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1. Hospital Resilience Guidance

This report informed the consideration of earthquake and tsunami hazards for the local mitigation strategies developed or updated for the 2022 Coos County Multi-Jurisdictional Natural Hazard Mitigation Plan Update.

Cascadia Region Earthquake Workgroup (CREW) Guidance Documents

The guidance documents provide basic information on the importance of preparing hospitals by addressing issues related to building structures and the power and water services required to operate the hospital. They are designed to be easy to understand, promote resilience action planning, and point to detailed reference documents.

- Preparing Hospitals for Earthquakes: Structural and Nonstructural Issues (CREW Fact Sheet 9, 659 KB PDF) https://www.oregongeology.org/pubs/ofr/O-19-02/CREW_Fact Sheet_9_Hosp_07-23-2018_final.pdf
- Emergency Power for Hospitals: Preparing for Cascadia (CREW Fact Sheet 10, 1,033 KB PDF)
- Emergency Water for Hospitals: Preparing for Cascadia (CREW Fact Sheet 11, 808 KB PDF)
- https://www.oregongeology.org/pubs/ofr/O-19-02/CREW_Fact Sheet_10_Hosp_power_07-23-2018_final.pdf

2. Tsunami References & Maps

These maps informed the consideration of tsunami impact, extent, duration, and frequency which inform the metrics necessary to calculate evacuation routes and timing. Considerations made as a part of the 2022 Coos County Multi-Jurisdictional Natural Hazard Mitigation Plan Update included findings that inform life safety, building loss and exposure, and lifeline loss and exposure.

Allan, J.C. (2020). *Maritime tsunami response guidance for the Port of Coos Bay, Coos County, Oregon.* (MTRG-2020-OR-01). Newport, OR: Oregon Department of Geology and Mineral Industries. https://www.oregongeology.org/pubs/mtrg/MTRG-2020-OR-01_Port-of-Coos-Bay.pdf

Allan, J.C., Zhang, J., O'Brien, F.C., and L.L.S. Gabel. (2020). *Coos Bay tsunami modeling: Toward improved maritime planning response.* (Open-File Report O-20-08). Newport, OR: Oregon Department of Geology and Mineral Industries. https://www.oregongeology.org/pubs/ofr/p-O-20-08.htm

Gabel, Laura L. S., O'Brien, F.E., Bauer, J.M., and J.C. Allan. (2019). *Tsunami evacuation analysis of communities surrounding the Coos Bay estuary: Building community resilience on the Oregon Coast.* [Beat the Wave] (Open-File Report O-19-07). Newport, OR: Oregon Department of Geology and Mineral Industries. https://www.oregongeology.org/pubs/ofr/p-O-19-07.htm

Northwest Association of Networked Ocean Observing Systems (NANOOS). (2021). *Northwest Visualization System (NVS) Tsunami Evacuation Zones viewer*. http://nvs.nanoos.org/TsunamiEvac

Oregon Tsunami Clearinghouse. (2013). *Large-Extent Tsunami Evacuation Maps*. Newport, OR: Oregon Department of Geology and Mineral Industries. https://www.oregongeology.org/tsuclearinghouse/pubs-evacbro.htm

Wang, Yumei and K.L. Nourse. (2019.) *Resilience Guidance for Oregon Hospitals* (Open-File Report O-19-02). Portland, OR: Department of Geology and Mineral Industries. https://www.oregongeology.org/pubs/ofr/O-19-02/O-19-02_report.pdf

Tsunami Inundation Maps (TIMs) SERIES: COOS 01-17

Coos-01	*12/18/2012*	preview/download	Coos	Lakeside West
Coos-02	*12/18/2012*	preview/download	Coos	Lakeside East
Coos-03	*12/18/2012*	preview/download	Coos	Saunders Lake
Coos-04	*07/17/2012*	preview/download	Coos	Haynes Inlet
Coos-05	*07/15/2012*	preview/download	Coos	Coos Bay - North Bend
Coos-06	*07/19/2012*	preview/download	Coos	Coos River North
Coos-07	*07/19/2012*	preview/download	Coos	Coos River South
Coos-08	*07/17/2012*	preview/download	Coos	Charleston - Cape Arago
Coos-09	*07/17/2012*	preview/download	Coos	Barview - South Slough
Coos-10	*07/12/2012*	preview/download	Coos	Isthmus Slough
Coos-11	*07/12/2012*	preview/download	Coos	Catching Slough
Coos-12	*09/10/2012*	preview/download	Coos	Bullards Beach
Coos-13	*09/10/2012*	preview/download	Coos	Leneve
Coos-14	*09/10/2012*	preview/download	Coos	Coquille
Coss-15	*09/11/2012*	preview/download	Coos	Coquille River
Coos-16	*09/12/2012*	preview/download	Coos	Bandon
Coos-17	*09/12/2012*	preview/download	Coos	New River

Bandon Example

https://www.oregongeology.org/pubs/tim/p-TIM-Coos-16.htm

Distant Tsunami Inundation Map:
https://www.oregongeology.org/pubs/tim/Coos16_Bandon_Plate2_onscreen.pdf

Local Tsunami Inundation Map:

https://www.oregongeology.org/pubs/tim/Coos16_Bandon_Plate1_onscreen.pdf

3. Local Tsunami Evacuation Planning

City of North Bend

Tsunami Evacuation Route Improvement Plan Appendix of the Transportation System Plan

https://www.oregon.gov/lcd/OCMP/Documents/NorthBend_TEFIP_Final_Jan2021.pdf

Tsunami Hazard Overlay Zone Map

https://www.oregon.gov/lcd/OCMP/Documents/NorthBend-THOZ-Map.pdf

For more information about tsunami planning, see:

https://www.oregon.gov/lcd/OCMP/Pages/Tsunami-Planning.aspx

Coos County

In October 2019, Coos County adopted a Tsunami Evacuation Facility Improvement Plan (TEFIP) in addition to other improvements to the Coos County Comprehensive Plan to guide development away from harm by natural hazards. Details of these changes can be found online in the signed ordinance.

https://www.co.coos.or.us/sites/default/files/fileattachments/planning/page/19201/signed_ordinance.pdf

Coos County Tsunami Evacuation Facility Improvement Plan Appendices present tsunami risk in three types of maps: Tsunami Inundation Maps (TIMs), Wave Arrival times, and Beat the Wave pedestrian evacuation timing maps; potential funding opportunities are also highlighted.

TEFIP Appendix A: Tsunami Inundation Map

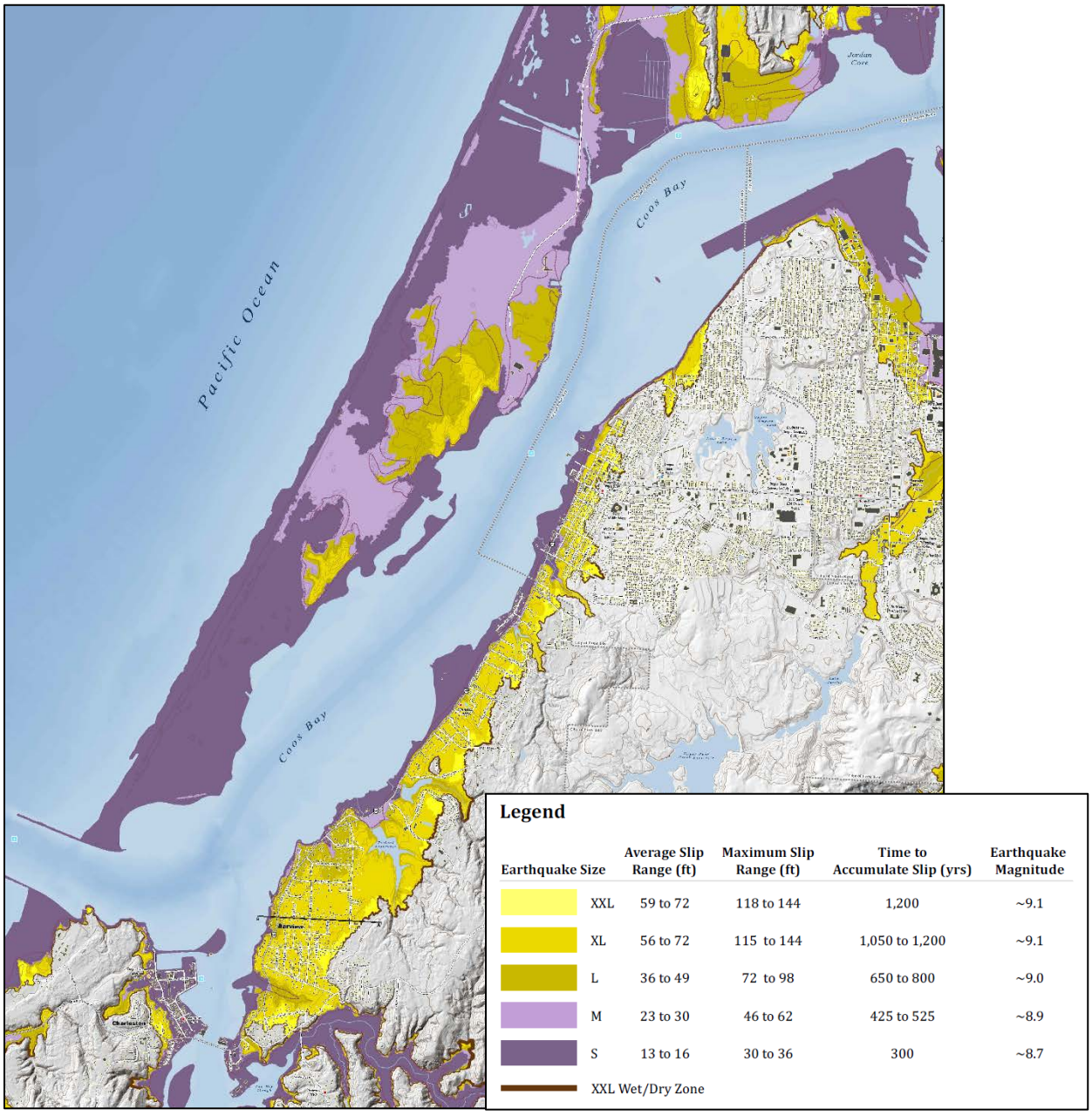
TEFIP Appendix B: Wave Arrival Times

TEFIP Appendix C: Beat the Wave Maps

Appendix A: Tsunami Inundation Map

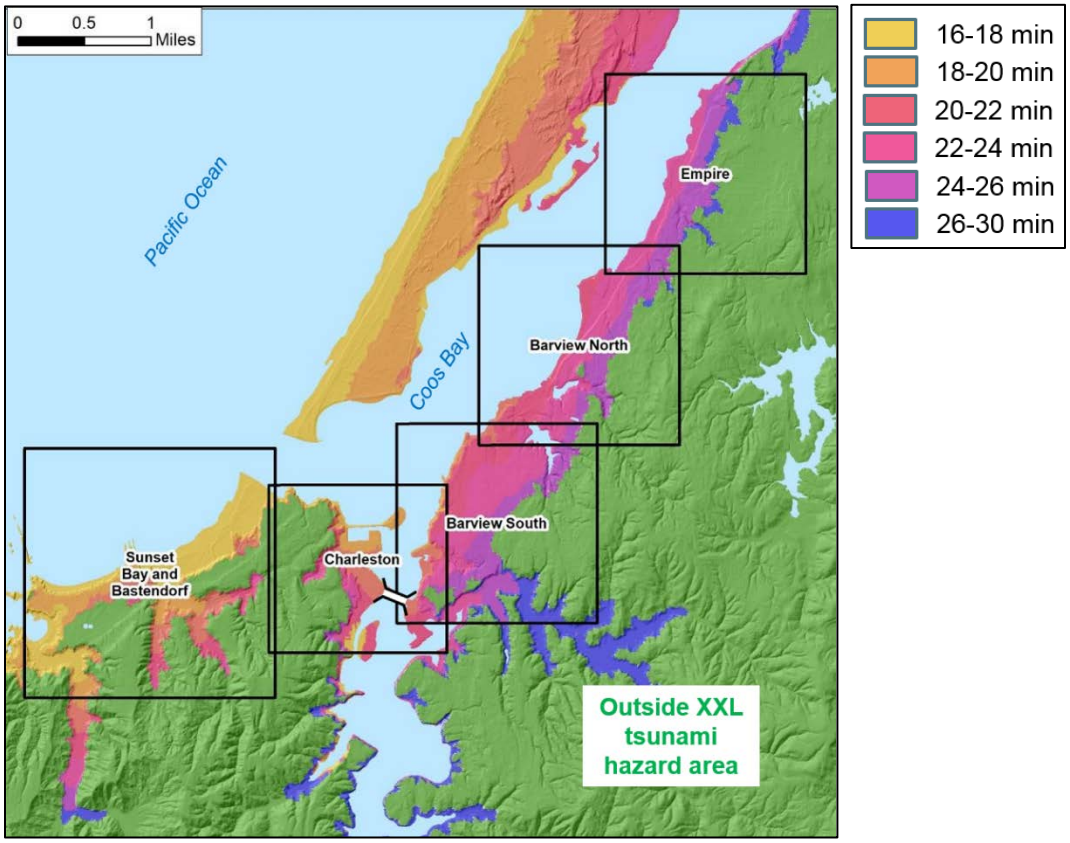
The Tsunami Inundation Map (TIM) series depicts the projected tsunami inundation zone from five different magnitude seismic and tsunami events: small, medium, large, extra-large, or extra extra-large (S, M, L, XL, XXL). These different modeled events are associated with differing levels of risk in terms of the relative likelihood of tsunami inundation (Appendix A). These maps are referenced in Chapter IV Balance of County Zones, Overlays & Special Consideration Section 4.11.260 Tsunami Hazard Overlay Zone.

Below is a portion of the Coos Bay estuary TIM. See www.oregongeology.org/tsuclearinghouse/pubs-inumaps.htm for the whole map and for more information.

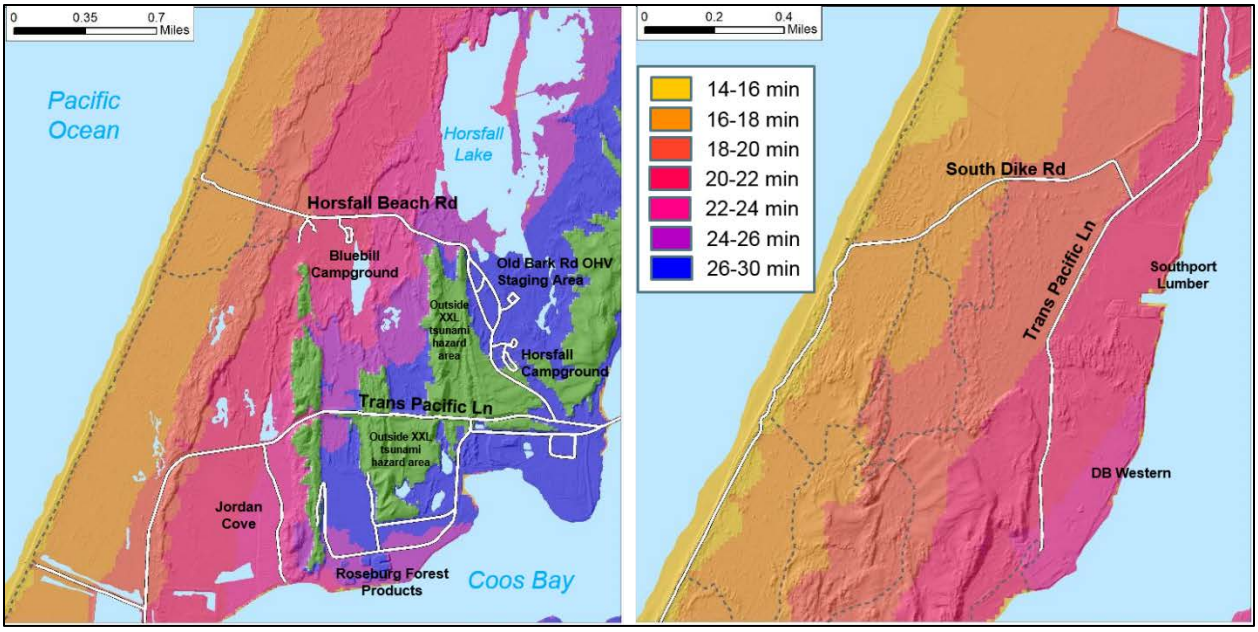


Appendix B: Wave Arrival Times

Map of XXL tsunami wave arrival times after a Cascadia subduction zone earthquake for the Coos Bay estuary.

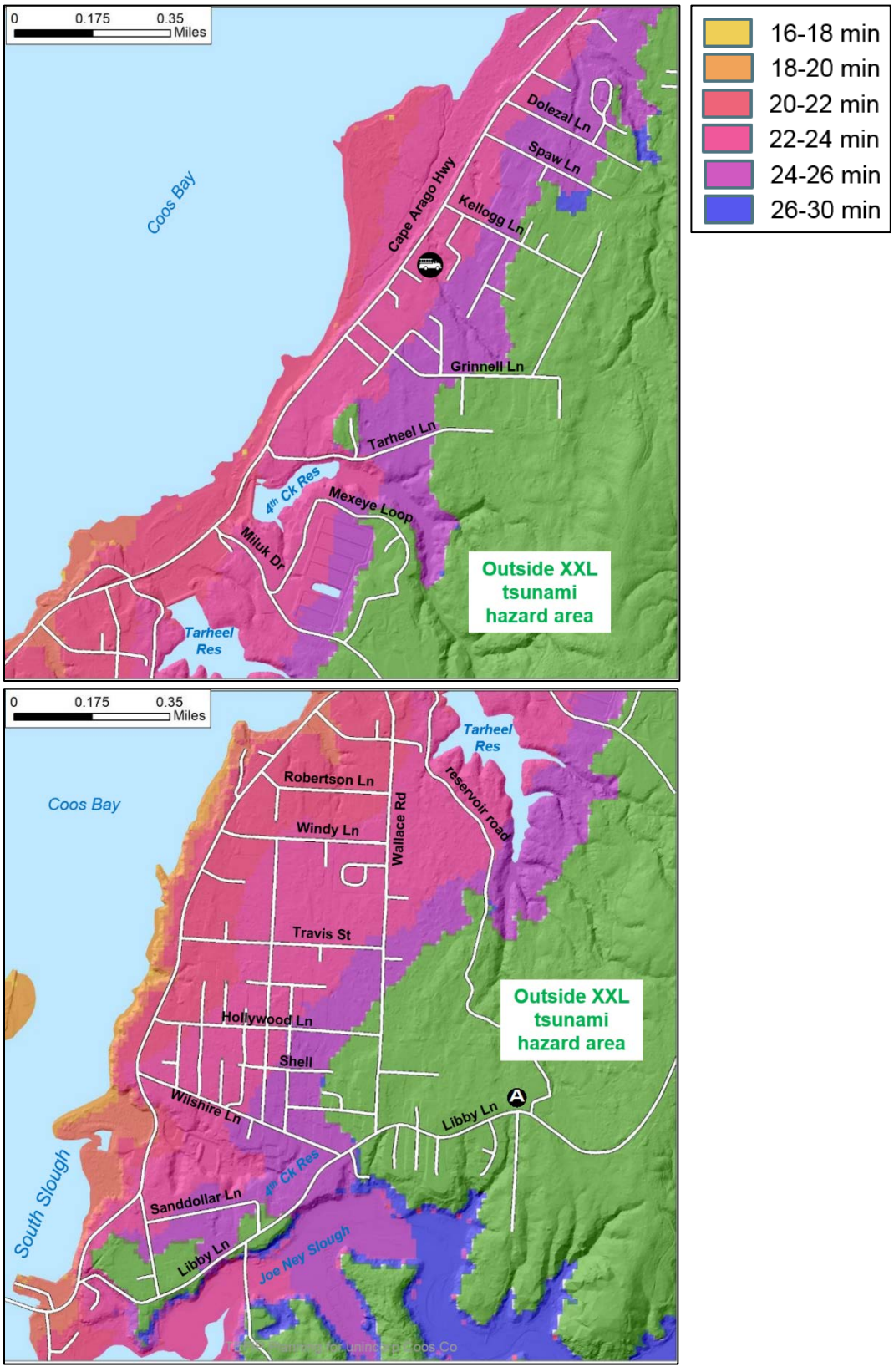


B.1 North Spit Wave Arrival Times:

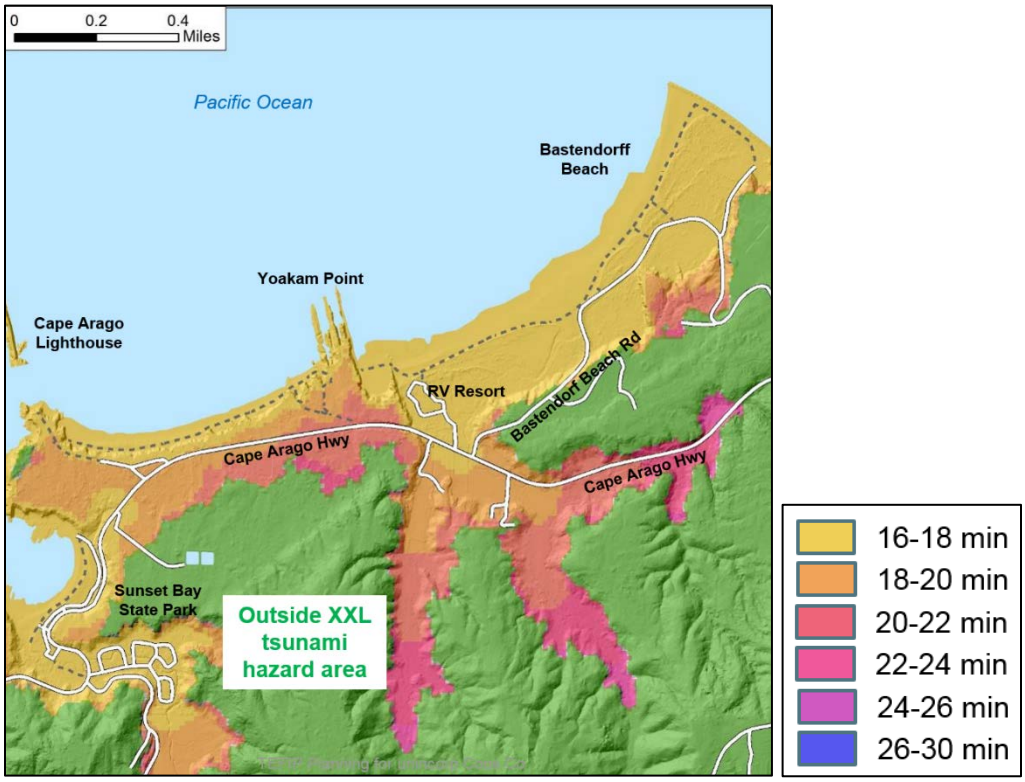


Open-File Report O-19-07, Tsunami evacuation analysis of communities surrounding the Coos Bay Estuary: Building community resilience on the Oregon coast, by Laura L. S. Gabel, Fletcher E. O'Brien, John M. Bauer, and Jonathan C. Allan; 60 p. report. www.oregongeology.org/pubs/ofr/p-O-19-07.htm.

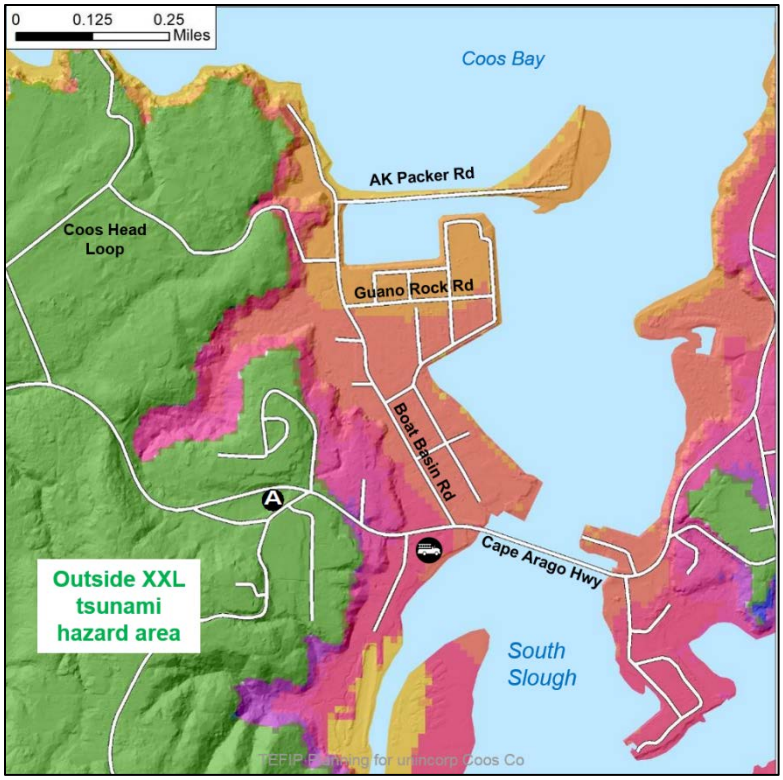
B.2 Barview Wave Arrival Times (north and south):



B.3 Charleston Wave Arrival Times:



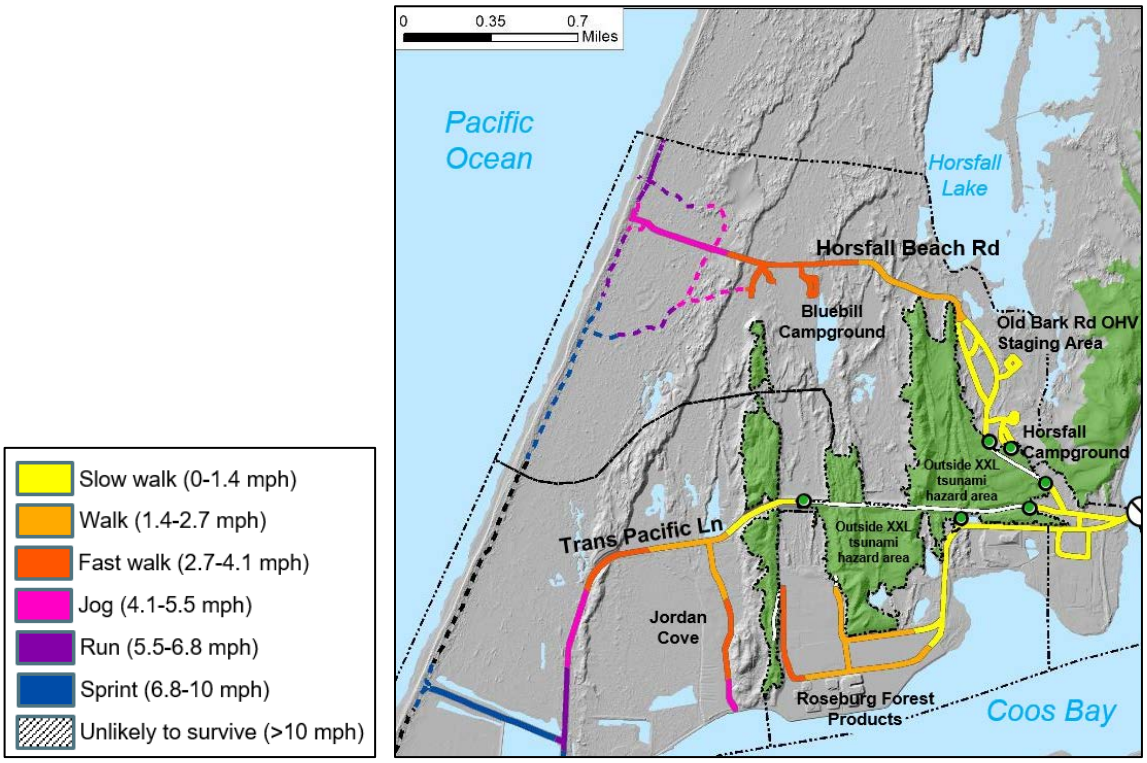
B.4 Bastendorff Beach & Sunset Bay State Park Wave Arrival Times:

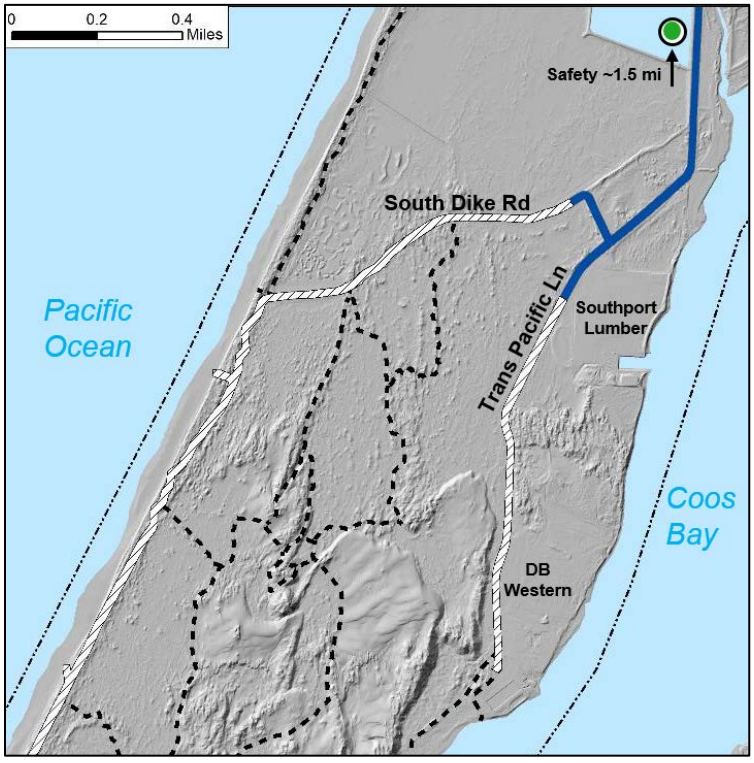


Appendix C: Beat the Wave Maps

C.1 North Spit, north (top) and south (bottom) – existing conditions:

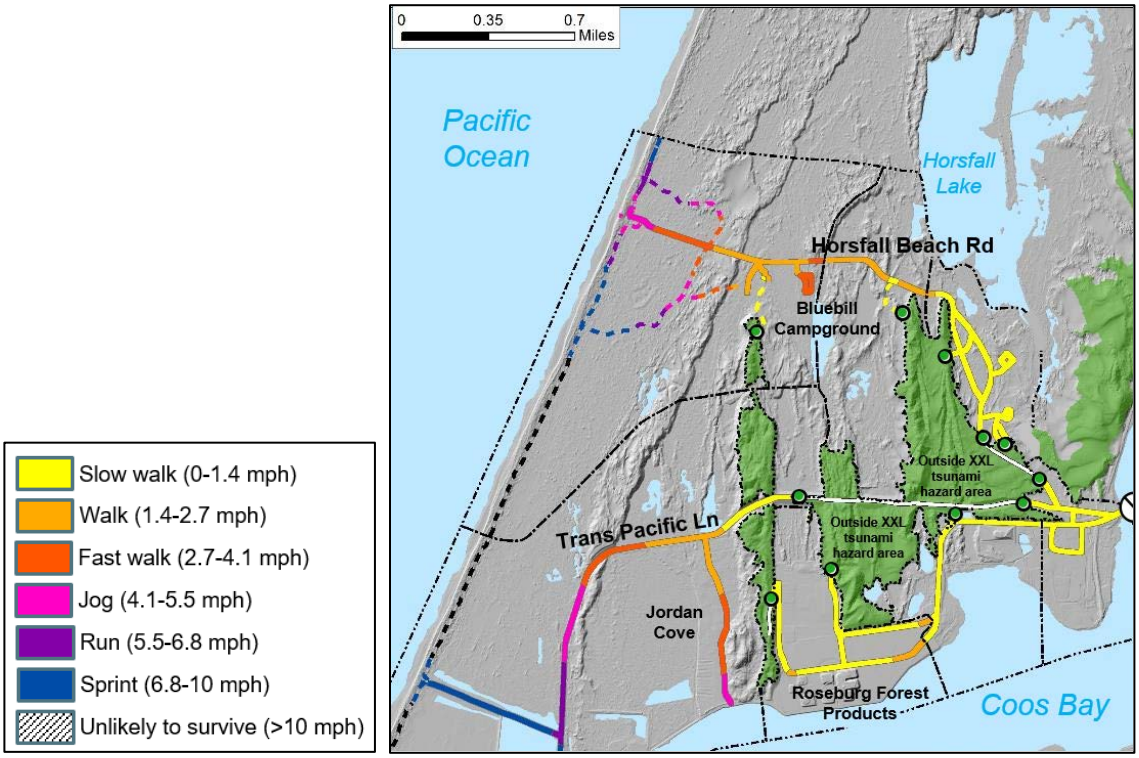
Beat the Wave pedestrian evacuation speeds are indicated by road color. Green dots indicate safety destinations and green shaded areas are outside of the XXL tsunami inundation zone.

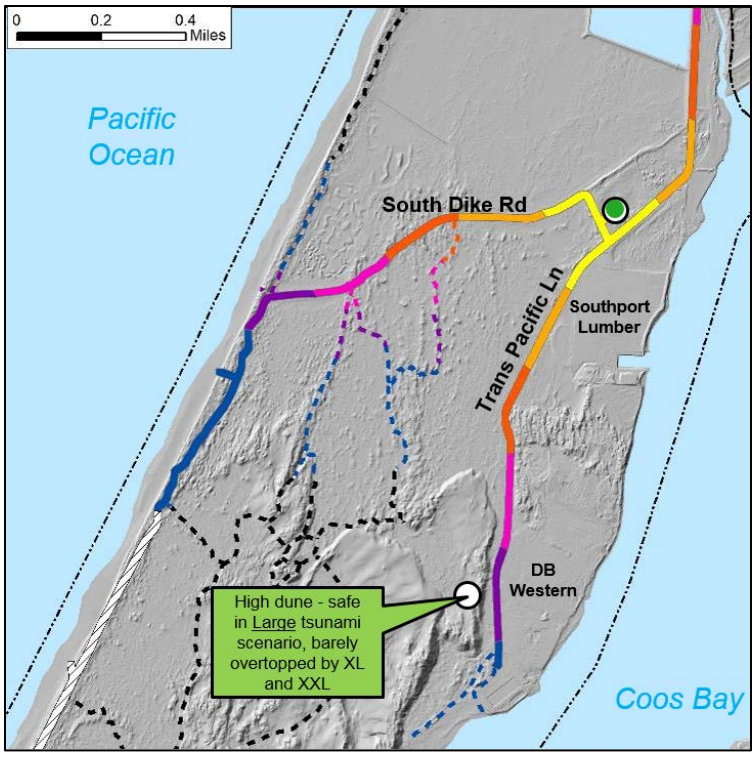




C.2 North Spit, north (top) and south (bottom) with hypothetical mitigation options:

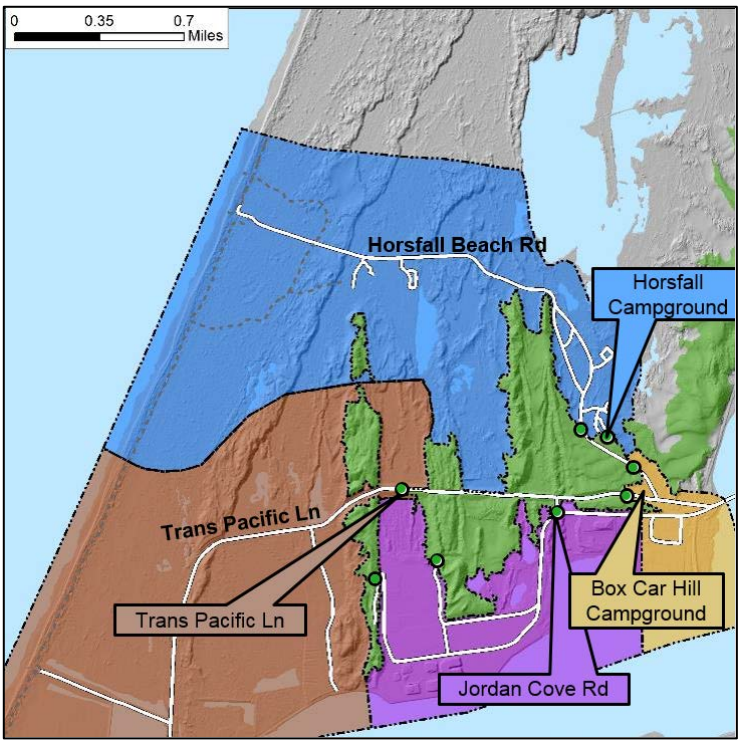
Beat the Wave pedestrian evacuation speeds are indicated by road color. On the north image, yellow dotted lines indicate hypothetical pedestrian trails off Horsfall Beach Rd. On the south image, the green dot near Southport Lumber indicates a hypothetical vertical evacuation structure. Green dots indicate safety destinations and green shaded areas are outside of the XXL tsunami inundation zone.

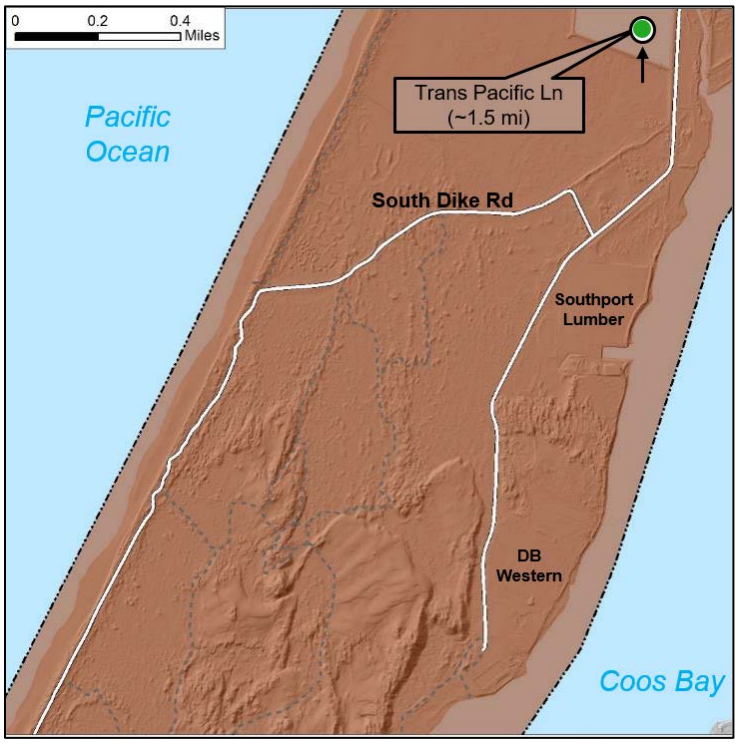




C.3 North Spit, north (top) and south (bottom) – evacuation communities:

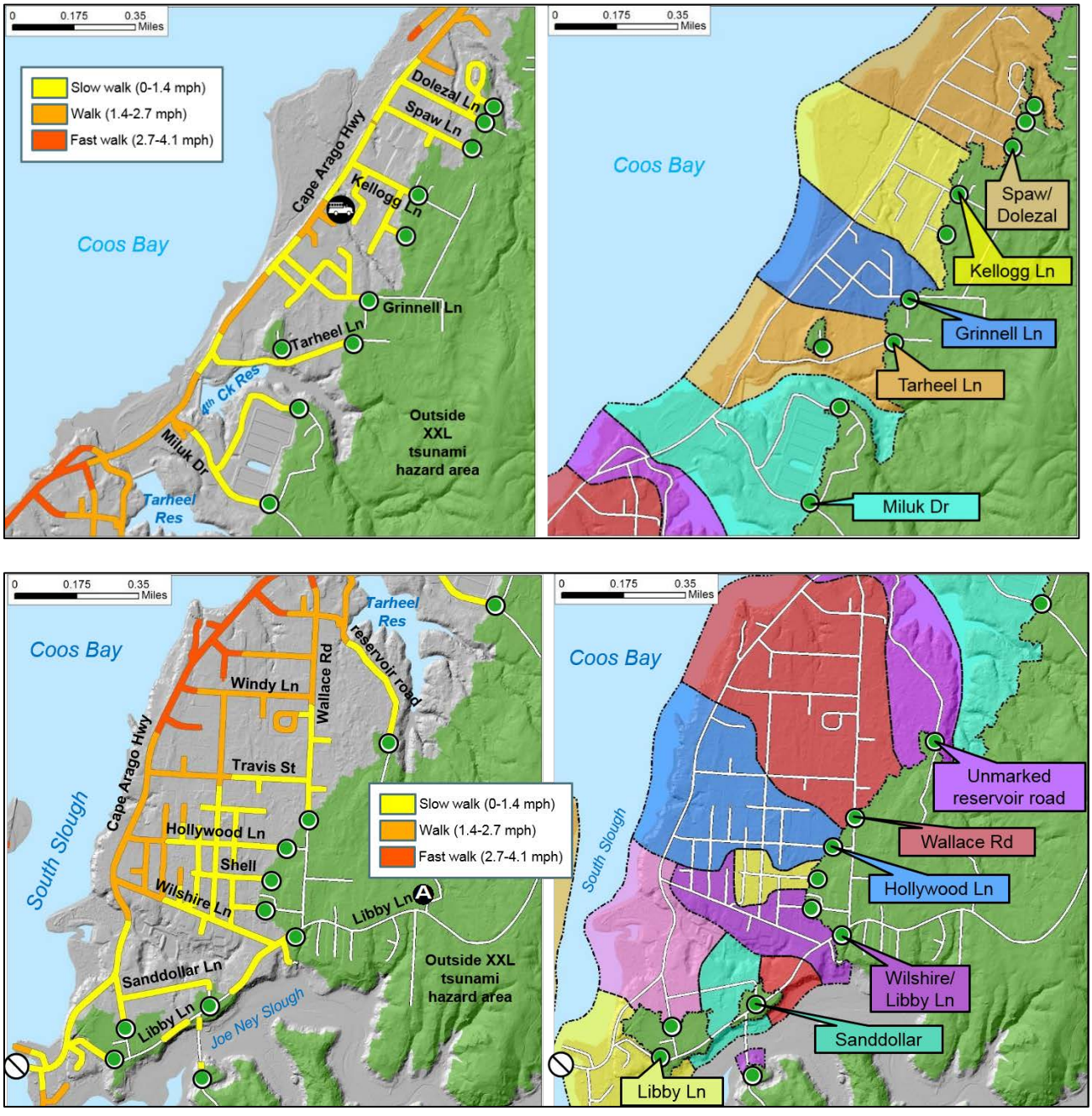
Colored areas bounded by black dotted lines indicate evacuation communities. People should evacuate to the green dot nearest them, which indicates high ground from the XXL tsunami event. On the southern part of the spit, the closest safety destination is on Trans Pacific Lane. Green shaded areas are outside of the XXL tsunami inundation zone.





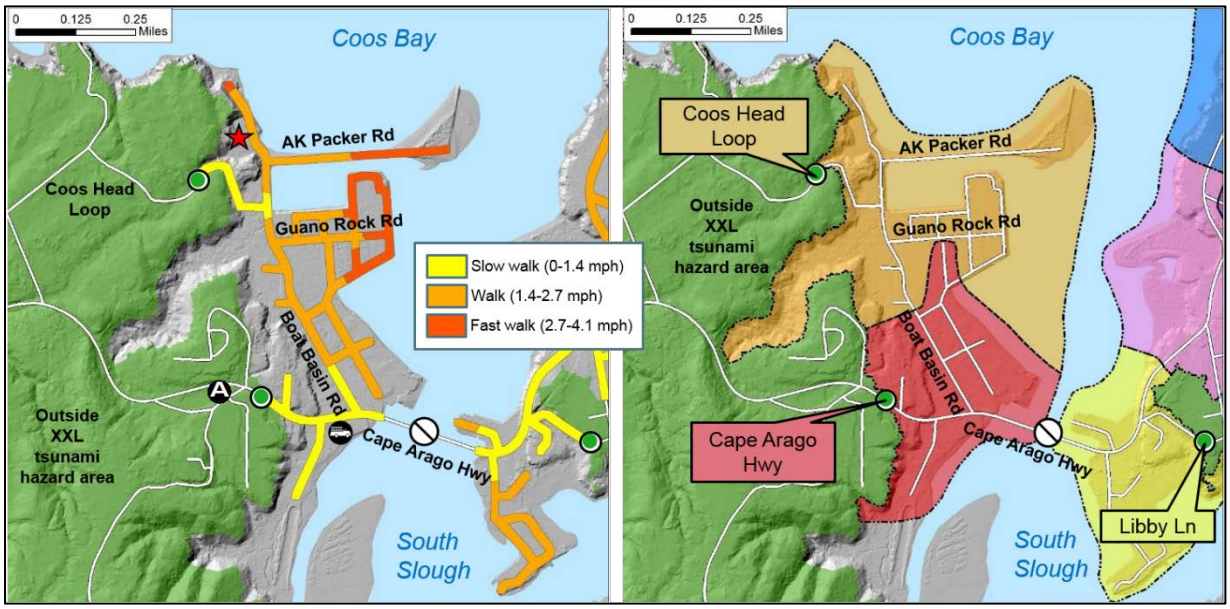
C.4 Barview, north (top) and south (bottom) – pedestrian speeds & evacuation communities:

Beat the Wave pedestrian evacuation speeds are indicated by road color on the left. Evacuation communities (colored areas – on the right) define the area of evacuation and the associated nearest safety destination(s) indicated by the green dots. Green shaded areas are outside of the XXL tsunami inundation zone.



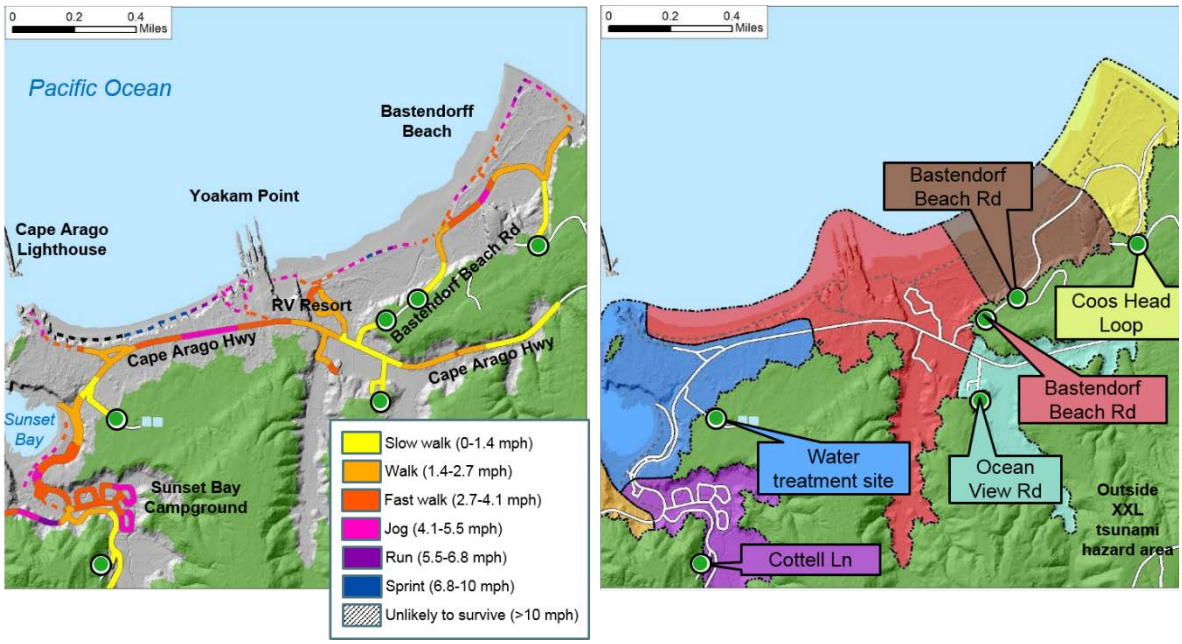
C.5 Charleston – pedestrian speeds & evacuation communities:

Beat the Wave pedestrian evacuation speeds are indicated by road color on the left. Evacuation communities (colored areas – on the right) define the area of evacuation and the associated nearest safety destination(s) indicated by the green dots. Green shaded areas are outside of the XXL tsunami inundation zone.



