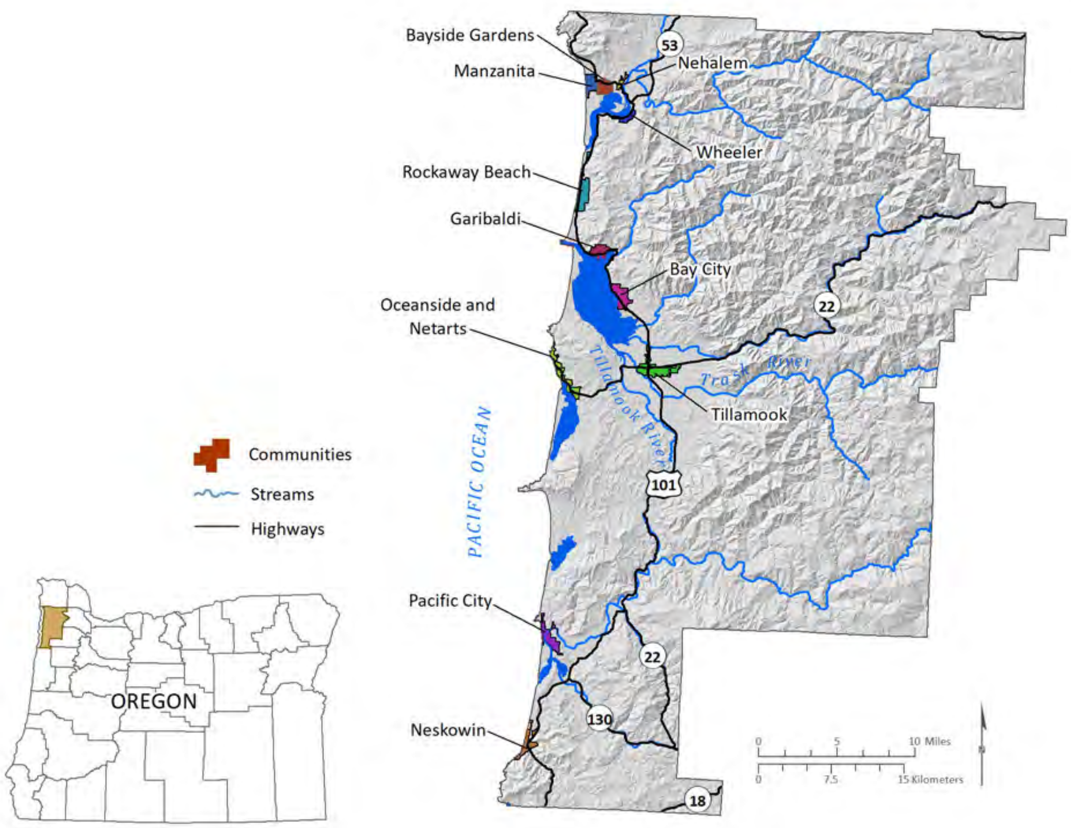
State of Oregon
Oregon Department of Geology and Mineral Industries
Ruarri J. Day-Stirrat, State Geologist

OPEN-FILE REPORT O-23-01

MULTI-HAZARD RISK REPORT FOR TILLAMOOK COUNTY, OREGON

INCLUDING THE CITIES OF BAY CITY, GARIBALDI, MANZANITA, NEHALEM, ROCKAWAY BEACH, TILLAMOOK, AND WHEELER AND THE UNINCORPORATED COMMUNITIES OF BAYSIDE GARDENS, NESKOWIN, OCEANSIDE, NETARTS, AND PACIFIC CITY



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

2023

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

DISCLAIMER

This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication.

Cover image: Study area of the Tillamook County Risk Report. Map depicts Tillamook County, Oregon and incorporated communities included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of a natural hazard risk assessment for Tillamook County communities. The risk assessment can help communities better plan for disaster.

Oregon Department of Geology and Mineral Industries Open-File Report O-23-01
Published in conformance with ORS 516.030

For additional information:
Administrative Offices
800 NE Oregon Street, Suite 965
Portland, OR 97232
Telephone (971) 673-1555
https://www.oregongeology.org
https://oregon.gov/DOGAMI/

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAP PLATES

Appendix E

GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

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

Tillamook_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

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

Metadata in .xml file format:

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

EXECUTIVE SUMMARY

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

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

- In the first task, we created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, FEMA Hazus®-MH general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. Using these data we were able to represent accurate spatial locations and vulnerabilities on a building-by-building basis.
- The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI and were produced using high-resolution, lidar topographic data. Although not all the data sources used in the report provide complete, countywide information, each hazard dataset used was the best available at the time of the analysis.
- In the third task, we analyzed risk using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using the Hazus-MH methodology, and (2) calculated the number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides, coastal erosion, and wildfire.

The findings and conclusions of this report show the potential impacts of hazards to communities within Tillamook County. A Cascadia Subduction Zone (CSZ) event (earthquake and tsunami) will cause extensive damage and losses throughout the county. Our findings indicate that most of the study area's critical facilities are at high risk during a CSZ event. We demonstrate the potential for the reduction in damages and losses from seismic retrofits through building code simulations in the Hazus-MH earthquake model. We also found that the hazards with the highest potential of population displacement are earthquake, tsunami, and landslide hazards. Flooding is a threat for some communities in the study area and we quantify the number of elevated structures that are less vulnerable to flood hazard. Our analysis shows that areas with moderate to steep slopes or at the base of steep hillsides are at greatest risk to landslide hazards, which are present throughout the communities and rural county. Over 1,200 buildings along the coast of Tillamook County were exposed to coastal erosion. Wildfire exposure analysis show a higher risk for buildings within the wildland-urban interface (WUI) portions of the county.

The information presented in this report is designed to increase awareness of natural hazard risk, to support public outreach efforts, and to aid local decision-makers in developing comprehensive plans and natural hazard mitigation plans. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. The results of this study are designed to be used to help communities identify and prioritize mitigation actions that will improve community resilience. This analysis improves on the 2020 DOGAMI natural hazard risk assessment, which relied on less accurate and outdated hazard and building data.

Results were broken out for the following geographic areas:

- Unincorporated Tillamook County (rural)
- Community of Neskowin
- Community of Pacific City
- City of Garibaldi
- City of Nehalem
- City of Tillamook
- Community of Bayside Gardens
- Communities of Oceanside and Netarts
- City of Bay City
- City of Manzanita
- City of Rockaway Beach
- City of Wheeler

Selected Countywide Results
Total buildings: 27,090
Total estimated building value: $6.9 billion

Cascadia Subduction Zone Magnitude-9.0 Earthquake[a]
Red-tagged buildings[b]: 2,123
Yellow-tagged buildings[c]: 5,541
Loss estimate: $1.5 billion

Happy Camp Fault Magnitude-6.6 Earthquake Scenario
Red-tagged buildings[b]: 1,136
Yellow-tagged buildings[c]: 3,648
Loss estimate: $992 million

Landslide Exposure (High and Very High Susceptibility)
Number of buildings exposed: 9,690
Exposed building value: $2 billion

Wildfire (High and Moderate Risk)
Number of buildings exposed: 657
Exposed building value: $136 million

Cascadia Subduction Zone Magnitude-9.0 Tsunami Inundation
Number of buildings damaged: 4,931
Loss estimate: $1 billion

100-year Flood Scenario
Number of buildings exposed: 2,574
Exposed building value: $91 million

Coastal Erosion Exposure (Moderate Hazard)
Number of buildings exposed: 1,227
Exposed building value: $280 million

[a]Results reflect damage caused by the earthquake to buildings outside of the tsunami zone. The combined earthquake and tsunami results estimate the total damage from a CSZ Mw-9.0 event.
[b]Red-tagged buildings are considered uninhabitable due to complete damage
[c]Yellow-tagged buildings are considered limited habitability due to extensive damage

1.0 INTRODUCTION

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

Key Terms:

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

This report is a multi-hazard risk assessment analyzing individual buildings and resident population in Tillamook County. Tillamook County is situated in the northwestern part of Oregon, between the Oregon coast and the Oregon Coast Range and is subject to many natural hazards, including earthquakes, tsunamis, riverine and coastal flooding, landslides, coastal erosion, and wildfires. This report provides a detailed and comprehensive analysis of these natural hazards and provides a comparative perspective not previously available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Tillamook County communities.

1.1 Purpose

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

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

The body of this report describes our methods and results. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to assess risk. Results for each hazard type are reported on a countywide basis within each hazard section, and community based results are reported in detail in **Appendix A: Community Risk Profiles**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size maps showing countywide buildings, population, and hazards.

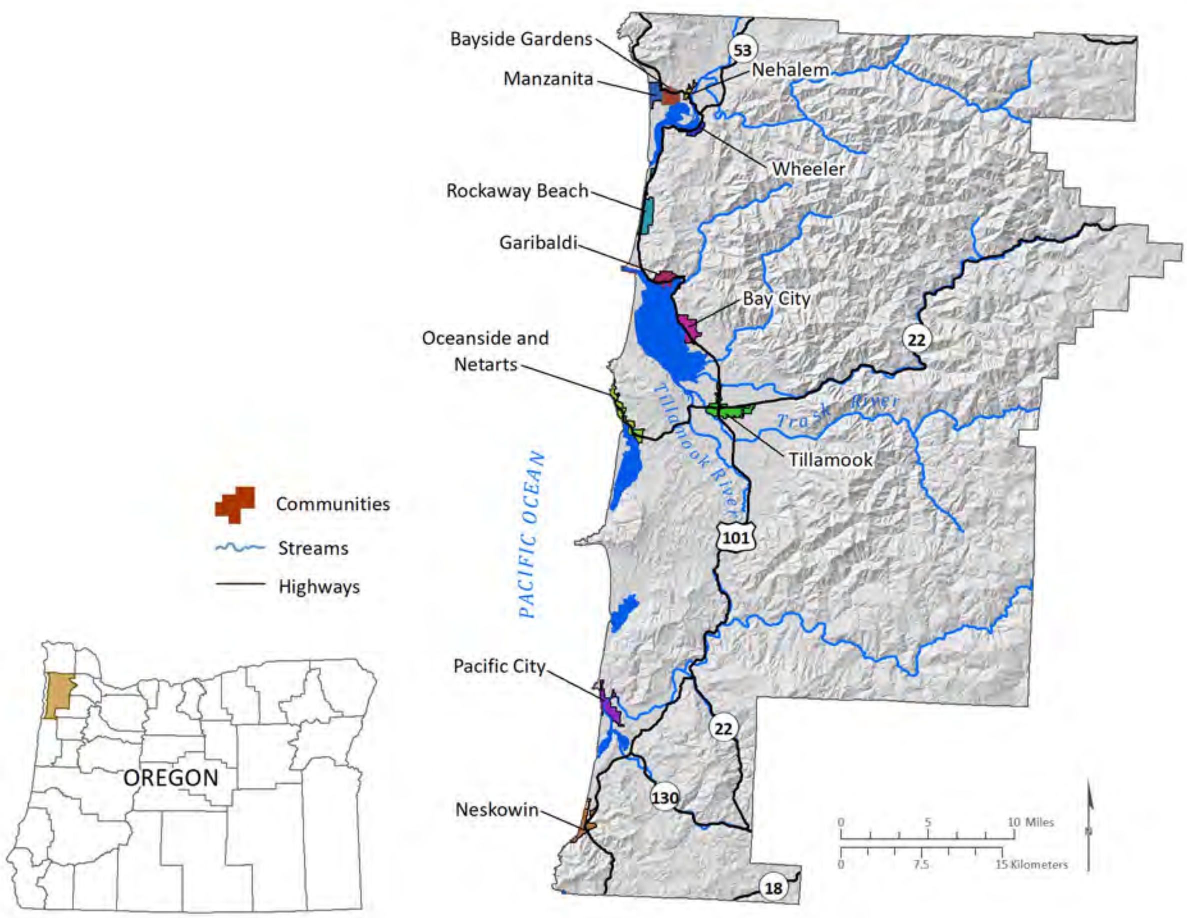
1.2 Study Area

The study area for this project includes the entirety of Tillamook County, Oregon (**Figure 1-1**). Tillamook County is a coastal county located in the northwestern portion of the state and is bordered by Clatsop County to the north, Washington and Yamhill counties to the east, Polk and Lincoln counties to the south, and the Pacific Ocean to the west. The total area of Tillamook County is approximately 1,125 square miles (2,914 square kilometers). A significant portion of the county is within the Tillamook State Forest or is managed as industrial forestland.

"Tillamook County includes seven major rivers draining the steep Coast Range and meeting the Pacific Ocean, including the Nehalem River draining into Nehalem Bay, the Miami, Kilchis, Wilson, and Tillamook rivers flowing into the broad, extensive Tillamook Bay, and the Nestucca River flowing into Nestucca Bay. The area is characterized by a diverse array of landforms and geomorphology, including resistant coastal headlands, active and inactive sand dunes, estuaries, deltas, river valleys, marine terraces, coastal foothills and very steep highlands (Fillmore and Shipman, 2013). Tillamook County experiences some of the highest average annual precipitation in the state of Oregon (PRISM Climate Group, 2020). The coastal lowlands average 65-80 inches per year, with the headlands and highlands exceeding 130-160 inches per year. The summer is generally drier; the wettest months are November through March. The elevation within the study area ranges from sea level to 3,300 ft above sea level (asl) (1,005 m asl), with pronounced relief along the five coastal headlands in the study area (Cape Falcon, Cape Meares, Cape Lookout, Cape Kiwanda, and Cascade Head)" (Calhoun and others, 2020).

The population of the study area is 27,628 based on an estimated population for each community in 2021 from the Portland State University (PSU) Population Research Center https://www.pdx.edu/population-research/population-estimate-reports. The county seat and county's largest community is the city of Tillamook. All the communities in the study, incorporated and unincorporated, are in the western portion of the county within a few miles of the Pacific Ocean. The incorporated communities are Bay City, Garibaldi, Manzanita, Nehalem, Rockaway Beach, Tillamook and Wheeler (**Figure 1-1**). The unincorporated communities are Bayside Gardens, Neskowin, Oceanside and Netarts, and Pacific City.

Figure 1-1. Study area: Tillamook County with communities in this study identified.



1.3 Project Scope

For this risk assessment, we limited the project scope to natural hazard impacts on buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not directly analyze impacts to the local economy, transportation routes, community lifelines, stored hazardous materials, land values, socially vulnerable populations, or the environment. While we recognize that climate change does affect, and in many cases increases, risk from natural hazards, it was also not examined in this study. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler methodology, in which buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), city and county population numbers from the PSU Population Research Center data was used to distribute people into residential structures based on square footage (https://www.pdx.edu/population-research/population-estimate-reports).

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

Earthquake Risk Assessment

- Hazus-MH loss estimation from a CSZ earthquake magnitude (Mw) 9.0 scenario. Includes earthquake induced or “coseismic” liquefaction, soil amplification class, and landslides.
- Hazus-MH loss estimation from a Happy Camp fault Mw-6.6 scenario. Includes earthquake induced or “coseismic” liquefaction, soil amplification class, and landslides.

CSZ Tsunami Risk Assessment

- Exposure to five potential CSZ tsunami scenarios

Flood Risk Assessment

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

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (low to high) and updated Tillamook County landslide mapping (very high).

Coastal Erosion Risk Assessment

- Exposure based on coastal erosion zones (none to high)

Wildfire Risk Assessment

- Exposure based on Overall Wildfire Risk Index (low to high)

Table 1-1. Hazard data sources for Tillamook County.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake	CSZ Mw 9.0	Regional	DOGAMI (Madin and others, 2021)
	Happy Camp Fault Mw 6.6	Countywide	USGS (Personius, 2017) accessed via Hazus fault database
-Coseismic landslide	Susceptibility – wet (3-10 hazard classes)	Statewide	DOGAMI (Madin and others, 2021)
-Coseismic liquefaction	Susceptibility (1-5 classes)	”	”
-Coseismic soil amplification class	National Earthquake Hazards Reduction Program (A-F classes)	”	”
Tsunami	Local Source: Small (300 yr) Medium (425-525 yr) Large (650-800 yr) Extra Large (1,050-1,200 yr) Extra Extra Large (1,200 yr)	Oregon Coast	DOGAMI (Priest and others, 2013)
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	DOGAMI – derived from FEMA (2018) data
Landslide	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016)
	Landslide Deposits	Inhabited portions of Tillamook County	DOGAMI (Calhoun and others, 2020)
Wildfire	Overall Wildfire Risk (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Gilbertson-Day and others, 2018)
Coastal Erosion	Susceptibility (Not Exposed, Low, Moderate, High)	Portions of the coast within Tillamook County	DOGAMI (Stimely and Allan, 2014)

1.4 Previous Studies

Two previous earthquake risk assessments that include Tillamook County have been conducted by DOGAMI. Wang (1998) ran two general level Hazus-MH earthquake analyses, a magnitude 8.5 CSZ earthquake and a 500-year probabilistic earthquake scenario, for the entire state of Oregon. In those analyses Tillamook County had a higher loss ratio than most counties in the state.

Wang and others (2001) conducted a Hazus-based earthquake study specifically for Tillamook County. The 2001 study used the same earthquake scenarios as in the Wang (1998) study. The primary difference was that the 2001 study used an updated version of Hazus-MH, including an updated building inventory and updated seismic hazard maps. The building inventory was further augmented by using a variety of sources (Wang and others, 2001).

Williams and others (2020) conducted a multi-hazard risk assessment for Tillamook County. Many of the methods, datasets, and report formatting, used in the current report were derived from this previous risk assessment report. Several of the hazard datasets (tsunami, flood, and coastal erosion) have not changed between the two reports. However, much of the data used in this report were not available at the time of writing the 2020 report, such as the building inventory, earthquake site specific data (coseismic landslide, liquefaction, and National Earthquake Hazard Reduction Program or NEHRP soil classification) and ground shaking, landslide susceptibility, and wildfire. The report titled "IMS-58, Natural hazard risk report for Tillamook County, Oregon" is accessible from https://www.oregongeology.org/pubs/ims/p-ims-058.htm. The significant difference between the results (total loss or exposure) are due to the valuation of building stock applied. The 2020 study used "real market value" derived from the county assessor records, while this study used a method that estimates replacement cost based on square footage and building type.

A landslide hazard risk assessment for Tillamook County was conducted by Calhoun and others (2020) that quantified the number of buildings and residents at risk from landslide hazard. They also used Hazus-MH to estimate the impacts of coseismic landslide hazard that could potentially be generated during a CSZ Mw-9.0 event.

An earthquake and tsunami impact study for five cities along the Oregon Coast by Bauer and others (2020) included the city of Rockaway Beach. The report evaluated building loss, post-disaster debris, and estimated casualties and displaced population from a CSZ Mw-9.0 earthquake and subsequent tsunami. This study estimated the number of visitors and permanent residents that could potentially be impacted by the earthquake and tsunami to better understand the total number of people at risk.

Many of the methods and datasets used in the Oregon Coast earthquake and tsunami impact study by Bauer and others (2020) were used in a Tillamook County coastline study by Allan and others (2020). A close analysis of the various impacts to property, critical infrastructure, and the permanent and temporary population for Tillamook County coastal communities from a CSZ Mw-9.0 earthquake and tsunami were examined in the study. The study used previously developed tsunami evacuation modeling ("Beat the Wave"), demographic information, and the FEMA Hazus Tsunami Model to help the coastal communities of Tillamook County prepare for this potential disaster.

We did not compare the results of this project with the results from previous studies. Some studies utilized a much lower level of detailed building information and site-specific earthquake hazard inputs. Other studies very thoroughly examined specific hazards that were more broadly examined in this report. Additionally, this study analyzed two earthquake scenarios (CSZ and crustal) instead of only the CSZ in the previous risk assessment from 2020. Comparative analysis was not part of the scope of this project.

2.0 METHODS

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

2.1 Hazus-MH Loss Estimation

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

Key Terms:

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

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

Damage functions are at the core of Hazus-MH. The damage functions stored within the Hazus-MH data model were developed and calibrated from the observed results of past disasters. We estimated damage and loss by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity (e.g., depth of flooding) and building characteristics (e.g., first floor height). **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis by showing the percentage of building loss from flood and in some cases (in yellow) where a building's first floor height is above the level of flooding.

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

Figure 2-1. 100-year flood zone and building loss estimates example in the city of Tillamook, Oregon.

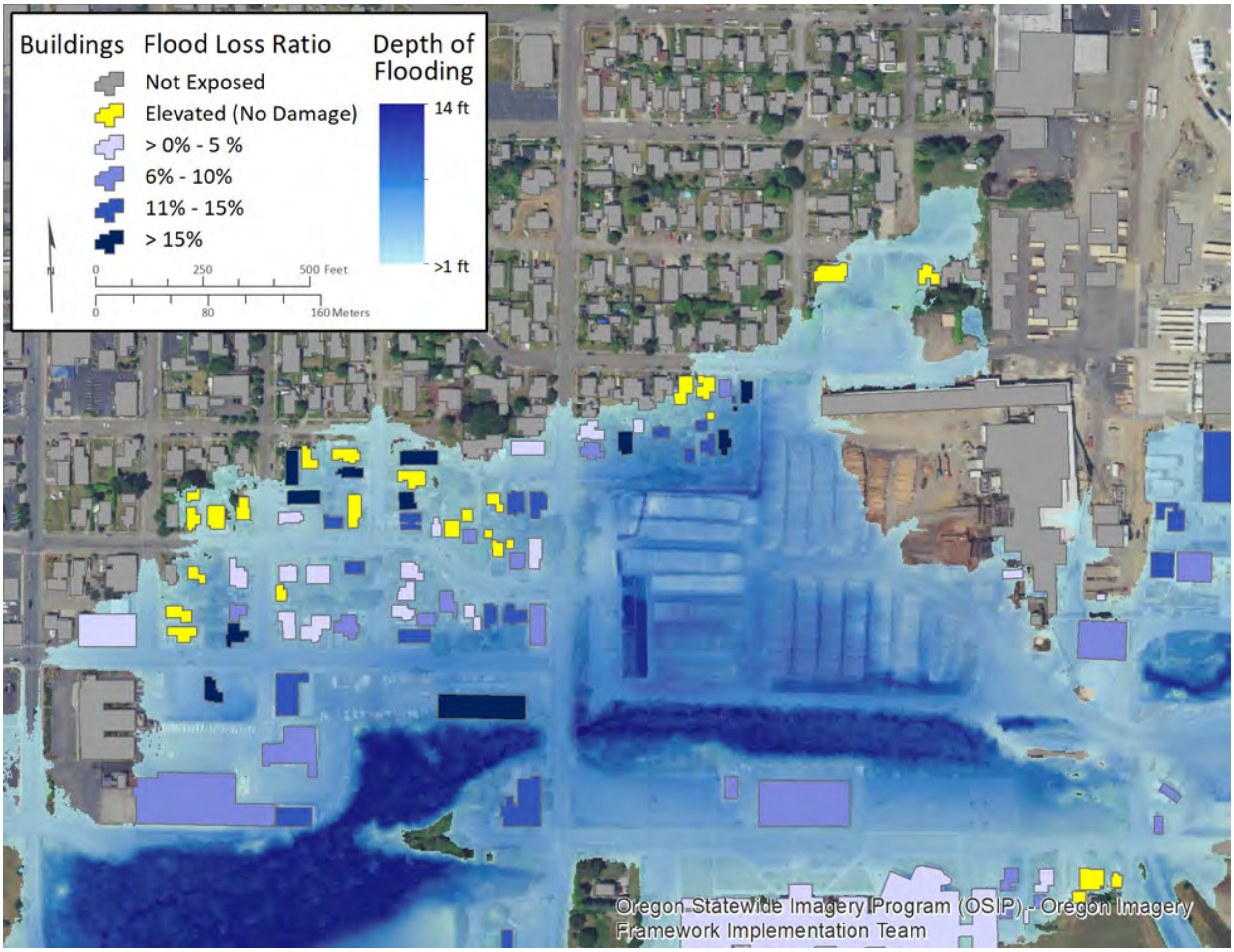


Image source: Oregon Statewide Imagery Program, 2018

Depth grid: Derived from the effective FEMA Flood Insurance Rate Map data for Tillamook County, 2017

2.2 Exposure

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

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

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

Figure 2-2. **Landslide susceptibility areas and building exposure in Netarts, Oregon.**

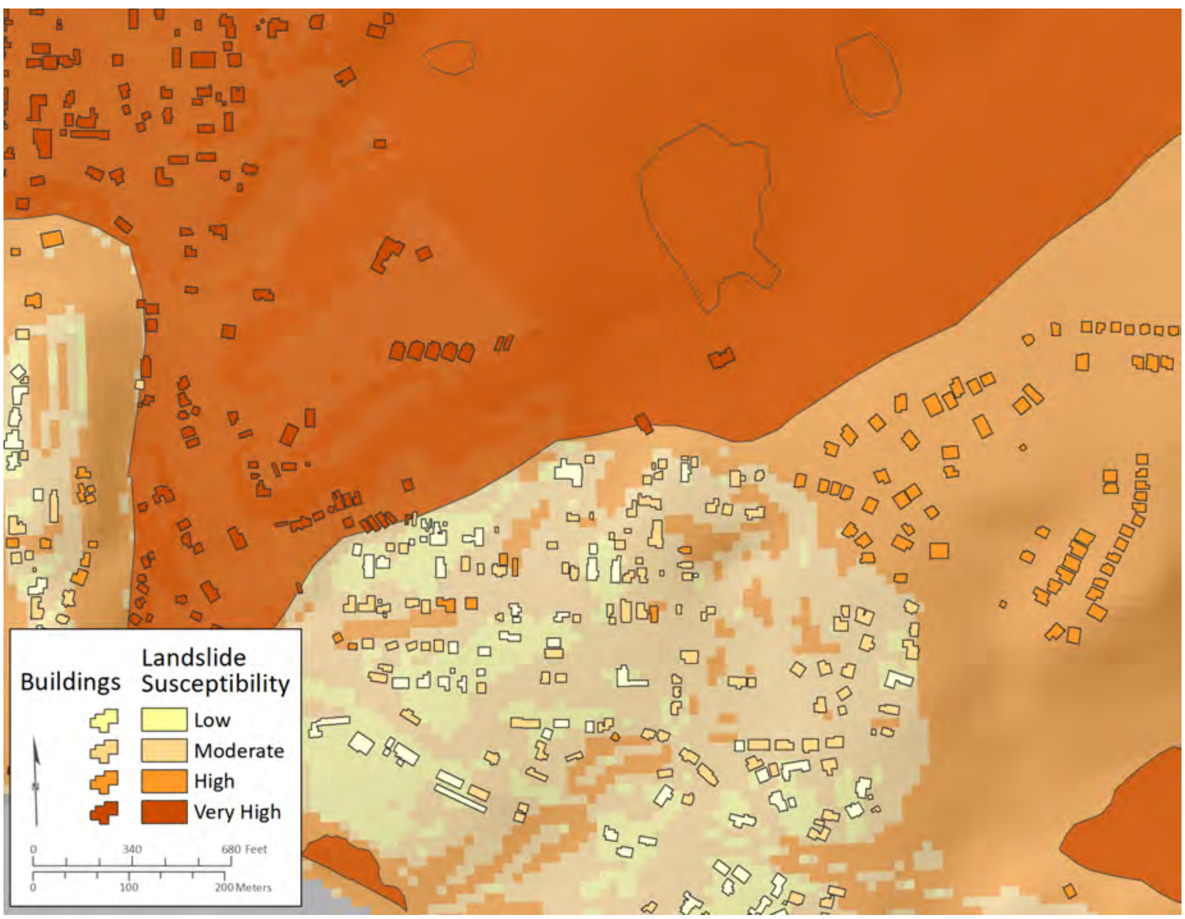


Image source: Oregon Statewide Imagery Program, 2018

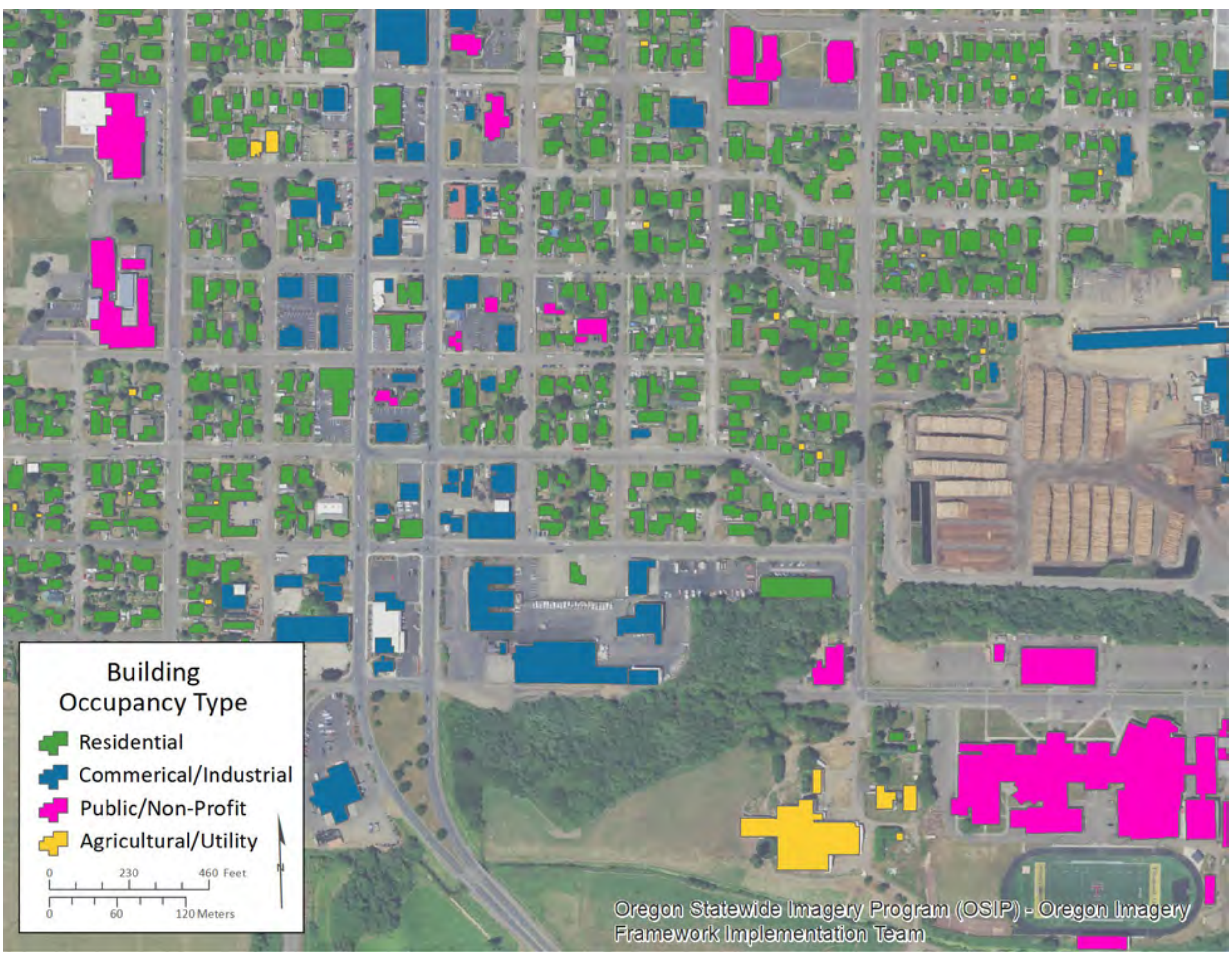
Landslide data source: Landslide susceptibility overview map of Oregon, (Burns and others, 2016) and Landslide hazard and risk study of Tillamook County, Oregon (Calhoun and others, 2020).

