacific Northwest is shown in Figure 77.

Figure 77. Probable Geographic Extent of Volcanic Ashfall from Select Volcanic Eruptions in the Pacific Northwest



Source: Scott et al. (1997)

Vulnerability

The Cascade Mountains, which separate Western Oregon from Central Oregon, pose the greatest threat for volcanic activity. Within the State of Oregon, there are several volcanoes that may pose a threat of future eruption. These include Mount Hood, which most recently erupted about 200 years ago, Newberry Volcano with recent eruptions about 1,300 years ago, and the Three Sisters and Mount Jefferson with eruptions about 15,000 years ago. Eruptions from volcanoes in Washington State, like the Mount St. Helens eruption in 1980, can also significantly impact Oregon.

The volcanic Cascade Mountain Range is not near Tillamook County; consequently, the risk from proximal volcano-associated hazards (e.g., lahars, pyroclastic flows, lava flows, etc.) is not a priority consideration. However, there is some risk from volcanic ashfall. This fine-grained material, blown aloft during a volcanic eruption, can travel many miles from its source. For example, the cities of Yakima (80 miles) and Spokane (150 miles), Washington, were inundated with ash during the May 1980, Mount St. Helens eruption. Ashfall can reduce visibility to zero, and bring street, highway, and air traffic to an abrupt halt. The material is noted for its abrasive properties and is especially damaging to machinery. It would be prudent for communities that may be exposed to ashfall to identify disposal areas for large quantities of ash.

While considered a low risk, ashfall within the Port of Tillamook Bay's industrial park would wreak major havoc. Aside from lack of visibility, the Port's economy and infrastructure would be impacted. For example, building HVAC systems inundated with ash would be unusable for some time. The consequences of impacts to critical infrastructure, such as the Tillamook Municipal Airport, would echo throughout the County.

For the Port of Garibaldi, excessive accumulation of volcanic ash carries a moderate risk. Volcanic ash falling directly into Tillamook Bay and imported by the five rivers that flow into it may cause excessive sediment build-up in both the Bay and boat basin, making navigation difficult and requiring additional expensive dredging. Water contaminated with volcanic ash may also hinder the operation of vessels in the area and damage local fish stocks, hurting the local commercial seafood and sport fishing industries.

8. Wildfires

Introduction

Wildfires are a common and widespread natural hazard in Oregon; the state has a long and extensive history of wildfire. A significant portion of Oregon's forestland is dominated by ecosystems dependent upon fire for their health and survival. In addition to being a common, chronic occurrence, wildfires frequently threaten communities. These communities are often referred to as the "wildland-urban interface" (WUI), the area where structures and other human development meet or intermingle with natural vegetative fuels.

Oregon has in excess of 41 million acres (more than 64,000 square miles) of forest and rangeland that is susceptible to damage from wildfire. In addition, significant agricultural areas of the Willamette Valley, north central, and northeastern Oregon grow crops such as wheat that are also susceptible to damage by wildfire.

Wildfires occur throughout the state and may start at any time of the year when weather and fuel conditions combine to allow ignition and spread. The majority of wildfires take place between June and October, and primarily occur in inland southwest, central, and northeastern Oregon. Historically, Oregon's largest wildfires have burned in the Coast Range where the average rainfall is high, but heavy fuel loads created a low-frequency, high-intensity fire environment during the dry periods.

According to OEM, extreme winds are experienced throughout Oregon. The most persistent high winds occur along the Oregon Coast and the Columbia River Gorge. Wind is a primary factor in fire spread, and can significantly impede fire suppression efforts.

Historically, 70% of the wildfires suppressed on lands protected by the Oregon Department of Forestry (ODF) result from human activity. The remaining 30% result from lightning. Typically, large wildfires result primarily from lightning in remote, inaccessible areas.

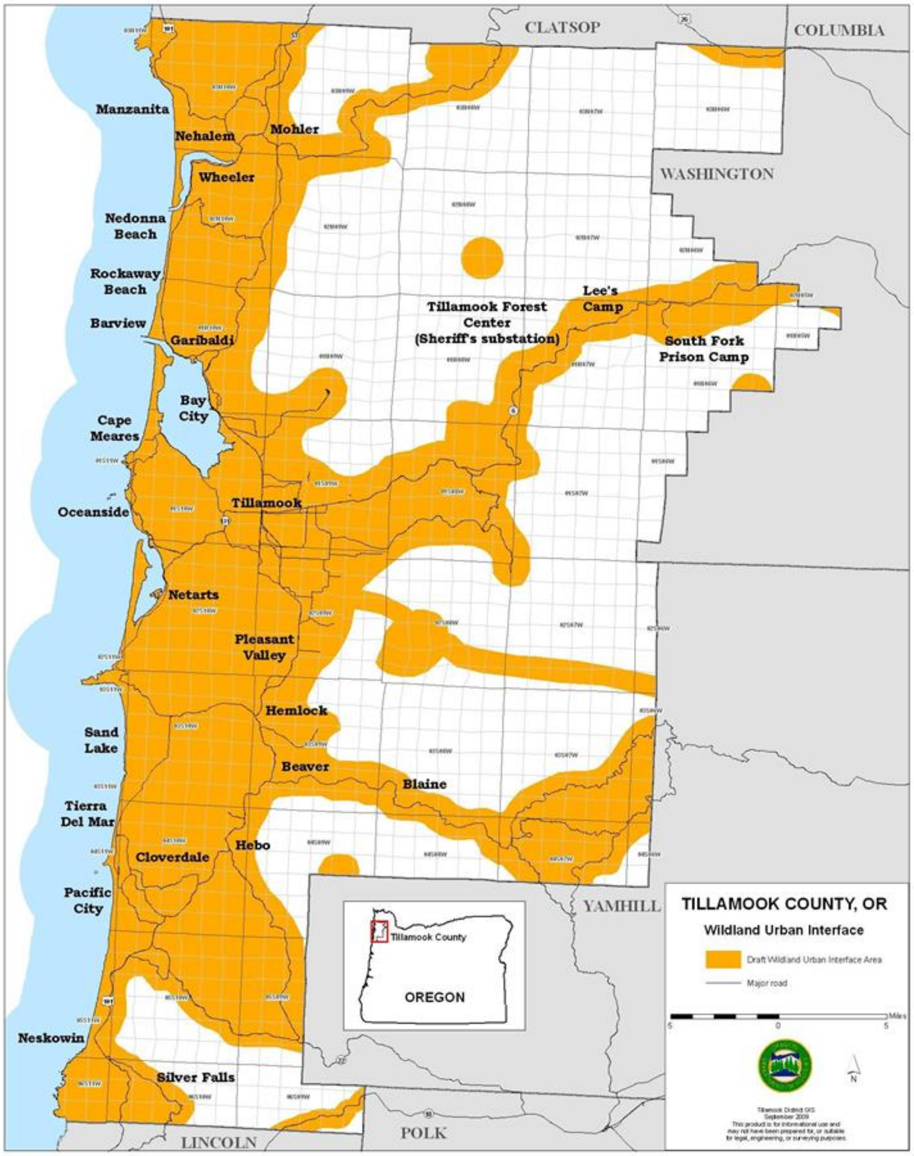
According to a University of Oregon study, *The Economic Impacts of Large Wildfires* (https://ewp.uoregon.edu/largefires/content), conducted between 2004 and 2008, the financial and social costs of wildfires impact lives and property, and cause negative short- and long-term economic and environmental consequences.

Life safety enhancement and cost savings may be realized by appropriate mitigation measures, starting with coordinated fire protection planning by local, state, tribes, federal agencies, the private sector, and community organizations. Additionally, and often overlooked, is the role that individual WUI property owners play in this coordinated effort.

Wildfire suppression costs escalate dramatically when agencies must adjust suppression tactics to protect structures. The cost of mobilizing personnel and equipment from across the state is significant. Non-fire agencies may also incur costs for providing or supporting evacuations, traffic control, security, public information, and other services during WUI fire incidents. These costs vary widely and have not been well documented.

The number of people living in Oregon's Wildland-Urban Interface (WUI) areas is increasing. Where people have moved into these areas, the number of wildfires has escalated dramatically. Many people arriving from urban settings expect an urban level of fire protection. The reality is many WUI homes are located in jurisdictions with limited capacity for structural protection and sometimes no fire protection whatsoever. Many Oregon communities (incorporated and unincorporated) are within or abut areas subject to serious wildfire hazards. In Oregon, there are about 240,000 homes worth around $6.5 billion within the WUI, which has greatly complicated firefighting efforts and significantly increased the cost of fire suppression. While Oregon's Emergency Conflagration Act helps protect WUI communities that have depleted their local resources when threatened by an advancing wildfire, the escalating number of fires has led to the recognition that citizens in high fire risk communities need to provide mitigation and an appropriate level of local fire protection. Oregon's seller disclosure law requires a statement of whether or not property is classified as forestland-urban interface. Collaboration and coordination is ongoing among several agencies to promote educational efforts through programs like Firewise, the Oregon Forestland-Urban Interface Fire Protection Act, and Fire Adapted Communities from the National Cohesive Wildfire Strategy.

Figure 78. Wildland-Urban Interface in Tillamook County



Source: Tillamook County Community Wildfire Protection Plan (White et al., 2006)

Increasing construction in vulnerable areas increases risk for vulnerable populations. Oregon's Statewide Planning Goals 4 (Forest Lands) and 7 (Areas Subject to Natural Hazards) play critical roles in guiding development in these areas. Measures to enhance life safety and save costs include Community Wildfire Protection Plans (CWPPs), coordinated fire protection planning, and coordination by local, state, tribal, federal agencies, the private sector, and community organizations. Many local communities incorporate their CWPPs into their local Natural Hazards Mitigation Plans (NHMPs).

Wildfire mitigation discussions are focused on reducing overabundant, dense forest fuels, particularly on public lands. The Healthy Forest Restoration Act aims to create fuel breaks by reduce overly dense vegetation and trees. It provides funding and guidance to reduce or eliminate hazardous fuels in National Forests, improve forest fire fighting, and research new methods to reduce the impact of invasive insects.

Oregon's efforts in and near WUI areas are massive, and are resulting in improvements. Sustaining the work over the many years it takes requires a substantial, ongoing financial commitment. Progress is often challenging because fuel mitigation methods are not universally accepted and are often controversial. However, recurring WUI fires continue to bring the issue into public focus as well as unite communities and stakeholders in a common set of objectives.

While Tillamook County is heavily forested, its cool, moist climate contributes to its primarily moderate risk of wildfire. Most of the areas considered to be at high risk are in areas along Highway 6 east of the City of Tillamook and along Highway 101, most notably near the cities of Bay City, Garibaldi, Tillamook, and Rockaway Beach, within the wildland-urban interface area established in the Tillamook County CWPP (White et al., 2006), **Figure 78**. The communities in Tillamook County located within the WUI are:

- Bay City
- Beaver
- Blaine
- Cape Meares
- Cloverdale
- Foley Creek
- Garibaldi
- Hebo
- Hemlock
- Jordan Creek
- Lees Camp
- Manzanita
- Nehalem
- Neskowin
- Oceanside/Netarts
- Oretown
- Pacific City-Woods
- Pleasant Valley
- Rockaway Beach
- Sandlake
- Siskeyville
- Tierra del Mar
- Tillamook
- Winema Beach

Wildfires in the wildland-urban interface (WUI) pose serious threats to life and endanger property, critical infrastructure, water resources, and valued commercial and ecological forest resources. Although the wildfire risk in Tillamook County is considered moderate, when a wildfire does occur it can be catastrophic. The historic Tillamook Burn, comprising devastating wildfires every 6 years between 1933 and 1951, burned a total of 355,000 acres. Much of the burn was attributed to powerful east wind events and heavy fuels.

Location

Table 68. Jurisdictions Subject to Wildfires

Jurisdiction	Wildfires
Unincorporated Tillamook County (rural)	X
Neskowin	X
Oceanside-Netarts	X
Pacific City–Woods	X
Bay City	X
Garibaldi	X
Manzanita	X
Nehalem	X
Rockaway Beach	X
Tillamook	X
Wheeler	X
Port of Tillamook Bay	X
Port of Garibaldi	X

Source: Derived from DOGAMI (2016)

Hazard Characterization

Types of Wildfire

Wildfires burn primarily in vegetative fuels located outside highly urbanized areas. Wildfires may be broadly categorized as agricultural, forest, range, or WUI fires.

Agricultural

Fires burning in areas where the primary fuels are flammable cultivated crops, such as wheat. This type of fire tends to spread very rapidly, but is relatively easy to suppress if adequate resources are available. Structures threatened are usually few in number and generally belong to the property owner. There may be significant losses in terms of agricultural products from such fires.

Forest

The classic wildfire, forest fires burn in fuels composed primarily of timber and associated brush, grass, and logging residue. Due to variations of fuel, weather, and topography, forest fires may be extremely difficult and costly to suppress. In wilderness areas they are often monitored and allowed to burn for the benefits brought by the ecology of fire, but also pose a risk to private lands when they escape the wilderness areas.

Range

Fires that burn across lands typically open and lacking timber stands or large accumulations of fuel. Such lands are used predominantly for grazing or wildlife management purposes. Juniper, bitter-brush, and sage are the common fuels involved. These fires tend to spread rapidly and vary from being easy to difficult to suppress. They often occur in areas lacking both wildland and structural fire protection services.

Wildland-urban interface (WUI)

These fires occur where urbanization and natural vegetation fuels are mixed together. This mixture may allow fires to spread rapidly from natural fuels to structures and vice versa. Such fires are known for the large number of structures simultaneously exposed to fire. Especially in the early stage of WUI fires, structural fire suppression resources may be quickly overwhelmed, which may lead to the destruction of a large number of structures. Nationally, wildland interface fires have frequently resulted in catastrophic structure losses.

Common Sources of Wildfire

For statistical tabulation purposes, wildland fires are grouped into nine categories based on historically common wildfire ignition sources.

Arson

Oregon experienced a rapid rise in the frequency of arson caused fires in the early 1990s. 1992 was the worst fire season for arson with 96 fires attributed to the category. In response, the state instituted aggressive arson prevention activities with solid working relationships with local law enforcement and the arson division of the Oregon State Police. The result is a slight decline in the 10-year average with just 41 fires occurring annually since 2004.

Debris burning

Historically, debris burning activities have been a leading source of human-caused wildfires. Aggressive prevention activities coupled with increasing local burning bans during the wildfire season have begun to show positive results. Many debris burning fires occur outside of fire season, resulting in increased awareness during the spring and fall months.

Equipment use

This source ranges from small weed eaters to large logging equipment; many different types of equipment may readily ignite a wildfire, especially if used improperly or illegally. Although fire agencies commonly limit or ban certain uses of fire-prone equipment, the frequency of fires caused by equipment has been trending upward in recent years. This increase may be related to the expansion of the wildland interface, which results in more people and equipment being in close proximity to forest fuels.

Juvenile

The trend in the incidence of juveniles starting wildland fires is downward in recent years. This is attributed to concerted effort by local fire prevention cooperatives to deliver fire prevention messages directly to school classrooms and the Office of the State Fire Marshal's (OSFM's) aggressive youth intervention program. In 1999, according to the ODF, juveniles were reported to have started 60 wildland fires. Conversely, juveniles accounted for just 17 fires in 2013 and, on average, have only accounted for 25 fires per year over the last 10 years. Additionally, parents or guardians, under Oregon Law, are responsible for damages done by fires started by their children. ORS 30.765 covers the liability of parents; ORS 163.577 holds parents or guardians accountable for child supervision, ORS 477.745 makes parents liable for wildfire suppression costs of a fire by a minor child, and ORS 480.158 holds a parent liable for fireworks-caused fires. Additionally, parents may be assessed civil penalties.

Lightning

There are tens of thousands of lightning strikes in Oregon each year. Of the nine categories, lightning is the leading ignition source of wildfires. In addition, lightning is the primary cause of fires that require activation of Oregon's Conflagration Act.

Miscellaneous

Wildfires resulting from a wide array of causes: automobile accidents, burning homes, pest control measures, shooting tracer ammunition and exploding targets, and electric fence use are a few of the causes in this category. The frequency of such fires has been rising in recent years.

Railroad

Wildfires caused by railroad activity are relatively infrequent. In the early twentieth century, this had been a major cause of fires, but has been decreasing for many years. Over the past 10-year period, the number of railroad-caused fires has leveled out. In the past few decades, Oregon has responded to railroad-caused fires with aggressive fire investigation and cost recovery efforts. Oregon Department of Forestry works with the railroad on hazard abatement along tracks and requires water cars and chase vehicles during high fire danger. The resulting quick return to normal fire incidence showed that railroad fires are preventable.

Recreation

The trend in fires caused by people recreating in and near Oregon's forests has been rising over the past 10 years. This trend may reflect the state's growing population and as well as a greater interest in outdoor recreation opportunities.

Smoking

Fires caused by smoking and improperly discarded cigarettes is down. It is not known if this is due to fewer people smoking, recent modifications producing fire standard compliant cigarettes, or better investigation of fire causes.

According to the *Tillamook County Community Wildfire Protection Plan* (White et al., 2006), the leading cause of fires in Tillamook County is **recreation**, primarily due to escaped, abandoned, or unattended warming or cooking fires. Fires caused by recreation are most prevalent during major holidays, extremely hot weather, school breaks and hunting season. The second leading cause is **debris burning**, both general and slash pile burning. There are a number of reasons for this from inadequate clearing, inability to control, failure to recognize the severity of burning conditions, burning prohibited material, failure to follow permit instructions, inadequate mop-up, and inattention. Escaped slash burning accounts for a small percentage of the number of fires, but impacts a large area. And finally, the third leading cause is **equipment use**. Sparks or friction from the rigging and the cable system of logging equipment have caused fires.

Secondary Hazards

Increased risk of landslides and erosion are secondary hazards associated with wildfires that occur on steep slopes. Wildfires tend to denude the vegetative cover and burn the soil layer creating a less permeable surface prone to sheetwash erosion. This in turn increases sediment load and the likelihood of downslope failure and impact.

Wildfires can also impact water quality (e.g., drinking water intakes). During fire suppression activities some areas may need coordinated efforts to protect water resource values from negative impact.

Wildfire smoke may also have adverse effects on air quality and visibility, and create nuisance situations. Strategies to limit smoke from active wildfires are limited, but interagency programs exist to alert the public of potential smoke impact areas where hazardous health or driving conditions may occur.

Poor Air Quality

Causes and Characteristics

The hazard of Poor Air Quality has been named for inclusion in several recent NHMP updates as communities recognize the impacts smoke as an impact of wildfire smoke and due to inversion layers trapping particulates in smoke from wood stoves, prescribed fire, wildfire, field burning, and leaf burning.

Geographic Causes

The nature of air movement or stagnation in a valley causes inversion layers to form. At the valley floor daytime temperatures heat the air. In the evening, air further up the slope of the mountains cools faster than the air lower down the slope. Because cool air is slightly heavier than warm air, the cool air sinks in to the valley which displaces the warm air above it to form a "lid". If the weather creates stagnant conditions this inversion "lid" may persist trapping air pollutant discharges to create poor air quality.

Air quality issues can occur in some valley locations in Tillamook County primarily affecting the in land unincorporated rural areas. There are many microclimates throughout the county which result in localized issues.

Sources of Pollutants

Wildfires[15] tend to provide a wide-ranging source of smoke that can blanket large areas and be detrimental to the health of people, animals, and plants. Wood burning stoves tend to be a more concentrated, point source type of pollution that decreases air quality. Field burning is an agricultural technique that can contribute to air quality issues. Diesel emissions, often from vehicles on roads, also contribute to lower air quality. If a volcano were to erupt, ashfall could inundate the areas sufficiently to impact transportation and cause widespread health concerns.

Regulatory Framework

Federal Regulations

The Clean Air Act of 1970 and the U.S. Environmental Protection Agency (EPA) established health-based National Ambient Air Quality Standards (NAAQS) for six air pollutants: carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). The areas that fail to meet the standards are designated "non-attainment" and are required to develop plans to come into compliance with the standards. Once compliance with the standard is achieved, a maintenance plan is developed to ensure that air quality will not be compromised in the future.[16]

The Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings. The Clean Air Act requires periodic review of the science upon which the standards are based and the standards themselves.[17]

---

[15] See the Wildfire Hazard Annex for more information about wildfire impacts.

[16] Peter Brewer, DEQ, personal communication, 8/5/19.

[17] *Air Quality in Pendleton Documen*t, Greg Lacquement, personal communication, 2/4/21.

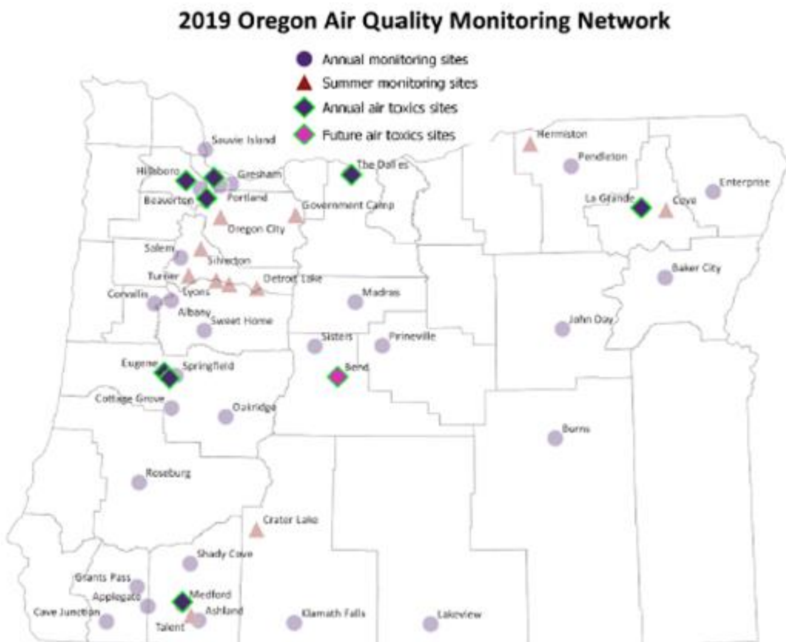
Oregon Regulations

The Oregon Department of Environmental Quality (DEQ) is a regulatory agency with the responsibility to protect and enhance the quality of Oregon's environment. DEQ is responsible for providing accurate scientific data concerning the State of Oregon's air quality "to ensure that the state meets the National Ambient Air Quality Standards (NAAQS) as required by the Federal Clean Air Act." [18]

Air Quality Pollutants

Oregon DEQ operates the ambient monitoring network for the entire state with the exception of Lane County which is operated by the Lane Regional Air Protection Authority (LRAPA). These air quality monitoring networks measure ambient concentrations of the criteria pollutants - ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, lead. Air quality pollutants are monitored at the locations shown on Figure 4. There are no such air monitoring stations in Tillamook County[19]

Figure 79.   Oregon's 2020 Ambient Air Monitoring Network (ODEQ and LRAPA sites)



Source: DEQ, 2019 *Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan,* https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf.

DEQ collects data on air quality pollutant trends for Ozone, $PM_{2.5}$, PM_{10}, carbon monoxide, sulfur dioxide, nitrogen dioxide, air toxics, and greenhouse gases. Each of these trends is described below.

Ozone

DEQ describes that

> "Ozone is a secondary pollutant formed when there are elevated levels of nitrogen dioxide (NO2) and volatile organic compounds (VOCs) that undergo chemical reactions in high temperatures, and sunlight. In Oregon, elevated ozone occurs in the summer and can be formed by human-caused pollution from fossil fuel combustion and also by naturally caused pollution

[18] DEQ, *Air quality home*, retrieved September 1, 2016 from http://www.oregon.gov/DEQ/aq/Pages/default.aspx.

[19] DEQ, 2019 *Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan,* https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf. Remains the same in the *2020 Plan*.

> from wildfire smoke, which contains NO_2 and. In 2017, most of the state experienced elevated ozone because the wildfire smoke introduced natural precursors on top of the human-caused emissions. With global warming we expect more fires in the Northwest and higher temperature days; this will result in more elevated ozone days."[20]

DEQ states that "data with wildfire contributions is included because it is very difficult to determine if the ozone would have exceeded the NAAQS without the smoke from wildfires."[21] DEQ notes that the wildfire smoke in 2017 contributed to the elevated ozone levels most likely caused Portland to violate the NAAQS. However, it is very difficult to determine what the ozone level would have been but for the wildfire smoke.

The *2020 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan* describes the 10 Oregon DEQ and LRAPA monitoring sites for ozone.

$PM_{2.5}$

Fine particulate matter ($PM_{2.5}$) is a concern due to smoke impacts from woodstoves, fireplaces and other wood burning appliances besides wildfire smoke in the summer. Other sources of $PM_{2.5}$ include open burning, prescribed burning, wildfires, smoke from industrial stacks, and some road dust from vehicle travel.

DEQ notes that it is useful to understand how much wildfire smoke contributed to particulate levels above the NAAQS standard, because this shows the effectiveness of local air quality improvement in communities with particulate reduction plans to promote such actions as wood stove efficiency programs.

There are harmful effects from breathing particles measuring less than 10 microns in diameter (PM_{10}). Most recent research indicates that even smaller particles, those measuring less than 2.5 microns in diameter ($PM_{2.5}$) may be responsible for the most significant health effects, like premature mortality, hospital admissions, and respiratory illness. These particles can be inhaled deeply into the lungs where they enter the bloodstream or can remain for years. The health effects of particulate matter vary with the size, concentration, and chemical composition of the particles."[22]

PM_{10}

The PM_{10} trend chart shows the values in the city with the highest concentration, the average, concentration, and the lowest concentration. All cities are well below the standard, but EPA requires DEQ to continue monitoring in PM_{10} maintenance areas and in cities over 500,000 people.[23]

Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide

The carbon monoxide, sulfur dioxide, and nitrogen dioxide trends for cities in Oregon as compared to the federal standards are measured. These are not a hazard concern for Wallowa County.

---

[20] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf.

[21] Ibid.

[22] *Air Quality in Pendleton Document*, Greg Lacquement, personal communication with T. Sears, DLCD, 2/4/21.

[23] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf

Air Toxics

Oregon DEQ and LRAPA began sampling for air toxics in Oregon in 1999. This section of the *Oregon Air Quality Annual Report: 2017* describes data for the toxics of concern: benzene, acetaldehyde, arsenic, cadmium, lead, and manganese.

The information is for neighborhood monitoring only; it does not include monitoring next to industrial facilities. That information is presented in separate reports issued by the Oregon Health Authority, specific to the monitoring project and facility.[24]

Greenhouse Gases

Information about greenhouse gas emissions in Oregon are presented on DEQ's website at https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx. According to this page, "Oregon's sector-based inventory measures human-caused greenhouse gas emissions produced within Oregon by economic sector. It also includes the emissions associated with the electricity used in Oregon regardless of where that electricity is generated." [25] Figure 5 is excerpted from that report and shows Oregon's greenhouse gas emissions from 1990 through 2019 by sector. Emissions from transportation and electricity use are Oregon's largest sources of greenhouse gas emissions.

Identifying Poor Air Quality

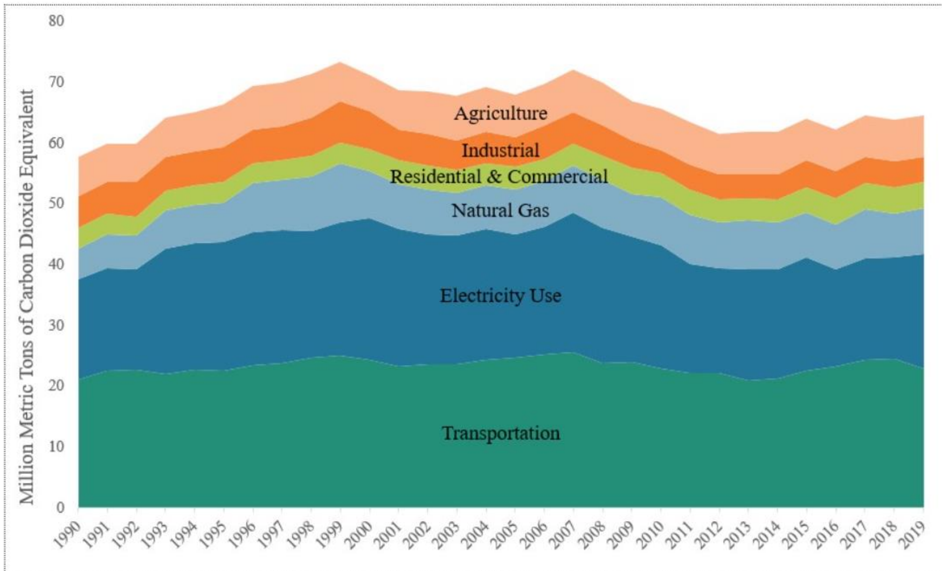
Both specific measures of components of poor air quality and a general Air Quality Index are methods for determining the quality of the air.

Standards for air quality as determined by the US Environmental Protection Agency (EPA) have changed over time. In 1987 particulate matter was measured using the national PM_{10} levels as 24-hour concentrations and as average annual concentrations. The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards. In 1996 the impact of 2.5-micron particles was recognized and the national $PM_{2.5}$ 24-hour National Ambient Air Quality Standard (NAAQS) was established at 65 ug/m^3, and the annual average NAAQS set at 15 ug/m^3. In 2006 the national $PM_{2.5}$ 24-hour standard was reduced to 35 ug/m^3. In 2012 the national $PM_{2.5}$ annual average NAAQS was further reduced to 12 ug/m^3. The PM_{10} annual average was revoked.

[24] DEQ, *Oregon Air Quality Annual Report: 2017,* https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf

[25] DEQ, *Oregon Greenhouse Gas Sector-Based Inventory Data*, https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx, accessed 2/26/21

Figure 80. Oregon Greenhouse Gas Emissions 1990-2019



Source: DEQ, Oregon Greenhouse Gas Sector-Based Inventory Data, https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx, accessed 2/26/21

The Air Quality Index is a daily index of air quality that reports how clean the air is and provides information on potential health risks. Oregon's index is based on three pollutants regulated by the federal Clean Air Act: ground-level ozone, particle pollution and nitrogen dioxide. The highest of the AQI values for the individual pollutants becomes the AQI value for that day. For example, if values are 90 for ozone and 88 for nitrogen dioxide, the AQI reported would be 90 for the pollutant ozone on that day. A rating of good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous are designated for the AQI providing a daily air quality rating (Table 6). EPA provides all states with the AQI equation for national uniformity. DEQ and Lane County Regional Air Protection Authority (LRAPA) report the AQI for cities in Oregon. The *Oregon Air Quality Annual Report* provides a review of the health levels over the past year.[26]

[26] DEQ, *Oregon Air Quality Annual Report: 2020*, https://www.oregon.gov/deq/FilterDocs/AQmonitoringplan.pdf

Table 69. Air Quality Index Ranges and Episode Stages

Air Quality Rating	Air Quality Index (AQI)	$PM_{2.5}$ 24-hour Average (µg/m³)	Ozone 8-hour Average (ppm)
GOOD	0 - 50	0.0 - 12.0	0.000 - 0.054
MODERATE	51 - 100	12.1 - 35.4	0.055 - 0.070
UNHEALTHY FOR SENSITIVE GROUPS	101 - 150	35.5 - 55.4	0.071 - 0.085
UNHEALTHY	151 - 200	55.5 - 150.4	0.086 - 0.105
VERY UNHEALTHY	201 - 300	150.5 - 250.4	0.106 - 0.200
HAZARDOUS	>300	>250.5	>0.200

Source: DEQ, *Oregon Air Quality Monitoring Annual Report: 2019,*
https://www.oregon.gov/deq/FilterDocs/aqMonitorAnnualRep2019.pdf

For 2020, the air pollutants of greatest concern in Oregon were[27]:

- Fine particulate matter (mostly from combustion sources) known as **$PM_{2.5}$** (2.5 micrometers and smaller diameter).
- **Air Toxics -** pollutants that cause or may cause cancer or other serious health effects.
- Ground-level **ozone**, a component of smog.
- **Greenhouse gas** (GHG) emissions and global climate change are also concerns in Oregon. Oregon state agencies track GHG emissions from a wide variety of products, services, utilities, and fuel providers. These emissions data are available on DEQ's web site under Air Quality/ AQ Programs / Greenhouse Gas Reporting Home. This is an overall issue across all of Oregon but more considered in the higher population density areas.

History of Air Quality in the Tillamook County

The data available to track poor air quality conditions in the Tillamook County are limited.

The EPA maintains a real time Fire and Smoke monitoring map that map provide useful for NHMP plan holders to use in using the plan.[28] Below is an example of output from this real time mapping tool on July 14, 2021 in Wallowa County. Should there be a concern about air quality, this tool may be useful.

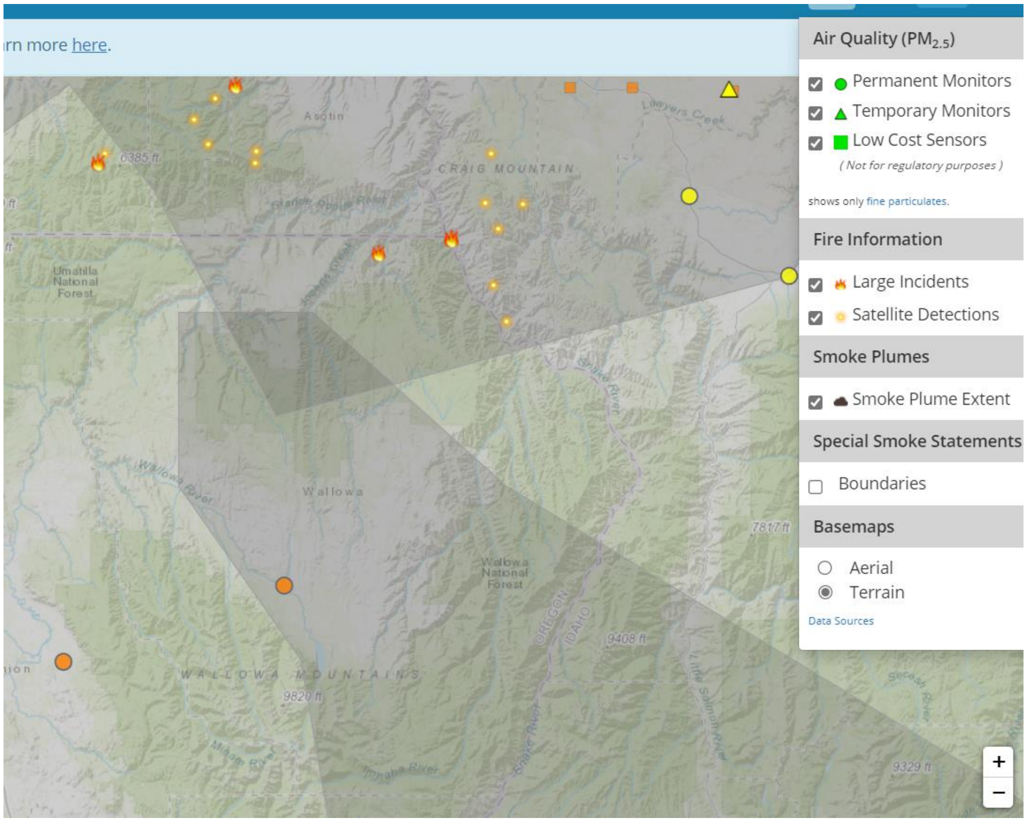
Due to the limited ability to track poor air quality conditions, no events of poor air quality have been included in this plan.

---

[27] Peter Brewer, DEQ, personal communication, 3/11/21 and the *Oregon Air Quality Annual Report: 2017*, https://www.oregon.gov/deq/FilterDocs/2017aqannualreport.pdf.