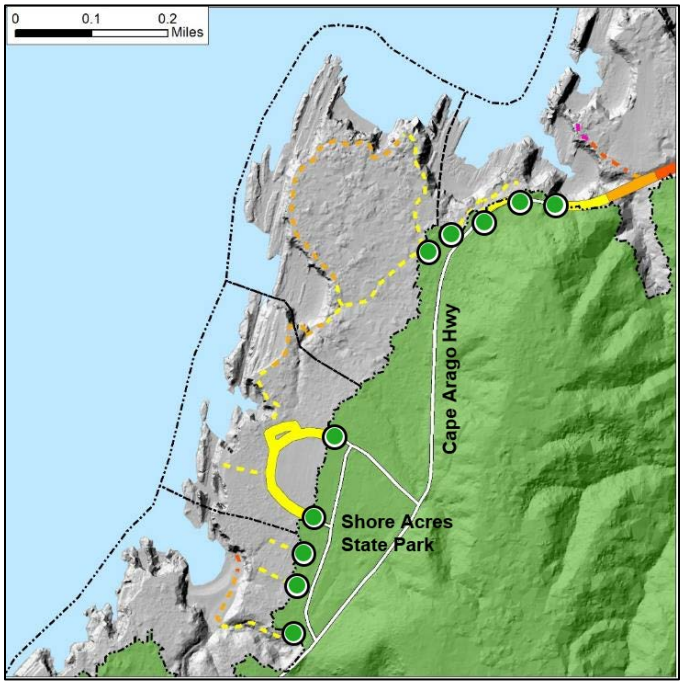
C.6 Outer Coast (south of Coos Bay Estuary) – pedestrian speeds & evacuation communities:

Beat the Wave pedestrian evacuation speeds are indicated by road color on the left. Evacuation communities (colored areas – on the right) define the area of evacuation and the associated nearest safety destination(s) indicated by the green dots. Green shaded areas are outside of the XXL tsunami inundation zone.



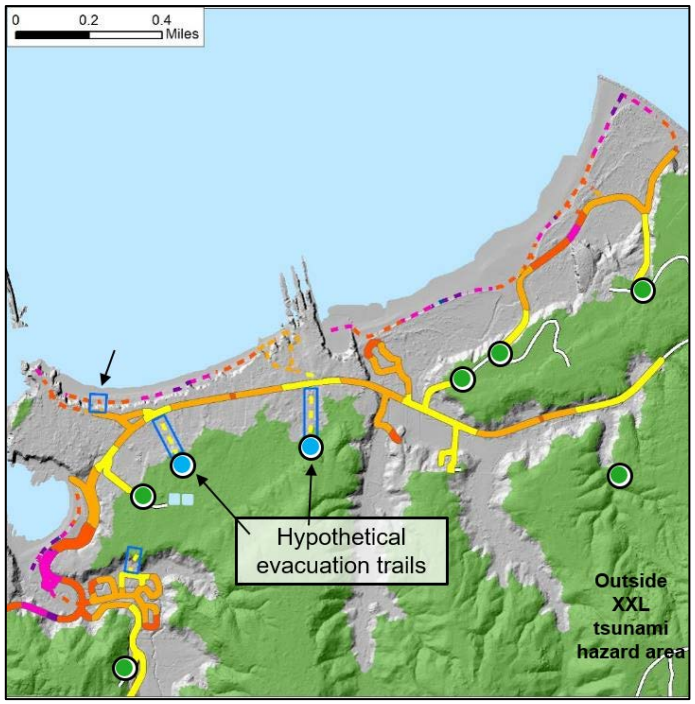
C.7 Shore Acres State Park – pedestrian evacuation speeds:

Beat the Wave pedestrian evacuation speeds are indicated by road color. Green dots indicate safety destinations and green shaded areas are outside of the XXL tsunami inundation zone.



C.8 Sunset Bay State Park with hypothetical mitigation options:

Beat the Wave pedestrian evacuation speeds for Sunset Bay to Bastendorff Beach with hypothetical pedestrian trails indicated in blue boxes (leading to blue dots). Such trails would help reduce evacuation speeds. Green shaded areas are above the XXL tsunami scenario.



4. Earthquake and tsunami impact analysis

The report below, released in 2022, supports the risk assessment for the 2023 Coos County Multi-Jurisdictional Natural Hazard Mitigation Plan Update. It is cited as Allan and O'Brien, 2022 within this document.

Open-File Report O-22-06, Earthquake and tsunami impact analysis for coastal Lane, Douglas, and Coos Counties, Oregon, by Jonathan C. Allan and Fletcher E. O'Brien; 124 p. report, including data tables and community-specific profiles.

WHAT'S IN THIS REPORT?
This report evaluates a Cascadia Subduction Zone earthquake (MW 9.0) and tsunami (M1, L1, and XXL1 scenarios) affecting coastal Lane, Douglas, and Coos counties, Oregon, to understand the degree of potential destruction, including building losses, debris generated, fatalities and injuries, and estimated numbers of the displaced populations. The goal is to help coastal communities prepare for this inevitable disaster.

PUBLICATION DOWNLOADS
The following are available at: https://www.oregongeology.org/pubs/ofr/O-22-06/p-O-22-06.htm

Report and appendix (124 p., 65 MB PDF), including an appendix of 42 tabloid-page-size community-specific profiles for Florence, Dunes City, Siltcoos River Campgrounds, Reedsport, Winchester Bay, Umpqua South Jetty, Lakeside, Coos Bay, North Bend, Barview, Charleston, Sunset Bay State Park, Bullards Beach State Park, and Bandon.
Report only (80 p., 3.1 MB PDF)
Appendix A community profile sheets only (44 p., 62 MB PDF)
Spreadsheets only (Three Excel spreadsheets, 163 KB .zip file) - contains all the data that are the basis for this report's tables and figures

Publication bundle (report, appendix, spreadsheets; 61 MB .zip file

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

OPEN-FILE REPORT O-22-06

EARTHQUAKE AND TSUNAMI IMPACT ANALYSIS FOR COASTAL LANE, DOUGLAS, AND COOS COUNTIES, OREGON

By Jonathan C. Allan[1] and Fletcher E. O'Brien[2]

2022

[1]Oregon Department of Geology and Mineral Industries, Coastal Field Office, P.O. Box 1033, Newport, OR 97365
[2]Oregon Department of Geology and Mineral Industries, 800 NE Oregon Street, Suite 965, Portland, OR 97232

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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.

WHAT'S IN THIS REPORT?

This report evaluates a Cascadia Subduction Zone earthquake (M_W 9.0) and tsunami (M1, L1, and XXL1 scenarios) affecting coastal Lane, Douglas, and Coos counties, Oregon, to understand the degree of potential destruction, including building losses, debris generated, fatalities and injuries, and estimated numbers of the displaced populations. The goal is to help coastal communities prepare for this inevitable disaster.

Cover: Photo from Wikimedia commons: https://commons.wikimedia.org/wiki/File: US Navy 110315-N-5503T-307 An aerial view of damage to Otsuchi, Japan, after a 9.0 magnitude earthquake and subsequent tsunami devastated the area in northern Japan.jpg.

U.S. Navy photo by Mass Communication Specialist 3rd Class Alexander Tidd, March 15, 2011

Oregon Department of Geology and Mineral Industries Open-File Report O-22-06
Published in conformance with ORS 516.030

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https://oregon.gov/DOGAMI/

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EXCEL SPREADSHEET

A Microsoft Excel spreadsheet for each county showing data that are the basis for this report's tables and figures is available in the digital file set of this report.

EXECUTIVE SUMMARY

This report provides an evaluation of the potential impacts of a Cascadia earthquake and accompanying tsunami in coastal Lane, Douglas, and Coos counties. The analyses presented here include an assessment of the number of people, businesses, and critical facilities located in three Cascadia tsunami inundation zones (M1, L1, and XXL1). XXL1 represents the maximum-considered inundation scenario given our knowledge of the Cascadia Subduction Zone (CSZ). Large (L1) and Medium (M1) tsunami zones reflect smaller earthquake and tsunami scenarios that are more likely to occur than XXL1. L1 captures 95% of the uncertainty in tsunami modeling (there is a ~5% chance that the tsunami could exceed the L1 tsunami zone), whereas the M1 scenario captures 78% of the uncertainty (there is a ~22% chance that the tsunami could exceed the M1 tsunami zone).

A major focus of this study is to provide improved estimates of local population demographics in each community to better understand evacuation challenges that could affect different population groups, as well as socioeconomic impacts associated with a CSZ earthquake and tsunami. The results and analyses presented here reflect a comprehensive effort to document the likely effects the next great earthquake and tsunami will have on all three counties.

We used previously developed physical models of a CSZ earthquake and tsunami, "Beat the Wave" tsunami evacuation modeling, and the recently published Federal Emergency Management Agency (FEMA) Hazus Tsunami Model to develop standardized damage loss estimates for each community, as well as estimates of injuries, fatalities, and displaced population. From the building damage losses, we estimated the amount of debris generated. Our population model improves upon previous studies by providing spatially detailed estimates of permanent and temporary populations — the latter quantifying numbers of visitors, which vary widely throughout the calendar year. The tsunami injury and fatality modeling evaluates a nighttime (2 AM) evacuation scenario, which assumes people are in their homes/hotels/campgrounds at the time of the event (as opposed to on the beach or walking around town). We also maximize visitor occupancy by assuming all hotels/second homes/campgrounds are at capacity, to fully quantify potential impacts to permanent and temporary residents. Our major findings include the following:

- Total populations in coastal Lane, Douglas, and Coos counties that are within a tsunami zone are summarized below:

	Permanent population (M1 – XXL1)	**Permanent + temporary population (M1 – XXL1)**
Lane	550 – 1,870	2,600 – 6,040
Douglas	1,050 – 1,970	3,360 – 5,430
Coos	1,330 – 10,340	4,970 – 20,850

- The fraction of permanent residents within the three tsunami zones varies considerably between communities. These variations reflect contrasting patterns in the general shape and elevation of the county coastlines, whether it is open coast versus up an estuary; inundation extents; and the distribution of permanent residents within the communities. Notable observations:
    - **Siltcoos**, **Sunset Bay**, and **Bullards Beach** campgrounds are 100% inundated in all three scenarios.
    - For the M1 scenario, communities with the largest number of people in the tsunami zone include **Charleston** (32%), **Winchester Bay** (54%), and **Umpqua South Jetty** (49%).
    - **Winchester Bay** is mostly located in the M1 tsunami zone and is 100% within the L1 and XXL1 tsunami zones.

  - **Barview**, **Charleston**, and **Bandon** each have relatively large numbers of people located in the XXL1 tsunami zone — 73%, 52%, and 68% respectively.
  - **Florence**, **Dunes City**, **Lakeside**, **North Bend** and **Coos Bay** have relatively few people in the various tsunami zones.
- All 17 communities and parks distributed along the Lane, Douglas and Coos coastlines can experience significant influxes of visitors, well exceeding their local resident populations. Of note, the population of **Florence** can swell by ~420% to 300% (M1 to XXL1), **Winchester Bay** by ~1,360% to 950%, and **Bandon** by ~210% to 225%. The popularity of these communities as centers of tourism present challenges associated with preparing such a large transient population for a CSZ earthquake and tsunami.
- An understanding of how population demographics are geographically distributed within each tsunami zone can provide an insight into those communities that may experience evacuation challenges. We use people over 65 years of age as a proxy for those who may experience increased evacuation difficulty (reduced evacuation travel speeds). Numbers of people over 65 years of age within a particular tsunami zone is summarized below:

	% of population ≥65 years	Number of ≥65 within M1	Number of ≥65 within L1	Number of ≥65 within XXL1
Lane	35% (M1 & L1), 34% (XXL1)	189	324	715
Douglas	34% (M1 to XXL1)	325	526	617
Coos	33% (M1), 31% (L1), 28% (XXL1)	436	914	2,749

  - At the community level, **Florence**, **Winchester Bay,** and **Bandon** each have a large proportion (41%) of their resident population ≥65 in the XXL1 tsunami zone.
- The number of buildings located in a tsunami zone is a useful metric for determining exposure to the tsunami hazard. Building counts in the tsunami zones are particularly large in **Barview**, **Bandon**, **Coos Bay**, and to a lesser degree **Florence**. Interestingly, the largest single number of buildings fall within the "other" category (~2,102) in unincorporated Coos County, reflecting residential buildings established along the open coast outside of community boundaries, as well as along the shores of the Coos and Coquille estuaries. Communities with particularly high exposure to the tsunami hazard include:

	% buildings inside the tsunami zone		
	M1	**L1**	**XXL1**
Winchester Bay	56%	98%	98%
Charleston	58%	59%	70%
Barview	6%	17%	76%

- Building damage caused by earthquake shaking in the three coastal counties is estimated to be:
  - Lane County: $1.23 billion
  - Douglas County: $420 million
  - Coos County: $4.42 billion

  The large loss estimates for Coos County can be attributed to the effects of liquefaction (and lateral spreading) that are particularly damaging to bayfront infrastructure. Earthquake damage losses in the communities of **Coos Bay** and **North Bend** are substantial and are estimated to reach ~$1.8 billion. Nevertheless, the largest earthquake losses fall within the "other" category (~$1.9 billion) in Coos County, which reflect those buildings located throughout unincorporated Coos County.

- An M1 event could yield damage levels that range from ~10% at **Dunes City** to ~90% at **Bandon** and **Charleston**. Damage caused by the XXL1 tsunami reveals destruction levels of >70% in most coastal communities, including **Florence**, **Reedsport**, **Winchester Bay**, **Coos Bay**, **North Bend**, **Barview**, **Charleston**, and **Bandon**; complete destruction occurs at the Siltcoos, Bullards Beach and Sunset Bay campgrounds. These findings can be attributed to the powerful hydraulic forces associated with the tsunami, and the prevalence of light-frame construction material (i.e., wood frame) on the Oregon Coast.
- Combined earthquake and tsunami damage losses for each tsunami zone and scenario are estimated to be significant:

	M1	L1	XXL1
Lane	$1.25 billion	$1.27 billion	$1.36 billion
Douglas	$440 million	$464 million	$530 million
Coos	$4.52 billion	$4.62 billion	$5.14 billion

These estimates reflect community-wide losses associated with the earthquake, combined with destruction caused by the tsunami. Note that these estimates exclude building content losses, such that the numbers may be viewed as minimum estimates.

- The destruction of buildings in coastal Lane, Douglas, and Coos counties is expected to generate substantial debris:

	M1	L1	XXL1
Lane	40,000 tons	50,500 tons	108,000 tons
Douglas	71,200 tons	106,000 tons	149,000 tons
Coos	191,300 tons	358,000 tons	785,000 tons

This equates to ~4,000 dump trucks for M1 in Lane County to as much as 78,500 dump trucks for an XXL1 event in Coos County (assuming dump truck capacity of ~10 yd^3). These estimates are almost certainly on the low end, as they do not include debris associated with content from buildings (personal items, business equipment, furniture etc.), road rip-ups, vehicles, and vegetation.

- Modeled tsunami casualties (injuries and fatalities) vary widely between communities. This is due to many factors, but the most important is the relative distance to high ground. We estimate that, combined, countywide fatalities from the tsunami could reflect the following:

	M1	L1	XXL1
Lane	20	50	200
Douglas	610	1,180	1,380
Coos	440	1,070	5,290

  - Low casualties associated with the M1 scenario in Lane County is indicative of the fact that high ground is located close to the population centers, allowing for quick access to high ground, or the tsunami simply was not large enough to reach them.
  - For the XXL1 tsunami scenario — the largest-considered — the potential for significant fatalities is apparent for **Bandon** (~1,900), the "other" category in Coos County (~1,400), **Winchester Bay (**~1,200), and **Barview (**~980). Overall, the bulk of the fatalities (>61%) are likely to be from the temporary visitor population.

  - High casualties associated with the temporary visitor population is predicated on the assumption that these facilities are at 100% occupancy.
  - Several additional sites with the potential for large visitor fatalities include **Siltcoos River** Campground, **Umpqua South Jetty**, **Sunset Bay** campground and **Bullards Beach** campground. Fatalities in these areas are due to a combination of early wave arrivals and long travel distances required to reach high ground.
  - These results demonstrate a need to evaluate alternative forms of high ground (e.g., vertical evacuation structures) and/or evaluate retrofitting bridges (e.g., Winchester Bay) to withstand the earthquake shaking, thereby allowing for faster evacuation.
- Following the earthquake and accompanying tsunami, communities will have to deal with many hundreds to potentially thousands of displaced people requiring immediate short-term shelter and care (for days to a few weeks), after which many people are likely to be evacuated from the coast. Hazus modeling indicates that the number of displaced people is significantly higher in the XXL1 scenario (~25,400) compared to the M1 scenario (~9,800). We expect large numbers of displaced people to severely challenge the following communities: **Florence**, **Reedsport**, **Coos Bay**, **North Bend**, **Barview** and **Bandon**. Furthermore, an estimated 4,800 people outside of community urban growth boundaries (UGB) and unincorporated boundaries will require shelter and care.
- Compared to fatalities, injuries from the earthquake were found to be moderately low. Overall, the number of critically injured (requiring hospitalization) as a result of the earthquake is on the order of:
  - Lane County: 150
  - Douglas County: 30
  - Coos County: 380
- Injuries caused by the tsunami are expected to be on the order of:

	M1	L1	XXL1
Lane	~20	5	90
Douglas	~590	40	80
Coos	~180	350	1,700

Although each community in coastal Lane, Douglas, and Coos counties has unique circumstances and challenges, our results unequivocally demonstrate that in every community, ***injuries and fatalities from a tsunami can be minimized if people evacuate on foot toward safety as soon as possible and travel as fast as possible.***

1.0 INTRODUCTION

The destructive and life-threatening forces of tsunamis are well known globally, as demonstrated by the 2011 Tōhoku, Japan event that resulted in 15,899 killed and another 2,529 missing (as of September 10, 2020; National Police Agency of Japan, 2020). Most of the deaths in the event were due to drowning (Mori and Takahashi, 2012). The earthquake and tsunami destroyed 121,992 buildings. A total of 282,920 buildings experienced partial collapse, and 730,359 buildings were partially damaged. A total of 4,198 roads were damaged, along with 116 bridges (National Police Agency of Japan, 2020).

The Oregon Coast is similarly exposed to large megathrust subduction zone earthquakes, capable of generating catastrophic tsunamis (Witter and others, 2011). The Cascadia Subduction Zone (CSZ) geologic record contains evidence of at least 19 earthquakes >8.5 M_W over the past 10,000 years (Goldfinger and others, 2012, 2017; Priest and others, 2009; Satake and others, 2003; Walton and others, 2021; Witter and others, 2012). The most recent tsunami generated on the CSZ occurred on January 26, 1700 (Atwater and others, 2005). Goldfinger and others (2017) estimated the conditional probability of an earthquake on the CSZ at ~16–22% in the next 50 years; a partial rupture of the CSZ impacting the southern Oregon Coast has a conditional probability of ~37–43% (Goldfinger and others, 2012). Because many communities on the Oregon Coast have large numbers of people, residences, and businesses located in the tsunami zone, there is a high potential that the next great earthquake and tsunami will result in many fatalities, catastrophic destruction of local infrastructure, and lasting damage to Oregon's economy. The objective of this report is to examine community exposure to tsunami inundation and earthquake shaking and provide estimates of infrastructure damage and casualties for Coos, Lane and Douglas County on the southcentral Oregon Coast. In providing such information, we address a specific need expressed in the 2013 Oregon Resilience Plan — to document the "who," "what," and "where" in terms of population exposure, building damage, and socioeconomic impacts (OSSPAC, 2013). The overall approach presented here follows comparable efforts undertaken for Clatsop, Tillamook, and Lincoln counties (Allan and others, 2020a,b; Allan and O'Brien, 2021). The difference here is that we use an updated Cascadia earthquake scenario developed by Wirth and others (2020) and new geologic data summarized in Madin and others (2021).

Following the 2011 Tōhoku, Japan, tsunami, Federal Emergency Management Agency (FEMA) commissioned an effort to standardize quantification of tsunami impacts (FEMA, 2013), which was refined and eventually incorporated into FEMA's Hazus framework (FEMA, 2017). Hazus is a geospatial information system (GIS) software model that produces loss estimates for earthquakes, floods, hurricanes, and tsunamis based on state-of-the-art scientific and engineering risk analyses. Critical inputs needed by Hazus include a wide variety of tsunami modeling, engineering, and societal information, including earthquake ground motion and ground deformation, tsunami inundation, flow velocities and flow depths, building inventories, and population demographics.

In Oregon, considerable mapping and modeling has been undertaken by the Oregon Department of Geology and Mineral Industries (DOGAMI) to better advise local and state government agencies on the various geologic hazards that could impact the state. For example, DOGAMI and the U.S. Geological Survey (USGS) published ground motion/deformation maps for a magnitude (M_W) 9.0 CSZ earthquake (Madin and Burns, 2013). These data were integral in initial efforts to evaluate impacts from a CSZ event throughout Oregon (OSSPAC, 2013). The work of Madin and Burns (2013) have since been updated by Madin and others (2021) to account for new geological data, including updated soil, liquefaction and landslide information, as well as recently compiled Cascadia earthquake ensemble modeling undertaken by Wirth and others (2020).

Between 2010 and 2013, DOGAMI combined high-resolution terrestrial lidar-derived digital elevation models (DEMs) with detailed bathymetry to model five scenarios for CSZ generated tsunamis (Priest and others, 2013g; Witter and others, 2011). More recently, DOGAMI pioneered techniques for tsunami evacuation modeling ("Beat the Wave," BTW) at Seaside and Gearhart (Priest and others, 2015), Warrenton/Hammond (Gabel and Allan, 2016), Rockaway Beach, (Gabel and Allan, 2017), Pacific City (Gabel and others, 2018a), Reedsport and Florence (Gabel and others, 2018b), Newport (Gabel and others, 2019a), Lincoln City/unincorporated Lincoln County (Gabel and others, 2019c), the Coos estuary (Gabel and others, 2019b), unincorporated Lincoln County (Gabel and others, 2019d), Port Orford (Gabel and others, 2020a), Nehalem Bay (Gabel and others, 2020b), and Gold Beach (Gabel and others, 2021). These BTW studies graphically demonstrate evacuation challenges and mitigation opportunities but do not quantify potential loss of life. Since 2015, Williams and others (e.g., Williams and others, 2021) developed a Hazus-compatible building inventory for all seven Oregon coastal counties, identifying the location, size, and primary usage (e.g., residential, commercial) of buildings, information fundamental to addressing fatalities and building damage potential.

Although most data needed by Hazus to model the effects of earthquake and tsunami impacts are in place, one key missing element is a spatially explicit population model for the Oregon Coast. Specifically, how many people are located in the tsunami zone, their demographics, and where they are located relative to safety from the tsunami at the time of the earthquake. Such a model is complicated because many Oregon coastal communities experience large influxes of daytime and overnight visitors throughout the year (Dean Runyan Associates, 2018). Many homes and condominium units located in the tsunami zone are second homes or vacation rentals (Raskin and Wang, 2017). Additionally, numerous coastal parks and campgrounds are located in the tsunami zone and potentially host many thousands of overnight visitors per day (White, 2018). Each of these considerations must be carefully evaluated and accounted for in order to generate meaningful statistics of both local and visitor populations and, ultimately, potential casualties and displaced populations associated with a CSZ earthquake and tsunami. Furthermore, *population estimates should assume the highest seasonal occupancy so that design capacities will be based on the maximum potential evacuation need,* while also identifying vulnerable population groups within the tsunami zone that may present special evacuation challenges (DLCD, 2015).

The purpose of this report is to evaluate the potential effect of a CSZ earthquake and accompanying tsunami in coastal Coos, Douglas, and Lane counties (**Figure 1-1**). Specifically, we evaluate estimates of potential building losses, generated debris, fatalities, and injuries, as well as estimates of the number of displaced people. The study also provides an assessment of vulnerable populations, essential facilities, and critical infrastructure, which is important to response and recovery. This study integrates previous tsunami modeling with a new Cascadia earthquake model and new population model (comprising permanent and temporary people) for the purpose of:

1. evaluating tsunami evacuation challenges and opportunities on the coast.
2. completing a detailed socioeconomic analysis using several data sources to identify vulnerable communities in the tsunami zone.

This report initially describes and documents our overall Hazus approach. Results from the countywide assessments are provided in Section 3, with broad conclusions outlined in Section 4. Summary information specific to each community and tsunami inundation zone is provided in Appendix A.

Figure 1-1. Location map showing coastal Lane, Douglas, and Coos county communities. Yellow zone depicts the XXL1 tsunami zone.

2.0 METHODS

2.1 Overview

Baseline information required by Hazus includes:

1. A physical description of the earthquake and tsunami hazard.
2. A comprehensive building database, with each building populated with an occupancy estimate derived from our population model.

For the earthquake hazard, we used the median CSZ M_W 9.0 earthquake, which is derived from an ensemble of 30 Cascadia earthquakes (Wirth and others, 2020). For the tsunami hazard, we provide results for three tsunami inundation zones: Medium (M1), Large (L1), and Extra Extra Large (XXL1) (Priest and others, 2013g; Witter and others, 2011). Thus, Hazus model results presented here reflect earthquake-related damage, debris weight, and casualties simulated for the entire community and for each of the three tsunami inundation scenarios. We do not model the earthquake damage and casualties that would occur for those communities located well inland from the coast (e.g., Eugene) that are part of a particular county. For injury and fatality estimation we analyzed a "2 AM" scenario, in which an earthquake strikes during the summer (when the number of visitors is the highest) at 2 a.m. (when most people are asleep). The modeling distinguishes the number of casualties experienced by both permanent residents as well as the temporary visitor population. We did not evaluate a 2 PM scenario because the 2 AM scenario defined for summer occupancy conditions assumes maximum occupancy and we believe it is sufficiently conservative to account for uncertainty associated with the movement patterns of day trippers.

2.2 Natural Hazard Dataset Development

2.2.1 Earthquake

Wirth and others (2020) recently developed ground-shaking estimates from 30 M_W 9.0 CSZ earthquakes, determined using a logic-tree approach that varied the location within the earth where the earthquake rupture starts, down-dip rupture limit, slip distribution, and location of strong-motion-generating sub-events. From these data, they produced an ensemble suite of ShakeMaps[1] based on the median scenario ±1σ and ±2σ, which spans the 2nd and 98th percentile ground motions. For the median ensemble ShakeMap, they observed that the Modified Mercalli intensity (MMI), a measure of the ground-shaking intensity, is likely to range from MMI 8 ("severe" shaking) along the Oregon Coast to MMI ~7 ("very strong" shaking) within inland locations such as the Willamette Valley. The southern Oregon Coast could experience MMI ~8-9, which equates to "violent" shaking. According to Wirth and others (2020), the difference between the 2nd and 98th percentile ground motions (i.e., ±2σ around the medium) spans ~1.5-2 MMI units. For the purposes of this risk assessment, we used the bedrock ground motions associated with the median M_W 9.0 CSZ earthquake (Wirth and others, 2020) for use in the FEMA Hazus Advanced Engineering Building Module (AEBM; FEMA, 2010). The median M_W 9.0 CSZ earthquake data were compiled along with local ground characteristics that influence the amplification of ground shaking, namely liquefaction of soils, and earthquake-induced landslides by Madin and others (2021) to produce a

[1] https://earthquake.usgs.gov/data/shakemap/

new statewide seismic hazard map for Oregon. These latter datasets reflect years of surficial geologic mapping using high-resolution lidar data to produce accurate maps of areas subject to different coseismic geohazard conditions.

The bedrock ground motions were adjusted for discrete areas using National Earthquake Hazards Reduction Program (NEHRP) recommended site amplification factors (FEMA, 2015a, implemented as piecewise linear equations by Bauer and others, 2018, Appendix B). Updated NEHRP site classification (Figure 2-4 in Madin and others, 2021) and Hazus-scale liquefaction susceptibility GIS data (Figure 2-5 in Madin and others, 2021) were used in this study. Sites with NEHRP site classification "F" (meaning soil requires site-specific evaluations, as defined by FEMA, 2003, Section 3.5) were reclassified as "E" (soft soils) — a commonly implemented assumption for loss estimation purposes (Bauer and others, 2018; Madin and others, 2021). For liquefaction modeling, we assumed a water table level of zero feet (i.e., fully saturated soil). Hazus-scale landslide susceptibility data were obtained by processing landslide susceptibility GIS data compiled by Madin and others (2021). We mapped the 1–4 scale defined by Madin and others (2021) to the FEMA Hazus landslide susceptibility scale of 0–10 as follows: "Low" corresponds to 1, "Moderate" corresponds to 4, "High" corresponds to 7, and "Very High" corresponds to 10. The mapping corresponds to the "WET" scenario described by FEMA (2011, Table 4.15).

2.2.2 Tsunami

The earthquake scenarios and corresponding surface deformation used to simulate tsunami inundation for the Oregon Coast reflect a full-length rupture of the Cascadia megathrust (Witter and others, 2011, 2013). Four representative earthquake slip models were defined and tested, including slip partitioned to a hypothetical splay fault in the accretionary wedge and models that varied the updip limit of slip on the megathrust. Recurrence information was defined from a suite of scientific studies, including work undertaken in coastal estuaries (Nelson and others, 1996, 2006; Peterson and others, 1995; Witter and others, 2003) and on the continental shelf (Goldfinger and others, 2012). Inter-event time intervals that separate the 19 full-margin earthquakes and tsunamis range from as little as 110 to ~1,150 years (Witter and others, 2011, Table 1). Each tsunami scenario was then weighted using a logic tree, to account for the different models, convergence rates, and recurrence. From these data, four time intervals (mean values rounded to the nearest quarter century) were defined as representative of four general earthquake size classes:

- Small (SM) – Five events, mean inter-event time of 300 years (range=~110 to 480 years).
- Medium (M) – 10 events, mean inter-event time of 525 years (range=~310 to 660 years).
- Large (L) – Three events, mean inter-event time of 800 years (range=~680 to 1,000 years).
- Extra Large (XL) – One event, mean inter-event time of 1,150 years, rounded to 1,200 years.

The mean inter-event time interval multiplied by the CSZ plate convergence rate at each latitude equates to the amount of slip deficit released in each scenario earthquake. Slip was also reduced progressively from north to south on the CSZ to account for evidence in the paleoseismic record of increasing numbers of partial CSZ ruptures from north to south (Goldfinger and others, 2012; Witter and others, 2013). A fifth scenario termed Extra Extra Large (XXL1), which simulated a maximum-considered tsunami not seen in the geologic record, was eventually used to guide evacuation planning (Witter and others, 2011). This last hypothetical scenario assumes 1,200 years of slip deficit release but without any reduction of slip from north to south. According to Witter and others (2013), the defined earthquake size classes correspond to approximate recurrence rates as follows: SM, 1/2,000 years; M, 1/1,000 years; L, 1/3,333 years; and XL, <1/10,000 years. Recurrence for the XXL1 event is not known.

Maximum flow depths were obtained from Priest and others (2013a,b,c,d,e,f), and the maximum momentum flux was derived from Priest and others (2014a,b,c,d,e,f). The unstructured computational grid data were converted to raster format for use in Hazus using the Esri® ArcGIS Spatial Analyst Natural Neighbor tool. We specified a 3-m (~10-ft) grid resolution, noting that the mean distance between points in the terrestrial regions within the XXL1 tsunami zone was ~5 m (~16 ft). The Hazus tsunami building damage and casualty fragility curve parameters (determined by engineers) are based on median depth and momentum flux values, rather than maximum values (FEMA, 2017, section 4.6). To that end, the raster data were subsequently converted to both median depth and median momentum flux using a 0.66 multiplier; the results were also converted to non-SI (English) units for use in Hazus.

Wave arrival times at the tsunami runup limit were obtained from data originally developed by Priest and others (2013a,b,c,d,e,f). As documented by Bauer and others (2020), an independent spreadsheet that implements the Hazus tsunami casualty model was developed to facilitate analysis and reporting of injuries and fatalities resulting from a tsunami (see Section 2.6). The original approach relied on a single average wave arrival time per community. For this study, however, we modified the approach to support per-record maximum wave arrival times at the tsunami runup limit (in minutes). This was necessary due to the large variation in maximum wave arrival times observed along the Oregon Coast, especially within the various estuaries. For example, wave arrival times ranges from as little as 12 minutes for a tsunami arriving at the open coast near the mouth of the Coos estuary, compared with 42 minutes for the tsunami to reach downtown Coos Bay. These differences have an enormous bearing on the number of modeled casualties. To resolve this limitation, we used the evacuation flow zone polygons defined in our various "Beat the Wave" studies to associate a group of buildings with a particular tsunami safety destination or exit point. We then determined the maximum wave arrival time at a particular watershed's exit point and assigned that value (in minutes) to the polygon. All buildings within that watershed were then associated, via a spatial overlay, with that wave arrival time. In some open coast communities, such as Bastendorff Beach, the maximum wave arrival time varies only slightly, and a single value was assigned to all buildings. Wave arrival times for areas located outside our detailed "Beat the Wave" investigations were defined based on average wave arrival times for that particular section of coast.

2.3 Building Database Development

A Hazus-compatible building database contains a record for each distinct building. Each record contains essential information for estimating potential damage to the structure and harm to the building's occupants (**Table 2-1**). Information associated with the building record is populated primarily from county assessor records or, from ancillary datasets, and when better data is available (e.g., Lewis, 2007). We followed the methods established by Bauer and others (2018), starting with the incorporation of building records previously developed (e.g., Williams and others, 2021) and modifying or amending records where better information was available.

The User-Defined Facilities (UDF) datasets developed by DOGAMI attempts to identify all buildings that can be considered a residential facility, including traditional single-family residences, manufactured housing, multifamily residential buildings, condominiums, motels, and hotels, dormitories and assisted living facilities. The datasets contain information on building primary usage (Hazus "occupancy class"), square footage, number of stories, year built, and building type (e.g., wood frame, steel frame construction, etc.). Although the UDF dataset was a good starting point, it did not always correctly classify residential structures. Therefore, it required a thorough review, during which many records were manually updated to correct existing attributes.

We augmented the UDF dataset as follows. We added a "number-of-units" field, identifying the number of rooms, where available, for motels, multifamily residential, and dormitory building types (Hazus occupancy types "RES4," "RES3," "RES5," respectively). We further augmented the UDF dataset by adding records to capture the locations of individual tent and yurt sites, recreational vehicle spots, and boat slips in marinas that permit overnight docking. Such locations were digitized as points using orthoimagery and other ancillary data sources, such as Oregon State Park campground maps. We note that the Hazus earthquake and tsunami building damage model is limited to traditional buildings, and thus our building loss estimates exclude damage to temporarily occupied structures such as tents, recreational vehicles, and boats.

Table 2-1. Building information required by Hazus earthquake and tsunami model.

Hazus Attribute	Example	Purpose
Location of building	latitude, longitude	Extract ground motion and ground deformation data
Building usage	Single-family Residential; Retail Commercial	Repair/replacement cost; number of people per building
Building material	wood; steel	Building response to ground motion; debris
Year built	1968	Seismic design level: building response to ground motion
Number of stories	2	Building response to ground motion
Square footage	2,250	Building repair/replacement cost; debris; number of people per building
First floor height	3.0	(in feet) Tsunami nonstructural building damage estimate
Daytime occupancy[+]	2.1	Casualty estimate
Nighttime occupancy[+]	3.4	Casualty estimate

[+]*Daytime* and *Nighttime occupancy* are Hazus terminology. For our analysis purposes we populate *Daytime occupancy* with the number of temporary residents in the building at 2 p.m. and *Nighttime occupancy* with the number of permanent residents in the building at 2 a.m.

We used the RSMeans valuation method for estimating a building's replacement cost (Charest, 2017) where:

$$\text{RSMeans} = \text{building square footage} \times \text{standard cost per square foot} \quad (1)$$

Per-square-foot replacements costs are derived from the Hazus 5.0 database[2], which incorporated the 2014 RSMeans valuation. Adjustments for inflation or regional variation to the tabular data were not incorporated.

Building replacement cost is not the same as a property's assessed value. For analysis purposes, we assume repair or replacement costs to damaged structures will be charged at standard construction rates, independent of a building's age or the land on which the building is placed. Assessed value includes the land's value, which may fluctuate greatly depending on real estate markets, and home improvements. Assessors may also factor in the building's depreciation into the assessed value.

An abnormal shortage of skilled labor or materials can occur following a large-scale disaster. "Demand surge" is a phenomenon resulting in a higher cost to repair buildings after large disasters, compared with

[2] FEMA Hazus SQL tables [dbo].[hzRes1ReplCost] for single-family residential; [dbo].[hzReplacementCost] for all other occupancy types.

the same repair for damage after a small disaster (Olsen and Porter, 2011). Adjusting repair/replacement costs due to a likely demand surge was beyond the scope of this project.

Williams and others (2021) used street-level imagery to determine the building type of all non–single-family residential buildings, using the guidance provided by FEMA (2015b); selected records were updated with information from Lewis (2007) and other ancillary data sources. Williams and others (2021) were unable to locate additional building information that might have helped further refine the building type assignment, or any seismic retrofitting datasets that could be used to update an individual building's seismic design level. Finally, our observations from numerous field visits and analysis of street-level imagery suggested that the statistical distributions for building types identified by FEMA (2011, Tables 3.A1–3.A.10) are not applicable to the Oregon Coast. This is because most commercial and industrial buildings built on the Oregon Coast use wood-frame construction. For single-family residential buildings, our field observations confirmed the FEMA Hazus assumption of 99% wood/1% other (FEMA, 2011, Table 3A.17). For simplicity, we assigned wood frame to all single-family residences except manufactured housing.

2.4 Population Modeling

To estimate injuries and casualties from damaged buildings, the FEMA Hazus earthquake model requires estimates of individual building occupancy (FEMA, 2010). People occupying tents, yurts, recreational vehicles, and boats, or who happen to be outside of a building at the time of the earthquake are assumed uninjured from the ground motion. To estimate injuries and fatalities from a tsunami, the FEMA Hazus tsunami model requires the user to refine the population model further to include locations, numbers, population demographics (age), and distance to safety outside the tsunami zone (FEMA, 2017). Typically, people are associated with a building in tsunami modeling, but they can also be placed in temporary lodging, such as in a tent or recreational vehicle, or out on a beach. Given the dynamic human environment, the modeler must therefore make several assumptions about each parameter in order to simulate fatalities and injuries.

To minimize the complexity associated with a dynamic human environment, FEMA Hazus documentation recommends modeling be undertaken for two time periods:

- a midweek "2 PM" scenario, in which people are dispersed among work, institutional, and home buildings.
- a "2 AM" scenario, in which most people are in a residential structure (in the Hazus model, hotels/motels are considered residential structures; temporary structures such as a tent or RV were also accounted for in our model).

Such divisions, however, are inadequate to meet the needs of this project (Bauer and others, 2020). This is because Oregon coastal communities experience significant temporal (daily, seasonal, and annual) population fluctuations, with large visitor influxes occurring on weekends and in the summer months (Dean Runyan Associates, 2018). Community planners have expressed strong interest that our population model accounts for such variations, which could then be used to assist with identifying tsunami evacuation challenges and short-term sheltering needs. To better understand these effects, we distinguish two broad population groups:

- *permanent residents*, who have established residence within the tsunami zone.
- *temporary residents*, who are visiting the community.

At night, temporary residents occupy residential facilities such as second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds; permanent residents typically occupy residential structures. During the day permanent and temporary residents may occupy institutional, educational, commercial, and industrial buildings, along with residential buildings, or may be dispersed throughout the tsunami zone (e.g., at the beach) and thus may not be directly associated with any particular building type.

Development of a detailed temporary population model was therefore motivated by several important factors (Bauer and others, 2020):

1. Computing an overall injury/fatality ratio[3] for the permanent population and assuming that the ratio could be applied to the temporary population could lead to significantly underestimating the numbers of fatalities and injuries. For example, analysis of U.S. Census data and observation of real estate dynamics on the Oregon Coast indicate a strong spatial correlation between the temporary population's preference to be close to the ocean, and thus farther away from tsunami safety, when compared to the permanent population (Raskin and Wang, 2017; illustrated with 2010 U.S. Census data in **Figure 2-1**).
2. It is reasonable to assume that the temporary population may be less aware of tsunami risk, locations of tsunami safe zones, signage, temporal urgency (e.g., if you feel strong ground shaking, evacuate immediately), and local evacuation routes compared to permanent residents.
3. Community planners expressed a need for detailed estimates of tsunami injuries and fatalities, as well as estimates of the number of displaced people following a Cascadia event. These data are essential for effective mass care planning. Thus, our modeling of tsunami-caused injuries and fatalities is undertaken assuming maximum occupancy, combining permanent and temporary residents, and distinguishing injuries and fatalities between the respective population groups. By doing so, we established a range that planners can use to estimate impacts at non-maximum occupancy periods.

Given project scope constraints and discussions with community members, we focused our attention on developing a summer weekend 2 AM population model for all communities to maximize estimates of the temporary population and thus provide a more realistic worst-case tsunami evacuation scenario for those communities. Although our summer weekend 2 AM population scenario does not account for day trippers to the coast, the injury, fatality, and displaced population estimates derived from this scenario may be considered a conservative estimate (i.e., upper bound), as the population model assumes maximum (100%) occupancy. Conversely, planners can use the permanent resident casualty estimates as a baseline (i.e., lower bound). FEMA guidelines (FEMA, 2012a, p. 3–6) note that full occupancy at the individual building level happens only occasionally and that "point-in-time population models can be used to develop a better understanding of the uncertainty in casualties associated with time, but it is necessary to perform a large number of realizations […] to do this in a meaningful way." Such extensive modeling for all communities was beyond the scope of this project. Accordingly, within the baseline (permanent resident population) and upper bound population that includes temporary visitors, planners can estimate the number of temporary residents present in their communities at other times of year and assume the injury and fatality estimates will scale proportionally.

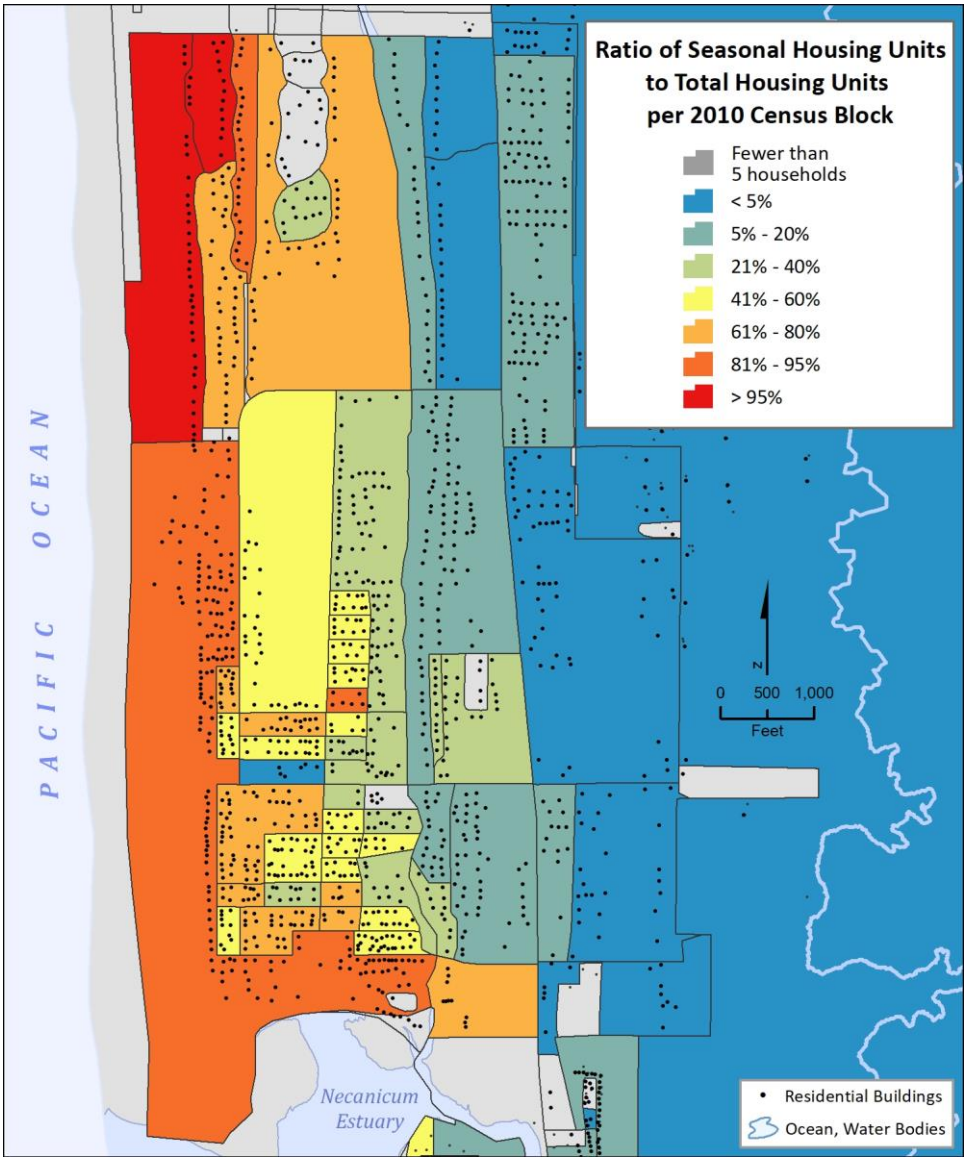
Our summer 2 AM weekend scenario assumes permanent residents are at their homes and that all available designated temporary lodging such as vacation rentals, second homes, vacation condominiums,

[3] Total number of tsunami injuries and fatalities divided by the total exposed permanent population.

campsites, marina boat slips, and recreational vehicle spots are fully occupied (i.e., 100% occupancy). Institutions and businesses, with certain exceptions, are considered to be unoccupied.

For permanent resident occupancy, we established locations, numbers of individuals, and age groups using 2010 U.S. Census data. Bauer and others (2020) used geocoded Oregon Department of Motor Vehicle (DMV) driver license registration records as of September 2017 to perform similar analyses for five coastal communities, as DMV records are typically associated with a single-family residential home. Although such an approach is more accurate for defining the permanent population, the time required to process DMV records on a countywide basis was beyond the scope of this investigation.

Figure 2-1. Example of "seasonally occupied households" as a percentage of total households per census block in Gearhart, Oregon, relative to the distance to the coast. XXL1 tsunami inundation zone shown as a light blue line on the far right. Census blocks with fewer than five households as of 2010 are shown in gray. Residential buildings shown as dots and include buildings constructed since 2010 that were not captured in the 2010 census. Census block data source: https://www.census.gov/data.html.