2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 100 square feet (19 square meters), as determined from existing building footprints (Williams, 2021). **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Tillamook County. See also Appendix B, **Table B-1** and Appendix E, **Plate 1** and **Plate 2.**

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

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



The number of buildings and total building value varies by community in Tillamook County, which ranges from 239 buildings and $56 million for Nehalem to 2,221 buildings and $1 billion for Tillamook

(**Table 2-1**). A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

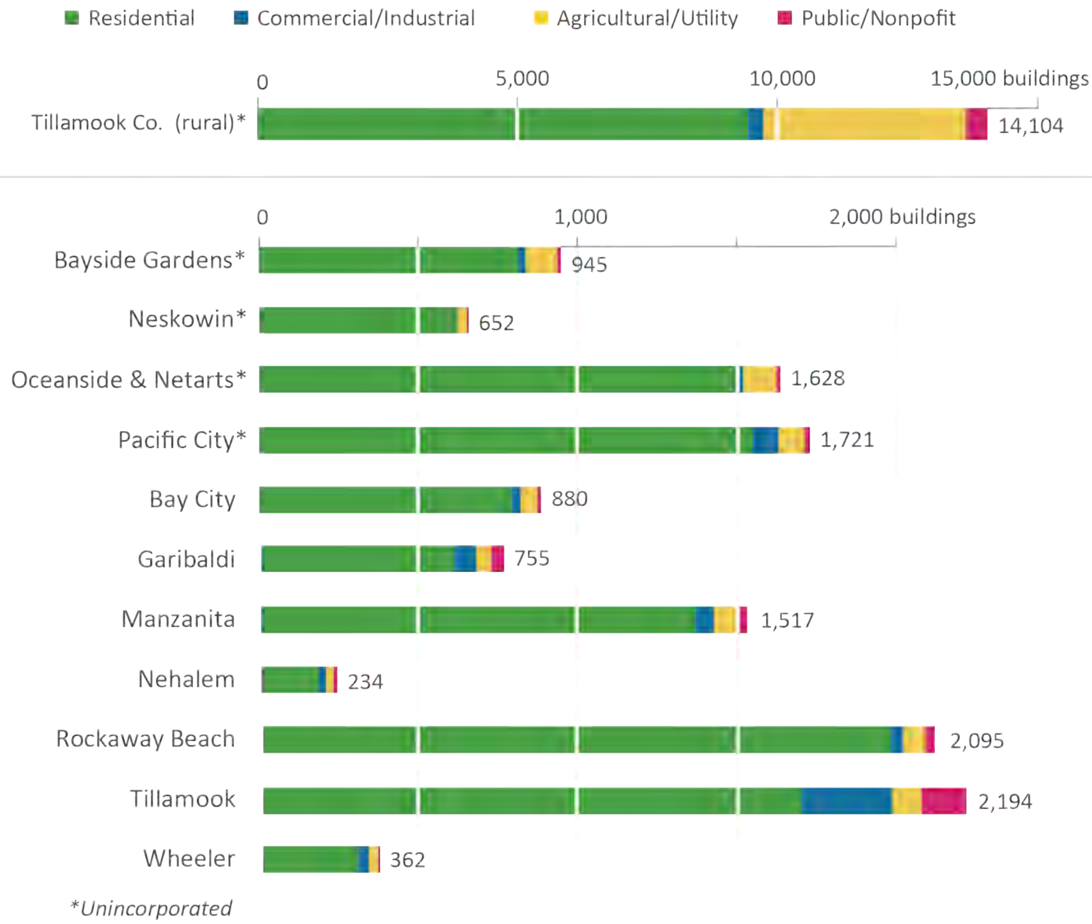
The building inventory was developed from a statewide building footprints dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021), which covers all of Tillamook County. The building footprints provide a location and 2D outline of each structure. The total number of buildings within the study area was 27,090. We considered buildings to be permanent structures with walls and a roof that can be occupied by people (Williams, 2021). Other structures, such as dams, water tanks/towers, sewage and water treatment tanks, tents, small garden sheds, hoop-houses or other plastic-covered greenhouses, and grain silos were not considered buildings and were not included in this analysis.

Table 2-1. 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%

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

Figure 2-4. Community building value and count in Tillamook County by occupancy class.



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

Table 2-2. Tillamook County critical facilities inventory.

Community	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
	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).

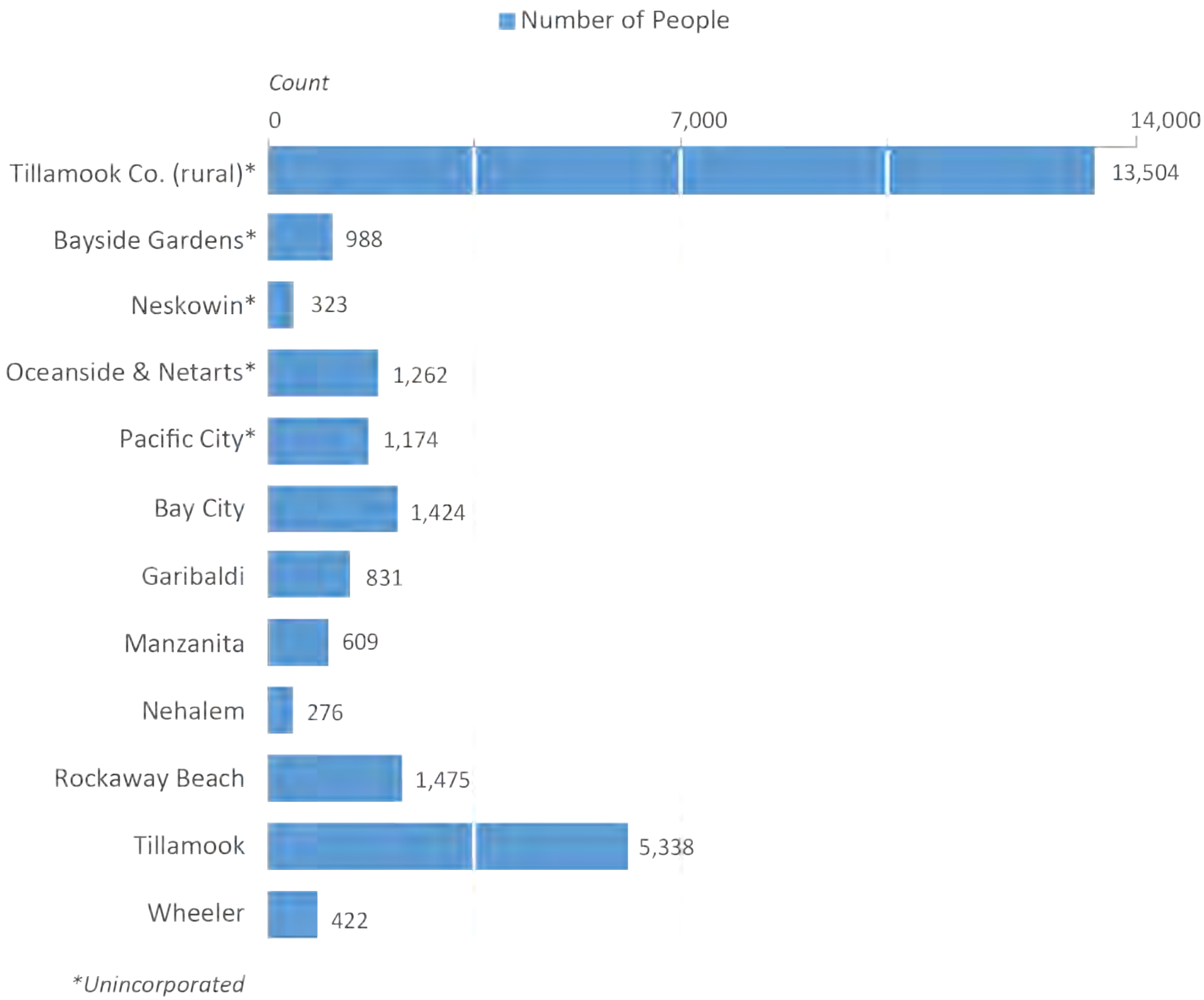
2.4 Population

The UDF database was designed to allow us to estimate the number of people at risk from natural hazards. Within the UDF database, the PSU Population Research Center estimates of permanent residents was distributed proportionally among residential buildings based on building area. Estimates for every incorporated community, as well as the entire county, were available from the PSU data (**Figure 2-5**).

We did not examine the impacts of natural hazards on nonpermanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the county assessor records, the population distribution includes vacation homes, which in many communities may make up a significant portion of the residential building stock. From information reported in the 2010 U.S. Census, American FactFinder regarding vacation rentals within the county, it is estimated that approximately 7% to 12% of residential buildings are vacation rentals in Tillamook County (U.S. Census Bureau, 2010b).

From the PSU Population Research Center data, we assessed the risk of the 27,627 residents within the study area that could be affected by a natural hazard. For each natural hazard, except for the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population distribution by Tillamook County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

In this risk assessment, we considered six natural hazards (earthquake, tsunami, flood, landslide, coastal erosion, and wildfire) that pose a risk to Tillamook County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. While results of this risk assessment do not typically represent singular hazard events, they do quantify the potential overall level of risk present for assets and residents. The loss estimation and exposure results, as well as the rich dataset included with this report, can lead to greater understanding of the potential impact of natural disasters. Communities can become more resilient to future disasters by utilizing the results in plan updates and developing future action items for risk reduction.

In this section, results are presented for the entire study area. The study area includes all unincorporated areas and cities within Tillamook County. Individual community results are in **Appendix A: Community Risk Profiles**.

3.1 Earthquake

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

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

3.1.1 Cascadia Subduction Zone and Happy Camp Fault earthquake scenarios

Just off Oregon's coast, the Juan de Fuca tectonic plate slides under the North American Plate. This area of interaction between the two plates is known as the Cascadia Subduction Zone (CSZ). The pressure and friction created by this convergent motion builds potential energy at the plate boundary until the overriding plate suddenly slips, releasing energy that manifests as strong shaking spread over a wide area (an earthquake). Earthquakes as large as Mw 8-9 occur along the CSZ on average every 230-540 years (Goldfinger and others, 2012, 2017).

Another risk factor associated with the CSZ event is coseismic subsidence. According to Peterson and others (1997), a CSZ earthquake can result in coastal subsidence of up to 10 feet (1–3 meters). Low-lying developed areas near beaches and estuaries are most susceptible to this long-term hazard. A significant and permanent lowering of coastal terrain would expose buildings and infrastructure to tidal inundation in low-lying coastal areas that were formerly above high tide (Madin and Burns, 2013). Analysis of this potentially significant hazard is beyond the scope of this project.

Understanding the connection between CSZ earthquakes and tsunamis

During a large CSZ earthquake, the sudden uplift of the North American Plate along the CSZ margin is likely to displace enough water to produce a tsunami that will have an impact along the Oregon coast. The proximity of the CSZ to the coastal areas of Oregon make them especially threatened by earthquakes and tsunamis (Madin and Burns, 2013).

Although we discuss CSZ earthquakes and tsunamis as separate hazards in this report, these hazards are closely associated. Their widespread effects and almost simultaneous occurrence present a challenge to planners and communities.

The other earthquake scenario examined for this 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 (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.

3.1.2 Data sources: CSZ

Most of the hazard data inputs for our Hazus-MH earthquake analysis were originally created for the Oregon Seismic Hazard Database, release 1.0 (OSHD-1), which included ground shaking and site-specific data for a CSZ Mw-9.0 event (Madin and others, 2021). In recently published work, the USGS (Wirth and others, 2021) ran 30 CSZ Mw-9.0 simulations that represented the variability of shaking that Madin and others (2021) used to develop the ground shaking datasets in the OSHD-1.

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

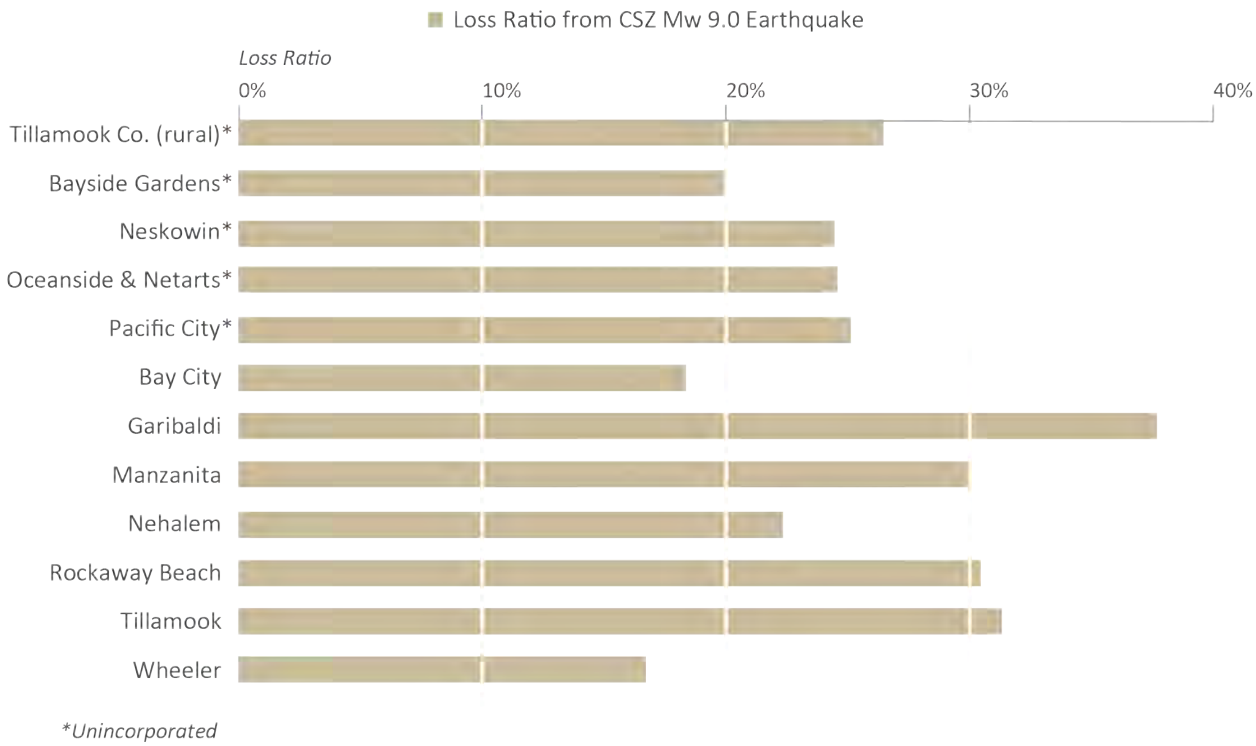
The following hazard layers used for the loss estimation analysis are derived from work conducted by Madin and others (2021): NEHRP soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction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

While the loss estimates and exposure results of the earthquake and tsunami presented in this report both describe a single CSZ scenario, the hazard data used in these analyses are the product of different sources that equate to a slightly different event magnitude. The Medium-sized tsunami scenario was modeled with a CSZ Mw-8.9 earthquake (Priest and others, 2013). The earthquake bedrock ground motions from a Mw-9.0 CSZ earthquake were produced by Wirth and others (2021) and then modified to include site class soil factors (Madin and others, 2021). While the tsunami scenario is associated with a specific amount of slip needed to generate a tsunami, the earthquake model is independent of slip with the earthquake energy distributed over the rupture zone.

3.1.3 Countywide results: CSZ

The CSZ event will produce severe ground shaking and ground failure, as well as a large and swift moving tsunami (Madin and Burns, 2013). Due to the nearly simultaneous timing of these two natural hazards, we have parsed loss estimate results to avoid double counting. That is, earthquake caused losses that occurred within the (Medium-sized) tsunami zone are not included in the overall earthquake loss estimate, because damage from the tsunami would override any damage caused by the earthquake. Based on recent tsunami events in Japan, Sumatra, and Chile, we assumed that buildings are a complete loss within the entirety of the tsunami inundation area (Bauer and others, 2020). Tsunami results are provided in the subsequent tsunami section. **Figure 3-1** shows the loss estimates by community for Tillamook County from a CSZ Mw- 9.0 event without the effects from tsunami.

Figure 3-1. Earthquake loss ratio from CSZ Mw-9.0 by Tillamook County community, without tsunami inundation.



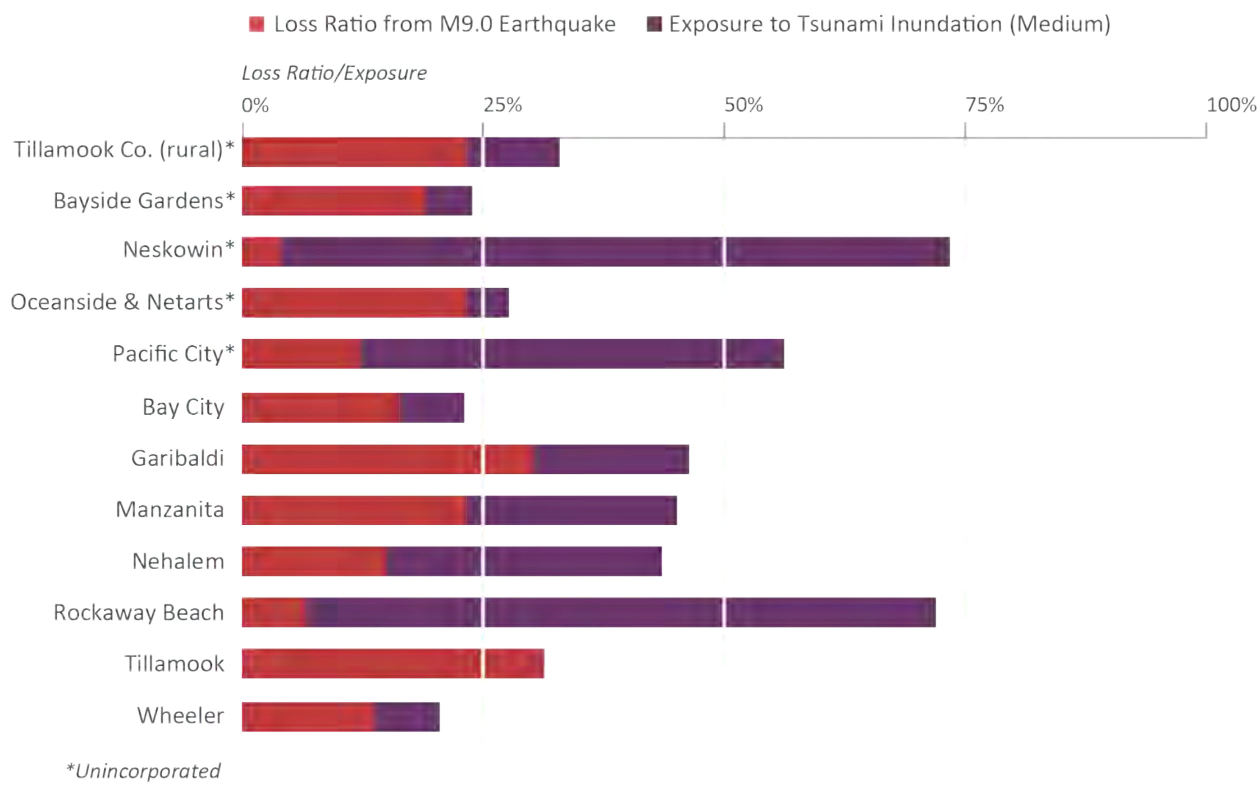
Because an earthquake can affect a wide area, it is unlike other hazards in this report—every building in Tillamook County, to some degree, will be shaken by a CSZ Mw 9.0 earthquake (see **Appendix E, Plate 3**). Hazus-MH loss estimates (see **Appendix B, Table B-2**) for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the building dollar value to obtain a loss estimate (FEMA, 2012b). Earthquake loss estimates reported are for buildings that are located *outside* of the (Medium-sized) tsunami inundation zone. **Figure 3-2** shows loss ratios from the CSZ event (both tsunami and earthquake) for the communities of Tillamook County.

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

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

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

Figure 3-2. CSZ Mw-9.0 event loss ratio in Tillamook County, for both earthquake and tsunami inundation.



Note: Due to the nearly simultaneous timing of a Cascadia Subduction Zone earthquake and tsunami, loss estimate results have been parsed to avoid double counting. That is, buildings within the (Medium-sized) tsunami zone are reported on the basis of exposure only, while buildings outside the tsunami zone are reported on the basis of Hazus-MH earthquake loss estimates. Tsunami losses to buildings are assumed to be complete within the inundation area.

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 tends to be composed of highly liquefiable soil.

To identify how much coseismic landslide damage could occur during a CSZ Mw-9.0 earthquake, Calhoun and others (2020) performed Hazus-MH analyses both with and without landslides considered in the model. Damage and losses from landslides alone (wet scenario), induced by a CSZ earthquake, may result in an estimated $147 million in damage, which is ~11% of the total losses and would result in an additional 1,800 moderately damaged homes and 600 completely damaged homes. Calhoun and others (2020) did not consider landslide impacts on linear infrastructure, such as roads, sewers and water systems, or the energy grid. The coseismic landslide impact on this type of infrastructure may be significant. It should also be noted that the study area of Calhoun and others (2020), includes all of the communities we include in this risk assessment, but did not include the entirety of rural Tillamook County.

Tillamook countywide CSZ Mw-9.0 earthquake results (not including buildings or population within the Medium-sized tsunami zone):

- Number of red-tagged buildings: 2,123
- Number of yellow-tagged buildings: 5,541
- Loss estimate: $1,519,554,000
- Loss ratio: 22%
- Non-functioning critical facilities: 66
- Potentially displaced population: 1,971

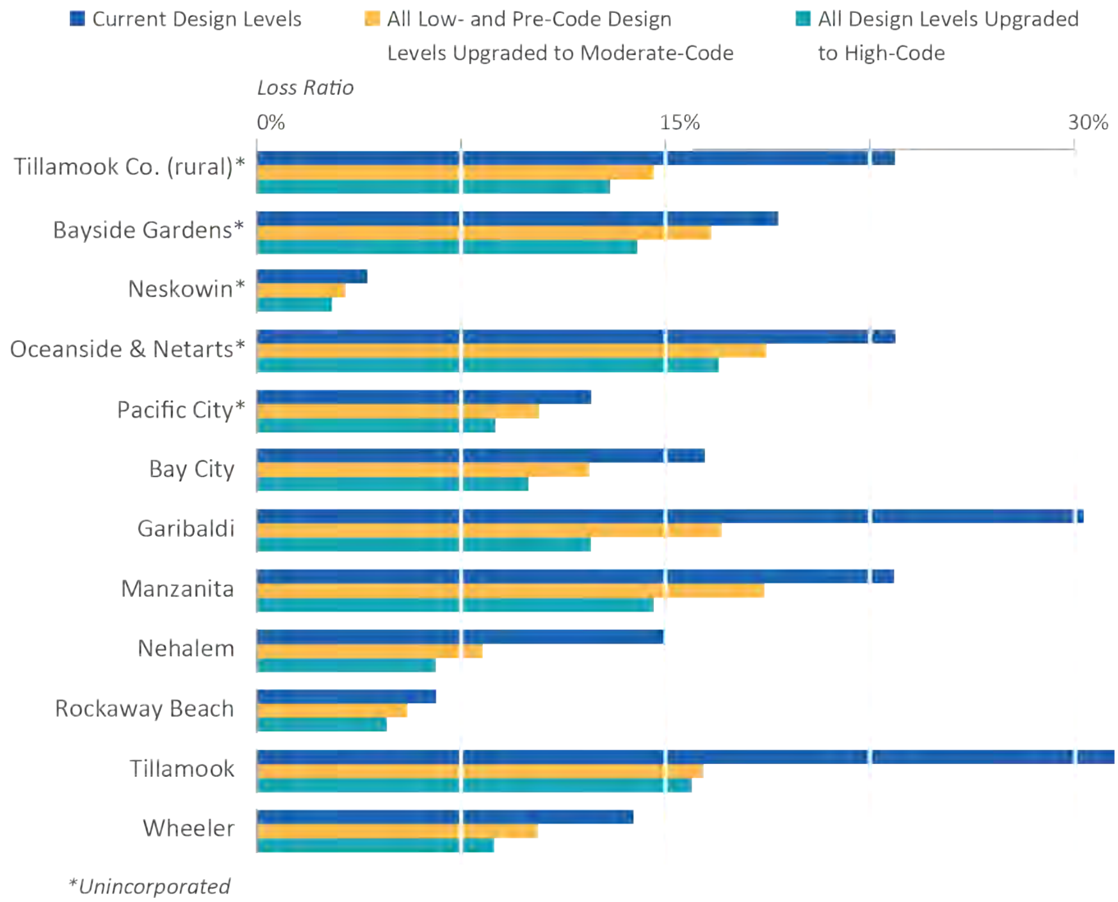
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in damage estimates. The first seismic building codes were implemented in Oregon in the 1970s (Judson, 2012) and by the 1990s modern seismic building codes were being enforced. Nearly half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

If buildings could be seismically retrofitted to Moderate or High code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that the number of red-tagged buildings drop from 2,123 to 1,219, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, for areas of high landslide or liquefaction, additional geotechnical mitigation may be necessary to affect losses. Two simulations of a CSZ Mw-9.0 earthquake where all buildings are upgraded to Moderate code standards or to High code standards show a reduction in loss estimates (**Figure 3-3**).

Key Terms:

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

Figure 3-3. CSZ Mw-9.0 earthquake loss ratio in Tillamook County, with simulated seismic building code upgrades.



Note: Loss estimates shown are for buildings outside the tsunami zone only and are reported on the basis of Hazus-MH earthquake loss estimates. Tsunami losses to buildings are assumed to be complete within the inundation area.