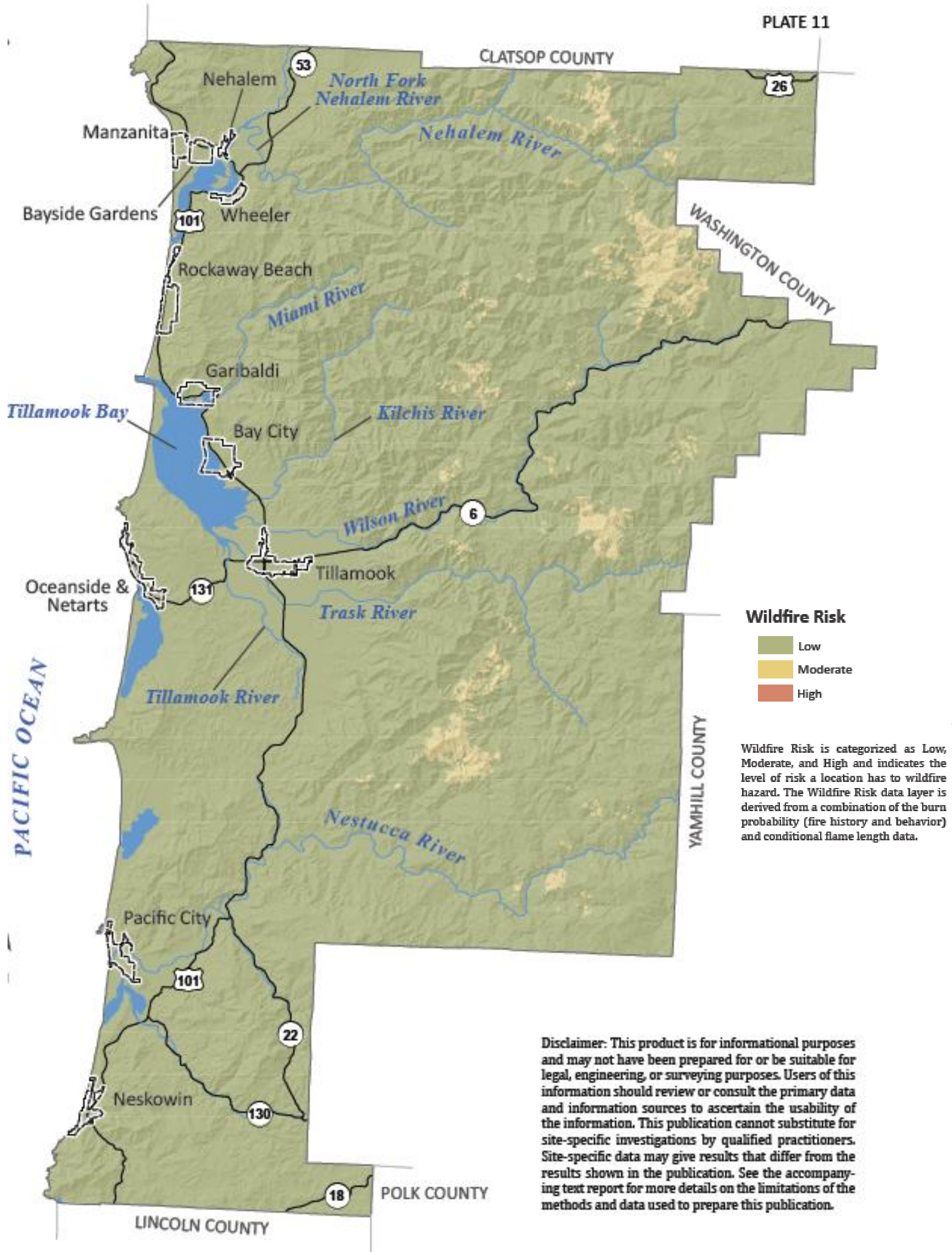
[28] Fire and Smoke Map (airnow.gov)

Figure 81. Example: AirNow Fire and Smoke Map of Wallowa County on 7/14/2021



Source: Fire and Smoke Map (airnow.gov)

Figure 82. Wildfire Risk



Source: DOGAMI (2016)

Historic Wildfire Events

Table 70. Historic Wildfires in Tillamook County

Date	Name	Description
1853	Nestucca	burned more than 320,000 acres
1933, 1939, 1945, 1951	Tillamook County	the Tillamook Burn included four fires occurring every 6 years over an 18-year period that burned 355,000 acres and killed one person
Aug. 1933	Tillamook Fire	burned 240,000 acres; the Tillamook Forest burned every 6 years between 1933 and 1951; total acreage burned was over 350,000 acres; together, the four events are called the Tillamook Burn; dry forest conditions seems to have been a major factor
Aug. 1939	Saddle Mountain Fire	burned 190,000 acres; much of the land had already been burned in the previous fires; burned 50,091 new acres
Jul. 1945	Salmonberry Fire Wilson River Fire	the two fires burned together; much of the land had already been burned in the previous fires; burned 65,150 new acres
Apr. 1951 Jul. 1951 Sep. 1951	North Fork Trask Fire Elkhorn Fire Edwards Creek Fire	burned 33,000 acres total; the Edwards Creek Fire was a re-kindling of the Elkhorn Fire; all of the acreage had been burned in the Elkhorn and North Trask Fires
Oct. 1970	Smith Creek Fire	burned 202 acres
Oct. 1976	Cronin Creek Fire	burned 834 acres
Oct. 1986	Prouty Creek Fire	burned 105 acres
Sep. 1995	Steampot Fire	burned 30 acres
Nov. 2002	Butte Creek Fire	burned 45 acres
Nov. 2002	Blue Lake Fire	burned 45 acres
Nov. 2002	Bay Overlook Fire	burned 46 acres
Jul. 2006	Spring Creek Fire	Burned 35 acres

Source: Oregon Natural Hazards Mitigation Plan (Oregon Department of Land Conservation and Development, 2015); Tillamook County Community Wildfire Protection Plan (White et al., 2006)

Probability

The potential that wildland fires, both small and large, will threaten life, property and natural resources is a reality. The natural ignition of forest fires is largely a function of weather and fuel. Dry and diseased forests can be mapped accurately and some statement can be made about the probability of lightning strikes. Human-caused fires add another dimension to the probability.

On lands protected by ODF, the 10-year trend in both the incidence of human-caused fires and the acres they burn is rising. Population growth and development continue to encroach into and fragment forests. Fire statistics show that fire incident rates, and therefore risks, are prevalent in WUI areas.

The probability of significant fire activity occurring in Tillamook County is most likely during the late summer and early fall months when temperatures remain high, vegetation has had the entire summer to dry out and east winds coming out of the Columbia Gorge are more prevalent.

Climate Change

El Niño winters can be warmer and drier than average. This often leads to an increased threat of large wildfires the following summer and autumn, even in cool, wet Tillamook County. According to ODF, state firefighting agencies will continue to monitor correlations between seasonal weather conditions and wildfire occurrences and severity to refine planning tools for fire seasons and to aid in the pre-positioning of firefighting resources to reduce the vulnerability posed by large wildfires to natural resources and structures.

Vulnerability

Vulnerability expresses the impacts to people and the built environment anticipated from wildfire. The greatest impacts of wildfire in Tillamook County will be to people and property in the WUI area and to the timber, recreation, and tourism industries.

Tillamook County has moderate risk of wildfire throughout based primarily on cool, moist weather conditions and infrequent activity. However, the County has had some of the largest wildfires that posed threats to communities when they occurred. Any new development within or on the edge of the forest would increase vulnerability to wildfire.

While the risk of wildfire impacting the Port of Tillamook Bay is considered low, should a wildfire spread to the Port damage to buildings, contents, and critical infrastructure could have a chilling effect on the County's economy.

The economic stability of the County is also dependent on a major state highway (US-101) that runs along the Oregon Coast and several east-west highways connecting the County to Portland and Salem. Should a major wildfire (or other natural hazard event) threaten or impact these routes, coastal tourism and recreational economies would come to a halt.

Exposure

The *Multi-Hazard Risk Report for Tillamook County* (DOGAMI, 2022) provides a wildfire exposure analysis for Tillamook County. Error! Reference source not found. provides shows the WWA's Fire Risk Index and building exposure analysis. Exposure analysis results are shown in **Table 71** and **Table 72**, and **Figure 83** illustrates those results.

Table 71. Wildfire Exposure: Tillamook County and Cities

			(all dollar amounts in thousands)								
			High Risk			**Moderate Risk**			**Low Risk**		
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**
Unincorp. County (rural)	14,107	3,610,281	2	356	0%	605	124,632	3%	6,054	1,246,892	35%
Bayside Gardens	945	186,325	0	0	0%	6	1,703	0.9%	189	32,177	17%
Neskowin	652	141,094	0	0	0%	0	0	0%	196	43,060	31%
Oceanside & Netarts	1,628	302,588	0	0	0%	1	159	0%	428	89,284	30%
Pacific City	1,721	361,114	0	0	0.0%	8	2,549	1%	306	66,543	18%
Total Unincorp. County	**19,050**	**4,598,402**	**2**	**356**	**0%**	**620**	**129,043**	**3%**	**7,173**	**1,477,956**	**32%**
Bay City	880	229,175	0	0	0.0%	17	3,632	2%	127	40,461	18%
Garibaldi	755	179,063	0	0	0.0%	0	0	0%	24	6,119	3%
Manzanita	1,517	274,658	0	0	0%	0	0	0.0%	162	27,666	10%
Nehalem	234	54,360	0	0	0%	0	0	0%	20	4,339	8%
Rockaway Beach	2,095	454,733	0	0	0.0%	17	2,886	1%	238	56,950	13%
Tillamook	2,194	982,931	0	0	0.0%	0	0	0%	47	42,450	4%
Wheeler	362	81,137	0	0	0%	0	0	0%	83	14,818	18%
Total Tillamook County	**27,090**	**6,854,759**	**2**	**356**	**0.0%**	**654**	**135,561**	**2.0%**	**7,874**	**1,670,759**	**24%**

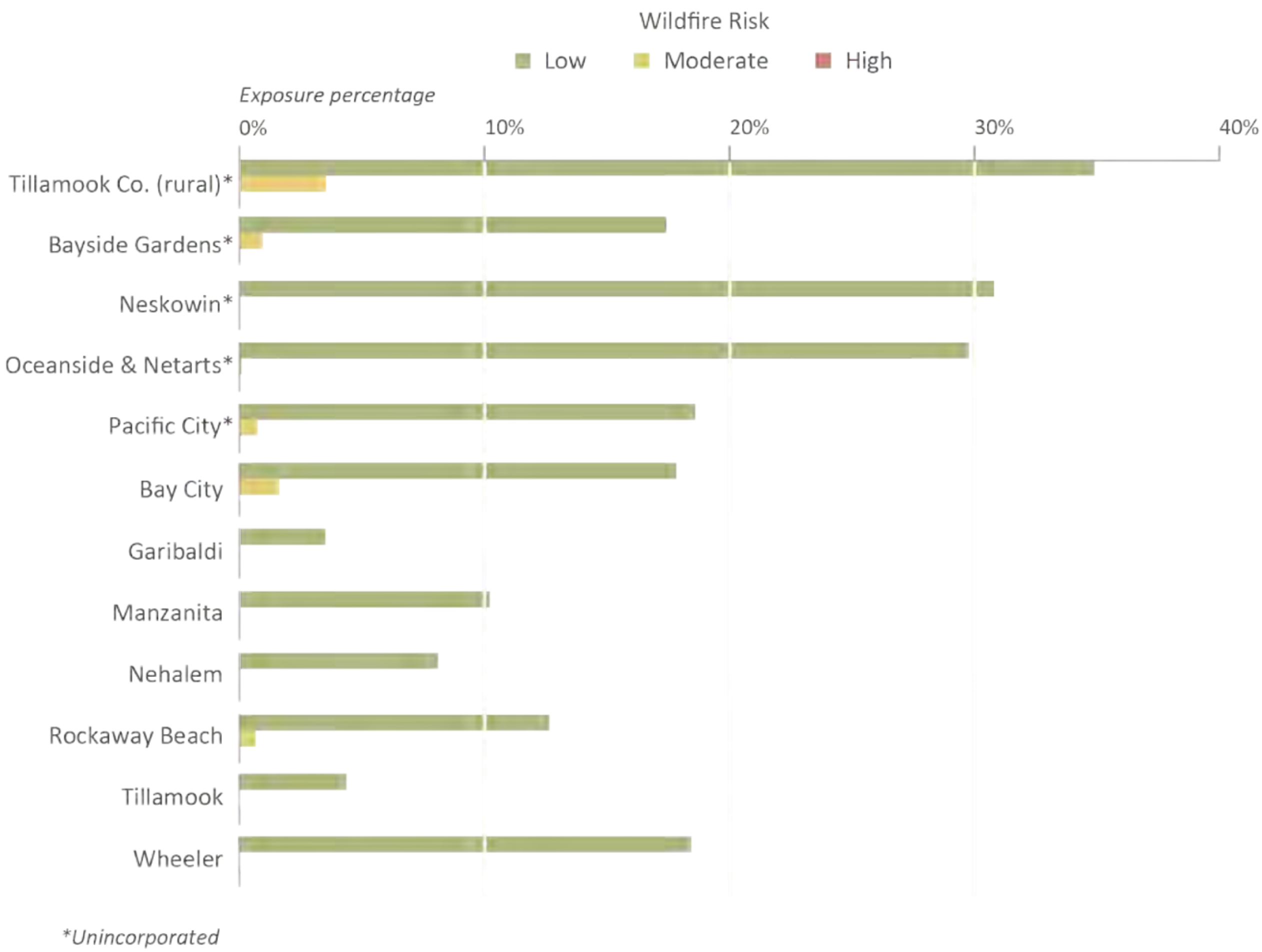
Source: DOGAMI (2022)

Table 72. Wildfire Exposure: Port of Tillamook Bay and Port of Garibaldi

			High Risk			Moderate Risk		
	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Ratio of Exposure Value	Number of Buildings	Building Value ($)	Ratio of Exposure Value
Port of Garibaldi	36	8,035,760	0	0	0.00%	0	0	0%
Port of Tillamook	83	61,545,144	0	0	0.00%	0	0	0%

Source: Derived from DOGAMI (2016)

Figure 83. Wildfire Risk Exposure by Community



*Unincorporated communities.
Source: DOGAMI (2022)

D. Risk Profiles

Risk Profiles summarize the risk assessment and include a multi-hazard map set for each community. In addition, they provide risk reduction strategies for each community except the Ports to consider. Areas of mitigation interest were not analyzed for the Ports.

1. Unincorporated Rural Tillamook County

Risk Profiles for the Nehalem Bay Fire and Rescue District (NBFRD), Nestucca Valley School District (NVSD), and Tillamook People's Utility District (TPUD) are highlighted within this section for Unincorporated Rural Tillamook County.

Nehalem Bay Fire and Rescue District is within the unincorporated community of Bayside Gardens, so it is included in that subsection. The NBFRD maintains two fire stations. The main station is in within the city of Nehalem Urban Growth Boundary (UGB) and the second is located within the unincorporated area of the county. Due to the county-wide reach of the TPUD, its assets are widely dispersed both in unincorporated land and within cities. Those critical facilities are listed within the jurisdiction where they are located. Nestucca Valley School District is located in Cloverdale, an unincorporated community that was not separately analyzed by DOGAMI. The schools are identified in Table 2 below.

The natural hazards to which rural Tillamook County is most vulnerable are the CSZ-related events (earthquake and tsunami), flood, and landslide. Coastal erosion and wildfire to a lesser extent are also hazard risks (Table 1). As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Developments along the Pacific Coast and in estuarine areas have exposed a huge amount of the coastal region of rural Tillamook County to tsunami hazard, as well as to coastal erosion. Potential flooding from riverine and coastal sources can affect many buildings in the low-lying rural areas in the 100-year flood zone. Risk of landslide exists throughout the county.

Rural Risk Assessment Summary

Table 73. Hazard Profile: Unincorporated Tillamook County

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Unincorporated Tillamook County	13,540	14,104	42	3,607,281,000

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	1,161	8.6%	1,013	1	60,068,000	1.7%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	815	6.0%	4,062	24	846,758,000	24%
Earthquake	CSZ Mw 9.0 within the tsunami zone	110	0.8%	813	3	114,629,000	3.2%
Earthquake	Happy Camp Mw 6.6 Deterministic	585	4.3%	2,708	17	548,865,000	15%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	898	6.6%	1,620	2	349,607,000	9.7%
Landslide	High and Very High Susceptibility	5,469	40.4%	5,527	11	1,172,931,000	33%
Coastal Erosion	High Hazard	85	0.6%	513	0	105,734,000	2.9%
Wildfire	High Risk	2	0%	2	0	356,000	0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

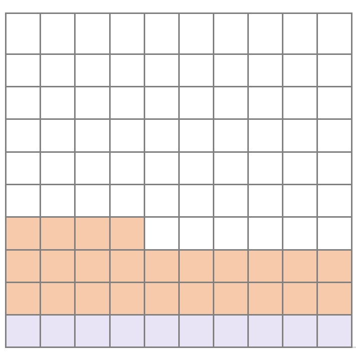
[1]Facilities with multiple buildings were consolidated into one building complex.

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

Note: The statistics in this section include the rural portion of unincorporated Tillamook County. They do not include the unincorporated communities of Bayside Gardens, Neskowin, Oceanside-Netarts, or Pacific City. Those communities are summarized separately.

The CSZ event is a significant natural hazard risk to rural Tillamook County and is a priority hazard for this community. Moderate to high liquefaction zones exist throughout the county, which increases the risk from earthquake. Another consideration of these areas is that liquefaction could present difficulties for evacuation from the subsequent tsunami. The combination of earthquake and tsunami will have a tremendous impact on the entire coastal and estuarine portions of rural Tillamook County.

Figure 84. Loss Ratio from CSZ Event: Unincorporated Tillamook County



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely

†Each cell represents 1% of building value

= Estimated losses due to tsunami.
= Estimated losses due to earthquake (outside of tsunami zone).

Many of the buildings built along the streams and the coast are exposed to the 100-year flood in rural parts of the county. Although there are some elevated buildings in the flood-prone areas, which have greatly reduced overall flood risk, there are still many buildings that can be impacted by flood. It is estimated that nearly half of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding. So, while the buildings themselves would not be damaged from flood, access to these buildings could be an issue.

Roughly one third of the buildings in rural Tillamook County are at risk of landslide hazard. Low susceptibility landslide zones generally correspond to estuaries and floodplains near estuaries that also are in the vicinity of the county's populated areas. However, outside of these areas, susceptibility is high to very high almost everywhere. The rugged terrain of rural Tillamook County lends itself to potential landslide hazard.

To a lesser extent coastal erosion and wildfire hazards pose some concerns. Coastal erosion hazards exist all along the coast, but much of coastal rural Tillamook County is undeveloped. Wildfire risk is high for hundreds of homes within this community, but the overall exposure percentage is fairly low.

Table 74. Essential Facilities: Unincorporated Tillamook County

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Adventist Clinic South		X			X		
Bay City Water Treatment		X	X				
Cape Meares Fire Station 73							
Cloverdale STP		X					
Fire Mountain School		X			X		
Garibaldi Rural Fire District		X			X		
Neah-Kah-Nie Jr/Sr High School		X		X			
Nehalem Bay STP		X					
Neskowin Valley School		X			X		
Nestucca High School					X		
Nestucca RFPD - Beaver Station 83		X	X				
Nestucca RFPD - Blaine Station 86		X					
Nestucca RFPD - Hebo Station 87	X				X		
Nestucca RFPD - Neskowin Station 84		X		X	X		
Nestucca RFPD - Sandlake Station 85							
Nestucca Valley Elementary					X		
Netarts-Oceanside STP		X	X		X		
Port of Tillamook Main		X	X				
Port of Tillamook Septage Receiving		X			X		
Siuslaw National Forest – Hebo Ranger Station		X			X		
South Prairie Elementary School		X	X				
Substation – Beaver							
Substation – Hebo			X				
Substation – Garibaldi							
Substation – Mohler							
Substation – Nehalem							
Substation – Nestucca							
Substation – South Fork							
Substation – Trask River			X				
Substation – Wilson River			X				
TPUD - Transformer Shop			X				
TPUD – Oil Containment			X				

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
TPUD – Hebo							
Tillamook Adventist School		X	X				
Tillamook Airport			X				
Tillamook County Emergency Management			X				
Tillamook County Public Works - South		X			X		
Tillamook County Sheriff's Office			X				
Tillamook – South Prairie Fire Station #72		X	X				
Tillamook Industrial Park STP		X	X				
Tillamook Public Works		X	X				
Twin Rocks WWTP		X					

Nestucca Valley School District

The Nestucca Valley School District #101 serves the communities of Beaver, Hebo, Cloverdale, Pacific City/Woods, Sandlake, and Neskowin.

Local Risk Assessment Review

Based on interviews with the Nestucca Valley School District (NVSD) representative and on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the NVSD representative differentiated the relative risks to the district. These differences are also indicated in the Risk Assessment section in Table 3 in the column for NVSD.

The NVSD representative evaluated its relative vulnerability to natural hazards and made the following assessments. The recent retrofitting of the high school and the renovations and new construction for the K8 building reduces the vulnerability to earthquake as compared to the vulnerability of the county as a whole. Vulnerability to tsunami is also lower than the county as a whole. Winter Storm and Windstorms are the most concerning natural hazard for the school district. Wildfire is more of a concern, but the high school has a composite roof with a rubber membrane. The K8 Building has lots of defensible space around it, whereas the high school may have some vegetation nearer to the building. The school district is also vulnerable to Pandemic and Endemic disease, but is not as concerned about Flood, Landslide or Drought. The upgrades to the K8 Building improve resilience to Poor Air Quality and Extreme Temperatures. Coastal Erosion and Algal Blooms are not applicable natural hazards for the school district.

Essential Facilities and Critical Infrastructure: Success Story

Nestucca K8 Campus

The Nestucca Valley School District has invested in its facilities by constructing an addition to the elementary school building that is rated for immediate occupancy and in the renovated section for life safety functions in an emergency. Improvements to the NVSD's elementary school include a 45,500 square foot two-story addition, transforming the existing 27,900 square foot Cloverdale elementary school into NVSD's K-8 campus. The existing school was torn down to the studs and built back up. The school was also moved from a boiler system to a heat pump and cooling system. The school facilities include new cafeteria, commons, classrooms, regulation-size double gymnasium, parking, playground, and renovated utilities in the existing elementary facilities including a new well, plumbing, electrical, new windows and septic system improvements.[29] The improvements also include a 60,000-gallon underground water storage tank for firefighting. .[30]

In 2016, Nestucca Valley School District began conceptualizing the renovation and expansion of the original 1950s era building. "Going through the planning system," Nestucca Valley School District Superintendent Misty Wharton said, "the whole community was concerned about the emergency preparedness of a facility to go if there's a tsunami. Using bond funds, state grants, and seismic retrofit grants, the school district actively began the nearly $26 million construction project in 2019 and completed it in 2021. The Nestucca Valley School District and their general contractor, O'Brien & Company, have received the Daily Journal of Commerce Primary Education-Small First Place Award for the project.[31]

The new addition is rated to be immediately occupied following an earthquake while the old, but renovated section of the building is now rated for life safety functions[32]. The Nestucca Elementary School has served as a shelter and the Nestucca Valley School District provided buses to assist in the evacuation of people stranded by flood waters in the Neskowin RV park during the November 12, 2021 flood event. The NVSD K-8 school is now the largest structure in south Tillamook County and serves as a community and civic center for south Tillamook County. Expectations are to equip the facility to serve as a shelter for 1,300 people in the event of a natural hazard event. [33]

Nestucca High School

In 2019 Business Oregon's Seismic Rehabilitation Grant Program awarded Nestucca Valley School District 101 a grant of $2,476,280 to accomplish a seismic rehabilitation of the Nestucca High School gym and cafeteria. The project was completed in 2020.[34]

Nestucca Valley Early Learning Center

The Nestucca Valley Early Learning Center is located near the Nestucca Rural Fire Protection District station in Hebo.

Transportation Infrastructure/Bridges

The principal route between the K8 campus and the High School campus may be compromised during a Cascadia earthquake event. U.S. Highway 101 crosses three waterways between the High School and the K8 Campus. A bridge failure or culver collapse could jeopardize access for the K8

[29] Nestucca Valley introduces new K-8 campus | News | tillamookheadlightherald.com

[30] Nestucca school bond would fix 'orange' water and triple campus size | News | tillamookheadlightherald.com

[31] Nestucca K8 building expansion wins awards | News | tillamookheadlightherald.com

[32] Ibid.

[33] Personal communication Chad Holloway, June 6, 2022

[34] Ibid.

students to the community of Cloverdale. Jenck Road may provide an alternative route but has its own crossing points over Queens Creek and Arstell Creek.

The NVSD has a Safe Routes to School project underway. There are substantial concerns about southern Tillamook County being cut off from neighboring communities during a major earthquake. The Cascadia Island Mapping work of the Department of Emergency Management provides analysis of these projections. [35] [36]

Water
The water source for the K8 campus is a deep well. The Nestucca Valley Early Learning Center is connected to the Hebo water system. The High School uses a surface water source.

Energy
The school district has electric service through Tillamook PUD. In addition, all three buildings have propane generators. The generators at the K8 Building and at the Nestucca Valley Early Learning Center are propane and the generator at the High School runs on diesel. The High School has three 1000-gallon fuel storage tanks and the K8 campus has two 1000-gallon fuel storage tanks.

Communications
All of the buildings are wired with fiber and served by Wave/Astound Broadband. There are also walkie talkies that can reach from the K8 campus to the High School. The school district is considering housing CERT equipment at the K8 Building.

Emergency and Public Services
The school district depends on the County Sheriff for law enforcement concerns. The Nestucca Valley Early Learning Center is located very close to the Nestucca Rural Fire Protection District station. County services provide other public services such as road maintenance and stormwater management.

Events, Festivals and Tourism
A variety of events are hosted at the schools, both for students and for community members who may rent the school facilities. They include graduation and athletic events, community funerals, tournaments, both during the school year and during the summer.

Vulnerable populations
Students served by the school district range in age from 3 years to 21, although most seniors are 18. Some students and staff struggle with health issues. Spanish is commonly spoken by the 26% of the district population which is Hispanic. Nestucca K8 School is a Title 1 school that receives federal funds to assist the school in meeting the needs of students living in poverty or dealing with other related issues such as drug use.

---

[35] Oregon Department of Emergency Management : Cascadia Island Mapping : Hazards and Preparedness : State of Oregon
[36] Plate12_Pacificcity.pdf (oregon.gov)

Tillamook People's Utility District

Local Risk Assessment Review

Based on interviews with the Tillamook People's Utility District (TPUD) representative and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the TPUD representative differentiated the relative risks to the district. These differences are also indicated in the Risk Assessment section in Table 3 in the column for TPUD.

The TPUD representative evaluated the district's relative vulnerability to natural hazards and made the following assessments. Windstorm and Winter Storm are natural hazards of top concern for the TPUD because they can affect the whole territory and can cause damage to the system resulting in a loss of power. The maximum threat of damage from wildfire can threaten the critical infrastructure of the TPUD system because the system extends through undeveloped forest land. Landslide can be a concern for the TPUD with respect to infrastructure located on Cape Meares. Flood is also a concern for the district, perhaps less than for the county, because flooding can reduce access to portions of the system limiting the ability to conduct repairs. The impacts of Pandemic/Public Health Emergency and Earthquake may be less for the TPUD than for the county as a whole with the TPUD office and its employees being the most susceptible to these natural hazards. The TPUD does not experience risk from Algal Blooms.

Essential Facilities and Critical Infrastructure

TPUD essential facilities and critical infrastructure consists of the main and secondary lines that provide electricity from the Bonneville Power Administration's hydroelectric dams to the Tillamook PUD system. That system consists of both overhead and underground power lines, poles, vaults, and substations. The district depends on the county and state roads and bridges to access this infrastructure. Similarly, the district depends on the water and wastewater infrastructure of the City of Tillamook to serve the TPUD offices located there.

The cities and communities in Tillamook County depend on the power provided by TPUD. In particular cities and communities in Tillamook County depend on the TPUD electric service to power essential facilities such as water treatment and distribution systems, and wastewater pumping and treatment facilities. The TPUD has established a 10-year work plan to assist in prioritizing projects that improve the resilience of the system. Electric service to these locally important essential facilities is usually provided via underground connections. The district's capital improvement budget of about $5 million annually is used to improve infrastructure as it ages and requires replacement. Burying power lines, replacing fuses with non-sparking fuses, and increasing the size of above ground poles are among the most common ways the district improves resiliency when replacing portions of the system infrastructure.

Rural Areas of Mitigation Interest

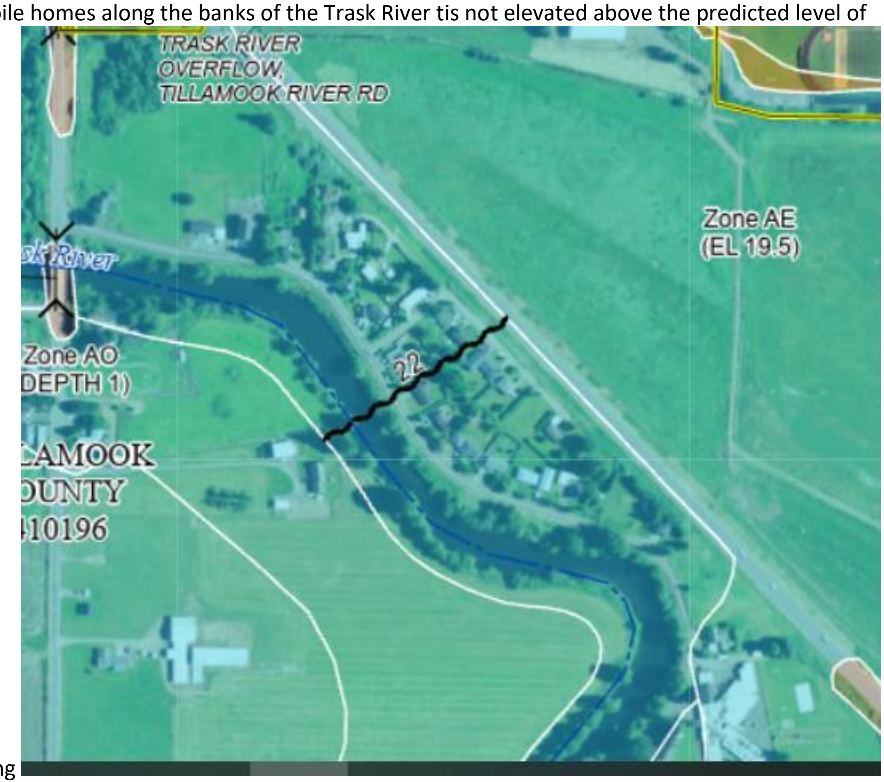
Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be described as Areas of Mitigation Interest. The 2022 DOGAMI Multi-hazard Risk Assessment provides these additional areas of mitigation interest throughout the report. They have been assembled here in Table 75 for a comprehensive presentation. In Table 76 only the areas that fall within the county are listed. The rest have been copied to their respective cities or communities.in the sections that follow and integrated with the areas of mitigation interest identified in the 2016 DOGAMI MHRA and then into the 2016 Tillamook County MJ NHMP

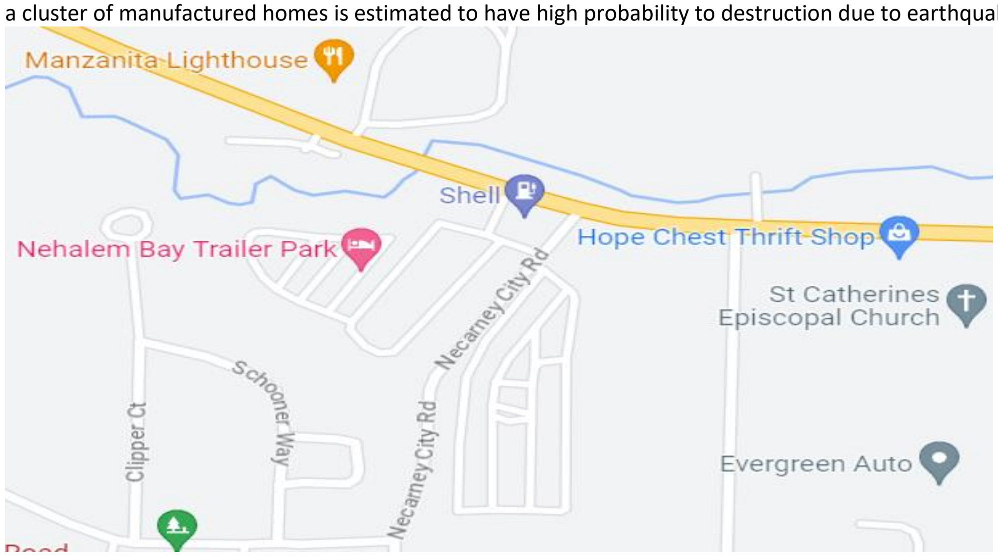
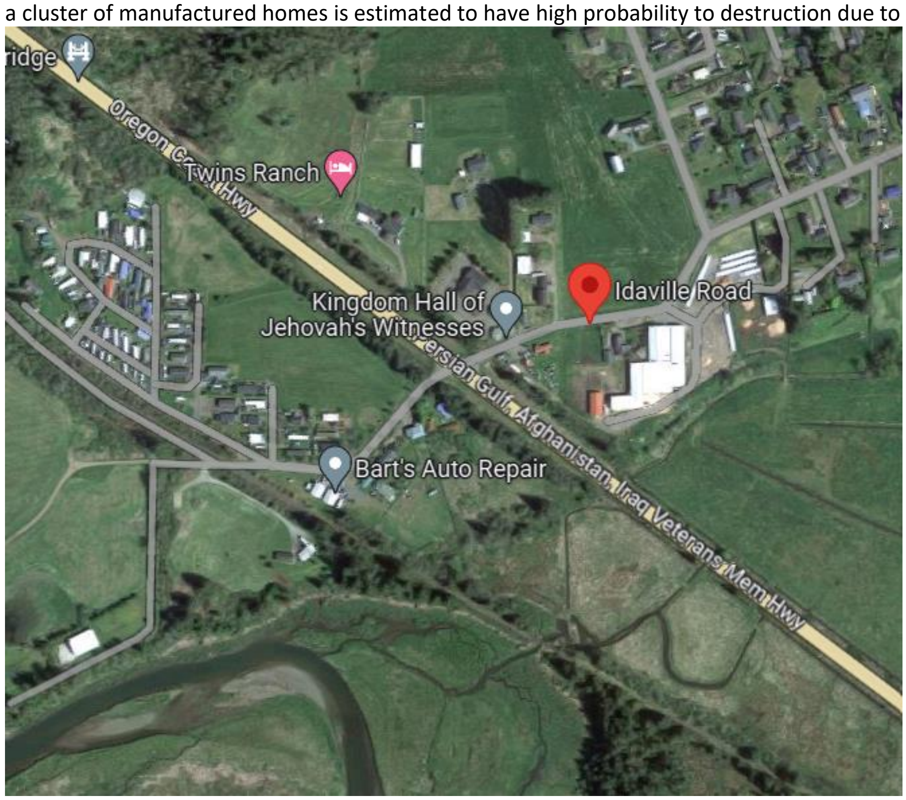
Table 75. Areas of Mitigation Interest: Entirety of Tillamook County

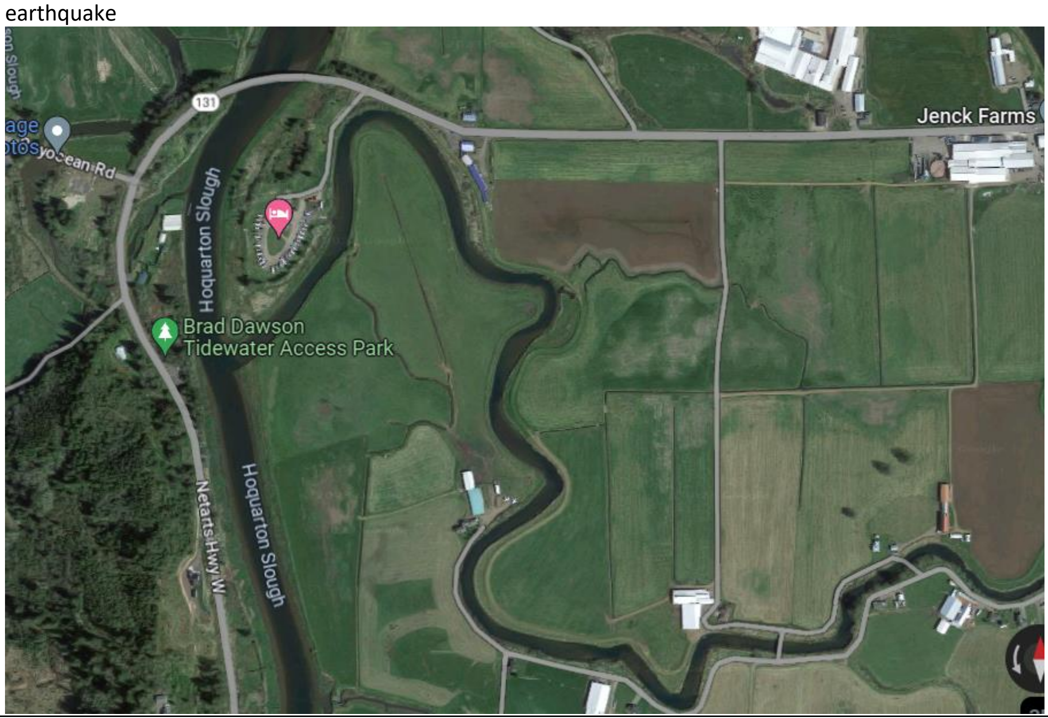
Hazard	Area	Description
Flood	Many buildings in the low-lying business area of Nehalem	The area along the riverbank, is within the 100-year flood SFHA due to the close proximity of the Nehalem River. Past mitigation actions, such as elevating buildings, have alleviated some problems.
Flood	City of Tillamook in floodplain created by Tillamook, Trask, Kilchis, and Wilson rivers	Many buildings in the low-lying areas of the city and surrounding areas are exposed to the 100-year flood.
Flood	Tillamook Cheese Factory	the top employer in Tillamook County is within the area predicted to flood due to a 100-year flood
Flood	Many buildings located adjacent to Trask River	a cluster of mobile homes along the banks of the Trask River tis not elevated above the predicted level of 100-year flooding
Flood	Rockaway Beach along the Pacific Ocean, Rock Creek, and other minor creeks	Many buildings in the low-lying areas of Rockaway Beach along the Pacific Ocean, Rock Creek, and other minor creeks are exposed to the 100-year flood.
Flood	Neskowin Creek, Kiwanda Creek, and the Pacific Ocean	Developed areas within Neskowin along Neskowin Creek, Kiwanda Creek and the Pacific Ocean are exposed to the 100-year flood.
Flood	Nestucca River in Pacific City	Many buildings along the Nestucca River in Pacific City are at risk from flooding.
Earthquake	A mobile home park off Necarney City Rd and Hwy 101 (Bayside Gardens?)	a cluster of manufactured homes is estimated to have high probability to destruction due to earthquake
Earthquake	Many buildings located adjacent to Nehalem River, just upstream of the City of Nehalem	clusters of buildings along the banks of the Nehalem River are within a high liquefaction zone and have high probability to destruction due to earthquake
Earthquake	A mobile home park off of Hwy 101 and Idaville Rd	a cluster of manufactured homes is estimated to have high probability to destruction due to earthquake
Earthquake	A cluster of homes adjacent to Highway 131 and near the Tillamook River	a cluster of buildings is within a high liquefaction zone and has high probability to destruction due to earthquake
Earthquake	Along Tillamook Bay, portions of the coast, and along the Nestucca River	Buildings in high liquefaction susceptible areas along Tillamook Bay, portions of the coast, and along the Nestucca River are at higher risk of damage from coseismic liquefaction-induced ground deformation
Earthquake	In the communities of Neskowin, Bay City, Garibaldi, and Tillamook	Older buildings that are more vulnerable to earthquake shaking
Tsunami	Along the Nestucca River in Pacific City	Buildings and people along the Nestucca River in Pacific City are exposed to tsunami hazard,
Tsunami	Neskowin and Manzanita along the open coast	Buildings and people in these areas are exposed to tsunami hazard
Tsunami	Along Tillamook Bay in Bay City and Garibaldi	Buildings and people along Tillamook Bay in Bay City and Garibaldi are exposed to tsunami hazard.