U.S. Census population data are organized into hierarchical spatial units of varying sizes, the smallest of which is the census block. Census blocks are typically "bounded by visible features such as roads, streams, and railroad tracks, and by nonvisible boundaries such as property lines, city, township, school district, and county limits, and short line-of-sight extensions of roads" (U.S. Census Bureau, n.d.). One level above that is the census block group, which is how the U.S. population is defined and distributed. Error! Reference source not found. provides summary statistics for census block groups in Lane, Douglas, and Coos counties:

Table 2-2. Census block group statistics for Lane, Douglas, and Coos counties.

		Census Block Group Size	
	Number of People	**Size Range**	**Mean Area**
Lane	1,160 people (ρ = ± 390)	110 hectares (270 acres) to 56,525 hectares (139,680 acres)	12,220 hectares (30,200 acres)
Douglas	980 people (ρ = ± 450)	40 hectares (100 acres) to 83,450 hectares (206,220 acres)	23,600 hectares (58,320 acres)
Coos	1,010 people (ρ = ± 430)	28 hectares (70 acres) to 86,635 hectares (214,080 acres)	6,780 hectares (16,750 acres)

In urban areas, census blocks are usually defined at the city block level, whereas in rural areas, census blocks may cover a several hundred square kilometers (few hundred square miles). Within each census block group, the population may range from negligible to several thousand people. However, unlike DMV records that associate a person with a specific address, census block groups provide a single aggregated population count. For our purposes, we used updated population statistics obtained from the American Community Survey (ACS; 2014–2018 census data downloaded from the U.S. Census Bureau; https://www.census.gov/programs-surveys/acs; data accessed 2021) at the census block group level. To estimate the size and distribution of the permanent population in our study area, we distributed the population per census block group among the residential buildings and pro-rated based on square footage. The specific steps associated with this process are summarized in **Table 2-3A** for the permanent population.

After populating the buildings, or in the case of multifamily residential structures, units, with permanent residents, we then assumed the proportion of residential buildings or units that are not occupied by a permanent resident are occupied on a temporary basis by out-of-town visitors. For single-family residential houses, we used the number of bedrooms (units) to determine temporary occupancy (**Table 2-3B**). We populated motels, campgrounds, recreational vehicle parks, and marinas using the number of rooms, tent or RV sites, or boat slips as a baseline, and multiplying by a people-per-unit occupancy assumption (**Table 2-3B**). To accomplish these steps, we used the 2010 census data to identify the residential household vacancy rate[4] at the census block level. For each UDF, we then multiplied the corresponding vacancy rate by the number of units, establishing the number of units occupied by temporary residents. This value is then multiplied by the people-per-unit value to derive a temporary population per household unit (**Table 2-3B**).

Finally, researchers have recognized that demographic factors can be an important factor in tsunami casualties (summarized by González-Riancho Calzada and others, 2015). This is because specific age groups have been recognized as having different evacuation speeds, which affects their evacuation

[4] H005006, "Total for seasonal, recreational, or occasional use" in the Total Vacancy data per census block, 2010 U.S. Census divided by total number of households in the census block, obtained from Table S1101.

potential. Accordingly, FEMA (2013, 2017) incorporated population demographics into the FEMA Hazus casualty model. This is accomplished by differentiating those people <65 years with those ≥65 years in the Hazus tsunami casualty model (FEMA, 2017), with the latter group assumed to evacuate at slower walking speeds. A 0.8 walking speed reduction factor was used to account for travel speeds used by persons ≥65 (see Section 2.6.2.4). Hence, for our tsunami casualty modeling purposes, an individual is identified as:

1) either permanent or temporary.
2) either < 65 years of age or ≥ 65 years (**Table 2-3**).

Table 2-3. Summary parameters and explanation used to define the process for distributing the permanent resident and visitor populations across U.S. census block groups.

	Occupancy Type	Number of Units	People Per Unit	People per UDF: Explanation	People Per UDF: Math	Age < 65 Ratio
A) Permanent Population	Single-family Residential	1 unit	The ACS 2014–2018 census data reports the number of permanent residents at the CBG level. For each CBG in the study area, divide the permanent population number by the total number of units within the CBG. This established a people-per-unit value.	The people-per-unit value is then multiplied by the total number of units belonging to each UDF to assign the total number of permanent residents.	[Number of Units] × ([Number of permanent people in CBG] / [number of units in CBG])	0.7
	Multifamily Residential	1 unit per 800 ft^2				0.7
	Dormitories	1 unit per 400 ft^2				0.9
	Assisted Living	1 unit per 600 ft^2				0.05
B) Temporary Population	Single-family Residential	2 units < 1,500 ft^2	2.0	The 2010 census data reports the residential vacancy rate at the census block (CB) level. For each residential UDF, the corresponding vacancy rate was multiplied by the number of units, establishing the number of units occupied by temporary residents. This was then multiplied by the people-per-unit value.	[People Per Unit] × [Number of Units] × [CB vacancy rate]	0.7
		3 units < 2,700 ft^2				
		4 units < 4,000 ft^2				
		5 units < 5,500 ft^2				
		6 units ≥ 5,500 ft^2				
	Multifamily Residential	1 unit per 800 ft^2	2.2			0.7
	Hotel/Motel	1 unit per 455 ft^2	1.7			0.7
	Dormitories	1 unit per 400 ft^2	1.0			0.9
	Recreational Vehicle	1 unit	3.22	For mapping simplicity, some UDF points are assigned multiple units, such as docks in boat marinas.	[Number of Units] × [People Per Unit]	0.3
	Tent, Yurt	1 unit	3.22			0.9
	Boat	1 unit	0.1			0.9

Notes:

Permanent population numbers are taken from ACS 2014–2018 census data at the census block group level.

Temporary vacancy rates are taken from 2010 census data at the census block level.

No permanent residents are assigned to Hotel/Motel, Recreation Vehicle, Tent, Yurt, or Boat.

No temporary residents are assigned to Assisted Living.

Average number of people staying in a recreational vehicle (includes camper trailers), tent, or yurt. Mean value derived from T. Bergerson (Visitor survey of day use and overnight use at Oregon State Park coastal region parks, unpublished Oregon State Parks report, 2012, 151 p.), who evaluated the numbers of recreational visitors camping in coastal state parks.

Estimates of those residing on a boat were derived from consultation with local ports and marinas in both Clatsop and Lincoln County.

2.5 Building Damage and Building Debris Estimation

2.5.1 Earthquake

To calculate combined building losses from an earthquake and tsunami, the Hazus model requires the user to first model earthquake damage using the Hazus User-Defined Facilities (UDF) earthquake model (FEMA, 2011, 2017). In the Hazus earthquake simulation, we used Hazus 5.0 to model a fully saturated soil scenario, with groundwater level at the surface, thereby incorporating the potential impacts of liquefaction. We believe this is a reasonable assumption for low-lying coastal areas.

As noted previously, we model the effects of three discrete tsunami inundation scenarios described by Witter and others (2011) and Priest and others (2013e): M1, L1, and XXL1. These reflect the following CSZ earthquake moment magnitudes (M_W): 8.9 (M1), 9.0 (L1), and 9.1 (XXL1) respectively. Each event is characterized by a unique deformation model to account for the coseismic response. These scenarios contrast with the terrestrial ground motion data from Madin and others (2021), which assume a moment magnitude (M_W) 9.0 CSZ earthquake. For Hazus loss estimation purposes, we determined that the ±0.1 difference in moment magnitude is minor and accounted for by our choice of the "default betas" in the Hazus Advanced Engineering Building Model (probability of damage state; Kircher and others, 2006; Kircher, 2002). The default betas (also referred to as relaxed betas) were crafted by Hazus earthquake model developers to account for greater uncertainties in the ground motion for an earthquake scenario compared to an instrumented earthquake event.

Building repair cost estimates were obtained by using the probability of damage state (PDS) values for each building[5]. The Hazus UDF earthquake model currently overestimates repair costs for UDFs by using overly conservative PDS multipliers for determining a building loss ratio (Bauer, 2016); the building loss ratio reflects the ratio of building damage states relative to the total number of buildings. Using corrected PDS multipliers (described by Bauer, 2016), we calculated per-building repair cost estimates, and then summarized building repair costs due to earthquake ground motion and earthquake-induced ground deformation by community.

2.5.2 Tsunami

The M1, L1, and XXL1 median depth and momentum flux grids were input into the Hazus tsunami tool as "Level 3" tsunami data (FEMA, 2017), which reflect advanced level user-provided tsunami model scenarios. We summarized building repair costs for the M1, L1, and XXL1 tsunami events by community[6].

2.5.3 Combined earthquake and tsunami

The Hazus tool combines the per-building damage state probabilities from the earthquake and tsunami into an overall damage state probability and then calculates per-building repair cost estimates (FEMA, 2017, Section 5.7). We summarized the combined building repair costs for the earthquake and for each of the tsunami inundation scenarios by community[7].

[5] Hazus SQL table [dbo].[eqUserDefinedFlty].

[6] Per-building repair cost estimates from the tsunami event by itself were obtained by exporting the Hazus SQL table [dbo].[tsUserDefinedFlty].

[7] Per-building repair costs that combine earthquake and tsunami events were obtained by exporting the Hazus SQL table [dbo].[tsCombUserDefinedFlty]. The table also contains structural and nonstructural probability of damage state (PDS) data for each building.

Building recovery times are provided in the FEMA Hazus methods (FEMA, 2017, Table 7.10), but we chose not to report them, as Bauer and others (2020) argued that the assumptions behind the tabular entries are overly optimistic given the spatial scale of a M_w 9.0 CSZ earthquake and tsunami and the likely catastrophic nature of the event on core infrastructure. Thus, access to labor, material, and investment capital may be constrained for prolonged periods during recovery, in large part due to the anticipated damage to western Oregon's transportation network, infrastructure, and fuel supply (ODOE, 2017; ODOT, 2014; OSSPAC, 2013).

2.5.4 Building debris

The Hazus version 5.0 model (FEMA, 2017, 2018) presently does not provide support for debris estimation from a tsunami event, due in part to the challenges of accounting for debris redistribution from advection, including debris washed out to sea, sediment transport, and uprooted vegetation. While recognizing the complexities associated with estimating debris caused by the earthquake and tsunami, we contend that estimates of debris tonnage derived from damaged buildings are valuable for community planners to better understand the scale of the disaster and, importantly, to develop post-disaster community debris plans. Timely recovery from a major earthquake and tsunami will depend not only on the localized damage in each community, but also on the ability of communities to stage and dispose of earthquake- and tsunami-generated debris. To that end, for each community, we provide estimates of debris generated by the earthquake and the three tsunami scenarios.

Estimates of the amount of debris (expressed as tonnage) generated by the earthquake can be obtained using guidelines provided by FEMA (2010). Our building debris estimates combine guidelines provided by FEMA (2013, Chapter 7, and 2011, Chapter 12). The Hazus tsunami model, when run in conjunction with the Hazus earthquake model, provides the combined probability of damage states for a building's structural and nonstructural components. We first calculated the weight of the building based on the model building type using the values provided by FEMA (2011, Table 12.1). Using the building weight, together with the probability of damage states estimate for each building (Section **2.5.3**), we estimated the debris tonnage using the FEMA (2011) equation 12-3.

2.6 Injury and Fatality Estimation

We independently evaluated injuries and fatalities resulting from a CSZ earthquake and tsunami, using, the Hazus AEBM model (FEMA, 2010) and the Hazus tsunami model (FEMA, 2017), respectively. Unlike the building damage estimates described previously, the FEMA Hazus methods currently do not provide a method for combining injury and fatality estimates from the two events. The approach we used is described in more detail in the next two sections.

2.6.1 Injuries and fatalities from earthquake

We used the Hazus AEBM model (FEMA, 2010) to calculate injuries and fatalities, populating the individual buildings with the permanent and temporary population, 2 AM summer weekend occupancy estimates. The *DayOccupants* and *NightOccupants* fields were used as Hazus AEBM inputs for the two population groups. We note that the *DayOccupants* and *NightOccupants* are simply Hazus field names, and their usage does not suggest we modeled a daytime building occupancy.

The Hazus AEBM model first calculates a building's structural and nonstructural PDS from the ground motion and liquefaction/landslide data provided to the model. It then uses the PDS values to calculate injuries and fatalities based on the number of user-specified people occupying the building and the

building type. The methodology assumes a strong correlation between building damage and the number and severity (injury level) of casualties (FEMA, 2011). According to FEMA (2011), casualties (both injuries and fatalities) are classified into four levels: minor injuries, injuries requiring hospitalization, life-threatening injuries, and deaths (**Table 2-4**).

Table 2-4. Hazus earthquake casualty level descriptions (FEMA, 2011).

Injury Severity Level	Injury Level Description
Level 1: Minor Injuries	Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Examples: a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self-treated are not estimated by Hazus.
Level 2: Injuries Requiring Hospitalization	Injuries requiring a greater degree of medical care and use of medical technology such as X-rays or surgery, but not expected to progress to a life-threatening status. Examples: third-degree burns or second-degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration, or exposure.
Level 3: Life-Threatening Injuries	Injuries that pose an immediate life-threatening condition if not treated adequately and expeditiously. Examples: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
Level 4: Deaths	Instantaneously killed or mortally injured.

Earthquake-induced casualties have been summarized by community, casualty level, and resident status (permanent versus temporary). For comparison with the Hazus tsunami casualty model, we summarized earthquake casualty levels 1 through 3 as "injuries" and casualty level 4 as "fatalities." We note that in Oregon coastal communities, most residents occupy wood-frame structures at 2 a.m., and such structures are much less likely to be severely damaged in an earthquake compared to other building types (FEMA, 2011).

2.6.2 Injuries and fatalities from tsunami

The Hazus tsunami casualty model estimates are based on a rational actor pedestrian evacuation model in which all persons in the tsunami zone have acute awareness of the impending tsunami, that they possess knowledge of or can quickly determine the most optimal route to a tsunami safety area, and that all individuals seek safety as pedestrians and not via vehicles. The model assumes a group average (median) departure time and travel (walking) speed and accounts for individual variations from the group average using a lognormal distribution (FEMA, 2017). Although human behavior in an emergency is likely to be highly variable, we believe the results from the Hazus tsunami casualty model provide critically important data for planners to assess the likely impacts of a tsunami and identify areas in their communities where injury and fatality rates will likely be higher, while also providing the ability to quantify the efficacy of proposed mitigation solutions such as tsunami vertical evacuation structures. The following sections describe, in more detail, the overall approach and assumptions used to define injuries and fatalities from a CSZ tsunami.

2.6.2.1 Model implementation

Bauer and others (2020) integrated the Hazus tsunami casualty model into a standalone Excel spreadsheet to estimate the likelihood of a casualty for every person, incorporating the individual's distance to the nearest tsunami safety destination, assumptions on group median departure time, and median travel speed. A travel dispersion coefficient (C_{STD}) was also incorporated in the spreadsheet to account for variations (uncertainty) within the group's departure time and evacuation travel speeds. Motivations for developing the spreadsheet versus using the dedicated Hazus tsunami tool are:

1. Our existing tsunami evacuation modeling already provides the needed distance to safety data needed by the Hazus tsunami casualty model; the Hazus tsunami casualty model includes the USGS Pedestrian Evacuation Analyst Tool (PEAT; Jones and others, 2014), which performs the same calculations as the DOGAMI approach. Thus, rerunning this capability within Hazus is not warranted.
2. Our project requires a model with considerable flexibility for evaluating alternative population and evacuation scenarios (including distinguishing temporary and permanent residents), and, crucially, for testing population assumptions and model parameter settings.
3. Importantly, the Hazus tsunami model currently estimates casualties at the census block level, not at the building level, and thus uses a worst-case assumption of time-to-safety for all occupants within a particular census block (D. Bausch, written communication, July 2018). The Hazus approach is thus too coarse for our objective, which includes a more refined population model disbursed across individual buildings and campgrounds.

More detail on our spreadsheet casualty model is provided by Bauer and others (2020, Appendix C). There, the functional equivalence of the spreadsheet with the FEMA Hazus tsunami Level 2 casualty tool is demonstrated. To minimize confusion, we use the term "Hazus tsunami casualty model" to refer to the FEMA-established methods of estimating injuries and fatalities resulting from a tsunami, and not a specific tool or spreadsheet.

A local source tsunami provides no warning — the ground shaking itself is the signal to evacuate. Thus, the warning time (T_W) discussed by FEMA (2017) is assumed to be zero for a CSZ tsunami. Furthermore, tsunami modeling by Witter and others (2011) indicates that the maximum tsunami runup from a CSZ earthquake is typically associated with the first wave arrival[8].

2.6.2.2 Distance to safety

The Hazus tsunami casualty model requires the user provide a GIS file that specifies the distance to tsunami safety at all points along the established evacuation routes. Previous "Beat the Wave" efforts undertaken for multiple coastal communities (Gabel and Allan, 2016, 2017; Gabel and others, 2018a,b, 2019a,b,c,d, 2020a; Priest and others, 2015) have used the anisotropic least-cost distance approach established by Wood and Schmidtlein (2012) to calculate a distance to safety at all locations along evacuation routes. The distance to safety (referred to as "path distance") is adjusted to account for the slope of the ground (steep versus flat) and terrain type (e.g., sand versus pavement) that may slow down a person's ability to evacuate. Given that tsunami evacuation nearly always requires the evacuee to move up in elevation, this adjusted distance to tsunami safety is always greater than the straight line distance

[8] The Hazus tsunami casualty model is one-dimensional and does not incorporate time-sensitive inundation information en route to safety; it simply assumes an evacuee arrived at the maximum tsunami runup (tsunami safety) in time (T_{MAX}). Complex decision points, such as early wave arrivals or bridge failures that are likely to preclude or impact evacuation along certain routes are not evaluated.

measured on a map. In this report, our usage of "distance to safety" reflects the combined slope and adjusted walking distance.

We associate each building and its occupants with the tsunami evacuation network that specifies the distance to tsunami safety by using the Esri ArcGIS Near function. The linear distance from the building footprint's centroid to the evacuation network is added to the distance to safety from the GIS file to derive an overall distance to tsunami safety. We did not implement the method of Wood and others (2016), which has pedestrians evacuating via driveways typically generated on paths perpendicular to the road network. Visual inspection suggested the distance from the building centroid to the evacuation network was minor relative to the overall distance to safety, and such a refinement would only marginally improve the accuracy of the model's results. Moreover, the time to evacuate a building may be accounted for as simply an evacuation delay, which is described further below.

A community often has more than one tsunami evacuation scenario defined, which can include the impact of damaged bridges and/or the inclusion of a tsunami vertical evacuation structure. Each scenario has a unique distance to safety GIS dataset, which can be captured separately, when needed. Such scenarios have been evaluated previously for multiple communities including Florence and Reedsport (Gabel and others, 2018b) and the Coos estuary (Gabel and others, 2019b); modeling is currently underway for Bandon. For the purpose of this countywide Hazus assessment, we used the most conservative bridge-out scenario, to account for the likely failure of non-retrofitted bridges. Bridges that have been retrofitted or rebuilt to current engineering standards are designed to withstand the intense ground motion caused by the earthquake.

2.6.2.3 Departure time

The Hazus tsunami casualty model uses the term "Community Preparedness Level" to reflect the time between the tsunami warning (i.e., earthquake shaking) and actual evacuation of the community (FEMA, 2017). The degree of preparedness is classified according to three categories — good, fair, or poor — and is dependent on a suite of factors, including tsunami awareness (education/knowledge), preparation of evacuation routes and signage, a community's risk management level, and the presence of emergency loudspeakers and tsunami sirens (FEMA, 2017). According to FEMA, a community with a "good" rating could be one that is designated "Tsunami Ready" by the National Oceanic and Atmospheric Administration (NOAA) National Weather Service. However, we contend that such designations do not truly reflect a community's level of preparedness given the large uncertainty in individuals' hazard awareness, their knowledge of evacuation routes, their actual response at the time of the event, and the degree of pre-disaster preparation undertaken by communities to prepare for such an event. Thus, for the purposes of this report we chose not to use the "Community Preparedness" terminology; instead, we focused our efforts on the importance of group departure times.

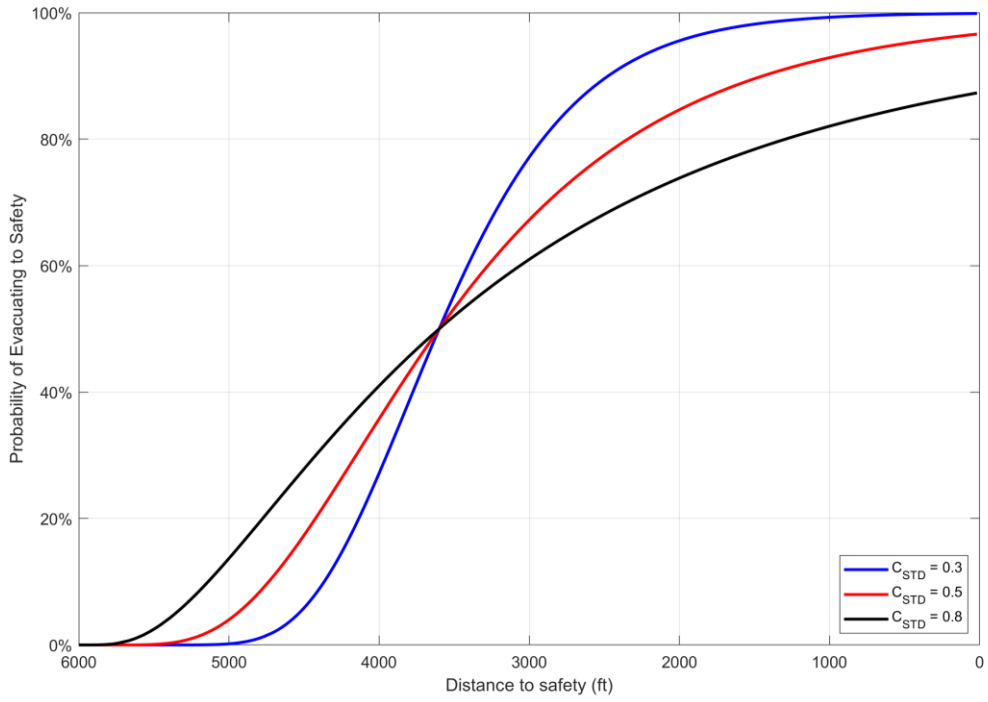
It is essential that our injury and fatality estimates quantify the impact of delays in departure times — often referred to as "milling time" in the literature (Buylova, 2018; Mostafizi and others, 2017; Wood and others, 2016; Wood and Schmidtlein, 2013). In this study, we provide injury and fatality estimates assuming 10-minute (good) and 15-minute (fair) group departure (delay) times; we did not model a poor preparedness level, as the casualty numbers associated with this specific category are very large and probably unrealistic.

The 10-minute (*good*) departure delay is the default value used in all our BTW tsunami evacuation modeling and refers to the time elapsed since the start of the earthquake. It accounts for up to five minutes of earthquake shaking during which people drop, cover, and hold on, followed by an additional five minutes of individual preparation — donning shoes and outdoor clothing, gathering immediate family, or

collecting a go-bag — before leaving the building. We also model a 15-minute (*fair* level of preparedness) departure time to demonstrate how additional delay time causes community fatalities to increase significantly.

The departure time is assumed to be the group median value. In reality, some individuals may leave earlier and others later. Some may walk faster or slower than the group median evacuation speed. The Hazus tsunami casualty model accounts for these variations by adopting a dispersion factor (defined by a lognormal distribution), which can be accounted for by specifying a standard deviation (or *beta*) value (referred to as C_{STD} by FEMA, 2017). For the purposes of our study, we used the Hazus tsunami casualty model defaults of 0.3 and 0.5 for the 10-minute and 15-minute departure times, respectively, corresponding to the good/fair community preparedness levels noted above; theses values are the default standard deviation (C_{STD}) recommendations provided by FEMA (2017, Table 6.3). **Figure 2-2** illustrates the probabilistic nature of the lognormal distribution model. It assumes a group departure time of 10 minutes, a walking speed of 1.2 m per second (mps) (4 fps), and a wave arrival time of 25 minutes. An individual departing given those specifications can cover 1,097 m (3,600 feet). The standard deviation term, C_{STD}, models the dispersion in individual evacuation times and evacuation walking speeds. The model effectively assigns a probability of evacuating to safety that ranges between 0 and 1. As a result, an individual having traveled 1,097 m (3,600 feet) is not assumed to have safely evacuated but instead is assigned a probability of 0.5 of evacuating safely. As previously discussed, this value accounts for dispersion in departure times and walking speeds. Note the asymmetric nature of the lognormal distribution: it implements a conservative assumption regarding a tendency for humans to delay their departure times.

Figure 2-2. Hazus tsunami casualty model predictions for a hypothetical wave arrival time of 25 minutes (with no warning time), a group departure time of 10 minutes, an evacuation walking speed of 1.2 m per second (4 fps), and variations in the lognormal standard deviation term (C_{STD}).



We are unable to quantify how earthquake-induced building damage may inhibit rapid evacuation from a building prior to the arrival of a tsunami. This understudied concern may be important in older manufactured housing units that may slip off their foundation supports, warping framing and possibly jamming doorframes and windows (EERI, 2014; Maison and Cobeen, 2016; OBCD, 2010; SPA Risk LLC, 2014). The situation can also arise due to unsecured nonstructural elements such as large bookcases that are likely to tip over during shaking and block potential exits. FEMA (2012b, Section D) provides guidelines on minimizing potential constraints to egress, including advice on storing large crowbars and sledgehammers near primary door(s) to facilitate emergency exiting.

2.6.2.4 Evacuation speed

We assume a standard 1.2 mps (4 ft per second, fps) evacuation speed, which equates to 2.7 miles per hour (mph) as a baseline for estimating tsunami injuries and casualties; the 1.2 mps (4 fps) travel speed reflects a pace that may be used to define crosswalk times. Variations in individuals' walking speeds are incorporated into the C_{STD} standard deviation value discussed previously.

The Hazus tsunami casualty model incorporates a travel (walking) speed reduction factor for persons aged 65 and over (FEMA, 2017). This assumption is based on analyses of fatalities in recent tsunamis (González-Riancho Calzada and others, 2015; Koyama and others, 2012; Suppasri and others, 2016). Accordingly, we used a 0.8 walking speed reduction factor to account for travel speeds used by persons ≥65, which equates to an evacuation speed of 1 mps (3.2 fps, or 2.2 mph). It is important to emphasize that travel speed is modeled for the group average (median) and is applicable for the entire evacuation route.

The distance covered by an evacuee can be calculated as follows:

$$\text{Distance Covered} = (T_{ARRIVE} - T_{DEPART}) \times \text{WalkSpeed} \quad (2)$$

where T_{ARRIVE} is the time interval between the earthquake start and the tsunami first wave arrival, T_{DEPART} is the time interval between the start of the earthquake and when the population begins evacuating, and WalkSpeed is the specified travel (walking) speed. For reference, we calculate the distance an individual could travel prior to a tsunami arriving by using a range of evacuation speeds and wave arrival times (**Table 2-5**). As noted previously (Section **2.6.2.3**), although the group average (median) departure time may be 10 minutes, the Hazus tsunami casualty model accounts for individual variations from the group average by using the cumulative lognormal distribution and dispersion factor.

2.6.2.5 Tsunami injury and fatality estimation

The Hazus tsunami casualty model assumes a 99% likelihood of fatality and 1% likelihood of injury to an individual caught up in a tsunami where the wave depth exceeds 1.8 m (6 feet; FEMA, 2017). Conversely, where the tsunami wave depth is less than 1.8 m (6 ft) the model assumes a likelihood of 50% fatality and 50% injury for individuals caught by the tsunami; this region is referred to as the "partial safety zone." In practice, because the topography of many Oregon coastal communities is relatively steep, the horizontal distance between the 1.8 m (6 ft) and the 0-elevation contour (tsunami safety) is generally small compared to the typical distance to safety an individual must travel. Analyses by Bauer and others (2020) indicated that these partial safety distances along the open coast range from ~30 to 90 m (100 to 300 feet, **Figure 2-3**) from the tsunami inundation runup limit. However, more recent evaluations suggest that the partial safety zone can in fact vary substantially, especially in areas subject to broad gentle slopes (**Figure 2-3**). To address this issue, we defined a partial safety zone by creating a depth grid in which all areas of

the raster <1.8 m (6 ft) were extracted. The extracted partial safety raster was then manually reviewed, and any false islands or spurious data were removed. Accordingly, the casualty estimates are reduced to 50% once individuals reach this latter zone. The Hazus tsunami casualty model provides injury and fatality estimates for each individual, with a likelihood between 0 and 1. We summarize the individual injury and fatality likelihoods to obtain overall injury and fatality estimates at the community level.

Table 2-5. Distance walked for several departure times and tsunami wave arrival times at the tsunami runup limit. We assume warning time is zero. Departure time is the time after earthquake ground motion begins.

Tsunami First Wave Arrival Time (minutes)	Walking Speed Category	Walking Speed		Distance Walked (in feet) for Various Departure Times (in minutes)			
		fps	mph	5 min	10 min	15 min	20 min
15	Slow Walk	2	1.4	1,200	600	—	—
	Moderate Walk	4	2.7	2,400	1,200	—	—
	Fast Walk	6	4.1	3,600	1,800	—	—
	Jog	8	5.5	4,800	2,400	—	—
	Run	10	6.8	6,000	3,000	—	—
20	Slow Walk	2	1.4	1,800	1,200	600	—
	Moderate Walk	4	2.7	3,600	2,400	1,200	—
	Fast Walk	6	4.1	5,400	3,600	1,800	—
	Jog	8	5.5	7,200	4,800	2,400	—
	Run	10	6.8	9,000	6,000	3,000	—
25	Slow Walk	2	1.4	2,400	1,800	1,200	600
	Moderate Walk	4	2.7	4,800	3,600	2,400	1,200
	Fast Walk	6	4.1	7,200	5,400	3,600	1,800
	Jog	8	5.5	9,600	7,200	4,800	2,400
	Run	10	6.8	12,000	9,000	6,000	3,000
30	Slow Walk	2	1.4	3,000	2,400	1,800	1,200
	Moderate Walk	4	2.7	6,000	4,800	3,600	2,400
	Fast Walk	6	4.1	9,000	7,200	5,400	3,600
	Jog	8	5.5	12,000	9,600	7,200	4,800
	Run	10	6.8	15,000	12,000	9,000	6,000

Note: "—" indicates individuals traveling at the designated speed would not reach safety before tsunami arrival.

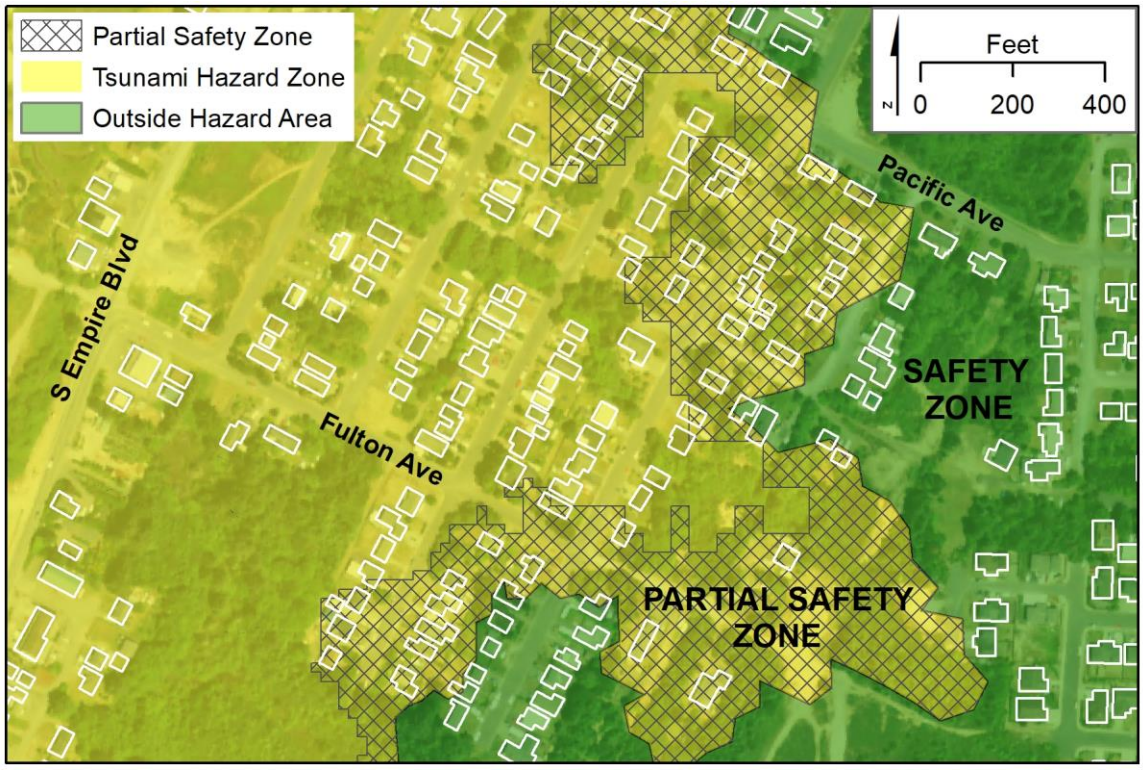
2.6.2.6 Sensitivity testing

We varied evacuation speeds (2 to 10 fps in 1-fps increments) and departure times (5 minutes to 20 minutes in 1-minute increments) consistent with Wang and others (2016) and calculated overall injuries and fatalities for each community. Such data can assist in gaining a better understanding of evacuation challenges facing communities. Furthermore, when presented in graphical form, these data can be used in education and outreach materials to reinforce existing tsunami evacuation messaging, stressing key points such as the need to evacuate immediately and, importantly, to travel as fast as possible in order to reach safety in time. We adjusted the dispersion factor (C_{STD}) as specified in section **2.6.2.3** proportionally for 10-minute and 15-minute departure times.

2.6.3 Combining earthquake and tsunami casualty estimates

The Hazus approach does not provide a method for combining injury and fatality estimates derived from the earthquake and tsunami modules. Some portion of the people injured during the earthquake may not be able to evacuate in a timely manner as they may be disoriented, need to tend to their own injuries or injuries sustained by another household member, or have sustained injuries that prevent or slow an on-foot evacuation. We report both sets of casualty numbers (earthquake and tsunami) to provide planners with a more complete accounting of the potential situation. The estimates do not include injuries or fatalities arising from, for example, heart attacks, bridge failures, automobile or maritime accidents, electrocutions from downed power lines, exposure to released hazardous materials, upstream dam failures, ground failures such as earthquake-induced landslides, or fires. Furthermore, large-scale natural disasters are known to contribute to illness, injury, or death from other factors such as lack of access to clean water or medicine, interruption of power to life-sustaining medical equipment, exposure due to lack of shelter, disease outbreak, domestic violence, and civil unrest. Quantifying these latter causes of injury or death were beyond the scope of the present investigation.

Figure 2-3. Example of median tsunami depth zone for an XXL1 tsunami at Empire, Coos County (yellow shading) and partial safety zone (hashed area), where the median water depth falls below 2 m (6 ft) near the tsunami inundation limit, per Hazus methods (Section 2.6.2.5). The green zone defines the safe area outside of the tsunami zone. Buildings depicted in white.



2.6.4 Displaced population

For mass care planning purposes, we calculated the number of uninjured individuals likely to have safely evacuated from the tsunami zone. Those individuals will need shelter, as their homes, motels, recreational vehicles, boats, and tents are assumed to be destroyed by the tsunami. The temporary population that happens to be visiting when the earthquake and tsunami strike will also have shelter needs that may be on the order of days to a few weeks, as arrangements for transportation out of the disaster zone may be delayed.

2.7 Essential Facilities and Key Infrastructure

We provide the names of essential facilities, special facilities, and key infrastructure located within each city's tsunami zone. For this report we use the "essential facility" definition provided in Oregon Revised Statute 455.447, "Regulation of certain structures vulnerable to earthquakes and tsunamis; rules" (2017[9]):

"Essential facility" means:

(A) Hospitals and other medical facilities having surgery and emergency treatment areas.
(B) Fire and police stations.
(C) Tanks or other structures containing, housing or supporting water or fire-suppression materials or equipment required for the protection of essential or hazardous facilities or special occupancy structures.
(D) Emergency vehicle shelters and garages.
(E) Structures and equipment in emergency-preparedness centers.
(F) Standby power generating equipment for essential facilities.
(G) Structures and equipment in government communication centers and other facilities required for emergency response.

We define a "special facility" as one that is likely to contain population segments that may present additional tsunami evacuation challenges. This builds on, but is not limited to, the "special occupancy structure" definition provided in Oregon Revised Statute 455.447. Examples include assisted living facilities, detention facilities, facilities where groups of children are placed in the care of non–family-member adults, and facilities with particular focus on persons with a disability. Facilities with incidental usage by persons with disabilities are not included. Geocoded Quarterly Census of Employment and Wages (QCEW) data obtained from the Oregon Employment Division in September 2018 was another dataset used to evaluate other potential facilities. We created a lookup table wherein we identified a subset of employer types based on their six-digit North American Industrial Classification System code (OMB, 2017) that may host a population that may face additional tsunami evacuation challenges. The table was joined to the QCEW data, which identified specific businesses that could be considered a special facility.

Although great care was taken to develop as complete a list of special facilities in the tsunami zone as feasible, it is acknowledged that not all businesses may have been included. This is mainly because of the provisional nature of the QCEW data, such that some business locations may not have been captured in our overlay analysis. Furthermore, it is important to note that the designation of a building as a "special

[9] https://www.oregonlegislature.gov/bills_laws/ors/ors455.html

facility" should not be interpreted as any statement on the building owner or operator's level of tsunami preparedness. The analysis simply identifies those businesses located in the tsunami zone.

The "key infrastructure" list includes facilities necessary for community recovery but not covered in the essential facilities list and includes such facilities as water treatment plants and electrical substations. We constructed this list from visual inspections of orthoimagery and other ancillary geospatial data sources such as Homeland Infrastructure Foundation-Level Data (https://gii.dhs.gov/hifld/). As with the essential facilities and special facilities list, every effort was taken to develop as complete a list as possible.

2.8 Social Characteristics

The Department of Land Conservation and Development (DLCD; 2015) recommended that a tsunami risk and vulnerability assessment include analyses of the characteristics and locations of populations that may have additional needs or requirements for evacuation. Our modeling allowed us to provide demographic information classified into two broad age groups — <65 years of age and ≥65 years — for each tsunami zone. In addition to basic demographic information, we further queried the ACS data (U.S. Census Bureau, 2018, Table 1.1), in order to extrapolate additional information that may be useful for informing community tsunami education and evacuation planning. These included:

- S0101 Age and Sex.
- S1601 Limited English-Speaking Households.
- S1810 Disability Characteristics.

We obtained the selected ACS tables at the city ("community" in ACS terminology), county, and state level. The 2014–2018 ACS five-year estimates were based on data collected between January 1, 2014, and December 31, 2018. We chose the ACS five-year estimates based on U.S. Census guidance for smaller geographies (U.S. Census Bureau, 2018, Table 3.1). We note that the ACS estimates are for the city jurisdiction and not its UGB, and that the ACS data are not available by tsunami zone or at any unit finer than the city. We include the ACS-provided margin of error (MOE) to emphasize the sampling nature and uncertainty of the survey. The U.S. Census Bureau sets a 90% confidence level, where the estimate and the actual population value will differ by no more than the value of the MOE.

2.9 Model and Data Limitations

2.9.1 Earthquake

Our earthquake ground motion and deformation model is based on various assumptions about the Cascadia rupture zone (Madin and others, 2021). Soil amplification, liquefaction susceptibility, and landslide susceptibility values were assigned based on the best available local geologic data, mapped using high-resolution lidar imagery. Nevertheless, soils, liquefaction and landslide information compiled by Madin and others (2021) may include generalizations about local conditions that could be better refined in the future, with more detailed community or site-specific mapping efforts.

2.9.2 Debris

The weight of damaged building contents such as refrigerators and furniture and, where applicable, business inventory such as groceries were not included in our estimates of debris. Furthermore, we do not quantify the amount of buoyant debris from damaged buildings that may be washed out to sea, nor do we estimate the weight of concrete and asphalt that would be produced from damaged roads and bridges.

Debris from damaged automobiles, trucks, recreational vehicles, shipping containers, boats, and logs in staging areas are not included, but an estimate can be obtained by using the weights provided by FEMA (2013, Table 7.6). Estimates of the weight of sediment redistributed across the landscape or vegetation removed and transported by the tsunami were also excluded from our analyses.

Commercial movers provide guidelines for estimating the weight of typical household content (e.g., https://www.isapa.org/estimate-weight-household-goods-moving/). The contents of a three-bedroom house is generally estimated to weigh around five tons. Although we do not report on content damage in this study, a reasonable assumption is that nearly all the content of a house in the tsunami zone will be destroyed and will be added to the total debris. The building database developed for this study could be used to calculate the added weight of debris associated with household content.

2.9.3 Economic losses

Our economic loss estimates are limited to the direct cost of repairing a damaged building or replacing a severely damaged building with an equivalent structure. Our model assumes standard labor and material costs and availability of capital and credit. It does not factor in demand surge, which occurs following large disasters and results in higher costs to repair building damage relative to comparable damage observed in smaller disasters (described previously in section **2.3**). Olsen and Porter (2011) reported demand surges ranging from 10% to 40% following several large-scale disasters. Adjusting repair/replacement costs due to a likely demand surge was beyond the scope of this project. Further, we do not quantify permanent loss of use, and thus value, of the land due to ground failure, presence of spilled hazardous materials, loss of buildable land due to scour and erosion from the tsunami, or loss of use from tidal flooding due to coseismic subsidence.

2.9.4 Population models

Estimates of the permanent population in the tsunami zone are derived from U.S. Census data collected in 2010 and ACS data maintained by the U.S. Census Bureau. This approach differs from the approach of Bauer and others (2020), which used Oregon Department of Motor Vehicle records to identify the number of permanent people in the tsunami zone.

Table 2-6 presents results for four communities where we can compare the approach of Bauer and others (2020) to the approach developed here. With respect to defining the population, **Table 2-6** highlights two differences. First, both approaches yield comparable permanent population numbers in the communities of Gearhart and Rockaway Beach. This is due entirely to the fact that both these communities are virtually completely inundated under the XXL1 scenario, the extent of which is comparable to the boundaries of the CBG. Hence the values reported are similar. In contrast, **Table 2-6** indicates that the CBG results for the permanent population in Lincoln City and Newport are significantly (~20% to 40%) higher when compared with the DMV approach. There are three possible explanations. First, it may be a function of both communities having narrow inundation zones (having been built on high ground), with large portions of the communities outside of the tsunami zone. Thus, the CBGs in these areas account for people located outside of the tsunami zone. Hence, the process of distributing the permanent population across the UDFs based on those buildings in the tsunami zone may be overestimating the number of people actually residing in the tsunami zone. Second, it may be a function of the ACS data having more up-to-date population statistics, though this seems less likely given that DMV records should provide a good representation of numbers of people residing in both communities. Third, it is possible that Bauer and other (2020) may have undercounted the number of people residing in Lincoln City and Newport.

In contrast, estimates of the temporary population in the four communities (**Table 2-6**) using the population model approach developed in these countywide assessments are generally lower, when compared with the Bauer and others (2020) approach. For example, the visitor population in Lincoln City is substantially lower — a 45% difference. This change is primarily due to the number of people assigned to each room/unit. Bauer and others (2020) used a value of three people per room for Lincoln City; this was the preferred choice by community planners. However, for the purposes of this study, we chose to use a standard value of two people per room. Despite the lower numbers of temporary visitors observed in our latest population modeling and given the large uncertainty in the numbers of visitors in any given community on any given day, we remain confident in our overall estimates of potential visitor numbers in coastal Lincoln County.

Table 2-6. Comparison of the Bauer and others (2020) population model approach with the approach used in this study.

Community	Bauer and others (2020) (DMV Records)		This Study (CBG Approach)		Population Difference		Building Count		
	Permanent	Temporary[1]	Permanent	Temporary	Permanent	Temporary	XXL	Entire CBG[2]	Difference[3]
Gearhart	1,495	5,459	1,447	4,532	−3 %	−20 %	1,651	1,961	310
Rockaway Beach	1,440	7,592	1,503	6,642	4 %	−14 %	2,372	4,056	1,684
Lincoln City	2,154	11,844	2,692	8,167	20 %	−45 %	2,523	8,499	5,976
Newport	1,161	7,171	2,002	6,161	42 %	−16 %	1,642	8,394	6,752

Notes:

[1] The temporary population modeling script used by Bauer and others (2020) differed slightly from the present study. In Bauer and others, Lincoln City was assigned three people/bedroom when estimating the temporary population. In the present study we assign two people/bedroom for all communities.

[2] This is the total building count within all CBGs that intersected the community boundary.

[3] Difference in both building counts.

The potential for inaccurate population data in a census block group, including undercounting by Bauer and others (2020), is probably the most likely explanation for differences observed in **Table 2-6**. Inaccurate data may be a function of building UDFs not having been fully evaluated for attribute accuracy, leading to over- or undercounting of the local population. In the approach developed here, great care was taken to evaluate building attributes within the XXL inundation zone. The specific steps followed are:

1. Is the building a residential occupancy type? If it is, then it contains residents.
2. What type of residential building is it? For example, if it is a multifamily building such as an apartment, it likely contains both permanent and temporary residents, but if it is a hotel then it only contains temporary residents.
3. What is the square footage of the building? Depending on the occupancy type, the square footage determines the number of units/rooms, which influences the number of residents estimated to live there.

Manually checking the many thousands of buildings outside of the tsunami zone is challenging. An example of how the population statistics may be skewed is described here. Consider an apartment building housing 200 permanent residents that is located partly outside the tsunami zone, but within a CBG; the latter includes an area both within and outside the tsunami zone. Because the apartment building is located outside of the tsunami zone, it may have been skipped for further evaluation. However, because

the apartment is included in the census block group, those 200 people are inadvertently counted as residing in the tsunami zone.

Continuing with this example, let us say that the apartment building was categorized as a hotel and no permanent residents were assigned to it. Now those 200 permanent residents, which are part of the CBG total, are distributed elsewhere in the CBG, skewing the results in other locations.

Other possible ways in which inaccurate population modeling may occur include:

1. A building is not categorized as a residential building – that means no residents are assigned to it.
2. The square footage is incorrect. That means that either more people or fewer people will be assigned to the building than is realistic.

In summary, although great care was taken to evaluate building UDF attributes, especially those adjacent to the tsunami zone boundary that could potentially skew the population statistics (e.g., multifamily residential), it is possible some of these buildings were misattributed.

Our assignment of 0.318 children for every adult between 18 and 64 years of age (described by Bauer and others, 2020, Appendix B) may either overestimate or underestimate actual numbers. Temporary resident estimates and age demographics were based on several key assumptions as described by Bauer and others (2020) and are without doubt the largest challenges when specifying the visitor population on any given day. Finally, our population model does not account for people living in the tsunami zone who are experiencing homelessness. Homeless encampments are likely present within the tsunami zone of many Oregon coastal communities.

2.9.5 Hazus tsunami casualty model

The Hazus evacuation modeling assumes the following responses:

1. Everyone in the tsunami zone will evacuate on foot at some time after the ground stops shaking.
2. Their exit from the building is unimpeded.
3. They take the most optimal route to safety.
4. Their evacuation speed is not limited by congestion from fellow evacuees or vehicles or the presence of obstacles on roads and trails.