3.1.4 Data sources: Happy Camp Fault scenario

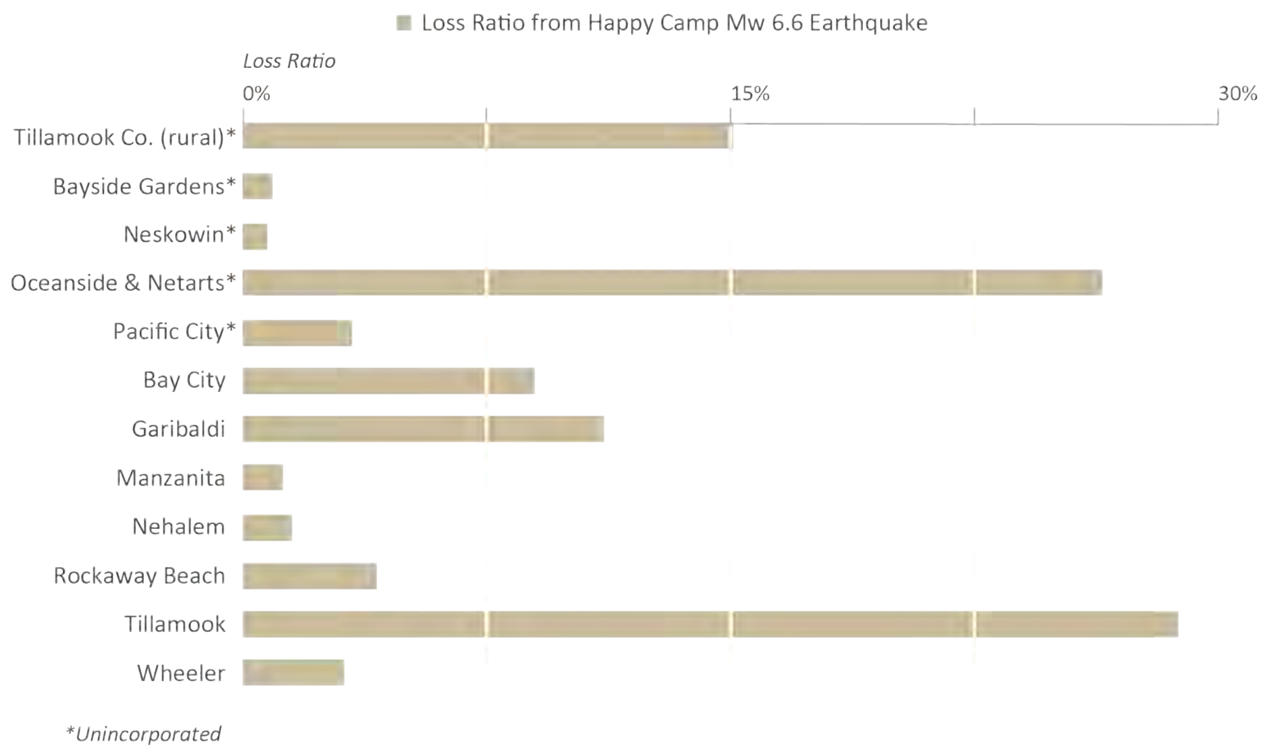
The Happy Camp Fault deterministic scenario with a magnitude of 6.6 was selected as the most appropriate for communicating an alternative earthquake risk for Tillamook County. The default Hazus-MH earthquake scenario database contained the location and orientation of the fault and provided a recommended maximum magnitude for use in a simulated earthquake event. The epicenter was manually selected and was located at the closest proximity to buildings within the study area.

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): NEHRP soil classification, landslide susceptibility (wet), and liquefaction susceptibility. The liquefaction and landslide susceptibility layers were used by the Hazus-MH tool to calculate the probability and magnitude of permanent ground deformation caused by these factors. Hazus-MH uses a characteristic magnitude value to calculate the impacts of liquefaction and landslides. For this study, we followed the details provided in the default Hazus-MH database and used Mw-6.6 as the characteristic event.

3.1.5 Countywide results: Happy Camp Fault scenario

While a CSZ event will cause substantial widespread damage throughout the entire study area, our results indicate a Happy Camp fault Mw 6.6 earthquake will cause significant damage (10 - 30% in losses) in the communities around Tillamook Bay and in Oceanside and Netarts. It is unknown if an event similar to the scenario modeled in this study would cause a tsunami and therefore was not part of the analysis. Because an earthquake can affect a wide area, it will also cause damage in the other communities in Tillamook County, but to a lesser degree. **Figure 3-4** shows loss ratios from this earthquake scenario for the communities of Tillamook County.

Figure 3-4. Earthquake loss ratio from Happy Camp Mw-6.6 by Tillamook County community.



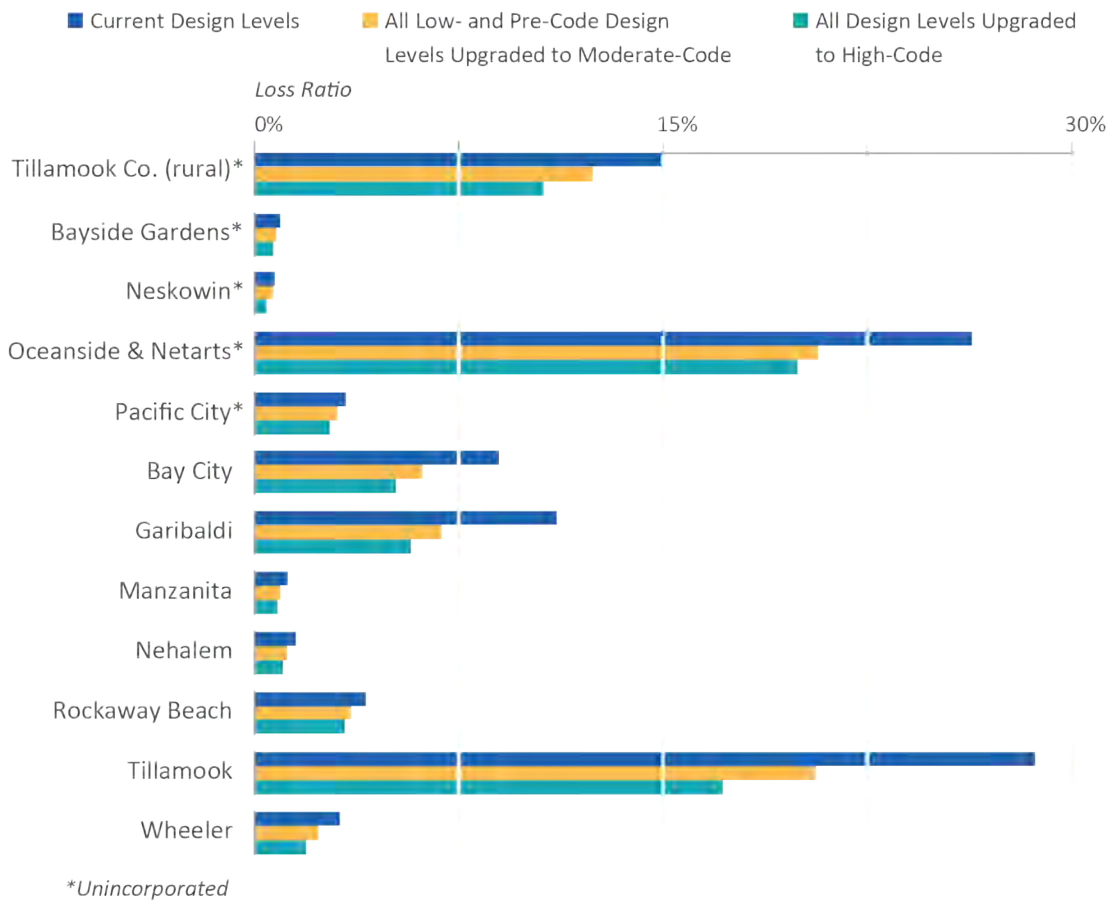
The results indicate that Tillamook County will incur losses nearing $1 billion or 14% of their total building assets due to a Happy Camp Fault Mw-6.6 earthquake. These results are strongly influenced by the proximity of buildings to the epicenter of the simulated earthquake. Communities around Tillamook Bay are not only close to the epicenter, but also are in areas of highly liquefiable soils. In addition to the proximity, liquefaction would exacerbate the level of risk from this earthquake scenario for the communities around Tillamook Bay.

Tillamook countywide Happy Camp Mw-6.6 earthquake results:

- Number of red-tagged buildings: 1,136
- Number of yellow-tagged buildings: 3,648
- Loss estimate: $991,959,000
- Loss ratio: 14%
- Non-functioning critical facilities: 33
- Potentially displaced population: 1,519

As with the CSZ earthquake hazard, if buildings could be seismically retrofitted to Moderate- or High-code standards, the impact of this event would be greatly reduced. In a simulation by DOGAMI, Hazus-MH earthquake analysis shows that loss estimates drop from 15% to 11% when all buildings are brought up to at least Moderate-code level. Although these upgrades can decrease earthquake vulnerability, the benefits are minimized in landslide and liquefaction areas, where buildings would need additional geotechnical mitigation to affect losses. **Figure 3-5** illustrates the reduction in loss estimates from a Happy Camp Fault Mw-6.6 earthquake through two simulations where all buildings are upgraded to at least Moderate-code standards and then all buildings to High-code standards.

Figure 3-5. Happy Camp Mw-6.6 earthquake loss ratio in Tillamook County, with simulated seismic building code upgrades



3.1.6 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk from earthquake hazard based on results from the CSZ scenarios:

- 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.
- Older buildings that are more vulnerable to earthquake shaking in the communities of Neskowin, Bay City, Garibaldi, and Tillamook contribute to the level of estimated losses.

- 68 of the 91 critical facilities in the study area are estimated to be nonfunctioning due to a CSZ earthquake like the one simulated in this study.

3.2 Cascadia Subduction Zone Tsunami

Tsunamis are a natural hazard threat that exists for many of the communities along the Oregon Coast. The tsunami scenario addressed in this report is caused by the abrupt movement of the seafloor accompanying an earthquake. In a megathrust earthquake, like the CSZ event, the sudden uplift of seafloor is converted into wave energy (Priest and others, 2013). While not included in this report, other important processes that may trigger a tsunami include landslides that start below the water surface and landslides that enter a deep body of water from above the water surface (Witter and others, 2011). Tsunamis can travel thousands of miles across oceans, so that a particular coastal area may be susceptible to two different types of tsunami hazard (Priest and others, 2013):

- Tsunamis caused by distant sources and that travel across the ocean basin, and
- Tsunamis caused by local sources such as the CSZ and that occur immediately adjacent to a coast.

During a CSZ earthquake, the sudden uplift of a portion of the North American Plate along the CSZ margin is likely to produce a tsunami that will have an impact along the Oregon Coast. This locally generated tsunami poses a significant risk to low-lying coastal and estuarine developed areas in Coos County due to the limited warning time of an approaching tsunami. Tsunami inundation zone maps created by DOGAMI can serve as a tool for planning and mitigation efforts. We chose the "Medium" tsunami scenario shown on these maps to describe the level of risk to communities, because, according to Priest and others (2013), the Medium scenario tsunami is the most likely to occur triggered by a CSZ event.

3.2.1 Data sources

The tsunami hazard data used in this report are from Priest and others (2013). Priest and others modeled areas of expected inundation from five local (CSZ) tsunami scenarios and two distant source scenarios and created a series of inundation maps. The distant source tsunami scenarios were not used in this report. The local tsunami scenarios used in this report for exposure analysis were CSZ "t-shirt" sizes of Small (Sm), Medium (M), Large (L), Extra Large (XL), and Extra-Extra Large (XXL).

The CSZ tsunami scenarios that were developed by Priest and others (2013) are based on "time intervals over which the maximum amount of coseismic slip accumulates (creating a "slip deficit") and is then released during long (>800 km) ruptures of the subduction zone megathrust." Slip deficit time intervals simply put is the interval between CSZ events and their corresponding tsunami size. The slip deficit time intervals for each local source tsunami scenario are as follows (Priest and others, 2013):

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

The estimated annual recurrence (percentage chance in a given year) rates are from Witter and others (2011) and are:

- XXL = unknown (not seen in 10,000-year record)
- XL = <1/10,000 = <0.01%
- L = 1/3,333 = 0.03%
- M = 1/1,000 = 0.1%
- Sm = 1/2,000 = 0.05%

For this risk assessment, DOGAMI compared the locations of buildings and critical facilities to the geographic extent of the local source tsunami inundation zones to assess the exposure for each community. The exposure results shown below are based on the Medium scenario only (see **Appendix B, Table B-4** for all scenarios). The total dollar value of exposed buildings was summed for the study area and is reported below. We were also able to estimate the number of people at risk from tsunami hazard. See **Appendix B: Detailed Risk Assessment Tables** for cumulative multi-scenario analysis results.

3.2.2 Countywide results

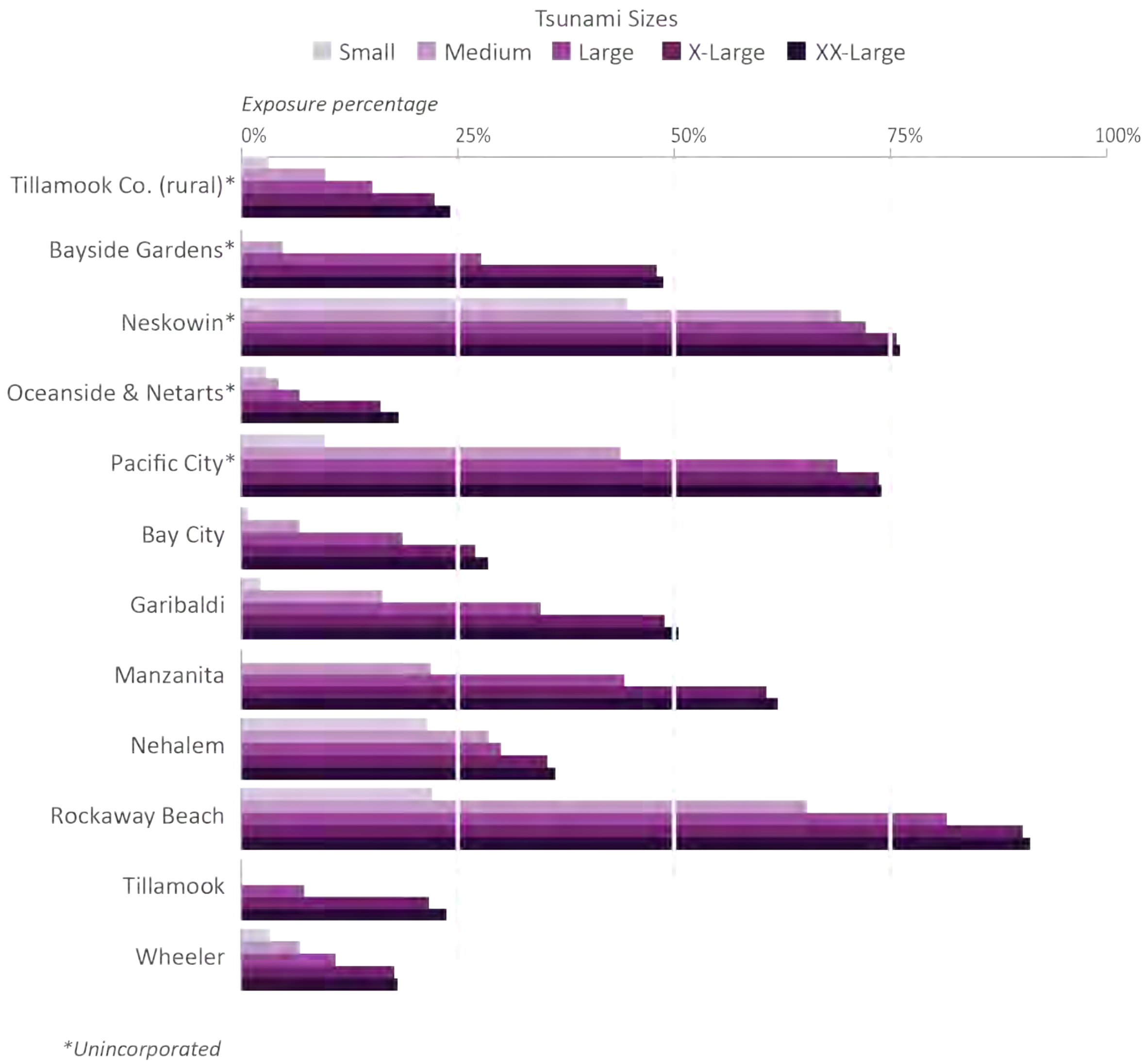
Most of the inhabited areas in Tillamook County are relatively near the Pacific Ocean and nearly all communities in the study area would be affected by the largest of the DOGAMI-calculated tsunami scenarios. Allan and others (2020) estimated that the number of permanent residents of Tillamook County within a tsunami zone ranges from ~3,300 (Medium scenario) to ~7,700 (XX-Large scenario) and as high as ~18,400 (Medium scenario) to ~29,000 (XX-Large scenario) when including the temporary (visiting) population. However, the Medium-sized tsunami was chosen to describe the level of risk because that is the scenario that is most likely to occur. Tillamook County's communities built along the open coast are at a higher risk to tsunami hazard than communities along the bays and estuaries.

Tillamook countywide CSZ Mw-9.0 tsunami inundation (Medium tsunami scenario):

- Number of buildings exposed: 4,931
- Exposure value: $1,055,974,000
- Percentage of exposure value: 15%
- Critical facilities exposed: 17
- Potentially displaced population: 2,755

The combination of earthquake and tsunami will have a significant impact on the entire coastal and estuarine portions of rural Tillamook County. Low-lying areas within coastal communities are predicted to be inundated by the Medium-sized tsunami scenario. Approximately 15% of the county's buildings have exposure to tsunami inundation under the Medium-sized scenario. In some communities, such as Neskowin, Pacific City, and Rockaway Beach, a very high percentage of development is exposed to tsunami hazard. 2,000-3,000 permanent residents could be impacted from a CSZ tsunami event and require medical and shelter services. Because there is a high risk of tsunami along the entire coast and estuarine areas of Tillamook County, awareness is important for the emergency response immediately after the event and for future planning and mitigation efforts in these areas (**Figure 3-6**).

Figure 3-6. Tsunami inundation exposure by Tillamook County community.



3.2.3 Areas of vulnerability or risk

We identified locations within the study area that are comparatively more vulnerable or at greater risk from a CSZ Mw-9.0 tsunami (Medium-sized scenario):

- Buildings along the Nestucca River in Pacific City are exposed to tsunami hazard, as portions of the city are within the tsunami zone.
- Buildings along Tillamook Bay in Bay City and Garibaldi are exposed to tsunami hazard.
- Buildings in Neskowin and Manzanita along the open coast are exposed to tsunami hazard
- 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.
- Buildings in Wheeler and Nehalem along the Nehalem River are exposed to tsunami hazard.

3.3 Flooding

The frequency and severity of flooding may change over time due to changes in climate and precipitation patterns, land use, and how we manage our waterways. This study represents our current understanding of flood hazards and flood risk, but we recognize that flood models and risk assessments will need to be updated with time and changing conditions.

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

A typical method for determining flood risk is to identify the probability and impact of flooding. The annual probabilities calculated for flood hazard used in this report are 10%, 2%, 1%, and 0.2%, henceforth referred to as 10-year, 50-year, 100-year, and 500-year scenarios, respectively. The ability to assess the probability of a flood, and the level of accuracy of that assessment is influenced by modeling methodology advancements, better knowledge, and longer periods of record for the stream or water body in question.

All the rivers in Tillamook County drain westward and, eventually, into the Pacific Ocean. The major rivers within the county are the Nehalem, Miami, Wilson, Trask, Tillamook, and Nestucca. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain. Other flooding effects are due to coastal flooding from the Pacific Ocean for low-lying coastal developments and within Tillamook County's five estuaries.

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

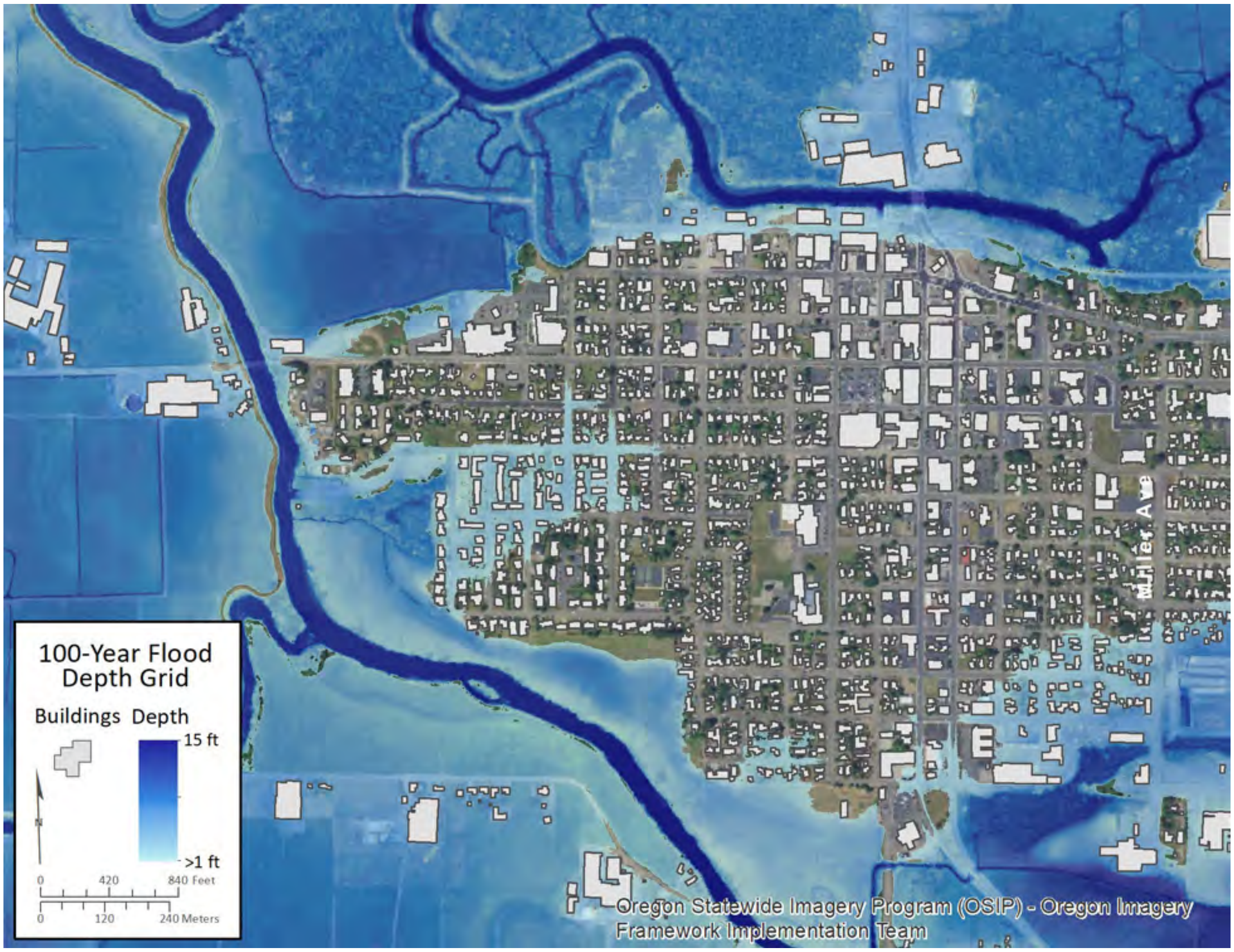
3.3.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for Tillamook County were updated starting in 2016 (FEMA, 2018) and included a study of coastal flooding (Allan and others, 2015); these were the primary data sources for the flood risk assessment in this report. These data sources were adopted by Tillamook County to regulate flood zones in 2018. Further information regarding the National Flood Insurance Program (NFIP) related statistics can be found on the FEMA website: https://www.fema.gov/policy-claim-statistics-flood-insurance. While no place is completely risk-free from flood hazard, these were the only flood data sources that we used in the analysis.

Depth grids, developed by DOGAMI in 2016 to revise the Tillamook County FIRMs, were used in this risk assessment to determine the level to which buildings are impacted by flooding. DOGAMI developed the 10-, 50-. 100-, and 500-year depth grids from detailed stream model information within the study area. The lidar data that DOGAMI used to create the depth grids were from high-resolution lidar collected in 2009 (North Coast project, Oregon Lidar Consortium high-resolution lidar collected in 2009 (North Coast project, Oregon Lidar Consortium; see https://www.oregongeology.org/lidar/collectinglidar.htm). Both sets of depth grids were used in this risk assessment to determine the level to which buildings are impacted by flooding.

The depth grids were used in this risk assessment to determine the level to which buildings are impacted by flooding. Depth grids are raster GIS datasets in which each digital pixel value represents the depth of flooding at that location within the flood zone (**Figure 3-7**). Depth grids for four riverine flood recurrence intervals (10-, 50-, 100-, and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis. Each flood scenario is designated by a recurrence interval or the probability in any given year of a flood of that magnitude occurring. For example, the 100-year flood has a 1% annual chance of occurring.

Figure 3-7. **Flood depth grid example in the city of Tillamook, Oregon.**



The Hazus-MH flood model uses an individual building's depth of flooding, first floor height above ground, and presence of a basement to estimate the flood damage. The model's damage functions are unique based on building type; for example, a mobile home is predicted to experience a different level of damage than a concrete, commercial building given the same depth of flood. Hazus-MH flood model and damage functions were created based on decades of historical flood damage observations.

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

3.3.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for four flood scenarios (10-, 50-, 100-, and 500-year). We used the 100-year flood scenario as the primary scenario for reporting flood results (also see **Appendix E, Plate 4**). The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. See **Appendix B, Table B-4** for multi-scenario cumulative results.

Tillamook countywide 100-year flood loss:

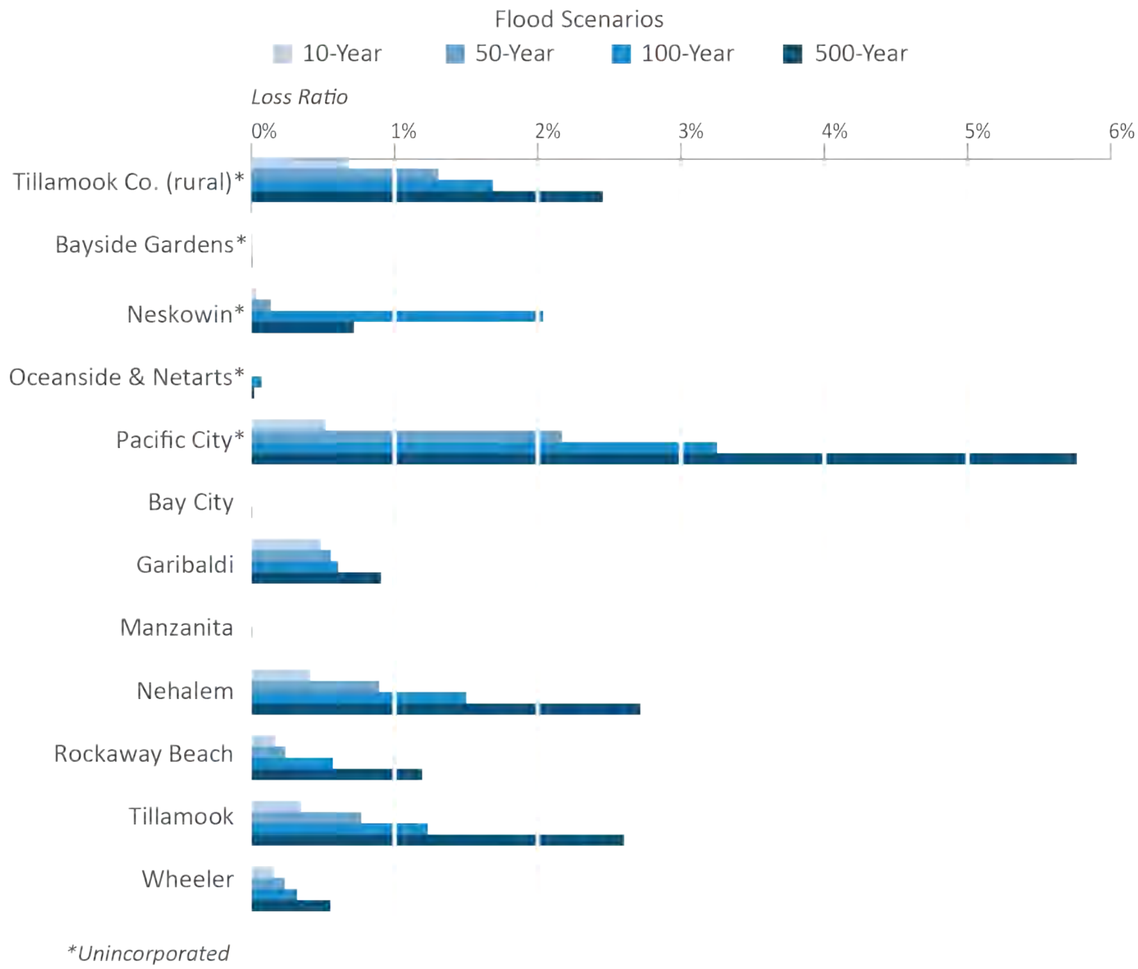
- Number of buildings damaged: 1,880
- Loss estimate: $91,345,000
- Loss ratio: 1.3%
- Damaged critical facilities: 13
- Potentially displaced population: 2,272

3.3.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario across the entire county is more than $90 million. While the loss ratio of flood damage for the entirety of Tillamook County is only 1.3%, the impact to areas of development near flood-prone streams is significant (**Figure 3-8**). In communities where most residents are not within flood-designated zones, the loss ratio may not be as helpful as the actual replacement cost and number of residents displaced to assess the level of risk and impact from flooding. The Hazus-MH analysis also provides useful flood data on individual communities so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Tillamook County are in the within floodplain of the Tillamook, Trask, Kilchis, and Wilson rivers near the city of Tillamook. Frequent flooding occurs on the rivers that form a very large floodplain upstream of Tillamook Bay. In addition, flooding on the Nehalem and Nestucca rivers put many residents and buildings at risk (**Figure 3-8**).