Hazard	Area	Description
Tsunami	Rockaway Beach	Coastal and low-lying areas of Rockaway Beach are predicted to be inundated by a tsunami. A significant portion of the community is exposed to this tsunami zone.
Tsunami	Wheeler and Nehalem along the Nehalem River	Buildings and people in Wheeler and Nehalem along the Nehalem River are exposed to tsunami hazard.
Coastal Erosion	An area of homes in the unincorporated community of Terra del Mar along the shoreline	a long strip of houses that is within the high coastal erosion designated zone
Coastal Erosion	All of coastal Rockaway Beach,	During times of high tide occurring along with powerful storms, the rate of erosion can greatly increase. A long strip of houses is within the high coastal erosion designated zone.
Coastal Erosion	In Neskowin along the coast and north of the Neskowin Creek	The residential area in Neskowin along the coast and north of the Neskowin Creek mouth is likely to experience coastal erosion.
Coastal Erosion	Pacific City	Coastal erosion risk exists in Pacific City for several homes along the beach just north of the Pacific Avenue Bridge.
Landslide	Oceanside and Netarts	Much of the community of Oceanside and Netarts is at high or very high risk from landslide hazard.
Landslide	Northwest part of Bay City	The hilly residential area in the northwest part of Bay City is within a Very High landslide susceptibility zone.
Landslide	Garibaldi, Nehalem, and Wheeler	The majority of Garibaldi, Nehalem, and Wheeler are at High risk from landslide hazard.
Landslide	Eastern edge of Rockaway Beach	Residential structures on the eastern edge of Rockaway Beach are built on top of a preexisting landslide which is considered Very High risk.
Wildfire	East of the City of Tillamook	Areas to the east of the city of Tillamook are at higher levels of risk from wildfire than other areas in Tillamook County.
Wildfire	Along the Nestucca River	Buildings along the Nestucca River have an elevated risk from wildfire.

Table 76. Areas of Mitigation Interest in Unincorporated Tillamook County

Hazard	Area	Description
Flood	Many buildings located adjacent to Trask River	a cluster of mobile homes along the banks of the Trask River tis not elevated above the predicted level of 100-year flooding 

Hazard	Area	Description
Earthquake	A mobile home park off Necarney City Rd and Hwy 101 (Bayside Gardens?)	a cluster of manufactured homes is estimated to have high probability to destruction due to earthquake 
Earthquake	A mobile home park off of Hwy 101 and Idaville Rd	a cluster of manufactured homes is estimated to have high probability to destruction due to earthquake 

Hazard	Area	Description
Earthquake	A cluster of homes adjacent to Highway 131 and near the Tillamook River	a cluster of buildings is within a high liquefaction zone and has high probability to destruction due to earthquake 
Earthquake	Along Tillamook Bay, portions of the coast, and along the Nestucca River	Buildings in high liquefaction susceptible areas along Tillamook Bay, portions of the coast, and along the Nestucca River are at higher risk of damage from coseismic liquefaction-induced ground deformation
Coastal Erosion	An area of homes in the unincorporated community of Terra del Mar along the shoreline	a long strip of houses that is within the high coastal erosion designated zone
Wildfire	East of the City of Tillamook	Areas to the east of the city of Tillamook are at higher levels of risk from wildfire than other areas in Tillamook County.
Wildfire	Along the Nestucca River	Buildings along the Nestucca River have an elevated risk from wildfire.

Bayside Gardens and Nehalem Bay Fire and Rescue District

Local Risk Assessment Review

Based on interviews with a Nehalem Bay Fire and Rescue District (NBFRD) representative and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the NBFRD representative differentiated the relative risks to the district. These differences are also indicated in the Risk Assessment section in Table 3 in the column for NBFRD.

The NBFRD representative evaluated the district's relative vulnerability to natural hazards and made the following assessments. The NBFRD is more vulnerable to Windstorm than the county as a whole based on the district's service area location and exposure on the coast. The district also experiences higher risk from Poor Air Quality than the county as a whole because its personnel respond to calls for assistance to those served by the district with respiratory vulnerabilities. The NBFRD is less at risk from Extreme Temperatures than the county as a whole due to the location of the district service area.

The Risk Assessment Summary developed through DOGAMI's Multi-Hazard Risk Assessment for the unincorporated community of Bayside Gardens encompasses the district's main station and reflects the relative risks from flood, earthquake (both CSZ and a crustal earthquake scenario), tsunami, coastal erosion, and wildfire to this portion of the county.

Risk Assessment Summary

The natural hazards to which the community of Bayside Gardens and the NBFRD main station are most vulnerable are the CSZ-related events (earthquake and, to a lesser extent, tsunami). As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. The landslide hazard poses a moderate risk for the community of Bayside Gardens and the NBFRD main station, the potential impact of which is a serious concern.

Table 77. Hazard Profile: Unincorporated Community of Bayside Gardens

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Bayside Gardens		988	945		4	186,325,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0.0%	1	0	7,000	0.0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	88	8.9%	342	4	35,746,874	19.2%
Earthquake	CSZ Mw 9.0 within the tsunami zone	5	0.5%	19	0	1,867,478	1.0%
Earthquake	Happy Camp Mw 6.6 Deterministic	3	0.3%	18	0	2673,000	1.4%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	55	5.5%	51	0	9,065,000	4.9%
Landslide	High and Very High Susceptibility	49	5.0%	70	2	14,936,000	8.0%
Coastal Erosion	High Hazard	0	0%	0	0	0	0%
Wildfire	High Risk	0	0%	0	0	0	0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

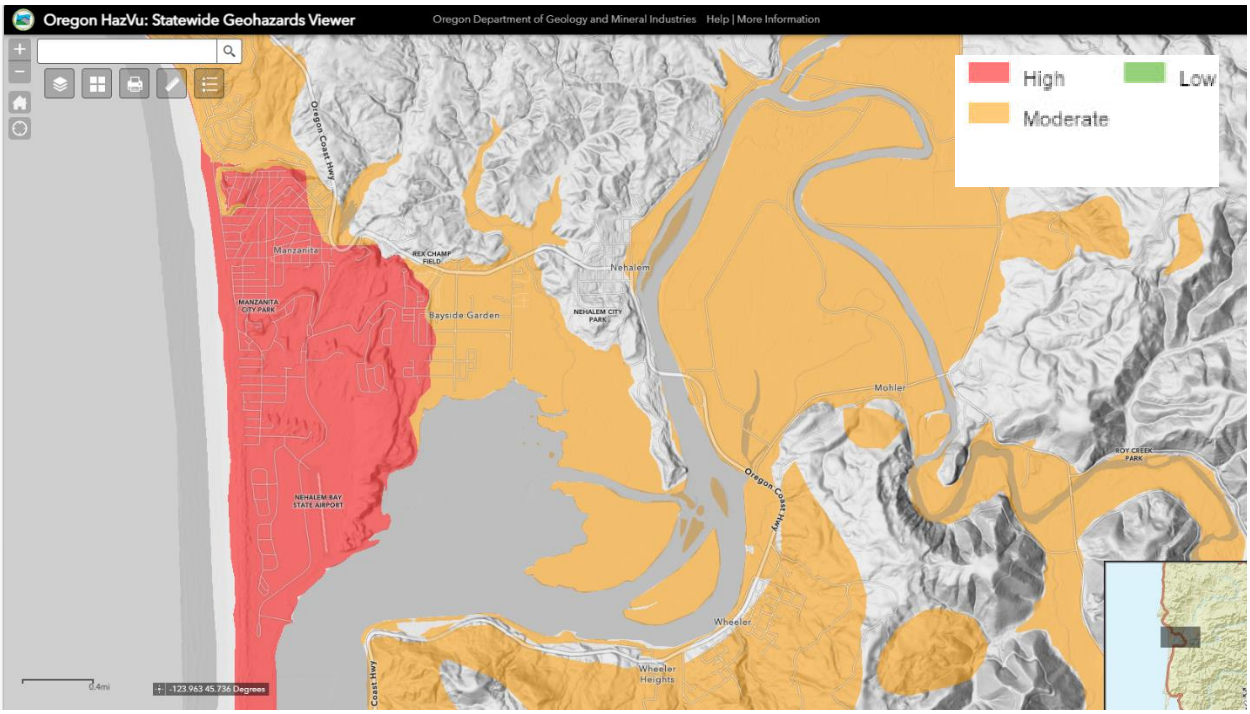
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

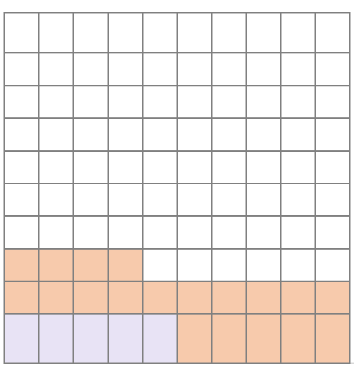
The CSZ event is a significant natural hazard risk to the community of Bayside Gardens and the NBFRD main station and is a priority hazard for this community. Moderate to high liquefaction zones exist throughout the community, which increases the risk from earthquakes. These liquefaction areas also correspond closely with the areas predicted to be inundated by the most likely tsunami scenario. Since DOGAMI deemed buildings within the tsunami zone to be red-tagged, these buildings have been excluded from the earthquake loss estimates. Another consideration of these areas is that liquefaction could present difficulties for evacuation from the subsequent tsunami. The combination of earthquake and tsunami will have a tremendous impact on this community.

Figure 85. Liquifiable Soils in Bayside Gardens, Manzanita, Nehalem, and Wheeler



Source: Oregon HazVu Geohazards Viewer

Figure 86. Loss Ratio from CSZ Event: Unincorporated Community of Bayside Gardens



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

Table 78. Essential Facilities: Unincorporated Community of Bayside Gardens

Critical Facilities by Community	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed	Exposed	Exposed
Adventist Clinic North		X			X		
Manzanita Water Treatment		X			X		
Nehalem Bay Fire and Rescue - Station 13		X					
TPUD - Nehalem		X					

Transportation Infrastructure
U.S. Highway 101 and State Highway 53 are the principal transportation routes for the NBFRD. However, in a flood event the intersection of these two roads is often completely shut down. Previously Mohler Road was used to circumnavigate, but that road has been obstructed and has been impassable for many years according to NBFRD's Chief Beswick. He is working on a plan with the county to reopen Mohler Road. Another alternative could be MacDonald Road, but the dike on MacDonald is not sufficient and it floods annually.

Evacuation Routes and Assembly Areas
The district has developed an evacuation plan that identifies the district's substation as a collection point.

Energy
Fuel for the district's vehicles is commonly sourced from the Shell station located in Nehalem.

Electricity is provided by Tillamook PUD and the main station is equipped with a backup diesel generator. The district has an informal agreement with the City of Manzanita to use its fuel trailer, a mobile 250-gallon diesel fuel reserve. The second station is equipped with a propane generator. There is potential difficulty in refueling that propane generator located on State Highway 53 near MacDonald Road given the reliance on State Highway 53.

The district is developing a grant application for a 25-kilowatt solar powered source to run the main station and is also interested in seeking funding and installing solar panels with battery storage to serve the second station.

Water and Wastewater
The City of Nehalem provides both drinking water and wastewater service to the district. The district collaborates with Nehalem Public Works to provide emergency water delivery.

Communications
Phone lines are served by Rural Telecom Inc.; however, the system is outdated and problematic. Spectrum provides the district with cable and internet service. Chief Beswick stated that his biggest concern is if a cell tower becomes non-functional and limits or removes internet connectivity. The district is interested in addressing this vulnerability through a satellite communication system.

Radio communications, both HAM and dispatch radios, are dependent on the relay equipment located on towers.

Two-way emergency General Mobile Radio Service (GMRS) "Yellow radios" were provided to the district by the Emergency Volunteer Corps of Nehalem Bay (EVCNB).

Emergency and Public Services
The district depends on Adventist Health for medical transport. The district's main station is to serve as a dedicated Emergency Operations Center (EOC) and there are agreements in place with the cities of Manzanita, Nehalem, and Wheeler to activate it.

Vulnerable populations
The largest potential vulnerable population are summer tourists. The median age of people living in the district's service area is in the vicinity of 57 years old. A telling fact about the vulnerabilities of residents in Manzanita is that of the 900 homes in Manzanita, 200 are equipped with elevators. Many people are part time residents, so it is not always clear when a home is used as a permanent residence or as a short-term rental. The district maintains a registry of residents who request to be included on it, but it is voluntary and not a complete listing of vulnerable residents.

Neskowin

Risk Assessment Summary

The natural hazards to which Neskowin is most vulnerable are the CSZ-related events (earthquake and tsunami), flood, and coastal erosion. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Development along the Pacific Coast has exposed a huge section of Neskowin to tsunami hazard, as large portions of the community are within the Medium-sized tsunami zone. Potential flooding from riverine and coastal sources can affect many buildings in the low-lying areas of the community. Many of the residences built adjacent to the beach are also exposed to coastal erosion risk.

Table 79. Hazard Profile: Unincorporated Community of Neskowin

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Neskowin		323	652		0		141,094,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	50	15%	73	0	2,837,000	2.0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	4	1.1%	40	0	5,780,316	4.1%
Earthquake	CSZ Mw 9.0 within the tsunami zone	19	5.8%	222	0	28,972,778	21%
Earthquake	Happy Camp Mw 6.6 Deterministic	1	0.3%	8	0	1605,000	1.1%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	199	62%	456	0	98,438,000	70%
Landslide	High and Very High Susceptibility	81	25.2%	134	0	28,177,000	20.0%
Coastal Erosion	High Hazard	43	13.3%	116	0	32,475,000	23%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

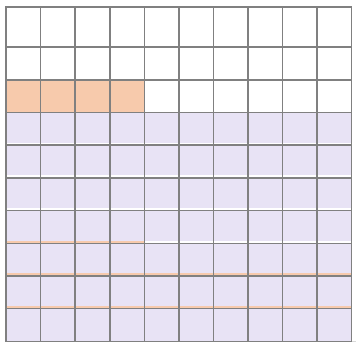
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

The CSZ event is a significant natural hazard risk to Neskowin and is a priority hazard for this community. Moderate to high liquefaction zones exist throughout the community, which increases the risk from earthquakes. These liquefaction areas also correspond closely with the areas predicted to be inundated by the most likely tsunami scenario. Since we have deemed buildings within the tsunami zone to be red tagged, these buildings have been excluded from the earthquake loss estimates. Another consideration of these areas is that liquefaction could present difficulties for evacuation from the subsequent tsunami. The combination of earthquake and tsunami will have a tremendous impact on this community.

Figure 87. Loss Ratio from CSZ Event: Unincorporated Community of Neskowin



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

Note: the unincorporated community of Neskowin has no identified critical facilities.

Developed areas within the community along Neskowin Creek, Kiwanda Creek, and the Pacific Ocean are exposed to the 100-year flood. Although there have been efforts to elevate buildings in the flood-prone areas, which has greatly reduced overall flood risk, there are still many buildings that can be impacted by flood. It is estimated that nearly half of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding. So, while the buildings themselves would not be damaged from flood, access to these buildings could be an issue.

Coastal erosion is another hazard that is a concern and can have a major impact for many within the community. The residential area along the coast and north of the Neskowin Creek mouth is likely to experience coastal erosion. The current placement of riprap at the base of these areas is reducing the rate of erosion.

While vulnerabilities to landslides do exist within Neskowin, they do so to a far smaller degree than flood, coastal erosion, and CSZ-related hazards. Monitoring for ground movement, especially during particularly wet conditions, is one way of increasing public safety from landslide.

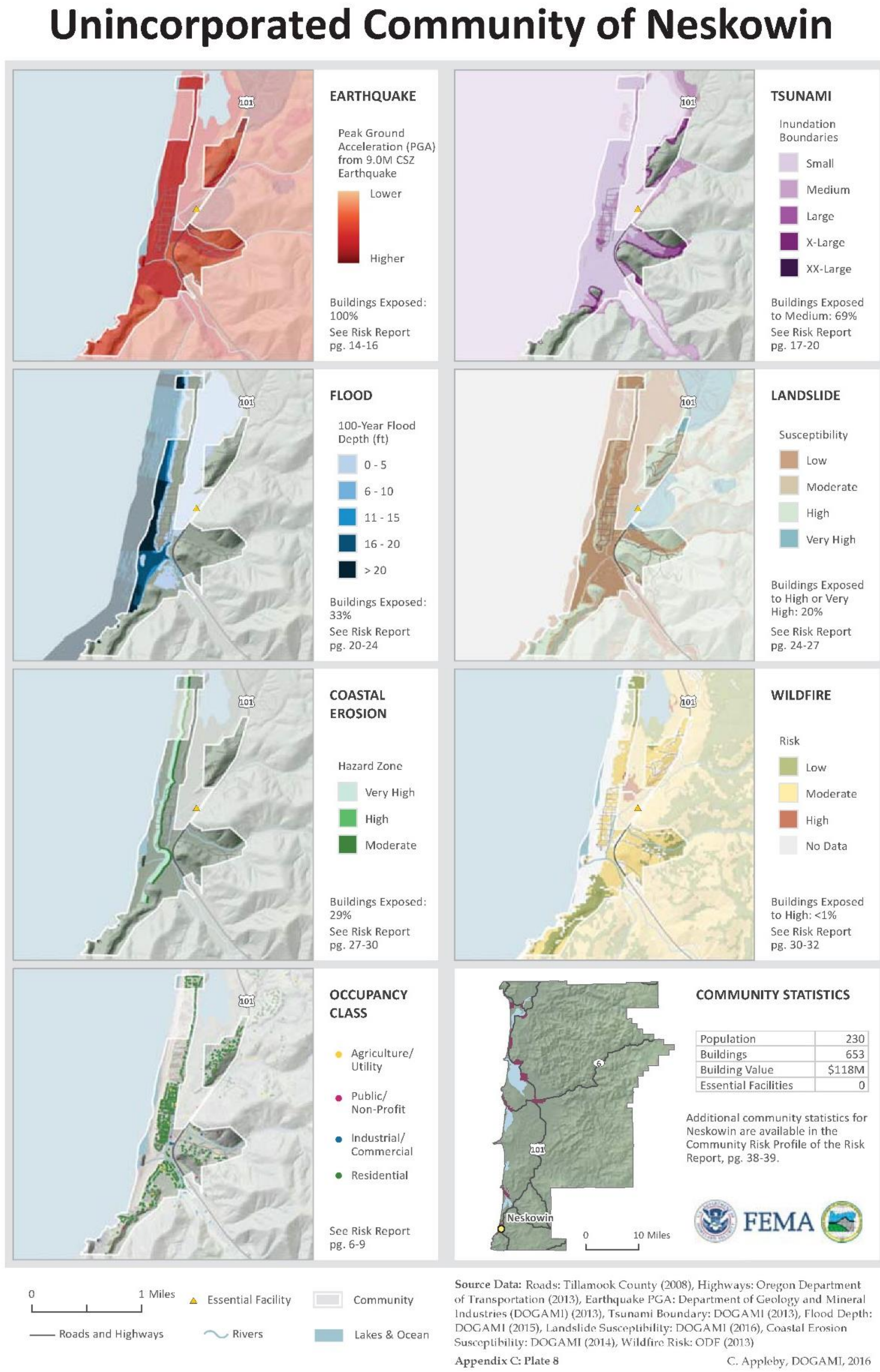
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 80. Areas of Mitigation Interest: Unincorporated Community of Neskowin

Hazard	Area	Description
Flood	Primary commercial area subject to 100-year flooding	Neskowin's primary commercial area experiences tidal flooding from the Pacific Ocean; many structures are not elevated above predicted level of 100-year flooding
Flood	Neskowin Creek, Kiwanda Creek, and the Pacific Ocean	Developed areas within Neskowin along Neskowin Creek, Kiwanda Creek and the Pacific Ocean are exposed to the 100-year flood.
Coastal Erosion	In Neskowin along the coast and north of the Neskowin Creek a large number of homes along the shoreline	The residential area in Neskowin along the coast and north of the Neskowin Creek mouth is likely to experience coastal erosion. There is a a long strip of houses all within the high coastal erosion designated zone
Earthquake	In the communities of Neskowin, Bay City, Garibaldi, and Tillamook	Older buildings that are more vulnerable to earthquake shaking
Tsunami	Neskowin and Manzanita along the open coast	Buildings and people in these areas are exposed to tsunami hazard

Figure 88. Multi-Hazard Community Map Set: Neskowin



Source: DOGAMI (2016)

Oceanside and Netarts

Risk Assessment Summary

Table 81. Hazard Profile: Unincorporated Communities of Oceanside and Netarts

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Oceanside and Netarts		1,262	1,628		2		302,588,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	11	0.9%	20	0	214,000	0.1%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	118	9.4%	651	2	71,050,629	24%
Earthquake	CSZ Mw 9.0 within the tsunami zone	3	0.2%	36	0	3,814,345	1.3%
Earthquake	Happy Camp Mw 6.6 Deterministic	132	10%	656	2	74538,000	25%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	25	2.0%	75	0	13,195,000	4.4%
Landslide	High and Very High Susceptibility	776	61.5%	1,089	2	208,069,000	68.8%
Coastal Erosion	High Hazard	31	2.5%	306	0	58,766,000	19%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

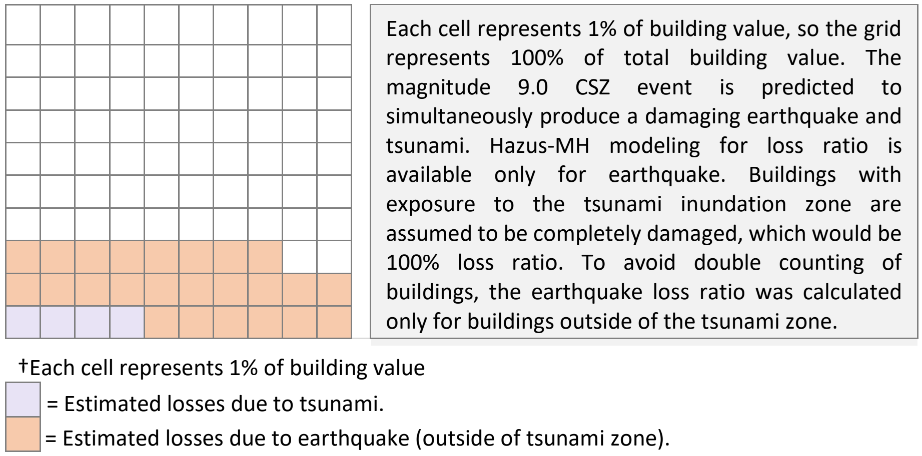
[1]Facilities with multiple buildings were consolidated into one building complex.

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

The level of risk to most natural hazards in the communities of Oceanside and Netarts is relatively low compared to the other communities of Tillamook County. The level of risk to the CSZ earthquake is still considerable, but these communities fare better than other coastal communities. Landslide hazard is the primary natural hazard threat to these communities.

While the threat of earthquake is still a major issue, damages from shaking are reduced due to a younger building stock. High liquefaction soils are found throughout Oceanside and Netarts, except for the northern hilly section of the community. There is some exposure to the Medium-sized tsunami for buildings along the estuary in Netarts.

Figure 89. Loss Ratio from CSZ Event: Unincorporated Communities of Oceanside and Netarts



The landslide hazard for Oceanside and Netarts poses the biggest risk to the community and its potential impact is a serious concern. An area deemed very high susceptibility to landslides makes up a large portion of Oceanside. The rest of the communities, for the most part, are within moderate to high susceptibility zones. There are few options for future development in low landslide hazard areas within these communities.

Table 82. Essential Facilities: Unincorporated Communities of Oceanside and Netarts

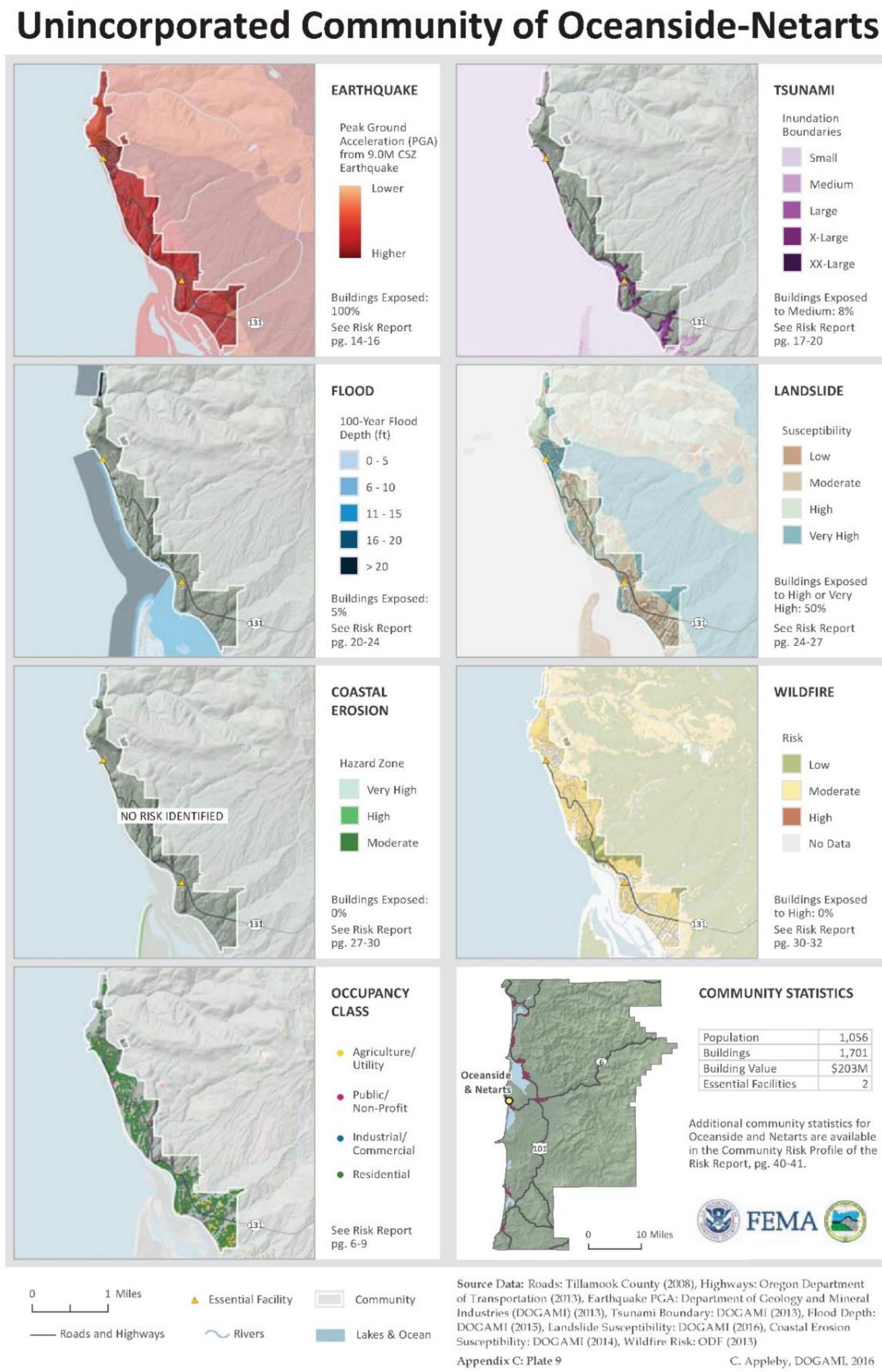
	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Netarts Oceanside RFPD Station #61		X	X		X		
Netarts Oceanside RFPD Station #62		X	X		X		

Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Hazard	Area	Description
Landslide	Oceanside and Netarts	Much of the community of Oceanside and Netarts is at high or very high risk from landslide hazard.

Figure 90. Multi-Hazard Community Map Set: Oceanside and Netarts



Source: DOGAMI (2016)

Pacific City

Risk Assessment Summary

The natural hazards to which Pacific City is most vulnerable are the CSZ-related events (earthquake and tsunami) and flood. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Development along the Nestucca River has exposed part of Pacific City to tsunami hazard, as portions of the city are within the Medium-sized tsunami zone. Another risk to the community is flood hazard, which is along the Nestucca River floodplain.

Table 83. Hazard Profile: Unincorporated Community of Pacific City

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Pacific City		1,174	1,721		4	361,114,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	325	27.7%	369	3	11,593,000	3.2%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	47	4.0%	347	1	44,443,019	12%
Earthquake	CSZ Mw 9.0 within the tsunami zone	59	5.0%	380	3	46,940,821	13.0%
Earthquake	Happy Camp Mw 6.6 Deterministic	14	1.2%	114	0	13452,000	3.7%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	492	41.9%	788	3	159,893,000	44%
Landslide	High and Very High Susceptibility	149	12.7%	184	1	34,409,000	9.5%
Coastal Erosion	High Hazard	3	0.2%	31	0	9,631,000	2.7%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

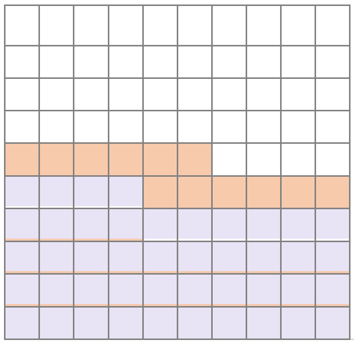
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

For the most part, the Medium-sized tsunami zone corresponds to the Nestucca floodplain within this community and is the source of the majority of damages from the CSZ event. While the threat of earthquake is still a major issue, damages from shaking are reduced due to a younger building stock. Moderate to high liquefaction is throughout Pacific City, except for the southern hilly section of the community. The combination of earthquake and tsunami will have a tremendous impact on this community.

Figure 91. Loss Ratio from CSZ-Event: Unincorporated Community of Pacific City



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value
= Estimated losses due to tsunami.
= Estimated losses due to earthquake (outside of tsunami zone).

Flooding from the Nestucca River is from a riverine source instead of tidal flooding from the Pacific Ocean. Several buildings that are within the 1% flood zone are elevated above the estimated level of flooding. The central part of the community is most affected from this flooding, while the Cape Kiwanda area is not at risk. Although there are many buildings elevated in the flood-prone areas, there are still many that can be impacted by flooding. It is estimated that nearly a quarter of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding. However, while the buildings themselves would not be damaged from flood, access to these buildings could be an issue.

To a lesser extent landslide and coastal erosion hazards pose some concern. Landslide hazards are highest in the most southern and northern sections of the community. Coastal erosion risk exists for several homes along the beach just north of the Pacific Ave. Bridge. The higher loss ratio compared to the percentage of building exposure implies that higher value homes are exposed to coastal erosion.

Table 84. Essential Facilities: Unincorporated Community of Pacific City

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Bayshore Family Medicine	X	X		X	X		
Nestucca RFPD - Pacific City Station 82	X	X		X			
Pacific City JWSA		X					
Pacific City State Airport	X	X		X			

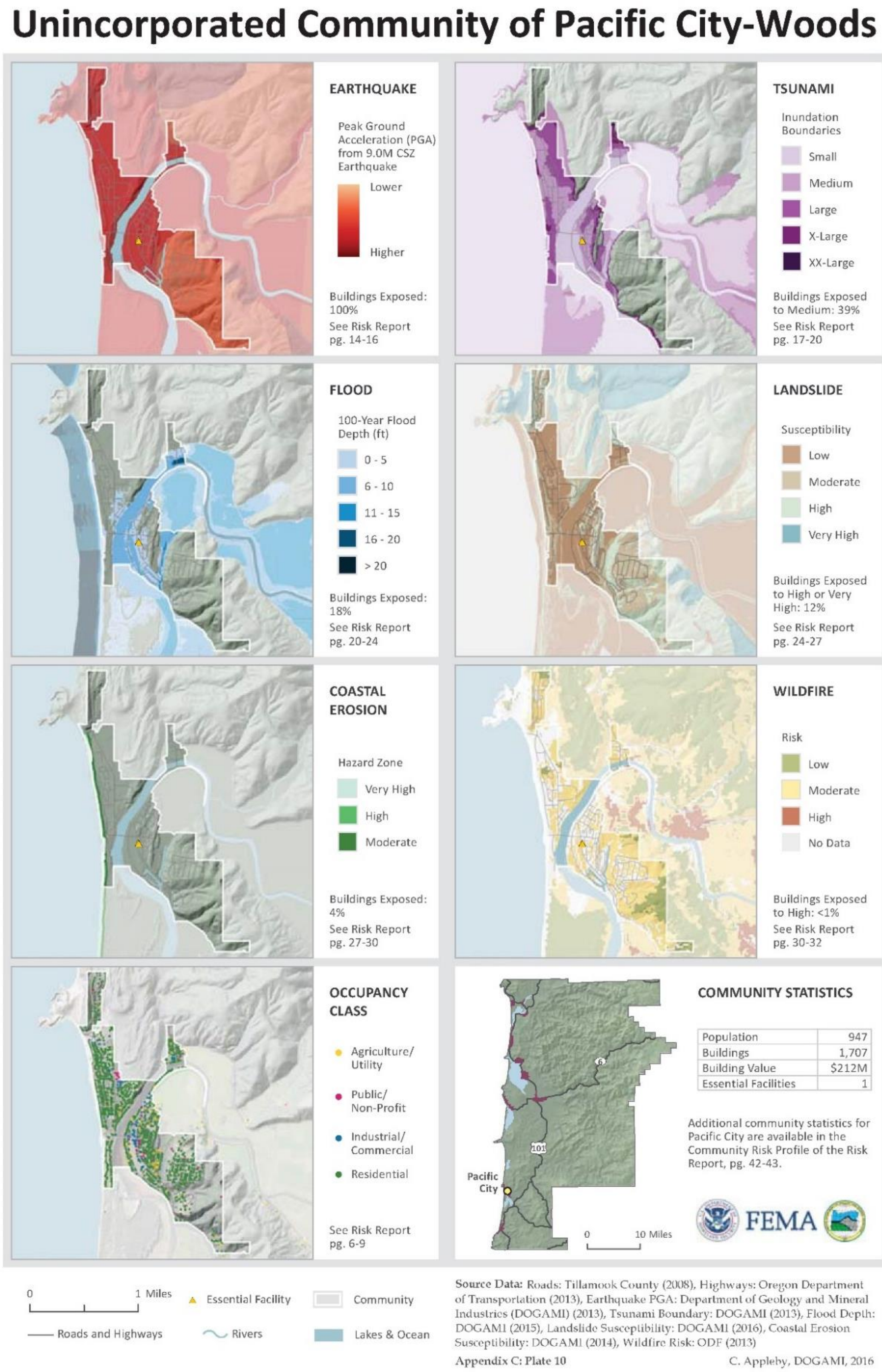
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 85. Areas of Mitigation Interest: Unincorporated Community of Pacific City

Hazard	Area	Description
Flooding	Nestucca River in Pacific City and the primary commercial area are subject to 100-year flooding	Pacific City's primary commercial area experiences flooding from the Nestucca River; many structures are not elevated above predicted level of 100-year flooding
Coastal Erosion	Pacific City	Coastal erosion risk exists in Pacific City for several homes along the beach just north of the Pacific Avenue Bridge.
Earthquake	Two (2) mobile home parks near Pacific Ave and Booten Rd.	clusters of manufactured homes estimated to have high probability to destruction due to earthquake
Tsunami	Buildings along the Nestucca River in Pacific City	Buildings and people along the Nestucca River in Pacific City are exposed to tsunami hazard,
Flood, Tsunami and Earthquake	Volunteer fire department exposed to natural hazards	Pacific City's only essential facility is at risk to flood and tsunami; this building is also in a very high liquefaction zone; during an emergency situation this building might be non-functional

Figure 92. Multi-Hazard Community Map Set: Pacific City



Source: DOGAMI (2016)

2. City of Bay City

Local Risk Assessment Review

Based on interviews with city representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the City of Bay City representatives differentiated the relative risks to the city. These differences are also indicated in the Table 3 in the Risk Assessment section in the column for Bay City.