Furthermore, it does not account for certain human behaviors and other factors that could result in higher fatality rates. For example, some portion of the population may be unaware of the impending threat and thus do nothing. Others may be fully aware of the threat but for various reasons, including a fatalistic outlook (Johnston and others, 2013), choose not to evacuate. Some may tend to a person with disabilities or a person who sustained injuries during the earthquake and thus fail to leave in a timely manner or are greatly limited in their travel speeds. Still others may spend time checking on neighbors. Fatigue may impact a portion of the population over longer travel distances, especially individuals with limited mobility or health-related problems. Delay introduced by descending multiple flights of stairs in multistory structures is also not considered.

Other non-behavior factors that the model does not account for include structural failures in a building leading to jammed doorways and blocked hallways and doorways, all of which may limit egress. Evacuation on roads and trails is likely to be affected by building debris produced by the ground shaking strewn onto roadways and sidewalks, deformed roads and trails due to lateral spreading resulting from liquefaction, the presence of liquefaction sand boils, and downed power lines. Depending on the number of evacuees, pedestrian and vehicle congestion at chokepoints could also influence evacuation travel speeds.

Occupants of boats docked in marinas are assumed to recognize the signs of a major earthquake and be able to safely leave their vessels and exit to high ground via intact docks and dock ramps. Neither seiching within enclosed marinas nor potential damage to the dock or its walkway to dry land is modeled.

Although the Hazus earthquake model estimates earthquake-induced building damage, the Hazus tsunami casualty model does not factor in how damage to a building from the earthquake itself may restrict egress and thus possibly impede evacuation of damaged buildings prior the arrival of a tsunami. This understudied concern may be especially pronounced in older manufactured housing units that may slip off their foundation supports, warping framing and possibly jamming doorframes and windows.

Although one can identify shortcomings with the FEMA Hazus tsunami modeling, given its assumptions of ideal behavior on the part of evacuees and intact, unimpeded evacuation routes, the injury and casualty results from the model should be perceived "as starting points and not an end point for tsunami risk-reduction discussions" (Wood and Schmidtlein, 2013, p. 1,625).

3.0 RESULTS

This section presents results of the Hazus analysis used to quantify earthquake and tsunami related impacts (i.e., building damage, debris, injuries, fatalities, etc.) for communities along the Coos, Douglas, and Lane County coastline. Each community is characterized by diverse population demographics, historical and contemporary development patterns, socioeconomic characteristics, tsunami risk, and bathymetric, topographic, and geologic circumstances that influence evacuation potential and building damage. These factors in turn influence community preparation, response, and, ultimately, recovery following a CSZ earthquake and tsunami.

3.1 Population Demographics

Summary population and demographic information for coastal Coos, Douglas, and Lane counties is presented in **Table 3-1** and **Figure 3-1**. Both identify the permanent population within each community's tsunami zone and include a conservative estimate of the temporary population that may also be present. As a reminder, the temporary population is determined from a summer 2 AM weekend scenario that maximizes visitor occupancy (i.e., assumes 100% occupancy in all hotel/motels, vacation homes and camping spots). Examination of **Table 3-1** indicates the following results:

1. The total population present on the Lane, Douglas, and Coos county coastline within a tsunami zone reflect the following:
    a. *Lane County*: ranges from ~550 (M1) to ~1,870 (XXL1) permanent residents (**Table 3-1**), increasing to ~2,600 (M1) to ~6,040 (XXL1) people when accounting for the temporary visitor population.
    b. *Douglas County*: ranges from ~1,050 (M1) to ~1,970 (XXL1) permanent residents (**Table 3-1**), increasing to ~3,360 (M1) to ~5,430 (XXL1) people when accounting for the temporary visitor population.
    c. *Coos County*: ranges from ~1,330 (M1) to ~10,340 (XXL1) permanent residents (**Table 3-1**), increasing to ~4,970 (M1) to ~20,850 (XXL1) people when accounting for the temporary visitor population.

    Such dramatic increases in the local coastal population are indicative of the large number of vacation homes, hotels/motels, and campgrounds distributed throughout the three coastal counties.

2. As expected, the number of permanent and temporary residents within each tsunami zone increase as the tsunami inundation zone increases (i.e., from M1 to XXL1, **Figure 3-1**). By far the largest change occur between the L1 and XXL1 tsunami scenarios, especially in Barview, Charleston, and Bandon.
3. The fraction of the total permanent resident population residing within the three tsunami zones varies widely among communities and parks (**Figure 3-1**). For example, Winchester Bay is mostly located in the M1 tsunami zone and is 100% within the L1 and XXL1 tsunami zones (**Table 3-1**). Siltcoos, Sunset Bay, and the Bullards Beach campground are 100% inundated in all three scenarios. Barview, Charleston, and Bandon each have relatively large numbers of people located in the XXL1 tsunami zone (73%, 52%, and 68% respectively). Within the L1 zone, Charleston, Umpqua South Jetty, and Reedsport have 33%, 49%, and 24% of their populations in the tsunami zone, respectively. For the M1 scenario, communities with the largest number of people in the tsunami zone include Charleston (32%), Winchester Bay (54%), and Umpqua South Jetty (49%). Thus, Winchester Bay, Charleston and the Umpqua South Jetty are especially vulnerable since they have a relatively large proportion of their permanent (and visitor) populations in all three tsunami zones.
4. Florence, Dunes City, Lakeside, North Bend and Coos Bay have relatively few people in the various tsunami zones (**Figure 3-1**, center plot). Florence and North Bend are largely perched on marine terraces and therefore are mostly elevated out of the tsunami inundation zone. Similarly, Dunes City and Lakeside have few people in the tsunami zones, due to these communities being located at the distal end of the tsunami zone such that the tsunami has lost much of its energy as it travels up the Siltcoos River and Tenmile Creek.
5. All 17 communities and parks can experience relatively large influxes of visitors, with totals far exceeding their local resident populations (**Table 3-1** and **Figure 3-1**, right plot). Of note, Florence can swell by ~420% to 300% (M1 to XXL1), Winchester Bay can increase by ~1,360% to 950% (M1 to XXL1), and Bandon can increase by ~210% to 225% (M1 to XXL1). Accordingly, **Figure 3-1** demonstrates the importance of each of these communities as major tourist destinations with potentially large numbers of visitors located in the tsunami zones. Accompanying their popularity as centers of tourism, are challenges associated with preparing such a large transient population for a CSZ earthquake and tsunami.

Table 3-1. The number of residents in the tsunami-hazard zone for coastal communities in Coos, Douglas, and Lane counties, Oregon, based on census block and tsunami-hazard data.

Community	Total Permanent Resident Population	Combined Population (Permanent + Temporary[1])	Number of Permanent Residents			Permanent Residents (%)[2]			Number of Temporary Residents[1]			Permanent + Temporary Percent (%) Increase		
			Medium	Large	XX-Large	Medium	Large	XX-Large	Medium	Large	XX-Large	Medium	Large	XX-Large
Florence	10,291	16,669	404	612	1,326	4	6	13	1,289	1,622	2,709	10	13	24
Dunes City	1,208	2,555	3	6	43	0	0	4	6	11	109	0	1	6
Siltcoos	2	518	2	2	2	—	—	—	516	516	516	100	100	100
Other	5,871	9,796	141	286	495	2	5	8	232	454	841	4	8	14
Lane County Total	17,372	29,538	550	906	1,866	2	4	8	2,043	2,604	4,175	29	30	36
Reedsport	3,932	5,241	553	954	1,115	14	24	28	384	497	635	18	28	33
Winchester Bay	227	2,107	121	222	222	54	98	98	1,527	1,873	1,873	78	99	99
Umpqua South	83	389	41	41	43	49	49	52	301	301	301	88	88	88
Other	1,654	2,612	339	409	594	20	25	36	90	560	644	16	37	47
Douglas County Total	5,896	10,350	1,054	1,626	1,974	34	49	53	2,303	3,231	3,454	50	63	67
Lakeside	1,709	2,386	0	4	108	0	0	6	0	4	68	0	0	7
Coos Bay	15,652	19,483	448	1,022	2,517	3	7	16	545	1,054	1,630	5	11	21
North Bend	9,592	12,123	58	469	1,255	1	5	13	169	209	1,000	2	6	19
Barview	3,122	5,022	147	464	2,286	5	15	73	779	965	1,690	18	28	79
Charleston	190	724	61	62	98	32	33	52	475	476	487	74	74	81
Sunset Bay Park	0	425	—	—	—	—	—	—	425	425	425	100	100	100
Bullards Beach	5	669	5	5	5	100	100	100	284	664	664	43	100	100
Bandon	3,227	6,748	310	465	2,182	10	14	68	338	766	2,706	10	18	72
Other[3]	26,327	36,291	300	838	1,892	1	3	7	626	994	1,833	3	5	10
Coos County Total	59,824	83,872	1,328	3,329	10,343	7	11	34	3,642	5,557	10,503	28	38	54

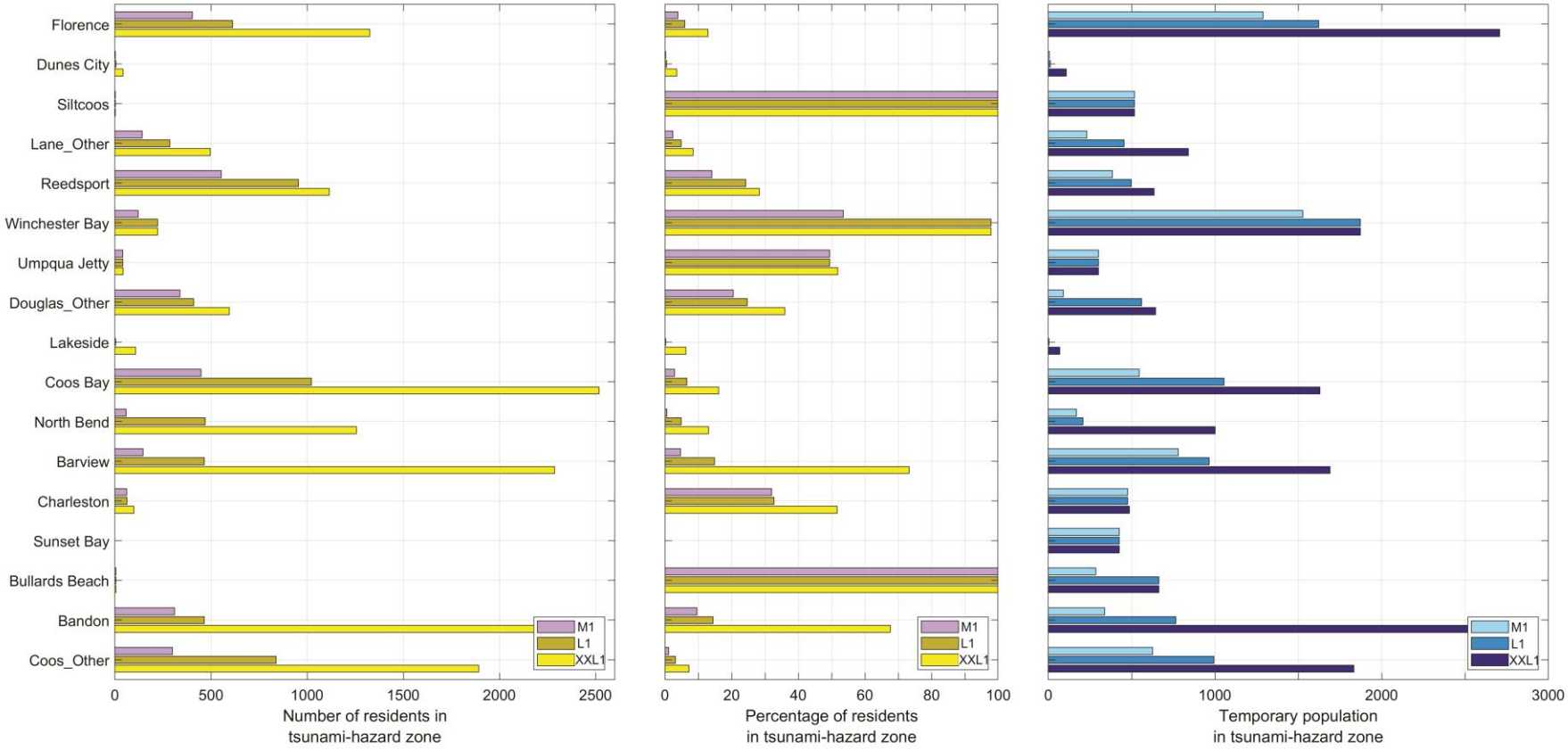
Notes:

[1] Assumes 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

[2] Expressed as a proportion of the total resident population.

[3] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

Figure 3-1. A breakdown of permanent and temporary populations inside the tsunami zone, by community. Left and center show the number and ratio, respectively, of permanent residents. Right shows the number of temporary (visitor) population. Note the larger x-axis, highlighting the significant influx of visitors to many of these communities.



Notes:

Percentage of residents expressed as a proportion of the total resident population.

Temporary population estimate assumes 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

Figure 3-2 and **Table 3-2** differentiate the local resident population by age group (<65 and ≥65 years of age). Resident age has an important bearing on the ability of people to evacuate quickly, as it directly relates to the speed at which people may be able to travel by foot; recall that the evacuation speed for those ≥65 is reduced by 20% (a 0.8 walking speed reduction factor, see section 2.6.2.4). Thus, communities with larger numbers of people ≥65 years of age may want to consider evaluating where these people are situated, with a focus toward developing community evacuation response plans specific to their needs (e.g., prioritizing mitigation efforts such as constructing a vertical evacuation structure in one part of town over another because more older adults live in that area). As can be seen from **Table 3-2**, the countywide resident population ≥65 for Lane, Douglas, and Coos counties are:

1. *Lane County*: ~35% of the total population in the M1 and L1 tsunami zones, increasing slightly to 36% for XXL1; this equates to ~189, 324, and 715 Lane County residents ≥65 years of age in the M1, L1, and XXL1 zones, respectively.
2. *Douglas County*: ~34% of the total population in all three tsunami zones; this equates to ~325, 526, and 617 Douglas County residents in the M1, L1, and XXL1 zones, respectively, who are ≥65 years of age.
3. *Coos County*: ~33% of the total population in the M1 tsunami zone, decreasing to 31% in the L1 and 28% in the XXL1 tsunami zones; this equates to ~436, 914, and 2,749 Coos County residents in the M1, L1, and XXL1 zones, respectively, who are ≥65 years of age.

The actual number of people age ≥65 and older varies from one community to another, with Florence, Winchester Bay, and Bandon each having a much larger proportion (41%) of people ≥65 in the XXL1 tsunami inundation zones then other communities (**Table 3-2**).

Figure 3-2. Local resident population demographics. Example provided is for the XXL1 tsunami zone. Community profiles in Appendix A provide similar statistics for the M1 and L1 tsunami zones.

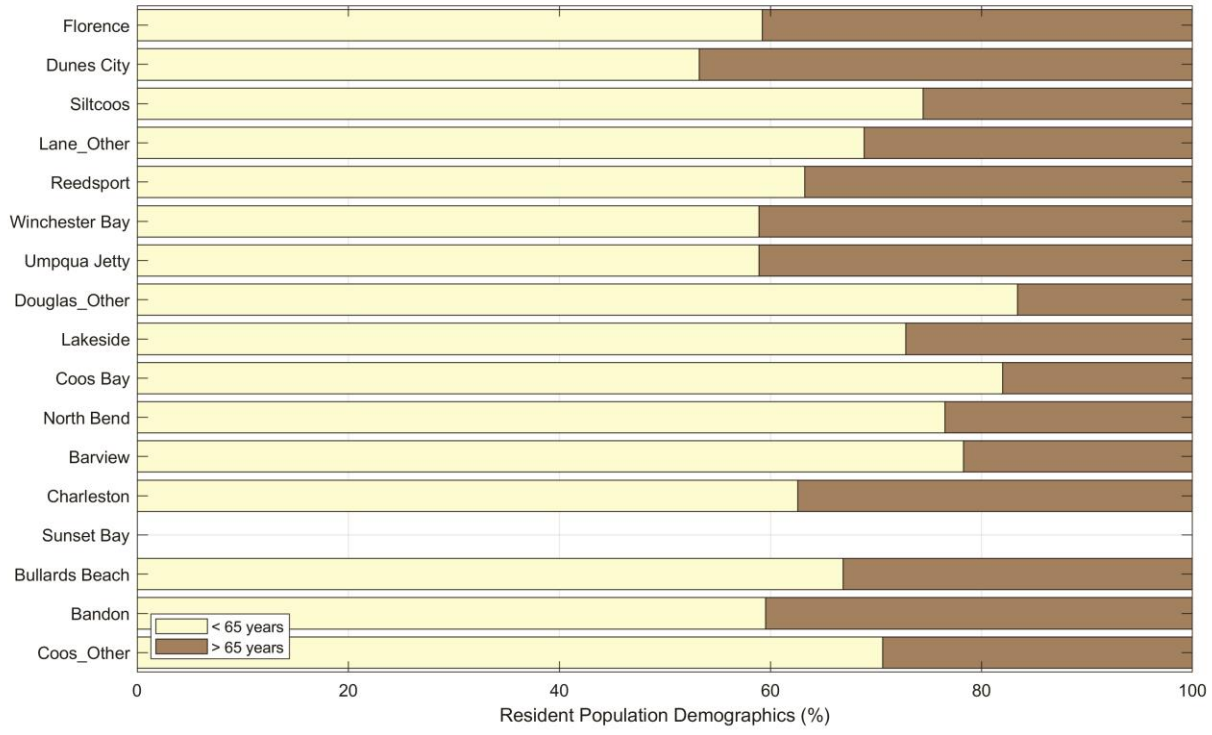


Table 3-2. Permanent resident age demographics per tsunami zone.

	M1			L1			XXL1		
Community	<65	≥65	Older Age Ratio[1]	<65	≥65	Older Age Ratio[1]	<65	≥65	Older Age Ratio[1]
Florence	259	144	36	379	233	38	785	541	41
Dunes City	2	1	47	3	3	47	23	20	47
Siltcoos	2	1	26	2	1	26	2	1	26
Other[2]	98	43	30	198	88	31	341	154	31
Lane County Total	361	189	35	582	324	35	1,151	715	36
Reedsport	349	204	37	603	352	37	705	409	37
Winchester Bay	71	50	41	131	91	41	131	91	41
Umpqua South	24	17	41	24	17	41	25	18	41
Other[2]	284	55	16	343	66	16	496	99	17
Douglas County Total	729	325	34	1,100	526	34	1,357	617	34
Lakeside	0	0		3	1	25	79	29	27
Coos Bay	385	63	14	858	163	16	2,065	453	18
North Bend	43	15	26	351	118	25	961	295	23
Barview	119	28	19	355	110	24	1,790	496	22
Charleston	38	23	37	39	23	37	61	37	37
Sunset Bay Park	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bullards Beach	4	2	33	4	2	33	4	2	33
Bandon	107	203	65	182	283	61	1,299	883	40
Other[2]	197	103	34	624	214	26	1,336	556	29
Coos County Total	892	436	33	2,415	914	31	7,594	2,749	29

Notes:

[1] Ratio of ≥65 relative to total resident population.

[2] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

3.2 Building Damage and Debris

The number of residents (permanent and temporary) per building occupancy type and within the XXL1 tsunami zone is provided for each community in **Table 3-3** and summarized graphically in **Figure 3-3**. Apparent from both the table and figure are notable differences in where people live or visit among the communities. Permanent residents overwhelmingly reside in single-family dwellings, especially in Bandon (70%), Barview (69%), and Dunes City (69%). Multifamily residential buildings in the XXL tsunami zone are more common in North Bend (60%), Coos Bay (46%), Charleston (39%), Florence (37%), and Reedsport (31%). The Umpqua Jetty area (60%) reflects a small sub-section of the Winchester Bay community that contains few buildings as it is mostly dedicated to camping. Countywide averages for permanent residents reflect the following:

1. *Lane County*: single-family residential (74%), manufactured housing (13%), and multifamily residential (13%).
2. *Douglas County*: single-family residential (34%), manufactured housing (29%), and multifamily residential (37%).
3. *Coos County*: single-family residential (60%), manufactured housing (14%), and multifamily residential (25%).

There are notable differences in the predominant building occupancy type among the communities with respect to temporary residents. For example, hotel/motel availability is highest in Coos Bay (52%), followed by North Bend (50%), Florence (27%), Reedsport (26%), and Bandon (23%, **Table 3-3**; **Figure 3-3**). Apparent also from **Figure 3-3** are the large number of single-family residential rental units or vacation homes (e.g., VRBO or Airbnb) available throughout the three coastal counties. For example, Bandon is characterized with a large number (63%) of second homes that are used by temporary visitors, while 37% of homes in Florence are listed as second homes and may be used for vacation purposes. Similarly, Lakeside (84%), Barview (34%), and Reedsport (23%) also have notable numbers of vacation homes. RV and tent sites are particularly abundant in Winchester Bay (82%), Umpqua Jetty (95%), Charleston (82%), Barview (61%), and North Bend (32%); RV and tent camping comprise 100% the occupancy at Siltcoos, Bullards Beach and the Sunset Bay campgrounds. These latter results are especially important as they identify those locations where there are likely to be high visitor concentrations in the tsunami zone. Visitors may have little knowledge of the earthquake and tsunami risk and are less likely to know what to do following a major earthquake or how to locate the nearest area of high ground.

The number of permanent and temporary residents residing in single-family residential buildings in coastal Lane, Douglas, and Coos counties is further evaluated in the final two columns of **Table 3-3**. We focus on single-family residential buildings because they are the dominant housing type on the Oregon Coast and account for a potentially large group of vacationers that may not be directly exposed to tsunami awareness material or evacuation guidance that is occasionally found in hotels, motels, and campgrounds (Bauer and others, 2020). As can be seen in **Table 3-3**, the countywide ratio of permanent residents to single-family homes averages ~1.7, 1.5, and 1.84 in Lane, Douglas, and Coos respectively. Unlike Lincoln, Tillamook, and Clatsop counties, where we identified a surplus of single-family residential homes relative to the actual permanent population in those communities, no such surplus is apparent for Lane, Douglas, and Coos counties.

Table 3-3. Number of residents (permanent and temporary) per building occupancy type in the XXL1 tsunami zone in each community.

Community	Total Number of Single-Family Residential Homes	Number of Residents														Ratio of Permanent Residents to Number of Single-Family Residential Homes	Ratio of Permanent and Temporary Residents to Number of Single-Family Residential Homes, Summer Weekend
		Single-Family Residential		Manufactured Housing		Multifamily Residential		Hotel/ Motel		Mobile[1]		Other[2]		Total[3]			
		Perm	Temp	Perm	Temp	Perm	Temp	Perm	Temp	Perm	Temp	Perm	Temp	Perm	Temp		
Florence	639	586	1,003	248	114	492	345	0	722	0	524	0	0	1,326	2,709	1.30	3.05
Dunes City	26	29	48	9	6	4	1	0	22	0	32	0	0	43	109	1.47	3.52
Siltcoos	1	2	1	0	0	0	0	0	0	0	515	0	0	2	516	2.19	3.15
Other	251	408	436	67	20	21	10	0	49	0	325	0	0	495	841	1.89	3.71
Lane County Total	917	1,025	1,488	324	140	517	356	0	794	0	1,397	0	0	1,866	4,175	1.72	3.36
Reedsport	527	394	144	378	78	343	80	0	167	0	167	0	0	1,115	635	1.46	1.89
Winchester Bay	186	80	127	106	49	35	40	0	114	0	1,543	0	0	222	1,873	1.00	1.95
Umpqua South Jetty	13	3	2	10	3	30	10	0	0	0	287	0	0	43	301	1.00	1.35
Other	162	351	161	58	4	186	25	0	0	0	454	0	0	594	644	2.52	3.54
Douglas County Total	888	827	433	552	134	594	154	0	280	0	2,451	0	0	1,974	3,454	1.5	2.18
Lakeside	49	70	58	31	9	6	2	0	0	0	0	0	0	108	68	2.07	3.43
Coos Bay	609	1,152	276	210	9	1,156	111	0	852	0	382	0	0	2,517	1,630	2.24	2.70
North Bend	268	473	108	25	2	757	65	0	503	0	322	0	0	1,255	1,000	1.86	2.27
Barview	968	1,587	570	571	52	128	19	0	15	0	1,034	0	0	2,286	1,690	2.23	2.87
Charleston	48	53	26	6	1	38	9	0	51	0	400	0	0	98	487	1.24	1.79
Sunset Bay Park	0	0	0	0	0	0	0	0	0	0	425	0	0	0	425	NA	NA
Bullards Beach	3	5	4	0	0	0	0	0	0	0	660	0	0	5	664	NA	NA
Bandon	988	1,395	1,693	227	37	364	210	0	624	0	143	0	0	1,986	2,706	1.64	3.39
Other[4]	1,140	1,478	793	338	32	37	5	0	5	0	938	0	59	1,852	1,833	1.59	2.32
Coos County Total	4,073	6,214	3,527	1,408	142	2,485	420	0	2,050	0	4,304	0	59	10,108	10,503	1.84	2.68

Notes:

[1] Mobile includes tents, boats, and recreational vehicles.

[2] Other includes dormitories, retirement villages and private camps.

[3] Aggregate of all permanent and temporary building occupancy types.

[4] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

"Perm" is permanent and "Temp" is temporary population.

Figure 3-3. Building occupancy type for permanent (left) and temporary (right) residents in the XXL1 tsunami zone, by community. ***(continued on next page)***

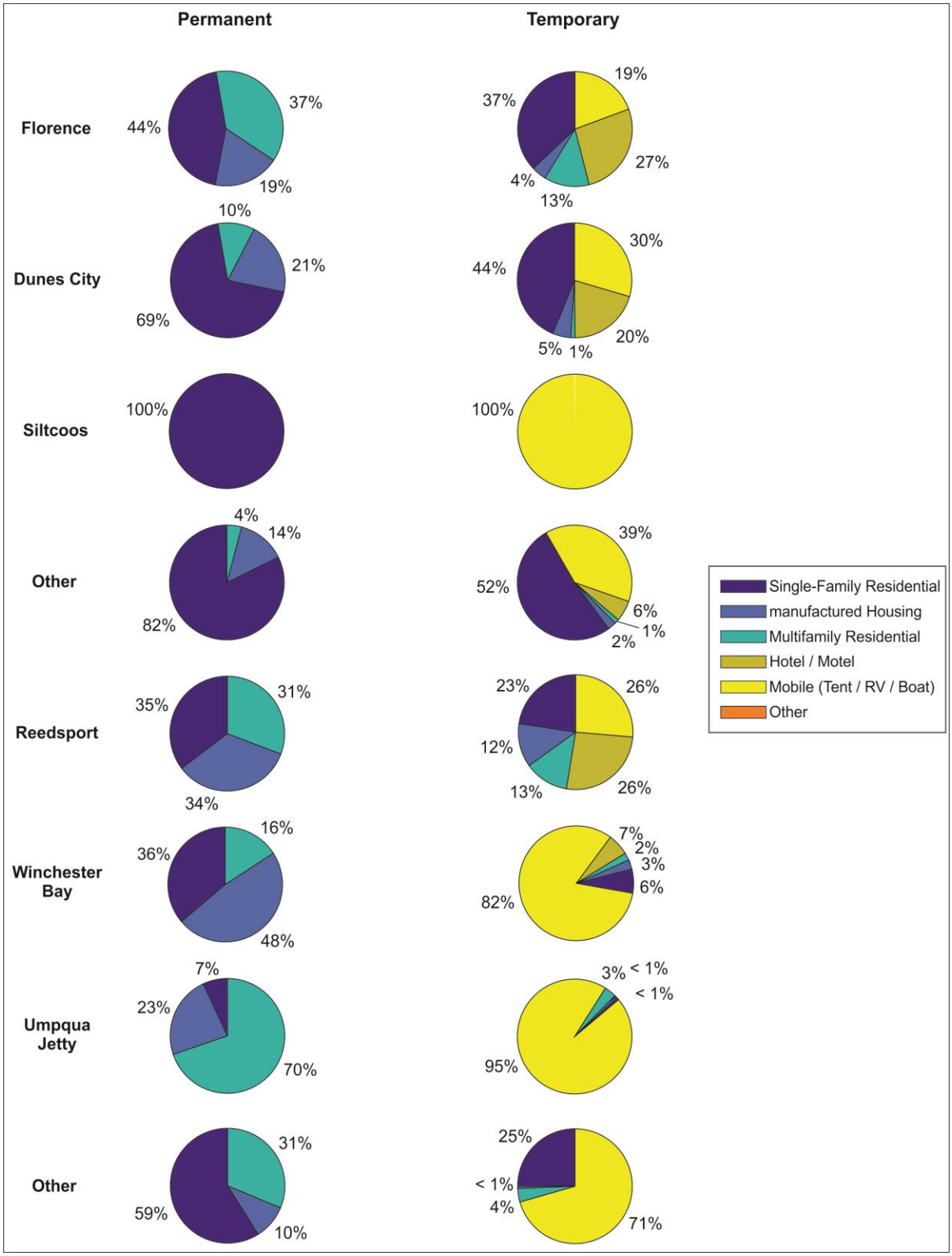
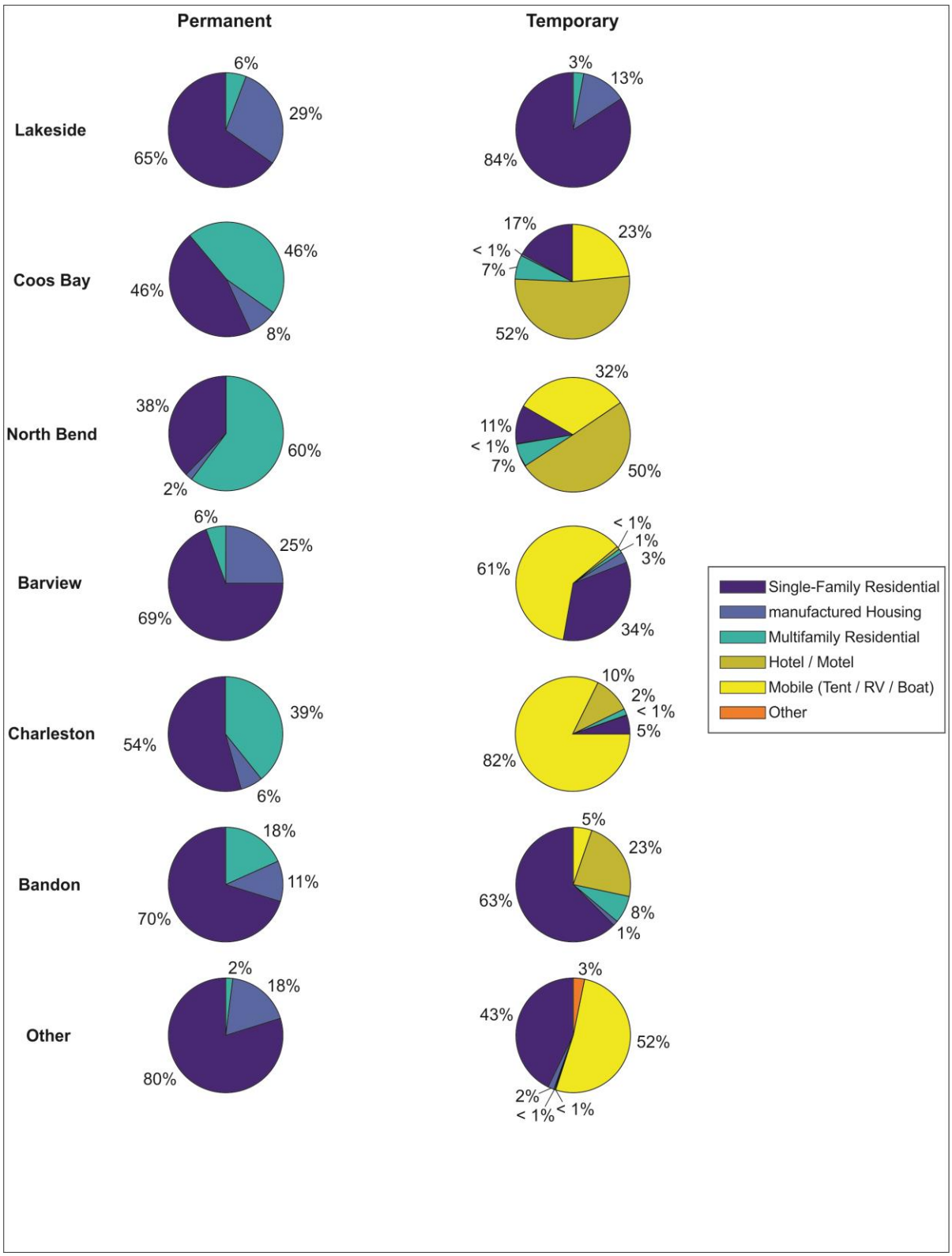


Figure 3-3. ***(continued)*** **Building occupancy type for permanent (left) and temporary (right) residents in the XXL1 tsunami zone, by community.**



An evaluation of the ratio of permanent and temporary visitors is provided in the final column of **Table 3-3**. It indicates the degree to which the local population may grow as visitors (predominantly vacationers) stay in those destinations. Larger ratios imply the availability of more beds, thereby highlighting those communities that are more likely to be major recreation destinations. In addition, the results may further help to highlight the importance of vacation homes, especially during a summer weekend when visits to the coast tend to be maximized compared with the baseline that considers just the permanent residents; compare the last two columns of **Table 3-3**. Bandon (3.4) and Florence (3.05) have the highest permanent and temporary populations relative to the number of single-family residential homes. Large ratios are also observed in the Lane and Douglas County "other" category (3.71% and 3.5%, respectively), which is likely capturing second homes located in the Heceta Beach and Gardiner areas. Hence, the local community in these areas may at times have an unusually large visitor population that may not be aware of the Cascadia tsunami hazard, let alone be prepared to deal with such an event.

Integral to pre- and post-disaster planning is knowledge of what will happen to buildings in the various communities because of earthquake ground motion and subsequent tsunami forces. These data are presented in **Table 3-4**. Note **Table 3-4** also includes estimates of the broader community-wide earthquake-related damage expected to occur both inside and outside of the tsunami zone. **Figure 3-4** graphically summarizes the results of **Table 3-4**.

The number of buildings located in each of the three tsunami zones is provided in the second through fourth columns of **Table 3-4** and plotted as bar graphs in **Figure 3-4** *(*upper left). Not surprisingly, Florence, Reedsport, Coos Bay, Barview, and Bandon have large numbers of buildings located in a tsunami zone. Nevertheless, in total the largest number of buildings occurs outside of the Coos County community boundaries and reflects those buildings summarized in the "other" category (~2,100). The bulk of these are residential buildings, established mainly along the shores of the Coos and Coquille estuaries, outside the city boundaries. For Charleston and to a lesser extent Umpqua River jetty, the relatively small change between M1 and XXL1 is indicative of the fact that these areas are inundated by tsunamis in all three scenarios, such that the exposure risk at these sites is especially high.

Building replacement costs (assuming complete destruction) are shown in **Figure 3-4** (upper right) for each of the tsunami zones. Coos Bay ($711 million), Bandon ($540 million), North Bend ($402 million), and Coos County "other" ($599 million) are likely to see significant building losses in the XXL1 tsunami zone. Countywide building replacement costs for each tsunami zone reflect the following:

1. Lane County: total $152 million (M1), $223 million (L1), and $385 million (XXL1).
2. Douglas County: total $204 million (M1), $306 million (L1), and $372 million (XXL1).
3. Coos County: total $675 million (M1), $1.25 billion (L1), and $2.63 billion (XXL1).

Damage caused by earthquake shaking is presented in **Figure 3-4C** for each tsunami zone, along with the community-wide earthquake-related damage estimate (cyan bars). These latter data reflect earthquake damage across the entire community urban growth boundary along the Oregon Coast. Since Lane and Douglas counties extend well into the Willamette Valley, we exclude those areas from the analyses and results presented here. As can be seen in **Table 3-4**, the costs associated with earthquake damage across the three tsunami zones are estimated to be:

1. Lane County: $84 million (M1), $114 million (L1), and $187 million (XXL1).
2. Douglas County: total $125 million (M1), $178 million (L1), and $209 million (XXL1).
3. Coos County: total $399 million (M1), $700 million (L1), and $1.3 billion (XXL1).

Table 3-4 and **Figure 3-4** show discrete community earthquake damage losses, which range from $400 million in Coos Bay to ~$2 million at the Umpqua South Jetty site. The state parks and recreation areas show damage levels in the tens of thousands. Earthquake damage losses in areas beyond the specified communities ("other" category) are estimated to reach $273 million in Coos County.

The countywide earthquake damage losses outside the tsunami zones are the difference between losses inside a tsunami zone and the countywide totals (determined from **Table 3-4**); this equates to ~$5.47 billion (M1), $5.09 billion (L1), and $4.35 billion (XXL1) in losses outside of the tsunami zones. These data become important when considering the total damage losses caused by the combined tsunami and earthquake. The decrease in damage losses outside the tsunami zones is indicative of the increasing inundation (and tsunami-caused damage) as one moves from M1 to XXL1.

Combined earthquake and tsunami damage for each tsunami zone is included in **Table 3-4** and **Figure 3-4D**. These results indicate losses that range from ~$733 million (M1) to ~$2.7 billion (XXL1) across the three counties. Factoring in the additional earthquake losses outside the tsunami zones, our analyses indicate total losses on the order of:

1. Lane County: ~$1.25 billion (M1), ~$1.27 billion (L1), and ~$1.36 billion (XXL1).
2. Douglas County: total ~$440 million (M1), ~$464 million (L1), and ~$530 million (XXL1).
3. Coos County: total ~$4.52 billion (M1), ~$4.62 billion (L1), and ~$5.14 billion (XXL1).

Note that these estimates exclude building content losses and damage to roads, so these totals may be viewed as minimum estimates. At the community level, Coos Bay experiences the largest combined losses (i.e., inside and outside the tsunami zone), which reaches ~$1.2 billion, followed by damage losses in areas beyond the specified communities ("other" category) at ~$2.1 billion.

As can be seen from the earthquake building loss ratio (**Table 3-4E**), earthquake damage accounts for the bulk of the total building damage in Lane County. Significant building damage due to earthquake shaking is observed in Florence, Reedsport, Coos Bay, Charleston and Bandon. This is probably due to a combination of factors, including ground failure through liquefaction and lateral spreading, and the presence of older buildings.

Incorporating damage caused by the tsunami results in destruction levels for an M1 event that range from ~10% (Dunes City) to 90% (Charleston and Bandon; **Figure 3-4E)**. Destruction levels for an M1 event are especially high in Barview (79%), Coos Bay (72%), North Bend (70%), and Reedsport (70%). For an XXL1 size event, **Table 3-4** indicates >84% destruction in multiple communities, including Florence, Reedsport, Winchester Bay, Barview, Charleston and Bandon. The lowest destruction levels are generally observed in the more distal tsunami zone, such as Dunes City (~56% destruction) and Lakeside (52% destruction). Significant destruction at Winchester Bay, Barview, Charleston, and Bandon is indicative of the large number of buildings in the tsunami zone, large hydraulic forces associated with the tsunami and the prevalence of light-frame construction material (i.e., wood frame) on the Oregon Coast. Combined earthquake and tsunami damage estimates (**Table 3-4**) are:

1. Lane County: ~67% destroyed in the M1 event, 69% in the L1 event, and 81% in the XXL1 event.
2. Douglas County: ~69% destroyed in the M1 event, 71% in the L1 event, and 85% in the XXL1 event.
3. Coos County: ~73% destroyed in the M1 event, 72% in the L1 event, and 78% in the XXL1 event.

Although not included in **Table 3-4**, our Hazus analyses indicate that of the total number of buildings assessed, damage potential is estimated to be on the order of:

1. Lane County: 30% are expected to be destroyed, 27% are expected to experience extensive damage, and 22% of the buildings are expected to suffer moderate damage. 16% of the remaining buildings are expected to experience slight damage, and ~5% are expected to experience no damage.
2. Douglas County: 28% are expected to be destroyed, 21% are expected to experience extensive damage, and 17% of the buildings are expected to suffer moderate damage. 19% of the remaining buildings are expected to experience slight damage, and ~15% are expected to experience no damage.
3. Coos County: 23% are expected to be destroyed, 28% are expected to experience extensive damage, and 31% of the buildings are expected to suffer moderate damage. 14% of the remaining buildings are expected to experience slight damage, and ~3% are expected to experience no damage.

Finally, **Table 3-4** and **Figure 3-4F** indicate that the weight of debris generated countywide could range from ~33,000 tons (M1) in Lane County to ~785,000 tons (XXL1) in Coos Cunty. This equates to ~3,300 dump trucks for M1 and as many as 78,500 dump trucks for an XXL1 event. These estimates are almost certainly on the low end, as they do not include debris associated with content from buildings (personal items, business equipment, etc.), road rip-ups, vehicles, and vegetation. If we assume an additional five tons of personal items as debris per residential building (typical for most residential buildings), this adds ~4% additional weight to the building debris estimates provided in **Table 3-4**.

Table 3-4. Earthquake- and tsunami-induced building damage and debris estimates by community.

	Number of Buildings by Tsunami Zone			Building Replacement Cost by Tsunami Zone[1] ($ Million)			Earthquake Building Loss by Tsunami Zone[2] ($ Million)			Earthquake Building Loss by Community[3]		Combined Earthquake and Tsunami Building Loss by Tsunami Zone ($ Million)			Combined Earthquake and Tsunami Building Loss by Tsunami Zone (%)			Combined Earthquake and Tsunami Building Debris by Tsunami Zone (Tons)		
Community	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**($ Million)**	**Building Loss Ratio**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**
Florence	153	310	909	117	163	279	69	92	150	832	299%	81	120	241	70%	73%	86%	23,555	36,004	79,809
Dunes City	4	6	41	1	1	6	0	0	3	62	992%	0	0	4	10%	19%	56%	9	12	1,288
Siltcoos	1	1	1	0	0	0	0	0	0	0	53%	0	0	0	100%	100%	100%	71	71	71
Other[4]	153	290	477	34	59	100	15	22	34	336	337%	19	34	68	57%	57%	69%	9,299	14,383	26,766
Lane County Total	311	607	1,428	152	223	385	84	114	187	1,230	420%	101	154	313	59%	62%	78%	32,934	50,469	107,934
Reedsport	472	762	897	122	183	212	78	108	122	284	134%	86	123	177	70%	67%	84%	44,888	62,441	84,911
Winchester Bay	168	292	292	29	46	46	15	24	24	24	52%	18	38	45	60%	84%	98%	8,491	16,954	20,330
Umpqua South Jetty	26	27	31	6	6	7	2	2	2	5	75%	3	6	6	46%	94%	96%	972	1,695	2,053
Other[4]	134	210	349	46	71	107	30	45	61	111	104%	33	50	86	72%	71%	80%	16,845	24,789	41,491
Douglas County Total	800	1,291	1,569	204	306	372	125	178	209	424	91%	140	217	315	62%	79%	89%	71,196	105,878	148,784
Lakeside	0	6	75	0	4	17	0	2	7	100	608%	0	2	9		62%	52%	0	184	2,991
Coos Bay	312	619	1,233	298	511	711	186	308	400	1,061	149%	214	356	501	72%	70%	71%	88,628	150,401	203,529
North Bend	75	265	613	85	204	402	52	113	208	690	172%	60	137	288	70%	67%	72%	18,207	47,576	102,404
Barview	123	330	1,492	32	75	289	17	39	156	195	68%	25	61	271	79%	81%	94%	9,557	20,913	106,748
Charleston	186	189	223	64	64	71	41	42	44	51	72%	58	63	69	90%	97%	97%	25,394	28,068	30,806
Sunset Bay Park	3	3	3	0	0	0	0	0	0	0	81%	0	0	0	100%	100%	100%	187	188	188
Bullards Beach	13	13	14	2	2	2	1	1	1	1	47%	1	2	2	56%	95%	100%	471	749	919
Bandon	182	290	1,447	89	139	540	57	80	241	412	76%	80	117	480	90%	84%	89%	31,249	45,586	168,123
Other[4]	373	918	2,088	105	247	597	44	115	272	1,912	320%	54	158	422	52%	64%	71%	16,574	64,052	168,929
Coos County Total	1,267	2,633	7,188	675	1,246	2,630	399	700	1,329	4,424	177%	492	896	2,043	73%	72%	78%	190,266	357,717	784,638

Notes:

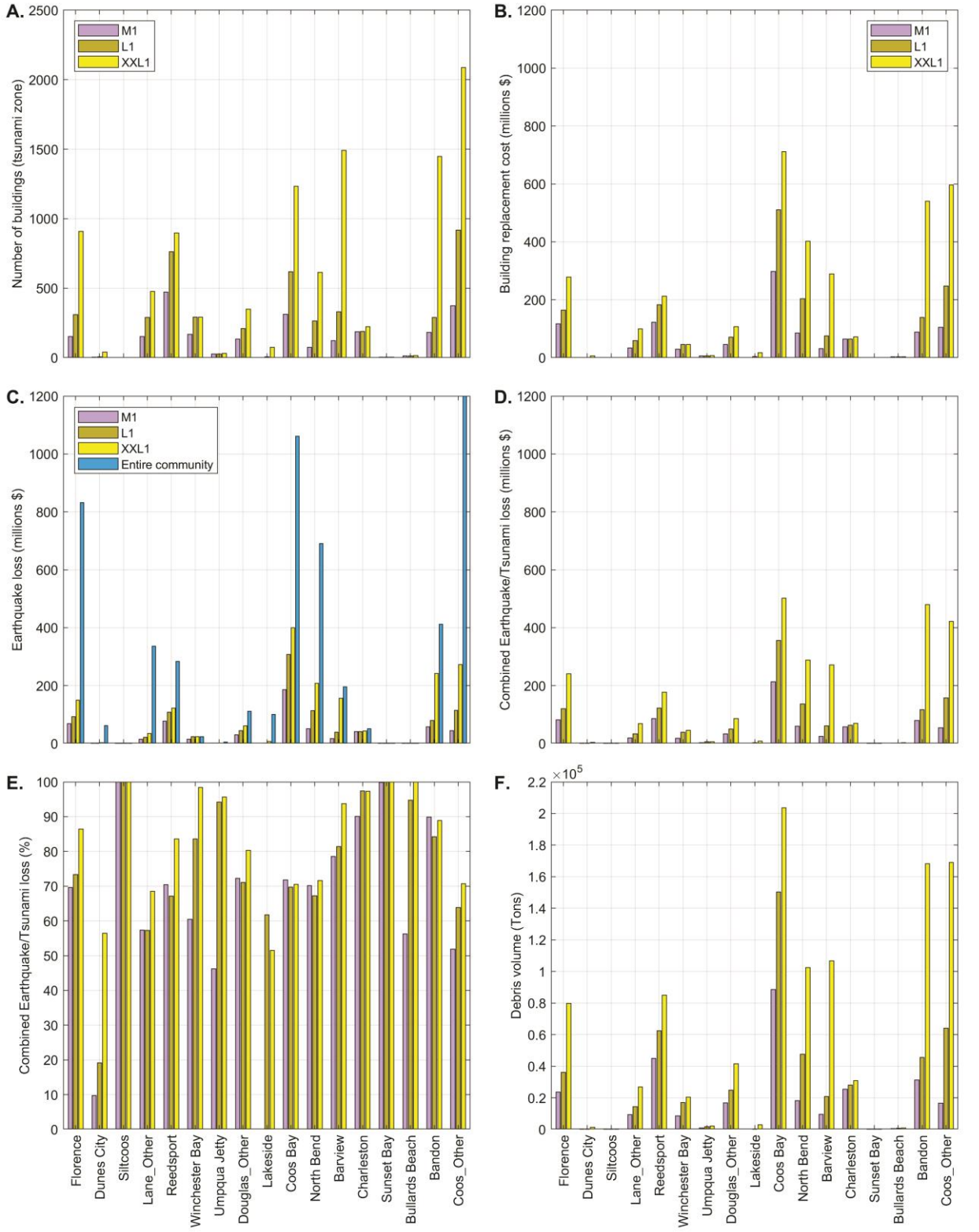
[1] Total cost to replace buildings in each tsunami zone

[2] Earthquake building losses defined for each tsunami zone

[3] Earthquake building losses defined for the entire community (inside and outside the tsunami zone)

[4] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

Figure 3-4. Community overview showing (A) number of buildings per tsunami zone, (B) total replacement costs (millions of $), (C) earthquake losses (millions of $), (D) combined tsunami and earthquake losses (millions of $), also expressed as a (E) ratio, and (F) debris generated (weight).