Figure 3-8. Ratio of flood loss estimates by Tillamook County community.



3.3.4 Exposure analysis

Separate from the Hazus-MH flood analysis, we did an exposure analysis by overlaying building locations on the 100-year flood extent. We did this to estimate the number of buildings that are elevated above the level of flooding and the number of displaced residents. This was done by comparing the number of nondamaged buildings from Hazus-MH to the number of exposed buildings in the flood zone. A large proportion (10%) of Tillamook County's buildings were found to be within designated flood zones. Of the 2,574 buildings that are exposed to flooding, we estimate that 694 (about 27%) are above the height of the 100-year flood. This evaluation also estimates that 2,272 residents might have mobility or access issues due to surrounding water. See **Appendix B, Table B-5** for community-based results of flood exposure.

3.3.5 Areas of significant risk

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

- The city of Tillamook lies within a very large floodplain created by the Tillamook, Trask, Kilchis, and Wilson rivers, and their many adjoining tributaries. Many buildings in the low-lying areas of the city and surrounding areas are exposed to the 100-year flood.
- Many buildings along the Nestucca River in Pacific City are at risk from flooding.

- Many buildings in the low-lying business area of Nehalem are particularly vulnerable to flooding. This area, along the riverbank, is subject to a 100-year flood due to the close proximity of the Nehalem River. Past mitigation actions, such as elevating buildings, have alleviated some problems.
- 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.
- Developed areas within Neskowin along Neskowin Creek, Kiwanda Creek, and the Pacific Ocean are exposed to the 100-year flood.

3.4 Landslide Susceptibility

This study represents our current understanding of landslide susceptibility within this study area. However, changing climate, precipitation patterns, land use, wildfire events, and land and forest management strategies may increase or decrease the susceptibility to landslides.

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

3.4.1 Data sources

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

SLIDO, release 3.2 (Burns and Watzig, 2014) is an inventory of mapped landslides in the state of Oregon. SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state.

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

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) and thus was not incorporated into the Statewide Landslide Susceptibility Map. For this risk assessment, we 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.

We 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. We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community (see **Appendix B, Table B-6**). The total dollar value of exposed buildings was summed for the study area and is reported in the following section. We 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.

3.4.2 Countywide results

Landslide hazard is present throughout the inhabited portions of Tillamook County. We found that portions of Oceanside and Netarts, Garibaldi, Nehalem, Rockaway Beach, Wheeler, and the unincorporated county have high levels of exposure to landslide hazards. Areas in terrain with moderate to steep slopes or at the base of steep hillsides may be exposed to landslides. Except for the city of Tillamook, every community in Tillamook County has some level of risk from landslide hazard. The percentage of building value exposed to Very high and High landslide susceptibility is approximately 30%, which equates to more than 9,000 buildings with a value more than $2 billion.

We combined High and Very High susceptibility zones as the primary scenarios to provide a general sense of community risk for planning purposes (see **Appendix E, Plate 9**). We determined the best way to communicate the level of landslide risk to communities was by combining the exposure results for both susceptibility zones. The High and Very High susceptibility zones represent areas most susceptible to landslides with the greatest impact to the community.

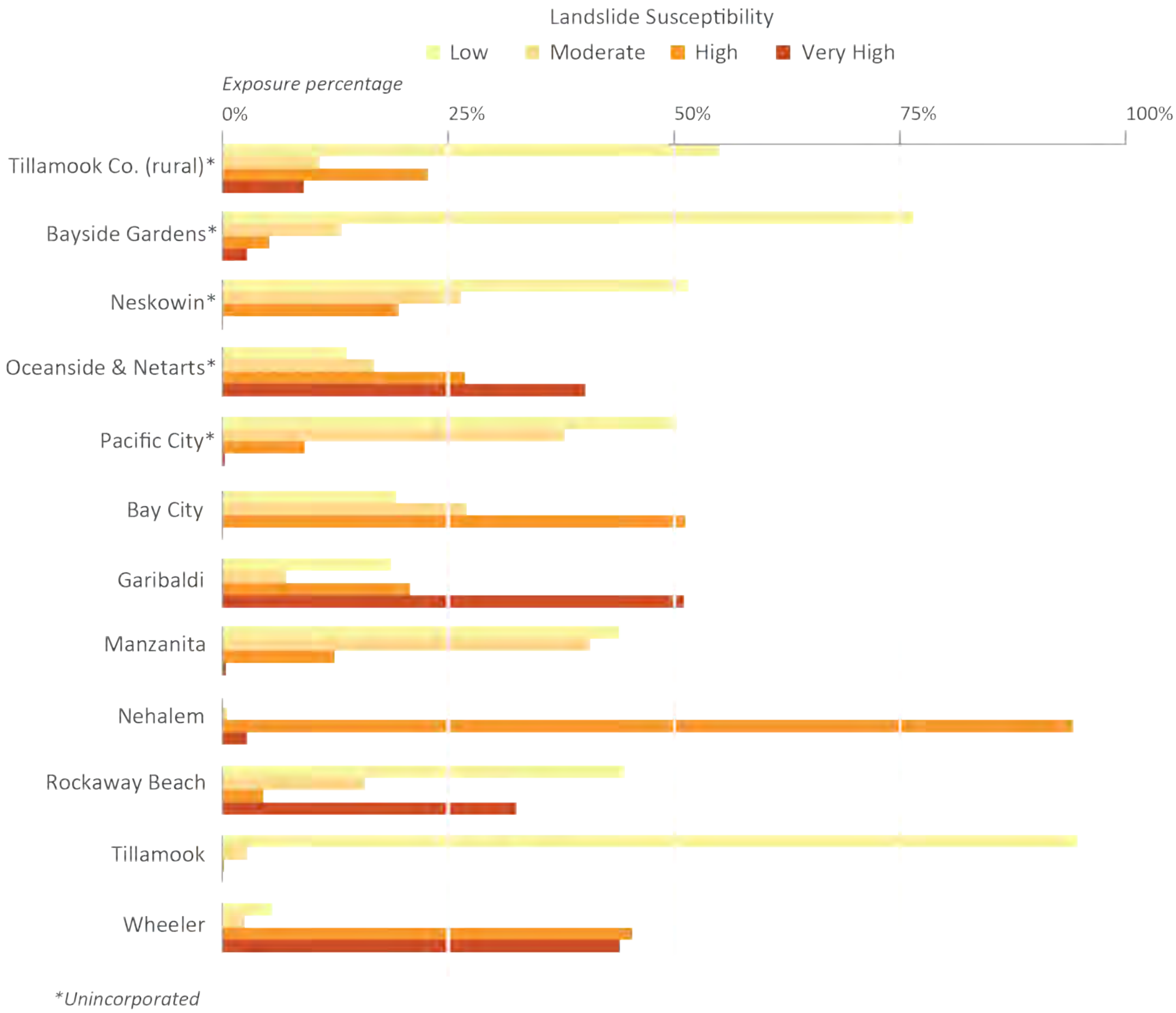
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-9**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Tillamook countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 9,689
- Value of exposed buildings: $2,049,677,000
- Percentage of total county value exposed: 30%
- Critical facilities exposed: 37
- Potentially displaced population: 9,527

Most of the developed land in Tillamook County corresponds to estuaries and floodplains, which are typically low-susceptibility landslide zones. Despite this development pattern, nearly a third of the study area's buildings have High or Very High susceptibility to landslides. Landslide hazard is also ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of Tillamook County.

Figure 3-9. Landslide susceptibility exposure by Tillamook County community.



3.4.3 Areas of significant risk

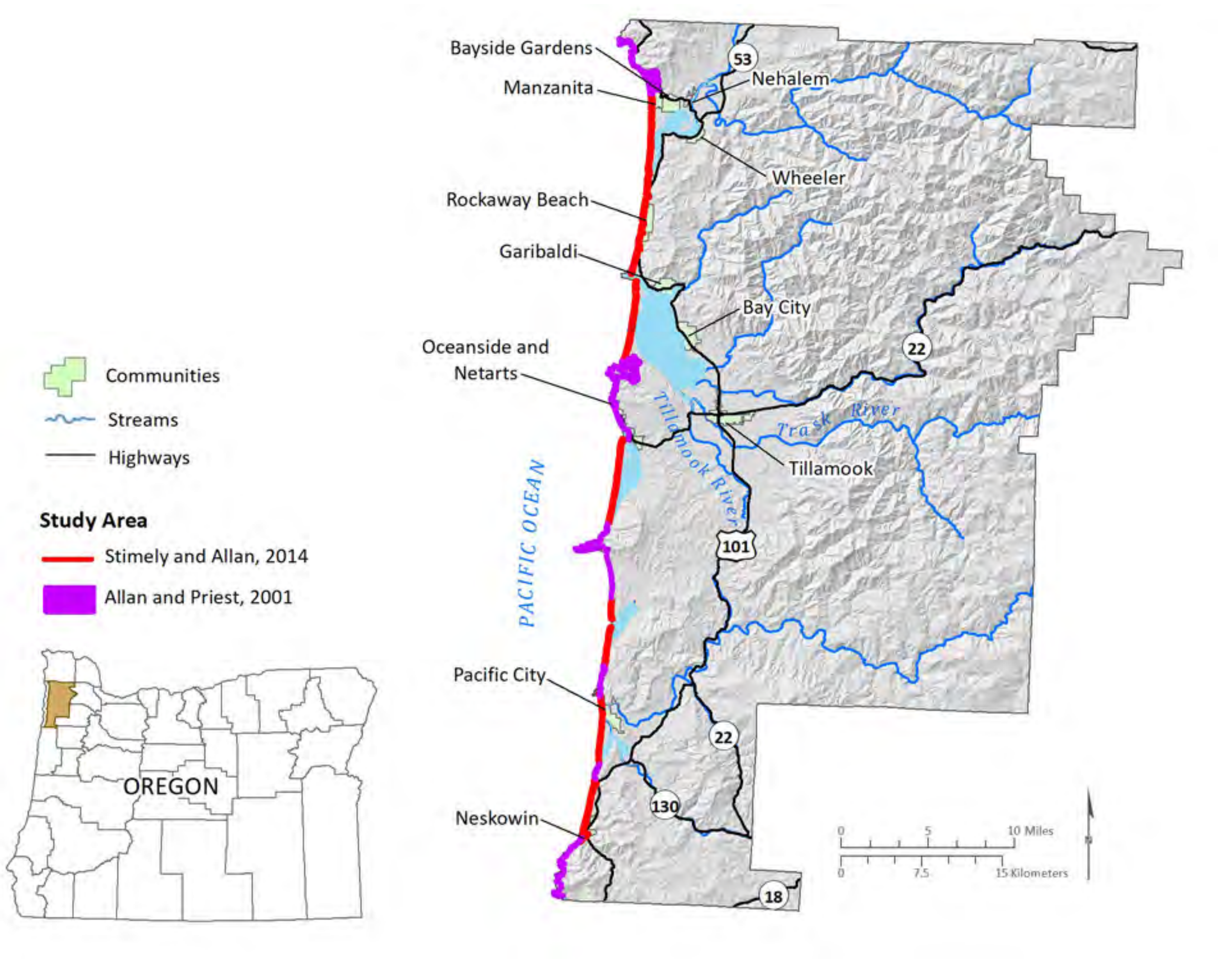
We identified locations within the study area that are comparatively at greater risk from landslide hazard:

- Much of the community of Oceanside and Netarts is at high or very high risk from landslide hazard.
- The hilly residential area in the northwest part of Bay City is within a Very High landslide susceptibility zone.
- The majority of Garibaldi, Nehalem, and Wheeler are at High risk from landslide hazard.
- Residential structures on the eastern edge of Rockaway Beach are built on top of a preexisting landslide which is considered Very High risk.
- Rural areas throughout Tillamook County with steep slopes are at increased risk from landslides.

3.5 Coastal Erosion

Erosion along the coast is a continuous process that occurs through a complex interaction of many geologic, atmospheric, and oceanic factors (including sea level rise). Beaches and dunes are highly susceptible to erosion, especially during large storms coupled with high ocean water levels. Coastal erosion is increasingly affecting people due to development near the beach or coastal bluffs. While shoreline stabilization efforts such as dynamic revetments and riprap slow down or stop additional erosion, they are not an effective long-term mitigation solution due to sea level rise and increased wave attack (Stimely and Allan, 2014). Whether it is a gradual process or rapid one, as can be the case with landslides, coastal erosion can cause loss of property, in some cases affecting an entire community. **Figure 3-10** shows the distribution of dune and bluff-backed sections of Tillamook County coastline subject to erosion studied by Stimely and Allan (2014) and Allan and Priest (2001).

Figure 3-10. Tillamook County location map showing the dune-backed sections of coast examined in Stimely and Allan (2014) and the bluff-backed sections examined in Allan and Priest (2001).



3.5.1 Data sources

Stimely and Allan (2014) determined coastal erosion hazard zones for dune-backed beaches in Tillamook County using the foredune erosion model (Komar and others, 1999) and a probabilistic analysis of storm-induced total water levels under a wide range of conditions. Their work also incorporated a worst-case Cascadia earthquake scenario and future sea level increases as projected by the National Research Council (2012). For this study we used their moderate dune erosion hazard zone representing a 1% annual chance (100 year) storm total water level and a mid-range estimate of sea level rise by the year 2050.

Allan and Priest (2001) determined coastal erosion hazard zones for bluff-backed beaches in Tillamook County using bluff slope, height, material properties (rock or soil composition), and the historical response of broad classes of bluffs to coastal erosion. For this study we used their moderate bluff erosion hazard zone representing the area that could be affected by active erosion in the next 100 years.

We overlaid buildings and critical facilities on the coastal erosion hazard zones to assess the exposure for each community. The total dollar value of the exposed buildings in the study area is reported below. We also estimated the number of people at risk from coastal erosion. Land value losses due to coastal erosion were not examined for this project.

3.5.2 Countywide results

Coastal erosion, for obvious reasons, affects only communities and areas along the open coast of Tillamook County. Coastal communities in Tillamook County all have some level of exposure to coastal erosion. The steep nature of the dunes and bluffs adjacent to the ocean offers dramatic scenery but also contributes to coastal erosion hazards.

The Moderate erosion hazard zones were chosen for this report because they best align with long-term planning by balancing a reasonable level of probability with a high level of impact to a community.

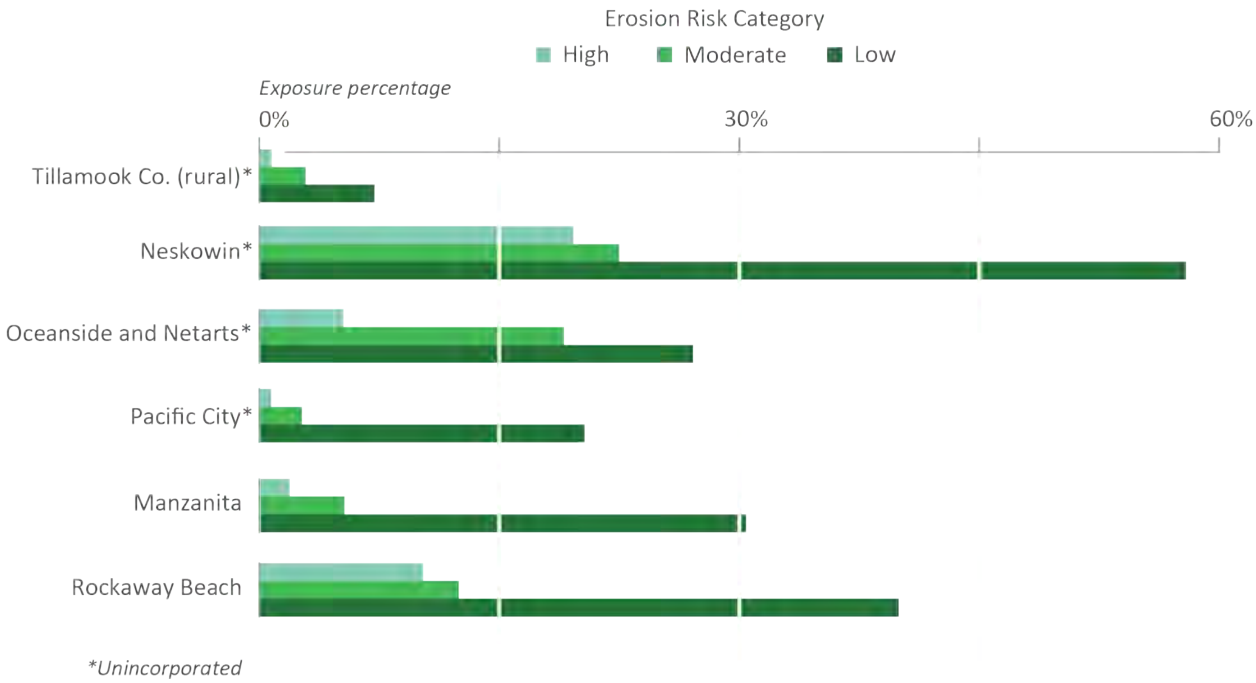
For this risk assessment, we limited the results of the exposure analysis to the open-coast communities included in the reports by Stimely and Allan (2014) and Allan and Priest (2001), as shown in **Figure 3-10**. The "Percentage of exposure value" below does not factor in the noncoastal incorporated communities of Tillamook County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Tillamook countywide coastal erosion exposure (Moderate dune and bluff erosion hazard):

- Number of buildings: 1,227
- Exposure value: $279,502,000
- Percentage of exposure value: 5.4%
- Critical facilities exposed: 1
- Potentially displaced population: 618

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. Awareness of this hazard is beneficial for reducing risk for future developments along Tillamook County's coastline. Long-term community plans that make allowance for coastal erosion encourage more resilience within the community. **Figure 3-11** illustrates the distribution of losses due to coastal erosion for the communities of Tillamook County.

Figure 3-11. Coastal erosion exposure by Tillamook County community.



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.

3.5.3 Areas of vulnerability or risk

We identified locations within the study area that are comparatively more vulnerable or at greater risk to coastal erosion hazard:

- The residential area in Neskowin along the coast and north of the Neskowin Creek mouth is likely to experience coastal erosion.
- Coastal erosion risk exists in Pacific City for several homes along the beach just north of the Pacific Avenue Bridge.
- All of coastal Rockaway Beach, which is predominantly residential, is likely to experience coastal erosion. During times of high tide occurring along with powerful storms, the rate of erosion can greatly increase.
- Areas outside of the study extent, namely the estuary shorelines, are also susceptible to erosion due to wave action and sea level rise.

3.6 Wildfire

The frequency, intensity, and severity of wildfires may change over time due to changes in climate, drought conditions, urbanization, and how we manage our forested lands. This study represents our current understanding of wildfire hazards and wildfire risk, but we recognize that wildfire models and risk assessments will need to be updated with time and changing conditions.

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

The Tillamook County Community Wildfire Protection Plan (TCCWPP), from 2010, recommended that the county develop policies that address fire restriction enforcement, wildland urban interface standards, and building code enforcement related to emergency access (Tillamook County Planning Commission, 2010). Forests cover approximately 90% of Tillamook County. Forests play an important role in the local economy but also surround homes and businesses (VLG Consulting and Pearson, 2011). Contact the Tillamook County Community Development for specific requirements related to the county's comprehensive plan.

3.6.1 Data sources

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

Using guidance from ODF, we categorized the Overall Wildfire Risk dataset into low, moderate, and high hazard zones for the wildfire exposure analysis. Overall Wildfire Risk was developed by the USFS as a combination of burn probability and the presence of infrastructure and assets. The range of values in the risk dataset describe level of potential impact and are characterized by very high negative values that indicate very high risk and negative values closer to zero which indicates low risk. This range of values were grouped into three categories of wildfire risk (Low, Moderate, and High). The risk dataset also includes positive values that represents uninhabited areas that benefit from wildfire, but these were combined into the low-risk category (Gilbertson-Day and others, 2018).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. In certain areas no wildfire data is present which indicates areas that have minimal risk to wildfire hazard (**Appendix B: Table B-8**). The total dollar value of exposed buildings in the study area is reported in the following section. We also estimated the number of people threatened by wildfire. Land value losses, infrastructure, and environmental impacts due to wildfire were not examined for this project.

3.6.2 Countywide results

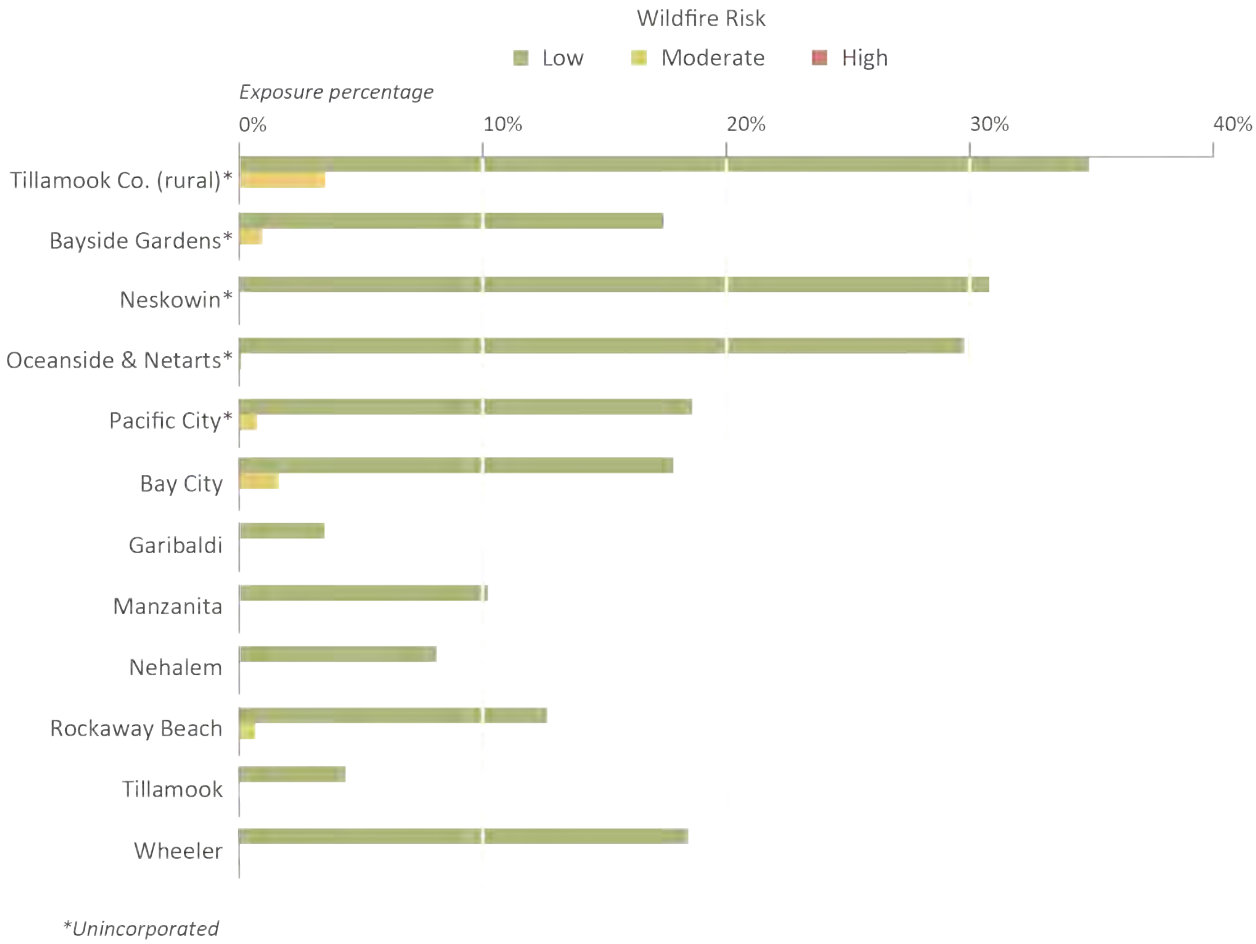
The High and Moderate hazard categories were chosen as the primary risk scenario for this report because these categories represent areas that have the highest potential for losses. However, Low hazard is not the same as no hazard. Moderate wildfire risk is included with High risk in this assessment, because under certain conditions Moderate risk zones can be very susceptible to burning. In combining the High and Moderate risk categories within Tillamook County, we can emphasize areas where lives and property are at greatest risk.

Tillamook countywide wildfire exposure (High or Moderate Risk):

- Number of buildings: 657
- Value of exposed buildings: $136,018,000
- Percentage of total county value exposed: 2.0%
- Critical facilities exposed: 2
- Potentially displaced population: 758

For this risk assessment, the building locations were compared to the geographic extent of the wildfire hazard categories. More than 600 buildings in unincorporated Tillamook County (rural) are exposed to High or Moderate wildfire hazard, but the incorporated communities have very little exposure to these hazard zones. The primary areas of exposure to this hazard are in the forested unincorporated areas in the eastern portions of the county (**Appendix E, Plate 6**). Nearly all of the buildings in the incorporated communities of Tillamook County fell into the Low-risk category. **Figure 3-12** illustrates the level of risk from wildfire for the different communities of Tillamook County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-12. Wildfire hazard exposure by Tillamook County community.



3.6.3 Areas of significant risk

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

- Areas to the east of the city of Tillamook are at higher levels of risk from wildfire than other areas in Tillamook County.
- Structures built within the WUI are at elevated risk from wildfire relative to structures in areas more densely developed.
- Buildings along the Nestucca River have an elevated risk from wildfire.

4.0 CONCLUSIONS

The purpose of this study is to provide a better understanding of potential impacts from multiple natural hazards at the community scale. We accomplished this by using the latest natural hazard mapping and loss estimation tools or exposure analysis to quantify risk to buildings and potential displacement of permanent residents. This detailed approach provides new context for the county's risk reduction efforts. We note several important findings based on the results of this study:

- **Extensive damage and losses for all areas in Tillamook County can occur from a CSZ Mw 9.0 earthquake and tsunami** — In the event of a CSZ Mw-9.0 earthquake and tsunami, every community in Tillamook County will experience significant losses and will be severely impacted. Results show that a CSZ event (earthquake and tsunami) would cause building losses ranging from 25% to 75% across all communities. Some communities like Rockaway Beach and Neskowin can expect a very high percentage of losses due to tsunami. Other communities like the city of Tillamook have little to no exposure to tsunami hazard but will have high losses from earthquake alone. The vulnerability of the building inventory from age of construction, the proximity to the CSZ event, the amount of development on liquefiable soils, and the amount of exposure to tsunami hazard all contribute to the estimated levels of losses expected in Tillamook County.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking**—Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We found that retrofitting to at least Moderate code was the most efficient mitigation strategy because the additional benefit from retrofitting to High code was minimal. In our simulation of upgrading buildings to at least Moderate code, the estimated loss for the entire study area was reduced from 22% to 14% for a CSZ event. Communities with older buildings that were constructed below the Moderate seismic code standards are both the most vulnerable and have the greatest potential for risk reduction. For example, the city of Tillamook could reduce losses from 32% to 16% for a CSZ event by retrofitting all buildings to at least Moderate code. While seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced liquefaction hazards will also be present in areas along the Nestucca River and around Tillamook Bay; these hazards require different geotechnical mitigation strategies.
- **Some communities in the study area are at Moderate risk from flooding**—Many buildings within the floodplain are vulnerable to significant damage from flooding. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages within individual communities relative to the other hazards we examined. This is due to the difference between the type of results from loss estimation and exposure analysis, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazards. We estimate that an average of 11% building value loss occurs for buildings within the 100-year flood zone. The areas that are most vulnerable to flood hazard within the study are some residential areas along the rivers that flow into Tillamook Bay (Tillamook, Trask, Wilson, and Kilchis), some areas in Pacific City and Nehalem along the Nestucca and Nehalem rivers, and coastal flooding in Neskowin.
- **Elevating structures in the flood zone reduces vulnerability**—We used flood exposure analysis in addition to Hazus-MH loss estimation to identify buildings that were not damaged but were within the area expected to experience a 100-year flood. By using both analyses in this way, we quantified the number of elevated structures within the flood zone. This showed possible

mitigation needs in flood loss prevention and the effectiveness of past activities. For example, Rockaway Beach has 148 buildings that are estimated to be elevated above the base flood elevation. Based on the number of buildings exposed to flooding in Neskowin, Pacific City, and Tillamook, many would benefit from elevating above the level of flooding

- **Landslide hazard is significant for steeper areas in the county—**The landslide mapping in this study was created using lidar and modern mapping methods, which resulted in very accurate landslide hazard maps. We used an exposure analysis to assess the threat from landslide hazards. Residential areas in large portions of Garibaldi, Nehalem, Wheeler, Oceanside and Netarts, and steeper areas in rural parts of the county are highly susceptible to landslides. Buildings in the northwest part of Bay City and the eastern edge of Rockaway Beach are at risk from landslide hazard.
- **Areas in Neskowin and Rockaway Beach are at risk from coastal erosion hazard—**Exposure analysis shows that some communities are vulnerable to coastal erosion hazard. The communities of Neskowin and Rockaway Beach, for example, have approximately one-quarter of their total building value exposed to High coastal erosion hazard.
- **Wildfire risk is higher in the wildland-urban interface portions of the county—**Exposure analysis shows that buildings in rural portions of the county are at higher risk from wildfire than other areas in the county. The forested and less populated eastern portions of the county are at risk from High and Moderate wildfire hazard. About 3% of the buildings in the unincorporated county are within areas of High or Moderate wildfire hazard.
- **Most of the study area's critical facilities are at greatest risk from a CSZ event relative to other hazards in the study area—**Because of their importance during and after a natural disaster, we identified and examined critical facilities within the county. We estimated that 75% (66 of 91) of Tillamook County's critical facilities will be nonfunctioning after a CSZ Mw-9.0 event (earthquake and tsunami). We found that 37 critical facilities are exposed to High or Very High landslide hazard.
- **Of the hazards examined in this study, the landslide hazard and a CSZ Mw-9.0 (earthquake and tsunami) are the greatest risks to people in Tillamook County—**Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that 34% (9,527) of the population in the county are within areas that are highly or very highly susceptible to landslide. We also estimated that 17% (4,726) of the population could be displaced from an earthquake and tsunami produced from a CSZ Mw-9.0 event. Some residents in the county are at risk from flood, with 2,272 residents within the 100-year flood zone. A small percentage of residents are vulnerable to displacement from coastal erosion and wildfire hazards.
- **The results allow communities to compare across hazards and prioritize their needs—**Each community within the study area was assessed for natural hazard exposure and loss. This allows for comparison of risk for a specific hazard between communities. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns for each individual community.