Bay City representatives evaluated its relative vulnerability to natural hazards and made the following assessments. Bay City is more vulnerable to windstorms but less vulnerable to drought than the county as a whole is. Whereas, the city is less vulnerable to flooding, both riverine and coastal flooding, and less vulnerable to coastal erosion than the county as a whole is. In addition, the representatives believe that the city is more vulnerable to tsunami than the county as a whole is. Vulnerability to other hazards were judged to be similar in the city to the vulnerability in the county.

Risk Assessment Summary

The natural hazards to which Bay City is most vulnerable are the CSZ-related events (earthquake and tsunami) and landslide. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Development along Tillamook Bay has exposed part of Bay City to tsunami hazard, as portions of the city are within the Medium-sized tsunami zone. Another risk to the community is landslide hazard, which comprises a large portion of Bay City. The few buildings that are within the 1% flood zone are elevated above the estimated level of flooding.

Table 86. Hazard Profile: City of Bay City

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Bay City	1,424	880	3	229,175,000

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	4	0.3%	0	0	0	0.0%
*Earthquake**	CSZ Mw 9.0 Deterministic	59	4.2%	189	1	37,778,930	17%
Earthquake	CSZ Mw 9.0 within the tsunami zone	11	0.8%	22	2	4,609,103	2.0%
Earthquake	Happy Camp Mw 6.6 Deterministic	30	2.1%	95	3	18,948,000	8.3%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	85	6.0%	59	2	15,421,000	6.7%
Landslide	High and Very High Susceptibility	774	54.3%	488	0	120,575,000	52.6%
Coastal Erosion	High Hazard	0	0.0%	0	0	0	0.0%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

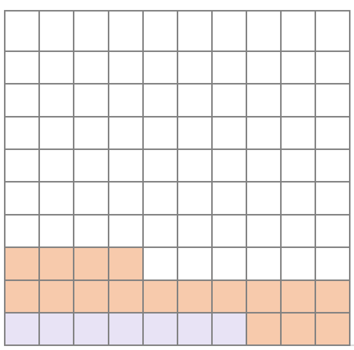
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

The CSZ earthquake hazard is a significant natural hazard risk to Bay City and is a priority hazard for this community. A large part of the community lies within an area of moderate liquefaction, which slightly increases the probability for structural damage to buildings. Also, the building inventory for Bay City is relatively older, which implies lower building design codes with regard to earthquake. The tsunami generated from the CSZ earthquake is not expected to cause as much damage, but still is a concern.

Figure 93. Loss Ratio from CSZ Event: City of Bay City



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

The landslide hazard for Bay City poses a great risk to the community and its potential impact is a serious concern. An area deemed very high susceptibility to landslides makes up approximately half of the entirety of Bay City. The hilly residential area in the northwest part of Bay City is within a very high landslide susceptibility zone. Monitoring for ground movement, especially during particularly wet conditions, is one way of increasing public safety from landslides.

Bay City staff report recent coastal erosion within Bay City although the DOGAMI analysis did not identify any that affected

While vulnerabilities to flood and wildfire do exist within Bay City, they do so to a far less degree than the CSZ event and landslide. Elevating structures and building outside of the flood zone as well as creating building buffers from forestland are examples to further reduce the risk to these hazards.

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City of Bay City.

Table 87. Essential Facilities: City of Bay City

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Bay City Fire Department		X	X				
Bay City Public Works		X	X	X			
Bay City Wastewater Treatment		X	X	X			

Transportation Infrastructure

U.S. Highway 101 is the principal transportation route out of the city. Alternative routes in the event of local obstruction of U.S. 101 may include Hobsonville Point Rd going north of the city and Doughty Road to Alderbrook Road going south. Locally Patterson Creek culvert at 7th Street experienced a failure in 2016. The $6 million project to repair it is at the 30% design stage.

Evacuation Routes and Assembly Areas

An assembly area at High Street and 4th Street and evacuation routes to higher ground in the event of a tsunami have been established by the Department of Geology and Mineral Industries in collaboration with Bay City.

Energy

The city depends on Tillamook People's Utility District for electric service. Bay City Fire has an emergency generator for power outage situations.

Water and Wastewater

The city's source of drinking water are three wells. A new well was established in 2022 to allow the city to continue to sell water to the Tillamook Cheese factory.

Communications

Spectrum provides land lines. There are no cell towers in Bay City.

Emergency and Public Services
The Tillamook County Sheriff provides law enforcement service. The Bay City Fire Department operates within the city limits. No specific location has been chosen for an Emergency Operations Center should one be needed.

Cultural and Historic Resources
The First Methodist Episcopal Church at 5695 D Street is an historic structure in Bay City.

Events, Festivals and Tourism
Bay City hosts the Pearl Festival which can bring tourists to the city.

Vulnerable populations
The proportion of residents of Bay City aged 65 is greater than the proportion of residents in that age bracket in Tillamook County as a whole.

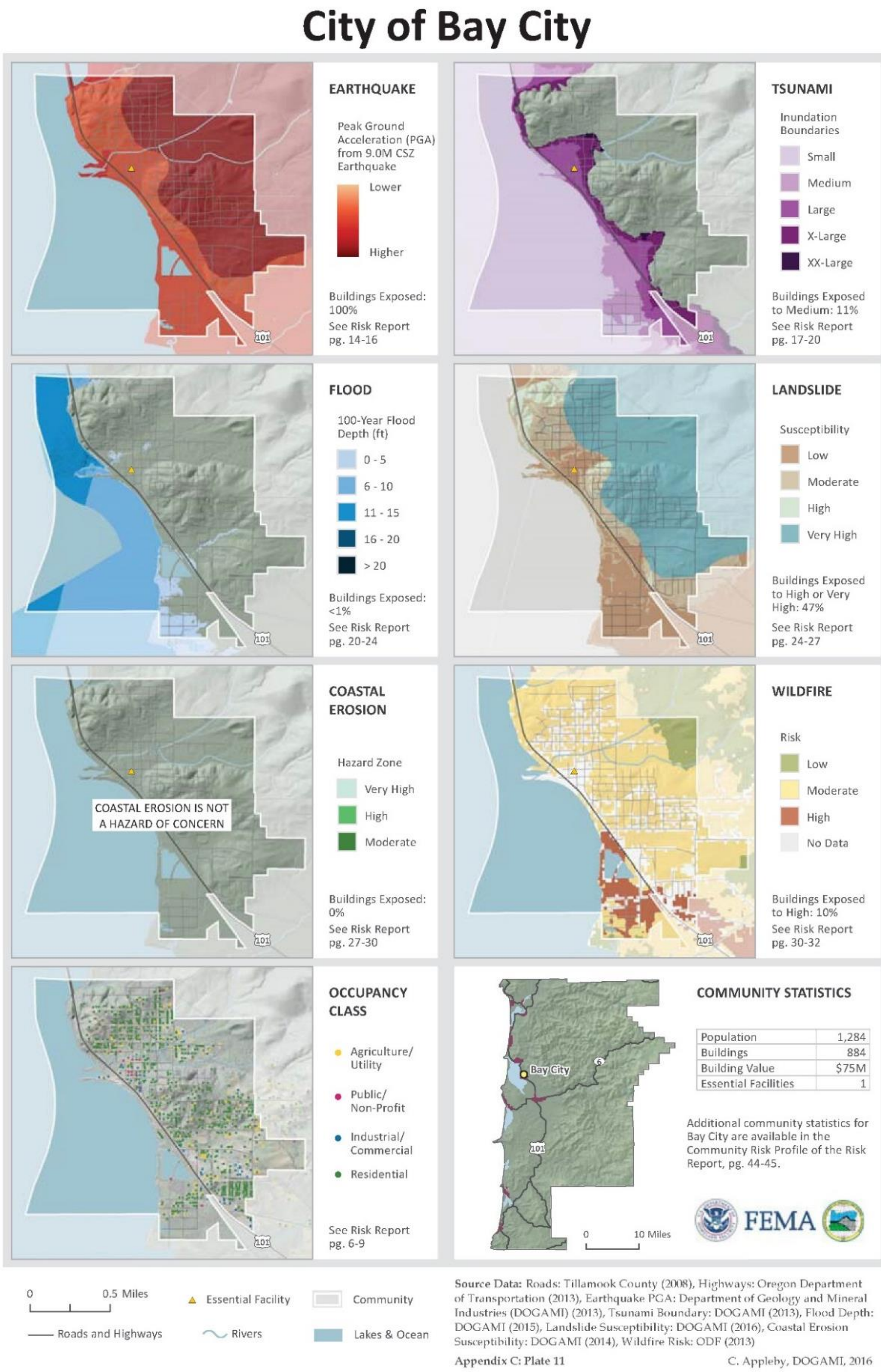
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 88. Areas of Mitigation Interest: City of Bay City

Hazard	Area	Description
Earthquake	A large percentage of the buildings in Bay City	Many buildings in the community are in high liquefaction and earthquake-induced landslide areas.
Tsunami	Areas along Tillamook Bay in Bay City and Garibaldi	Buildings and people along Tillamook Bay in Bay City and Garibaldi are exposed to tsunami hazard.
Landslide	northwest part of Bay City	The hilly residential area in the northwest part of Bay City is within a Very High landslide susceptibility zone.

Figure 94. Multi-Hazard Community Map Set: City of Bay City



Source: DOGAMI (2016)

3. City of Garibaldi

Local Risk Assessment Review

Based on interviews with City of Garibaldi and Port of Garibaldi representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the city and port representatives differentiated the relative risks to the city. These differences are also indicated in the column for Garibaldi in Table 3 within the Risk Assessment section.

High winds and Windstorms occur more frequently in Garibaldi than in the county as a whole. It can take time for the city or service providers to respond, and residents can experience a delay of service following a high wind event.

Winter flooding on the Miami River can impact access to the city because the river divides the Garibaldi Rural FD service area. This is more common when tourism is low.

Wildfire is a particular concern during high tourism season due to more frequent camp fires. The city representatives expressed concern about proper access for fire apparatus and concerns about adequate evacuation routes.

Earthquake could impact bridges and evacuation routes; Miami Foley Road would be the alternate route to US Highway 101.

Tsunami preparation is a standard focus of hazard mitigation communications for the city.

Risk Assessment Summary

The natural hazards to which Garibaldi is most vulnerable are the CSZ-related events (earthquake and tsunami) and landslides. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Developments along Tillamook Bay are exposed to tsunami hazard, as portions of the community are within the Medium-sized tsunami zone. Another substantial risk to the community is landslide hazard, since a large percentage of Garibaldi is within a very high susceptibility landslide zone.

The CSZ earthquake hazard is a significant natural hazard risk to Garibaldi and is a priority hazard for this community. A large part of the community lies within an area of moderate to high liquefaction, which increases the probability for structural damage to buildings. Also, the building inventory for Garibaldi is relatively older, which implies lower building design codes with regards to earthquakes. The tsunami generated from the CSZ earthquake is not expected to cause as much damage, but still is a concern.

Table 89. Hazard Profile: City of Garibaldi

Community Overview

Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Garibaldi	831	755	6	179,063,000

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	12	1.4%	18	1	1,070,000	0.6%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	97	11.7%	337	4	54,416,472	30%
Earthquake	CSZ Mw 9.0 within the tsunami zone	6	0.7%	55	2	13,548,751	7.6%
Earthquake	Happy Camp Mw 6.6 Deterministic	14	1.7%	87	3	17543,000	9.8%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	22	2.7%	82	2	29,140,000	16%
Landslide	High and Very High Susceptibility	758	91.2%	617	3	131,986,000	73.7%
Coastal Erosion	High Hazard	0	0.0%	0	0	0	0.0%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

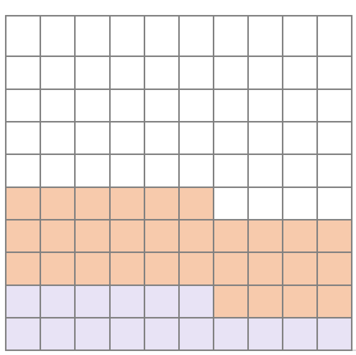
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

Figure 95. Loss Ratio from CSZ Event: City of Garibaldi



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

The landslide hazard for Garibaldi poses a great risk to the community and its potential impact is a serious concern. An area deemed very high susceptibility to landslides makes up the majority of Garibaldi. Monitoring for ground movement, especially during particularly wet conditions, is one way of increasing public safety from landslides.

While vulnerabilities to flood and wildfire do exist within Garibaldi, they do so to a far smaller degree than the CSZ event and landslide. Elevating structures and building outside of the flood zone as well as creating building buffers from forest land are examples to further reduce the risk to these hazards.

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City of Garibaldi.

Table 90. Essential Facilities: City of Garibaldi

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderat e Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
City of Garibaldi Fire Department / City Hall / Police		X			X		
Garibaldi Elementary School		X			X		
Garibaldi Public Works		X	X				
Coast Guard Station - Tillamook	X	X	X	X			
Tillamook Ambulance Quarters		X	X	X			
US Coast Guard - Admin		X			X		

Source: DOGAMI Multi-Hazard Risk Report for Tillamook County, Oregon, Williams, 2022

Transportation Infrastructure

U.S. Highway 101 is a primary route in Garibaldi and is undergoing an upgrade, currently in the design phase (2019-2023) to rebuild the road, sidewalks, and curb ramps between mileposts 54.8 and 55.9. The $10.631,500 project aims to improve sidewalk access for people with disabilities, including adding sidewalks to 3rd Street and 7th Street, manage stormwater runoff, increase safety for bicyclists and pedestrians downtown, improve traffic movement through Garibaldi, improve overall visibility, accessibility and usability of the road, improve 3rd Street and 7th Street rail crossings, and to develop transit stop locations on U.S. Highway 101.[37] The city representatives would like to consider undergrounding utilities in order to improve resilience to high wind events and other natural hazards that could damage electric infrastructure along the road. The project scope does not currently include this work. Construction is planned for 2024-2025.

[37] Oregon Department of Transportation : Project-Details : Projects : State of Oregon

Bridges
Bridges of concern to Garibaldi and the Port of Garibaldi include three on Miami Foley Road. Miami Foley over Minich Creek approximately 2.4 miles from U.S. Highway 101 and over Peterson Creek at about 4 miles from US 101; and over the Nehalem River near Foss Rd about 12 miles from U.S. 101. This bridge was repaired or rebuilt after the heavy rains, flooding, and landslides in 1996.

Evacuation Routes and Assembly Areas
The city has identified 6 assembly areas in the tsunami evacuation plan. They include the water towers at 6th and Holly St., 7th and Cypress Street, and the Ginger Building at 3rd and Ginger Avenue.

City property may exist in a suitable area for an assembly area that is out of both mapped landslide and tsunami hazard areas, but it has not been identified as such to date.

Supplies are located at the Ginger Avenue building near the water towers but may not be sufficient for more than the population in Garibaldi and although an inventory was done near the time of the interview done to gather this information, however this supply should be verified periodically.

Evacuation Routes include city roads that intersect directly with U.S. Highway 101. These are 7th Street, 3rd Street and Driftwood. There is alternative access north of the city on Miami Foley Road to Mohler and Wheeler. A likely destination if evacuating for emergency care may be Wheeler Red Cross Emergency.

Energy
The city has a diesel generator for the City Hall and for the Public Works. Electric service is provided by Tillamook People's Utility District.

Water and Wastewater
The city's drinking water source are wells located on Miami Foley Road.

Wastewater is treated at a location near the Port of Garibaldi at the Public Works facility.

The city is partnering with Business Oregon and has received funds through the American Rescue Plan Act (ARPA) to develop a wastewater resilience plan. Wastewater Facilities Master Plan is being developed to plan for remedy aging infrastructure, to identify deficiencies in the system and to plan for continued DEQ compliance. A study to identify inflow and infiltration of stormwater to the city's wastewater system and to map the city's wastewater facilities has been scoped. The city is interested in including consideration of earthquake resilience throughout the system in this plan.

Communications
There is no organized emergency communication system in place for the city's residents. Potential mitigation activity might be to promote use of emergency two-way radios ("yellow radios") to allow residents to communicate with each other if cut off from other communities due to transportation system failure. When practice with radios accompanies the provision of these devices, the community can be able to respond in an emergency.

Emergency and Public Services
- <u>Fire Department</u>: The department is interested in working to form a Fire District potentially to include Bay City, Rockaway Beach, and Garibaldi and other unincorporated communities.
- <u>County Sheriff</u> serves the city.

- Public Works Department: There are four staff that manage drinking water treatment and distribution; wastewater collection and treatment; and maintenance of the city's streets, stormwater system, and facilities, including parks.
- Medical: There are no clinics in the city.
- Emergency Operations Plan: The Fire Department recognizes the need to review the current EOP that dates from 2004. No Emergency Operations Center (EOC) or shelter facility have been identified in the city.

Possible Mitigation Action: Identify potential locations for EOC and evaluate alternatives. Determine whether building new or retrofitting an existing structure (Fire, EMS, Police, Coast Guard barracks, Port facility) would be the best alternative. USDA Rural Development Community Facilities Grant or the Ford Family Foundation could be sources of funds. Estimated cost is $12-15 million.

Cultural and Historic Resources

Coast Guard station boat house and some historic homes are being offered to the city. The mill chimney has sentimental value and historic significance. The contents of the museum are historic resources for the city.

Events, Festivals and Tourism

Garibaldi Days occur over three days in July and the Garibaldi Crab Races and festival during two days in March and both bring visitors to the city.

Vulnerable populations

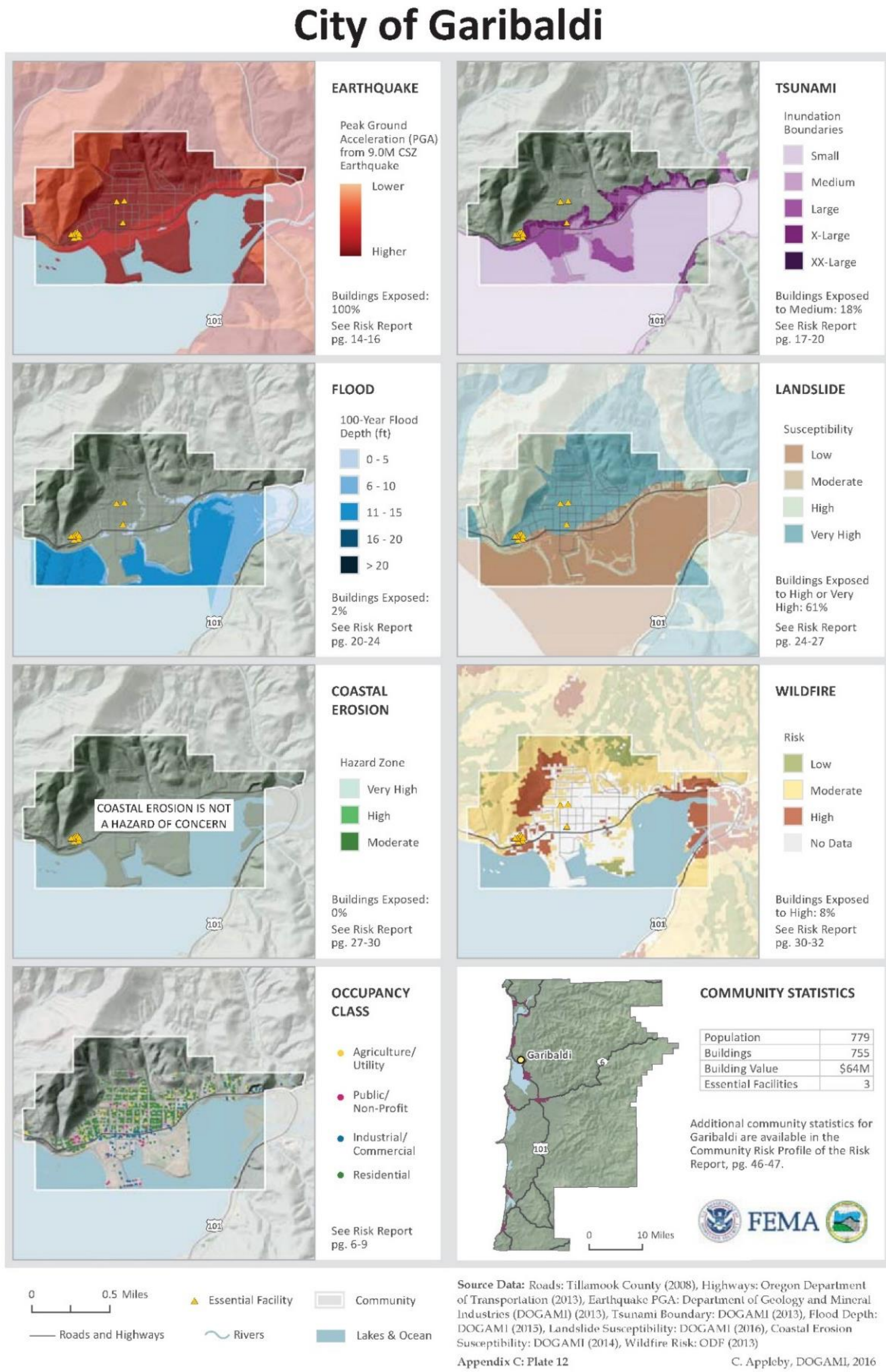
In the City of Garibaldi an older population some living on low or fixed incomes. There are several RV Parks in the city.

Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Hazard	Area	Description
Earthquake	In the communities of Neskowin, Bay City, Garibaldi, and Tillamook	Older buildings are more vulnerable to earthquake shaking.
Tsunami	Areas along Tillamook Bay in Bay City and Garibaldi	Buildings and people along Tillamook Bay in Bay City and Garibaldi are exposed to tsunami hazard.
Landslide	Garibaldi, Nehalem, and Wheeler	The majority of Garibaldi, Nehalem, and Wheeler are at High risk from landslide hazard.

Figure 96. Multi-Hazard Community Map Set: City of Garibaldi



Source: DOGAMI (2016)

4. City of Manzanita

Local Risk Assessment Review

Based on interviews with city representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the City of Manzanita representatives differentiated the relative risks to the city. These differences are also indicated in the column for Manzanita in Table 3 within the Risk Assessment section.

Manzanita representatives evaluated its relative vulnerability to natural hazards and made the following assessments. Manzanita experiences Windstorms to a greater extent than the county as a whole. There was a damaging tornado that occurred in 2017 which damaged 200-300 trees in the city and also damaged or destroyed several buildings on Main Street. Landslide is a hazard to U.S. Highway 101 and there is heightened concern about earthquake impacts to the City of Manzanita due to the topography of the city. The city is more at risk of tsunami than the county as a whole due to the city's location on the coast. The city is at risk of flooding, but to a lesser extent than the county as a whole. The city is at lower risk of damage due to Drought because the city is served by deep wells rather than from surface water sources which may be reduced during a drought. Coastal Erosion is less of a concern in Manzanita than in other coastal communities because there is more accretion occurring than erosion, particularly in the northern parts of the city near the state park. Wildfire as well is of less concern in Manzanita than it is in the county as a whole due to the high vapor pressure experienced near the ocean.

Risk Assessment Summary

Table 91. Hazard Profile: City of Manzanita

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Manzanita	609	1,517	4	274,658,000

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	0	0.1%	1	0	10,000	0.0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	67	11.1%	567	4	64,331,501	23.4%
Earthquake	CSZ Mw 9.0 within the tsunami zone	14	2.3%	168	0	18,508,390	6.7%
Earthquake	Happy Camp Mw 6.6 Deterministic	4	0.7%	36	0	4826,000	1.8%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	95	15.7%	346	0	60,365,000	22.0%
Landslide	High and Very High Susceptibility	95	15.5%	204	1	35,716,000	13.0%
Coastal Erosion	High Hazard	11	1.8%	69	0	14,699,000	5.4%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

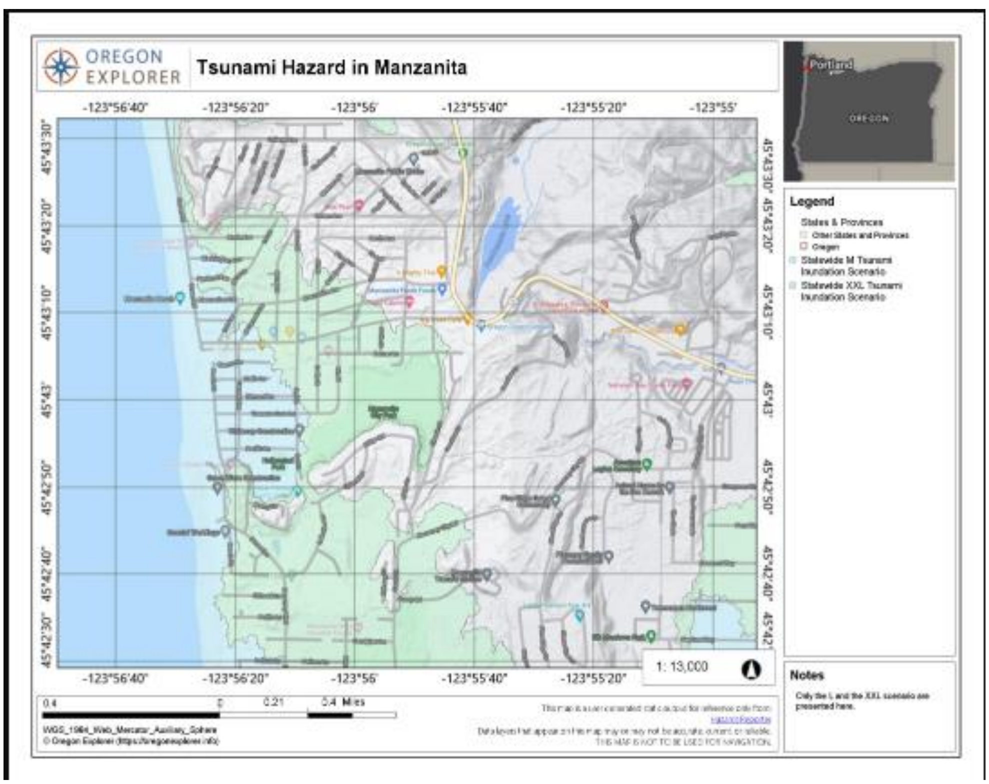
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

The natural hazards to which Manzanita is most vulnerable are the CSZ-related events (earthquake and tsunami). As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Developments along the coast are exposed to tsunami hazard, as large portions of the community are within the Medium-sized tsunami zone.

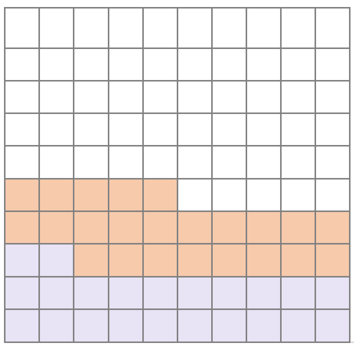
Figure 97. Tsunami Hazard from L and XXL tsunami scenarios in Manzanita



Source: Oregon Explorer Home | oregonexplorer | Oregon State University

The CSZ event is a significant natural hazard risk to Manzanita and is a priority hazard for this community. High liquefaction zones exist throughout the community, which increase the risk from earthquake. Another consideration of these areas is that liquefaction could present difficulties for evacuation from the subsequent tsunami. The coastal and low-lying areas of Manzanita are predicted to be inundated by the most likely tsunami scenario. Since DOGAMI geohazard analysts deemed buildings within the tsunami zone to be red-tagged, these buildings have been excluded from the earthquake loss estimates. The combination of earthquake and tsunami will have a tremendous impact to this community.

Figure 98. Loss Ratio from CSZ Event: City of Manzanita



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

To a lesser extent landslide and coastal erosion hazards pose some additional concerns. Landslide hazard risk is highest for several buildings in the northern section of the community near Highway 101. Coastal erosion risk exists for several homes along the beach in the community. It is unclear if any steps have been taken to limit the amount of erosion occurring. The presence of vegetation cover in many places can reduce the rate of erosion.

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City Manzanita.

Table 92. Essential Facilities: City of Manzanita

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Manzanita City Hall/Fire/Police Department		X					
Manzanita City Hall		X					

Manzanita Public Safety		X					
Manzanita Public Works		X			X		

Transportation Infrastructure

U.S. Highway 101 is the primary route to evacuation Manzanita either going north or going east and then south through Nehalem. The Cascadia Island Mapping performed by the Office of Emergency Management shows Manzanita separated from Nehalem and Wheeler.

Figure 99. Cascadia Island Mapping for Manzanita, Nehalem and Wheeler

Source: [Oregon Department of Emergency Management : Cascadia Island Mapping : Hazards and Preparedness : State of Oregon]; [Plate06_Manzanita_Nehalem_Wheeler.pdf (oregon.gov)]

Evacuation Routes and Assembly Areas

The Tsunami Inundation Zone Map for Manzanita shows four assembly areas and shelter facilities at the Calvary Bible Church where emergency supplies are located. The emergency Volunteer Corps of Nehalem Bay (EVCNB) supports emergency preparedness activities in Manzanita.

Energy

Loss of power could be a substantial problem in the city.

Water and Wastewater
The city's water supply comes from deep wells. Water tanks hold the city's supply of potable water; the twin water tanks serving the upper portion of the city need to be reconstructed in order not to be vulnerable to earthquake hazard. A Water System Resilience Study was conducted for the city. Subsequently the city applied for and was awarded an HMGP grant to develop a 10% engineering plan for the twin tanks. The city is expecting to apply for HMGP grant funds to bring engineering to 30%; the final phase would be to finish the engineering and to construct the replacement tanks using BRIC grant funding.

The Nehalem Bay Wastewater Agency manages Manzanita's wastewater. Pump stations move the effluent out of the city to the treatment facility in Nehalem.

Communications

Emergency and Public Services
The city now has an Emergency Manager on staff and has completed an incident command training in 2022. The emergency management operation is in a mobile unit and is intended to be located at the new City Hall location in the Underhill Plaza outside the tsunami inundation zone.

Cultural and Historic Resources

Events, Festivals and Tourism

Vulnerable populations

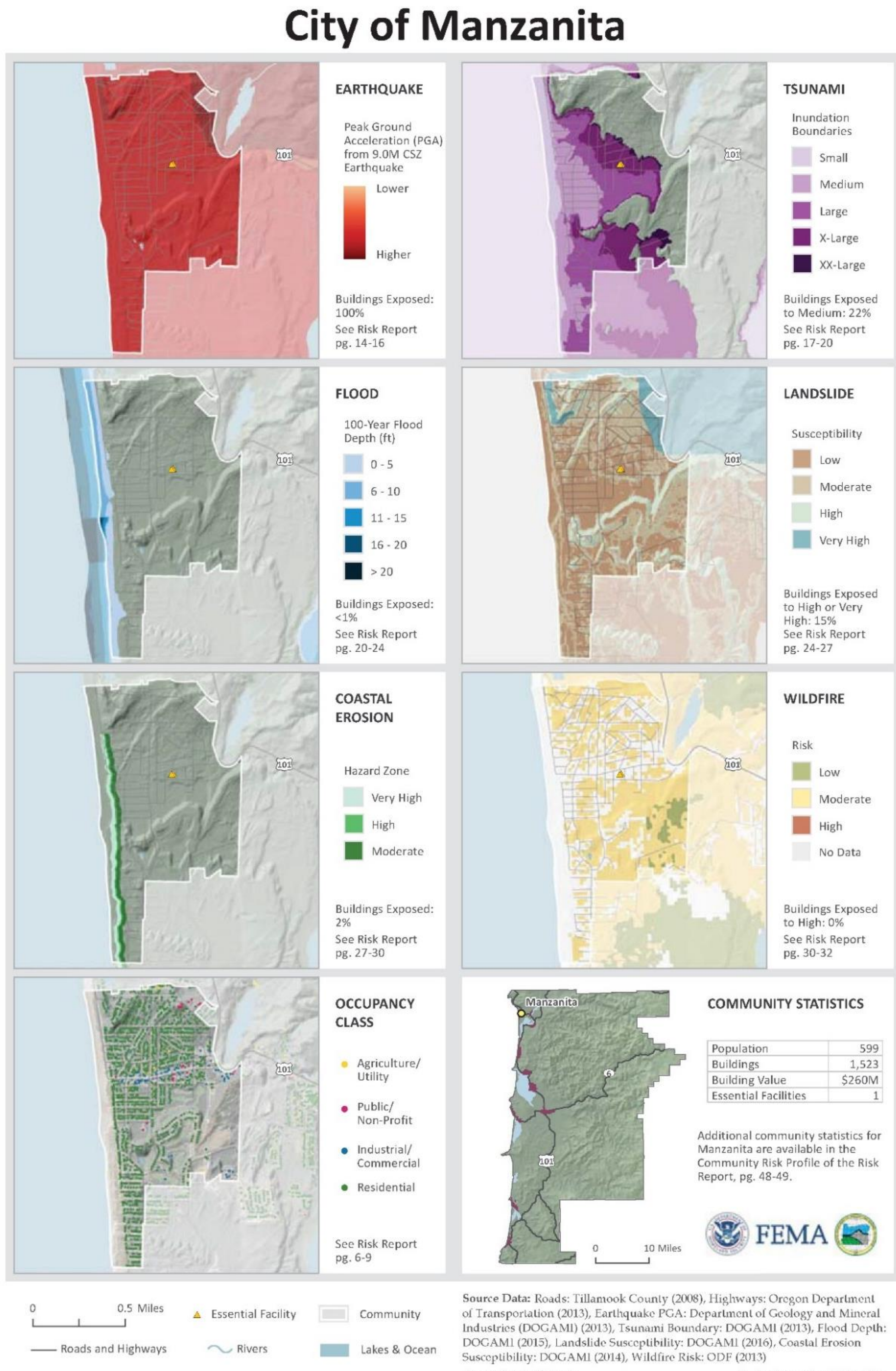
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Hazard	Area	Description
Tsunami	Neskowin and Manzanita along the open coast	Buildings and people in these areas are exposed to tsunami hazard

No particular locations were identified as areas of mitigation interest in the City of Manzanita.

Figure 100. Multi-Hazard Community Map Set: City of Manzanita



Source: DOGAMI (2016)

5. City of Nehalem

Local Risk Assessment Review

Based on interviews with city representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the City of Nehalem representatives differentiated the relative risks to the city. These differences are also indicated in the column for Nehalem in Table 3 within the Risk Assessment section.

Nehalem representatives evaluated its relative vulnerability to natural hazards and made the following assessments. Nehalem is subject to chronic flooding to a greater extent than the county as a whole, but may experience coastal erosion to a lesser extent than many of the communities on the coast. Poor Air Quality was also judged to be a lower risk to the people of Nehalem.