3.3 Earthquake-Caused Injuries and Fatalities

Our Hazus analyses indicate that injuries from a CSZ earthquake greatly outnumber fatalities (**Table 3-5**). Modeled injuries experienced by residents and visitors are expected to be highest in Florence, Coos Bay and North Bend, followed by the "other" category. The latter numbers are of concern as these will be spread out over a very broad area. This will make it extremely challenging and time consuming to medivac the injured to appropriate field hospitals.

Table 3-5. Earthquake-induced injuries and fatalities determined for each community, expressed as a total for the county.

		Permanent Residents				Temporary Residents			
Community Zone	**Total Population[2]**	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Florence	16,669	291	72	5	9	116	28	2	4
Dunes City	2,555	12	3	0	0	19	5	0	1
Siltcoos	518	0	0	0	0	0	0	0	0
Other[1]	9,796	98	23	1	2	42	10	1	2
Lane County Total	29,538	401	97	7	11	177	42	4	6
Reedsport	5,241	56	14	1	2	13	3	0	1
Winchester Bay	2,107	8	2	0	0	9	3	0	1
Umpqua South Jetty	389	2	0	0	0	0	0	0	0
Other[1]	2,612	31	7	1	1	6	1	0	0
Douglas County Total	10,350	96	24	2	4	28	7	1	2
Lakeside	2,386	47	12	1	2	13	3	0	1
Coos Bay	19,483	289	71	6	11	58	16	2	4
North Bend	12,123	157	39	4	7	51	15	2	4
Barview	5,022	86	21	2	3	16	4	0	0
Charleston	724	5	1	0	0	5	2	0	1
Sunset Bay State Park	425	0	0	0	0	0	0	0	0
Bullards Beach	669	0	0	0	0	0	0	0	0
Bandon	6,748	79	20	2	3	88	25	3	6
Other[1]	36,291	424	97	7	11	102	24	2	4
Coos County Total	83,872	1,088	261	21	37	333	87	10	19

Notes:

See **Table 2-4** for a more complete description of Hazus-defined injury levels. Level 1 denotes minor injuries, level 2 denotes injuries requiring hospitalization, level 3 denotes life-threatening injuries, level 4 denotes fatalities.

[1] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

[2] Assumes 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

Of the total number of injuries identified across all three counties (~2,000), Hazus estimates ~560 people are likely to require hospitalization (i.e. level 2 and level 3 injuries). The low fatality (~50) and injury estimates relative to the total population in these communities and caused by earthquake are likely due to the prevalence of wood-frame construction. However, we note that even if injuries are minor, impacted persons may delay evacuation from a tsunami zone while they tend to injuries.

3.4 Tsunami-Caused Injuries and Fatalities

Casualty numbers (injuries plus fatalities) attributed to a Cascadia tsunami are presented in **Table 3-6** and graphically in **Figure 3-5**. Overall, our Hazus modeling indicates that tsunami related casualties will greatly exceed earthquake-related casualties, especially when accounting for the combined resident and visitor populations. Notably, injuries caused by the tsunami average about 29% (±16%) of the total number of casualties, indicating that tsunami related deaths account for a larger proportion of the casualties (**Table 3-7**). This is because the Hazus tsunami casualty model estimates that people who do not escape from the tsunami zone are much more likely to die than to be injured and survive. Those who are injured are largely confined to a small narrow band where the tsunami flow depth falls below 1.8 m (~6 feet; see Section 2.6.2.5).

As can be seen in **Table 3-6** and **Figure 3-5**, modeled tsunami casualties vary widely between the communities. This is due to many factors, but most important is the relative distance to high ground. For the M1 scenario, estimated casualties are confined mainly to three areas: Winchester Bay (~6 residents/1,140 visitors), Charleston (~6 resident/195 visitor), and Sunset Bay State Park (~0 residents/145 visitors). Casualties in these three communities are overwhelmingly related to the campgrounds. Hence, for the M1 tsunami scenario, our Hazus modeling suggests either few or no casualties in the remaining three counties; note that these latter estimates fall within the margin of error in the Hazus modeling. Aside from the previously mentioned communities located at the open coast, low casualty numbers determined for the M1 scenario are indicative of the fact that most of the communities are:

1) built on high ground (e.g., marine terraces at Florence),
2) high ground is located close to the population centers allowing for quick access out of the inundation zone, or
3) are located well away from the coast (e.g., Dunes City and Lakeside) such that the M1 event does not reach them.

The number of casualties associated with the XXL1 tsunami scenario increase dramatically from the M1 scenario, ranging from no expected casualties (e.g., Dunes City, Reedsport, Lakeside, and North Bend) to as many as ~1,900 at Bandon, ~1,400 in the Coos County "other" category, ~1,200 in Winchester Bay, and ~980 in Barview (**Table 3-6**). In each of these areas, most of those expected to lose their lives (>69% in Lane and Douglas County and ~61% in Coos County) are likely to be visitors. Overall, we find the average number of fatalities observed in the permanent population across all three counties is low, averaging ~1.5% for the M1 scenario, increasing to 7.4% for the XXL scenario. For some communities such as Bandon and Barview, the percentage of resident fatalities are 38% and 21%, respectively, for the XXL1 scenario. Several additional sites characterized by the potential for large visitor fatalities include the Siltcoos River Campground, Umpqua South Jetty, Sunset Bay campground, and Bullards Beach campground. The large number of potential fatalities at each of the campgrounds can be attributed to a combination of early tsunami wave arrivals and the significant travel distances required to reach high

ground. High casualty numbers in Bandon and Winchester Bay are also due to early wave arrivals and potentially large numbers of people in the tsunami zone. Evacuation modeling of Winchester Bay (Gabel and others, 2018b) and Barview (Gabel and others, 2019b) identified a few key mitigation options that could be implemented to reduce fatalities, including retrofitting the Salmon Harbor Bridge in downtown Winchester Bay and improving signage in places like Barview. Use of a vertical evacuation structure in Barview was discounted largely because such structures would not effectively serve the community since no single road emerges as a primary evacuation route, with evacuation routes being broadly dispersed among several roads in the area.

We estimate that, combined, countywide fatalities from the tsunami could reflect the following:

1. Lane County: ~20 killed in an M1 event, ~50 in an L1 event, and ~200 in an XXL1 event.
2. Douglas County: ~610 killed in an M1 event, ~1,180 in an L1 event, and ~1,380 in an XXL1 event.
3. Coos County: ~440 killed in an M1 event, ~1,070 in an L1 event, and ~5,290 in an XXL1 event.

As noted above, most of the potential fatalities are likely to come from the temporary visitor population. Given that these casualty estimates are only for 11 communities and three major state parks, total deaths caused by even an M1 CSZ tsunami, when accounting for all 38 communities (and numerous state parks) on the Oregon Coast, will likely exceed Oregon Seismic Safety Policy Advisory Commission's original estimate of ~5,000 people killed (OSSPAC, 2013). For context, tsunami casualties provided by OSSPAC (2013) are based on an M1 tsunami earthquake scenario, which covers ~79% of the DOGAMI tsunami inundation scenarios and did not consider the temporary visitor population. Using the same event scenario, our combined assessment for Clatsop (Allan and others, 2020a), Tillamook (Allan and others, 2020b), Lincoln (Allan and others, 2021) and those reported here indicate ~4,100 fatalities within the resident population for the M1 scenario, along with an additional ~10,600 fatalities within the visitor population. These results indicate that estimates by OSSPAC (2013) are low for a major Cascadia event.

Figure 3-5 presents a graphical summary of the estimated fatalities and displaced population for all three tsunami scenarios. Casualties are presented on the left of **Figure 3-5**, and estimates of the displaced population are on the right. The permanent resident population reflects the following color scheme: purple (M1), gold (L1), and yellow (XXL1). We provide contrasting cool colors to characterize different visitor occupancy levels (we assume 10%, 50%, and 100% occupancy level scenarios).

Since the permanent resident population is easiest to define in our population model, we argue that this likely reflects a low-end estimate of casualty numbers associated with each of the three tsunami events. This is shown in **Figure 3-5** by the left edge of the dark blue bars. Conversely, the resident plus visitor population (assuming 100% occupancy), is characterized by the length of the entire bar (right edge of the pale blue shaded region). Accordingly, the area in between reflects the uncertainty associated with the visitor population that could be present in the tsunami zone within each of the communities. One could speculate on visitor occupancy as we have done here by developing scenarios that vary from 10% (e.g., winter occupancy conditions, dark blue shading) or 50% (an average visitor occupancy, cyan shading) to define the potential number of casualties and displaced people. Refining such estimates, guided by local input, would help clarify a range of possible scenarios leading to more informed evaluations. As noted previously, the large number of casualties estimated for Winchester Bay in Douglas County in each of the three Cascadia scenarios (**Figure 3-5**, left) demonstrates the importance of a single pedestrian bridge in that community for effective evacuation to high ground and hence safety from the tsunami. Discussions with county personnel suggest that this key bridge is expected to fail, which forces people to take a much longer evacuation route westward toward the Umpqua lighthouse, in the direction of the oncoming tsunami. Large casualty numbers may also occur at Barview and Bandon during an XXL1-size tsunami due

to the potentially large numbers of people and businesses in the tsunami zone. Conversely, low casualty numbers in most of the other communities are due entirely to the fact that high ground is close by (or the communities are at the distal ends of the tsunami zone), enabling more people to reach safety in time. Regardless of differences in local geography, it is evident from **Figure 3-5** that the number of casualties associated with even an M1 size event (especially when factoring in the temporary visitor population) has the potential to be large when scaled up to the rest of the Oregon Coast.

For the displaced population (**Figure 3-5**, *right* and **Table 3-8**), we can make similar assumptions about the local population groups. Apparent from the figure is the extremely large number of displaced visitors that each community could potentially have to deal with. This is most apparent for Florence, Coos Bay, North Bend, Barview, and Reedsport, each of which might potentially have to deal with several thousand people, many of whom would be nonresidents. The extremely large number of displaced people in the Coos 'Other' category after an XXL1 event will be especially challenging post disaster as many of these people will be disbursed widely across the county, making evacuation extremely difficult. Identifying these groups early on and providing or encouraging pre-disaster preparation (e.g., being two-week ready) will be key to their survival.

Although the number of displaced people increases significantly from M1 (~9,800) to XXL1 (~25,400) (**Table 3-8**), our Hazus results demonstrate that even a medium (M1) event would result in the displacement of many thousands of people. These numbers are indicative of the fact that many of these coastal communities are major tourist destinations with large numbers of vacation homes, camping spots, and to a lesser extent hotel/motels located in the tsunami zone. The low number of displaced people in places such as Sunset Beach State Park and Umpqua South Jetty under the XXL1 scenario (**Figure 3-5**, right) suggests that most people would be killed, because high ground under this scenario is not easily reached in time. In this case, evacuees traveling at a walking pace would not survive. In these areas, required evacuation speeds needed to survive the XXL1 event are faster than a walk (e.g., fast walk to jog).

Finally, the assumptions and observations described previously about tsunami casualties are predicated on the fact that people will evacuate from the tsunami zone within 10 minutes from the start of earthquake shaking. If people respond slowly and take an additional five-minute delay (i.e., a 15-minute departure time), the casualty numbers will increase significantly (**Table 3-7**). As can be seen from the table, a five-minute difference in the departure delay could cause the number of casualties to increase by 4,400 people. Thus, efforts directed at reducing human response times are critical for reducing overall casualties.

Table 3-6. Estimated injuries and fatalities associated with three CSZ tsunami scenarios by community, based on a 2 AM summer weekend scenario . Tsunami injury and fatality estimates assume a departure time of 10 minutes after the start of earthquake shaking.

	Number of Permanent Residents by Tsunami Zone			Estimated Number of Temporary Residents by Tsunami Zone[1]			Injuries and Fatalities to Permanent Residents by Tsunami Scenario			Injuries and Fatalities to Temporary Residents by Tsunami Scenario[1]			Injuries and Fatalities to Permanent Residents by Tsunami Scenario, Percent[2]			Injuries and Fatalities to Temporary Residents by Tsunami Scenario, Percent[3]		
Community Zone	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**	**Medium**	**Large**	**XX-Large**
Florence	404	612	1,326	1,289	1,622	2,709	0	0	5	0	0	14	0%	0%	0%	0%	0%	1%
Dunes City	3	6	43	6	11	109	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
Siltcoos	2	2	2	516	516	516	0	0	0	43	47	115	1%	1%	11%	8%	9%	22%
Other[4]	141	286	495	232	454	841	0	1	45	0	1	117	0%	0%	9%	0%	0%	14%
Lane County Total	550	906	1,866	2,043	2,604	4,175	0	1	50	43	49	246	0%	0%	5%	2%	2%	9%
Reedsport	553	954	1,115	384	497	635	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
Winchester Bay	121	222	222	1,527	1,873	1,873	5	8	19	1,138	1,143	1,244	4%	3%	9%	74%	61%	66%
Umpqua South Jetty	41	41	43	301	301	301	2	2	8	56	57	166	5%	5%	18%	19%	19%	55%
Other[4]	339	409	594	90	560	644	0	3	6	0	0	10	0%	1%	1%	0%	0%	2%
Douglas County Total	1,054	1,626	1,974	2,303	3,231	3,454	7	13	34	1,194	1,200	1,420	2%	2%	7%	23%	20%	31%
Lakeside	0	4	108	0	4	68	0	0	0	0	0	0		0%	0%		0%	0%
Coos Bay	448	1,022	2,517	545	1,054	1,630	0	0	9	0	0	9	0%	0%	0%	0%	0%	1%
North Bend	58	469	1,255	169	209	1,000	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
Barview	147	464	2,286	779	965	1,690	1	4	669	52	66	604	1%	1%	29%	7%	7%	36%
Charleston	61	62	98	475	476	487	6	10	32	195	261	377	10%	16%	33%	41%	55%	78%
Sunset Bay State Park	0	0	0	425	425	425	0	0	0	144	291	422				34%	68%	99%
Bullards Beach	5	5	5	284	664	664	0	1	5	32	111	324	2%	14%	91%	11%	17%	49%
Bandon	310	465	2,182	338	766	2,706	13	141	1,307	18	59	1,652	4%	30%	60%	5%	8%	61%
Other[4]	300	838	1,892	626	994	1,833	33	111	640	122	366	962	11%	13%	34%	19%	37%	52%
Coos County Total	1,328	3,329	10,343	3,642	5,557	10,503	52	267	2,662	561	1,152	4,350	4%	9%	22%	15%	21%	42%

Notes:

[1] Assumes 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

[2] Casualties expressed as percentage of those injured or killed in the tsunami zone relative to the total number of community-wide permanent residents.

[3] Casualties expressed as percentage of those injured or killed in the tsunami zone relative to the total number of community-wide temporary residents, assuming 100% occupancy.

[4] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

Table 3-7. Injury and fatality estimates for an XXL1 tsunami for two median departure times.

Community Zone	Number of Permanent Residents	Total Number of Residents (Permanent + Temporary[1])	10-Minute Departure				15-Minute Departure			
			Injuries	Fatalities	Total	Injuries Ratio[2]	Injuries	Fatalities	Total	Injuries Ratio[2]
Florence	10,291	16,669	1	18	19	7%	41	375	416	10%
Dunes City	1,208	2,555	0	0	0	26%	0	3	3	8%
Siltcoos	2	518	26	89	115	23%	28	290	318	9%
Other[3]	5,871	9,796	58	103	162	36%	70	341	411	17%
Lane County Total	17,372	29,538	86	210	296	23%	139	1,008	1,148	11%
Reedsport	3,932	5,241	0	0	0	49%	24	54	78	31%
Winchester Bay	227	2,107	55	1,208	1,264	4%	62	1,517	1,579	4%
Umpqua South Jetty	83	389	15	159	174	9%	12	242	254	5%
Other[3]	1,654	2,612	7	9	16	46%	30	138	168	18%
Douglas County Total	5,896	10,350	78	1,376	1,454	27%	129	1,950	2,079	15%
Lakeside	1,709	2,386	0	0	0	42%	1	3	4	18%
Coos Bay	15,652	19,483	7	11	18	37%	51	288	339	15%
North Bend	9,592	12,123	0	0	0	40%	12	60	73	17%
Barview	3,122	5,022	297	975	1,273	23%	318	1,999	2,317	14%
Charleston	190	724	55	354	409	14%	32	454	487	7%
Sunset Bay State Park	0	425	30	392	422	7%	17	406	423	4%
Bullards Beach	5	669	57	272	329	17%	38	472	510	7%
Bandon	3,227	6,748	1,047	1,913	2,960	35%	846	2,931	3,777	22%
Other[3]	26,327	36,291	229	1,373	1,602	14%	208	1,725	1,933	11%
Lincoln County Total	59,824	83,872	1,722	5,291	7,012	26%	1,523	8,338	9,861	13%

Notes:

[1] Assumes 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

[2] Tsunami Injuries ratio is the number of tsunami injuries divided by total number of tsunami casualties (injuries plus fatalities).

[3] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

Figure 3-5. Left: Estimated casualty numbers by community for M1, L1, and XXL1 tsunami events, assuming various visitor occupancy levels. Right: Estimates of the displaced population in each community, assuming various occupancy levels.

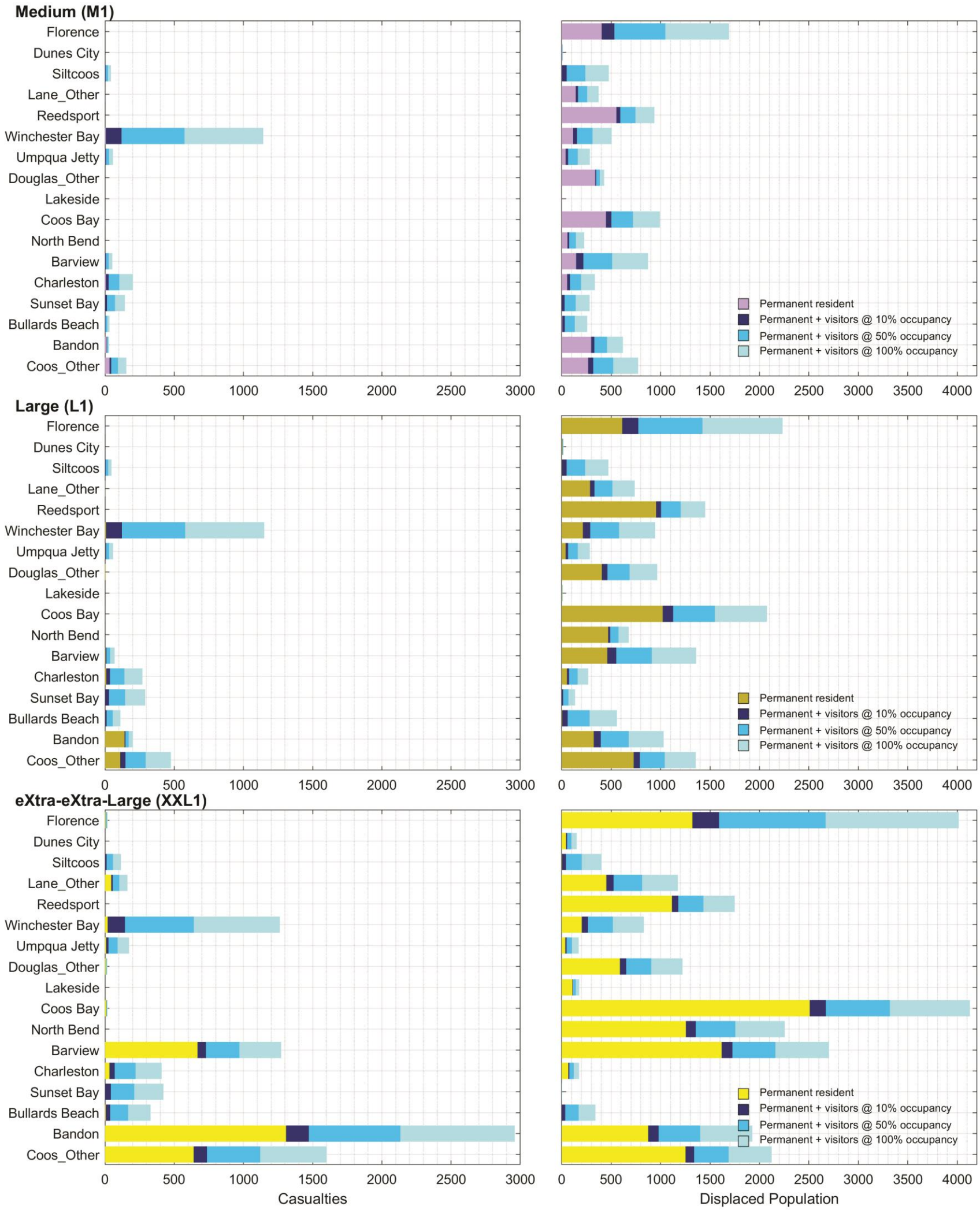


Table 3-8. Displaced population by tsunami zone.

	Displaced Population[1] by Tsunami Scenario		
Community Zone	**M1**	**L1**	**XXL1**
Florence	1,692	2,234	4,017
Dunes City	9	17	152
Siltcoos River Campgrounds	497	475	429
Other[2]	373	739	1,233
Lane County Total	2,571	3,465	5,831
Reedsport	937	1,451	1,750
Winchester Bay	1,074	977	886
Umpqua South Jetty	308	286	186
Other[2]	429	967	1,229
Douglas County Total	2,748	3,681	4,052
Lakeside	0	8	176
Coos Bay	993	2,075	4,136
North Bend	227	678	2,256
Barview	884	1,371	3,001
Charleston	433	307	231
Sunset Bay State Park	292	174	33
Bullards Beach State Park	272	593	397
Bandon	627	1,103	2,975
Other[2]	808	1,506	2,352
Coos County Total	4,535	7,816	15,556

Notes:

[1] Permanent plus temporary population. For the temporary population we assume 100% occupancy of second homes, vacation rentals, condominium units, bed and breakfast facilities, hotels, motels, and campgrounds.

[2] Denotes all other areas impacted by a Cascadia earthquake and tsunami.

3.5 Essential Facilities and Key Infrastructure

Table 3-9 provides a summary list of critical facilities and key infrastructure located in the M1, L1, and XXL1 tsunami hazard zones in Lane, Douglas, and Coos counties.

Table 3-9. Critical facilities and key infrastructure in coastal Lane, Douglas, and Coos county tsunami inundation zones.

				Tsunami Zone		
County	**Community**	**Description**	**Category**	**M1**	**L1**	**XXL1**
Lane	Florence	Water Treatment Plant	water treatment	x	x	x
		Siuslaw Valley F & R - Station 2	fire department	—	—	x
Douglas	Reedsport	Douglas County Sheriff's Office	police department	—	x	x
		Public Works - City Shop	public works	—	—	x
		Reedsport Water Treatment Plant	water treatment	—	—	x
		Reedsport Police Dept	police department	x	x	x
		Reedsport Fire Dept Station 1	fire department	x	x	x
		Reedsport Public Works	public works	—	x	x
Douglas	Winchester Bay	U.S. Coast Guard Umpqua River Station	U.S. Coast Guard Station	x	x	x
		Winchester Bay RFPD	fire department	x	x	x
		Water Treatment Plant	water treatment			
Douglas	Other	Communication Structure	communications	x	x	x
		Gardiner RFPD	fire department	x	x	x
Coos	Lakeside	Water Treatment Plant	water treatment	—	—	x
Coos	Coos Bay	Coos Bay Police Dept	police department	x	x	x
		Coos Bay Water Treatment Plant No. 1	water treatment	—	x	x
		Coos Bay Water Treatment Plant No. 2, Empire	water treatment	x	x	x
		Communication Structure	communications	x	x	x
		South Coast Head Start School	school	x	x	x
		U.S. Coast Guard Cutter Orcas	U.S. Coast Guard Station	x	x	x
Coos	North Bend	Bangor Elementary School	school	—	—	x
		North Bend Water Treatment Plant	water treatment	x	x	x
		North Bend Fire Dept Station 2	fire department	—	x	x
		Southwest Oregon Regional Airport	airport	—	x	x
		U.S. Coast Guard Air Station North Bend	U.S. Coast Guard Station	—	x	x
		Waterfall Medical Clinic	hospital	—	—	x
Coos	Barview	Charleston RFPD Station 1	fire department	—	—	x
Coos	Charleston	Charleston RFPD - Station 3	fire department	x	x	x
		U.S. Coast Guard Navigation Team Coos Bay	U.S. Coast Guard Station	x	x	x
		U.S. Coast Guard Station Coos Bay	U.S. Coast Guard Station	x	x	x

County	Community	Description	Category	Tsunami Zone		
				M1	L1	XXL1
Coos	Bandon	Bandon Police Dept	police department	—	—	x
		Bandon Water Treatment Plant	water treatment	x	x	x
		Bandon Fire Dept	fire department	—	x	x
		North Bend Medical Center	hospital	—	—	x
		Ocean Crest Elementary School	school	—	—	x
		U.S. Coast Guard Station Coquille River	U.S. Coast Guard Station	x	x	x
Coos	other	Communication Structure	communications	x	x	x
		Millington RFPD 5 Station 1	fire department	—	—	x

Notes:

"x" denotes present in the inundation zone.

3.6 Social Characteristics

We used American Community Survey (ACS) social characteristic data to identify some societal characteristics for each community throughout the three counties. Of specific interest are the distribution of Spanish-speaking households and individuals with disabilities. Both datasets are important because they have a direct bearing on tsunami outreach and education (e.g., providing translated informational materials or identifying individuals with disabilities who may need additional assistance with developing evacuation plans or actual evacuation). As noted previously, a limitation of these data is that they span the entire community and are not at a resolution that would allow us to better define these statistics by tsunami zone. Additional information relating to the use of ACS data may be found in Appendix A of Bauer and others (2020).

Table 3-10 identifies the number of Spanish-speaking households (and those speaking other languages) in coastal Lane, Douglas, and Coos counties. Overall, Spanish-speaking households are the most prevalent in the "other" Coos Bay category (~4%), North Bend (~3%), and Reedsport (~3%). Reedsport has the largest group of Spanish-speaking households that speak limited English (~2%).

Table 3-11 presents information on the percentages of people with disabilities throughout the three coastal counties. Overall, these results indicate the proportion of the local population with disabilities ranges from a low of ~19% in North Bend to highs of 32% in Florence and ~25% in Barview. Of particular concern is the relatively large number of individuals with vision, cognitive, or ambulatory disabilities. These include:

- ~12% of people in Barview have indicated vision challenges.
- Individuals with cognitive challenges make up ~22% of residents in Winchester Bay and ~12% of residents in Florence.
- Individuals with ambulatory needs make up sizable portions of Florence (~20%), Barview (~16%), Lakeside (~16%), and Coos Bay (~12%).

These results point to the need to better understand the distribution and needs of those with disabilities in the tsunami zone, as many of these people will almost certainly need help evacuating. Because the ACS data are not sufficiently detailed, not all of these individuals necessarily reside in the tsunami zone. Local emergency managers may wish to assess specific community needs.

Table 3-10. Household spoken language statistics.

Community	Number of Households Speaking Spanish	Percent of Households Speaking Spanish with MoE[1]	Number of Limited English-Speaking, Spanish Households	Percent of Households Speaking Spanish and with Limited English	Number of Limited English-Speaking, Other Language Households
Florence	29	0.7% ± 0.6%	—	—	10
Dunes City	4	0.7% ± 1.0%	—	—	—
Lane County	7,613	5.1% ± 0.3%	1,047	0.7% ± 1.0%	2,147
Reedsport	53	2.9% ± 2.1%	31	1.7% ± 1.6%	31
Winchester Bay	—	—	—	—	—
Douglas County	1,076	2.4% ± 0.4%	194	0.4% ± 0.2%	256
Lakeside	20	2.2% ± 3.5%	—	—	—
Coos Bay	255	3.8% ± 1.5%	41	0.6% ± 0.5%	41
North Bend	122	3.2% ± 1.9%	26	0.7% ± 1.1%	34
Barview	7	0.8% ± 1.4%	—	—	—
Charleston	—	—	—	—	—
Bandon	26	1.7% ± 2.7%	—	—	—
Coos County	838	3.2% ± 0.7%	120	0.5% ± 0.4%	141

Note:

Data taken from American Community Survey 2013–2017 five-year estimates.

[1]MoE denotes margin of error.

Table 3-11. Number of individuals with disabilities (by type) for coastal Lane, Douglas, and Coos counties.

Community	Total Number of Individuals*	Number of Individuals* with a Disability	Percent of Individuals with a Disability	Hearing	Vision	Cognitive	Ambulatory	Self-Care	Independent Living
Florence	8,646	2,798	32.4% ± 3.6%	11.4% ± 2.4%	6.0% ± 1.9%	12.4% ± 2.7%	20.3% ± 3.7%	7.0% ± 1.7%	12.2% ± 2.5%
Dunes City	1,304	252	19.3% ± 3.8%	6.9% ± 2.4%	1.5% ± 1.4%	8.0% ± 3.3%	9.6% ± 3.3%	3.7% ± 2.6%	10.1% ± 3.4%
Lane County	361,882	60,677	16.8% ± 0.5%	5.3% ± 0.3%	2.8% ± 0.2%	7.5% ± 0.4%	8.7% ± 0.3%	3.1% ± 0.2%	7.1% ± 0.3%
Reedsport	4,037	824	20.4% ± 3.4%	7.3% ± 2.4%	5.0% ± 2.0%	6.1% ± 2.4%	11.2% ± 3.2%	4.5% ± 2.0%	7.2% ± 2.7%
Winchester Bay	376	81	21.5% ± 15.0%	0.0% ± 8.3%	0.0% ± 8.3%	21.5% ± 15.0%	6.4% ± 11.4%	6.4% ± 11.4%	7.3% ± 12.5%
Douglas County	106,896	22,467	21.0% ± 0.8%	8.1% ± 0.5%	3.4% ± 0.4%	7.8% ± 0.7%	10.6% ± 0.6%	2.9% ± 0.3%	6.7% ± 0.6%
Lakeside	1,874	452	24.1% ± 6.9%	9.4% ± 3.8%	3.2% ± 2.3%	10.2% ± 4.2%	16.0% ± 5.4%	7.2% ± 3.4%	10.6% ± 4.1%
Coos Bay	15,888	3,518	22.1% ± 2.6%	4.8% ± 1.1%	3.9% ± 1.4%	11.1% ± 2.1%	12.3% ± 1.9%	5.1% ± 2.0%	12.0% ± 2.4%
North Bend	9,468	1,798	19.0% ± 3.1%	6.6% ± 1.6%	4.3% ± 1.7%	8.5% ± 1.9%	10.0% ± 2.5%	3.9% ± 1.4%	9.9% ± 2.4%
Barview	2,021	510	25.2% ± 6.7%	11.9% ± 4.5%	6.7% ± 3.7%	6.7% ± 3.6%	16.3% ± 6.2%	3.4% ± 2.2%	9.7% ± 4.0%
Charleston	—	—	—	—	—	—	—	—	—
Bandon	2,995	575	19.2% ± 5.6%	6.1% ± 3.2%	4.3% ± 3.2%	7.6% ± 3.6%	13.5% ± 4.6%	5.4% ± 2.9%	7.8% ± 3.8%
Coos County	62,058	14,509	23.4% ± 1.5%	7.6% ± 0.7%	4.1% ± 0.7%	9.9% ± 1.1%	13.8% ± 1.1%	5.2% ± 0.8%	10.5% ± 1.0%

Notes:

Data taken from ACS 2013–2017 five-year estimates.

An individual with a disability may have more than one difficulty.

* Permanent residents as defined from ACS.

4.0 DISCUSSION

This study extends the original work undertaken by Bauer and others (2020) and Allan and others (2020a,b, 2021) by implementing the 2017 FEMA Hazus methods on a countywide basis in order to estimate building damage, losses, and casualties from a CSZ earthquake and tsunami. The approach adopted here has been guided by the best available information on a CSZ earthquake (Mw 9.0; Madin and others, 2021; Wirth and others, 2020) and M1, L1 and XXL1 tsunami inundation scenarios (Priest and others, 2013e), together with a detailed building database and a population model that accounts for both permanent and temporary residents (2 AM occupancy). Although previous studies evaluated statewide casualty estimates for permanent residents (OSSPAC, 2013), our study significantly expands on this initial work by evaluating in greater detail the expected impacts of three different tsunami inundation scenarios that could impact coastal Lane, Douglas, and Coos counties. In particular, the present study extends the population model to include new information that helps us evaluate the temporary visitor population, types of housing that permanent and temporary residents occupy, and their relative distances to high ground and hence safety. Such information is critically important because communities on the Oregon Coast presently do not have adequate information on the likely socioeconomic effects of a CSZ earthquake and accompanying tsunami. Accordingly, we hope that the information presented in this report may be used to assist with community pre- and post-disaster planning, including addressing such needs as the development of tsunami evacuation wayfinding signage plans, mass-care planning, debris removal plans, vertical evacuation structure plans, and individual community tsunami evacuation facilities' improvement plans[10].

Building damage: Our analyses reveal that the earthquake alone accounts for significant community-wide building losses that range from a few tens of thousands of dollars in Dunes City to ~$1.06 billion in Coos Bay (**Table 3-4**). An estimated $832 million in damage is expected for the City of Florence. These variations reflect differences in the type and age of building construction, the size and purpose of the community, the density of buildings (e.g., a state park versus a town), and the number of buildings established in terrain that may be subject to landslides or liquefaction. Countywide losses in coastal Lane, Douglas, and Coos counties caused by a CSZ earthquake are projected to reach ~$6.08 billion, most of which will occur in Coos Bay, Florence, North Bend, and areas outside of the Coos County community boundaries ("other").

Damage to buildings from the tsunami is expected to be catastrophic — the smallest amount of earthquake/tsunami destruction this analysis predicts is ~10% of buildings lost for the M1 scenario at Dunes City campground. The greatest losses (>80%) are in the communities of Florence, Reedsport, Winchester Bay, Barview, Charleston, and Bandon in an XXL1 event. Siltcoos River Campground, Umpqua South Jetty, Sunset Bay State Park, and Bullards Beach State Park are effectively wiped out as well. Much of this destruction can be attributed to the magnitude of the tsunami hydraulic forces and the prevalence of light-frame (mainly wood) construction, which is vulnerable to tsunami damage. In addition, except for a few inland areas such as Lakeside and Dunes City, most of the communities and campgrounds are built on low-lying coastal plains or estuary deposits that are inundated in an XXL1 event.

[10] https://www.oregon.gov/LCD/Publications/TsunamiLandUseGuide_2015.pdf

Combined earthquake and tsunami damage indicate the following losses:

	M1	L1	XXL1
Lane	$1.25 billion	$1.27 billion	$1.36 billion
Douglas	$440 million	$464 million	$530 million
Coos	$4.52 billion	$4.62 billion	$5.14 billion

Note that these estimates are approximate and exclude building content losses, such that these are minimum estimates.

Building debris: Debris generated from the destruction of these of buildings will be scattered throughout the tsunami zone. Planners should consider that buoyant debris within the tsunami zone will be redistributed and may accumulate around low points, which often include key transportation routes (Park and Cox, 2019), within ports and harbors, and in navigation channels. Jetties such as those built at the mouth of the Siuslaw, Umpqua, and Coos estuaries are expected to be severely damaged or completely destroyed. Such effects are likely to compromise marine traffic access into the estuaries and thus the ports of Siuslaw, Winchester Bay, and Coos. Our analyses indicate that the approximate weight of debris produced from building damage could reflect the following:

	M1 (tons)	L1 (tons)	XXL1 (tons)
Lane	40,000	50,500	108,000
Douglas	71,200	106,000	149,000
Coos	190,300	358,000	785,000

This equates to ~4,000 dump trucks for M1 event in Lane County and as much as 78,500 dump trucks for an XXL1 event in Coos County. These estimates are almost certainly on the low end, as they do not include debris associated with content from buildings (personal items, business equipment, etc.), road rip-ups, vehicles, and vegetation. Nonetheless, the amount of debris listed here provides a starting point for communities as they begin the process of developing earthquake/tsunami debris plans.

Injuries and fatalities: Our analyses indicate that the permanent resident population present in each of the three counties is:

	M1	L1	XXL1
Lane	550	910	1,870
Douglas	1,050	1,630	1,970
Coos	1,330	3,330	10,340

Including the temporary (visitor) population visiting the coast in the calculation increases the overall coastal population substantially. Our Hazus analyses presented in **Table 3-1** suggest that the temporary visitor population could potentially reflect the following:

	M1	L1	XXL1
Lane	2,040	2,600	4,180
Douglas	2,300	3,230	3,450
Coos	3,640	5,560	10,500

These results highlight the tremendous burden that each community could potentially face following a CSZ earthquake and tsunami. However, it should be recognized that these totals are conservative since they assume every lodging facility is fully booked and in use at the time of the event. Although 100% occupancy is an unlikely scenario, the point remains that there is a high probability that significant number of displaced visitors will be on the coast, in addition to the displaced permanent residents, who

will need emergency care and support following a Cascadia event. Further refinements to these numbers are therefore critical for communities to develop short-term mass-care plans and for state and federal agencies to develop their long-term plans.

Our Hazus casualty results estimate the number of people killed in the tsunami zones in each county could reflect the following:

	M1	L1	XXL1
Lane	20	50	210
Douglas	610	1,180	1,380
Coos	440	1,070	5,290

Estimates provided in the Oregon Resilience Plan suggest that fatalities could range from ~600 to ~5,000 for the entire coast (OSSPAC, 2013). Of note, the results from OSSPAC were based on an M1 event that accounts for 79% of the expected inundation scenarios. Thus, the M1 results presented here are more consistent with the same size earthquake event used in the OSSPAC assessment. Combining results for the M1 scenario modeled in Lane, Douglas, and Coos counties with those from our Clatsop (Allan and others 2020a), Tillamook (Allan and others 2020b), and Lincoln County studies (Allan and O'Brien, 2021), we estimate ~4,100 permanent resident casualties, increasing to ~14,800 when factoring in the temporary visitor populations (assuming 100% occupancy). Accordingly, it is apparent that coast-wide tsunami fatality estimates for even an M1 tsunami could be substantial for the Oregon Coast, potentially approaching levels observed in the 2011 Tōhoku, Japan, event.

To assist the public, considerable hazard related information has been developed over the past decade to enable coastal communities and visitors to make informed decisions. These include detailed evacuation maps for every coastal community, which are available in print and online (e.g., http://nvs.nanoos.org/TsunamiEvac). In addition, recent tsunami evacuation modeling undertaken by DOGAMI has helped clarify where people need to evacuate to and how fast they need to travel to reach safety. These efforts demonstrate the simple fact that for every community:

Casualties attributed to a CSZ tsunami can be substantially reduced if people undertake the following simple steps:

1. ***Practice their evacuation routes.***
2. ***Evacuate as soon as possible after the earthquake.***
3. ***Travel as fast as possible (e.g., a fast walk, jog, or run) to safety.***

Building a culture of tsunami awareness on the Oregon Coast that reduces the potential injury and fatality rate can be accomplished through concerted education/outreach campaigns, developing school curricula on tsunami hazards, improving signage, and implementing frequent evacuation drills reminding people of where they need to go. Oregon Emergency Management has developed a guidance document for how to organize and hold a tsunami evacuation drill (OEM, 2017), providing a valuable starting point for coastal communities intending to pursue this option.

We quantified impacts to both temporary and permanent populations in our injury and fatality estimates for two reasons. First, planners can apply their own judgment to their community's population at offpeak times, such as assuming that wintertime temporary population is 10%–50% of peak summertime (e.g., **Figure 3-5**). Second, tsunami preparation and education awareness levels of permanent residents versus temporary populations are likely to differ. For example, temporary populations generally have little to no knowledge of the hazard, evacuation procedures, or optimal routes to safety and are more likely to engage in counterproductive milling (delay) behaviors that will lead to

greater risk of death. In contrast, we hypothesize that permanent residents are generally better prepared (are aware of the hazard and their evacuation routes) and are less likely to delay their departure following an earthquake. Again, planners can apply their own judgment on the level of preparedness, including departure times and evacuation speeds, between the groups, to better refine the estimates of injuries and fatalities that may occur in their community.

Depending on the community, the temporary population on average may be closer to the ocean — thus farther away from safety — compared with the permanent resident population. Market forces often drive such housing arrangements (Raskin and Wang, 2017). This is certainly the case for several Oregon coastal communities, including Seaside and Cannon Beach in Clatsop County, and Rockaway Beach in Tillamook County, where hotels, motels, and rental homes are located closest to the beach. This sets up a problematic situation where a presumed less-informed group is farther away from safety and may take longer to depart, with resultant higher proportion of fatalities compared to the permanent residents. Although some hotel/motels in Lane, Douglas, and Coos counties are similarly located next to the ocean, high ground is generally closer to these facilities when compared with similar establishments in the northern counties. In other locations such as inside the Coos and Umpqua estuaries, although hotel/motels may be close to the water, they are generally located further up the estuary and hence have a little more time to reach high ground.

However, even with permanent residents, our assumptions of individuals' preparation and awareness may not match actual preparedness. For example, we assume a 10-minute departure time after the earthquake begins. Grumbly and others (2019) noted that permanent residents in a Washington coastal town underestimated the distance to tsunami safety and were often not aware of the optimal route to safety at different locations in their community. The City of Seaside survey data gathered by Buylova (2018) pointed to a pressing need for continued education on the tsunami threat. That study targeted primary and secondary homeowners but did not sample vacationers. Regarding the initiation of evacuation, 29.6% of survey respondents indicated that they would likely wait for confirmation of a tsunami prior to evacuation (i.e. phone notification or hearing a siren). However, about half the population indicated they were unlikely or very unlikely to wait for tsunami confirmation (24.3% and 22.8%, respectively). Many of the respondents (78 out of 207, or 38%) indicated they would attempt to evacuate by driving, which would be problematic given Seaside's constrained road evacuation network. Oregon state and county emergency management officials strongly discourage vehicular travel following an earthquake and instead emphasize travel on foot. The top three behaviors respondents said they would very likely carry out after a major earthquake are evacuating to higher ground immediately following the earthquake (51%), contacting loved ones (49.5%), and checking social media and television (40.3%).

The underlying field survey data used in Buylova (2018) provided further insights into education challenges. Among the 209 respondents, 17% did not correctly identify their home as being in or out of the tsunami zone; many incorrectly identified their house as being outside the tsunami zone. Only a small portion of the respondents identified themselves as secondary homeowners (5% respondents), and no significant difference was observed in perceptions or in plans between primary and secondary homeowner groups. Continued tsunami education and outreach are critically important for local residents as well as visitors in order to build the necessary culture of awareness needed to survive such a disaster. Education and outreach can be achieved through awareness programs at local, state, and federal levels.

Displaced population: Given the near-complete destruction of buildings within the tsunami zone (**Table 3-8**), planners should assume that all people who were in the area impacted by the tsunami and who successfully evacuated will need short-term (days to weeks) and perhaps even longer-term shelter (weeks to months for permanent residents who previously resided in the tsunami zone). The large influx

of temporary visitors in the summertime will increase demands on mass care facilities, placing even greater strain on local, state, and federal emergency managers. A major concern identified for all three counties is the potentially large number of people outside of community boundaries who will also be impacted by the earthquake and tsunami. Given how spread out many of these people are, a major challenge for emergency managers will be figuring out how to get supplies to people, while also evacuating many of these people to centralized locations where emergency shelters are established. Key to this process is to ensure that these people are well prepared and hence are "two-week" ready to ensure they can survive until help arrives.

5.0 CONCLUSION AND RECOMMENDATIONS

This study has evaluated the degree of impact associated with three CSZ tsunami scenarios in order to document potential building losses, debris weight, fatalities, injuries, and displaced populations throughout coastal Lane, Douglas, and Coos counties. The overarching goal of this work is to assist communities in their overall hazard preparation by identifying some of the expected challenges that will occur when the next great earthquake occurs on the CSZ and a tsunami is triggered. Great care has been taken as part of this study to address the needs of local communities. Discussions with local community planners, undertaken by Bauer and others (2020), helped frame the overall study approach and assumptions applied in our latest countywide Hazus modeling.

Education

Our analyses have improved estimates of fatalities and identified the presence of potentially very large temporary visitor populations, variations in the spatial concentration of both population groups within each community, and potential challenges facing those with physical or mental disabilities. Addressing these factors will be an important part of education and outreach at both the local and state level.

Our community-based information on the types of lodging visitors may occupy (e.g., motels, vacation rentals, second homes, or tents) and where these lodgings are predominantly located provide insights about the potential challenges that may face a community. Such information may help local communities better target their tsunami education/outreach activities and messaging to address the lack of hazard awareness by visitors, while also meeting the unique needs of the residential community. For example, ~82% of people visiting Winchester Bay are likely to stay at the campground near the port dock. Although high ground is close by, the evacuation route is over a bridge that is likely to fail, compromising safe evacuation. The only alternative is evacuation up a steep bluff immediately behind the campground or toward the Umpqua lighthouse, both of which require the evacuees to run toward the incoming tsunami. The data in this report provides local governments with the necessary information needed to evaluate various options, such as the construction of a vertical evacuation structure or hardening a bridge, that may ultimately best serve residents and visitors.

Besides vacation homes, our analyses demonstrate that a number of the coastal communities have significant numbers of hotels/motels located in the tsunami zone (especially XXL1). Those that do include Coos Bay, North Bend, Florence, Reedsport, and Bandon, where hotels and motels account for 52%, 50%, 27%, 26%, and 23% of beds where visitors may stay, respectively. Luckily, high ground is relatively close for each of these communities such that investment in appropriate signage, education of lodging staff, and access to high-resolution "neighborhood" scale evacuation maps in every hotel/motel room may be sufficient. Thus, tsunami education and outreach targeting each of these lodging groups become essential in order to mitigate against the potentially large loss of life likely to occur without such measures.