5.0 LIMITATIONS

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

- **Spatial and temporal variability of natural hazard occurrence** – Flood, landslide, channel migration, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones, except for earthquakes. For example, areas mapped in the 100-year flood zone will be prone to flooding on occasion in certain watersheds during specific events, but not all at once throughout the entire county or even the entire community. While we report the overall impacts of a given hazard scenario, the losses from a single hazard event will probably not be as severe and widespread.
- **Loss estimation for individual buildings** – Hazus-MH is a model, not reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of data outliers.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards (described above) and the inability to perform loss estimations due to the lack of Hazus-MH damage functions for certain natural hazards. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not predict the level to which an individual building could be damaged.
- **Population variability** – Some of the communities in Tillamook County have a significant number (7% to 12%) of vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on a distribution of residents (based on PSU Population Research Center estimates) into residential structures that include vacation homes and rentals. While the effect of this is minor, the total number of displaced residents to a given hazard contains a small amount of uncertainty.
- **Data accuracy and completeness** – Some of the information used to compile the countywide building dataset contained incomplete attributes or other inaccuracies where estimations were necessary. Specific building characteristics such as construction materials, foundation type, number of occupants, or first floor height were, in most cases, based on reasonable assumptions that reflect a typical building of that occupancy type. We are aware that some uncertainty has been introduced from these data amendments at an individual building scale, but at community-wide scales the effects of the uncertainties are slight.
- **Changing Conditions** – This assessment did not account for potential changes in climate, land use, or population. Human-induced climate change poses a significant and widespread risk to people around the world. In Oregon, climate change is expected to impact future floods, coastal erosion, wildfires, and landslides, but quantifying this impact was beyond the scope of this study.

6.0 RECOMMENDATIONS

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

6.1 Awareness and Preparation

Awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community becomes a safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the amount of recovery time for a after a disaster—this ability is commonly referred to as "resilience."

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

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

6.2 Planning

Local decision-makers can make plans based on the geohazard and risk information presented in this report. The primary framework for accomplishing this is through the comprehensive planning process. A comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

Another framework is the natural hazard mitigation plan (NHMP) process. The NHMP focuses on characterizing natural hazard risk and identifying actions to reduce risk. The information presented in this report is a key resource because it directly informs the vulnerability assessment section of the NHMP plan.

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

6.3 Emergency Response

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

The building database that accompanies this report can guide pre-disaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and supported through awareness campaigns. These campaigns can be aimed at pre-disaster mitigation actions, such as seismic retrofitting. Emergency response entities can benefit from the use of the building dataset through identification of potential hazards and populated buildings before and during a disaster. Reduction of the magnitude of the disaster, emergency planning, and improved response time contribute to a community's natural hazard resilience.

6.4 Mitigation Funding Opportunities

Several funding sources are available to communities that are susceptible to natural hazards and have specific mitigation projects they wish to accomplish. State and federal funds are available for projects that demonstrate cost effective natural hazard risk reduction. The Oregon Office of Emergency Management (OEM) State Hazard Mitigation Officer (SHMO) can provide communities assistance in determining eligibility, finding mitigation grants, and navigating the mitigation grant application process.

At the time of writing this report, FEMA has three programs that assist states, local communities, tribes, and territories with natural hazard mitigation funding: Hazard Mitigation Grant Program (HMGP) Building Resilient Infrastructure and Communities (BRIC), and Pre-Disaster Mitigation (PDM) Grant Program. FEMA also has a grant program specifically for flooding called Flood Mitigation Assistance (FMA). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 CSZ Mw-9.0 Earthquake and Tsunami

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 84% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by a CSZ event described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify communities and buildings that would benefit from seismic upgrades.
- Evaluate the community evacuation plan, including consideration for viable vertical evacuation options.
- Evacuation planning utilizing a series of analysis and tsunami evacuation maps called "Beat the Wave" (Gabel and Allan, 2016; 2017), (Gabel and others, 2018; 2019; 2020) for coastal communities in Tillamook County.
- Complete a detailed earthquake analysis that includes seasonal population variability.

6.5.2 Flood

- Map areas of potential flood water storage areas.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/floods.

- Relocate or elevate vulnerable structures above the estimated base flood elevation. In some cases, communities can use FEMA's property acquisition or "buyout" program to remove structures that have repeatedly flooded in the past (https://www.fema.gov/node/does-fema-have-existing-guidelines-elevating-home-flood-zone).

6.5.3 Landslide

- Monitor ground movement in high susceptibility areas.
- Identify mitigation priorities for infrastructure resilience.
- Evaluate risks to transportation networks and land value losses due to landslide in future risk assessments.
- Study the risk from landslides that are experience channel erosion at the toe of the landslide.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/landslides-debris-flow.

6.5.4 Coastal erosion

- Update coastal erosion analysis and mapping to better characterize the current hazard areas.
- Monitor ground movement in high susceptible areas, especially during or after large storms.
- Identify critical facilities and infrastructure near high coastal erosion areas.
- Consider land value losses due to coastal erosion in future risk assessments.

6.5.5 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.
- Additional risk reduction strategies may be found on FEMA's website at https://www.ready.gov/wildfires.

7.0 ACKNOWLEDGMENTS

This natural hazard risk assessment was conducted by DOGAMI in 2022. It was funded by DLCD (Interagency Agreement #21022). DOGAMI worked closely with DLCD to complete the risk assessment and produce this report. DLCD is coordinating with communities on the next NHMP update, which will incorporate the findings from this risk assessment.

Many people contributed to this report at different points during the analysis phase and during the writing phase and at various levels. We are grateful to everyone who contributed, especially the following from DOGAMI: William Burns, Zee Priest, Jason McClaughry, and Alex Lopez.

Additionally, we would like to thank people from other agencies and entities who also assisted on this project – from FEMA: Rynn Lamb; from DLCD: Pam Reber and Marian Lahav.

8.0 REFERENCES

Allan, J. C. and Priest, G. R., 2001, Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Cascade Head to Cape Falcon, Preliminary technical report to Tillamook County: Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-01-03, 120 p. https://www.oregongeology.org/pubs/ofr/p-O-01-03.zip

Allan, J. C., Ruggiero, P., Garcia, G., O'Brien, F. E., Stimely, L. L., and Roberts, J. T., 2015, Coastal flood hazard study, Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 47, 274 p. https://www.oregongeology.org/pubs/sp/p-SP-47.htm

Allan, J. C., O'Brien, F. E., Bauer, J. M., and Williams, M. C., 2020 Earthquake and tsunami impact analysis for coastal Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-20-14, 121 p. https://www.oregongeology.org/pubs/ofr/p-O-20-14.htm

Applied Technology Council, 2015, Rapid visual screening of buildings for potential seismic hazards: A handbook (3rd ed.): Redwood City, Calif., FEMA Publication 154. https://www.fema.gov/sites/default/files/2020-07/fema_earthquakes_rapid-visual-screening-of-buildings-for-potential-seismic-hazards-a-handbook-third-edition-fema-p-154.pdf

Bauer, J. M., 2018, ArcGIS Python script alternative to the Hazus-MH Flood Model for User-Defined Facilities: Oregon Department of Geology and Mineral Industries Open-File Report O-18-04, 28 p. https://www.oregongeology.org/pubs/ofr/p-O-18-04.htm

Bauer, J. M., Allan, J. C., Gabel, L. L., O'Brien, F. E., and Roberts, J. T., 2020, Analysis of earthquake and tsunami impacts for people and structures inside the tsunami zone for five Oregon coastal communities: Gearhart, Rockaway Beach, Lincoln City, Newport, and Port Orford: Oregon Department of Geology and Mineral Industries Open-File Report O-20-03, 185 p. https://www.oregongeology.org/pubs/ofr/p-O-20-03.htm

Burns, W. J. and Madin, I. P., 2009, Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p. https://www.oregongeology.org/pubs/sp/p-SP-42.htm

Burns, W. J., and Watzig, R. J., 2014, Statewide landslide information layer for Oregon, release 3 [SLIDO-3.0]: Oregon Department of Geology and Mineral Industries, 35 p., 1:750,000, geodatabase

Burns, W. J., Mickelson, K. A., and Madin, I. P., 2016, Landslide susceptibility overview map of Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-16-02, 48 p. https://www.oregongeology.org/pubs/ofr/p-O-16-02.htm

Business Oregon, 2015, Oregon benefit-cost analysis tool for evaluation of seismic rehabilitation grant program applications: User's guide: Salem, Oreg., Infrastructure Finance Authority Division, 34 p. https://www.oregon.gov/biz/Publications/SRGP%20Application%20Documents/UserGuide.pdf

Calhoun, N. C., Burns, W. J., and Franczyk, J. J., 2020, Landslide hazard and risk study of Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-20-13, 44 p. https://www.oregongeology.org/pubs/ofr/p-O-20-13.htm

Charest, A. C. (ed.), 2017, Square foot costs with RSMeans® data (38th annual edition): Rockland, Md., Gordian Group, Inc., 563 p. https://www.rsmeans.com/products/books/2017-cost-databooks/2017-square-foot-costs-book.aspx

Federal Emergency Management Agency, 2012a, Hazus®-MH 2.1 User manual, Flood model: Washington, D.C., 382 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2012b, Hazus®-MH 2.1 Technical manual, Earthquake model: Washington, D.C., 718 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2012c, Hazus®-MH 2.1, Technical manual, Flood model: Washington, D.C., 569 p. https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals

Federal Emergency Management Agency, 2018, Flood insurance study: Tillamook County, Oregon and incorporated areas: Washington D.C., Flood Insurance Study Number 41057CV001A, v. 1, 140 p. https://map1.msc.fema.gov/data/41/S/PDF/41057CV001A.pdf?LOC=42ea9a56c774c67ed36c44e6eb4a7b49

Fillmore, M.H., and Shipman, J.A., 2013, Soil survey of Tillamook County, Oregon: U.S. Department of Agriculture National Resources Conservation Service.

Franczyk, J. J., Burns, W. J., and Calhoun, N. C., 2021, Statewide landslide information layer for Oregon, release 4 [SLIDO-4.4]: Oregon Department of Geology and Mineral Industries, 54 p., 1:750,000, geodatabase https://www.oregongeology.org/pubs/dds/p-slido4.htm

Gabel, L.L., and Allan, J.C., 2016, Local tsunami evacuation analysis of Warrenton and Tillamook Spit, Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-16-08, 62 p. https://www.oregongeology.org/pubs/ofr/p-O-16-08.htm

Gabel, L.L., and Allan, J.C., 2017, Local tsunami evacuation analysis of Rockaway Beach, Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-17-06, 56 p. https://www.oregongeology.org/pubs/ofr/p-O-17-06.htm

Gabel, L.L., O'Brien, F., and Allan, J.C., 2018, Local tsunami evacuation analysis of Pacific City, Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-18-06, 59 p. https://www.oregongeology.org/pubs/ofr/p-O-18-06.htm

Gabel, L.L., O'Brien, F., Bauer, J., and Allan, J.C., 2019, Tsunami evacuation analysis of some unincorporated Tillamook County communities: Building community resilience on the Oregon coast: Oregon Department of Geology and Mineral Industries Open-File Report O-19-08, 68 p. https://www.oregongeology.org/pubs/ofr/p-O-19-08.htm

Gabel, L.L., O'Brien, F., and Allan, J.C., 2020, Local tsunami evacuation analysis of Nehalem Bay, Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-20-07, 53 p. https://www.oregongeology.org/pubs/ofr/p-O-20-07.htm

Gilbertson-Day, J. W., Stratton, R. D., Scott, J. H., Vogler, K. C., and Brough, A., 2018, Pacific Northwest Quantitative Wildfire Risk Assessment: Methods and Results, final report, report to Oregon Department of Forestry and others, 86 p. http://oe.oregonexplorer.info/externalcontent/wildfire/reports/20170428_PNW_Quantitative_Wildfire_Risk_Assessment_Report.pdf

Goldfinger, C., and others, 2012, Turbidite event history: Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone: U.S. Geological Survey Professional Paper 1661-F, 178 p. https://doi.org/10.3133/pp1661F

Goldfinger, C., Galer, S., Beeson, J., Hamilton, T., Black, B., Romsos, C., Patton, J., Nelson, C.H., Hausmann, R., and Morey, A., 2017, The importance of site selection, sediment supply, and hydrodynamics: A case study of submarine paleoseismology on the Northern Cascadia margin, Washington USA: Marine Geology, v. 384, p. 4–16, 17, 25–46.

Judson, S., 2012, Earthquake design history: A summary of requirements in the State of Oregon: State of Oregon, Building Codes Division, Feb. 7, 2012, 7 p. http://www.oregon.gov/bcd/codes-stand/Documents/inform-2012-oregon-sesmic-codes-history.pdf

Lewis, D., 2007, Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings: Oregon Department of Geology and Mineral Industries Open-File Report O-07-02, 140 p. https://www.oregongeology.org/pubs/ofr/p-O-07-02.htm

Madin, I. P., and Burns, W. J., 2013, Ground motion, ground deformation, tsunami inundation, coseismic subsidence, and damage potential maps for the 2012 Oregon Resilience Plan for Cascadia subduction zone earthquakes: Oregon Department of Geology and Mineral Industries Open-File Report O-13-06, 36 p. 38 pl., GIS data. https://www.oregongeology.org/pubs/ofr/p-O-13-06.htm

Madin, I. P., Franczyk, J. J., Bauer, J. M., and Azzopardi, C. J. M., 2021, Oregon Seismic Hazard Database, release 1.0: Oregon Department of Geology and Mineral Industries Digital Data Series OSHD-1. https://www.oregongeology.org/pubs/dds/p-OSHD-1.htm

Oregon Building Codes Division, 2002, Oregon manufactured dwelling and park specialty code, 2002 ed.: Oregon Manufactured Housing Association and Oregon Building Codes Division, Department of Consumer and Business Services, 176 p. http://www.oregon.gov/bcd/codes-stand/Documents/md-2002-mdparks-code.pdf

Oregon Building Codes Division, 2010, 2010 Oregon manufactured dwelling installation specialty code: Department of Consumer and Business Services, Building Codes Division, 67 p. http://www.oregon.gov/bcd/codes-stand/Documents/md-2010omdisc-codebook.pdf

Personius, S. F., compiler, 2017, Fault number 882, Happy Camp fault, in Quaternary fault and fold database of the United States, U. S. Geological Survey website, https://earthquake.usgs.gov/cfusion/qfault/show_report_AB_archive.cfm?fault_id=882&section_id=

Peterson, C. D., Barnett, E. T., Briggs, G. G., Carver, G. A., Clague, J. J., and Darienzo, M. E., 1997, Estimates of coastal subsidence from great earthquakes in the Cascadia subduction zone, Vancouver Island, B. C., Washington, Oregon, and northernmost California: Oregon Department of Geology and Mineral Industries Open-File Report O-97-05, 44 p. https://www.oregongeology.org/pubs/ofr/O-97-05.pdf

Priest, G. R., Witter, R. C., Zhang, Y. J., Wang, K., Goldfinger, C., Stimely, L. L., English, J. T., Pickner, S. P., Hughes, K. L. B., Wille, T. E., and Smith, R. L., 2013, Tsunami inundation scenarios for Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-13-19, 18 p., GIS data. https://www.oregongeology.org/pubs/ofr/p-O-13-19.htm

PRISM Climate Group, n.d., Climate data web site: Oregon State University. http://prism.oregonstate.edu, accessed July 2020.

Rapp, C. F., and Abbe, T. B., 2003, A framework for delineating channel migration zones: Olympia, Wash., Washington State Department of Ecology Publication 03-06-027, 65 p.

Stimely, L., and Allan, J. C., 2014, Evaluation of erosion hazard zones for the dune-backed beaches of Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-14-02, 113 p., geodatabase. http://www.oregongeology.org/pubs/ofr/p-O-14-02.htm

Tillamook County Planning Commission, 2010, Tillamook County Community Wildfire Protection Plan, 42 p. https://digital.osl.state.or.us/islandora/object/osl:539182

U.S. Census Bureau, 2010a, Master Address File/Topologically Integrated Geographic Encoding and Referencing system or database: Oregon census block: United States Census Bureau. https://www2.census.gov/geo/tiger/TIGER2010/TABBLOCK/2010/

U.S. Census Bureau, 2010b, American FactFinder: Profile of General Population and Housing Characteristics: United States Census Bureau. Web. 10 November 2021. https://data.census.gov/cedsci/all?q=housing

U.S. Geological Survey, 2017, Earthquake hazards 101 — the basics. Retrieved from https://www.usgs.gov/programs/earthquake-hazards/science/earthquake-hazards-101-basics

VLG Consulting and Pearson, S., 2011, Tillamook County, Oregon multi-jurisdiction natural hazards mitigation plan, update 2011: Tillamook County Departments of Community Development and Emergency Management, 363 p. http://www.co.tillamook.or.us/gov/ComDev/documents/Tillamook%20County%20MJHMP%20Final%20to%20FEMA.pdf

Wang, Y., 1998, Earthquake damage and loss estimate for Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-98-3, 10 p. 2 app. https://www.oregongeology.org/pubs/ofr/O-98-03.pdf

Wang, Z., Hasenberg, C. S., Hasenberg, G. B., and Rad, F. N., 2001, Preliminary seismic hazard and risk assessments in Tillamook County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-01-06, 36 p. https://www.oregongeology.org/pubs/pubsearch.htm

Witter, R. C., Zhang, Y., Wang, K., Priest, G. R., Goldfinger, C., Stimely, L. L., English, J. T., and Ferro, P. A., 2011, Simulating tsunami inundation at Bandon, Coos County, Oregon, using hypothetical Cascadia and Alaska earthquake scenarios: Oregon Department of Geology and Mineral Industries Special Paper 43, 57 p. https://www.oregongeology.org/pubs/sp/p-SP-43.htm

Williams, M. C., Appleby, C. A., Bauer, J. M., and Roberts, J. T., 2020, Natural hazard risk report for Tillamook County, Oregon, including the cities of Bay City, Garibaldi, Manzanita, Nehalem, Rockaway Beach, Tillamook, and Wheeler and the unincorporated communities of Neskowin, Oceanside, Netarts, and Pacific City: Oregon Department of Geology and Mineral Industries Interpretive Map Series – 58, 95 p. https://www.oregongeology.org/pubs/ims/p-ims-058.htm

Williams, M. C., 2021, Statewide Building Footprints for Oregon, release 1.0: Oregon Department of Geology and Mineral Industries Digital Data Series SBFO-1. https://www.oregongeology.org/pubs/dds/p-SBFO-1.htm

Wirth, E.A., Grant, A., Marafi, N.A., and Frankel, A.D., 2021, Ensemble ShakeMaps for magnitude 9 earthquakes on the Cascadia Subduction Zone: Seismol. Res. Lett., v. 92, no. 1, 99–211, https://doi.org/10.1785/0220200240

9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

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

A.1 Unincorporated Tillamook County (Rural)

Table A-1. Unincorporated Tillamook County hazard profile.

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	22	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%

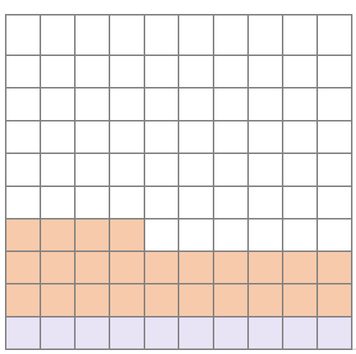
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-1. Unincorporated Tillamook County loss ratio from Cascadia subduction zone event.



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 A-2. Unincorporated Tillamook County critical facilities.

	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 Stn.		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				
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					

A.2 Unincorporated community of Bayside Gardens

Table A-3. Unincorporated community of Bayside Gardens hazard profile.

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%

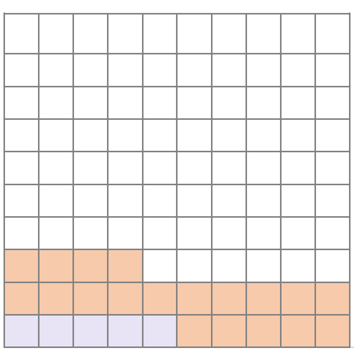
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-2. Unincorporated community of Bayside Gardens loss ratio from Cascadia subduction zone event.



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 A-4. Unincorporated community of Bayside Gardens critical facilities.

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					

A.3 Unincorporated community of Neskowin

Table A-5. Unincorporated community of Neskowin hazard profile.

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%

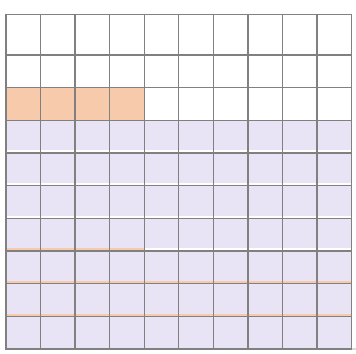
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-3. Unincorporated community of Neskowin loss ratio from Cascadia subduction zone event.



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.

A.4 Unincorporated communities of Oceanside and Netarts

Table A-6. Unincorporated communities of Oceanside and Netarts hazard profile.

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%

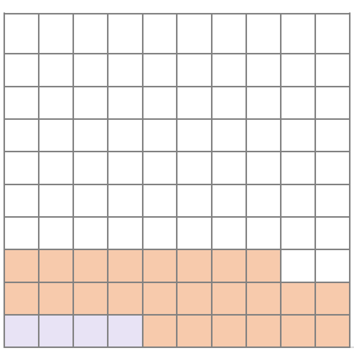
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-4. Unincorporated communities of Oceanside and Netarts loss ratio from Cascadia subduction zone event.



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 A-7. Unincorporated communities of Oceanside and Netarts critical facilities.

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
Netarts Oceanside RFPD Station #61		X	X		X		
Netarts Oceanside RFPD Station #62		X	X		X		

A.5 Unincorporated community of Pacific City

Table A-8. Unincorporated community of Pacific City hazard profile.

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%

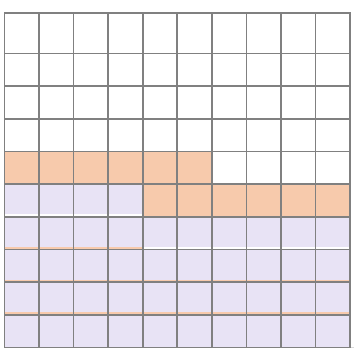
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-5. Unincorporated community of Pacific City loss ratio from Cascadia subduction zone event.



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 A-9. Unincorporated community of Pacific City critical facilities.

	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**
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			

A.6 City of Bay City

Table A-10. City of Bay City hazard profile.

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%

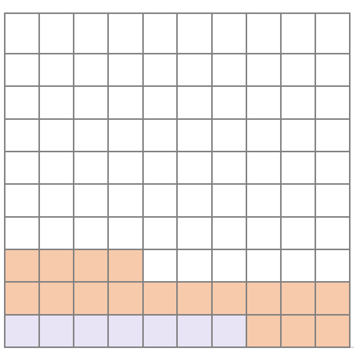
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-6. City of Bay City loss ratio from Cascadia subduction zone event.



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 A-11. City of Bay City critical facilities.

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
Bay City Fire Department		X	X				
Bay City Public Works		X	X	X			
Bay City Wastewater Treatment		X	X	X			

A.7 City of Garibaldi

Table A-12. City of Garibaldi hazard profile.

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%

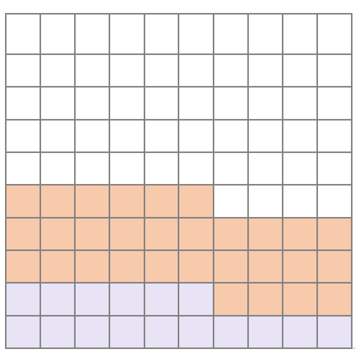
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-7. City of Garibaldi loss ratio from Cascadia subduction zone event.



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 A-13. City of Garibaldi critical facilities.

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**
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		

A.8 City of Manzanita

Table A-14. City of Manzanita hazard profile.

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%

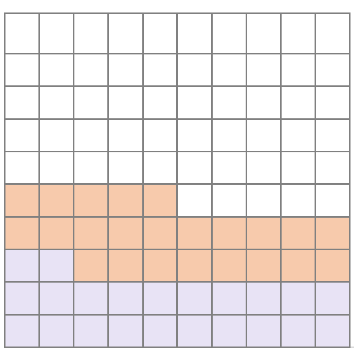
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-8. City of Manzanita loss ratio from Cascadia subduction zone event.



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 A-15. City of Manzanita critical facilities.

	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**
Manzanita City Hall/Fire/Police Department		X					
Manzanita City Hall		X					
Manzanita Public Safety		X					
Manzanita Public Works		X			X		

A.9 City of Nehalem

Table A-16. City of Nehalem hazard profile.

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	1135000	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%

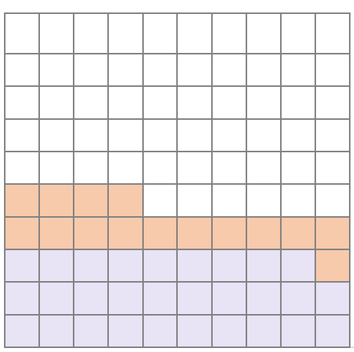
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-9. City of Nehalem loss ratio from Cascadia subduction zone event.



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 A-17. City of Nehalem critical facilities.

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**
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		

A.10 City of Rockaway Beach

Table A-18. City of Rockaway Beach hazard profile.

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 Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
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%

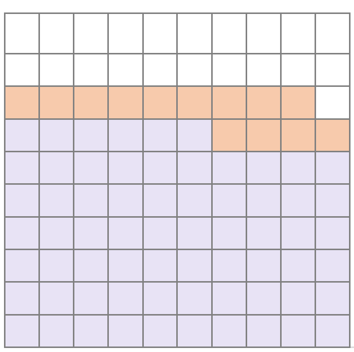
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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).

Figure A-10. City of Rockaway Beach loss ratio from Cascadia subduction zone event.



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 A-19. City of Rockaway Beach critical facilities.

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 and Public Works		X		X			
Rockaway Beach Fire Dept.		X		X			
Rockaway Beach Water Treatment Plant		X		X			
Rockaway Beach Police Dept.		X		X			

A.11 City of Tillamook

Table A-20. City of Tillamook hazard profile.

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%

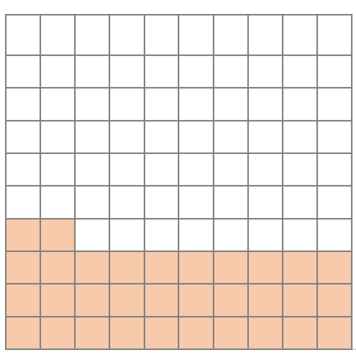
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-11. City of Tillamook loss ratio from Cascadia subduction zone event.



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 A-21. City of Tillamook critical facilities.

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				

A.12 City of Wheeler

Table A-22. City of Wheeler hazard profile.