Risk Assessment Summary

The natural hazards to which Nehalem is most vulnerable are the CSZ-related events (earthquake and tsunami), flood, and landslide. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Part of Nehalem is exposed to tsunami hazard, as the low-lying business area of this community is within the Medium-sized tsunami zone. Potential flooding from riverine sources can affect many buildings along the riverfront. Another substantial risk to the community is landslide hazard, since a large percentage of Nehalem is within a very high susceptibility landslide zone with a significant number of mapped landslides in and near the city.

Table 93. Hazard Profile: City of Nehalem

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Nehalem	271	234	6	54,360,000

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	46	16.9%	29	0	806,000	1.5%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	10	3.5%	39	3	8,198,791	15.1%
Earthquake	CSZ Mw 9.0 within the tsunami zone	4	1.4%	20	3	4,033,200	7.4%
Earthquake	Happy Camp Mw 6.6 Deterministic	1	0.4%	6	0	1,135,000	2.1%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	52	19.2%	57	3	15,629,000	28.8%
Landslide	High and Very High Susceptibility	271	99.8%	233	6	54,106,000	99.5%
Coastal Erosion	High Hazard	0	0.0%	0	0	0	0.0%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

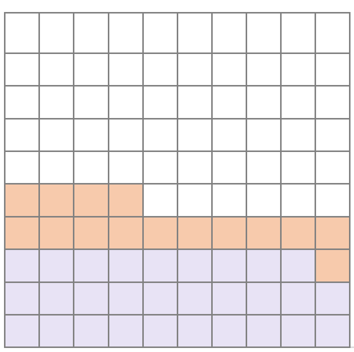
Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**17.

[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).

The CSZ event is a significant natural hazard risk to Nehalem and is a priority hazard for this community. Moderate liquefaction zones and areas at risk of earthquake-induced landslide exist throughout the community, which increases the risk from earthquake. Also, the building inventory for Nehalem is relatively older, which implies lower building design codes with regard to earthquakes. Low-lying areas of Nehalem are predicted to be inundated by the most likely tsunami scenario. Since DOGAMI geohazard analysists have deemed buildings within the tsunami zone to be red-tagged, these buildings have been excluded from the earthquake loss estimates. The combination of earthquake and tsunami will have a tremendous impact to this community and may potentially trigger landslides to which the community is particularly at risk.

Figure 101. Loss Ratio from CSZ Event: City of Nehalem



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

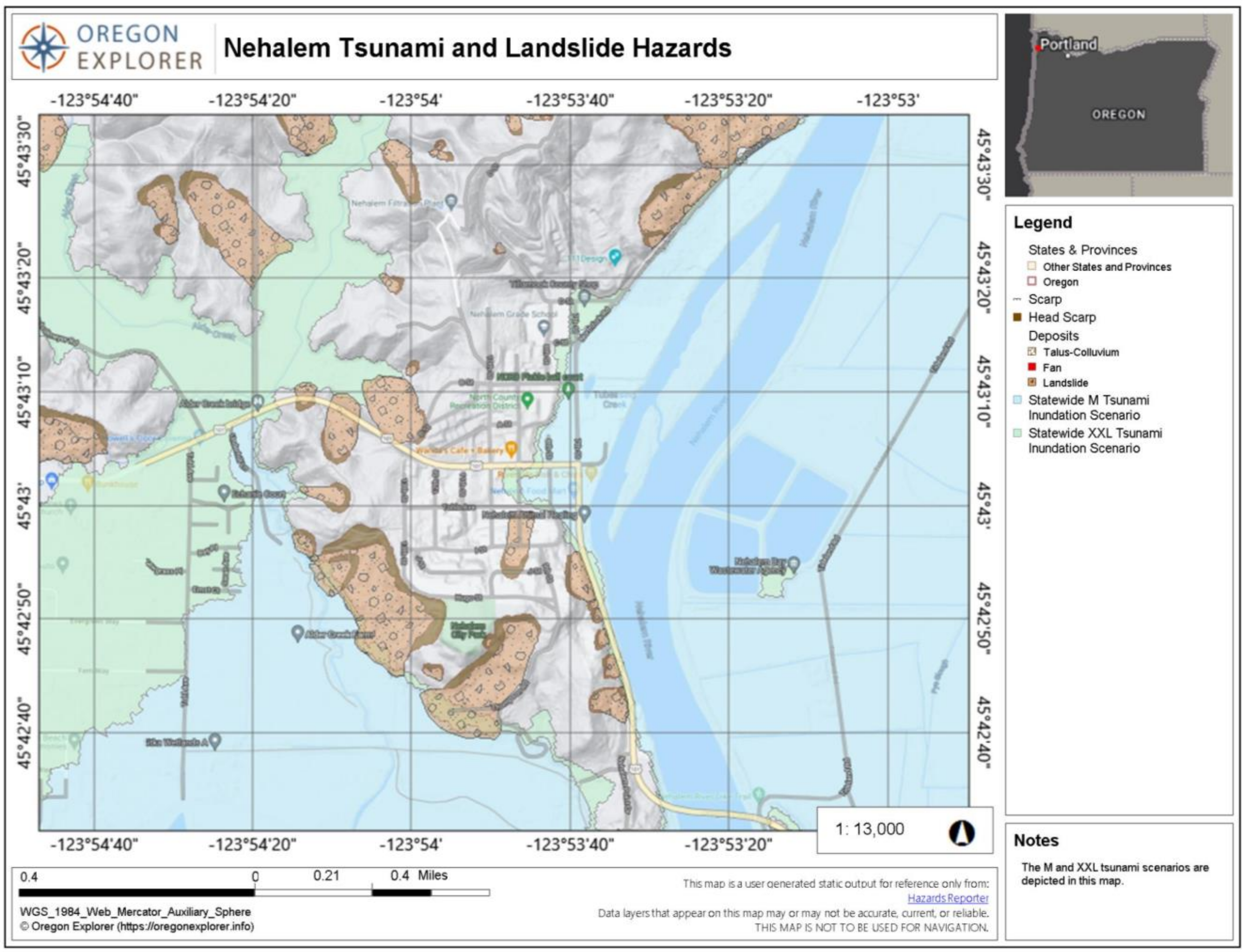
= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

Flooding continues to be a principal area of concern due to chronic flooding in the vicinity of U.S. Highway 101, H Street, and 7th Street a signalized intersection at the center of town. Many buildings in the low-lying business area of Nehalem are particularly vulnerable to flooding. This area, along the river bank, is subject to a 100-year flood due to the close proximity of the Nehalem River. Although there have been efforts to elevate buildings in the flood-prone areas particularly following the widespread flooding in 1996, which has greatly reduced overall flood risk, there are still many buildings that can be impacted by flood. This includes important local businesses that form part of the economic core of Nehalem. It is estimated that nearly half of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding. Of the 44 buildings exposed to the risk of flood damage, 15 of them are predicted to avoid damage. So, while the buildings themselves would not be damaged from flood, access to these buildings could be an issue.

The landslide hazard for Nehalem poses a great risk to the community and its potential impact is a serious concern. Landslides have occurred that blocked access along U.S. Highway 101 notably in 1983. A landslide zone, which is identified as very highly susceptible to landslides, has been designated for much of the Nehalem River and surrounding hills. An area deemed very high susceptibility to landslides makes up the majority of the community of Nehalem.

Figure 102. Nehalem Tsunami and Landslide Hazards



Source: Oregon Explorer Hazards Reporter, [Hazards Reporter (oregonexplorer.info)]

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City Nehalem.

Table 94. Essential Facilities: City of Nehalem

	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderat e Risk	Coastal Erosion Moderate Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
County Public Works - North		X			X		
Nehalem City Hall		X		X	X		
Nehalem Elementary School		X			X		
Nehalem Public Works	X	X		X	X		
Nehalem Wastewater Treatment	X	X		X	X		
North County Recreation Center		X			X		

The building currently utilized by the Public Works staff had served as the fire department. It is constructed of cinder block and is inadequate for protecting the functions of Public Works during a number of natural hazard events as the table above identifies. The City of Nehalem is working to identify a new location for a public works facility which might be constructed as a two-story building to provide a vertical evacuation structure to mitigate the impacts of a tsunami.

Transportation Infrastructure

U.S. Highway 101 is the principal route through Nehalem. Northfork Road runs north from 7th Street along the Nehalem River to McDonald Dike Road which connects to the east with State Highway 53 (Necanicum Highway). However, this route is noted by the Nehalem Bay Fire and Rescue District as an unreliable alternative route.

Bridges

The Oregon Department of Transportation identifies the U.S. Highway 101 bridge over the Nehalem River which was constructed in 1984 as being in Fair Condition and as Vulnerable to damage from seismic activity associated with a CSZ magnitude 8.0 event.[38]

Evacuation Routes and Assembly Areas

North County Recreation District facility is equipped to serve as a shelter. The Emergency Volunteer Corps of Nehalem Bay has stocked it with food, cots, and water so that it can be activated as a community shelter or Red Cross shelter with a daytime capacity of 185 and 92 overnight.

---

[38] ODOT Bridge Condition Report, 2022; Oregon Department of Transportation : Bridge Condition Report : Bridge : State of Oregon

Energy
Tillamook PUD is the provider of electric service to the City of Nehalem.

Water and Wastewater
The Nehalem Water Filtration Plant is located in the unincorporated area north of the city on a hill at top of 10th street. The construction of the plant required mitigation of landslide risk by stabilizing the hillside as the settling ponds sit on a ridge.

Communications

Emergency and Public Services
The city is interested in identifying a location for an Emergency Operations Center (EOC). The City Hall would be the first location for such an emergency service facility and the city is considering the use of a mobile facility that could serve this purpose potentially located at the Nehalem City Park. Another alternative might be a new Public Works Building with an upper story that could serve as an EOC, an alternative for which the city is trying to identify funding.

Cultural and Historic Resources

Events, Festivals and Tourism

Vulnerable populations

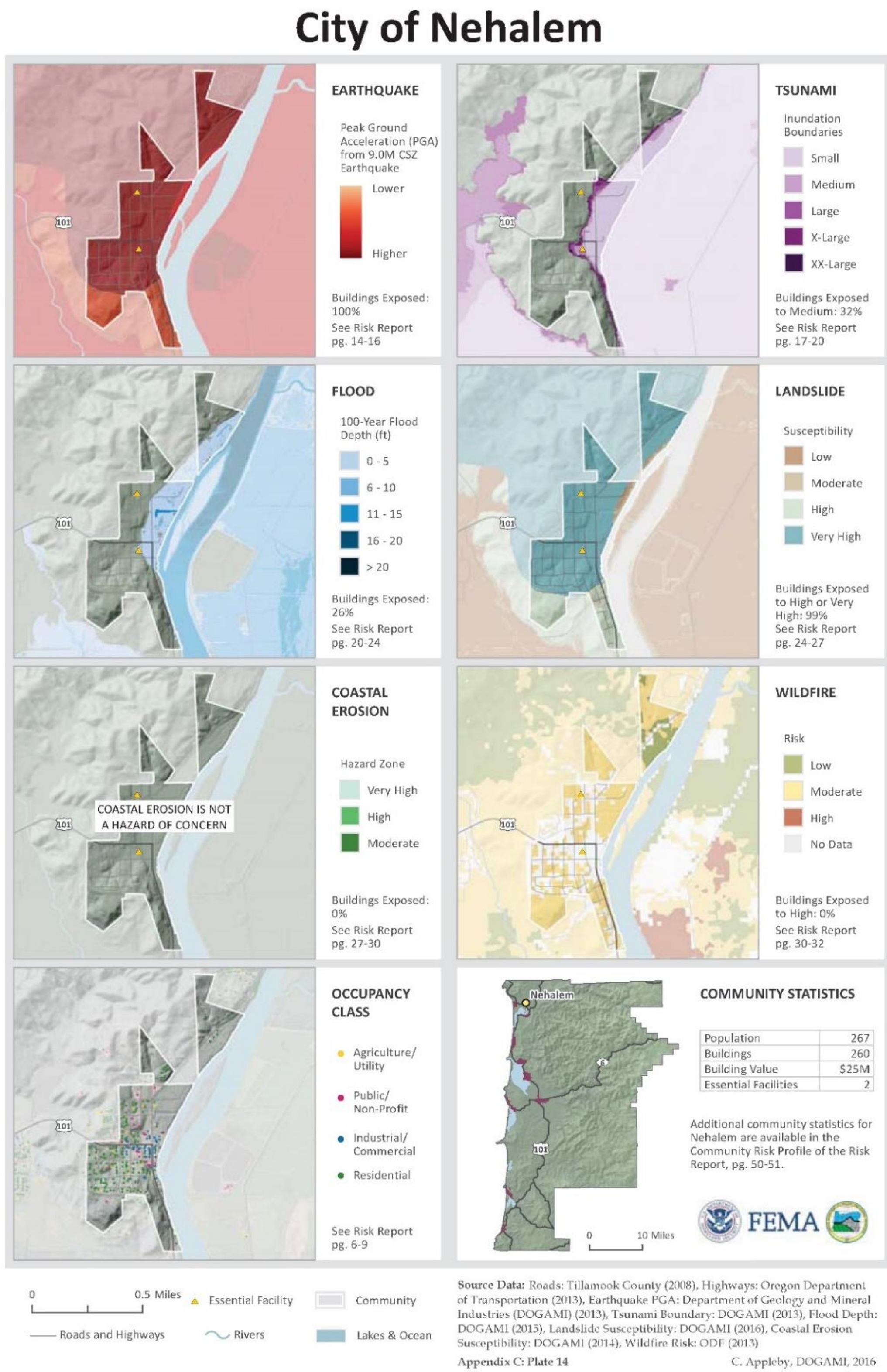
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 95. Areas of Mitigation Interest: City of Nehalem

Hazard	Area	Description
Flood	Many buildings in the low-lying business area of Nehalem adjacent to Nehalem River subject to 100-year flooding	Nehalem's primary commercial area experiences flooding from the Nehalem River; many structures are not elevated above predicted level of 100-year flooding. Past mitigation actions, such as elevating buildings, have alleviated some problems.
Earthquake	Many buildings located adjacent to Nehalem River, just upstream of the City of Nehalem	Clusters of buildings along the banks of the Nehalem River are within a high liquefaction zone and have high probability to destruction due to earthquake
Tsunami	Wheeler and Nehalem along the Nehalem River	Buildings and people in Wheeler and Nehalem along the Nehalem River are exposed to tsunami hazard.
Landslide	Garibaldi, Nehalem, and Wheeler	The majority of Garibaldi, Nehalem, and Wheeler are at High risk from landslide hazard.

Figure 103. Multi-Hazard Community Map Set: City of Nehalem



Source: DOGAMI (2016)

6. City of Rockaway Beach

Local Risk Assessment Review

Based on interviews with city representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted as with the Tillamook County NHMP Steering Committee, the City of Rockaway Beach representatives differentiated the relative risks to the city. These differences are also indicated in the column for Nehalem in Table 3 within the Risk Assessment section.

Rockaway Beach representatives evaluated its relative vulnerability to natural hazards and made the following assessments. The evaluation of City of Rockaway Beach staff was that the city is more at risk of damage from tsunami and from coastal erosion than the county as a whole. Whereas the city is at a lower risk of Extreme Heat, Wildfire, Poor Air Quality, and Drought than the county as a whole.

Risk Assessment Summary

Table 96. Hazard Profile: City of Rockaway Beach

Community Overview							
Community Name		Population	Number of Buildings	Critical Facilities[1]			**Total Building Value ($)**
Rockaway Beach		1,465	2,095		5		**454,733,000**
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	**Loss Ratio**
Flood[2]	1% Annual Chance	163	11.1%	154	0	2,546,000	**0.6%**
*Earthquake**	*CSZ Mw 9.0 Deterministic*	43	2.9%	225	0	30,077,203	**6.6%**
Earthquake	CSZ Mw 9.0 within the tsunami zone	147	10.1%	765	5	109,309,276	**24.0%**
Earthquake	Happy Camp Mw 6.6 Deterministic	23	1.6%	154	0	21934,000	**4.8%**
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Res	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	**Percent of Exposure**

			idents				
Tsunami	*CSZ Mw 9.0 – Medium*	822	56.2%	1,373	5	299,239,000	**65.8%**
Landslide	High and Very High Susceptibility	696	47.5%	803	1	173,174,000	**38.1%**
Coastal Erosion	High Hazard	48	3.3%	192	0	58,196,000	**13%**
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in Figure A-1.

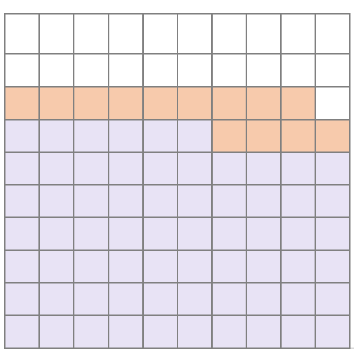
[1]Facilities with multiple buildings were consolidated into one building complex.

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

The natural hazards to which Rockaway Beach is most vulnerable are the CSZ-related events (earthquake and tsunami), flood, landslide, and coastal erosion. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. A significant portion of the community is exposed to the Medium-sized tsunami zone. Potential flooding from riverine and coastal sources can affect many buildings along the coast and in the flood-prone areas of local streams. A large number of the residences built adjacent to the beach are also exposed to coastal erosion risk.

The CSZ event is a significant natural hazard risk to Rockaway Beach and is a priority hazard for this community. High liquefaction zones exist throughout the community, which increases the risk from earthquakes. Another consideration of these areas is that liquefaction could present difficulties for evacuation from the subsequent tsunami. The coastal and low-lying areas of Rockaway Beach are predicted to be inundated by the most likely tsunami scenario. The combination of earthquake and tsunami will have a tremendous impact on this community.

Figure 104. Loss Ratio from CSZ Event: City of Rockaway Beach



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

On a more frequent basis, many buildings in the low-lying areas of Rockaway Beach along the Pacific Ocean, Rock Creek, and other minor creeks are exposed to the 100-year flood. Although there are many elevated buildings in the flood-prone areas, which will greatly reduce overall flood risk, there are still many buildings that can be impacted by flood. It is estimated that nearly half of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding. So, while the buildings themselves would not be damaged from flood, access to these buildings could still be an issue.

Coastal erosion is another hazard that is a major concern and can have a significant impact for many within the community. The entire mostly residential area along the coast is likely to experience coastal erosion. During times of high tide occurring along with powerful storms, the rate of erosion can greatly increase. The current placement of riprap at the base of some areas is helping to reduce the rate of erosion, however, the right to place shoreline armoring is restricted by Goal 18 of the Oregon Land Use Planning Goals.

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City of Rockaway Beach.

Table 97. Essential Facilities: City of Rockaway Beach

Critical Facilities by Community	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
	Exposed	>50% Prob.	>50% Prob.	Exposed	Exposed	Exposed	Exposed
Neah-Kah-Nie School District		X		X	X		
Rockaway Beach City Hall		X		X			
Rockaway Beach Fire Dept.		X		X			
Rockaway Beach Public Works		X		X			
Rockaway Beach Water Treatment Plant		X		X			

Transportation Infrastructure

U.S. Highway 101 is the principal route for evacuation of the city. There may be logging roads that can access Miami Foley Road which then intersects with State Highway 53 (Necanicum Highway) near Mohler, if U.S. 101 is blocked.

Evacuation Routes and Assembly Areas

The geography of the city, older infrastructure, and human settlement patterns in Rockaway Beach have created challenges for timely evacuation from a local tsunami. Coastal lakes, non-retrofitted bridges, manufactured homes, residents over 65 years of age, and visitors who tend to stay close to the ocean all create evacuation concerns for the city.

The tsunami evacuation mapping project "Beat the Wave" developed by the Department of Geology and Mineral Industries shows five assembly areas for Rockaway Beach, most of which are more than a quarter mile away from the beach. Evacuation routes on this map indicate that jogging may be necessary to reach safety in time.

Energy

Tillamook PUD is the provider of electric service to the City of Rockaway Beach.

Water and Wastewater

City drinking water is sourced from Jetty Creek and three wells. Water from two of these wells is treated before distribution.

Wastewater treatment requires multiple pumps due to the flat terrain in the city. The pipes are concrete and subject to damage from earthquakes.

Communications

North of Rockaway Beach at Nedonna Beach is the location for a fiber optic cable landing installed by WCI in 1999 with a cooperative agreement established with the area's fishing community.

Emergency and Public Services

The Tillamook County Sheriff serves the city's public safety needs. The city Fire Department is a mix of paid and volunteer staff. The Fire Chief serves as the city's Emergency Manager.

Success Story: UGB expansion for relocation of critical facilities outside the tsunami inundation zone.

All of the critical facilities in Rockaway Beach are located within the tsunami inundation zone. Ninety percent of the buildings within the city as well as most of the land within the UGB is located within the tsunami inundation zone.

The City of Rockaway Beach is addressing its vulnerability to tsunami and increasing preparedness and resilience through land use planning measures, with the goal of promoting life safety and successful evacuation in the event of a CSZ earthquake and tsunami. The city has developed two instruments to accomplish this objective. The Tsunami Hazard Overlay Zone adopted in 2019 prohibits the development of new critical facilities in the tsunami inundation zones and a Tsunami Evacuation Facilities Improvement Plan (TEFIP) also called the Master Plan for High Grounds developed the basis for purchase of 10.15 acres to be annexed into the city's Urban Growth Boundary and intended to house relocated city facilities outside the tsunami inundation zones.

The city has completed the development of the code and comprehensive plan amendments to create a Public Facilities Zone, completed a UGB expansion and changed the zoning designation of the target property to the newly recreated Public Facilities Zone. The city is now in the process of completing a land division to prepare for purchase of property and annexation into the city while developing a master plan for the development of the property. The Master Plan for High Grounds will help secure grants and other types of funding for emergency preparedness and resilience, detail a site design that minimizes environmental and neighborhood impacts, establishes a timeline for relocation. The intended relocation process will be a long-term effort. Some facilities have reached the end of their lifespan and will need to be moved within the next few years. Others have many years left in their functional life and will be moved over a longer term. Establishment of emergency equipment and supplies is a short-term priority for the city.

Cultural and Historic Resources

Events, Festivals and Tourism

Rockaway experiences high numbers of visitors in the spring and summer months. During the fourth of July weekend this number can reach over 10,000 visitors in the city.

Vulnerable populations

Many of the full-time residents are older and may have one or more disabilities. The schools located within the city limits may be more vulnerable during a natural hazared event.. Also, tourists may be unfamiliar with the hazards that can occur in Rockaway Beach or Tillamook County which could also be a type of vulnerable population.

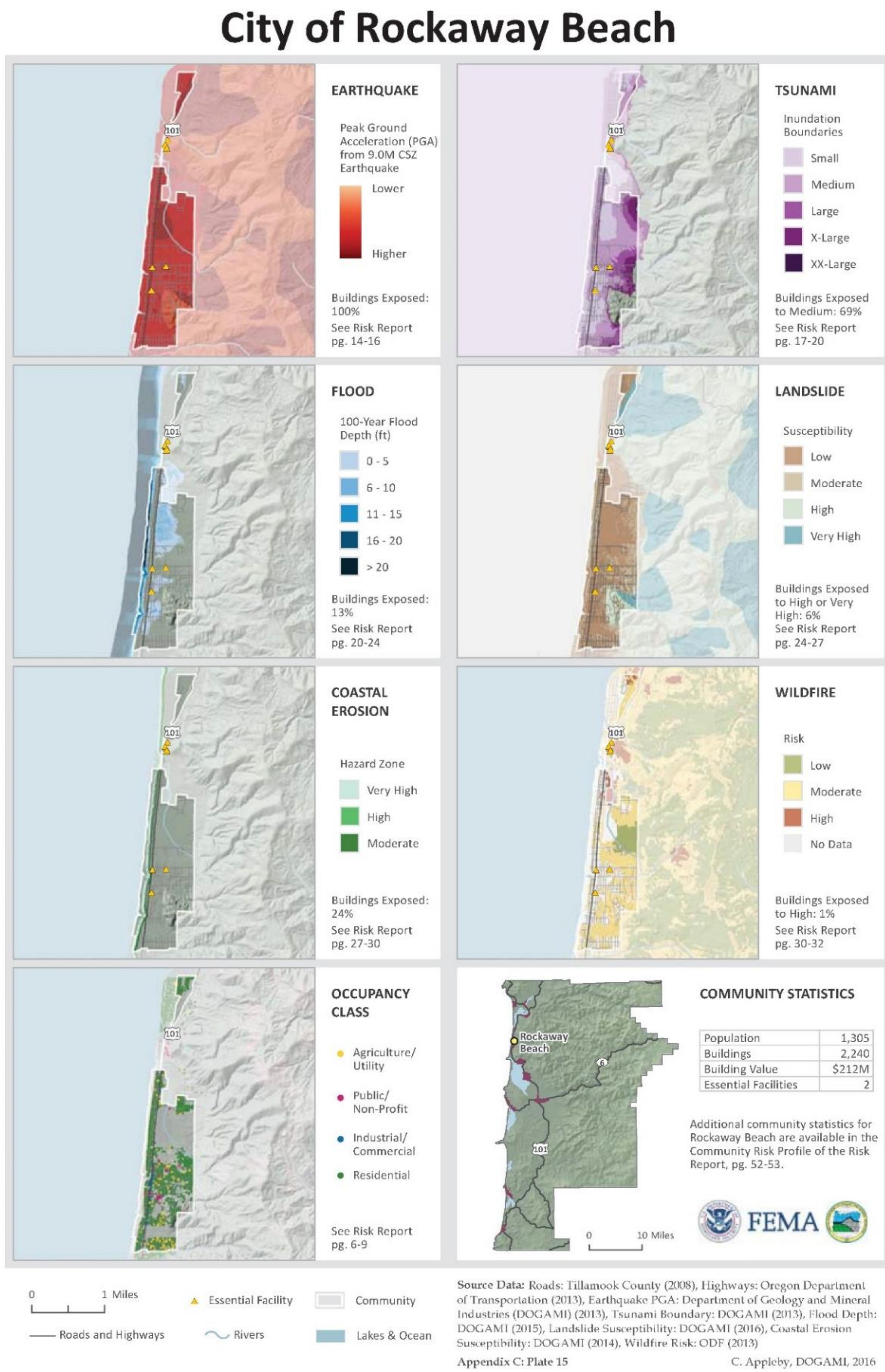
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 98. Areas of Mitigation Interest: City of Rockaway Beach

Hazard	Area	Description
Tsunami	Rockaway Beach In particular, the Police and Fire Departments are in the Medium tsunami zone.	Coastal and low-lying areas of Rockaway Beach are predicted to be inundated by a tsunami. A significant portion of the community is exposed to the tsunami zone. Inundation could make these emergency services nonfunctional during a Medium-sized tsunami; if functional, could provide much needed services during a tsunami crisis.
Earthquake	Many buildings located adjacent to Lake Lytle	A cluster of manufactured homes is in a very high liquefaction zone and is estimated to have high probability to destruction due to earthquake
Earthquake	Many buildings located adjacent to Clear Lake	A cluster of manufactured homes is in a very high liquefaction zone and is estimated to have high probability to destruction due to earthquake
Coastal Erosion	All of coastal Rockaway Beach, ~~Area of homes in Rockaway Beach along the shoreline~~	During times of high tide occurring along with powerful storms, the rate of erosion can greatly increase. A long strip of houses is within the high coastal erosion designated zone.
Flood	Rockaway Beach along the Pacific Ocean, Rock Creek, and other minor creeks	Many buildings in the low-lying areas of Rockaway Beach along the Pacific Ocean, Rock Creek, and other minor creeks are exposed to the 100-year flood.
Landslide	Eastern edge of Rockaway Beach	Residential structures on the eastern edge of Rockaway Beach are built on top of a preexisting landslide which is considered Very High risk.

Figure 105. Multi-Hazard Community Map Set: City of Rockaway Beach



Source: DOGAMI (2016)

7. City of Tillamook

Local Risk Assessment Review

Based on interviews with city representatives and based on the OEM Methodology Hazard Vulnerability Assessment conducted with the Tillamook County NHMP Steering Committee, the City of Tillamook representative differentiated the relative risks to the city. These differences are also indicated in the column for Tillamook in Table 3 within the Risk Assessment section.

City of Tillamook representatives evaluated its relative vulnerability to natural hazards and made the following assessments. The City of Tillamook is more at risk of damage from Flood than the county as a whole. This is due to the very flat topography of the city. There is less risk of Wildfire and of Landslide for the City of Tillamook than there is for the county as a whole.

Risk Assessment Summary

The natural hazards to which Tillamook is most vulnerable are the CSZ-related earthquake and flood. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Potential flooding from riverine sources can affect many buildings in the low-lying areas of the community.

The CSZ earthquake hazard is a significant natural hazard risk to Tillamook and is a priority hazard for this community. A large part of the community lies within an area of high liquefaction, which increases the probability for structural damage to buildings. Also the building inventory for Tillamook is relatively older, which implies lower building design codes with regards to earthquake.

Table 99. Hazard Profile: City of Tillamook

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Tillamook	5,317	2,194	22	982,931,000

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	499	9.4%	192	4	11,938,000	1.2%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	601	11.3%	784	9	309,757,221	31.5%
Earthquake	CSZ Mw 9.0 within the tsunami zone	0	0.0%	3	0	227,825	0.0%
Earthquake	Happy Camp Mw 6.6 Deterministic	705	13%	882	20	283,930,000	29%

Exposure Analysis Summary

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	0	0.0%	4	0	446,000	0.0%
Landslide	High and Very High Susceptibility	0	0.0%	1	0	1,108,000	0.1%
Coastal Erosion	High Hazard	0	0.0%	0	0	0	0.0%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

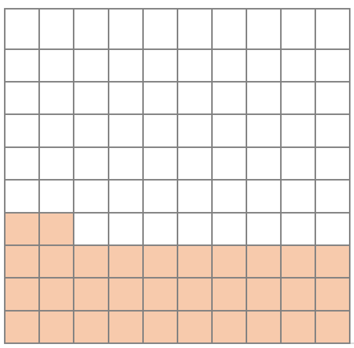
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

[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).

Figure 106. Loss Ratio from CSZ Event: City of Tillamook



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

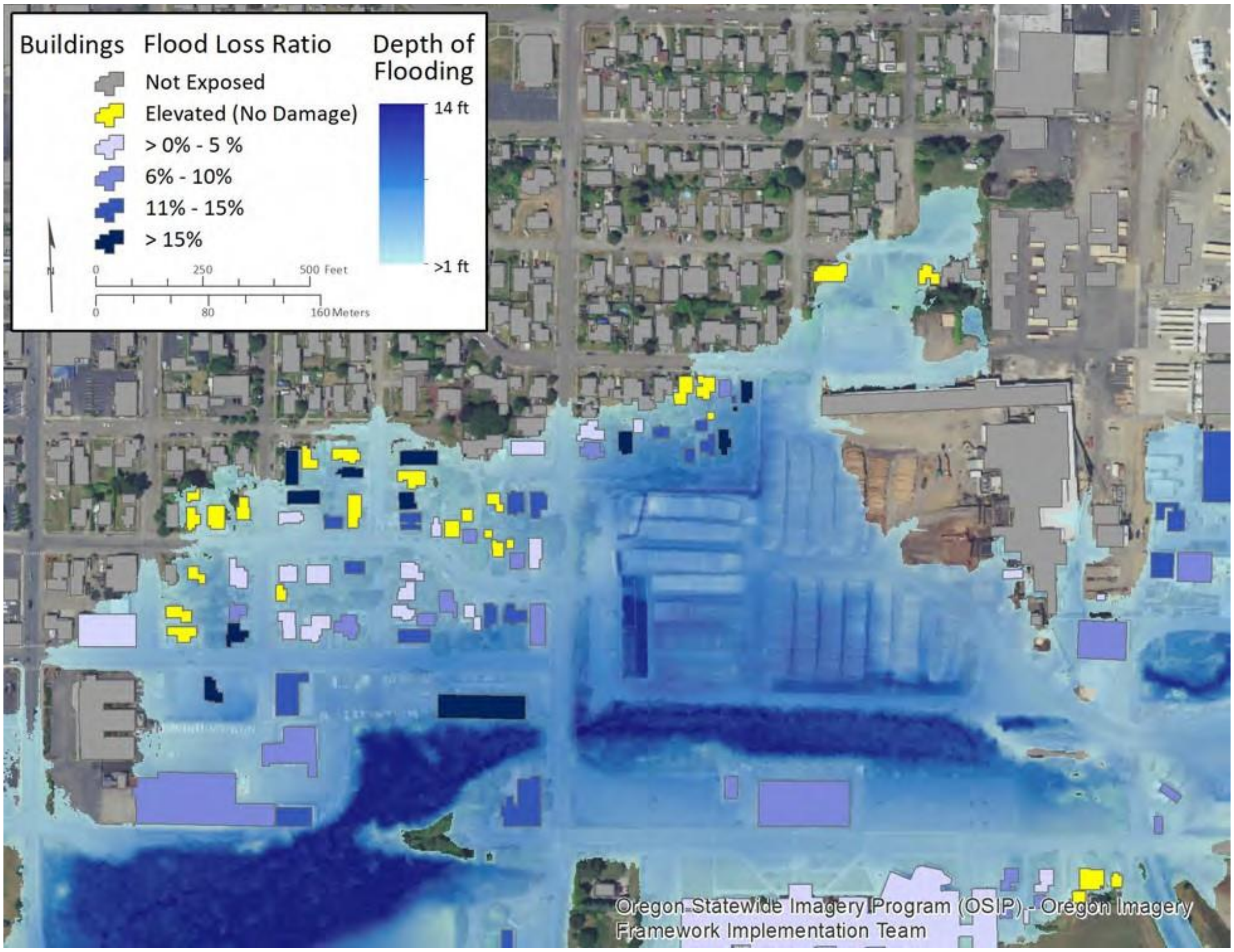
†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

The City of Tillamook lies between two major floodplains created by the Trask, Wilson, and Tillamook Rivers as well as many adjoining tributaries. Many buildings in the low-lying areas of Tillamook are exposed to the 100-year flood. Although there are many elevated buildings in the flood-prone areas, which will greatly reduce overall flood risk, there are still many buildings that can be impacted by flood. The DOGAMI analysis estimates that 64 of the 256 buildings in Tillamook exposed to flood will not be damaged by the flood. It is estimated that nearly a third of the buildings exposed to the 100-year flood are elevated above the predicted level of flooding as shown in the figure below from the 2022 DOGAMI Multi-Hazard Risk Report. While the buildings themselves would not be damaged from flood, access to these buildings could still be an issue.

Figure 107. Flood depth grid example in the City of Tillamook, Oregon



Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City of Tillamook.

Table 100. Essential Facilities: City of Tillamook

Critical Facilities by Community	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Bureau of Land Management Field Office							
County Health Department			X				
Early Learning Center	X		X				
East Elementary School		X	X				
Emergency 911			X				
Five Rivers Senior Living			X				
Liberty Elementary School		X	X				
Pacific Christian School			X				
Safeway			X				
TPUD – Tillamook Warehouse	X		X				
TPUD – Tillamook Office			X				
Tillamook Community College			X				
Tillamook County General Hospital		X	X				
Tillamook County General Hospital Building		X	X				
Tillamook County Public Works - Central		X	X				
Tillamook Fire Dist Main Station #71		X	X				
Tillamook High School	X	X	X				
Tillamook Junior High School		X	X				
Tillamook Police Department			X				
Tillamook Public Works							
Tillamook Public Library		X	X				
Tillamook Water Treatment Plant	X		X				

Transportation Infrastructure

Principal transportation infrastructure in the City of Tillamook includes U.S. Highway 101 and State Highway 6. Due to the local roads accessing farming and ranching land surrounding the City of Tillamook, there are alternative local emergency routes for short distances.

Evacuation Routes and Assembly Areas
The Tsunami Evacuation Map prepared by DOGAMI shows three Assembly Areas in the central city area, at Tillamook High School, Liberty Elementary, and the Tillamook County Library, and two north of the city at the Food Bank and north of the Tillamook Cheese Factory.

Energy
Tillamook PUD is the provider of electric service to the City of Tillamook.

The City of Tillamook has emergency generators available for its core services, including the water plant, wastewater plant, water wells, and sewer pumps. Many of these could be upgraded and a process for ensuring fuel is available may be a valuable mitigation action.

The Adventist Health Tillamook hospital has backup emergency generators, but they are in need up upgrading in order to function effectively in an emergency situation.