Two key approaches are in place to begin to address such needs:

1) The first is the development by Oregon Emergency Management of the "Tsunami Safe" program (*Hospitality Begins With Safety*). This effort focuses on increasing tsunami awareness among hospitality industry employees, including providing key tsunami and safety instructions that may be disseminated to hotel/motel guests. Trained hospitality staff can provide accurate messaging to the public before and during an event and, importantly, are able to help guide people out of the inundation zone. Evacuation guidance assumes that hospitality staff at every establishment know exactly where their nearest point of high ground is located.
2) To address evacuation information needs, DOGAMI staff, in partnership with the Northwest Association of Networked Ocean Observing Systems (NANOOS), developed a "print-your-own-tsunami-brochure" tool that is integrated in the NANOOS Visualization System (NVS) tsunami evacuation portal (http://nvs.nanoos.org/TsunamiEvac). This tool allows individuals or businesses to develop their own custom evacuation brochures for any location on the Oregon Coast. More recently, DOGAMI has initiated the development of higher-resolution tsunami evacuation neighborhood maps[11] that can be printed with conventional printers. It is thus conceivable that hotel/motel rooms could display tsunami evacuation maps in a manner similar to the fire escape exit maps required in every room. Increasing local awareness of these tools should thus be integrated in any future planned outreach activity.

Finally, building a culture of awareness is needed to survive the next CSZ tsunami. Such an effort could include funds to post and maintain tsunami wayfinding signage of sufficient density along core evacuation routes and to establish and support tsunami coordinators in every county. Tsunami coordinators could assist with identifying locations of people with disabilities, work with the local hotel/motel industry to develop appropriate evacuation map products, lead the planning of evacuation drills, and perform needed outreach at the grassroots level.

Mitigation

Tsunami evacuation modeling throughout coastal Lane, Douglas, and Coos counties demonstrates that improving existing evacuation trails for unimpeded passage — along with increased saturation of tsunami wayfinding signage — will help save lives. Of particular importance is having a sufficiently dense network of signs (posted and/or on road/path surfaces) that direct people along core routes to areas outside the tsunami zone. Such efforts, guided by our evacuation modeling results, are now being implemented in multiple communities on the northern Oregon Coast, including Seaside, Cannon Beach, Manzanita, and Newport. In each of these communities, a "beach to safety" plan has been developed for core evacuation routes, and signage consisting of posted signs as well as thermoplastic signage on roads and paths is being implemented. Signs of this nature need to be spaced sufficiently close together and illuminated at night so that the signage may be easily seen at all times.

Consideration should also be directed at barriers that may impede rapid evacuation. For example, downed power lines could pose a significant barrier to safe evacuation if the wires remain live following the earthquake. Communities could initiate conversations with local utility districts to assess if power can be immediately shut down during a major earthquake or if new power lines could be buried underground and existing ones relocated.

We recommend and encourage local communities to practice periodic tsunami evacuation drills, ideally on at least an annual basis, to instill a culture of tsunami-hazard awareness for residents and visitors. Studying an evacuation map is not the same as actually walking an evacuation route. Although we recognize that such an approach may be disruptive to the local economy and difficult to organize,

[11] https://www.oregongeology.org/tsuclearinghouse/pubs-evacbro_neighborhoods.htm

holding periodic drills will save lives. Such a culture is in practice in Japan and likely helped save many thousands of lives during the catastrophic tsunami event on March 11, 2011 (e.g., Nakaya and others, 2018; Sun and Yamori, 2018).

Mitigation options to improve evacuation may also include facility improvements such as seismic retrofits of key bridges or the construction of vertical evacuation structures. Although seismically retrofitting bridges will be critically important for post-disaster recovery (e.g., the Umpqua bridge by Reedsport or the Megler Bridge in Coos Bay), the only community we identified as having a dependency on bridges for evacuation purposes was Winchester Bay. Construction of vertical evacuation towers in a few key locations could potentially save lives. Of the communities examined here, the community of Barview is particularly exposed to the tsunami hazard (Gabel and others 2019b).

In many communities, people reside in older manufactured housing. Manufactured homes installed prior to 2003 are susceptible to slipping off their foundations during earthquake shaking (OBCD, 2010; SPA Risk LLC, 2014; Maison and Cobeen, 2016; EERI, 2014), potentially blocking or compromising egress. Even if a manufactured house is relatively close to high ground, compromised egress may hinder timely evacuation. Seismic upgrades of such structures to current building standards may be cost-prohibitive. FEMA (2012b, Section D) advises having large crowbars and sledgehammers stored near potentially compromised primary doors to facilitate emergency exiting. Such tools may provide manufactured housing occupants with a low-cost solution for rapidly exiting their structure in the critical time interval between earthquake cessation and tsunami arrival.

Response

Our analyses demonstrate that destruction of buildings in the tsunami zone will be virtually complete, whether the scenario is M1 or XXL1. Accordingly, all Oregon coastal communities will need to be prepared to shelter large numbers of people who escape the tsunami. The need for shelter is likely to last many weeks until tsunami evacuees can be relocated out of the disaster area. This will be especially challenging for communities with potentially large numbers of temporary residents, all of whom are unlikely to be able to return to their permanent homes for at least several weeks, given the anticipated disruption to the regional transportation network and fuel supply (ODOT, 2014; ODOE, 2017). As demonstrated here, depending on the time of year, the number of displaced persons could range from a few tens (e.g., Dunes City) to potentially many thousands (e.g., Coos Bay, Florence, North Bend, Barview, and Bandon, in a worst-case summer scenario with every vacancy filled).

Mass casualties will vary significantly from community to community due to exposure and access to high ground. Overall, injuries caused by the tsunami alone were found to be low, averaging about 4% to 15% across the coastal communities, depending on the scenario. This finding is not unexpected because most people who are unable to evacuate in time and are caught by the tsunami are killed. Combined earthquake and tsunami related injuries presented here reflect the following:

	M1	L1	XXL1
Lane	750	730	810
Douglas	750	200	240
Coos	1,980	2,150	3,520

Given that there are about 483 licensed beds at the 11 coastal hospitals (OSSPAC, 2013), these facilities can be expected to be quickly overwhelmed. Because of this capacity issue, Wang (2018) examined approaches for coastal hospitals to better prepare for a Cascadia event, including improving building seismic resiliency, establishing a resilience network where knowledge and training could be shared, and evaluating and planning for fuel and water needs. In addition to these suggestions, mass care planning is

necessary to prepare coastal hospitals for a potential surge in injuries and illness. To that end, further work is required to better refine these casualty numbers.

Recovery

A CSZ earthquake and tsunami will be catastrophic to both the state and local economies. At the local level, these impacts will vary substantially. Quantifying such economic impacts is well beyond the scope of this investigation. Nevertheless, we can speculate on several likely scenarios. Overall, building destruction in coastal Lane, Douglas, and Coos counties could yield an estimated ~302,000 tons of debris in the M1 scenario, increasing to ~515,000 tons for L1, and over one million tons in an XXL1 event. These estimates are almost certainly on the low end, as they exclude the content volume within buildings (e.g., personal and business-related items), vehicles, and other forms of debris. Utilizing the number of households throughout the three counties (5,878 buildings), we estimate an additional 29,400 tons (assuming five tons per household) of debris could be generated from personal effects. This equates to ~3% of the total volume of debris reported in Table 3-4. The estimated building replacement cost for coastal Lane, Douglas, and Coos counties is likely to exceed $6.2 billion in an M1 event, $6.4 billion in L1, and $7.0 billion in an XXL1 earthquake and tsunami. These numbers emphasize that regardless of the size and characteristics of the next Cascadia earthquake and tsunami, the impact will be severe for the Oregon Coast.

Wood-frame construction dominates many Oregon coastal communities. The majority of such buildings in the tsunami zone will probably be completely destroyed by the tsunami. This means that for Lane, Douglas and Coos counties, there is likely to be a significant shortage of suitable housing in the months and perhaps years following the disaster. In the absence of housing, tsunami refugees will likely migrate away from such communities, further decimating the local economy. The housing situation will likely be compounded by the altered coastal landscape due to subsidence effects caused by the earthquake. For example, the earthquake deformation models used to simulate tsunami inundation estimate that the coastline could drop by the following amounts (data derived from Witter and others, 2011):

	M1	L1	XXL1
Lane	0.8 m (2.6 ft)	1.2 m (3.9 ft)	1.8 m (5.9 ft)
Douglas	1.3 m (4.1 ft)	1.8 m (5.9 ft)	2.7 m (8.9 ft)
Coos	2.1 m (6.9 ft)	3.0 m (9.8 ft)	4.7 m (15.4 ft)

Such changes will inevitably lead to accelerated rates of coastal erosion along with increased incidences of coastal flooding in low-lying areas. These changes can be expected to be significant in the weeks to months following the event, with further change progressively decreasing over time as the coastline re-equilibrates to the new sea level regime.

Finally, our analyses indicate that many buildings in the tsunami zone are outside existing coastal or riverine FEMA flood zones. As a result, owners are not required by federally backed mortgage lenders to carry flood insurance. However, flood insurance is available to all building owners in the tsunami zone through the National Flood Insurance Program, which covers building loss due to a tsunami (FEMA, 2018), and can aid in community recovery. More information on the National Flood Insurance Program can be obtained from https://www.fema.gov/flood-insurance.

Vulnerable Populations

We provided population estimates from American Community Survey (ACS) data for selected population groups that may have special challenges understanding preparedness messages or evacuating (Section 3.6). The ACS estimates are for the entire community, including people outside the tsunami zone, so the

total number of individuals identified in this report is likely to be higher than those actually in the tsunami zone. Planners wanting to further understand the specific locations of vulnerable populations are encouraged to discuss the situation with their local public health preparedness coordinators. Other resources include the emPOWER database[12], which tracks electricity-dependent Medicare populations and the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS)[13], which tracks health-related risk behaviors, chronic health conditions, and use of preventive service by U.S. residents. Although our focus in this study was on quantifying casualties from a local tsunami, such information on vulnerable populations can also be useful when planning evacuation from distant-source tsunamis.

Finally, our model does not account for populations living in the tsunami zone who are currently experiencing homelessness. However, homeless encampments are likely present in the tsunami zones of many Oregon coastal communities, and outreach messaging should include this population.

6.0 ACKNOWLEDGMENTS

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[12] https://empowermap.hhs.gov/

[13] https://www.cdc.gov/brfss/index.html

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8.0 APPENDIX A: COMMUNITY PROFILES FOR LANE, DOUGLAS AND COOS COUNTIES

Appendix A includes additional summary information specific to each community. These data include the effects of both the earthquake and accompanying tsunami (M1, L1, and XXL1) that can inform preparation, recovery, and mitigation planning.

A) Area analyzed: We summarized data when possible within the community's designated urban growth boundary (UGB). Planners consider the UGB as a more inclusive and useful aggregation unit compared to city limits. However, some data are available only at the city limits level, specifically the most current population estimates and U.S. Census Bureau American Community Survey data. For unincorporated communities, we used a geospatial layer of unincorporated community boundaries compiled by the Department of Land Conservation and Development (DLCD). The summary community profile maps highlight several datasets, including the boundary used for analysis (UGB, city limits, or DLCD outline depending on data availability), building placements and tsunami zone. In addition, the maps include the results of the evacuation modeling (path distances) based on a 1.2 mps (4 fps; walk) evacuation speed (with 10-minute delay) out of the inundation zone. We distinguish the chance of successful evacuation (green lines) versus increased likelihood of fatality (red lines). In all cases, the likelihood of successful evacuation improves significantly if individuals increase their evacuation speed or leave sooner.

B) Population demographics: These data reflect the permanent (resident) population within each respective tsunami zone (M1, L1, and XXL1), expressed as absolute numbers and as a percentage of the total community population. A conservative estimate of the number of temporary visitors is also presented, assuming 100% occupancy of vacation homes, hotel/motels, and camping areas. Additional demographic information of the permanent population distinguishes those <65 years and those over 65 years of age.

C) Distance to safety: Distance to safety plots show the number of permanent and temporary residents as a function of distance to safety. The closer a person is to safety (i.e., right side of the figure) the greater the chance of successful evacuation. The distance to safety figure includes a 1.2 mps (4 fps) threshold line (vertical dash black line). Left of this line, the model assumes people will not be able to evacuate out of the inundation zone in time, while those to the right have a greater chance of surviving. We also include a two-standard-deviation gray dash line that highlights uncertainty in the 1.2 mps (4 fps) threshold, which is a function of the wave arrival time and uncertainty in peoples' travel speed. Finally, we include a cumulative percent curve to further define the proportion of people relative to safety in the community.

D) Distance to safety and building type: This figure is similar to C), with the exception that it now defines the tendency of people (permanent and temporary) to be in particular building types. Here we distinguish between the following building types: single-family residential, manufactured housing, multifamily residential, hotel/motel, and mobile (e.g., tent, RV, etc.). These data define where people tend to be predominantly located. For example, many coastal hotel/motels tend to be located close to the ocean and are mostly used by visitors.

E) Building losses: The effects of a M_w 9.0 Cascadia Subduction Zone earthquake and accompanying tsunami (M1, L1, and XXL1) in terms of economic losses and debris generated are included in this figure. For each tsunami zone, we define the number of buildings in the zone and the building replacement cost. Earthquake losses are defined for the tsunami zone and as a total for the entire community. These data are then combined with the tsunami losses calculated by Hazus. Finally,

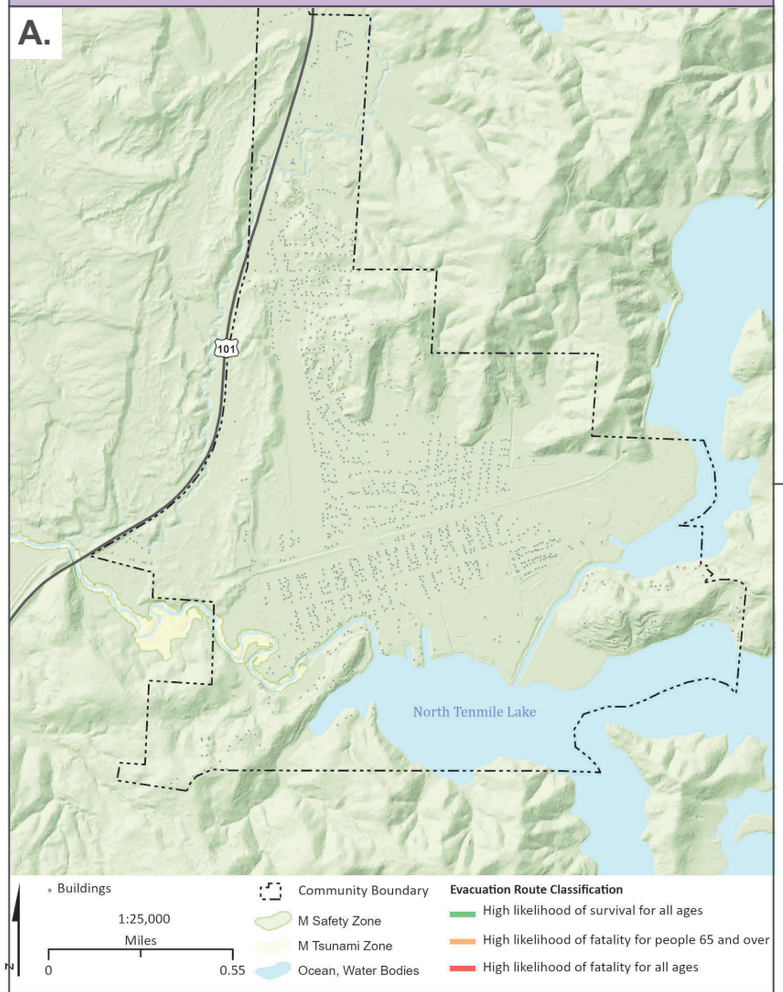
the weight of debris generated by the tsunami is also presented. As a reminder, these data do not include the weight of content in buildings and therefore reflect a minimum value.

F) Fatalities and displaced population: To standardize tsunami injury and fatality estimation across all communities, we assume the entire population, as a group, evacuates at 4 fps (2.7 mph), which is regarded as a moderate walk. In all cases, we factor in a 10-minute evacuation delay prior to getting underway that accounts for ~3 minutes of expected earthquake shaking and up to 7 minutes for people to organize themselves, leave the building, and begin to evacuate. For each community, we provide graphical representations of the modeled fatalities, for both permanent and temporary residents. For the temporary population we assume 10%, 50%, and 100% occupancy estimates. The displaced population is defined as the difference between the local (permanent) population and the fatalities (for permanent and temporary). Planners can apply their own judgment as to the occupancy levels associated with the temporary visitors and adjust downward from the 100% occupancy estimate.

Lakeside - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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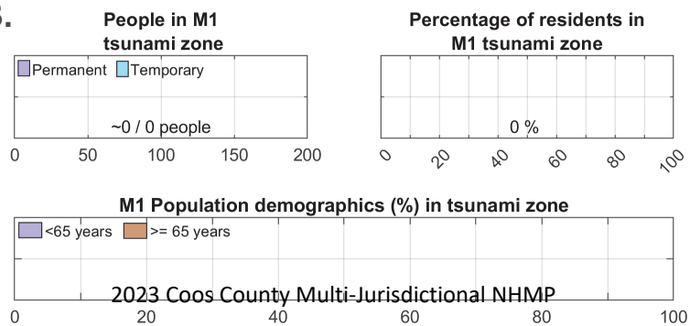

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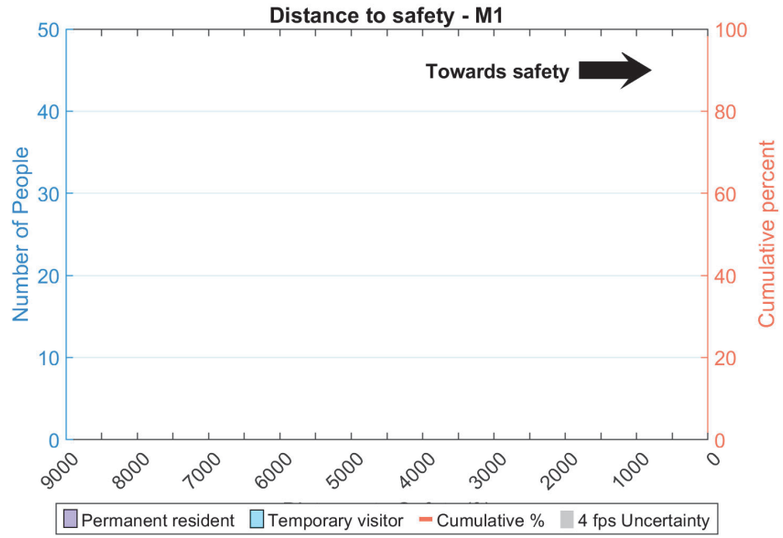

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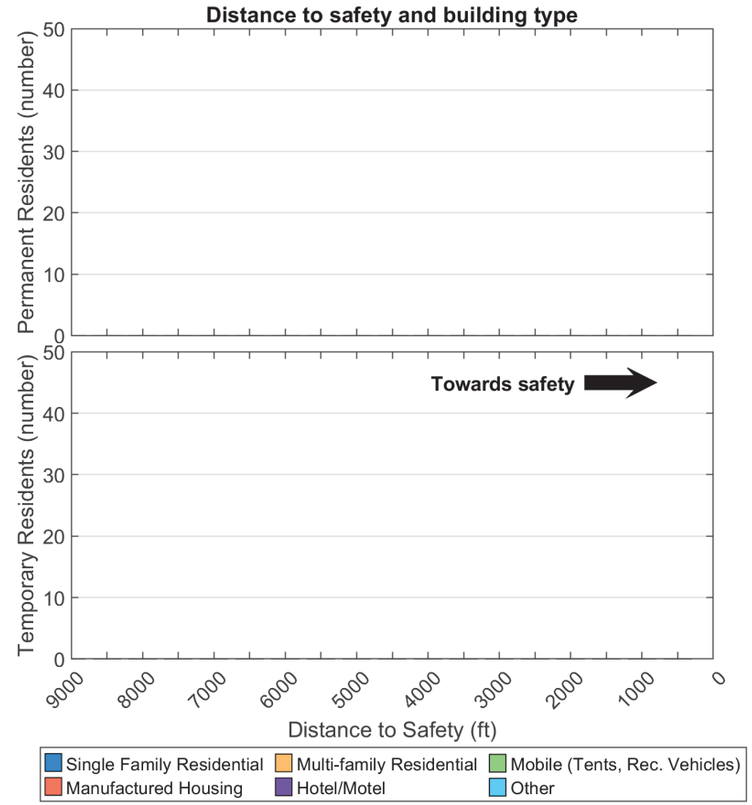

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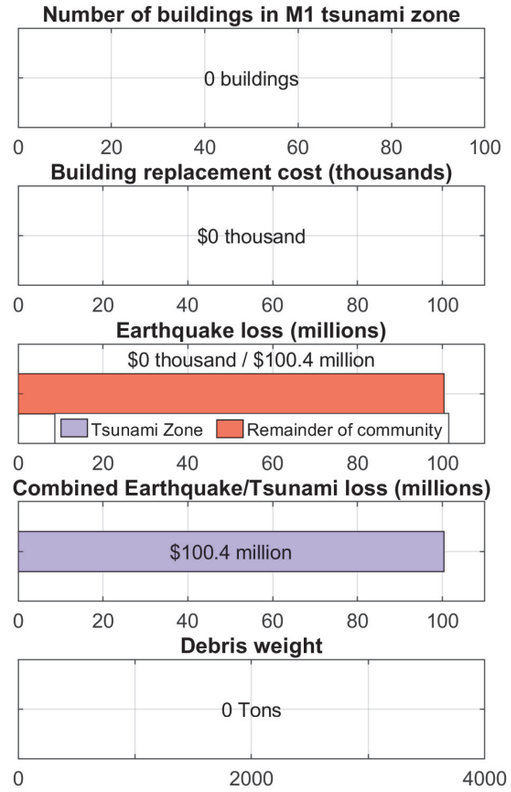

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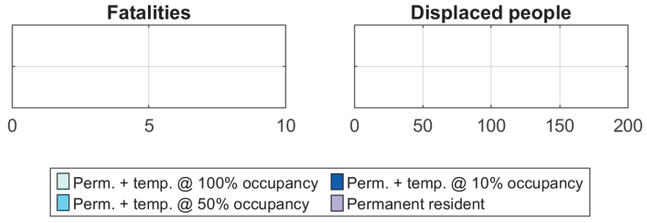
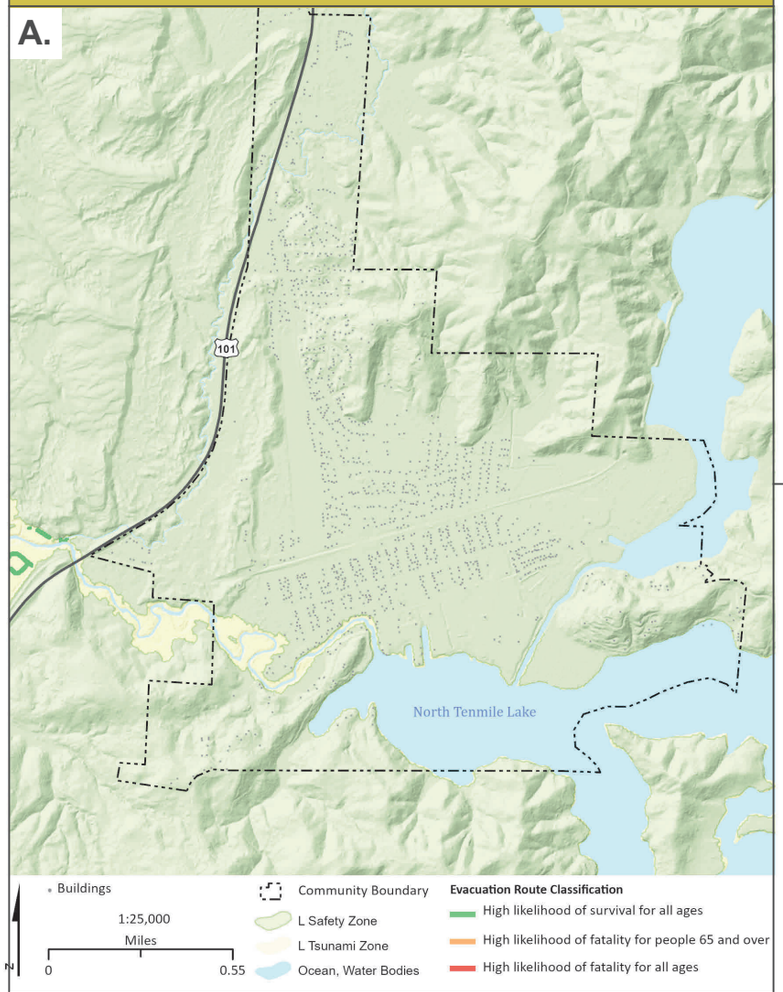


Description	Total
Earthquake Injuries (Entire Community)	76
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	0
Displaced Population - Permanent + Temporary	0

Lakeside - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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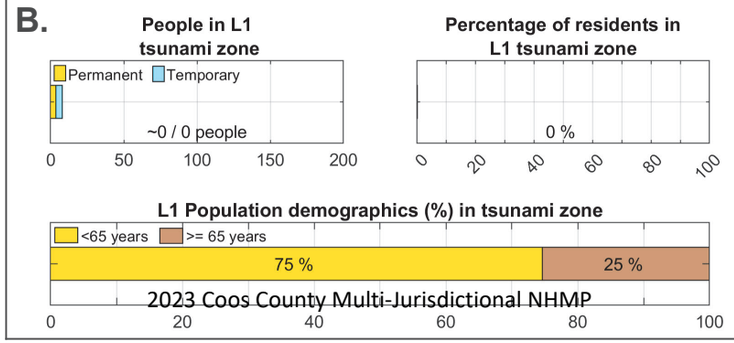

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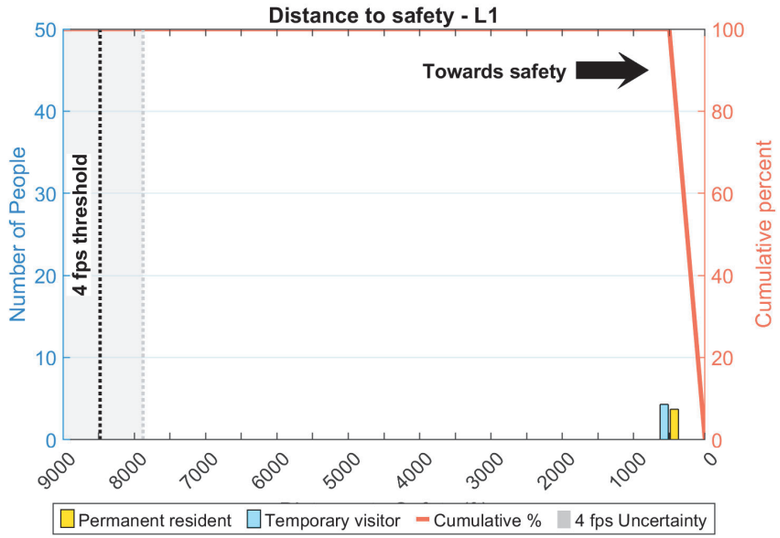
C.



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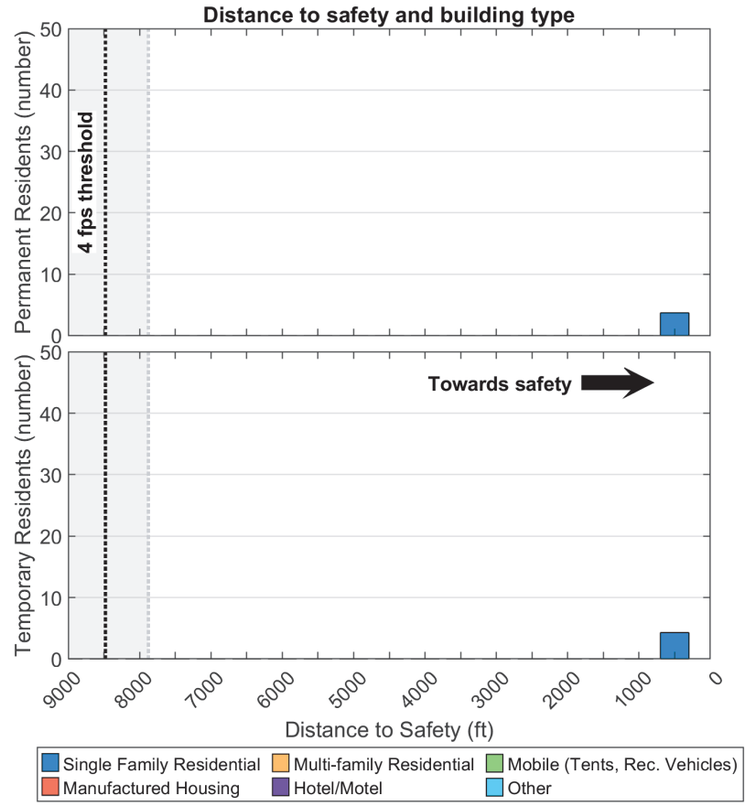

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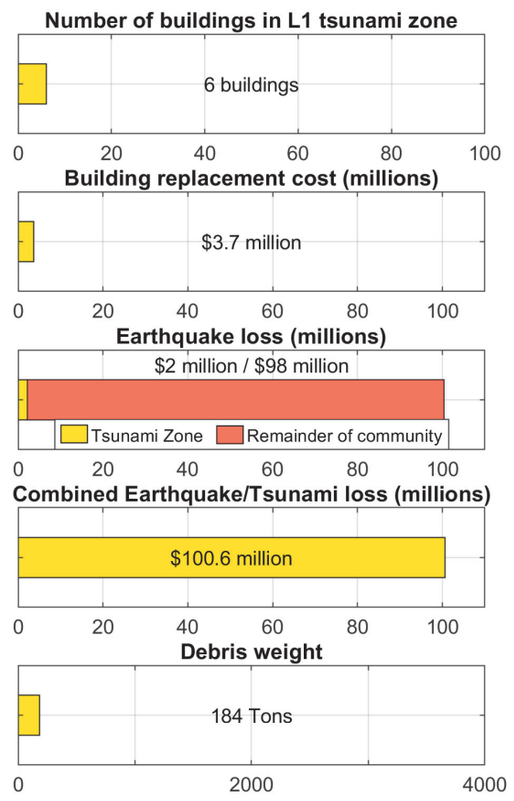

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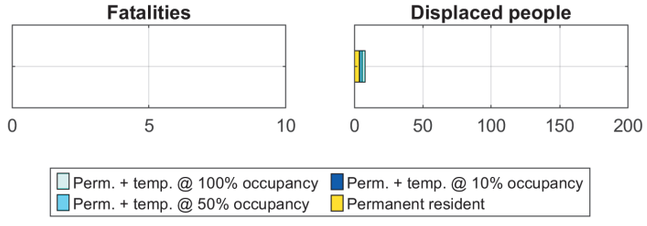

Description	Total
Earthquake Injuries (Entire Community)	76
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	4
Displaced Population - Permanent + Temporary	8

Lakeside - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

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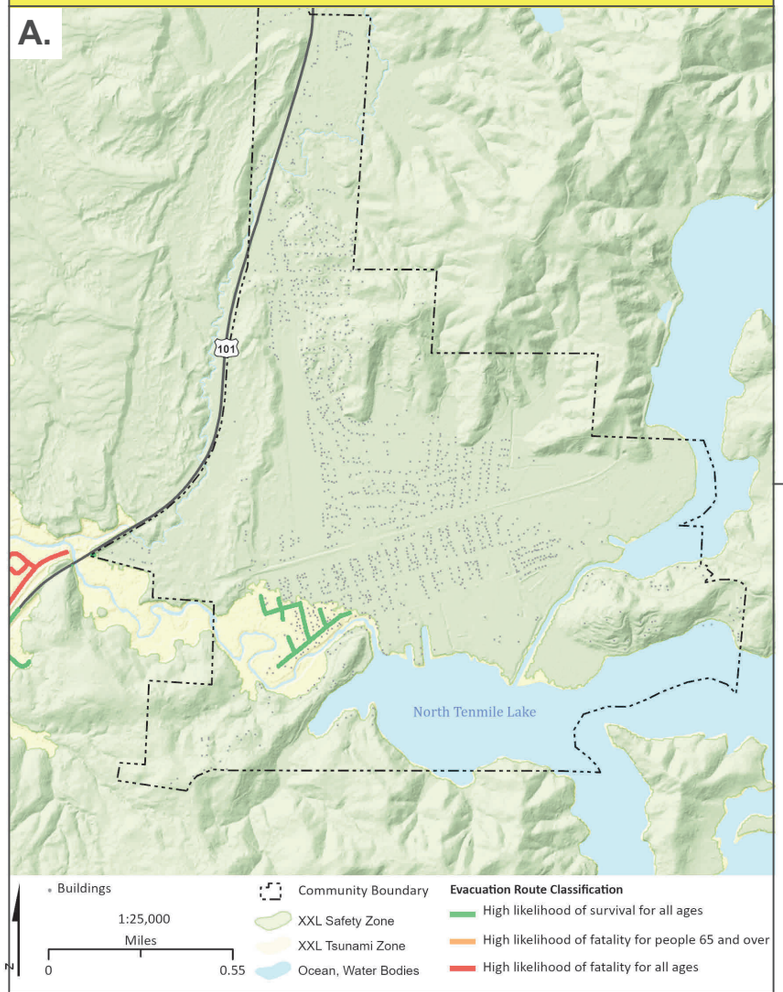

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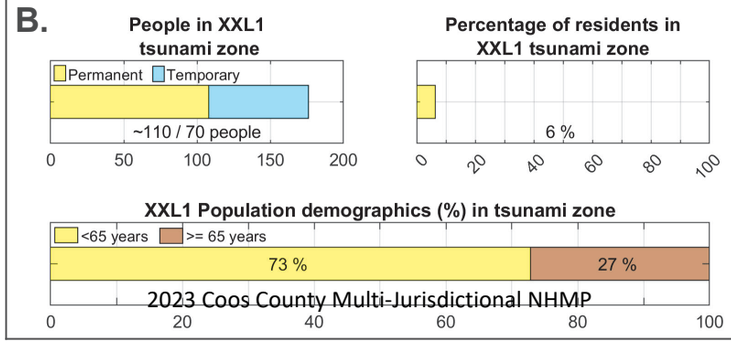

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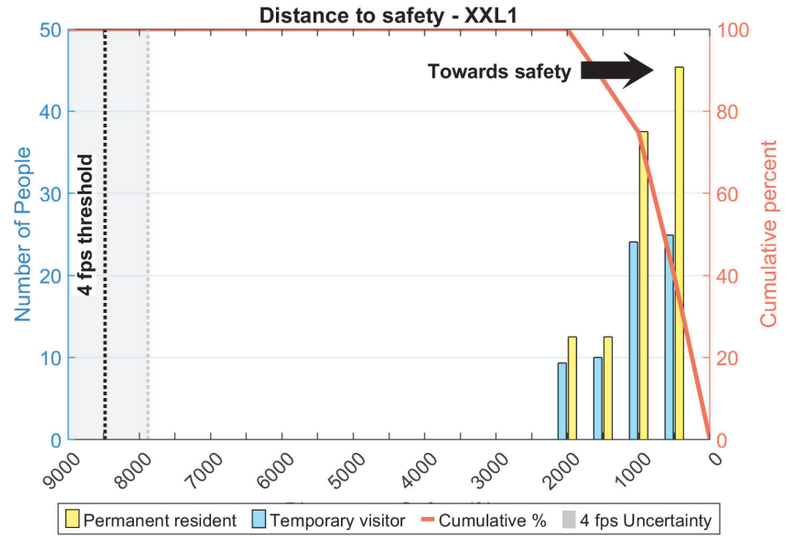

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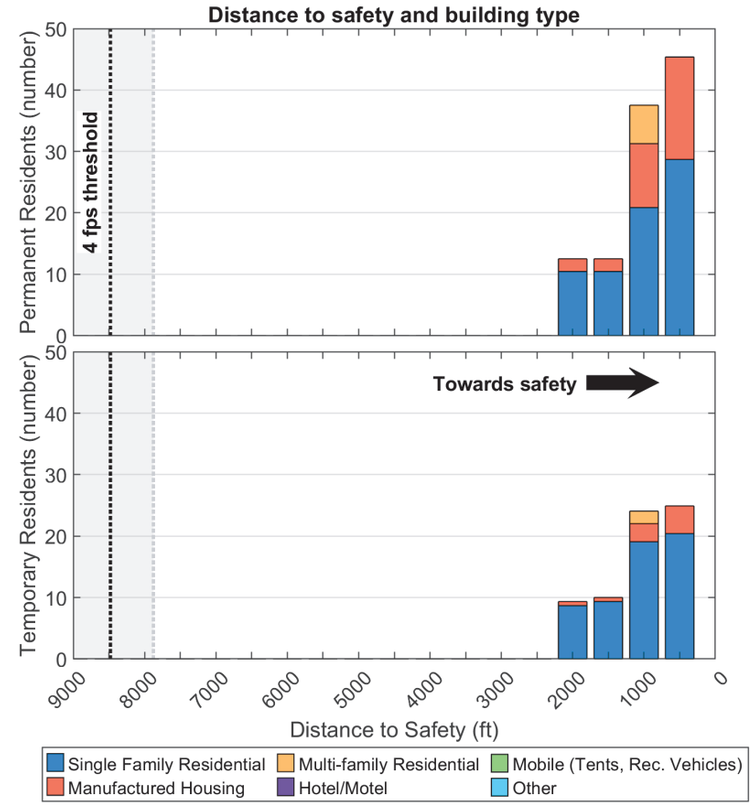

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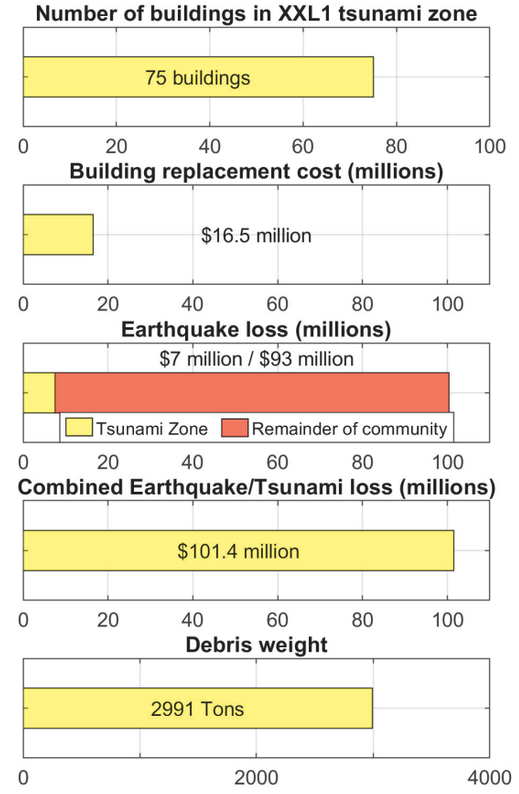

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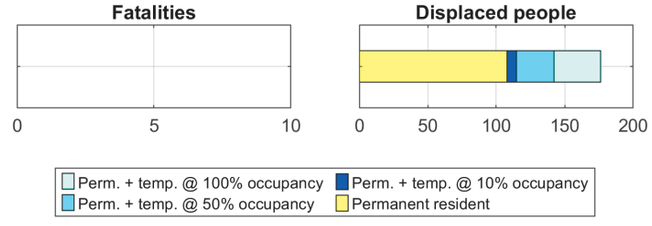
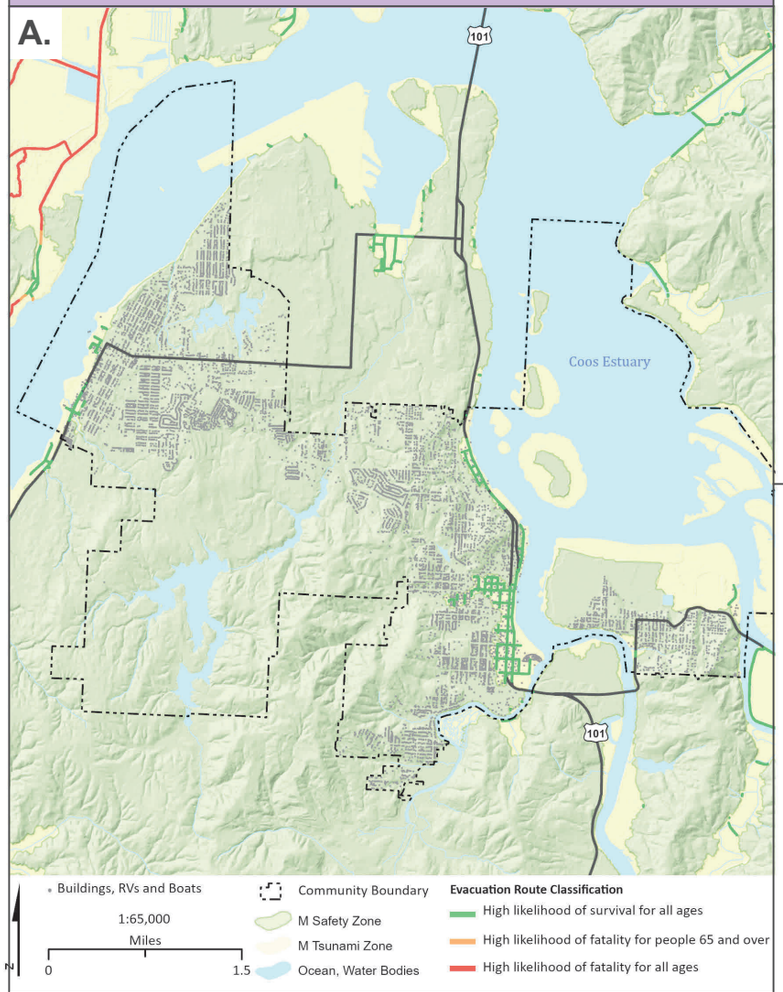


Description	Total
Earthquake Injuries (Entire Community)	76
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	108
Displaced Population - Permanent + Temporary	176

Coos Bay - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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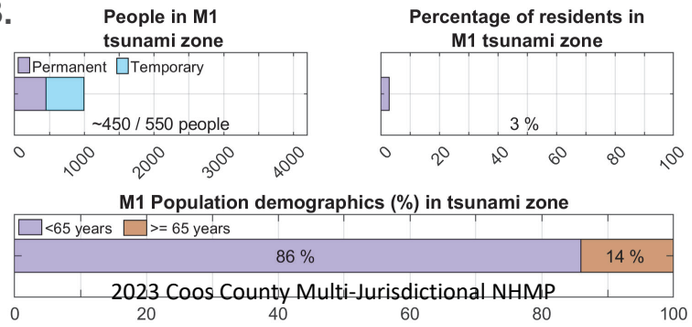

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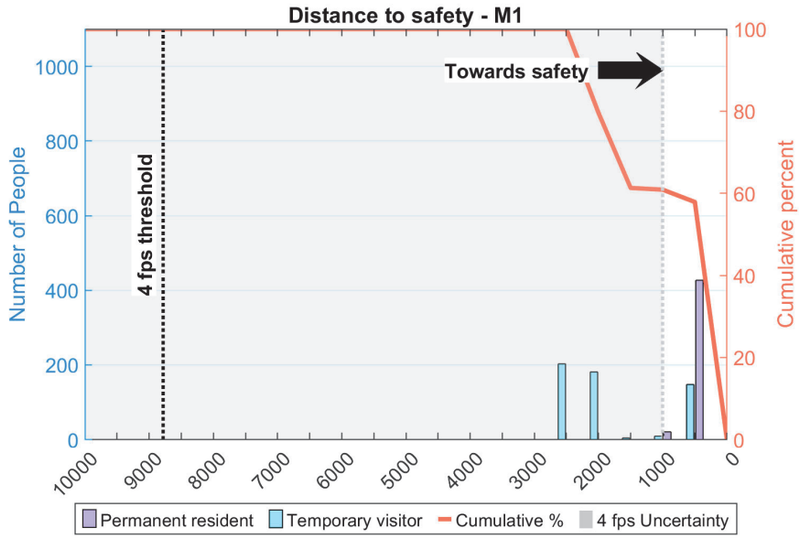

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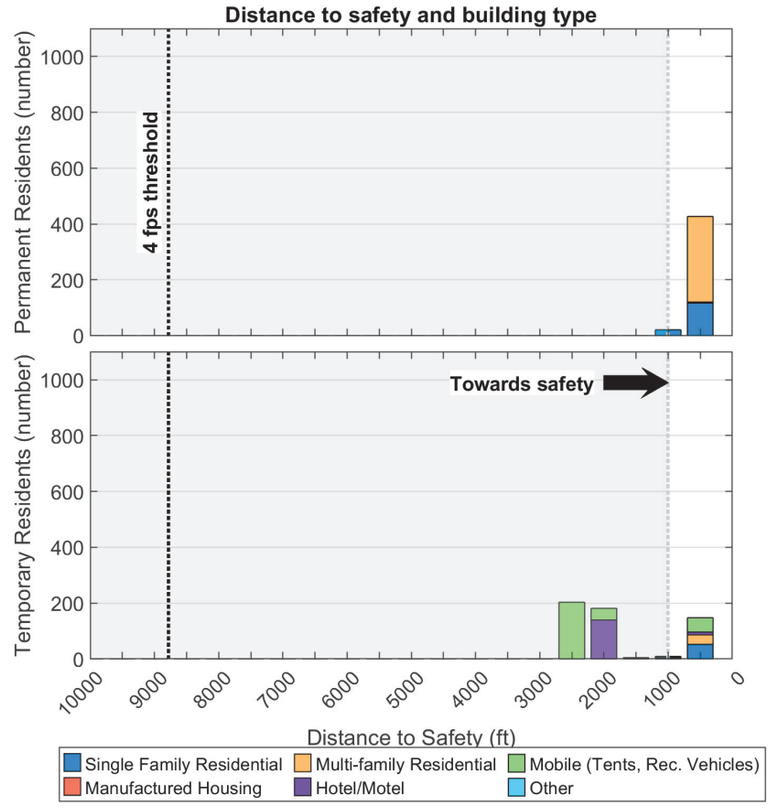

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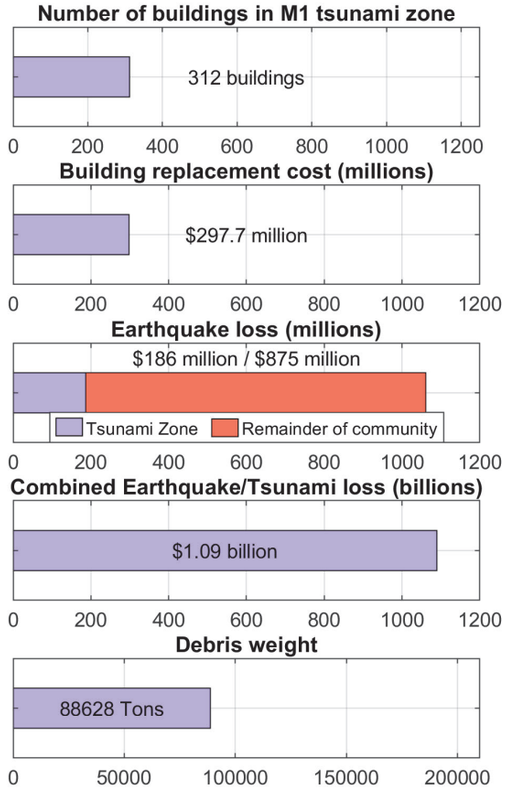