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%

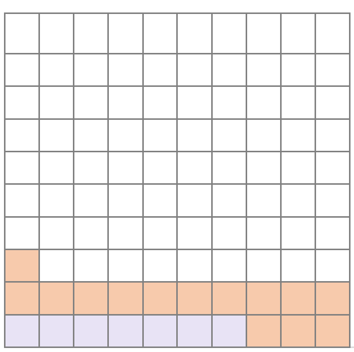
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 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).

Figure A-12. City of Wheeler loss ratio from Cascadia subduction zone event.



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 A-23. City of Wheeler critical facilities.

	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**
Nehalem Valley Care Center		X			X		
Nehalem Valley Care Center Rinehart Clinic		X			X		
Wheeler City Hall and Public Works		X			X		

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Tillamook County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			All Buildings			
Community	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Building Value ($)	Building Value per Community Total	Number of Buildings	Number of Buildings per County Total	Building Value ($)	Building Value per County Total
Unincorp. County (rural)	9,470	2,070,251	57%	307	167,204	4.6%	3,920	1,013,153	28%	410	356,973	9.9%	14,107	52%	3,610,281	53%
Bayside Gardens	807	161,204	87%	25	10,422	5.6%	99	4,126	2%	14	10,573	5.7%	945	3.5%	186,325	2.7%
Neskowin	615	138,206	98%	5	1,270	0.9%	25	514	0.4%	7	1,104	0.8%	652	2.4%	141,094	2.1%
Oceanside & Netarts	1,492	289,862	96%	17	4,519	1.5%	105	3,022	1.0%	14	5,185	1.7%	1,628	6.0%	302,588	4.4%
Pacific City	1,542	320,683	89%	79	28,019	8%	78	3,955	1.1%	22	8,457	2.3%	1,721	6.4%	361,114	5.3%
Total Unincorp. County	13,926	2,980,206	65%	433	211,434	4.6%	4,227	1,024,771	22.3%	467	382,290	8.3%	19,050	70%	4,598,402	67%
Bay City	785	186,224	81%	30	29,398	13%	52	5,478	2.4%	13	8,075	4%	880	3.2%	229,175	3.3%
Garibaldi	598	130,037	73%	73	25,207	14%	47	2,375	1%	37	21,444	12%	755	2.8%	179,063	2.6%
Manzanita	1,355	248,231	90%	56	14,393	5%	78	1,664	0.6%	28	10,369	4%	1,517	5.6%	274,658	4.0%
Nehalem	175	32,593	60%	27	8,711	16%	20	592	1%	12	12,464	23%	234	0.9%	54,360	0.8%
Rockaway Beach	1,959	420,417	92%	41	16,444	4%	67	2,528	1%	28	15,344	3.4%	2,095	7.7%	454,733	6.6%
Tillamook	1,678	501,692	51%	283	251,100	26%	94	11,152	1.1%	139	218,987	22%	2,194	8%	982,931	14%
Wheeler	292	56,132	69%	34	22,045	27%	30	1,378	2%	6	1,582	1.9%	362	1%	81,137	1%
Total Tillamook County	20,768	4,555,533	66%	977	578,732	8%	4,615	1,049,938	15%	730	670,555	10%	27,090	100%	6,854,759	100%

Table B-2. Cascadia subduction zone earthquake loss estimates.

(all dollar amounts in thousands)

			Total Earthquake Damage*		Earthquake Damage outside of Medium Tsunami Zone							
			Buildings Damaged		Buildings Damaged				Building Design Level Upgraded 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
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%

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

Table B-3. 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%

Table B-4. Tsunami exposure.

(all dollar amounts in thousands)

			Small (Low Severity)			Medium (Moderate Severity)			Large (High Severity)			X Large (Very High Severity)			XX Large (Extreme Severity)		
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	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	511	112,049	3.1%	1,620	349,607	9.7%	2,299	545,845	15%	3,162	807,490	22%	3,269	874,428	24%
Bayside Gardens	945	186,325	2	254	0.1%	51	9,065	4.9%	226	51,995	28%	405	90,114	48%	412	91,507	49%
Neskowin	652	141,094	264	63,296	45%	456	98,438	70%	479	102,497	73%	500	107,573	76%	503	108,086	77%
Oceanside & Netarts	1,628	302,588	48	8,670	2.9%	75	13,195	4.4%	125	20,548	6.8%	269	49,100	16%	307	55,473	18%
Pacific City	1,721	361,114	171	35,603	9.9%	788	159,893	44%	1,247	250,970	70%	1,350	268,493	74%	1,356	269,577	75%
Total Unincorp. County	19,050	4,598,402	996	219,872	4.8%	2,990	630,197	14%	4,376	971,855	21%	5,686	1,322,771	29%	5,847	1,399,070	30%
Bay City	880	229,175	3	1,731	0.8%	59	15,421	6.7%	126	42,955	19%	208	62,339	27%	221	65,700	29%
Garibaldi	755	179,063	13	3,735	2.1%	82	29,140	16%	186	62,063	35%	311	87,940	49%	325	90,860	51%
Manzanita	1,517	274,658	0	0	0%	346	60,365	22%	698	122,230	45%	920	167,665	61%	939	171,322	62%
Nehalem	234	54,360	41	11,744	22%	57	15,629	29%	62	16,400	30%	71	19,330	36%	72	19,835	37%
Rockaway Beach	2,095	454,733	472	100,598	22%	1,373	299,239	66%	1,733	373,045	82%	1,928	413,271	91%	1,947	417,219	92%
Tillamook	2,194	982,931	0	0	0.0%	4	446	0.0%	83	71,585	7.3%	392	214,053	22%	467	234,134	24%
Wheeler	362	81,137	13	2,704	3.3%	20	5,537	6.8%	28	8,893	11%	50	14,441	18%	52	14,745	18%
Total Tillamook County	27,090	6,854,759	1,538	340,383	5.0%	4,931	1,055,974	15%	7,292	1,669,027	24%	9,566	2,301,812	34%	9,870	2,412,884	35%

Table B-5. Flood loss estimates.

			(all dollar amounts in thousands)											
			10% (10-yr)			**2% (50-yr)**			**1% (100-yr)**			**0.2% (500-yr)**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate**	**Loss Ratio**
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%

Table B-6. Flood exposure.

			1% (100-yr)				
Community	**Total Number of Buildings**	**Total Population**	**Potentially Displaced Residents from Flood Exposure**	**% Potentially Displaced Residents from flood Exposure**	**Number of Flood Exposed Buildings**	**% of Flood Exposed Buildings**	**Number of Flood Exposed Buildings Without Damage**
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

Table B-7. Landslide exposure.

			(all dollar amounts in thousands)								
			Very High Susceptibility			**High Susceptibility**			**Moderate Susceptibility**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
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 B-8. Coastal erosion exposure.

(all dollar amounts in thousands)

Community*	Total Number of Buildings	Total Estimated Building Value ($)	High Hazard			Moderate Hazard			Low Hazard		
			Number of Buildings	Building Value ($)	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)	14,104	3,607,281	170	28,111	0.5%	513	105,734	2.1%	1,317	265,019	5.2%
Bayside Gardens	945	186,325	0	0	0.0%	0	0	0.0%	0	0	0.0%
Neskowin	652	141,094	99	28,343	0.6%	116	32,475	0.6%	379	83,556	1.6%
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%
Bay City	880	229,175	0	0	0.0%	0	0	0.0%	0	0	0.0%
Garibaldi	755	179,063	0	0	0.0%	0	0	0.0%	0	0	0.0%
Manzanita	1,517	274,658	25	5,105	0.1%	69	14,699	0.3%	477	85,199	1.7%
Nehalem	234	54,360	0	0	0.0%	0	0	0.0%	0	0	0.0%
Rockaway Beach	2,095	454,733	146	47,790	0.9%	192	58,196	1.1%	805	185,974	3.6%
Tillamook	2,194	982,931	0	0	0.0%	0	0	0.0%	0	0	0.0%
Wheeler	362	81,137	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total Tillamook County	21,717	5,141,468	529	128,016	2.5%	1,227	279,502	5.4%	3,763	778,318	15.1%

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

Table B-9. Wildfire exposure.

			(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%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 3.0 and ArcGIS® Desktop® 10.2.2.

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Tillamook County for use in both the flood and earthquake modules of Hazus-MH. The Tillamook County assessor database (acquired in 2021) was used to determine which taxlots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

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

C.2.2 Attributing building points

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

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

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

C.2.3 Seismic building codes

Oregon initially adopted seismic building codes in the mid-1970s (Judson, 2012). The established benchmark years of code enforcement are used in determining a "design level" for individual buildings. The design level attributes (pre code, low code, moderate code, and high code) are used in the Hazus-MH earthquake model to determine what damage functions are applied to a given building (FEMA, 2012b). The year built or the year of the most recent seismic retrofit are the main considerations for an individual design level attribute. Seismic retrofitting information for structures would be ideal for this analysis but was not available for Tillamook County. **Table C-1** outlines the benchmark years that apply to buildings within Tillamook County.

Table C-1. Tillamook County seismic design level benchmark years.

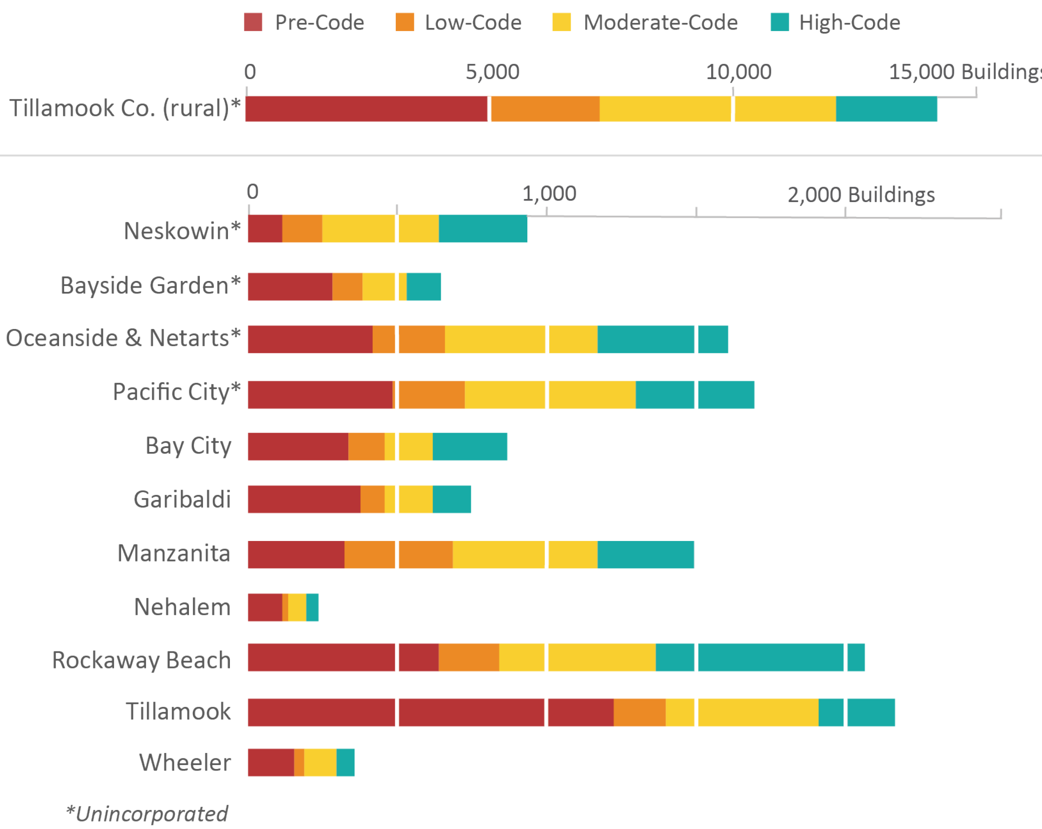
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured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

Table C-2 and corresponding **Figure C-1** illustrate the current state of seismic building codes for the county.

Table C-2. Seismic design level in Tillamook County.

		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%

Figure C-1. Seismic design level by Tillamook County community.



C.3 Flood Hazard Data

Depth grids for "Zone A" designated flood zones, or approximate 100-year flood zones, were developed by the Strategic Alliance for Risk Reduction (STARR) in 2015 to revise the Tillamook County FIRMs (FEMA, 2018). DOGAMI developed depth grids from detailed stream model information within the study area. Both sets of depth grids were used in this risk assessment to determine the level to which buildings are impacted by flooding.

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

Once the UDF database was developed into a Hazus-compliant format, the Hazus-MH methodology was applied using a Python (programming language) script developed by DOGAMI (Bauer, 2018). The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF's Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, liquefaction susceptibility and wet landslide susceptibility. The liquefaction and landslide susceptibility layers together with NEHRP were used by the Hazus-MH tool to calculate ground motion layers and permanent ground deformation and associated probability.

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

C.5 Post-Analysis Quality Control

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

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

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

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

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

D.2 Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX E. MAP PLATES

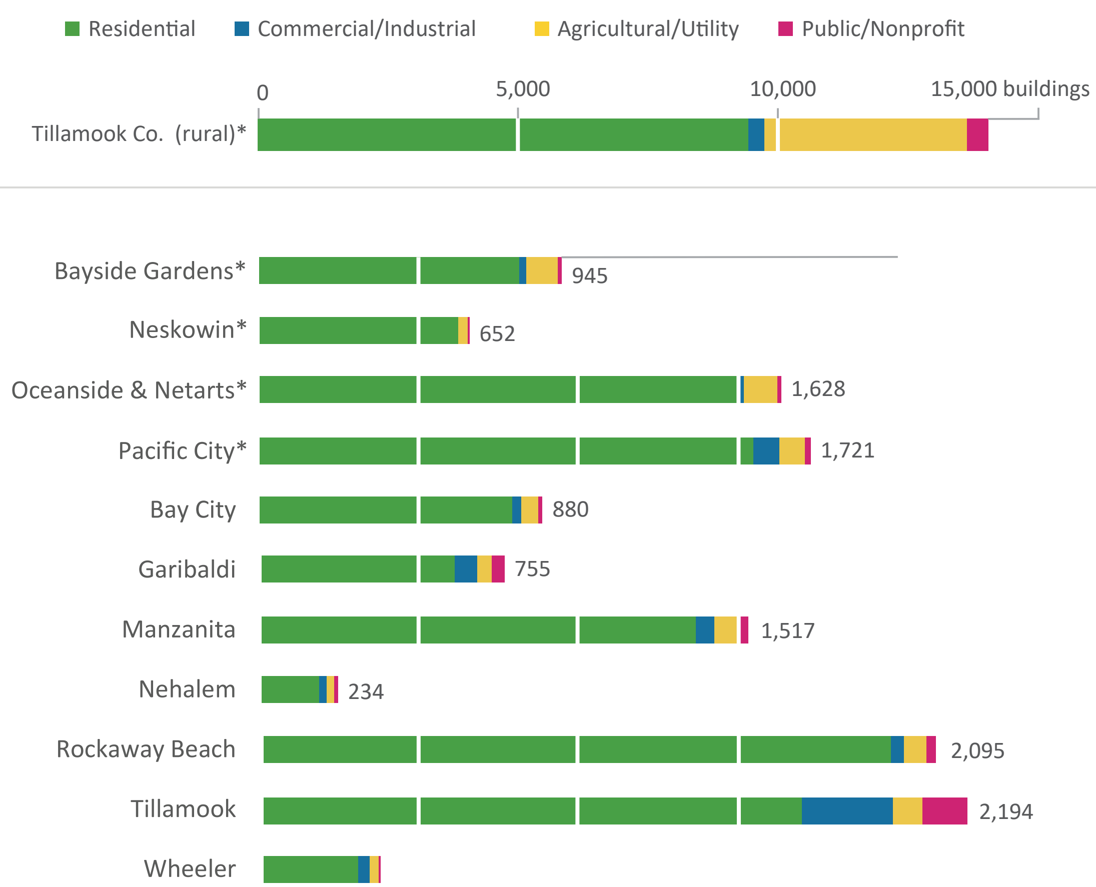
See appendix folder for individual map PDFs.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Building Distribution Map of Tillamook County, Oregon

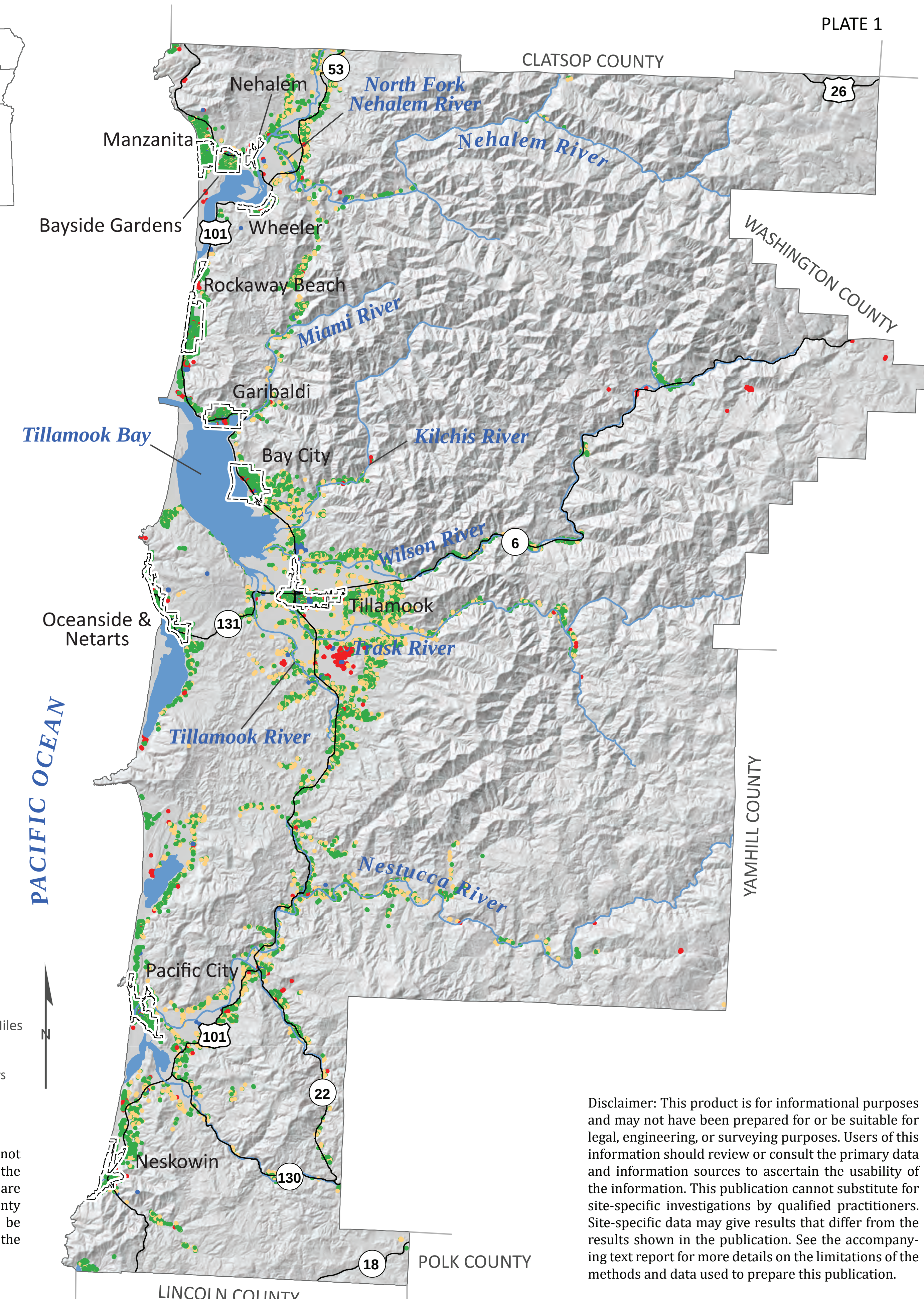
Study Location Map

PLATE 1



Building Occupancy

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



0 4 8 Miles
0 5 10 Kilometers

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

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

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

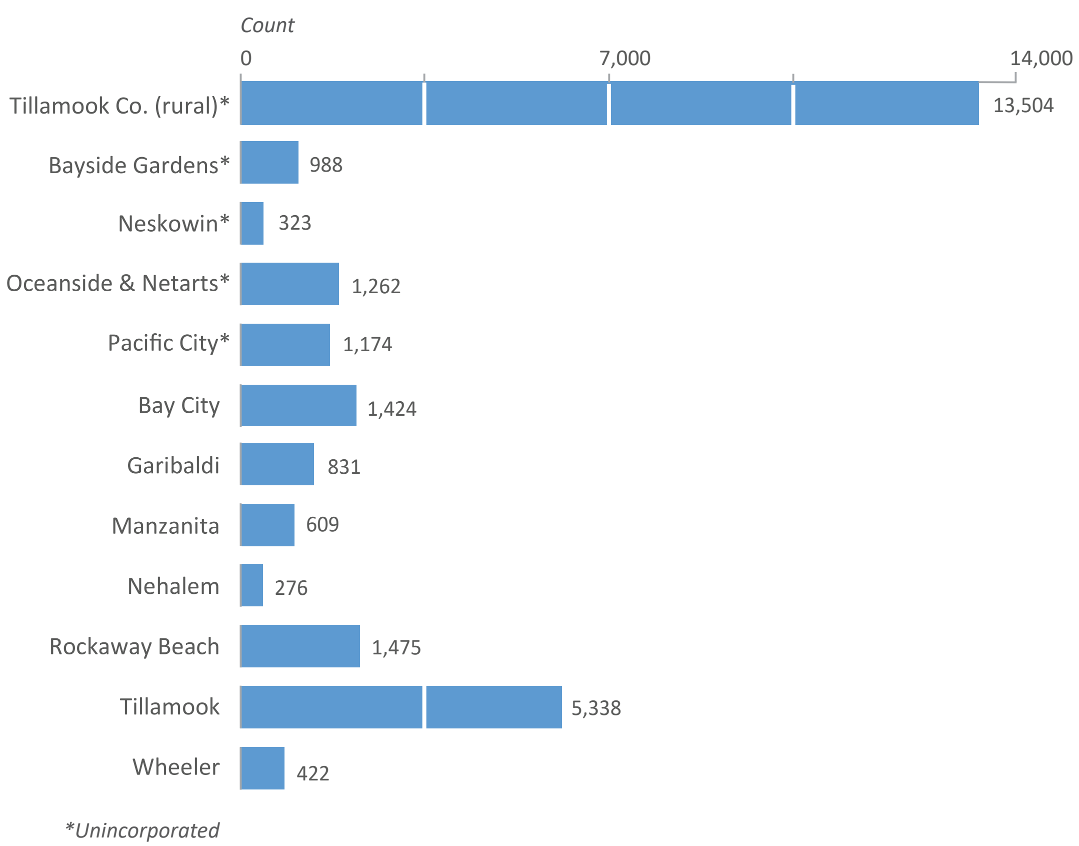
Cartography by:Matt C. Williams, 2022

PLATE 2

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Population Density Map of Tillamook County, Oregon

Study Location Map



People per 20 acres

- Building(s) present no permanent residents
- 1 - 5
- 6 - 10
- 11 - 20
- 21 - 40
- 41 +

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

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

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

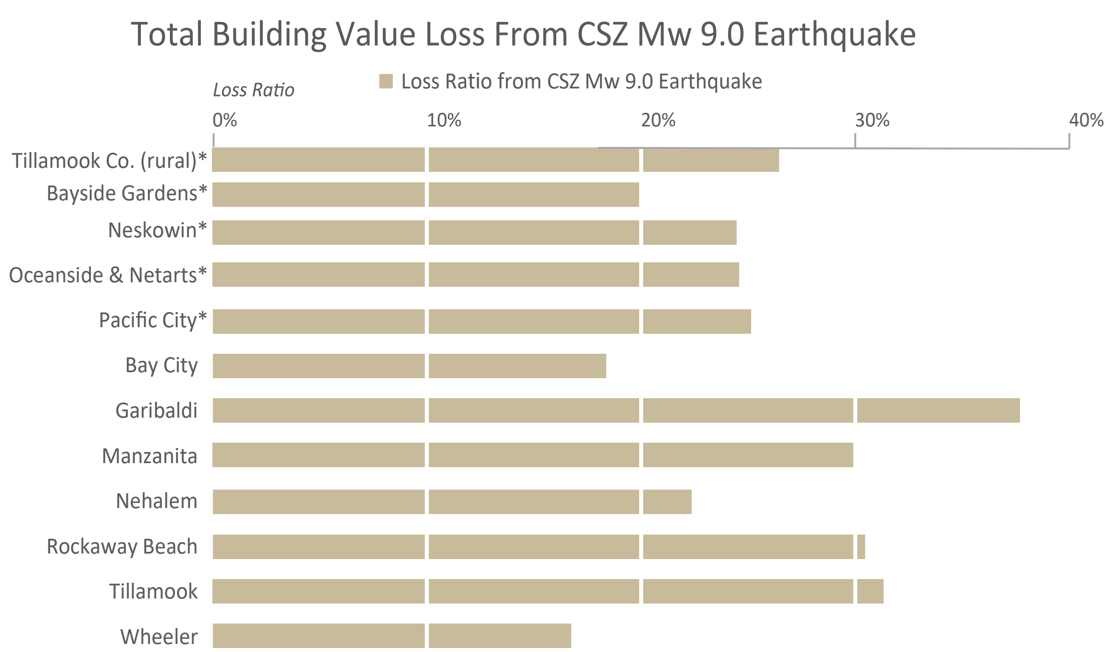
STATE OF OREGON
DEPARTMENT OF GEOLOGY
AND MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

CSZ Magnitude-9.0 Earthquake Shaking Map (PGA) of Tillamook County, Oregon

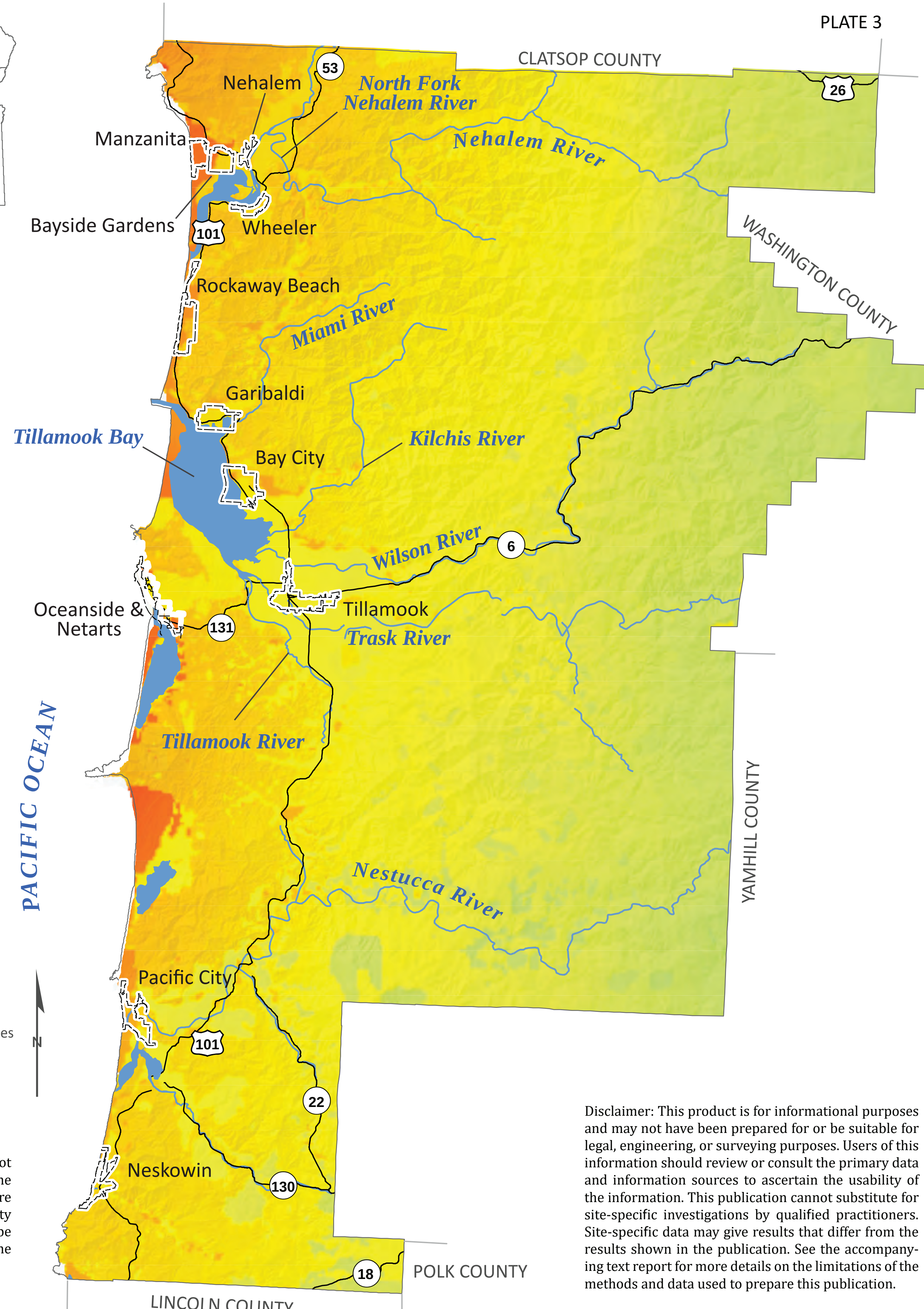
PLATE 3

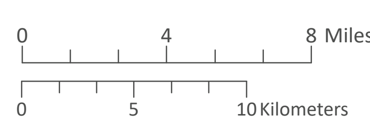
Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215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