Water and Wastewater

Communications

Emergency and Public Services

Cultural and Historic Resources

Events, Festivals and Tourism

Vulnerable populations

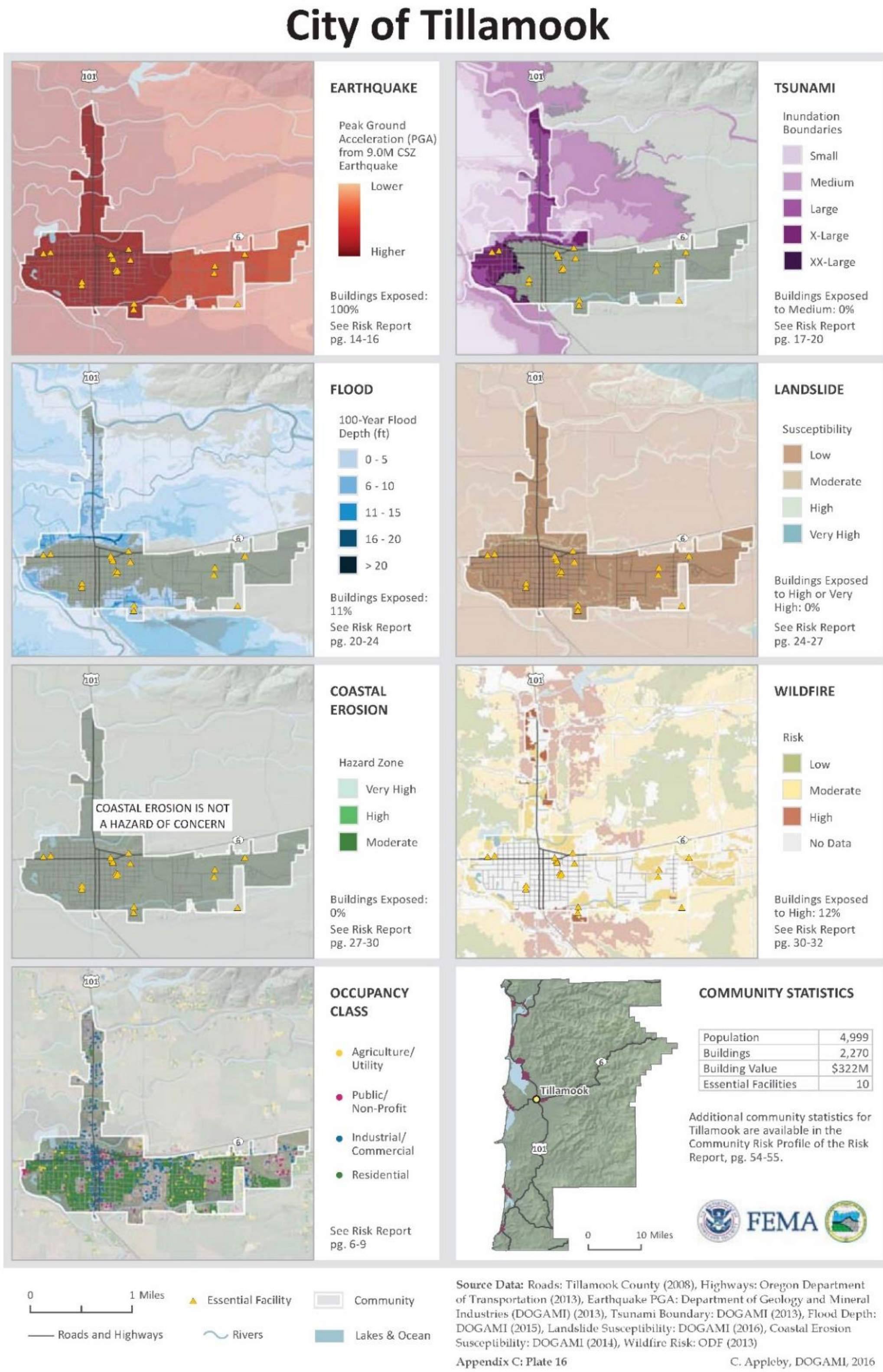
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest.

Table 101. Areas of Mitigation Interest: City of Tillamook

Hazard	Area	Description	Recommended Strategy
Flood	City of Tillamook in floodplain created by Tillamook, Trask, Kilchis, and Wilson rivers Many buildings located along Highway 101 and both north and south of downtown Tillamook are subject to 100-year flooding	Many buildings in the low-lying areas of the city and surrounding areas are exposed to the 100-year flood. Clusters of buildings are predicted to experience flooding from a 100-year event from tributaries of the Wilson River; many structures are not elevated above the BFE; flood waters would cut off a primary route for travelers Clusters of buildings are predicted to experience flooding from a 100-year event from the Trask River; many structures are not elevated above the BFE; flood waters would cut off a primary route for travelers. The Tillamook Cheese Factory, the top employer in Tillamook County, is within the area predicted to flood due to a 100-year flood.	
Flood	Tillamook High School is subject to 100-year flooding	Flooding from the Trask River would make the school nonfunctional during a 100-year flood event; if functional, could act as emergency shelter during periods of intense flooding	

Figure 108. Multi-Hazard Community Map Set: City of Tillamook



KD

Source: DOGAMI (2016)

8. City of Wheeler

Local Risk Assessment Review

Based on interviews with the city representative and based on the OEM Methodology Hazard Vulnerability Assessment conducted as with the Tillamook County NHMP Steering Committee, the City of Wheeler representative differentiated the relative risks to the city. These differences are also indicated in the column for Nehalem in Table 3 within the Risk Assessment section.

The City of Wheeler representative evaluated its relative vulnerability to natural hazards and made the following assessments. The city is significantly more at risk from landslide that the county in general and at less risk from coastal erosion and tsunami than the county communities.

Risk Assessment Summary

The natural hazards to which Wheeler is most vulnerable are the CSZ-related events (earthquake and tsunami) and landslide. As with every community in Tillamook County, the proximity to the CSZ makes earthquake a high-risk hazard. Developments along the Nehalem River are exposed to tsunami hazard, as portions of the community are within the Medium-sized tsunami zone. Another substantial risk to the community is landslide hazard, since a large percentage of Wheeler is within a very high susceptibility landslide zone.

Table 102. Hazard Profile: City of Wheeler

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Wheeler	422	362	3	81,137,000

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	0	0.0%	10	0	254,000	0.3%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	21	5.1%	80	3	11,214,913	13.8%
Earthquake	CSZ Mw 9.0 within the tsunami zone	2	0.5%	11	0	2,438,592	3.0%
Earthquake	Happy Camp Mw 6.6 Deterministic	7	1.7%	21	0	2,509,000	3.1%

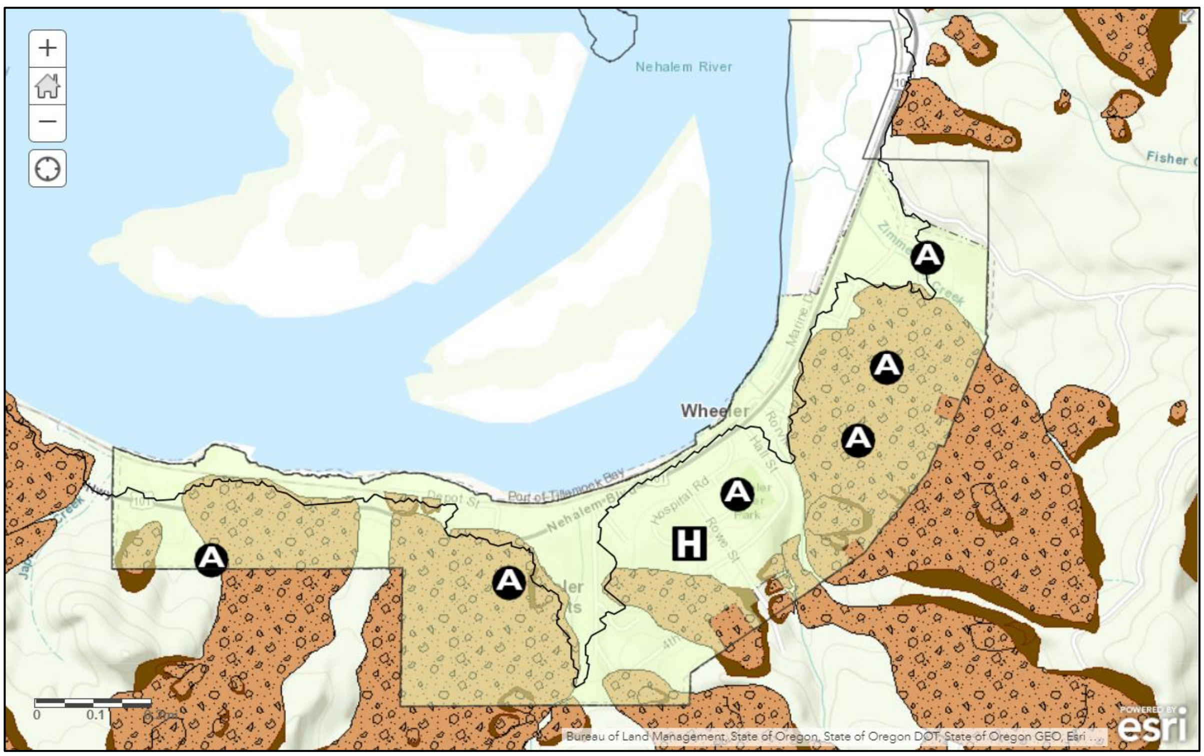
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Tsunami	*CSZ Mw 9.0 – Medium*	10	2.3%	20	0	5,537,000	6.8%
Landslide	High and Very High Susceptibility	407	96.5%	339	3	74,490,000	91.8%
Coastal Erosion	High Hazard	0	0.0%	0	0	0	0.0%
Wildfire	High Risk	0	0.0%	0	0	0	0.0%

*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another. Colors correspond to colors in **Error! Reference source not found.**.

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

Figure 109. Landslide Deposits, Tsunami Evacuation Line, Assembly Areas, and a Critical Facility

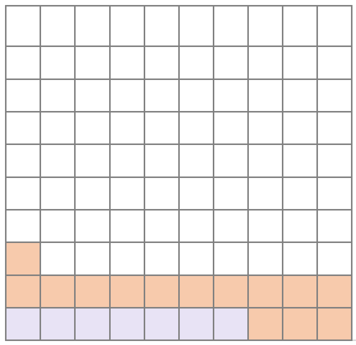


[2]No damage is estimated for exposed structures with "First floor height" above the level of flooding (base flood elevation). Source: State Landslide Information Database for Oregon (SLIDO) Public/SLIDO42 (MapServer) (oregon.gov) , also Tsunami Evacuation Zones Local Line, DOGAMI (state.or.us), and Tsunami Evacuation Zone Critical Facilities, DOGAMI (state.or.us), Oregon Department of Geology and Mineral Industries, various dates.

The landslide hazard for Wheeler poses a great risk to the community and its potential impact is a serious concern. An area deemed very high susceptibility to landslides makes up the majority of Wheeler. Monitoring for ground movement, especially during particularly wet conditions, is one way of increasing public safety from landslides.

The CSZ earthquake hazard is a significant natural hazard risk to Wheeler and is a priority hazard for this community. A large part of the community lies within an area of moderate liquefaction, which slightly increases the probability for structural damage to buildings. Also, the building inventory for Wheeler is relatively older, which implies lower building design codes with regard to earthquake. The tsunami generated from the CSZ earthquake is not expected to cause as much damage, but still is a concern.

Figure 110. Loss Ratio from CSZ Event: City of Wheeler



Each cell represents 1% of building value, so the grid represents 100% of total building value. The magnitude 9.0 CSZ event is predicted to simultaneously produce a damaging earthquake and tsunami. Hazus-MH modeling for loss ratio is available only for earthquake. Buildings with exposure to the tsunami inundation zone are assumed to be completely damaged, which would be 100% loss ratio. To avoid double counting of buildings, the earthquake loss ratio was calculated only for buildings outside of the tsunami zone.

†Each cell represents 1% of building value

= Estimated losses due to tsunami.

= Estimated losses due to earthquake (outside of tsunami zone).

Essential Facilities and Critical Infrastructure

The DOGAMI Multi-Hazard Risk Report provides the following assessment of exposure or probability of damage to the essential facilities identified by the City of Wheeler.

Table 103. Essential Facilities: City of Wheeler

Critical Facilities by Community	Flood 1% Annual Chance	CSZ Earthquake Moderate to Complete Damage	Happy Camp Fault Earthquake Moderate to Complete Damage	Tsunami CSZ M9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High and Moderate Risk	Coastal Erosion Moderate Hazard
	Exposed	**>50% Prob.**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**	**Exposed**
Nehalem Valley Care Center		X			X		
Nehalem Valley Care Center Rinehart Clinic		X			X		
Wheeler City Hall and Public Works		X			X		

Transportation Infrastructure

U.S. Highway 101 is the principal route through the city. The intersection with State Highway 53 is located just north of the city limits. There are limited options for alternative routes to evacuate the city.

Evacuation Routes and Assembly Areas
The city has identified a shelter/assembly site (Nehalem Valley Care Center), two cluster gathering sites (Top of Ridgeview and top of Gamble Streets) and five Assembly sites (3rd and Gregory, 3rd and Cedar, Upper Park, Paradise Cove marina and Pennsylvania Street). Tsunami evacuation routes were developed by DOGAMI for the City of Wheeler and many other coastal communities. The city has prepositioned "blue barrels" containing emergency supplies throughout the city. The Nehalem Valley Care Center also has some emergency equipment.

A helicopter landing pad has been established at the city's Upper Park, a location that is outside both the mapped area of high landslide susceptibility and the tsunami inundation zones.

Energy
The city receives electric served from Tillamook PUD.

Water and Wastewater

Communications

Emergency and Public Services

Cultural and Historic Resources

Events, Festivals and Tourism

Vulnerable populations

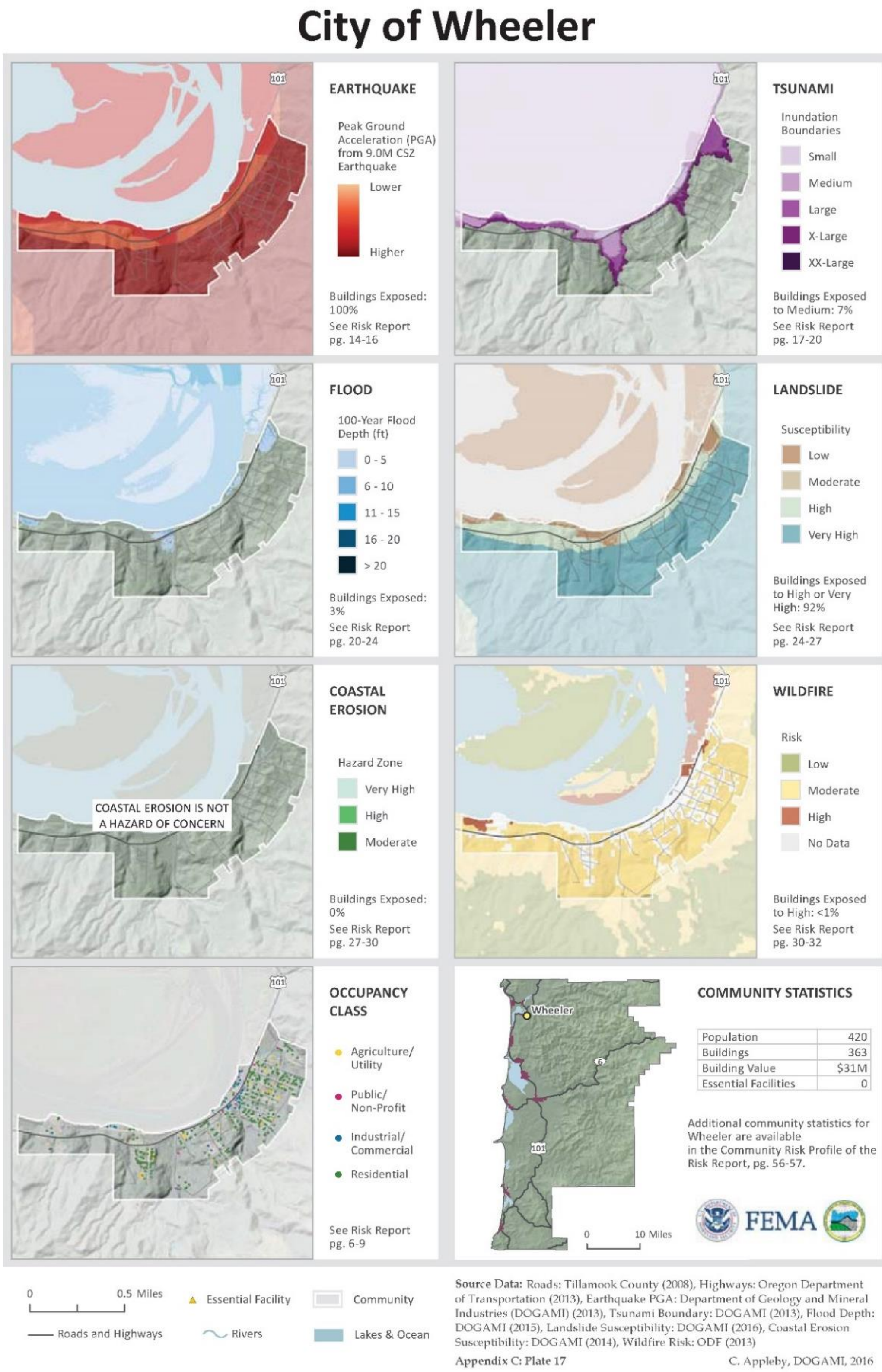
Areas of Mitigation Interest

Hazard results from Hazus and exposure analyses sometimes show specific locations where concentrations of high risk exist. These high-risk locations, when considered along with other factors like number of people affected, potential economic impact, and level of damage, can be determined Areas of Mitigation Interest. Potential mitigation strategies that would address these Areas of Mitigation Interest were selected from the current 2023 Tillamook County Mitigation Strategy and are included in the table below.

Table 104. Areas of Mitigation Interest: City of Wheeler

Hazard	**Area**	**Description**
Flood	commercial area on the riverside of Highway 101 subject to 100-year flooding	Wheeler's commercial area experiences flooding from the Nehalem River; many structures are not elevated above predicted level of 100-year flooding
Tsunami	Wheeler and Nehalem along the Nehalem River	Buildings and people in Wheeler and Nehalem along the Nehalem River are exposed to tsunami hazard.
Landslide	Garibaldi, Nehalem, and Wheeler	The majority of Garibaldi, Nehalem, and Wheeler are at High risk from landslide hazard.

Figure 111. Multi-Hazard Community Map Set: City of Wheeler



Source: DOGAMI (2016)

9. Port of Tillamook Bay

The Port of Tillamook Bay is located on land that was formerly occupied by the U.S. Naval Air Station — the home of blimp squadron during World War II. During the war, the facility consisted of two massive blimp hangars, administrative and residential quarters and more than 1,600 acres of land. The station was decommissioned in 1948 and has evolved into the core of Tillamook County's industrial sector in the 60 years since.

In 1911, the Port of Bay Ocean, an Oregon Municipal corporation, was formed by a special election to manage land at the entrance to Tillamook Bay. The Port incorporated additional land in 1948 to construct a jetty to protect the bay.

With the surrender of Japan, Tillamook Naval Air Station was no longer needed. The base, barely six years old, was decommissioned in 1948. With the departure of the Navy, the former base came under the jurisdiction of the new Tillamook County Airport Commission.

In 1953, the Port of Bay Ocean held a special election to incorporate the NAS Tillamook, the blimp hangars, airport and other buildings into its jurisdiction. On November 4, 1953, the name of the district became the Port of Tillamook Bay. More than a dozen buildings comprised the base. Most are now occupied by Port tenants. Unfortunately, Hangar A burned to the ground on August 22, 1992.

Risk Assessment Summary

Table 105. Hazard Profile: Port of Tillamook Bay

Community Overview							
Community Name	Population		Number of Buildings	Essential Facilities[1]		Total Building Value ($)	
Port of Tillamook Bay	0		83	0		61,545,144	
Hazus Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Essential Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0	0	0	0	0
*Earthquake**	*CSZ Mag 9.0 Deterministic*	*0*	*0*	*57*	*13*	*29,138,980*	*47%*
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
Exposure Analysis Summary							

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Essential Facilities	Building Value ($)	Exposure Ratio
Coastal Erosion	High Hazard	0	0%	0	0	0	0%
Tsunami	*CSZ Mag 9.0 – Medium*	*0*	*0%*	*0*	*0*	*0*	*0%*
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	0	0%	2	0	56,844	0.09%
Wildfire	High Risk	0	0%	0	0	0	0%

*Earthquake damage was calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another.

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

[2]No damage is estimated for exposed structures with "First Floor Heights" above the level of flooding (base flood elevation).

Essential Facilities and Critical Infrastructure

Transportation Infrastructure

The Tillamook Airport located at the Port of Tillamook Bay (POTB or the Port) serves to transport cargo and other non-passenger uses. Upgrades to the airport include a full grind and pave for the runway in 2016

Principal roadways for the Port include State Highway 6, State Highway 22, and U.S. Highway 101.

The POTB owns and operates a railroad formerly used as a freight line that has been transformed into a passenger line for tourism. Large sections of the roadbed of the rail line were destroyed in the Salmonberry River canyon during severe storms and flooding that occurred in December 2007, an event that also involved landslides and mudslides in northwestern Oregon. A federal disaster was declared (DR-1733) on December 8, 2007 for this event which occurred between December 1-17, 2007

The Port received $40 million in FEMA post-disaster mitigation funds from DR-1733 from the loss of the railroad system. Rather than spend FEMA funds to return the railroad to freight use, project funds were made available through FEMA's Public Assistance Program through the Port's request for alternate project funding. Warehouse facilities were repaired or constructed, upgrades were made to meeting and conference facilities, a new manure digester was funded and constructed, roads were rehabilitated, and improvements were made to the Port's water and septage receiving systems. Truck scales were upgraded and other projects such as new shops, equipment purchases, a hoop house project and support of the Southern Flow Corridor Landowner Preferred Alternative project were supported. The railroad was rehabilitated only to carry passengers for tourism on a portion of the original 8.5-mile line. [39]

Evacuation Routes and Assembly Areas

[39] FEMA Alternate Projects | Port of Tillamook Bay (potb.org)

Energy

Electric service is provided to the Port by Tillamook PUD.

In 2003 the POTB constructed a plug-flow digester that biologically processed manure from 4,000 of Tillamook County's 30,0000 dairy cows to methane which was then converted into electricity. The Hooley Digester went off line in 2013. There is no natural gas in Tillamook County, so there may be economic potential for converting manure to natural gas with the digester. The PTOB Digester facility was sold to Tillamook BioGas in December 2021.[40]

A new $5.6 million digester facility was built by DariTech and located within the former World War II blimp hangar adjacent to the Hooley Digester. This modern anaerobic digester produces electricity for the Tillamook People's Utility District. The fiber by-product is sold to nurseries and other horticultural users and the treated effluent is returned to the dairies for agricultural operations.[41]

There is an emergency generator at the airport that can operate the airport's fuel pumps and lights.

Water and Wastewater

Drinking water is purchased from the City of Tillamook. The wastewater system is a pressurized step system that goes into lagoons. The system was constructed in the 1980's and needs upgrades to retain its NPDES permit when the Oregon Department of Environmental Quality reviews the system's permit in 2024.

Communications

Tillamook Lightwave is an intergovernmental agency that brings together Tillamook County, Tillamook People's Utility District and the Port in a consortium developed to ensure that Tillamook County has access to ample high-speed telecommunications. Tillamook Lightwave currently serves such organizations as Tillamook County government, County Emergency Services and 911, the Tillamook School District #9, Tillamook Regional Medical Center, Tillamook Bay Community College and several local businesses. This network is limited by serves critical and essential facilities as well as some commercial establishments. There is potential to expand this system within Tillamook County.

The private company, Near Space Corporation, a 25-year-old company which designs and builds communication balloons for NASA and NOAA, can launch balloon with communications equipment in emergency situations. The county is looking to identify gaps in the county's communication systems, particularly with respect to emergency operations. Near Space Corporation works in this arena developing unmanned aircraft systems as well as drones to assist with search and rescue making it a potentially valuable partner in the county's and the Port's efforts to fill the gaps in emergency communications.

Emergency and Public Services

Near Space Corporation operates a facility within the POTB industrial park that could be converted into shelter.

---

[40] Michele Bradley, Personal communication

[41] WesternEnergyBrochureFront1 (hubspotusercontent-na1.net)

The Tillamook County Sheriffs office and Oregon State Police facilities are located adjacent to the Port. The county Emergency Operations Center would be located there if needed.

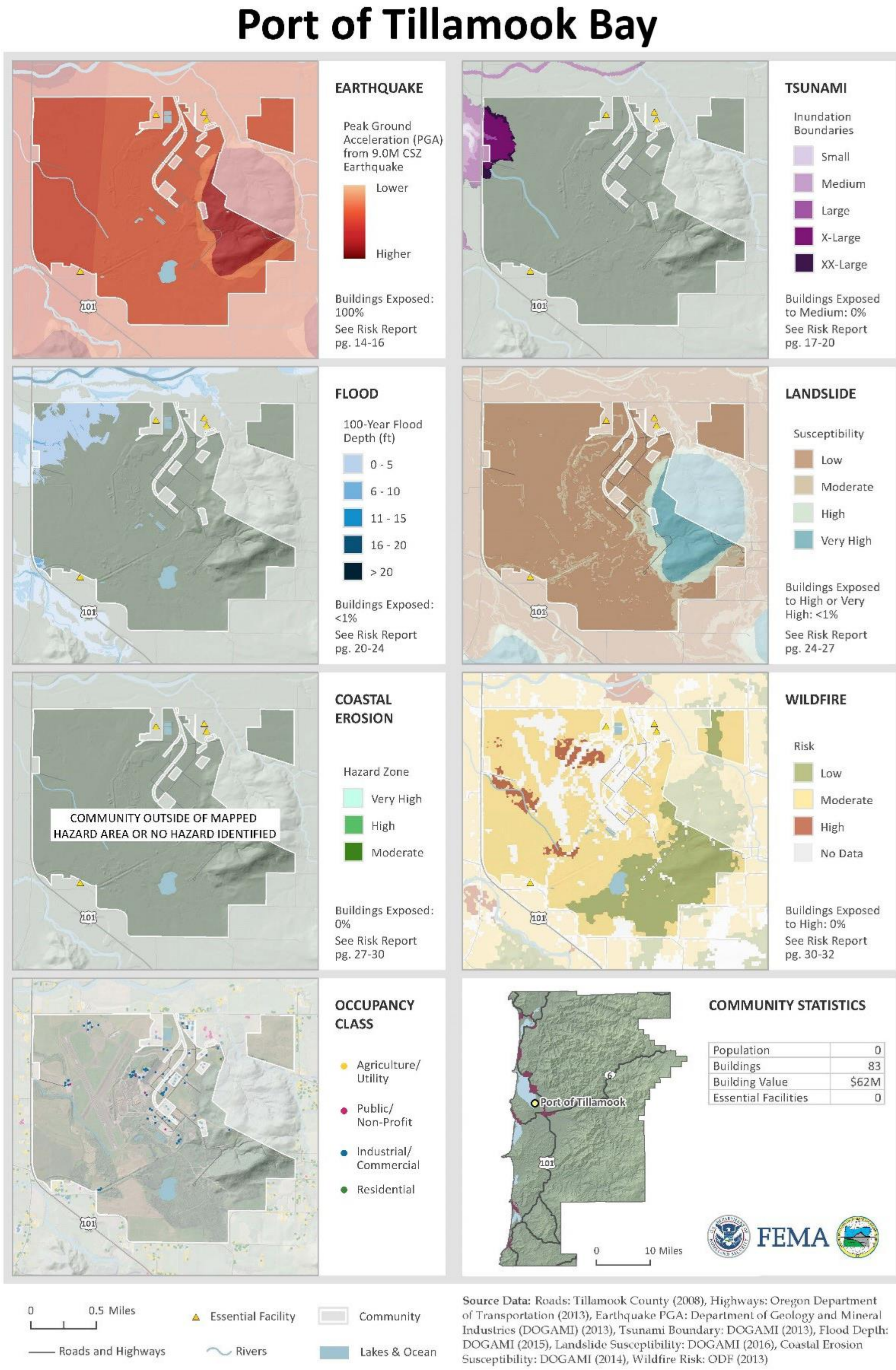
On the Port property there are two locations where Life Flight helicopters can land.

Cultural and Historic Resources
None have been identified during multiple NEPA reviews.

Events, Festivals and Tourism
Visitors and events are frequent occurrences at the Port. The Tillamook Air Museum attracts many visitors annually. There are events such as fly-ins and car shows held at the Port. Private parties commonly lease space for events at the Port and the Air Museum is rented periodically for large events dinners, Veteran's Day, Easter and Christmas events, and dances among other events..

Vulnerable populations
Vulnerable groups at the Port include those housed at the Tillamook County Jail, the Camp Tillamook Youth Transitional Facility and those who attend Trask River High School. The Port also houses Helping Hands homeless shelter. There is a children's day care facility called Tilly Tots located in the Tillamook Air Museum

Figure 112. Multi-Hazard Community Map Set: Port of Tillamook Bay



Source: DOGAMI (2016)

10. Port of Garibaldi

The Port of Garibaldi is a harbor of safe refuge due to the distance from other ports to the north and south. Harbor of safe refuge means a port, inlet, or other body of water normally sheltered from heavy seas by land and in which a vessel can navigate and safely moor.

The Port of Garibaldi district lands encompass three coastal towns, including Bay City, Garibaldi and Rockaway Beach. At the Port of Garibaldi property there is an RV park and lodging, restaurants, seafood processing, a lumber mill, and commercial and charter fishing. The Port's harbor has moorage for 277 vessels.

The Port of Garibaldi's property also features the Lion's Club Lumbermen's Park and an antique train display. A walking path is also a popular draw for locals as well as visitors to Garibaldi.

Risk Assessment Summary

Table 106. Hazard Profile: Port of Garibaldi

Community Overview							
Community Name		Population	Number of Buildings	Essential Facilities[1]		Total Building Value ($)	
Port of Garibaldi		0	36	0		8,035,760	
Hazus Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Essential Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0	0	0	0	0
*Earthquake**	*CSZ Mag 9.0 Deterministic*	*0*	*0*	*4*	*0*	*544,725*	*7%*
Earthquake (within Tsunami Zone)		0	0%	21	0	2,996,704	37%
Exposure Analysis Summary							

Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Essential Facilities	Building Value ($)	Exposure Ratio
Coastal Erosion	High Hazard	0	0%	0	0	0	0%
Tsunami	*CSZ Mag 9.0 – Medium*	*0*	*0*	*26*	*0*	*3,427,250*	*43%*
Tsunami	Senate Bill 379 Regulatory Line	0	100%	33	0	7,986,217	99%
Landslide	High and Very High Susceptibility	0	0%	2	0	78,810	0.98%
Wildfire	High Risk	0	0%	0	0	0	0%

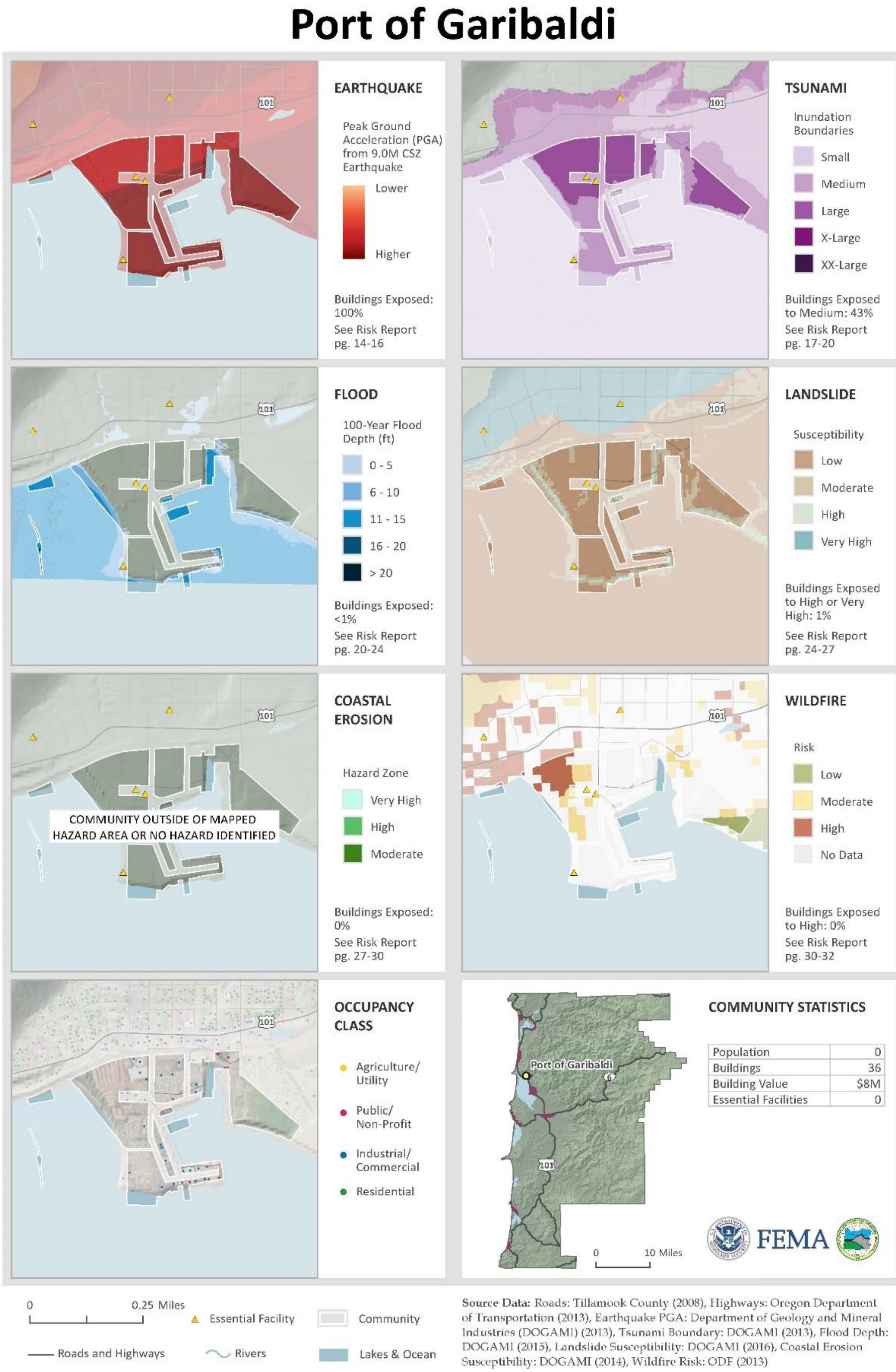
*Earthquake damage was calculated for buildings outside of Medium tsunami zone.

Rows with italicized text and shaded background indicate results should be considered in tandem as they are expected to occur within minutes of one another.

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

[2]No damage is estimated for exposed structures with "First Floor Heights" above the level of flooding (base flood elevation).

Figure 113. Multi-Hazard Community Map Set: Port of Garibaldi



Source: DOGAMI (2016)

Essential Facilities and Critical Infrastructure

Transportation Infrastructure
Internal roadways on the Port of Garibaldi property and U.S. Highway 101

Evacuation Routes and Assembly Areas

Energy

Water and Wastewater

Communications

Emergency and Public Services

Cultural and Historic Resources

Events, Festivals and Tourism
Visitors and events are frequent occurrences at the Port of Garibaldi. The Port hosts Night Markets in the summer and scavenger hunts throughout the year. Many visitors to the Port of Garibaldi are involved in fishing and crabbing both as a business and for pleasure.

Vulnerable populations
There are no permanent residents on the Port of Garibaldi property.

III. MITIGATION STRATEGY

A. Introduction

The Mitigation Strategy establishes a policy framework and implementation pathway for reducing risk from natural hazards over the long term. It presents the natural hazards mitigation goals and objectives of Tillamook County, its cities, the Ports of Garibaldi and Tillamook Bay, the Nehalem Bay Fire and Rescue District, the Nestucca Valley School District and the Tillamook People's Utility District. This section also describes mitigation actions to achieve the goals, a strategy for implementation, and a process for integrating the NHMP into other planning mechanisms. It also identifies the tools and assets that support implementation available to each jurisdiction. Further, it documents progress in achieving mitigation actions since the Tillamook County Multi-Jurisdiction Natural Hazards Mitigation Plan was last approved in 2016.

B. Goals and Objectives

The Steering Committee reviewed the existing three multi-jurisdictional goals and decided to retain them as without revision. Similarly, the objectives identified under each goal were also retained without revision. The overall priorities have not changed from the previous plan.