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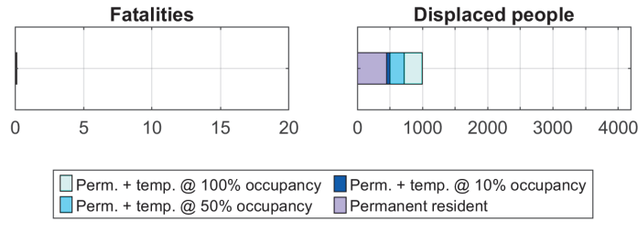
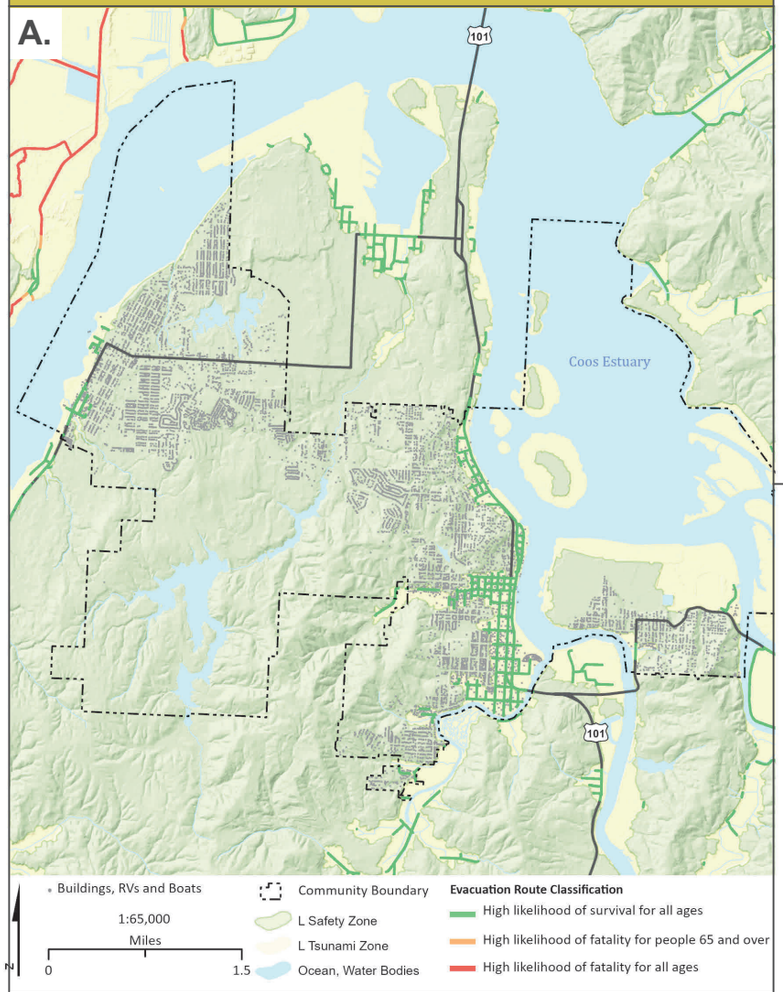


Description	Total
Earthquake Injuries (Entire Community)	441
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	448
Displaced Population - Permanent + Temporary	993

Coos Bay - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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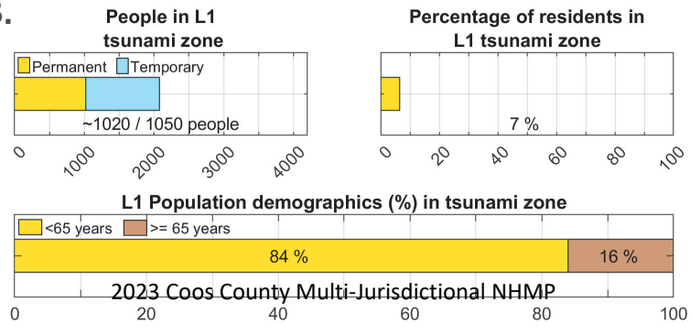

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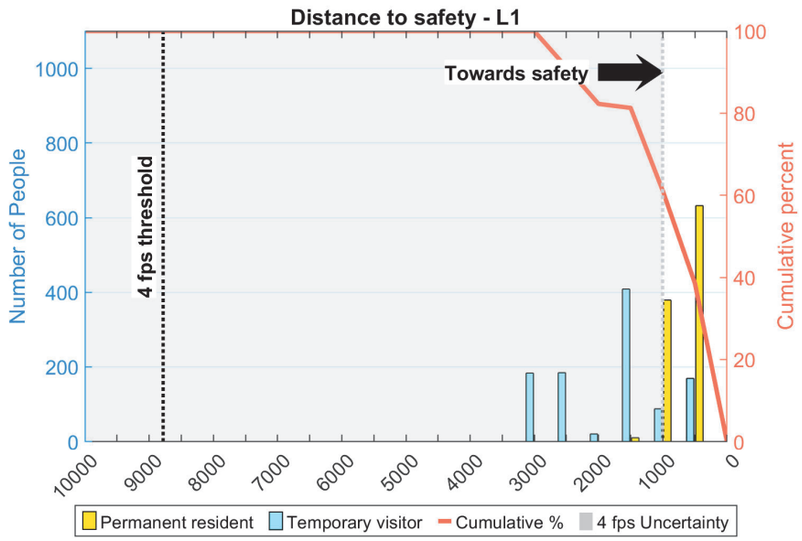

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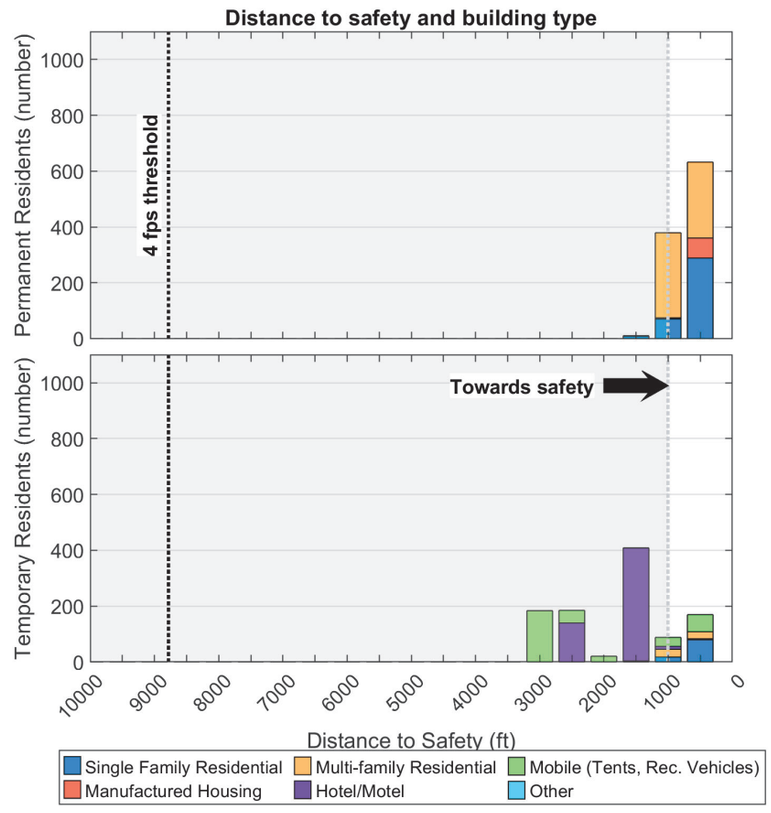

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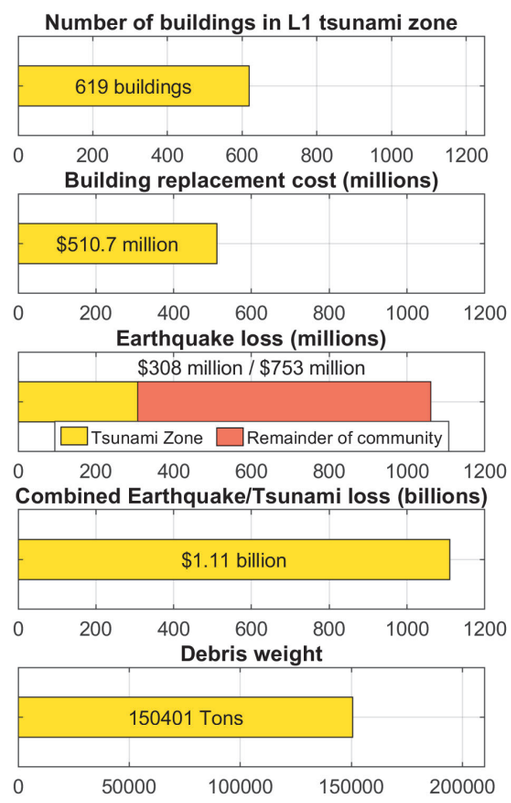

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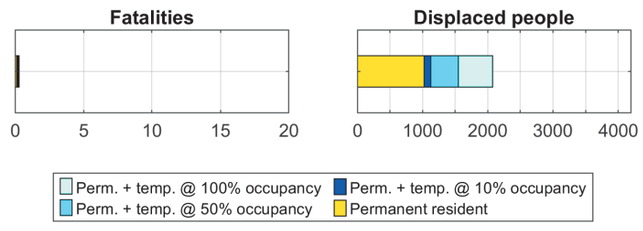
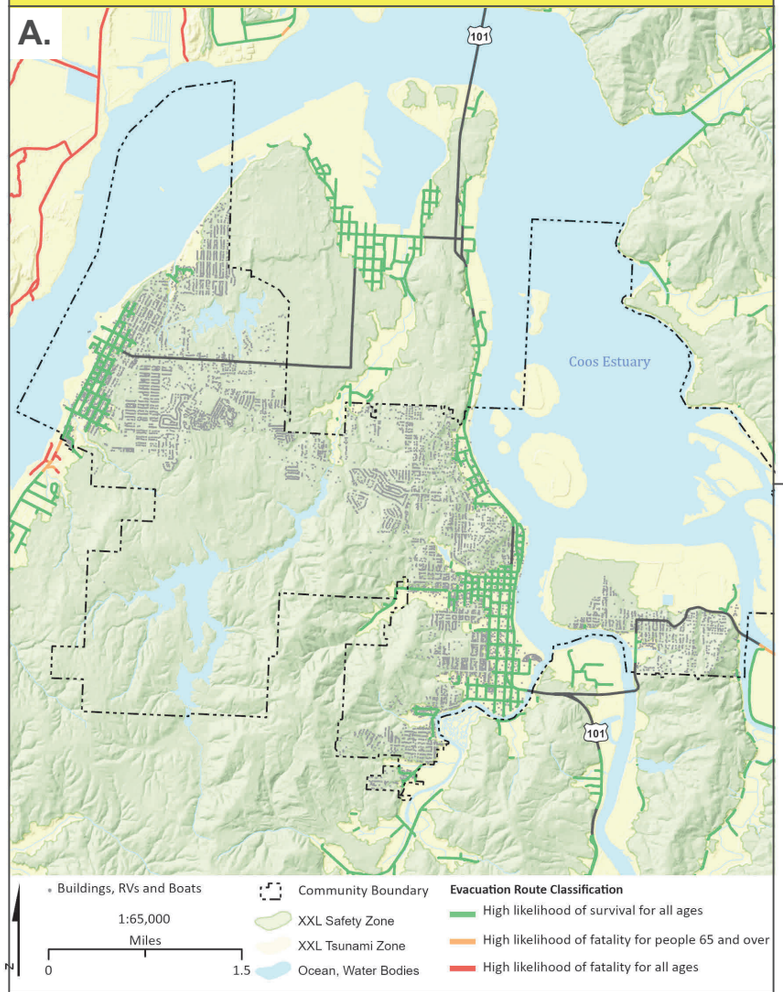


Description	Total
Earthquake Injuries (Entire Community)	441
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	1,021
Displaced Population - Permanent + Temporary	2,075

Coos Bay - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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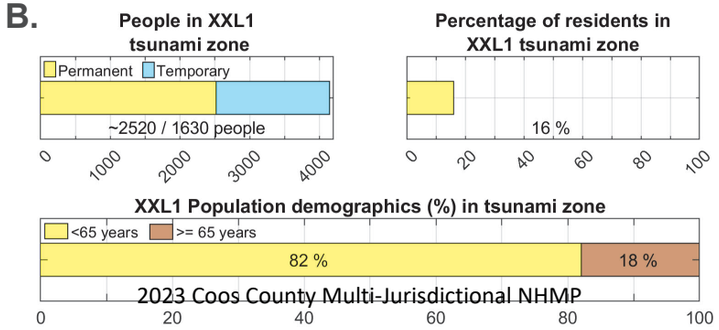

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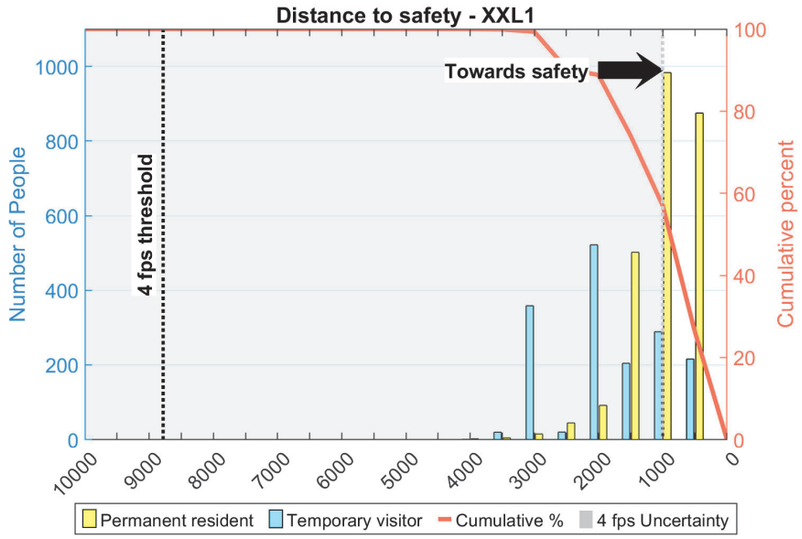

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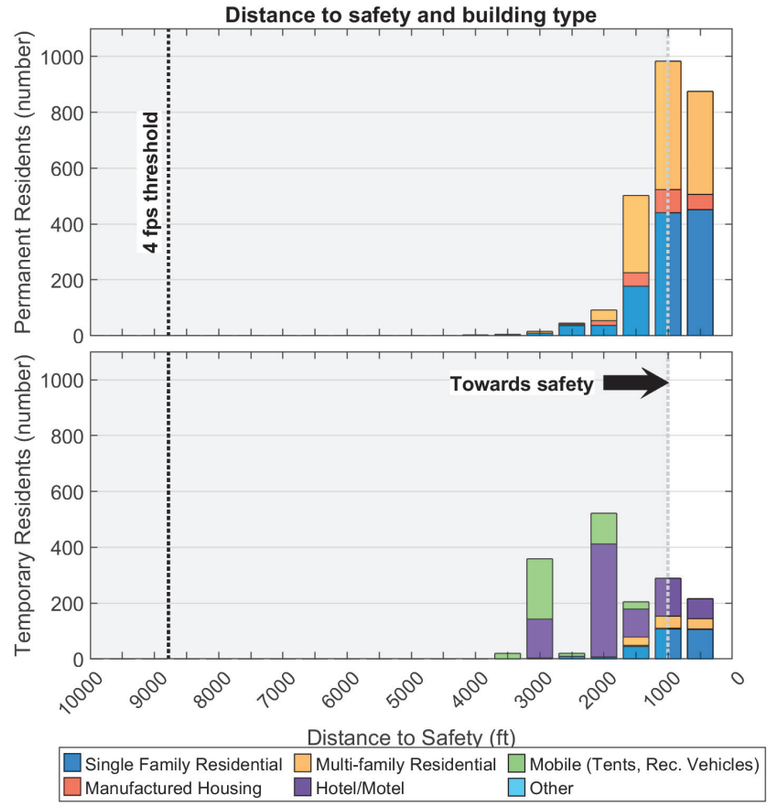

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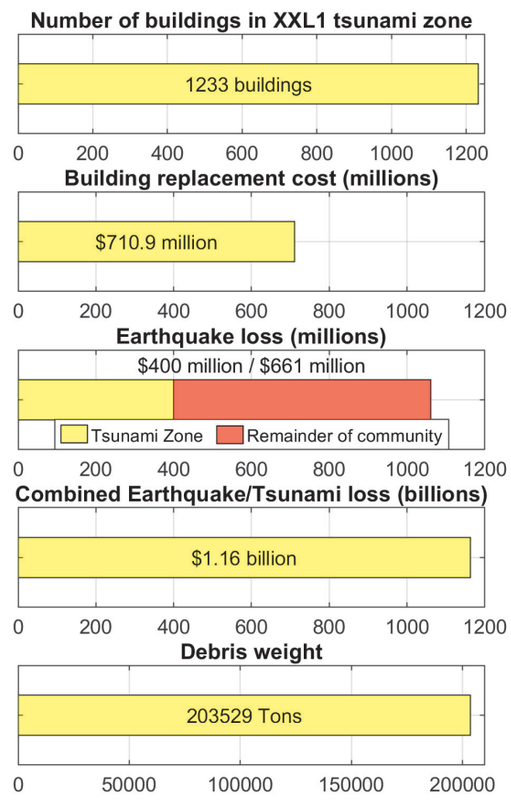

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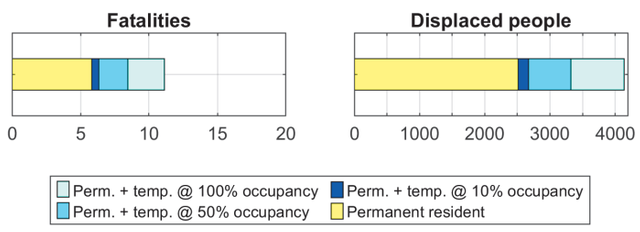
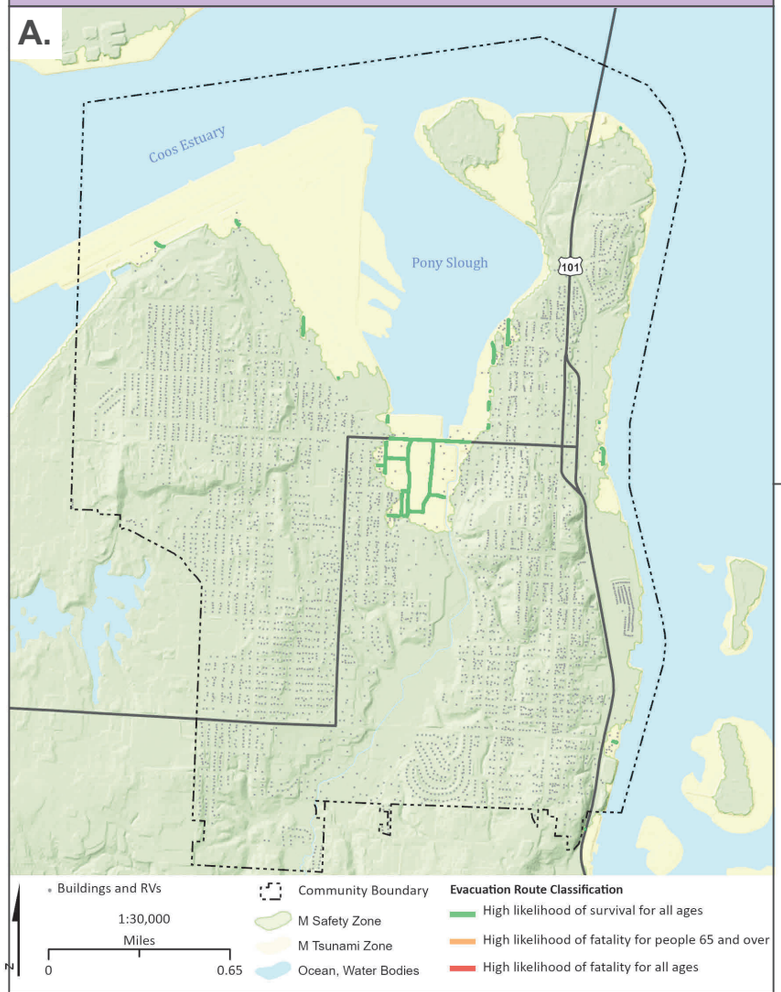


Description	Total
Earthquake Injuries (Entire Community)	441
Tsunami Injuries - Permanent + Temporary	7
Tsunami Fatalities - Permanent	6
Tsunami Fatalities - Temporary @ ~100% occupancy	5
Displaced Population - Permanent	2,511
Displaced Population - Permanent + Temporary	4,136

North Bend - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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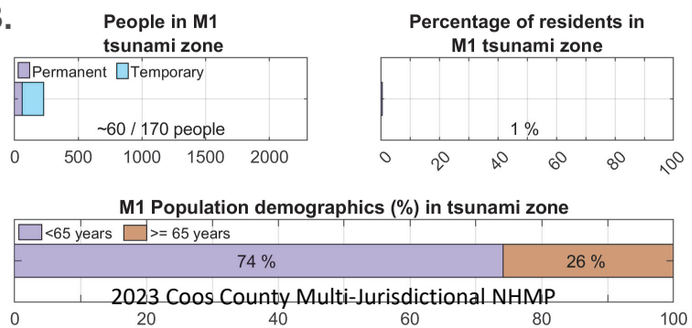

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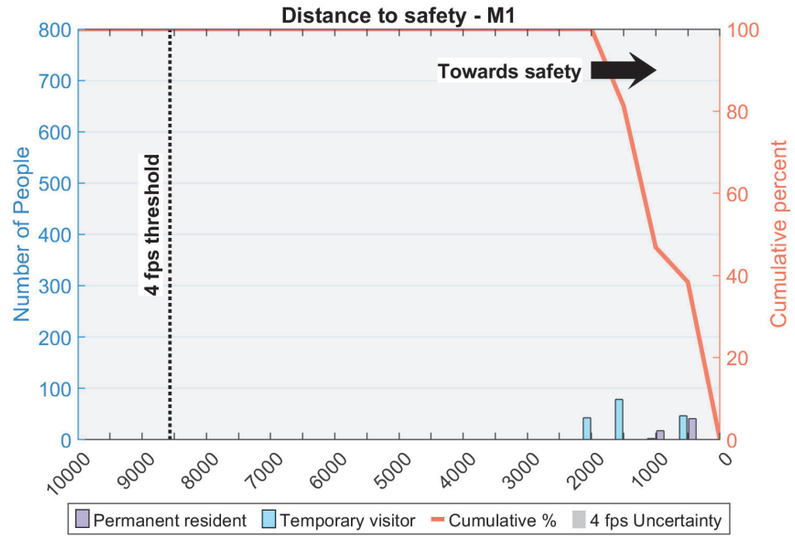
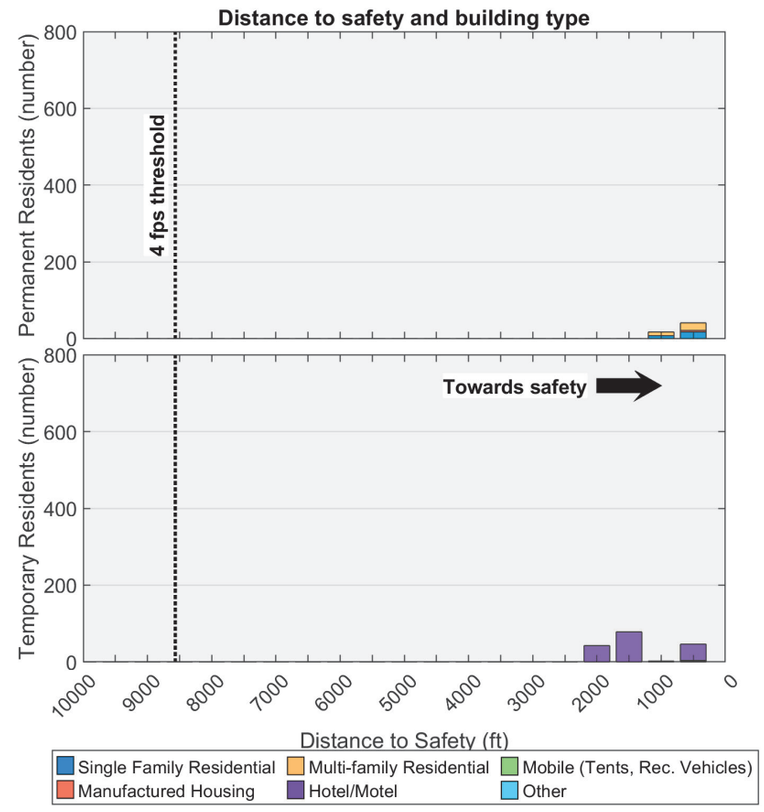


D.



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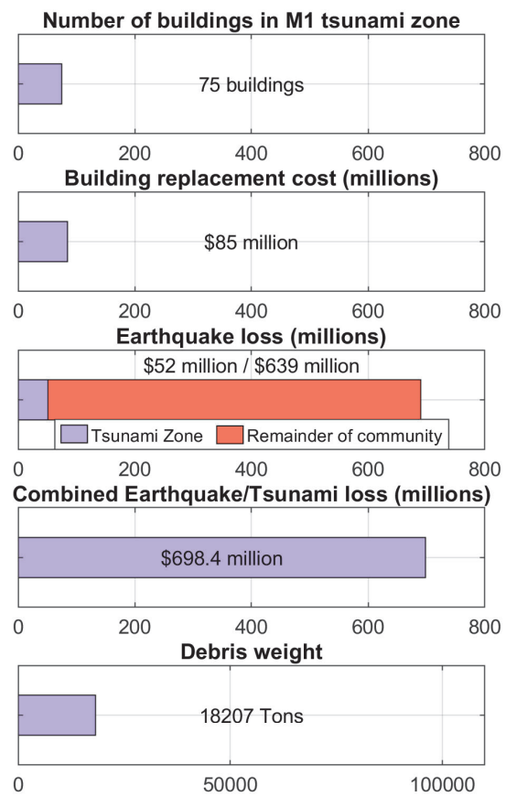

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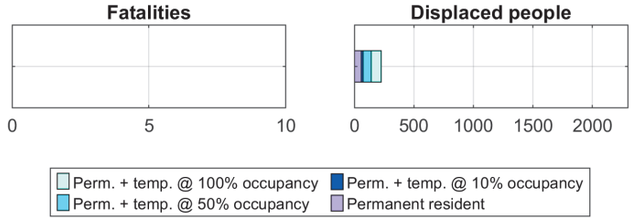
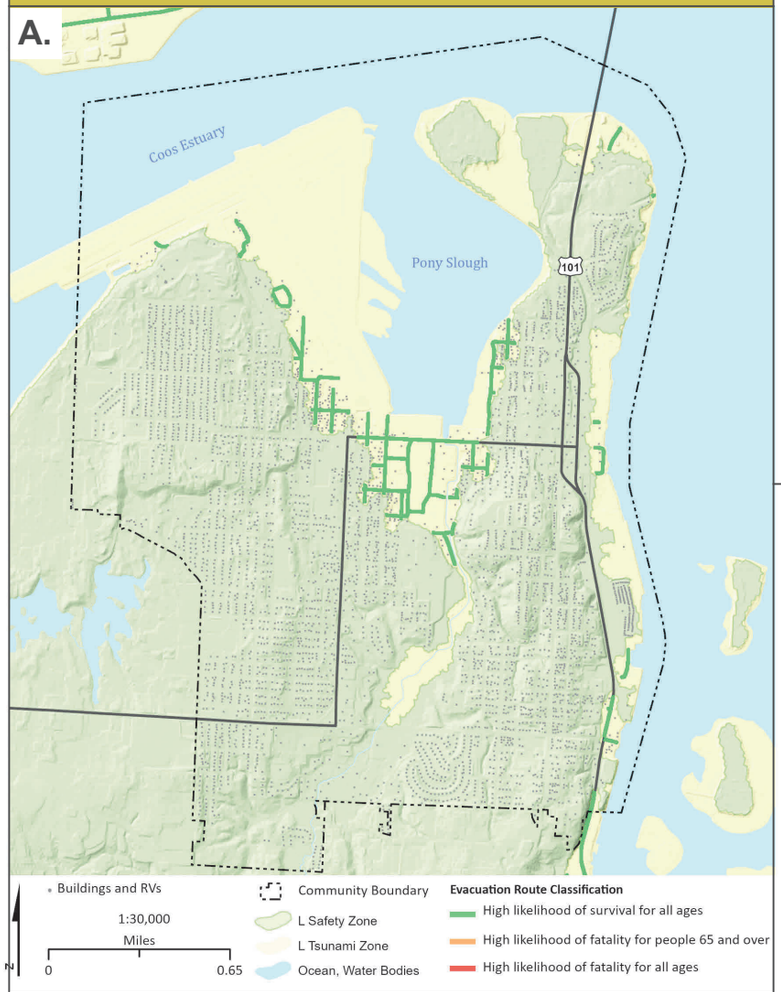


Description	Total
Earthquake Injuries (Entire Community)	267
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	58
Displaced Population - Permanent + Temporary	227

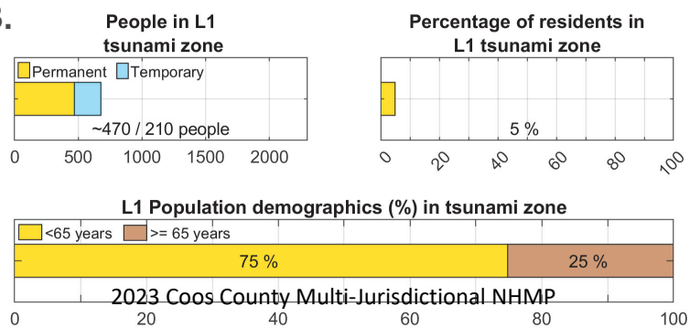
North Bend - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

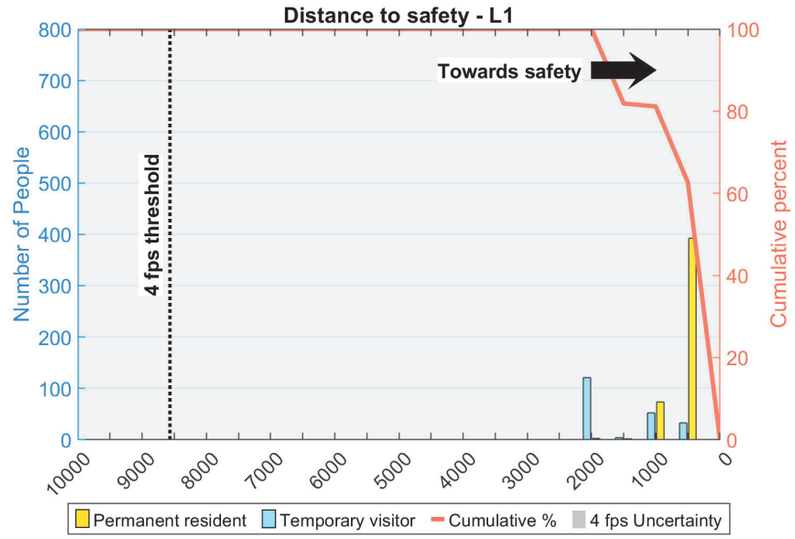
A.



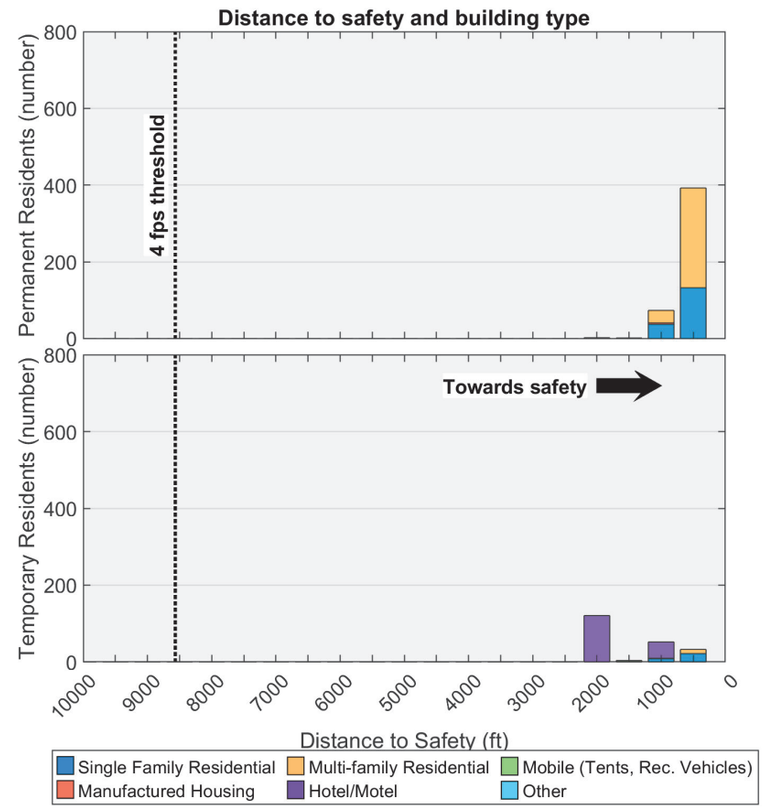
B.



C.



D.



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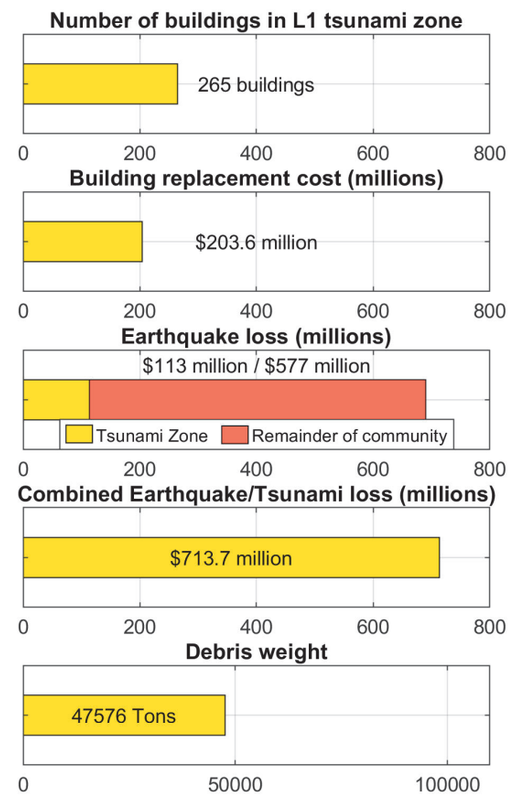

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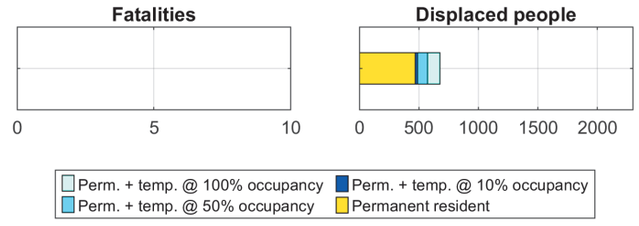
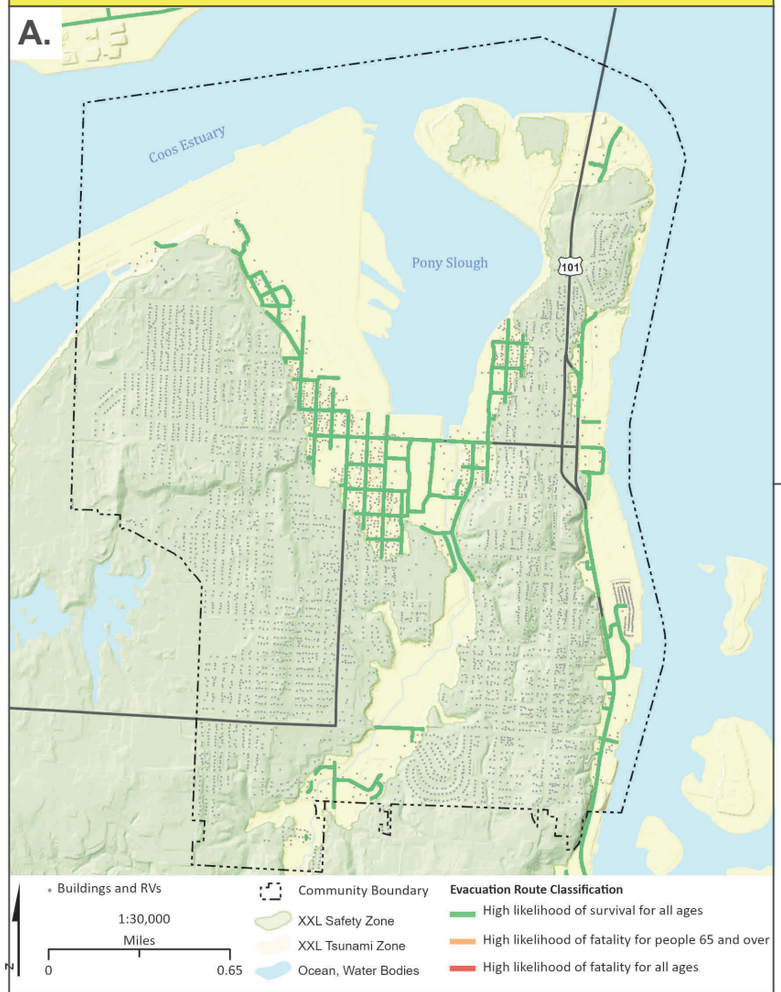


Description	Total
Earthquake Injuries (Entire Community)	267
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	469
Displaced Population - Permanent + Temporary	678

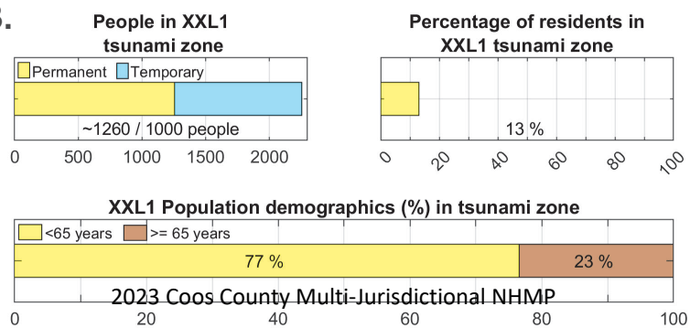
North Bend - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

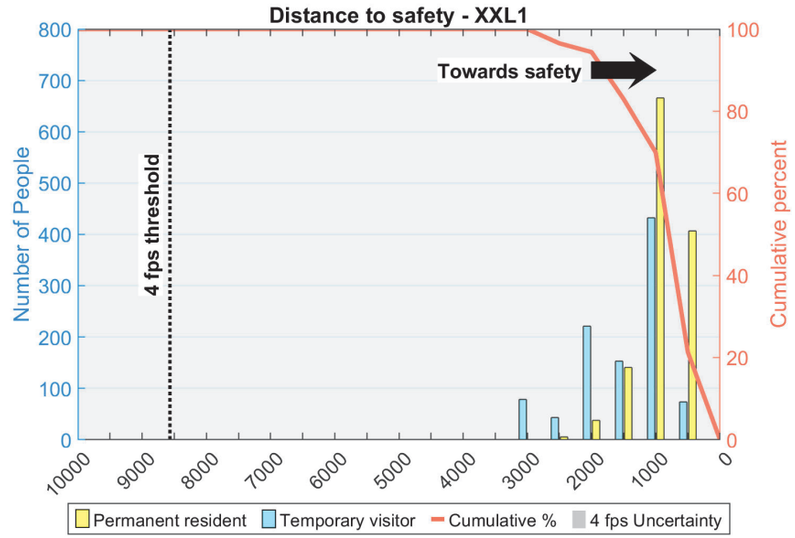
A.



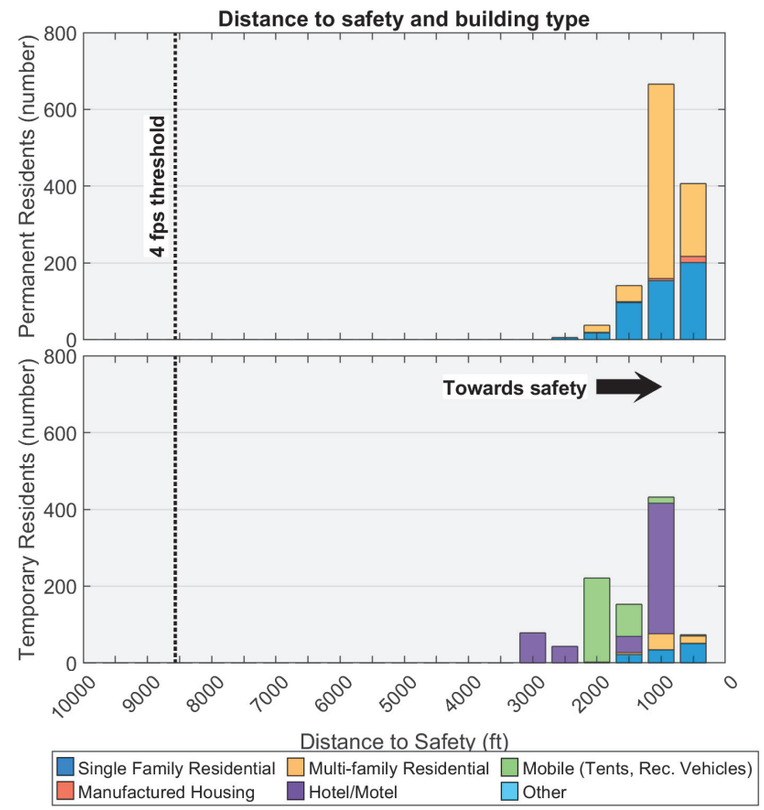
B.



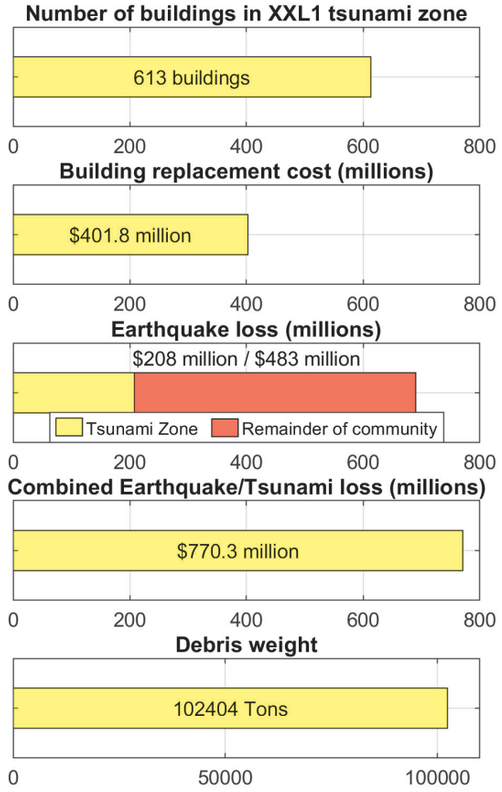
C.



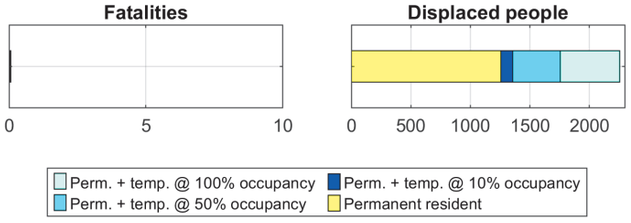
D.



E.



F.

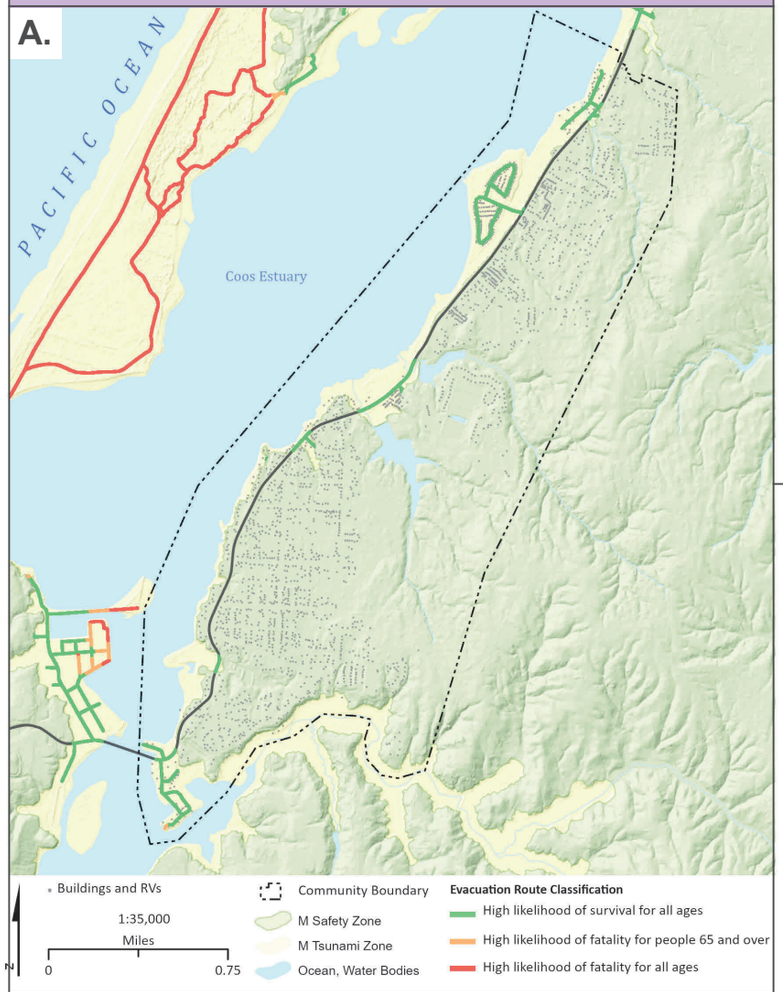


Description	Total
Earthquake Injuries (Entire Community)	267
Tsunami Injuries - Permanent + Temporary	0
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	0
Displaced Population - Permanent	1,255
Displaced Population - Permanent + Temporary	2,256

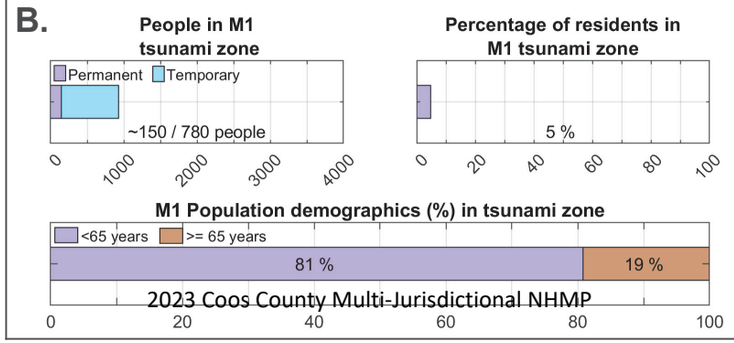
Barview - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



B.