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



*Unincorporated





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

Projection: NAD 1983 UTM Zone 10N
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by:Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

PLATE 4

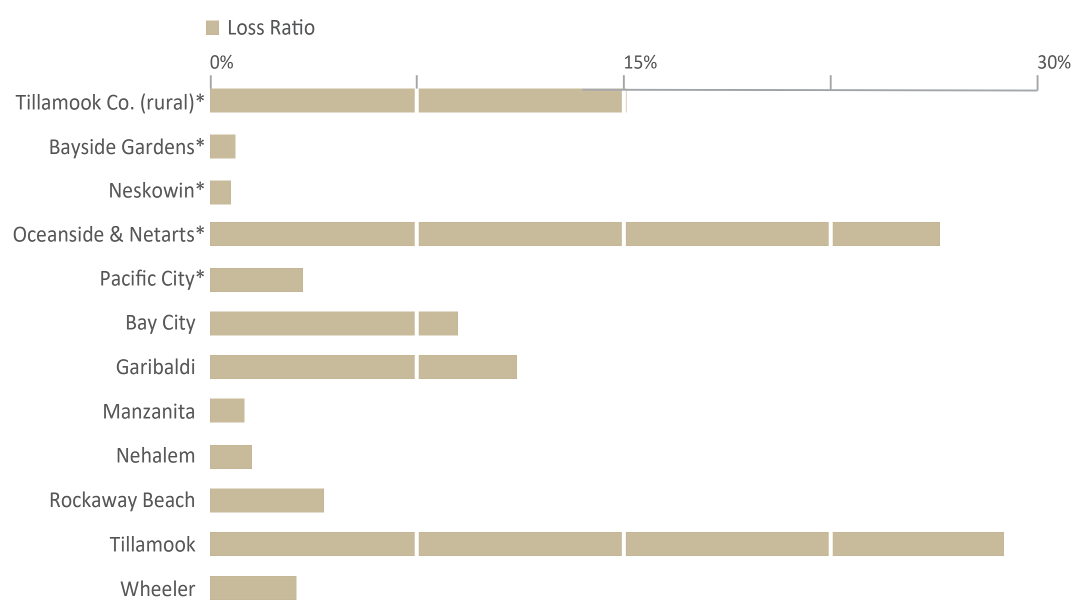
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Happy Camp Fault Magnitude-6.6 Earthquake Shaking (PGA) Map of Tillamook County, Oregon

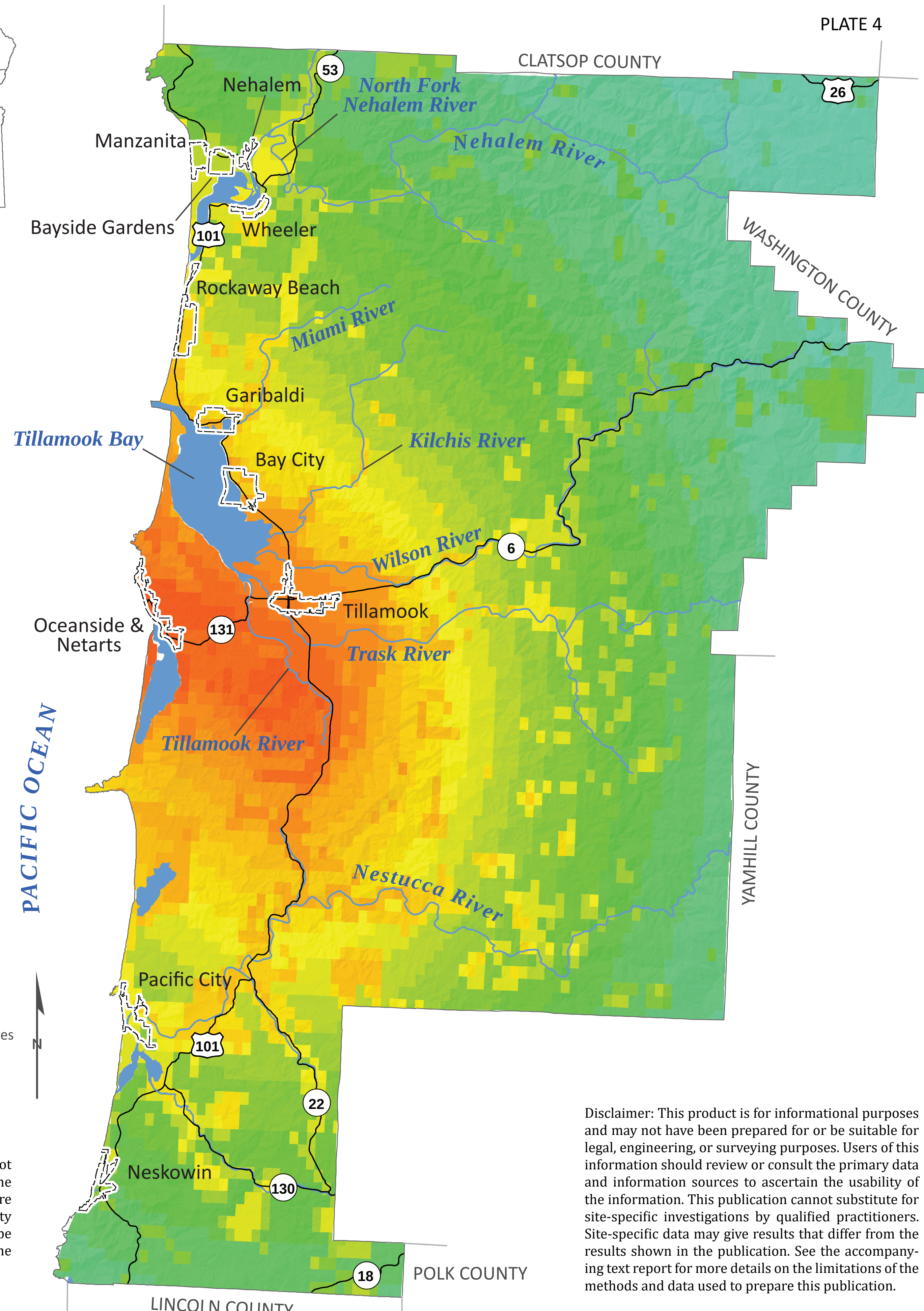
Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215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

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

Total Building Value Loss From Happy Camp Mw-6.6 Earthquake



*Unincorporated



This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

Data Sources:
Earthquake peak ground acceleration: Generated from Hazus 5.0 earthquake analysis (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

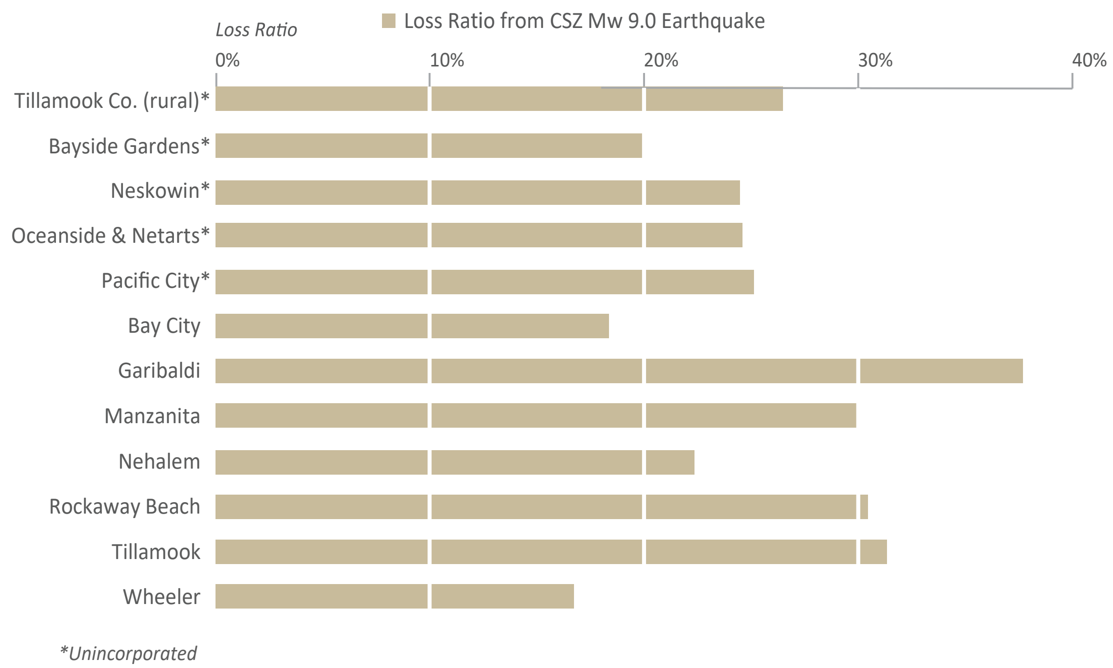
PLATE 5

STATE OF OREGON
DEPARTMENT OF GEOLOGY
AND MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Coseismic Landslide Susceptibility Map of Tillamook County, Oregon

Study Location Map

Total Building Value Loss From CSZ Mw 9.0 Earthquake

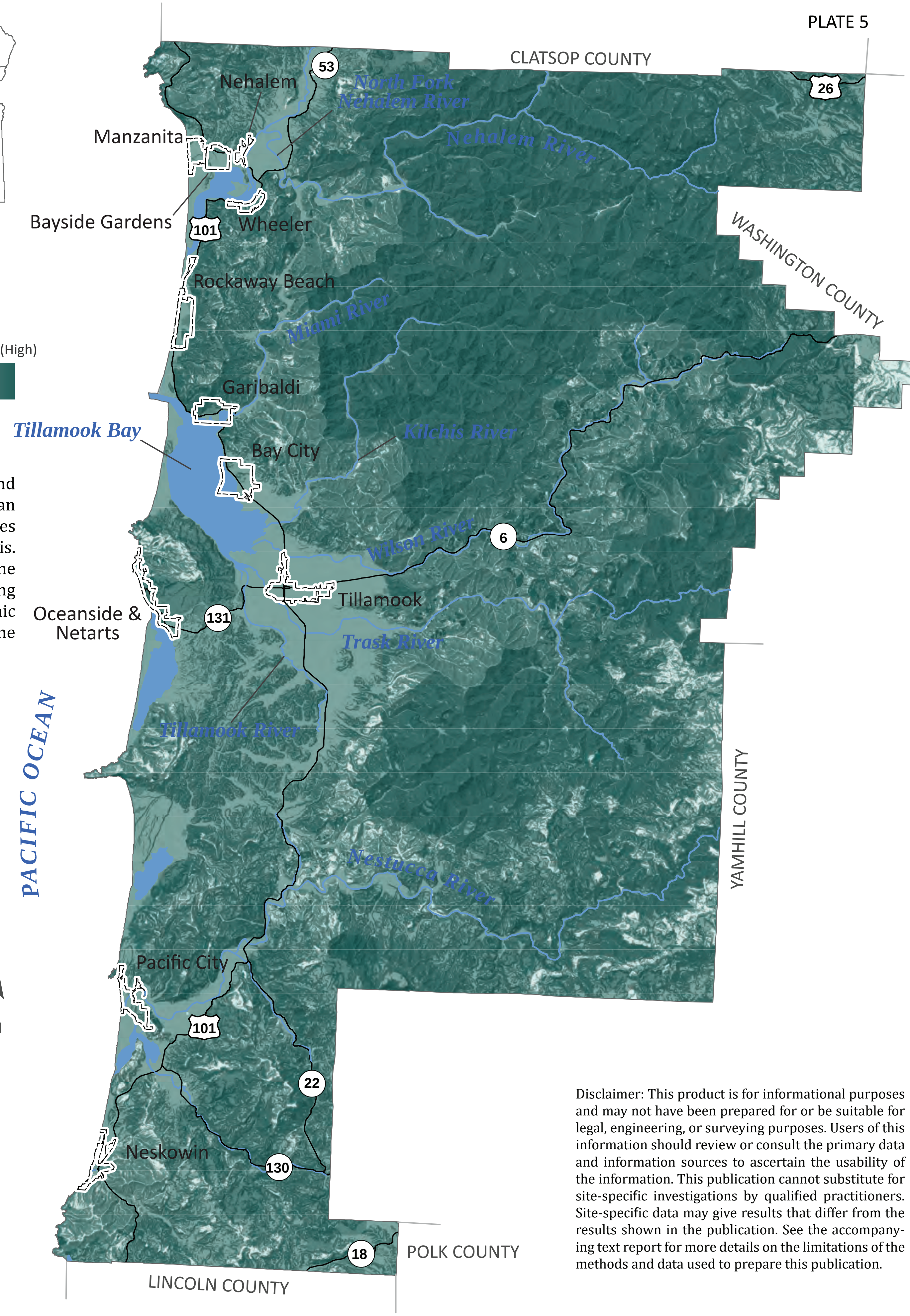


*Unincorporated

Coseismic Landslide Susceptibility (Wet)

0 (None) — 9 (High)

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



This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

Projection: NAD 1983 UTM Zone 10N
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by:Matt C. Williams, 2022

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

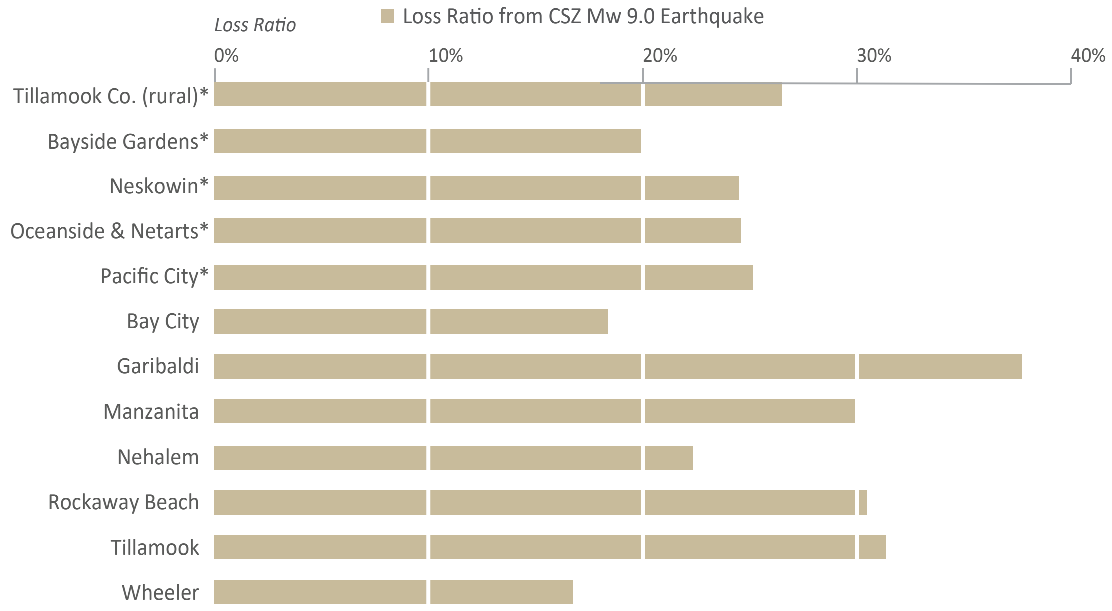
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Liquefaction Susceptibility Map of Tillamook County, Oregon

PLATE 6

Study Location Map

Total Building Value Loss From CSZ Mw 9.0 Earthquake

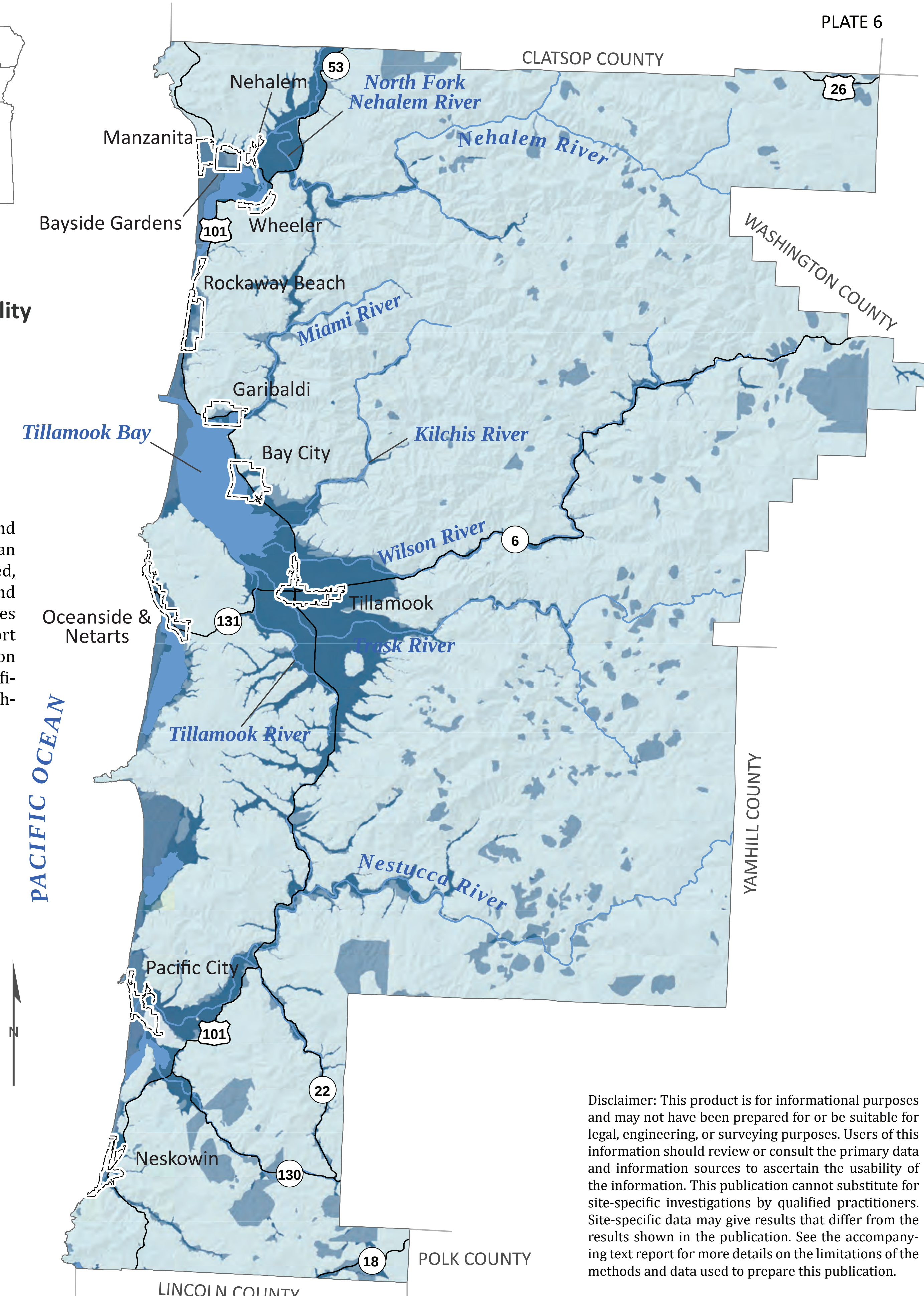


*Unincorporated

Liquefaction Susceptibility

- Low or None
- Moderate
- High
- Very High

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



This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

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

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

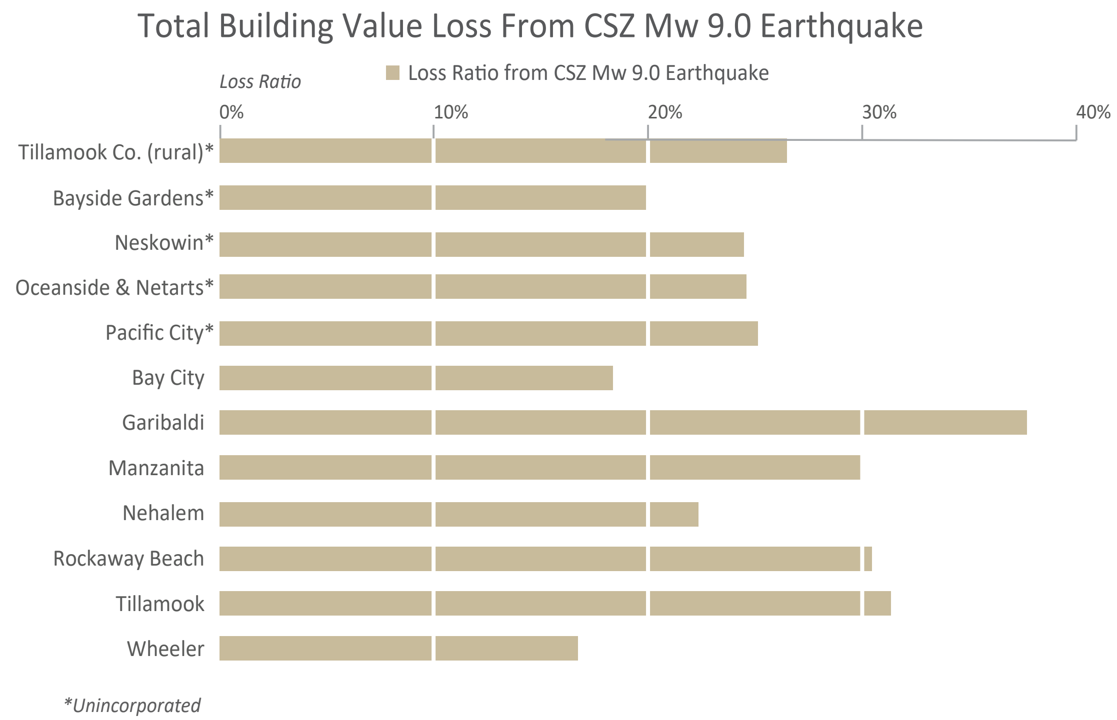
Cartography by:Matt C. Williams, 2022

PLATE 7

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Site Amplification Map of Tillamook County, Oregon

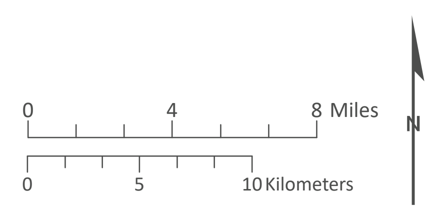
Study Location Map

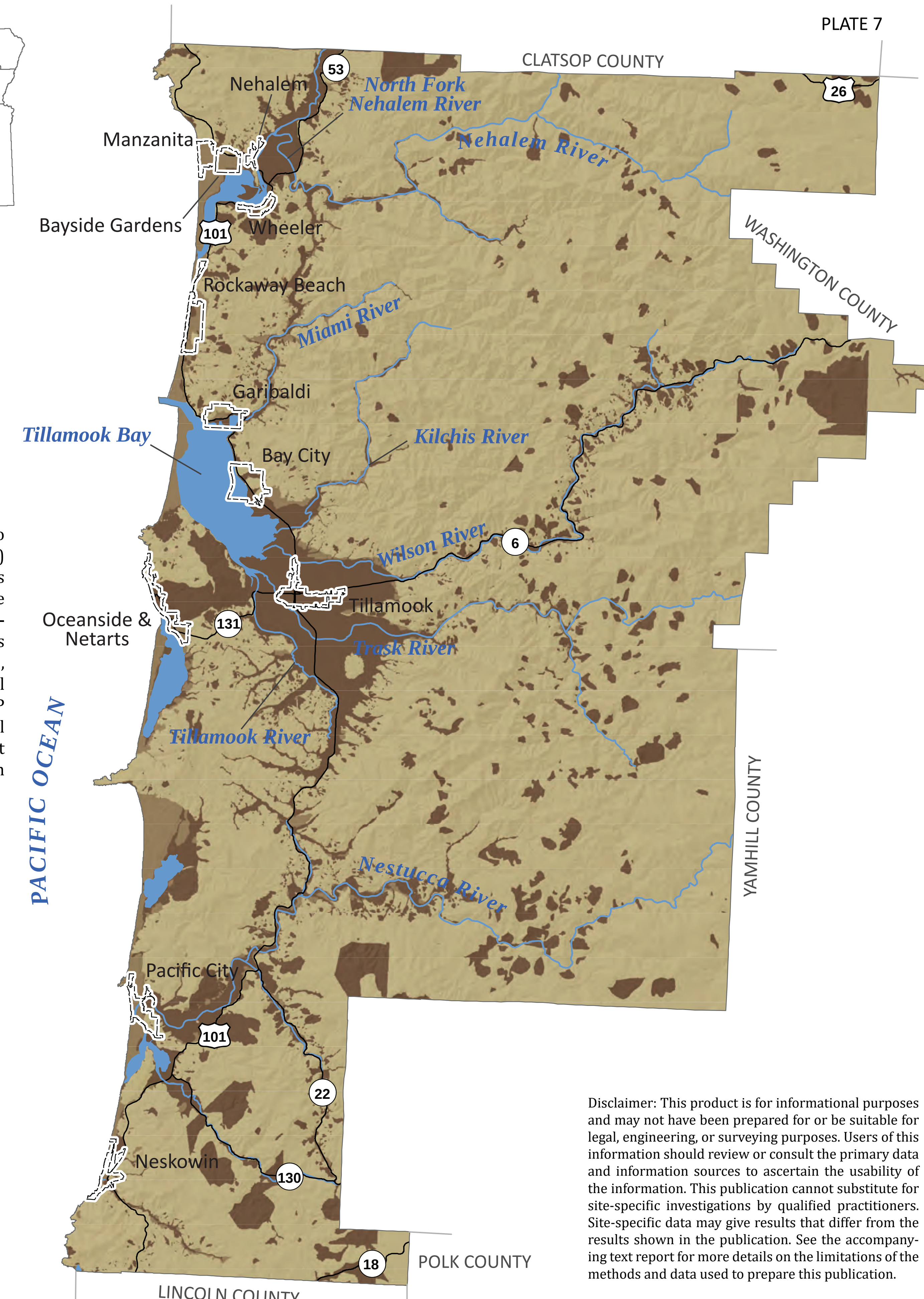


NEHRP Class

- B
- C
- D
- E, F

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





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

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

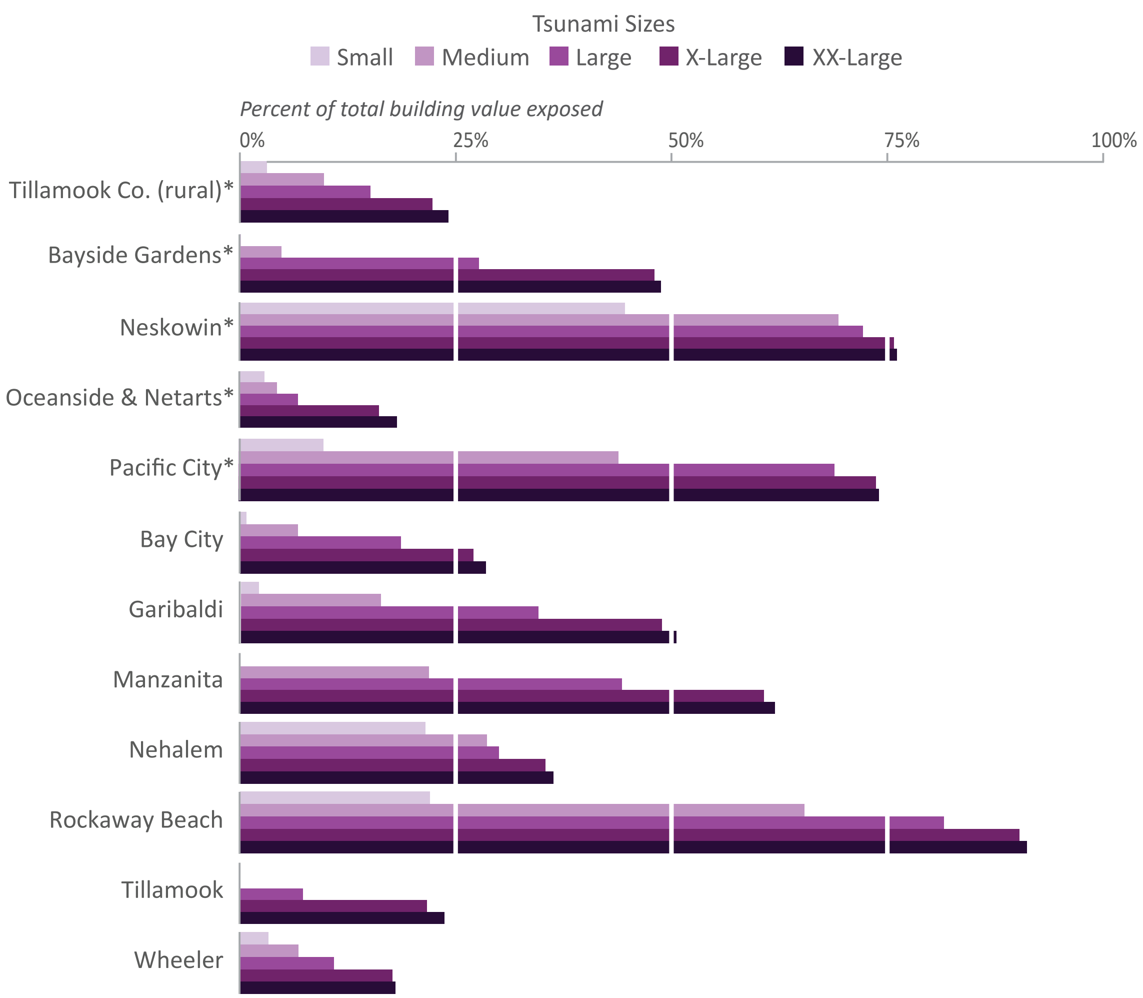
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication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