Goal 1. Develop and implement effective mitigation initiatives, projects, and activities to reduce hazards to life, businesses, property, and environmental systems.

Objective 1A. Maintain effective natural hazards mitigation plans and regulations.

Objective 1B. Promote purchase of insurance coverage to mitigate economic loss and enhance post-disaster resilience.

Objective 1C. Preserve environmental systems to serve natural hazard mitigation functions.

Objective 1D. Advance natural hazards mitigation with updated data and information as it becomes available.

Objective 1E. Educate the public about natural hazards and mitigation.

Objective 1F. Seek funding and partnerships as needed to implement mitigation initiatives, projects, and activities.

Goal 2. Enhance emergency services and the capabilities of local first responders.

Objective 2A. Enhance the ability of individuals and businesses to be self-reliant for an extended period of time.

Objective 2B. Seek funding to provide first responders with the training and tools they need to respond effectively to all hazard events.

Objective 2C. Strengthen emergency operations by improving communication and coordination.

Goal 3. Improve regional coordination and communication.

Objective 3A. Participate in the countywide Hazard Mitigation Steering Committee.

Objective 3B. Maintain active and collaborative emergency preparedness committees covering the county.

Objective 3C. Improve communication and collaboration between Emergency Operations Centers, including the Tillamook Citizens Corps Council, Emergency Volunteer Corps of Nehalem Bay, Community Emergency Response Teams, Incident Command Teams, Fire Districts, Emergency Services Departments, Public Works Departments, Law Enforcement Agencies, and others. In particular, collaborate on updating the County Emergency Response Plan.

Objective 3D. As funding becomes available, individual jurisdictions will continue to survey their populations about personal preparedness and develop coordinated response plans for each potential hazard.

C. Mitigation Actions

Mitigation actions are specific actions, projects, activities, or processes that reduce risk to people, property, and the environment from the impacts of natural hazard events.

For the 2016 MJ NHMP update, he University of Oregon's Community Service Center conducted a review of the Tillamook County Development Code, focusing on supplementing and strengthening code associated with natural hazard mitigation. The task included reviewing a range of regulatory and non-regulatory standards that could be used by Tillamook County to mitigate the risk of natural hazards impacting the County. This review remains a valid source for potential mitigation actions.

Table 107 through **Table 116** list each jurisdiction's prioritized mitigation actions and implementation strategy. Actions marked "ongoing" are those in which a jurisdiction engages regularly or continually and expects to continue doing so. Therefore these actions have not been assigned a specific timeline. Error! Reference source not found. shows progress in mitigation actions since the last plan update.

Each jurisdiction prioritized its mitigation actions qualitatively in accordance with their levels of necessity and urgency for the protection of people, property, and the environment; internal capacity or need for assistance to accomplish the action; and cost versus benefit. In general, actions considered to be of great necessity or urgency were assigned high priority even if they were expected to be extremely costly. Length of time to complete the action was not a criterion for prioritizing. Therefore some high-priority actions, even if they were considered urgent, have long timelines.

Table 107. Tillamook County Mitigation Actions - 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description	2023 Status	2023 Timeline	2023 Priority	2022-23 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Adopt new FIS and FIRM.	Complete				Reduce hazards to life, businesses, property, and environmental systems	DLCD	Tillamook County DCD	Tillamook County
Complete beach and dune code update.	Complete				Reduce hazards to life, businesses, property, and environmental systems	DLCD	Tillamook County DCD	Tillamook County
Amend Beach and Dune code.	Complete				Reduce hazards to life, businesses, property, and environmental systems	DLCD	Tillamook County DCD	Tillamook County
Continue to implement the Southern Flow Corridor Plan.	Complete				Reduce hazards to life, businesses, property, and environmental systems	Tillamook County	Southern Flow Corridor Plan Partners	POTB/TEP/ TBFID/Various state and federal agencies
Created and Adopted Tsunami Hazard Overlay Zone	New Action; Complete			Success Story; not on 2017 list				
Updated development requirements for geologic hazard areas	New Action; Complete			Success Story; not on 2017 list				
Implement three outreach events on hazard insurance (flood, earthquake) over the life of the NHMP.	Ongoing				Reduce hazards to life, businesses, property, and environmental systems	DCD	EM	Tillamook County
Maintain GIS natural hazards geodatabase and program capability	Ongoing			Using DOGAMI Open File report	Reduce hazards to life, businesses, property, and environmental systems	DCD	County Assessor/ DOGAMI/ DLCD	Tillamook County/FEMA/ NOAA
Continue outreach on natural hazards mitigation to residents and tourists.	Ongoing			The Short-Term Rental program requires that Tsunami evacuation information be posted in these rental units. The county is working with the Tillamook County Visitors Assoc. on this action.	Reduce hazards to life, businesses, property, and environmental systems	DCD	EM/ Oregon Coast/Tillamook County Visitor's Assoc.	Tillamook County Transit Lodging Tax funds

Mitigation Action Description	2023 Status	2023 Timeline	2023 Priority	2022-23 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Implement education and outreach strategies on seismic resilience, retrofitting, and the building code program.	Ongoing			Will start this soon to be an ongoing action; has been a staffing issue and time taken by high permit volumes	Reduce hazards to life, businesses, property, and environmental systems	Building Official	EM	Tillamook County
Update the Community Wildfire Protection Plan in coordination with ODF and the County Fire Board	Ongoing			The CWPP is updated periodically as required.	Reduce hazards to life, businesses, property, and environmental systems	ODF	Fire Board/Tillamook County	ODF
Complete tsunami “Beat the Wave” project.	Ongoing			Identify what is done on an ongoing basis to implement the "Beat the Wave" project.	Reduce hazards to life, businesses, property, and environmental systems	DCD		NOAA
Continue to replace culverts and bridges.	Ongoing			Check with Chris; working from larger list to add onto CIP annually	Reduce hazards to life, businesses, property, and environmental systems	PW	–	Tillamook County/ODOT/ FEMA
Develop a drainage asset management plan with a culvert repair/replacement schedule.	Progressing			Question: What has been done? What needs to be done?	Reduce hazards to life, businesses, property, and environmental systems	PW	–	Tillamook County/ODOT/ FEMA
Apply for funding to repair two levees (Shilo and Stillwell).	Retain; not started				Reduce hazards to life, businesses, property, and environmental systems	PW	–	
Re-join the CRS program.	Retain; progressing				Reduce hazards to life, businesses, property, and environmental systems	DCD	DLCD, FEMA	Tillamook County
Consult with the Watershed Councils and Tillamook Estuary Partnership about developing and partnering on strategies to preserve environmental systems to serve natural hazards mitigation functions.	Retain; will begin during the upcoming plan cycle			Use the DLCD supported Estuary Resilience Action Plan project that utilizes nature-based approaches to develop mitigation projects within estuaries. Michael Moses, the ERAP, project manager, presented his work at our steering committee meeting. Some of the participants in his project are represented on our steering committee as well. The report is included as an appendix in this update to the Tillamook County MJ NHMP.	Reduce hazards to life, businesses, property, and environmental systems	DCD	TCBOCC/TEP/ DLCD (Revise to add ERAP project?)	Tillamook County/TEP/ DLCD National Fish and Wildlife Foundation

Mitigation Action Description	2023 Status	2023 Timeline	2023 Priority	2022-23 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue to partner with DOGAMI through a DOGAMI grant to engage four communities in the "Follow the Elephant", an evacuation practice program. (Pacific City, Neskowin, Rockaway Beach, Manzanita, Nedonna Beach).				The term Follow the Elephant needs some explanation. Internet search turned up references to military exercises and an April Fools article about elephants. https://www.oregongeology.org/tsuclearinghouse/resources/pdfs/Price-TsunamiElephantsAprilFools2010.pdf	Reduce hazards to life, businesses, property, and environmental systems	DOGAMI	Tillamook County	Grant
Conduct a mass casualty exercise annually.					Enhance emergency services and local first responders	EM	Cities/ Ports/ OEM	Tillamook County
Maintain Nixel alert system.				Encourage citizens to sign up for alerts.	Enhance emergency services and local first responders	EM	–	Tillamook County
Maintain disaster event chain of command.					Enhance emergency services and local first responders	EM	–	Tillamook County
Maintain EVCNB agreement for assistance with NBRFD.					Enhance emergency services and local first responders	EM	–	Tillamook County
Provide significant ham radio training throughout the county.					Enhance emergency services and local first responders	~~IS~~ County EM and EVCs	EM/Cities/Ports	Tillamook County/ Cities/Ports/ OEM/FEMA
Work with the rural unincorporated communities to develop coastal erosion adaptation sub-plans based on the information in the "Framework Plan."	Not started				Reduce hazards to life, businesses, property, and environmental systems	DCD	Unincorporated Communities	Tillamook County/DLCD
~~Develop an Animal Mortality Plan~~	Remove			The Tillamook Creamery has an animal mortality plan. This action was removed because it is not an action that the county can or is taking.	Reduce hazards to life, businesses, property, and environmental systems	ODA	EM/DEQ/ TCHealth/ Creamery Assn/ POTB	ODA/DEQ/ FEMA/TC/ Creamery Association

Table 108. City of Bay City Mitigation Actions – 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Create new risk and flood maps using lidar.	Complete			New FEMA maps adopted in 2017; maps available on website	Reduce hazards to life, businesses, property, and environmental systems	FEMA	DOGAMI, DLCD	FEMA
Locate emergency supplies at evacuation sites in the community.	Completed			Bay City Emergency Volunteer Program was started during the prior planning period; sheds with equipment were established; City Council allocated $10K to make supply kits in paint buckets. Description revised to identify this project as distinct from the larger project of constructing a new structure to house PW equipment and EM supplies.	Reduce hazards to life, businesses, property, and environmental sys			
Design and implement an outreach program on hazard mitigation topics including outreach specific to non-English speakers and people with disabilities.	Ongoing	n/a	n/a	Assistance is needed with the outreach program especially to include outreach specific to non-English speakers and people with disabilities The city desires to support personnel who could help better coordinate between the cities and the county to support common efforts.	Reduce hazards to life, businesses, property, and environmental systems	City Emergency Preparedness Committee	OEM, Oregon Division of Financial Regulation (ODFR) - Insurance	City/OEM/ DLCD/Local Social Service Orgs.
Construct a building to store Public Works equipment and Emergency Management supplies. Relocate public works equipment and emergency supplies to evacuation sites in the community.	Progressing	Long Term >5 years		Revised description.	Reduce hazards to life, businesses, property, and environmental systems	Public Works	City	City/FEMA
Develop secondary access for the wastewater treatment plant and public works facilities that would result in direct access to US-101, avoiding interim access through the flood zone.	Progressing	Short Term 1-3 years		Secondary Access would be located on McCoy Avenue ROW. Access agreement made with TPUD.	Reduce hazards to life, businesses, property, and environmental systems	Public Works	ODOT, FHWA	City/FEMA
Reinvigorate the Emergency Preparedness and Mitigation Committee.	Progressing	Short Term 1-3 years		The committee restarted its efforts and constructed two (2) emergency supply sheds. They are in the process of stocking emergency supplies in these sheds.	Improve regional coordination and communication	City Council	City Manager	FEMA

Mitigation Action Description	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Assist Bay City Emergency Volunteer Program with pre-deploying supplies by placing containers at the north and south evacuation sites.	Progressing	Short Term 1-3 years		The supply sheds were constructed, and the city is developing the inventory. The suggestion was made that the sheds could be anchored to the ground. Revised to identify the Bay City Emergency Volunteer Program rather than the CERT.	Enhance emergency services and local first responders	City Emergency Preparedness Committee	CERT	City
Include infrastructure response plan in EOP.	Progressing	Short Term 1-3 years		Public Works Department improving generator reliability at WWTP and ground water well field.	Enhance emergency services and local first responders	Public Works Director	Fire Chief	City
Relocate the fire station and City Hall out of the tsunami impact area. Use impounding franchise tax fees to purchase land, then apply for funding for construction.	Progressing; working actively on this project	Long Term > 5 years	High	City reports $125K available in funds to accomplish this $10 million project. Budgeted through reserve fund to purchase location for Fire/City Hall;	Reduce hazards to life, businesses, property, and environmental systems	City	–	Other sources of funds for construction? FEMA?
Strengthen the banks of the wastewater treatment ponds to prevent erosion.	Retain and reviewed, but not started	Long Term > 5 years		Geologic hazards for this facility were reviewed; condition of facility is being monitored by Public Works	Reduce hazards to life, businesses, property, and environmental systems	City	–	City
Develop and implement an outreach program to encourage seismic retrofitting, particularly fastening structures to their foundations.	Retained; Revised			It would be helpful to develop information for new developers or guidance for builders; city staff might work with the building officials at the county level to develop an informational pamphlet and to provide resources to contractors.	Reduce hazards to life, businesses, property, and environmental systems	City Emergency Preparedness Committee	OEM	City/OEM/ State Division of Financial Regulation (Insurance)/ Tillamook County Building Dept.
Design redundancy into the wastewater collection system under U.S. Highway 101	New Action			Add a secondary 18-inch wastewater line under 101 and POTB RR ROW generally at McCoy Avenue ROW from the Smoker to WWTP.	Reduce hazards to life, businesses, property, and environmental systems			
Replace aging water distribution lines and design them for resilience against damage in an earthquake.	New Action				Reduce hazards to life, businesses, property, and environmental systems			

Mitigation Action Description	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Develop plan to replace culverts on Patterson Creek.	New Action; Progressing	Medium Term; 3-5 years		The culverts have exceeded their life expectancy. Design drawings have been completed to 30%. The city intends for this work to reduce localized flooding and to reduce infrastructure failure due to age. Failure of these culverts could result in isolation of Bay City following an earthquake.	Reduce hazards to life, businesses, property, and environmental systems			

Table 109. City of Garibaldi Mitigation Actions

Mitigation Action Description -Manzanita	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Equip reservoirs with seismically activated shut-off valves.	Retain				Enhance emergency services and local first responders	City Engineer	–	City Water Utility Revenue
Add surface water treatment. Develop an action plan for analyzing and decontaminating water in the event of an earthquake.	Reconsider			Reconsider whether this is a worthwhile mitigation action. Is there risk of contamination of drinking water source(s) following an earthquake?	Enhance emergency services and local first responders	City Engineer	–	City Water Utility Revenue
Support the work of the USACE, Tillamook County, Port of Garibaldi and the Port of Tillamook Bay to repair and maintain the jetties.	Retain; revised				Enhance emergency services and local first responders	City Manager	USACE, Tillamook County, Port of Tillamook Bay	USACE
Replace 2 miles of asbestos-concrete pipe.	Retain			The system may need to be analyzed the system first, before replacing the pipe.	Enhance emergency services and local first responders	City Engineer	–	City Water Utility Revenue
Install seismically sound fuel tanks (1 diesel, 1 gas), generators, and storage for emergency supplies on the least hazard-susceptible area out of the floodplain and tsunami zone.	Retain				Enhance emergency services and local first responders	City Engineer	City Manager	City Utility/General Revenues
Seismic retrofits to bridges and culverts on US-101 to prevent collapse in an earthquake.	Retain			Consider for upgrades during ODOT US Hwy 101 redesign project	Enhance emergency services and local first responders	City Engineer	City Manager	ODOT

Mitigation Action Description -Manzanita	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Complete Tourism Plan. The plan will incorporate (1) emergency management into tourism promotion operations so tourists are prepared for natural hazard events; and (2) evaluation of emergency facilities for accommodating tourism demand.	Retain			Comment was "Keep, especially for hotels; she gave the example of Wheeler where go bags are in each room of the Wheeler Hotel"	Reduce hazards to life, businesses, property, and environmental systems	Tourism Promotion Department	City Manager	City
Dismantle 200+ feet tall relic smoke stack.				This action may require more information such as whether the smoke stack has been reinforced and what entity owns it.	Reduce hazards to life, businesses, property, and environmental systems	City Manager	–	Private, Non-Profit
Identify evacuation route to Wheeler where there is a Red Cross emergency facility and develop agreements to use forest roads in an emergency or for disaster response.				Garibaldi has an observably high risk of isolation as a result of earthquake and tsunami events based on apparent vulnerability of transportation infrastructure. General vehicular access to Garibaldi is facilitated by US-101, which runs north and south along the Oregon Coast. Wheeler has a red cross emergency facility, so taking Miami Foley to Wheeler would be the most likely choice for emergency evacuation. The bridge at the curve over the Miami River might impede access to Bay City. Garibaldi can also be accessed through a series of forest land utility roads that interconnect throughout the Coast Range. However, use of these roads requires access to private property and no agreements are in place at this time for use of these roads in either an emergency or for emergency preparation.	Enhance emergency services and local first responders	City Manager	USFS, ODF, Private property owners	City, Private

Table 110. City of Manzanita Mitigation Actions – 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description - Manzanita	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Review and update Nehalem Bay Emergency Response Plan.	Complete			Complete and maintained as a living document	Reduce hazards to life, businesses, property, and environmental systems	EVCNB	Manzanita, Nehalem, Wheeler	Grants, Cities
Consider earthquake retrofit of City Hall. The City is considering whether to keep the building and retrofit it or move.	Completed			A location for a new City Hall has been identified and a design developed.	Reduce hazards to life, businesses, property, and environmental systems	CM	CC	City/FEMA
Update flood maps using lidar.	Complete				Reduce hazards to life, businesses, property, and environmental systems	FEMA	DLCD/	FEMA
Continue to educate the public about natural hazards mitigation through links to EVCNB's website, www.evcnb.org.	Ongoing	n/a	n/a		Reduce hazards to life, businesses, property, and environmental systems	City Manager (CM) /EVCNB	CM	EVCNB
Continue to provide first responders with training and equipment.	Ongoing	n/a	n/a		Reduce hazards to life, businesses, property, and environmental systems	CM	City Council (CC)	City
Enhance city organization self-sustainability by continuing to work with EVCNB, the fire districts, Nehalem, and Wheeler.	Ongoing	n/a	n/a	2022 NBEVC and City of Manzanita hosted ICS100 class for local governments and organizations. EVCNB is active in providing preparedness class with CM staff attending multiple class.	Enhance emergency services and local first responders	CM/EVCNB	CC	EVCNB/City
The City and EVCNB have begun outreach and training of neighborhood groups with the goal of increasing self-reported preparedness by 35% in 2017.	Ongoing	n/a	n/a	The city is supporting EVCNB with $10K annually until $400K is reached; also provide storage space for EVCNB	Enhance emergency services and local first responders	CM/EVCNB	CM	EVCNB
Continue to meet monthly with the EVCNB.	Ongoing	n/a	n/a	PW Director/EM participates with the PW Augmentation Team	Improve regional coordination and communication	PW/EVCNB	CM	EVCNB
The Nehalem Bay Community Emergency Preparedness Forum meets twice each year.	Ongoing	n/a	n/a		Improve regional coordination and communication	EVCNB	CM/PW	EVCNB/City
Maintain the wetland at City Park for conservation and natural hazards mitigation functions in perpetuity.	Ongoing	n/a	n/a		Reduce hazards to life, businesses, property, and environmental systems	CM	–	City

Mitigation Action Description - Manzanita	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Earthquake retrofits of water storage facilities. The water tanks serving the upper portion of Manzanita are older and not constructed to earthquake standards. The tanks need to be retrofitted so that water system capability can be maintained after an earthquake.	Progressing	Long Term > 5 years		In 2022 the city received a grant from FEMA to evaluate storage tank options and to complete 10% engineering. The report has been completed and can be found at http://ci.manzanita.or.us. Next step is to complete design to 30%. Emergency Manager applied for a grant to design seismic retrofitting for the water tanks serving the upper portion of Manzanita.	Reduce hazards to life, businesses, property, and environmental systems	PW	CM/CC	City/FEMA
Develop short-term and long-term communication systems for the city. In particular provide short-range and long-range communication systems in the water treatment plant and EOC.	Progressing			The city acquired an emergency radio tower; another part of the system are "Black boxes" to serve as movable communication packages; clarify the following note: "antennae at Trailer mounted radio tower and local communications through black boxes;" The EOC will be able to be mobile and will include a trailer mounted antennae to enable the EOC to be located as needed provided there is vehicular access. Jan 21, 2020 Tornado in Manzanita this was a test of the system 200-300 trees lost. Previous tornado occurred October 14, 2016	Reduce hazards to life, businesses, property, and environmental systems	CM	PW	City/FEMA
Establish a regional cooperative GIS system for utilities and for enhancing activities and communication of response teams. Focus in areas of greatest need.	Progressing	Short Term 1-3 years		Success Story: City of Manzanita, NBWA, Nehakahnie Water District, TPUD, have their own GIS systems. Data sharing to be completed in 2023.	Reduce hazards to life, businesses, property, and environmental systems	Nehalem Bay Community Emergency Preparedness Forum	Cities of Manzanita, Nehalem, and Wheeler	FEMA/City/NBWA
Review and update Community Wildfire Protection Plan (CWPP).	Retain	Short Term 1-3 years		City EM will be receiving training on formulation and implementation in 2023. Public education and city policy is set for the 2024 season. EM will be working with NBFRD.	Reduce hazards to life, businesses, property, and environmental systems	CM/NBFRD	CC	NBFRD/City/OEM/FEMA/OSFM
Implement strategies from the CWPP for wildfire safety.	Retain	Short Term 1-3 years			Reduce hazards to life, businesses, property, and environmental systems	CM/NBFRD	CC	NBFRD/City/OEM/FEMA/OSFM

Table 111. City of Nehalem Mitigation Actions - 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description - Nehalem	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue working with EVCNB to store supplies and emergency equipment	Complete			A pallet of supplies is stored to be ready for use in an emergency.	Enhance emergency services and local first responders	City Manager	PW	CIty
Continue purchasing yellow emergency radios for ham operators with EVCNB	Completed			Yellow emergency radios were purchased for all staff.	Enhance emergency services and local first responders	City Manager		CIty
Complete wayfinding project.	Completed			Wayfinding signs were installed in the city that included installation of tsunami evacuation route signs at both public docks and the downtown parking lot.	Reduce hazards to life, businesses, property, and environmental systems	CM	PW	CIty
Continue maintaining 11-acre wetland for conservation and hazard mitigation in perpetuity.	Completed			Property is restricted from development in perpetuity.	Reduce hazards to life, businesses, property, and environmental systems	CM	PW	CIty
Provide tsunami evacuation map to short-term rental applicants.	Ongoing	n/a	High	New short-term rental regulations were recently adopted that require property owners to post a tsunami evacuation map in the short-term rental and provide emergency go-bags.	Reduce hazards to life, businesses, property, and environmental systems	City Manager	–	City/FEMA
Continue to provide brochures about flood insurance and flyers about natural hazards to educate and provide outreach to residents and tourists.	Ongoing	n/a		Flood insurance brochures are provided as part of outreach for the CRS program. They are distributed to anyone who inquires and the information is posted on the city website. Flyers regarding natural hazards are available at City Hall and are posted on the city website. Links to evcnb.org and other resources are available on the website. Tsunami evacuation maps are available at City Hall.	Reduce hazards to life, businesses, property, and environmental systems	City Manager/Deputy City Recorder	–	CIty
Continue to encourage citizens to purchase yellow emergency radios with EVCNB	Ongoing	n/a		Local citizens were contacted and encouraged to participate in program. EVCNB provides an annual update at City Council meeting.	Enhance emergency services and local first responders	City Manager		CIty

Mitigation Action Description - Nehalem	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue supporting work with EVCNB to implement all Goal 3 mitigation actions to enhance emergency services and to support local first responders.	Ongoing	n/a		EVCNB is supported financially by the city with an annual contribution.	Enhance emergency services and local first responders	City Manager	Deputy City Recorder	CIty
Include information about flood insurance on water bills once each year.	Ongoing	n/a		This was completed in 2017 and is done annually to educate the public about flood information.	Reduce hazards to life, businesses, property, and environmental systems	Deputy City Recorder	City Manager	City
Support EVCNB in development of mass casualty and shelter plan.	Progressing		High	Attendance at the Able Readiness 1 exercise held in Manzanita by EVCNB and OR Dept of Human Services was part of the progress made on this action item. Funding for caches is still needed to implement the mass casualty/shelter plan.	Enhance emergency services and local first responders	EVCNB	City	ODHS
Public Works Building	New Action		High	A new Public Works Building will be constructed and located outside of the SFHA to the extent possible.		City Manager	PW	FEMA grant (connect CM with SHMO), Timber fund, Business Oregon
Purchase and train on use of mobile communication equipment as recommended by EVCNB.	New Action		Medium			City Manager/Deputy City Recorder	EVCNB	Grant to be identified

Table 112. City of Rockaway Beach Mitigation Actions – 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description – Rockaway Beach	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Consider purchasing emergency radios for staff and for sale to the public.	Complete			Radios purchase in about 2018; Community Response Team have locations in town and want to communicate among each other.	Enhance emergency services and local first responders	City	–	City/Grants
Maintain a link to FEMA's flood hazard mitigation information on the City's website.	Ongoing			Links to flood hazard mitigation information is posted on the city's new website.	Reduce hazards to life, businesses, property, and environmental systems	City	–	City
Budget for professional assistance as necessary for preparing the applications.; budget for this every year.	Ongoing				Enhance emergency services and local first responders	City	–	City
Manage the Nature Preserve for conservation and natural hazards mitigation in perpetuity.	Ongoing			During the past planning period the City of Rockaway Beach improved the 50 acre site by spending $2 million to install a raised boardwalk trail.	Reduce hazards to life, businesses, property, and environmental systems	City	–	City/OPDR Trails Grant
Continue to be NIMSCAST compliant.	Ongoing	1-3 years		Federal training	Enhance emergency services and local first responders	City	Fire Dept.	City/FEMA
Continue to send key players to FEMA/ICS classes and training.	Ongoing	1-3 years			Enhance emergency services and local first responders	City	Fire Dept.	City/FEMA
Help reorganize and re-start operation of our Emergency Volunteer Feeding Group (EVFG). This will be accomplished through the Emergency Preparedness Team already in place.	Ongoing	1-3 years		Emergency Preparedness team is doing this.	Enhance emergency services and local first responders	Emergency Preparedness Team and EVFG	City	City/EVFG/ Grants
A City Emergency Preparedness Team has been established. It will continue to meet regularly.	Ongoing; Revised	1-3 years		Emergency Preparedness team meets twice per month	Enhance emergency services and local first responders	City	CERT	City/Grants
Publish information in the city newsletter with flood hazard mitigation information each fall.	Retain; revised	1-3 years		This action was revised to identify the city newsletter as the vehicle for flood hazard mitigation information.	Reduce hazards to life, businesses, property, and environmental systems	City	DLCD	City/FEMA

Mitigation Action Description – Rockaway Beach	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue to draft an Emergency Operations Plan.	Ongoing	Short Term; 1-3 years			Enhance emergency services and local first responders	City	–	City/FEMA
Hire an Emergency Manager for the City.	Retain	Short Term (1-3 years)	Medium	No need yet identified by the city council or the city manager.	Improve regional coordination and communication	City	–	City
Consider executing the EVCNB survey or similar in Rockaway Beach.	Retain	Short Term (1-3 years)		The City Emergency Preparedness Team is working with the EVCNB.	Improve regional coordination and communication	City	–	City/Grants/ Universities
Prepare applications for mitigation projects to be ready when funding becomes available.	Retain	Short Term (1-3 years)			Enhance emergency services and local first responders	City	OEM/DLCD	City
Restock supply and return to selling Life Straws.	Retain; revised	Short Term (1-3 years)		The city sold them for a long time but are no longer doing it. Retain this action and restock the Life Straws to begin this action again.	Enhance emergency services and local first responders	City	–	City
Hold a table top exercise for a full-scale citywide evacuation drill every October in conjunction with Earthquake Awareness Month or the Great Oregon Shake-Out.	Retain; Revised	Medium Term (3-5 years)		This exercise has not been done during the planning period 2017 to present.	Reduce hazards to life, businesses, property, and environmental systems	CERT	City	City
Build a Communication Hub in Rockaway	New Action	Medium Term (3-5 years)				County	City	County/City
Build a “Public Safety Assembly Facility.”	Progressing	Long Term (>5 years)		**Success Story:** The first phase of achieving this has been to identify a location to relocate facilities to. An agreement has been reached by the city to purchase a 10-acre site for relocation of the Fire Department and Public Works and to establish a Communication Center where fuel and equipment can be located outside the floodplain and the tsunami zone. The City of Rockaway Beach succeeded in moving the UGB to include the identified relocation site and rezoned it as a Public Facility zone.	Reduce hazards to life, businesses, property, and environmental systems	City	–	City/Grants

Table 113. City of Tillamook Mitigation Actions – 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description - Tillamook	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Construct a ground-level reservoir tank.	Completed			PW Director indicated that the project is progressing.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook		City/FEMA
Develop 6-Day Storage Reserve for Disaster Preparedness.	Completed as written in 2017; New Action added to expand storage volume.			**Success Story:** After completing a water storage reserve that would provide 3-days of city water use, the Public Works Director and City Planner agree that a 6-day water storage reserve would be more protective of residents given the likely extent of a CSZ event.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	TSD 9/ FEMA	City/FEMA
Evaluate City Capital Improvement Plan.	Progressing			This is work currently underway; the CIP was being developed in June 2022. Some Capital Improvement projects are being drawn from the Wastewater Master Plan which identifies projects that need to be done; the wastewater pump station was at capacity in 2014; wastewater can back up into manholes making wastewater capital improvement projects a high priority for the CIP.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	–	City
Broaden methods for informing the public about how to be disaster-ready and self-reliant by using social media and the city's website to promote awareness about natural hazards and how to be prepared for them.	Ongoing			Maintain methods including flood focused letters and broaden methods used vary methods of communication.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	EVCNB, OEM, DLCD, ODFR - Insurance	City
Participate in the update of Tillamook County's Emergency Operations Plan.	Ongoing			Table top exercises and other emergency operations plan activities happen yearly.	Enhance emergency services and local first responders	City of Tillamook Police Dept.	Tillamook County EM	City
Coordinate with Tillamook County to ensure there is emergency radio equipment to provide continued, uninterrupted intra- and interagency communication during periods of emergency in/around the airport, industrial park complex and community, and maintain this emergency radio communication system equipment.	Ongoing; Revised			The action description was revised to reflect the city's role in supporting continued maintenance.	Enhance emergency services and local first responders	Tillamook County Emergency Mgmt.	City of Tillamook, Port of Tillamook Bay	City/POTB

Mitigation Action Description - Tillamook	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Relocation of Water Transmission Line - In cooperation with the POTB, the City will examine the relocation of the City's main water transmission line that currently runs under the Tillamook Municipal Airport and needs to be repaired to provide a functional water source in case of disaster.	Progressing				Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	POTB/ FEMA	City/FEMA
Complete repairs to tidegate on Dougherty Slough near Hadley Road North. The city is actively working on the slough near Hadley Rd. North to repare a tide gate that impedes flow in the slough.	Progressing	3-5 years	Medium Priority	Completion of this repair will improve flow within the slough and mitigate nuisance flooding that backs up onto U.S. Highway 101.				
Retrofit or replace school buildings to be earthquake resistant.	Retain			Some school facility seismic retrofits or replacements have been accomplished since the 2016 plan update. Although the school district would be the lead for this work, the City of Tillamook will support further siesmic retrofits or replacements for the school district. Tillamook Jr High is the next facility that the school district intends to focus on with respect to sesimic retrofitting or facility replacement.	Reduce hazards to life, businesses, property, and environmental systems	TSD 9	City of Tillamook, OEM	FEMA/OEM/TSD 9
Obtain generators for the school buildings to provide electricity, especially for the kitchen facilities.	Retain			Although the school district would be the lead for this work, the City of Tillamook will support proposals to obtain emergency power supplies for school facilities.	Reduce hazards to life, businesses, property, and environmental systems	TSD 9	City of Tillamook, FEMA	FEMA/OEM/TSD 9
Develop a sewer line connection with the POTB wastewater treatment plant.	Retain			There are two purposes for this project: general health, safety, welfare of the city's citizens and hazard mitigation to provide functional sewer connection to the POTB in case of disaster. The City of Tillamook Public Works Director believes this would be beneficial to both POTB and the City of Tillamook.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	POTB	City/POTB/ FEMA
Develop a post-disaster recovery plan and implementing code.	Retain				Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	OEM/DLCD	City/OEM/DLCD

Mitigation Action Description - Tillamook	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Preserve natural areas related to flooding through land use regulation, conservation easements, and buyouts where appropriate. Plan for maintainance of city-controlled natural areas that provide flood storage and mitigation.	Retain; Revised			Action description was revised to "preserve wetland and floodplain areas" Currently, FIRMs and the LWI are used to determine which areas are flood/wetland. Updating these maps is a long-term goal of the City Planner.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	FEMA	FEMA (NFIP)
Promote elevation of structures located on North Main Ave and within the southwest corridor.	Retain; Revised			The City of Tillamook promotes elevation of structures rather than buyouts to mitigate frequently flooded properties. If there is a block of properties that would benefit from elevation, perhaps FEMA funding for the group of properties identified would be way to accomplish this.	Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	FEMA	FEMA (NFIP)
Revise Floodplain Management Regulations	New Action				Reduce hazards to life, businesses, property, and environmental systems			
Revise Wetland Inventory in order to slow down and retain water to mitigate flooding	New Action				Reduce hazards to life, businesses, property, and environmental systems			DLCD Technical Assistance Grant
Improve the infrastructure in Holden Creek. Not active here. Mostly outside city limits; culverts under city jurisdiction; tide gate repair has to happen first (Long Term/Low Priority)	New Action			Infrastructure conveying Holden Creek includes culverts, one that slopes, and tide gates in the wrong places. The city is not actively working on these improvements as this project will likely require Salmon Superhighway recognition and funding. The project would be a collaboration with Tillamook County as it relies on moving a downstream tide gate located outside the city limits to improve drainage from the creek and open it up to salmon.	Reduce hazards to life, businesses, property, and environmental systems		Tillamook County, Salmon Super Highway	
Explore alternate siting for the hospital which is located partially in the tsunami inundation zone.	New Action			Initial ideas about where to relocate the hospital include the mill property or making room on the fairgrounds to allow the hospital to be located next to the community college where it could support the school's nursing program.				

Mitigation Action Description - Tillamook	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Develop options for tsunami warning systems, potentially including sirens	New Action			Sirens were mandated at one time, but some communities have dismantled theirs. The City of Tillamook no longer has these sirens, but the City of Rockaway still has theirs.				

Table 114. City of Wheeler Mitigation Actions – 2023

KEY: green highlight =complete, peach highlight=Active project now

Mitigation Action Description - Wheeler	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
DOGAMI, FEMA, and DLCD are creating new Risk Maps and Flood Maps using lidar. The City received the Preliminary maps, distributed as of 12/9/2106. Meetings are scheduled for April 2017 which will be followed by a 90 day appeal period.	Complete				Reduce hazards to life, businesses, property, and environmental systems	Wheeler	FEMA/ DLCD/ DOGAMI	FEMA
City will continue to update the Water Master Plan as required or as necessary.	Completed			Adopted in 2015; current; updates 7-10 years;	Develop and implement effective mitigation initiatives, projects, and activities to reduce hazards to life, businesses, property, and environmental systems.	Wheeler	–	Wheeler

Mitigation Action Description - Wheeler	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Establish evacuation routes above inundation zone, alternate to US-101.	Complete; Gates are in place and keys are in city hands; Emergency team informs city residents about this.			Establish evacuation routes along the Stimson logging roads above Wheeler. Stimson is requiring that a gravel base be laid down. Estimated cost: $4,500 for gravel. Completed central Wheeler access, but maintenance is an ongoing burden due to difficulty of access for maintenance by City equipment. South Wheeler access is accessible and maintained. North Wheeler access is currently unavailable and further development needs to be addressed with Stimson logging. Ongoing access to 3rd. St. easement must be maintained as well. This access is also compromised by difficulty to access by City maintenance equipment.	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	DOGAMI, OEM, Stimson Lumber	
Participate in the Countywide Hazard Mitigation Steering Committee.	Ongoing	n/a	n/a		Improve regional coordination and communication	Wheeler	–	Wheeler
Continue active participation with the Emergency Volunteer Corps of Nehalem Bay (EVCNB to develop response plans for potential hazards.	Ongoing; Revised	n/a	n/a	Comment was "collaborate with EVCNB" Suggest revision to identify the collaboration with the EVCNB as the ongoing action. There isn't an active regional Emergency Preparedness Committee at this time.	Improve regional coordination and communication	Wheeler	–	Wheeler
Strengthen emergency operations through improvements to communication and coordination such as: (a) acquisition and instillation of a repeater; (b) acquisition of backup power equipment; (c) acquisition of appropriate ancillary equipment; (d) updating of emergency operations plans (as necessary).	Mostly complete. Still need to acquire and install the repeater	Short Term (1-3 years)	High	a) Not sure will circle back b) Some; back up generators and solar panels acquired; mobile gas generators; c) Trailers equipped with solar panels; located in upper park d) emergency volunteers have updated eop; will circle back with this	Enhance emergency services and local first responders	Wheeler	–	Wheeler, FEMA

Mitigation Action Description - Wheeler	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Emergency Access Paving.	Partially Complete; Paving of 1st street to Hemlock is done; also 3rd street	Long Term (>5 years)	Med-Low	Establish access along paved portions of Wheeler street inventory for emergency evacuation and emergency response staging. The City of Wheeler has received a paving grant from ODOT to provide paving to 1st St. between Hwy 101 and Hemlock for North end evacuation. The city has also received paving funding to create access, parking, and staging areas at Wheeler Upper Park as this is the designated gathering point following a natural disaster. This will allow the city to consolidate supplies and recovery efforts. Additionally, the City will pave 3rd. St. between Hemlock and Cedar St. with ODOT paving funds as this will maintain the primary thoroughfare from Central to North Wheeler.	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	ODOT/ EVCNB	ODOT Small City Allottment grant, didn't go forward due to interest in funding repairs to already paved roads that access services OSFM, OEM/FEMA
Replace Gervais Creek Drainage.	Progressing	Medium Term (3-5 years)	High	The diversion of Gervais Creek to a 36" pipe (Current Stormwater System Gervais Creek) is reported to have been completed in the early 1900s. The pipe passes under developed properties and the business core of downtown Wheeler. Documented occurrences of flooding of at least one building of the business core has been recorded for the following periods: 1982, December 1994, January 1995, 1996, November 2000, January 2001, December 2002, February 2003, December 2007, and December 2015. It should be noted that these flooding events typically cause heavy damage to a number of buildings, both commercial and residential. Gervais Creek also has the potential to flood the east part of the business core if the intake structure is obstructed or if stream flows exceed the hydraulic capacity of the 36" line. The project is in an effort to reroute Gervais Creek (Drainage of Basin G2) under an existing city street, Rorvik St., state highway US-101, railroad right of way, and city park with an outfall into the Lower Nehalem Watershed (Proposed drainage of Basin G2). The work and location of the pipe would be located toward the center of Rorvik St. to avoid sidewalks and utilities, which reduces construction cost. This would also keep the project from having a direct impact on any existing structures. The proposed project will alleviate these hazards by mitigating storm events in meeting minimum hydraulic requirements of the system. Engineering has been done; in 2022 Mary was going before council to authorize application for an FEMA grant and a BRIC sub application has been submitted for construction. Wheeler meets the threshold for a Low to mod income community making it eligible for a 90/10 cost share. Business Oregon may provide the 10%	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	EVCNB/ Tillamook County/ NBFR	FEMA

Mitigation Action Description - Wheeler	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue to review utilization and evaluation of ordinances that reduce potential for hazards.	Current project	Short Term (1-3 years)	High	Geohazard report is currently required for grading; addresses stormwater, foundation. In 2022 The city was in the process of updating its development code, funded by a grant through DLCD.	Develop and implement effective mitigation initiatives, projects, and activities to reduce hazards to life, businesses, property, and environmental systems.	Wheeler	DLCD	Wheeler
Put together a handbook for new residents about evacuation routes and provide HELP/OK signs for use in emergency recovery efforts.	New Action	Short Term (1-3 years)	Med-Low					CTP
Develop a streets inventory to include information on ROW; access, paper roads, location of hydrants and emergency access routes	New Action; Underway with new PW Director	Short Term (1-3 years)	Medium-High	Such an inventory could also assist in tracking needed repairs and stormwater infrastructure, topics mentioned in other mitigation actions.		PW		City funds already allocated for PW
Re-route Zimmerman Creek.	Not yet started	Medium Term (3-5 years)	High	Zimmerman Creek is currently routed under a residential neighborhood in Wheeler and has contributed to two separate instances of roadway failure on Hemlock St. as inventoried during disaster event DR 1672 – OR and DR – 4258 – OR.	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	Nehalem Land Conservancy, EVCNB	Wheeler, FEMA
Develop a maintenance schedule and inventory lists for city infrastructure equipment used in preparing for and addressing the effects of natural hazards.	Retain	Short Term (1-3 years)	Medium-High	May have fallen by the wayside; may need to reconstitute all except the master plan inventory (equip and life expectancy, cost to replace; needed equipment for future needs) The city has a list of maintenance schedules and inventory for maintaining many of the systems within the infrastructure. These schedules are very helpful and are updated regularly. These lists include equipment lists, repair parts, water system inventory list and master plan inventory, and stormwater master plan inventory. The city maintains these lists and continually updates them as appropriate. These lists are kept as a separate inventory from this Hazard Mitigation Plan.	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	–	Wheeler

Mitigation Action Description - Wheeler	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Repair Hemlock Street.	Retain	Medium Term (3-5 years)	High	Inundated by rain in disaster event DR – 4258 – OR, Hemlock St. experienced surface cracking and degradation due to stormwater surplus overflow from the adjacent drainage that undercut the roadway. The City of Wheeler has applied for and received approval for FEMA Public Assistance funding to provide 75% of the repair cost. Springs and rainfall causing slide that disconnected pipe from main; emerg repair work was completed, but not done "deeply enough" Hemlock still needs work; re-engineering needed; needs more stabilization; gabion, storm drains needed; The underlying issues still need to be addressed. Emergency need now following winter 2022-23.	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	FEMA	Wheeler, ODOT SCA grant, FEMA
Update the Storm Water Master Plan.	Retain; Revised	Short Term (1-3 years)	Medium	The City is on constant vigilance with monitoring, maintenance, and repairs in the existing stormwater drainage system as the City is situated on the east side of the Nehalem Bay and is surrounded by hillsides that extend upwards approximately 1,300 feet in elevation and include a drainage area of 4,400 acres. Many of the streets lack sufficient surface curvature or crown to direct water effectively to a suitable ditch or intake. Rainfall sheets directly down roadways in many places. In some gravel roadways, the sheeting has eroded channels on the surface itself. The City of Wheeler has a Stormwater Master Plan that was produced by HGE Inc. which included extensive field work in winter and spring of 2005 to locate and document existing culverts and other stormwater related problems and infrastructure. A detailed list of capital improvements was generated identifying and prioritizing projects. Detailed mapping was prepared to show locations of existing physical features, drainage basins, general drainage flow patterns, and storm water infrastructure. The city budgets for these improvements each year and completes the high priority projects as budget allows. Plan adopted in 2005 and 5$/mo utility fee has been collected, but funds have not been used for the high priority projects; need new revenues to do these; 2005 plan needs review	Reduce hazards to life, businesses, property, and environmental systems	Wheeler	EVCNB	Wheeler, Grants

Table 115. Port of Tillamook Bay Mitigation Actions - 2023

Mitigation Action Description - POTB	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
POTB Emergency Operations Plan (Update as needed).	Ongoing	n/a	n/a		Enhance emergency services and local first responders	POTB	Stakeholders	POTB
Update of the Tillamook Municipal Airport Response Plan. Also identifies the Airport as an emergency fuel up spot for the Coast Guard and other agencies.	Ongoing	n/a	n/a		Enhance emergency services and local first responders	POTB	FAA	POTB/FAA
Participate in countywide Hazard Mitigation Steering Committee meetings, etc.	Ongoing	n/a	n/a		Improve regional coordination and communication.	POTB	–	POTB
Participate in planning meetings for hazard training events.	Ongoing	n/a	n/a		Improve regional coordination and communication.	POTB	–	POTB
Establish secondary ingress/egress at the industrial park.					Reduce hazards to life, businesses, property, and environmental systems	POTB	ODOT, FHWA, Tillamook County	Road Maintenance Fees
City of Tillamook water transmission line relocation. In cooperation with the City of Tillamook, this project would examine the relocation of its main water transmission line that currently runs underneath the Tillamook Municipal Airport to a more viable location along POTB's outside property boundary.					Reduce hazards to life, businesses, property, and environmental systems	City of Tillamook	POTB/ODOT	City of Tillamook/POTB to provide or revise easements
Emergency Drop Location. Worked with Tillamook County Health Department to identify the Tillamook Municipal Airport as an emergency drop location site for medical supplies.					Enhance emergency services and local first responders	Tillamook County Health Dept.	POTB/ Tillamook County Emergency Mgmt.	Tillamook County, POTB
Provide for needed improvements to Hangar B, a Nationally registered structure that houses the Tillamook Air Museum and other clients.	Progressing			Port continues to explore funding to complete improvements to the structure. POTB has a new condition assessment for Hangar B from December 2022	Reduce hazards to life, businesses, property, and environmental systems	POTB	Oregon Heritage Commission	Grants, Donations

Mitigation Action Description - POTB	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Community Points of Distribution (C-PODS). Worked with Tillamook County Emergency Management to identify the Tillamook Municipal Airport as a C-POD during periods of emergency.	Progressing			There is a pending MOA/IGA between the Port and ODHS to locate four Conex boxes/C-PODs at the Tillamook Airport	Enhance emergency services and local first responders	Port of Tillamook Bay	Tillamook County Emergency Management, Oregon Department of Human Services, Office of Resilience and Emergency Management	Tillamook County, POTB
Emergency Radio Communication System Upgrades. Acquisition of updated radio equipment to provide continued, uninterrupted intra- and interagency communication during periods of emergency in/around the airport, industrial park complex and community.	Progressing				Enhance emergency services and local first responders	POTB	City of Tillamook, Near Space Corp.	POTB, other non-federal sources
Provide for multiple Tillamook Municipal Airport improvements through continued participation in the FAA's Airport Improvement Program (AIP) to maintain adequate, uninterrupted airport service to the community. One such project is the replacement of a culvert adjacent to Long Prairie Road to mitigate recurrent floodwaters from the Trask River that may impede/block travel.	Retain			Another improvement identified during the 2022-23 NHMP update was the need to potentially raise the road to provide continuous access to the airport.	Reduce hazards to life, businesses, property, and environmental systems	POTB	FAA/ODA	FAA AIP (Revolving) Funds; Grants
Continue to support Tillamook County, the Port of Garibaldi and other stakeholders to obtain funding to undertake needed repairs to the South Jetty, which is located within Port's (northernmost) district boundary and is part of the primary entrance/exit to/from Tillamook Bay to the Pacific Ocean.	Retain				Reduce hazards to life, businesses, property, and environmental systems	Tillamook County	POTB/ Port of Garibaldi	Federal Appropriations Request

Mitigation Action Description - POTB	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Cooperate with stakeholders to establish a bovine mortality disposal facility in Tillamook County.	Retain				Reduce hazards to life, businesses, property, and environmental systems	TCCA	POTB/ ODA/ DEQ/ Tillamook Farming Comm./ TCoDCD/ TCo Emer. Mgmt.	Local, State, and Federal sources
Regional Water System Development: Develop Port's municipal water rights to provide independent water system to mitigate unanticipated interruption of water supply to Port's water users, as well as a regional approach to include and augment current water supply and infrastructure.	New Action			Most smaller districts have completed or are in process of completing condition assessments or master plans with support from the State. The City is out for RFP for engineering services for their City Water Line Re-route project. The Port is nearing completion of a supply/well development plan. These plans, when combined, will be the foundation for larger strategy for supply and interconnectivity between water users.		Port of Tillamook Bay, City of Tillamook, Special Districts Association, Long Prairie Water District	Adjacent Water Districts, OBDD	DEQ Clean Water; Business Oregon is supportive; Considering developing a regional water agency for cities and other water users
Replace POTB Stormwater system: the bulk of the Port's stormwater system was developed during WWII. A creek was re-routed to develop the airport runways. This created an issue with the Port's stormwater piping that is top-perforated, allowing groundwater to seep in, and impact the Port's DEQ permit, as well as potentially impact the water quality of the water that travels from the Port to Anderson Creek to Tillamook River to Tillamook Bay.	New Action	Long Term: > 5 years				Port of Tillamook Bay	Oregon DEQ, Oregon Department of Aviation, FAA	

Mitigation Action Description - POTB	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Fuel System Upgrade at Airport: redesign and replace/upgrade the fuel system at the airport with newer, larger fuel tanks for 100LL and Jet Fuel. Includes covered facility with solar power backup and/or generator, and fire suppression system. Also add a tank for additional fuel storage during fire season to assist Oregon Department of Forestry with airside support.	New Action	Medium Term: 3-5 years	High	High priority now due to fires and resulting smoke; looking to add solar power as a option for pumps; funding possibly through Dept of Aviation; for solar Dept of Energy; Jet A – POTB is the only source in the area. Added to the Port's CIP with the FAA (pending approval) for the 2028 FFY		Port of Tillamook Bay	ODF, ODOE, Tillamook County Emergency Management	
Main Office Retrofit: Retrofit the Port's main office with a generator, HVAC closure during fire/smoke/ash events, and with upgraded air conditioning for heat events.	New Action							
Fire Suppression service upgrades	New Action			Provide fire suppression service upgrades at the Tillamook Municipal Airport. Update to new Fire Marshal regulations for T-Hangars and fuel system fire suppression. OSFM required a new type of fire suppression methodology recently. This project might be included in a fuel system upgrade.				

Table 116. Port of Garibaldi Mitigation Actions - 2023

Mitigation Action Description - POG	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue to lobby for and support USACE funding to repair the Tillamook Bay South Jetty and push for continued support of entire jetty system.	Ongoing		High	Initial specifications estimated $40 million; now estimated at $62 million.	Reduce hazards to life, businesses, property, and environmental systems	POG	Tillamook County/ USACE, OPPA/ PNWA	USACE
Continue insuring boat/mooring basin and entrance channels are kept dredged and free from hazards to navigation.	Ongoing		High	POG is responsible for dredging the boat basin and owns submerged lands. The channel is USACE responsibility.	Reduce hazards to life, businesses, property, and environmental systems	POG (Boat Basin)/ USACE (Channel)	OSMB/ DSL	POG/USACE/ OSMB
Construct a seawall that would divert sediment into the channel and that would protect from storm surge.	New Action		High	Sediment comes down the Miami River and impedes navigation.				
Install break wall to protect boat/mooring basin from storm surge, excess sediment deposit, and tsunami surge.			High	**Is this the same as the New Action listed above** (install seawall that would divert sediment into the channel and that would protect from storm surge)? If not, what is the difference?	Reduce hazards to life, businesses, property, and environmental systems	POG	FEMA/ OSMB, DSL, USACE, FEMA	FEMA/OSMB/ EDA
Re-enforce mooring basin road sea wall to prevent undermining and erosion and to stabilize mooring basin road and boat basin from collapse.			High	Connecting the permitting with the final engineering is tricky. The Port can't afford to take the risk that the whole project would not be funded, so the Port intends to ask for engineering and construction all in one package. Basic engineering has been completed. The project requires $2.4 million to get to shovel ready status. Construction estimated at $20 million. Issues include the structure being undermined by erosion and that it is old, not seismically resilient. Storm surge and high tides cause concern and result in a need to reinforce with riprap.	Reduce hazards to life, businesses, property, and environmental systems	POG	ODOT/ City of Garibaldi/ USDOT/ OSMB	ODOT, USDOT
Replace 50-year-old timber commercial loading wharf with seismically stable concrete structure.				1st half of wharf replacement completed in 2015.	Reduce hazards to life, businesses, property, and post disaster recovery	POG		USDOT, MARAD, FEMA, USDA

Mitigation Action Description - POG	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Continue working with local vessel owners to create network of individuals to assist in catching fish and crab to assist feeding population during post event recovery period.				Still an interest but need to connect more with fishers about the project. The priority level is lower than it was given other higher priority work.	Enhance emergency services and local first responders	POG	Fishing community	EDA
Replace wooden loading pier with seismically engineered structure to serve as primary unloading platform for county disaster relief from ocean access.	Retain			Co-located with helicopter pad and coast guard, ideal for evacuation.	Reduce hazards to life, businesses, property, and environmental systems	POG	EDA/ Business Oregon	EDA/FEMA/ Business Oregon
Continue to develop post event Port of Garibaldi restoration of operations and return of services plan.			Medium		Reduce hazards to life, businesses, property, and environmental systems	POG	USCG, Business Owners	POG
Continue to support and coordinate with the City of Garibaldi on development of its Emergency Operations Plan.			Medium		Improve regional coordination and communication	City of Garibaldi	POG	City of Garibaldi/POG
Investigate, procure, and strategically stage equipment to help restore critical function following a disaster.			Medium		Reduce hazards to life, businesses, property, and environmental systems	POG	USCG, Utilities, Business Owners	POG/State of Oregon/Local Governments/ NGOs/ Businesses/ Other Stakeholders
Research feasibility of constructing tsunami safe structure for evacuation safety.			Low		Reduce hazards to life, businesses, property, and environmental systems	POG	DOGAMI, OEM, Oregon Building Codes Division	POG/FEMA/ OEM
Reinforce the Port shop and office so that they are seismically resilient	New Action		Medium		Reduce hazards to life, businesses, property, and environmental systems	POG		
Work with Garibaldi FD and other jurisdictions in the northern part of the county to develop a regional command center outside of the tsunami zone.	New Action			Collaborate with the Garibaldi Fire Department on this action.	Improve regional coordination and communication			

Table 117. Nestucca Valley School District Mitigation Actions - 2023

Mitigation Action Description - NVSD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Purchase supplies for use in a situation that requires establishing a shelter at the schools. This would include items like bedding, food provision and water. Both the K8 Building and the High School would need supplies.	New Action			Discussion to determine what sorts of actions need to occur to be able to accommodate those needing shelter; Developing network of contacts to effectuate the shelter	Reduce hazards to life, businesses, property, and environmental systems	School District	County Sheriff, County Public Works Dept., State Police, US Coast Guard, State Hazard Mitigation Officer; County Emergency Manager; STEVC	

Table 118. Nehalem Bay Fire and Rescue District Mitigation Actions - 2023

Mitigation Action Description - NBFRD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Tie Shake Alert into station to open bay doors.	New Action	Short Term; (1-3 years)		Underway; contact made between the district and Shake Alert	Reduce hazards to life, businesses, property, and environmental systems	District	Shake Alert system	
Develop solar energy sources on both the main station and the substation	New Action	Short Term; (1-3 years)		Current grant sub application for main station is in preparation; would like to add the substation in future grant rounds	Reduce hazards to life, businesses, property, and environmental systems	District	TPUD involved; led by District	
Develop a satellite communication system for the district using satellite phones and Starlink.	New Action	Short Term; (1-3 years)	Top concern	See above; District, cities and county could be involved; interoperability is key to resilience	Improve regional coordination and communication	District	District, cities and county	
Convince homeowners to include defensible space on private property; education	New Action	Ongoing		Conflicts between regulations and the objectives of defensible space; regarding construction materials HOAs may require materials that are flammable e.g. shake roofs; advocate residential sprinklers more costly for a retrofit; Dollars would help to add staff part time community specialist	Reduce hazards to life, businesses, property, and environmental systems	District	HOAs, State Fire Marshall; EVCNB	

Mitigation Action Description - NBFRD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Develop a program to improve private road access for rural homes	New Action	Long term; (>5 years)		This is a problem that is difficult for an individual to rectify; funding for assisting with the expansion of the road, tree trimming or reinforcing the base with gravel; staff to administer this sort of program would be key; Collaborate with Stimpson and Weyerhaeuser; just built a 7-mile-long road to improve access through as secondary route	Reduce hazards to life, businesses, property, and environmental systems	District	Stimpson and Weyerhauser lumber companies	

Table 119. Tillamook People's Utility District Mitigation Actions - 2023

Mitigation Action Description -TPUD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Underground Main Power Lines through Garibaldi	New Action	Short Term; 1-3 years; Target completion: 12/2024	High	Progress to date: 5% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages	Reduce hazards to life, businesses, property, and environmental systems	TPUD	City of Tillamook, ODOT	BRIC, FEEA, RUS
Undergrounding main power lines up state route 53 through heavily forested area	New Action	Short Term; 1-3 years; Target completion: 9/2025	Medium	Progress to date: 5% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents, Fish Hatchery	BRIC, FEEA, RUS
Maintenance of Right-of-Way, clearing of debris, tree removal, tree trimming	New Action; Ongoing	Annual	High	Progress to date: 50% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, County, ODF, Local residents	BRIC, FEEA, RUS

Mitigation Action Description -TPUD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Undergrounding main power lines up state route 6 through heavily forested area	New Action	Long Term; >5 years; Target completion: 12/2028	High	Progress to date: 20% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents, State Patrol, County Sheriff (2 radio repeater towers)	BRIC, FEEA, RUS
Undergrounding tap power line to radio tower through heavily forested area	New Action	Short Term; 1-3 years; Target completion: 9/2024	High	Progress to date: 5% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents, State Patrol, County Sheriff (2 radio repeater towers)	BRIC, FEEA, RUS
Undergrounding main power lines in Oceanside (2 locations) through heavily forested area	New Action	Short Term; 1-3 years; Target completion: 6/2024	High	Progress to date: 10% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents, wastewater treatment plant	BRIC, FEEA, RUS
Hebo Substation Relocation out of Flood Zone	New Action	Medium Term; 3-5 years; Target completion: 10/2026	Medium	Progress to date: 2% Design 0% Construction Purpose is resiliency during windstorms, flood	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODF, local residents	BRIC, FEEA, RUS

Mitigation Action Description -TPUD	2023 Status	2023 Timeframe	2023 Priority	2023 Notes or Revisions	Goal Addressed	Leads	Supporters	Actual or Potential Funding Sources
Undergrounding of main power line from Hwy 101 and Slab Creek Road through heavily forested area	New Action	Short Term; 1-3 years; Target completion: 6/2025	Medium	Progress to date: 0% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, County, ODF, Local residents	BRIC, FEEA, RUS
Beaver Feeder 25 - relocate overhead line out of streams and underground along state Hwy	New Action	Medium Term; 3-5 years; Target completion: 10/27	Low	Progress to date: 5% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents, ODF	BRIC, FEEA, RUS
Undergrounding main power lines along Hobsonville Road and US Hwy 101 through heavily forested area	New Action	Short Term; 1-3 years; Target completion: 12/2025	High	Progress to date: 20% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages, fire	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents,	BRIC, FEEA, RUS
Underground power line along State Hwy 22 south of Hebo	New Action	Short Term; 1-3 years; Target completion: 9/2025	Low	Progress to date: 10% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages	Reduce hazards to life, businesses, property, and environmental systems	TPUD	ODOT, local residents,	BRIC, FEEA, RUS
Underground power line in Nescove Drive through heavily treed area	New Action	Short Term; 1-3 years; Target completion: 3/2024	Low	Progress to date: 10% Design 0% Construction Purpose is resiliency during windstorms, winter storms, outages	Reduce hazards to life, businesses, property, and environmental systems	TPUD	Local residents, local water utility district	BRIC, FEEA, RUS

D. Integration

To achieve risk reduction, it is necessary to consider natural hazards mitigation in jurisdictional planning processes, from land use to infrastructure to emergency response. Every advance in mitigation reduces impact, decreasing the need for response and recovery and increasing resilience. Each jurisdiction engages in comprehensive planning and other processes (budget, capital facilities, public works and engineering, open space and recreation, environmental planning, etc.) within which mitigation can be considered and accomplished. However, it is not yet generally embedded in the context of these conversations. For most jurisdictions this will constitute a type of awareness campaign and require a change in organizational culture. The Port of Garibaldi has already successfully integrated natural hazards mitigation into its organizational culture, planning, projects, and operations. As it works closely on these issues with the City of Garibaldi, mitigation has also become an integral part of the City's considerations in its planning and operations.

Steering Committee members will be responsible for communicating the importance and necessity of integrating mitigation goals, objectives, and actions into the everyday business of the jurisdiction to those within their individual organizational structures responsible for developing and implementing the various planning and operations documents and processes. Steering Committee members will also engage in those planning and operations processes to the extent necessary and appropriate to ensure that mitigation goals, objectives, and actions are duly considered and incorporated as applicable and feasible.

DLCD has committed to assisting the jurisdictions with integration of the updated, FEMA-approved NHMP into comprehensive plans and other planning and operations processes and documents. The process for this endeavor will be determined with each participating jurisdiction after this updated NHMP is approved.

Table 120 identifies by jurisdiction the types of plans and implementing codes into which natural hazard mitigation goals, objectives, and actions may be integrated.

E. Tools and Assets

Beyond the planning and other processes available for integration, each jurisdiction has a variety of tools and assets available for implementing natural hazards mitigation. Many are the same or similar among the jurisdictions. A few are unique. **Table 121** identifies both.

The Cities of Manzanita, Nehalem, and Wheeler are fortunate to work with the Emergency Volunteer Corps of Nehalem Bay (EVCNB) on natural hazards mitigation and preparation activities. The Corps is a highly organized and effective organization that is well-respected far beyond the borders of Oregon. The other cities look to the activities of the Corp and the northern cities for examples of activities they can take on and partnerships they can form to enhance mitigation. During the planning period the South Tillamook Bay Emergency Volunteer Corps was formed, secured 501c3 status and took up operations similar to the EVCNB.

In general, the jurisdictions are small, understaffed, and deal with difficult financial circumstances. Even so, their long experience with natural disasters elevates their individual and collective commitment to mitigation. Their mitigation strategies ground their visions and aspirations, demonstrating that they will use and leverage their tools and assets as fully as possible to advance mitigation, focusing on improving communication, supporting their first responders, and reducing risk to people, businesses, property, and the environment.

Table 120. Plans and Codes for Potential Integration

	Strategic Plan	Comprehensive Plan	Capital Improvements Plan	Economic Development Plan	Emergency Response Plan	Post-Disaster Recovery Plan	Building Code	Zoning Code	Subdivision Code	Site Plan Review Code	Special Purpose Codes	Post-Disaster Recovery Code	Real Estate Disclosure Requirements	Comments
Tillamook County	X	X	X	X	X	X	X	X	X	X	X	–	X	Neskowin has real estate disclosure requirements.
Bay City	X	X	X	–	X	–	X	X	X	X	X	–	–	Enterprise zone. Continuity of Gov't plan.
Garibaldi	X	X	X	–	X	–	X	X	X	X	X	–	–	
Manzanita	X	X	X	–	X	–	X	X	X	X	X	–	–	Off-season tourism promotion plan. Working on post-disaster recovery plan – more than 5 years out.
Nehalem	X	X	–	–	X	–	X	X	X	X	X	–	–	Working forest funds capital projects. Working on post-disaster recovery plan – more than 5 years out. Only special purpose code is floodplain management.
Rockaway Beach	X	X	X	–	–	–	X	X	X	X	X	–	–	Draft ERP stalled.
Tillamook	X	X	X	–	X	–	X	X	X	X	X	–	–	CIP being updated. TSP to be updated next year.
Wheeler	X	X	X	–	X	–	X	X	X	X	X	–	–	Water/Sewer CIP. Draft TSP. Waterfront development plan. Water Operations Emergency Response Plan.
Port of Tillamook Bay	X	–	X	X	X	–	X	–	–	–	–	–	–	Subject to Tillamook County development codes.
Port of Garibaldi	X	–	X	X	X	–	X	–	–	–	–	–	–	Subject to City of Garibaldi development codes.

	Strategic Plan	Comprehensive Plan	Capital Improvements Plan	Economic Development Plan	Emergency Response Plan	Post-Disaster Recovery Plan	Building Code	Zoning Code	Subdivision Code	Site Plan Review Code	Special Purpose Codes	Post-Disaster Recovery Code	Real Estate Disclosure Requirements	**Comments**
Nestucca Valley School District	X		X											Governed by a five-member board and administrated by a district superintendent.
Nehalem Bay Fire and Rescue District					X									Governed by a five-member board of directors and administrated by the district fire chief.
Tillamook People's Utility District	X		X		X									Governed by a five-member board of directors and regulated by the Oregon Public Utilities Commission

Table 121. Tools and Assets Supporting Mitigation

	Land Use Planner or Engineer	Public Works or Construction Engineer	Natural Hazards Planner or Engineer	Floodplain Manager	Surveyor	Vulnerability Assessment Expertise	GIS or Hazus Expertise	Scientists with local Hazards Expertise	Emergency Manager	Grant Writing Expertise	CDBG	CIP Funding	Authority to Levy Taxes	Water, Sewer, Electric, Gas** Fees	Impact Fees	General Obligation Bonds*	Special Tax Bonds*	Private Activity Bonds*	Withhold Spending in Hazard Areas	Comments
Tillamook County	X	X	–	X	X	–	X	–	X	X	X	X	X	–	X	X	X	X	–	Water, sewer, electric provided by utility districts.
Bay City	X	X	X	X	X	X	–	–	–	X	X	X	X	X	–	X	X	X	–	Expertise by contract. Water and sewer SDCs. Electric provided by utility district.
Garibaldi	X	X	X	X	X	X	–	–	X	X	X	X	X	X	–	X	X	X	–	Floodplain Manager on contract. EOP Manager, Mayor, City Manager all have Emergency Manager responsibilities. Capital improvements funded internally and through USDA, Urban Renewal Agency, OR IFA. Occasional access to other grants such as assistance to fire fighters. Water and sewer SDCs. Electric provided by utility district.
Manzanita	X	X	X	X	X	X	–	–	–	X	X	X	X	X	–	X	X	X	–	Engineer and surveyor on contract. Working on securing GIS expertise. There are a number of highly educated people, not necessarily scientists, familiar with Manzanita's hazards. CIP funded by City, USDA, and Oregon State loans. Water fees through a regional sewerage agency. Electric provided by utility district. Stormwater utility fee being considered. Park fees.
Nehalem	X	X	X	X	X	X	X	X	X	X	–	X	X	X	–	X	X	–	–	Expertise obtained through contracts funded with timber receipts. CIP funded with timber receipts. SDCs for water system. Electric provided by utility district. Private activity bonds not used for mitigation.
Rockaway Beach	X	X	X	X	X	X	X	–	–	X	–	X	X	X	X	X	X	X	–	Planner, engineers, surveyor, vulnerability assessment expert, GIS expert all on contract. City wants to hire an Emergency Manager. CIP funded internally and through USDA and ARRA funds. City levies taxes for roads and streets. Water and sewer SDCs. Electric provided by utility district. Impact fees for transportation. City has never used its authority to bond.
Tillamook	X	X	–	X	X	X	–	–	–	–	X	X	X	X	–	X	X	X	–	Contract with County for building inspection. Public Works personnel are not engineers. Surveyor on contract. CIP funded through grants. Water and sewer SDCs. Electric provided by utility district.
Wheeler	X	X	X	X	X	X	–	X	–	X	X	X	X	X	–	X	X	X	–	Most expertise on contract or through the county. Electric provided by utility district. City does not use authority for special tax or private activity bonds.
Port of Tillamook Bay	–	–	–	–	–	–	–	–	–	X	–	X	X	–	–	X	X	X	–	
Port of Garibaldi	–	X	X	–	–	X	X	–	X	X	–	X	X	–	–	X	X	X	–	
Nestucca Valley School District		X				X							X							
Nehalem Bay Fire and Rescue District									X				X							
Tillamook People's Utility District		X					X			X				X						

*In general, all jurisdictions can incur debt through bonds, but only with voter approval.

**No gas service in Tillamook County.

F. Economic Analysis of Natural Hazard Mitigation Projects

This section is constructed from a paper developed by the Oregon Partnership for Disaster Resilience (n.d.) at the University of Oregon's Community Service Center. The paper has been reviewed and accepted by the Federal Emergency Management Agency as a means of documenting how the prioritization of actions shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.

The paper outlines three approaches for conducting economic analyses 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 Military Department – Office of Emergency Management, 2000), and Federal Emergency Management Agency Publication 331, *Report on Costs and Benefits of Natural Hazard Mitigation*. This section is not intended to provide a comprehensive description of benefit/cost analysis, nor is it intended 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 three methods is outlined below:

Benefit/Cost Analysis

Benefit/cost analysis is a key mechanism used by the state Oregon Military Department – Office of Emergency Management (OEM), the Federal Emergency Management Agency, and other state and federal agencies in evaluating hazard mitigation projects and is required by the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended.

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, avoiding 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 must have a benefit/cost ratio greater than 1 (i.e., the net benefits will exceed the net costs) to be eligible for FEMA funding.

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 that 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 or 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:

1. Request cost sharing from public agencies;
2. Dispose of the building or land either by sale or demolition;
3. Change the designated use of the building or land and change the hazard mitigation compliance requirement; or
4. 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 purchases. 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

Considering 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 that could be used to identify those mitigation activities that merit more detailed assessment. One of those methods is the STAPLE/E approach.

Using STAPLE/E criteria, mitigation activities can be evaluated quickly by steering committees in a synthetic fashion. This set of 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 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 city board of commissioners, 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.

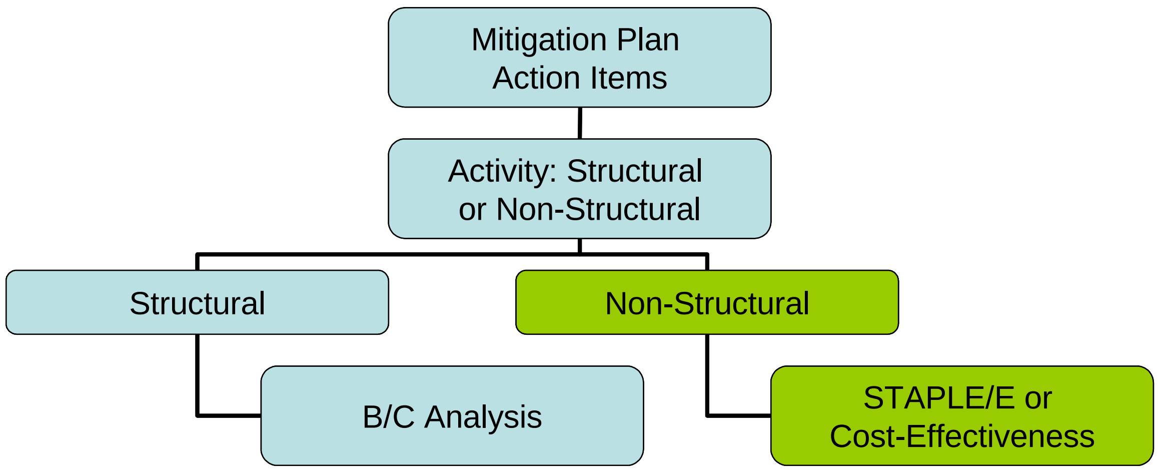
- How will the action impact the environment?
- Will the action need environmental regulatory approvals?
- Will it meet local and state regulatory requirements?
- Are endangered or threatened species likely to be affected?

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.

Figure 114. Economic Analysis Flowchart



Source: Oregon Partnership for Disaster Resilience (2005)

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.

1. Identify the Activities

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 projects 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 the expected future cost expressed in today's dollars. If the net present value is greater than the projected 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 land owners 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. 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

Federal Emergency Management Agency, *Report on the Costs and Benefits of Natural Hazard Mitigation*. Publication 331, 1996.

Goettel & Horner Inc., *Earthquake Risk Analysis Volume III: The Economic Feasibility of Seismic Rehabilitation of Buildings in the City of Portland*, Submitted to the Bureau of Buildings, City of Portland, August 30, 1995.

Goettel & Horner Inc., *Benefit/Cost Analysis of Hazard Mitigation Projects* Volume V, Earthquakes, Prepared for FEMA's Hazard Mitigation Branch, Ocbober 25, 1995.

Horner, Gerald, *Benefit/Cost Methodologies for Use in Evaluating the Cost Effectiveness of Proposed Hazard Mitigation Measures*, Robert Olsen Associates, Prepared for Oregon Military Department – Office of Emergency Management, July 1999.

Interagency Hazards Mitigation Team, *State Hazard Mitigation Plan*, (Oregon State Police – Office of Emergency Management, 2000.)

Risk Management Solutions, Inc., *Development of a Standardized Earthquake Loss Estimation Methodology*, National Institute of Building Sciences, Volume I and II, 1994.

VSP Associates, Inc., *A Benefit/Cost Model for the Seismic Rehabilitation of Buildings*, Volumes 1 & 2, Federal Emergency management Agency, FEMA Publication Numbers 227 and 228, 1991.

VSP Associates, Inc., *Benefit/Cost Analysis of Hazard Mitigation Projects*: Section 404 Hazard Mitigation Program and Section 406 Public Assistance Program, Volume 3: Seismic Hazard Mitigation Projects, 1993.

VSP Associates, Inc., *Seismic Rehabilitation of Federal Buildings: A Benefit/Cost Model*, Volume 1, Federal Emergency Management Agency, FEMA Publication Number 255, 1994.