PLATE 8

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Tsunami Inundation Map of Tillamook County, Oregon

Study Location Map

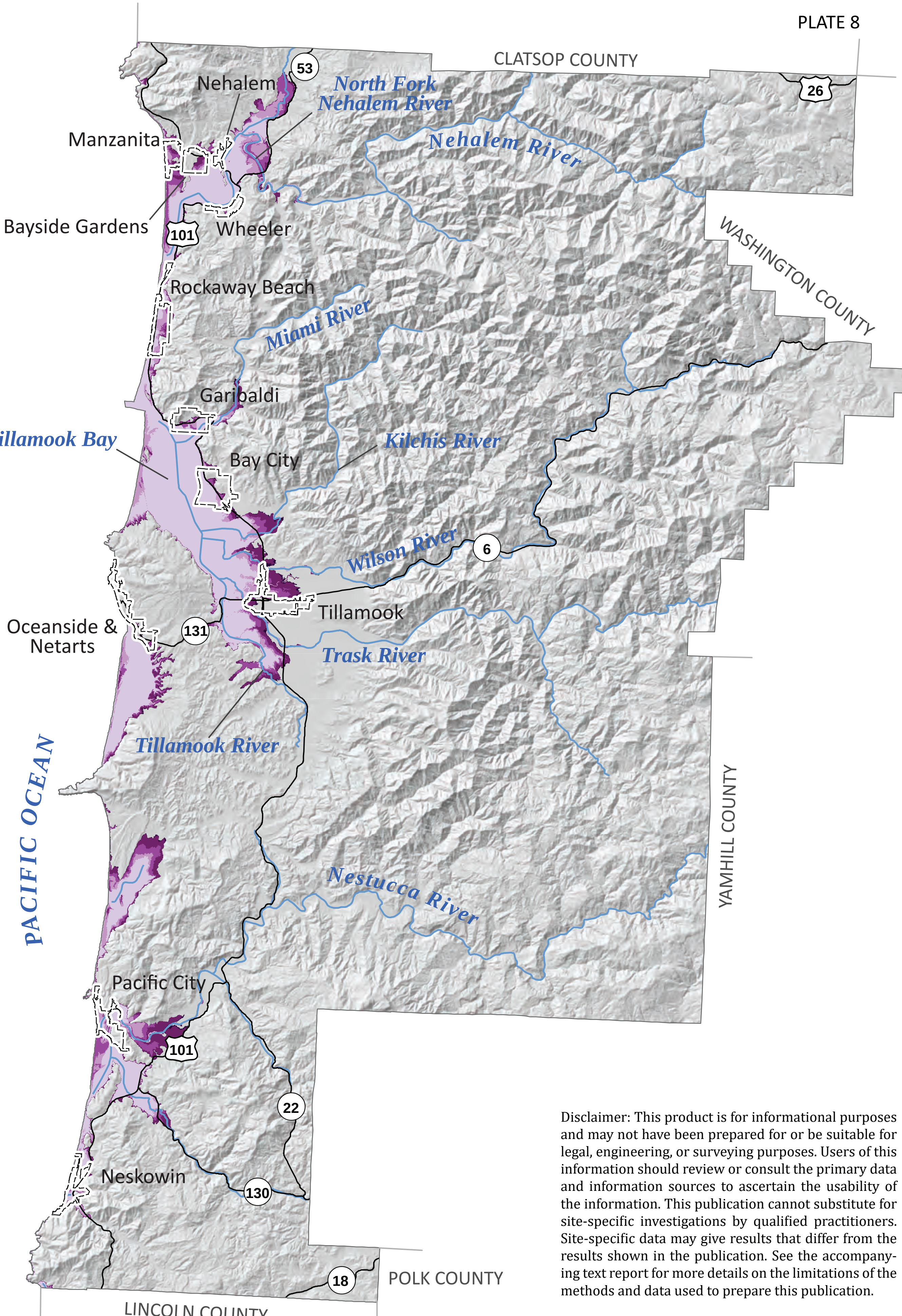


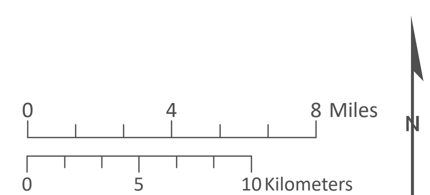
*Unincorporated

Tsunami Hazard Zone

- Small
- Medium
- Large
- X-Large
- XX-Large

The tsunami hazard data show areas of expected innundation from several local tsunami scenarios produced from a magnitude-9.0 CSZ earthquake. The scenarios were categorized based on "t-shirt" sizes, ranging from Small to XX-Large.





This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

Data Sources:
Tsunami hazard zones: Oregon Department of Geology, Priest and others (2013)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

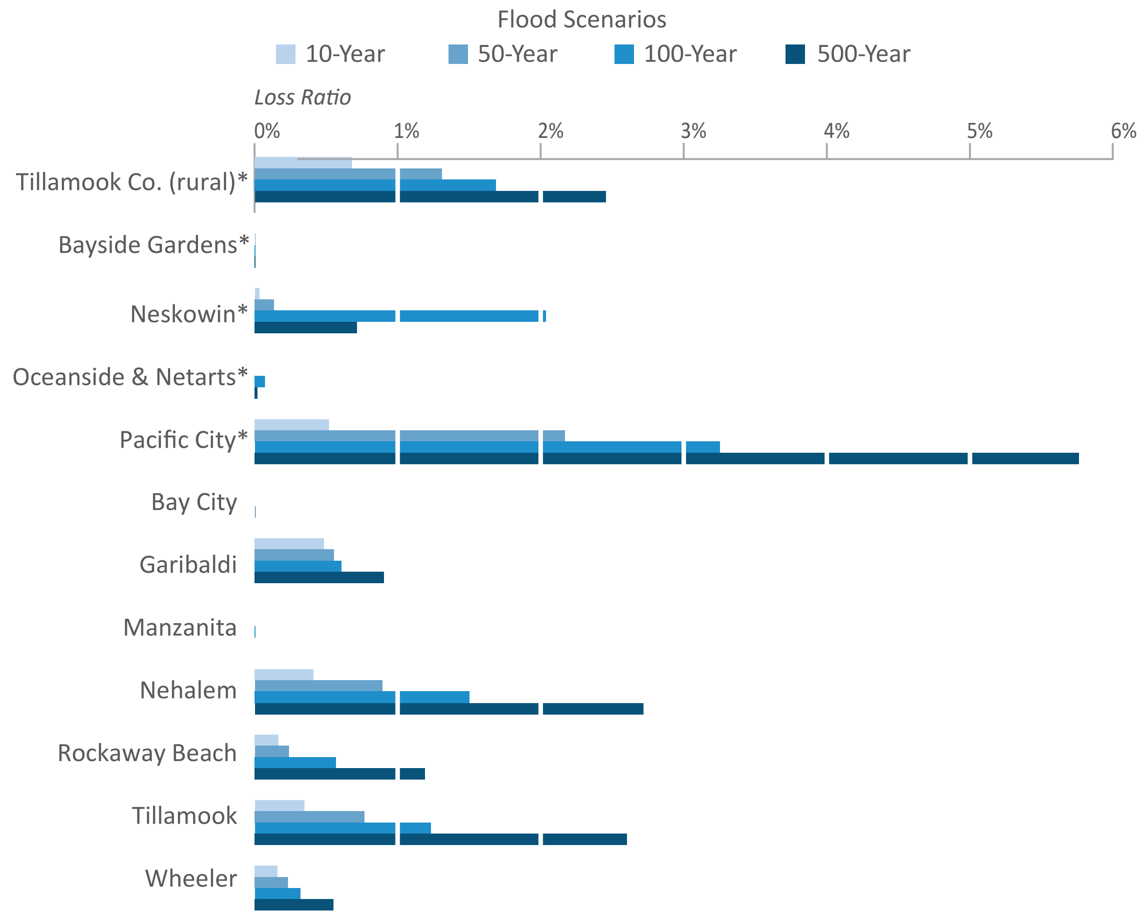
PLATE 9

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Flood Risk Map of Tillamook County, Oregon

Study Location Map

Total Building Value Loss From Flood

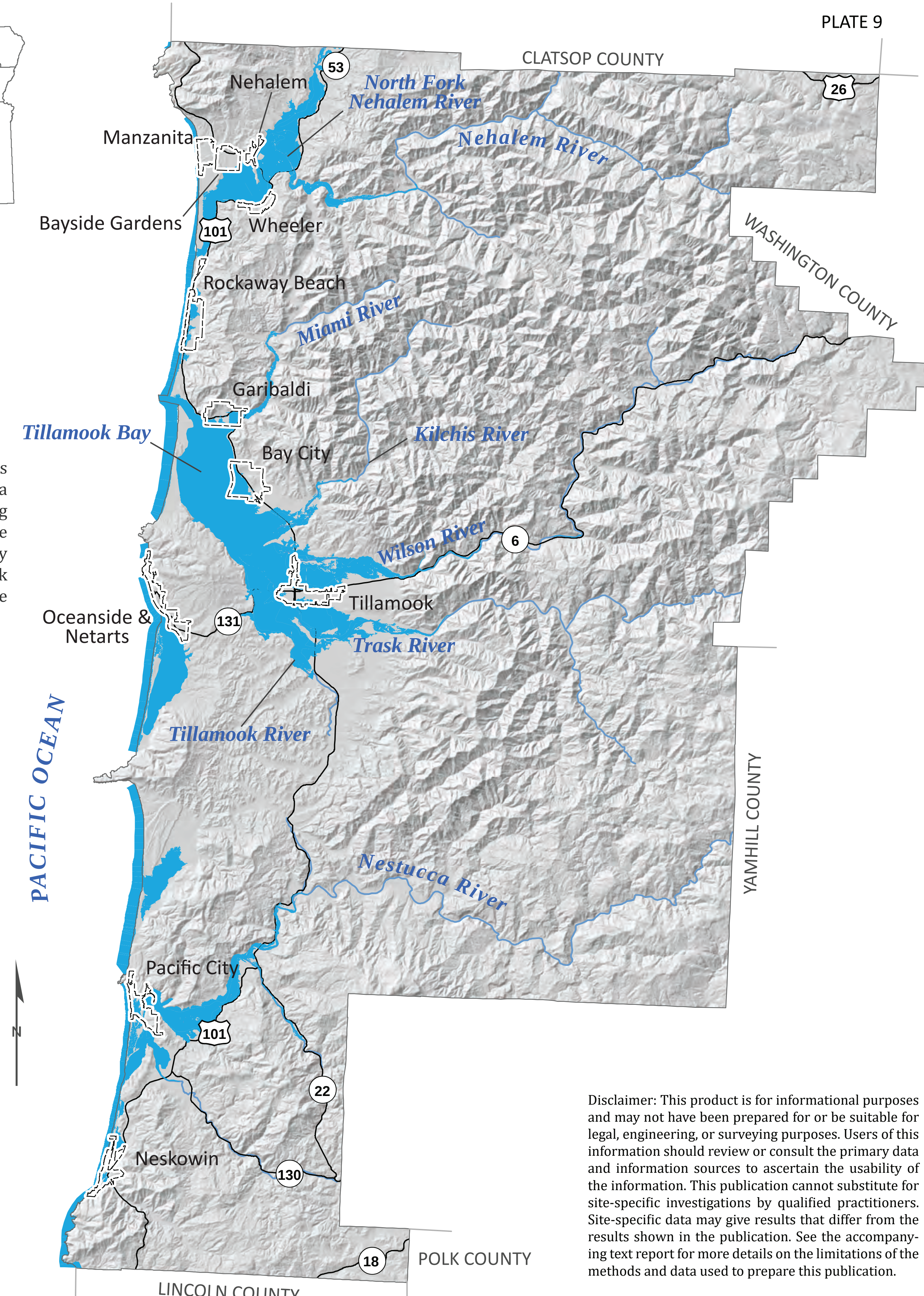


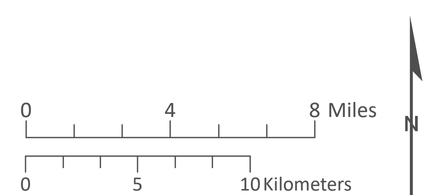
*Unincorporated

Flood Hazard Zone

100-Year Flood (1% annual chance)

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





Data Sources:
Flood hazard zone (100-year): Tillamook County Flood Insurance Rate Map (2018)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

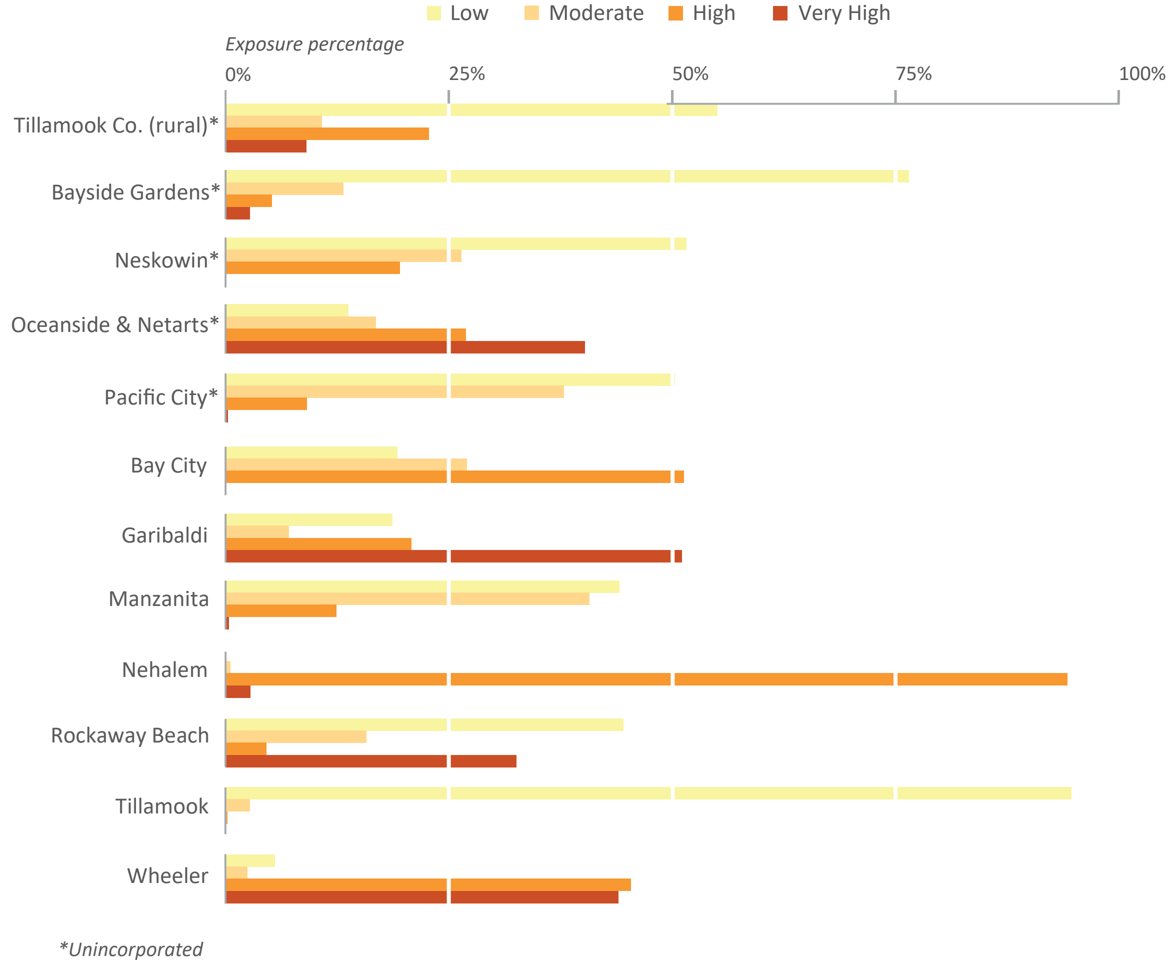
PLATE 10

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Landslide Susceptibility Map of Tillamook County, Oregon

Study Location Map

Percent of Total Building Value Exposed to Landslide Hazard

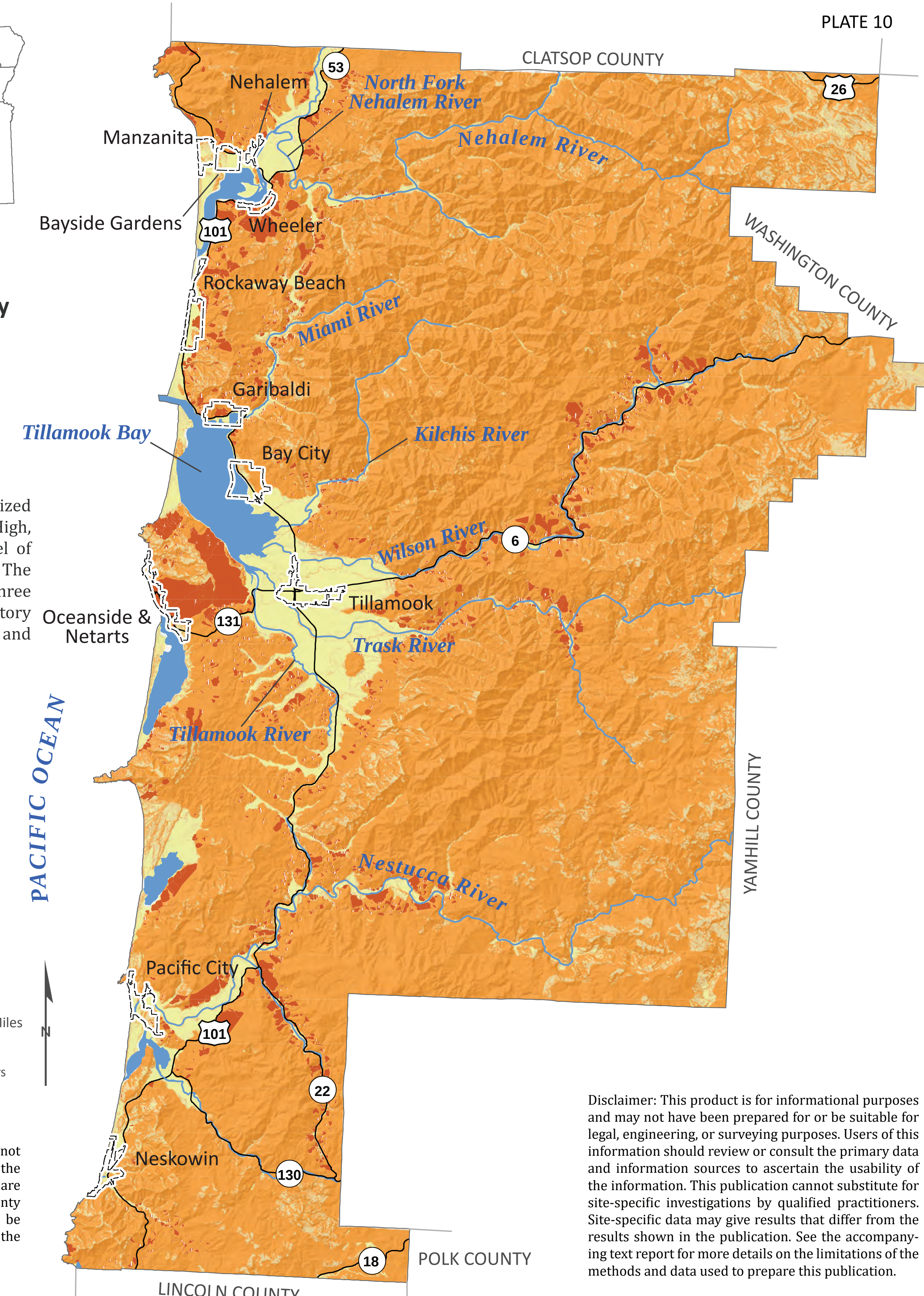


*Unincorporated

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.



0 4 8 Miles
0 5 10 Kilometers

This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

Data Sources:
Landslide susceptibility: Oregon Department of Geology and Mineral Industries, Burns and others (2016) & Calhoun and others (2020)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022

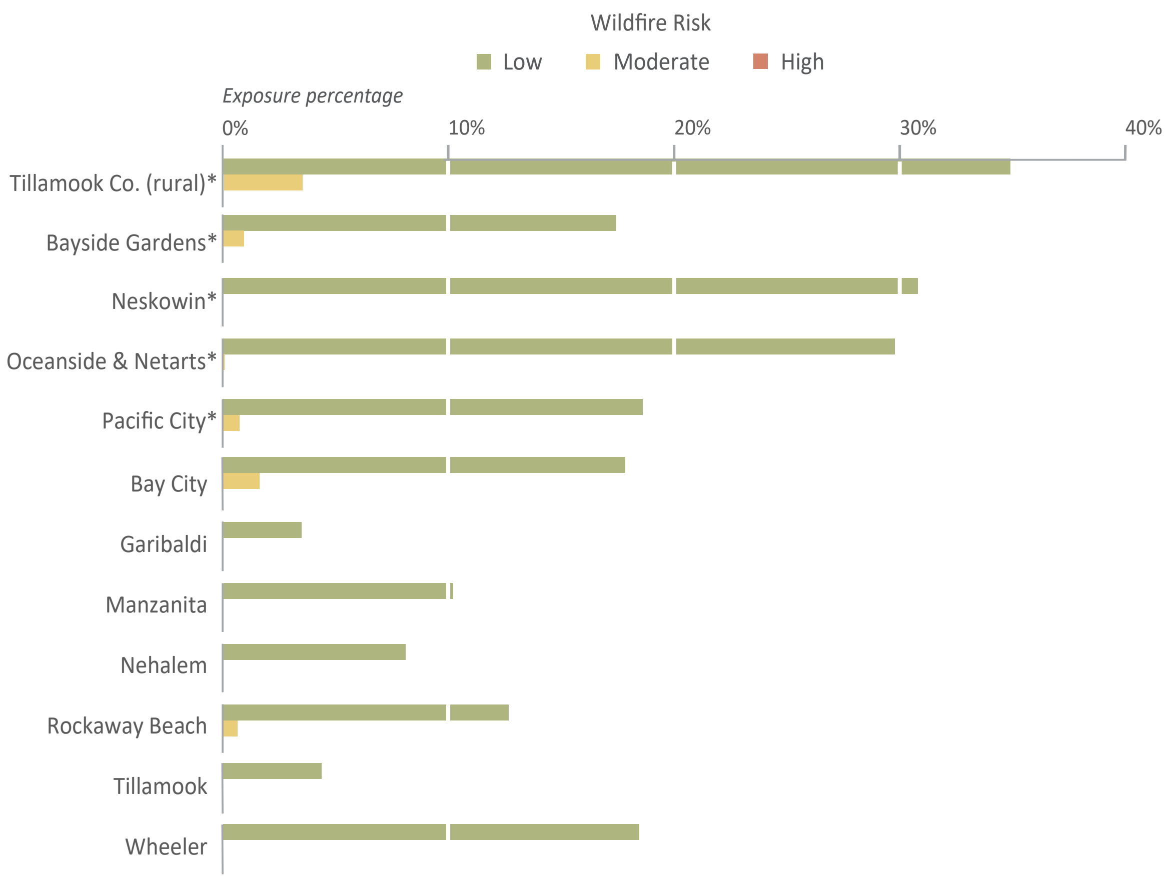
PLATE 11

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
RUARRI J. DAY-STIRRAT, STATE GEOLOGIST
www.oregongeology.org

Wildfire Risk Map of Tillamook County, Oregon

Study Location Map

Percent of Total Building Value Exposed to Wildfire

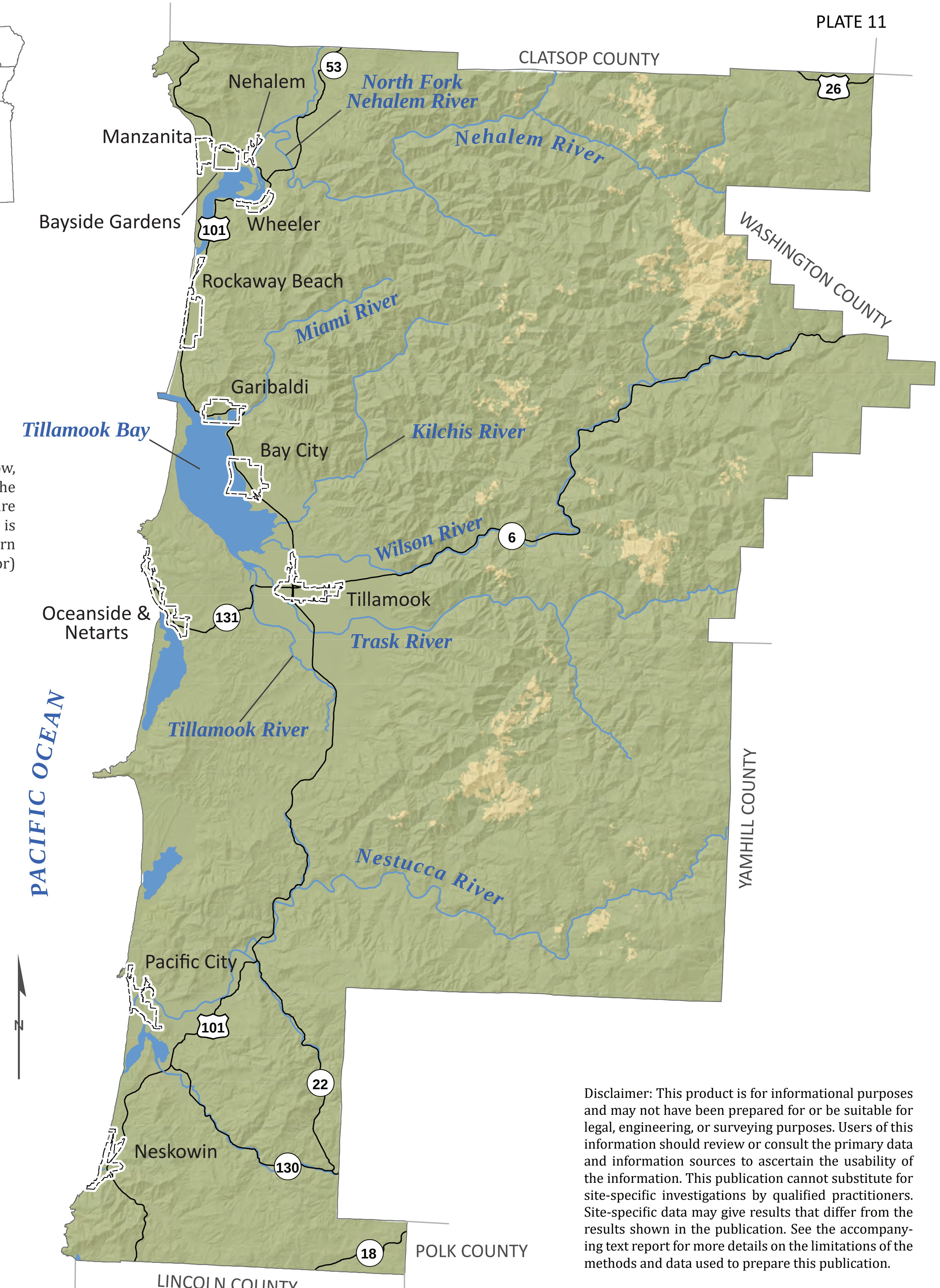


*Unincorporated

Wildfire Risk

- Low
- Moderate
- High

Wildfire Risk is categorized as Low, Moderate, and High and indicates the level of risk a location has to wildfire hazard. The Wildfire Risk data layer is derived from a combination of the burn probability (fire history and behavior) and conditional flame length data.



This map is an overview map and not intended to provide details at the community scale. The GIS data that are published with the Tillamook County Multi-Hazard Risk Assessment can be used to inform regarding queries at the community scale.

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

Data Sources:
Wildfire risk data: Oregon Department of Forestry, Pyrologix, LCC. (2018)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2014)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CC

Cartography by:Matt C. Williams, 2022