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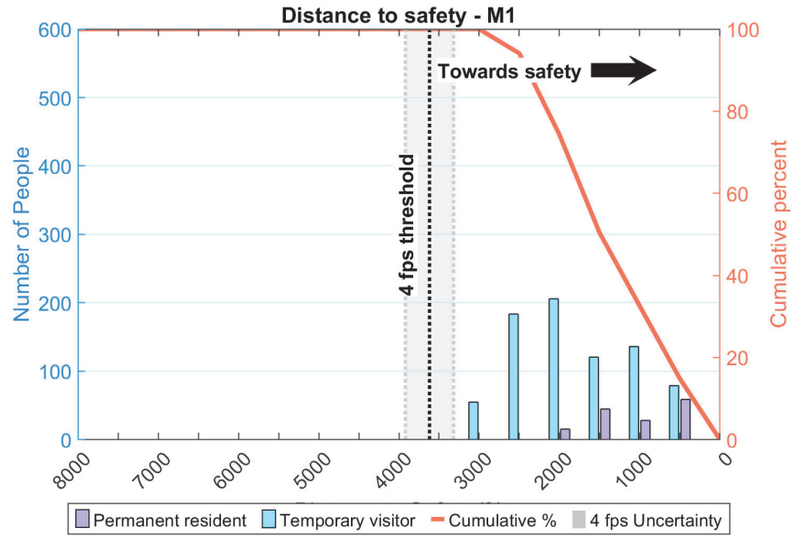
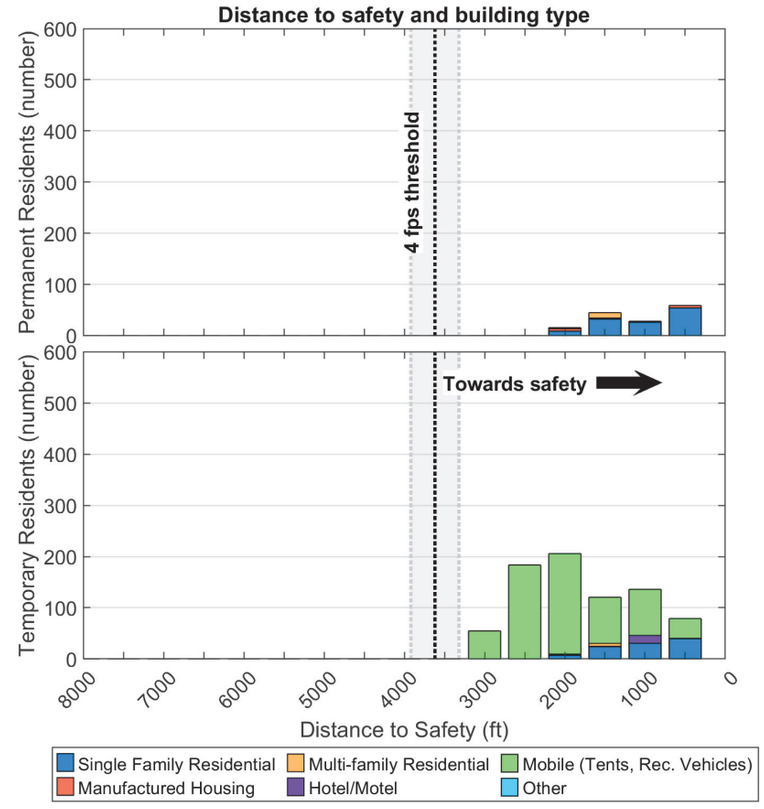


D.



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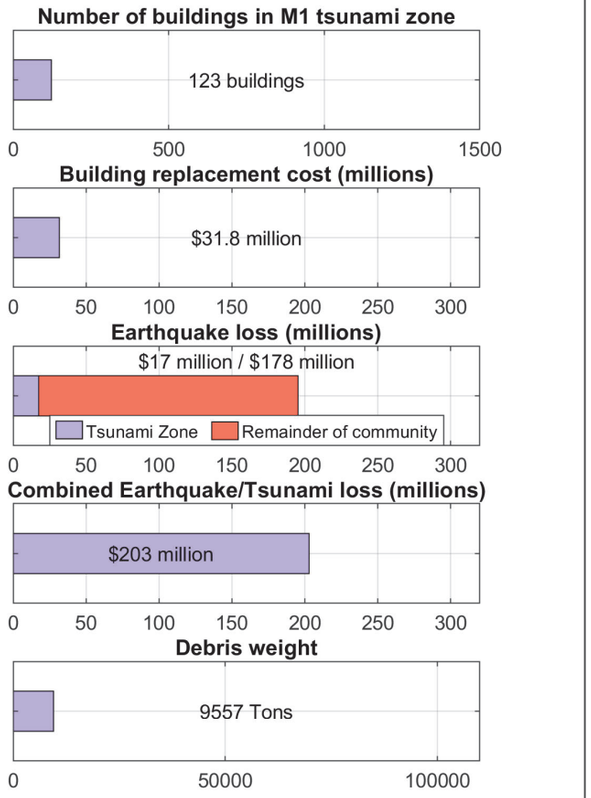
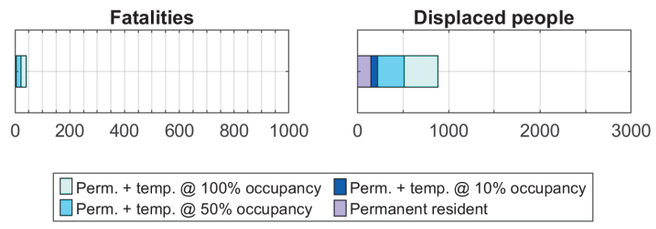


F.



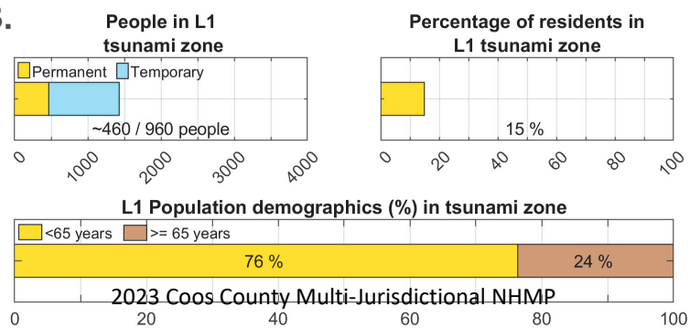
Description	Total
Earthquake Injuries (Entire Community)	130
Tsunami Injuries - Permanent + Temporary	11
Tsunami Fatalities - Permanent	1
Tsunami Fatalities - Temporary @ ~100% occupancy	41
Displaced Population - Permanent	146
Displaced Population - Permanent + Temporary	884

Barview - L1

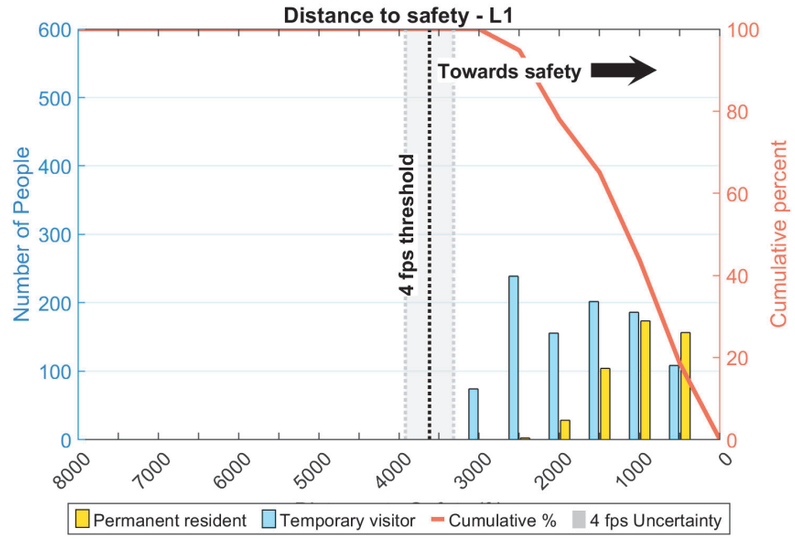
Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.

B.



C.



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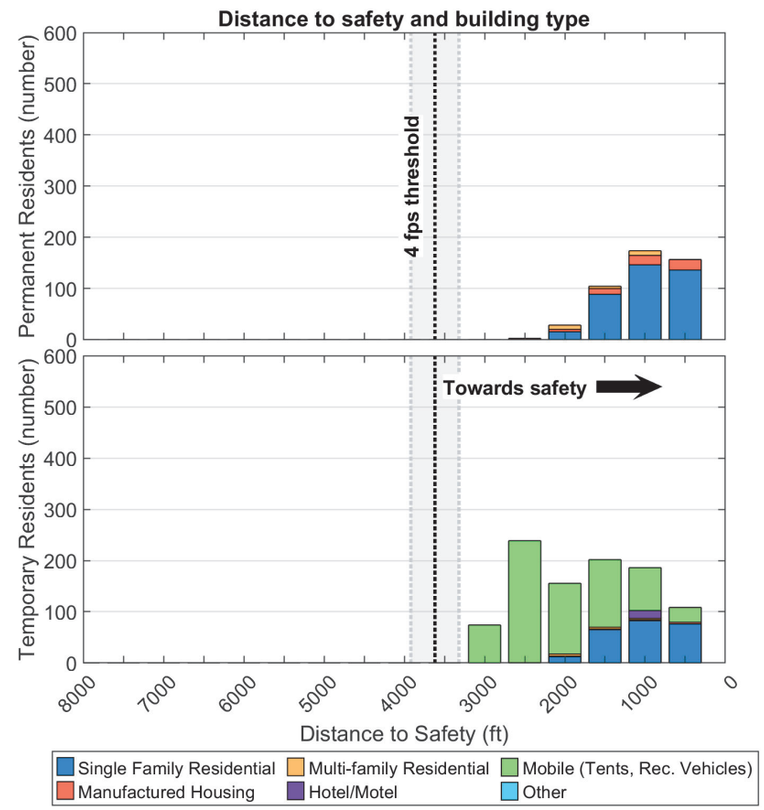
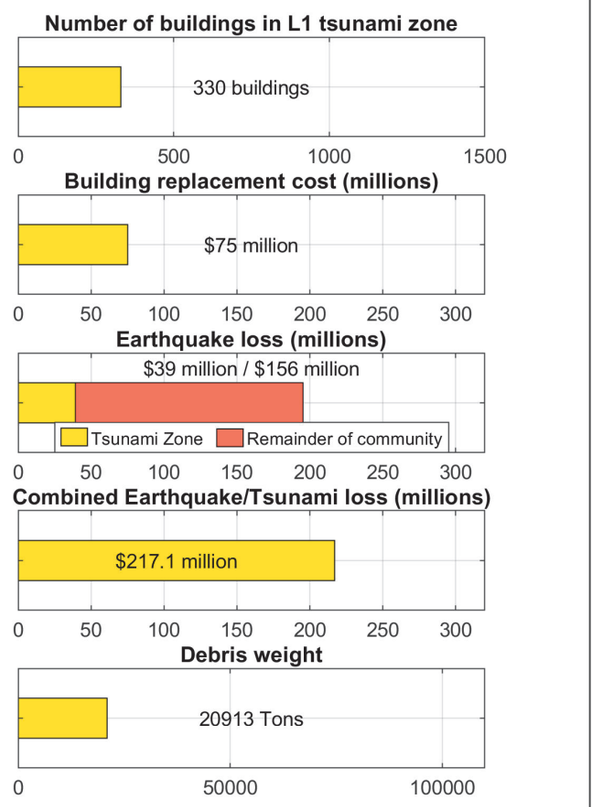


E.



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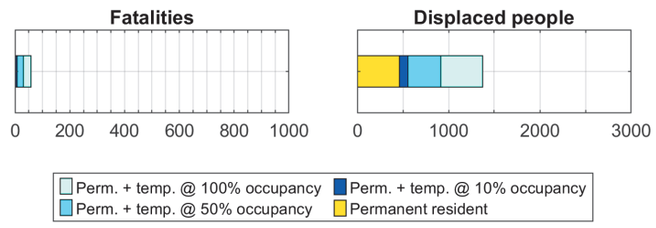
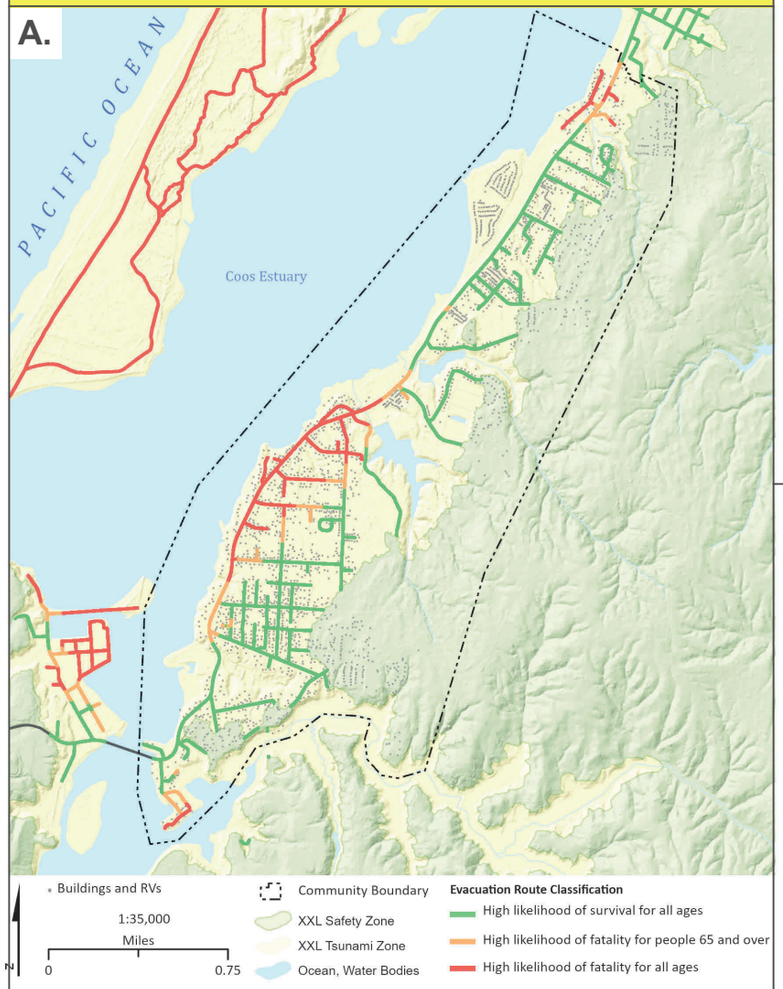


Description	Total
Earthquake Injuries (Entire Community)	130
Tsunami Injuries - Permanent + Temporary	12
Tsunami Fatalities - Permanent	3
Tsunami Fatalities - Temporary @ ~100% occupancy	55
Displaced Population - Permanent	462
Displaced Population - Permanent + Temporary	1,371

Barview - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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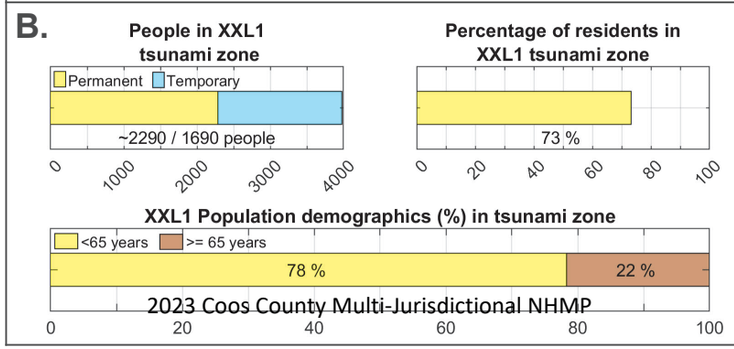

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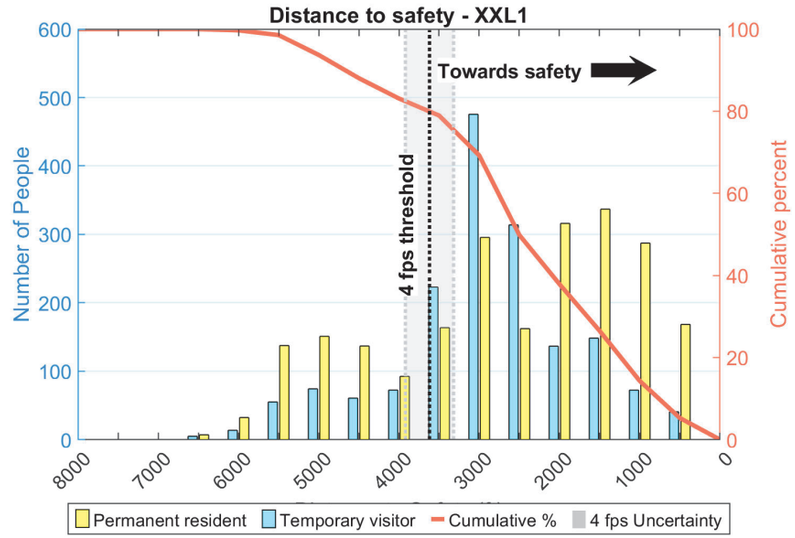
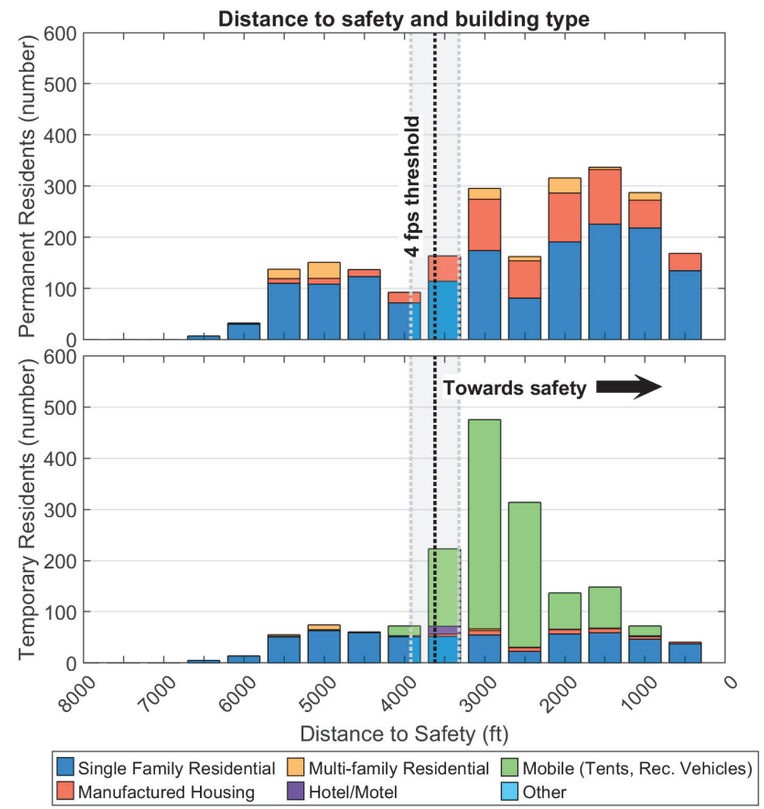
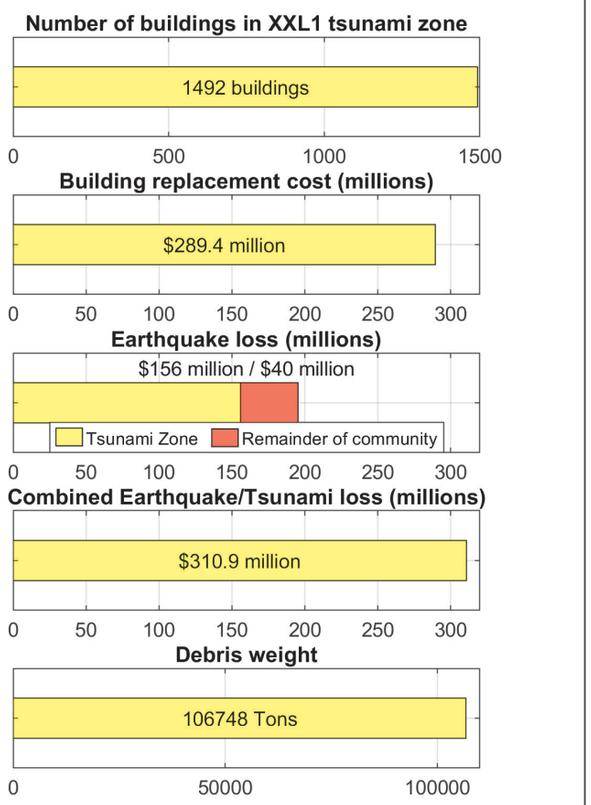


D.



E.



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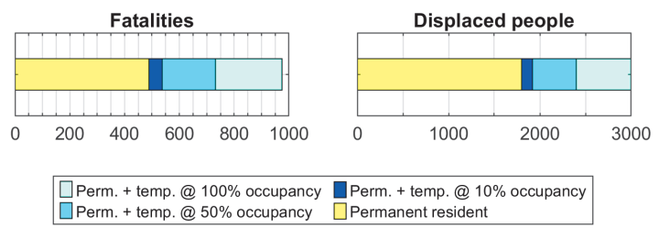
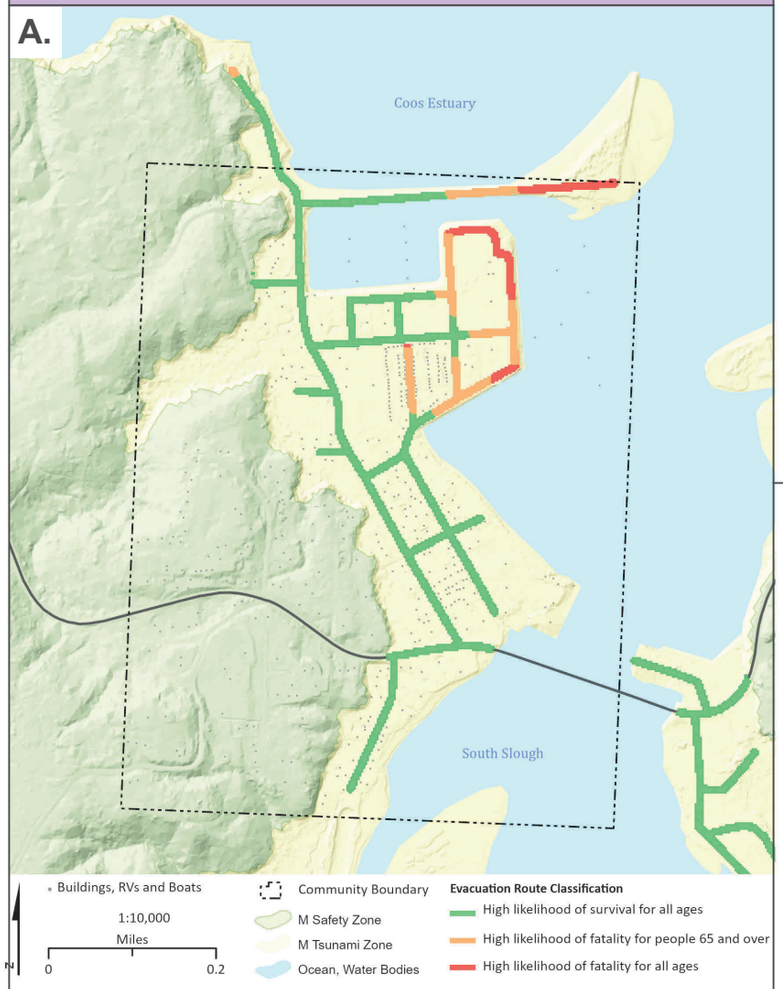


Description	Total
Earthquake Injuries (Entire Community)	130
Tsunami Injuries - Permanent + Temporary	297
Tsunami Fatalities - Permanent	488
Tsunami Fatalities - Temporary @ ~100% occupancy	487
Displaced Population - Permanent	1,798
Displaced Population - Permanent + Temporary	3,001

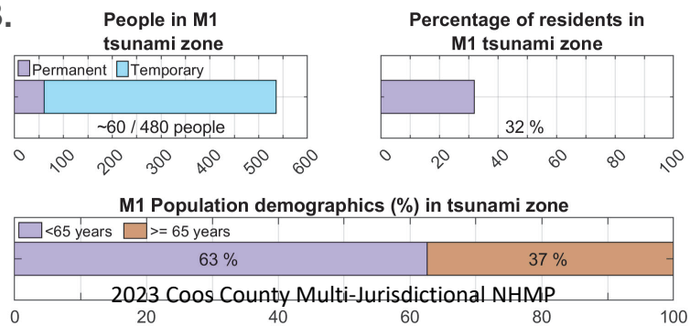
Charleston - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



B.



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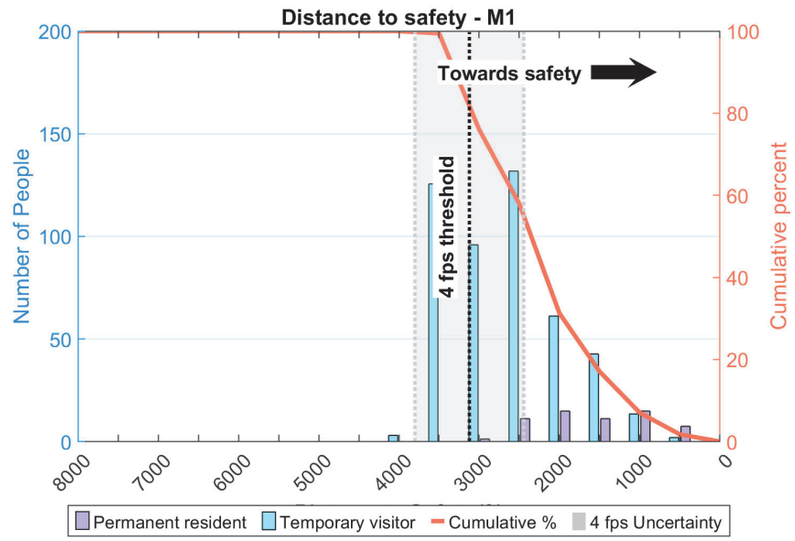
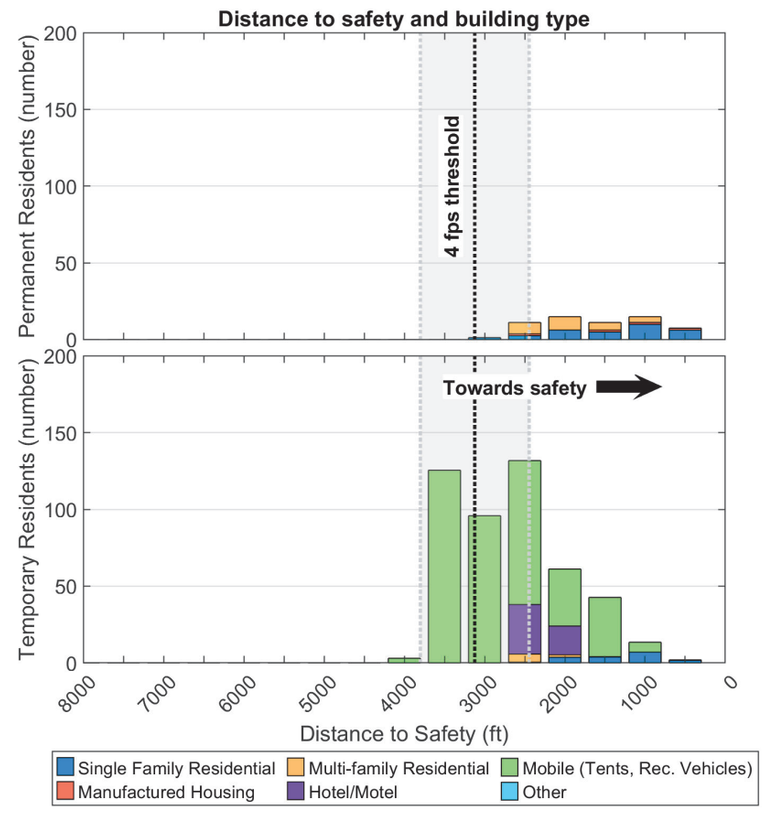
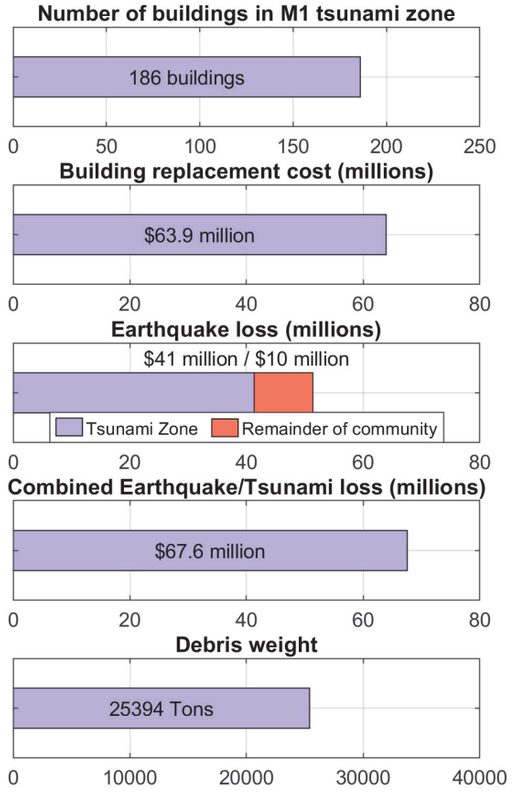


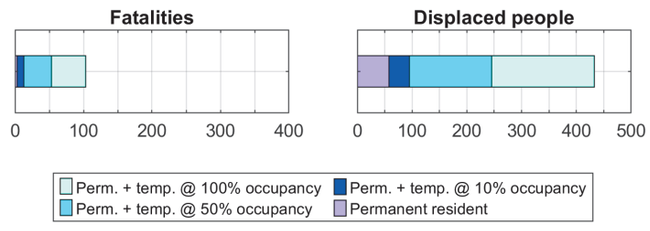
D.



E.



F.

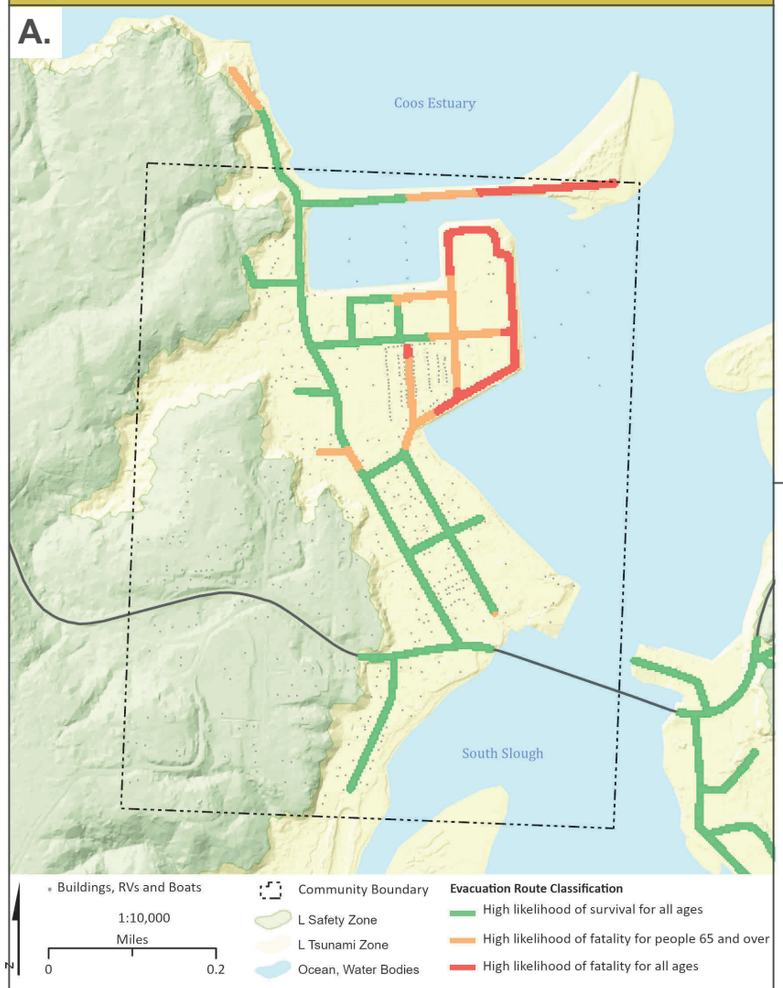


Description	Total
Earthquake Injuries (Entire Community)	14
Tsunami Injuries - Permanent + Temporary	98
Tsunami Fatalities - Permanent	3
Tsunami Fatalities - Temporary @ ~100% occupancy	100
Displaced Population - Permanent	58
Displaced Population - Permanent + Temporary	433

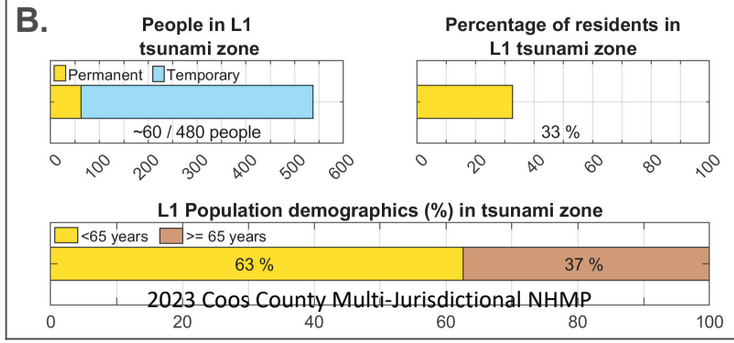
Charleston - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



B.



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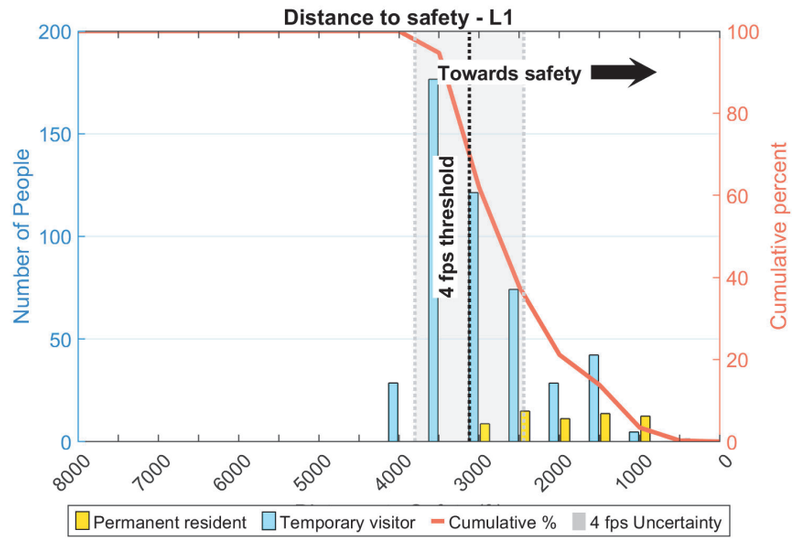
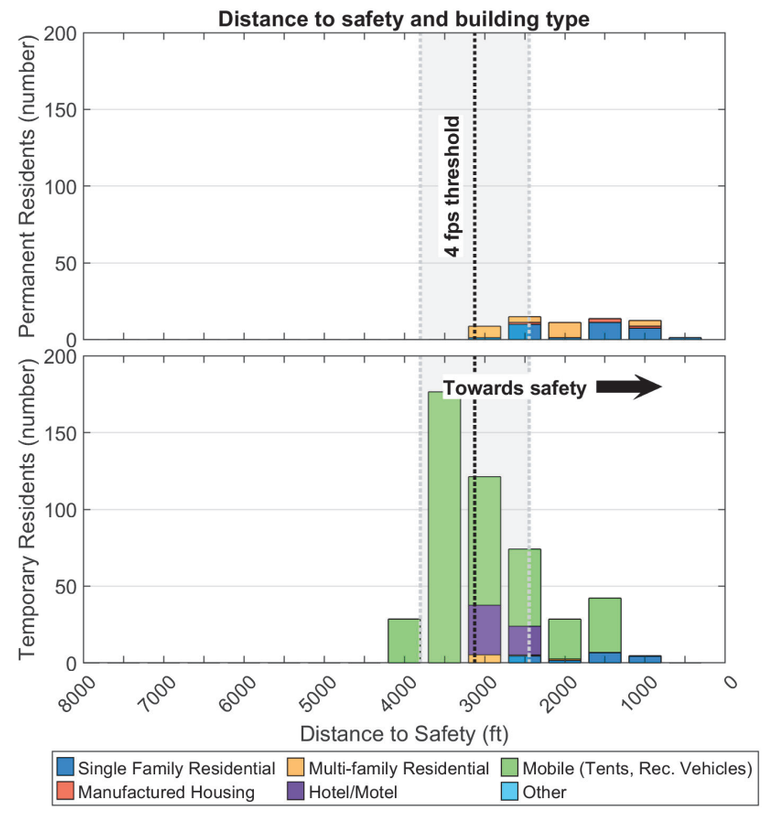
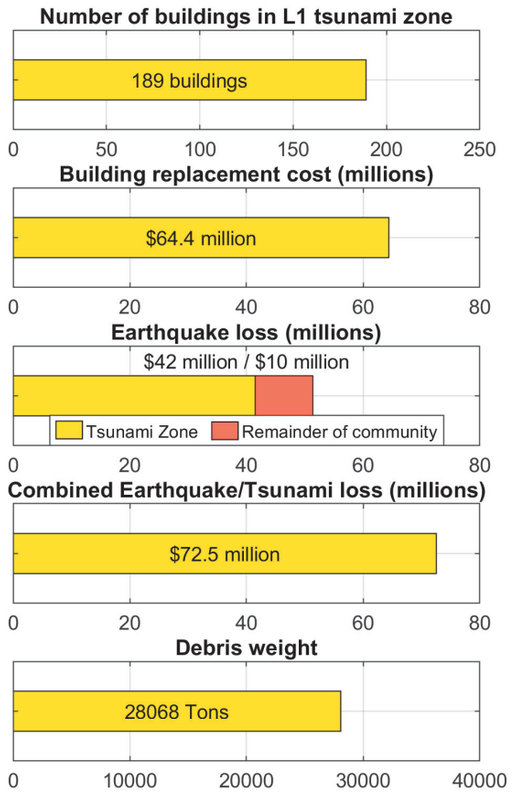


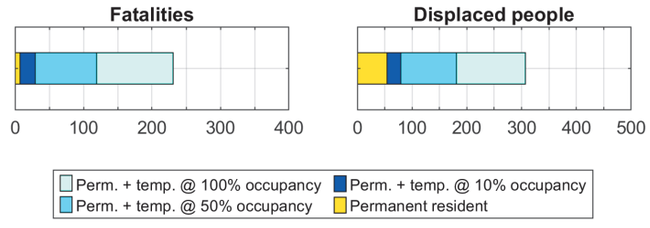
D.



E.



F.

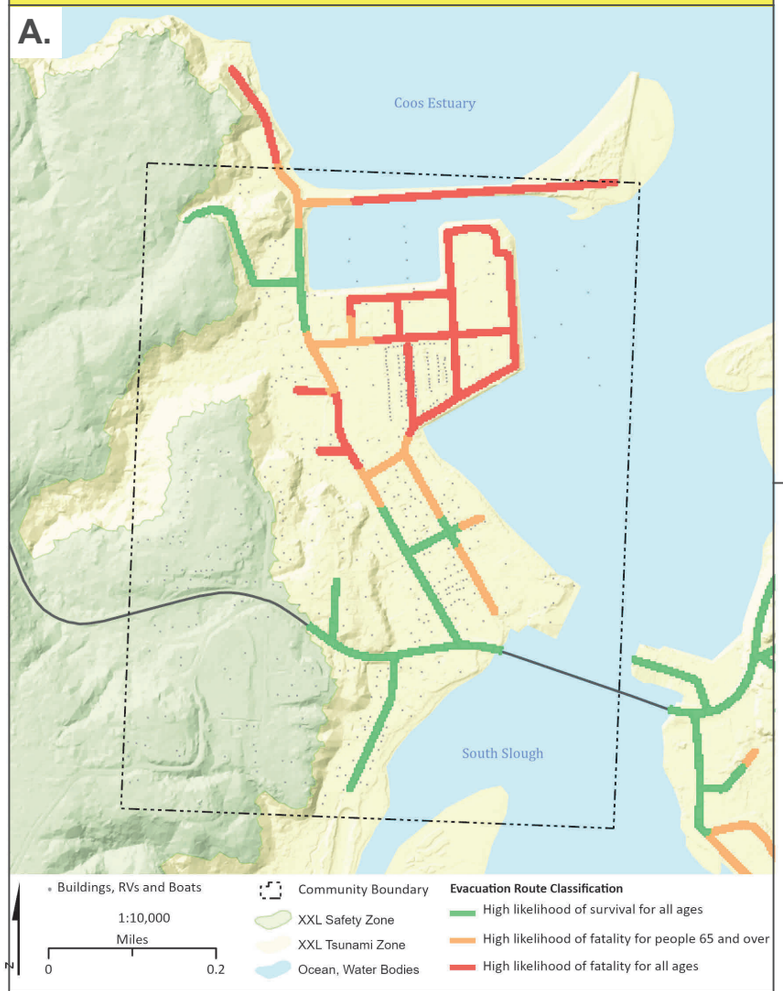


Description	Total
Earthquake Injuries (Entire Community)	14
Tsunami Injuries - Permanent + Temporary	40
Tsunami Fatalities - Permanent	7
Tsunami Fatalities - Temporary @ ~100% occupancy	223
Displaced Population - Permanent	54
Displaced Population - Permanent + Temporary	307

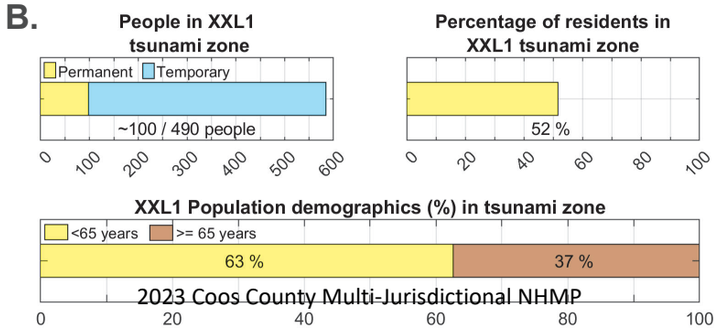
Charleston - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



B.



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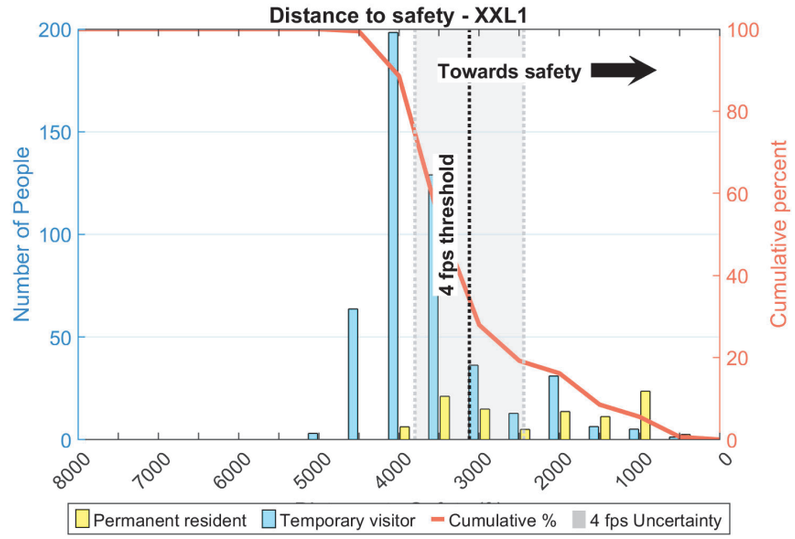
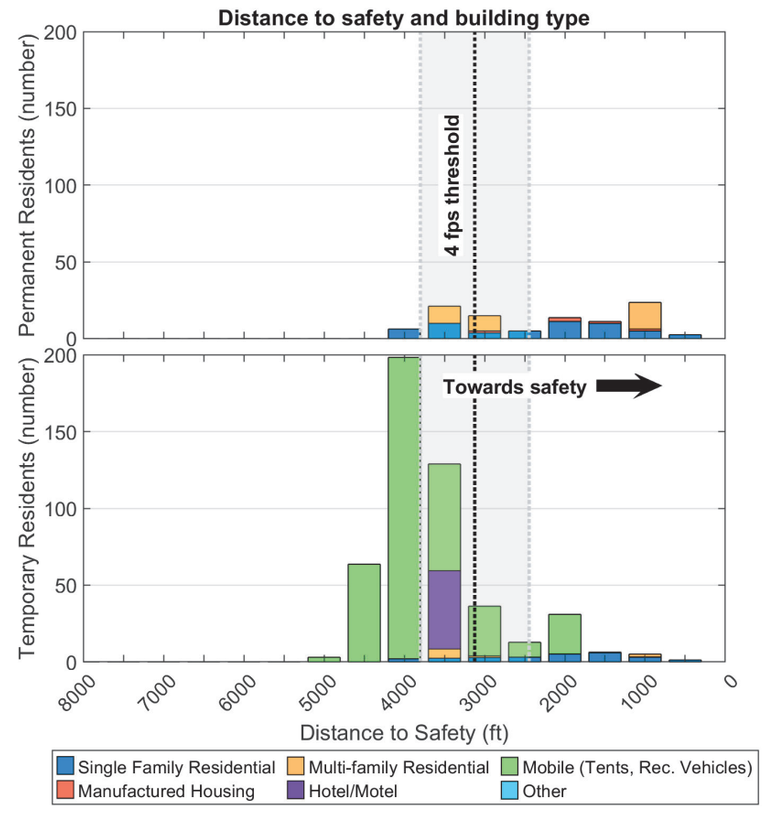
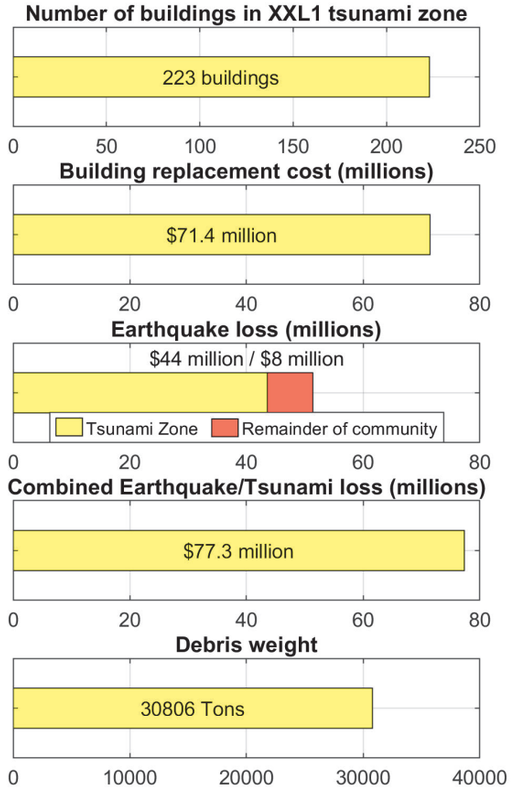


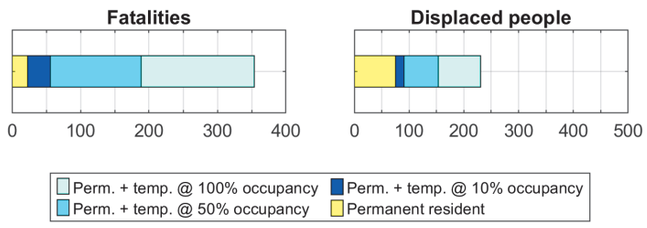
D.



E.



F.

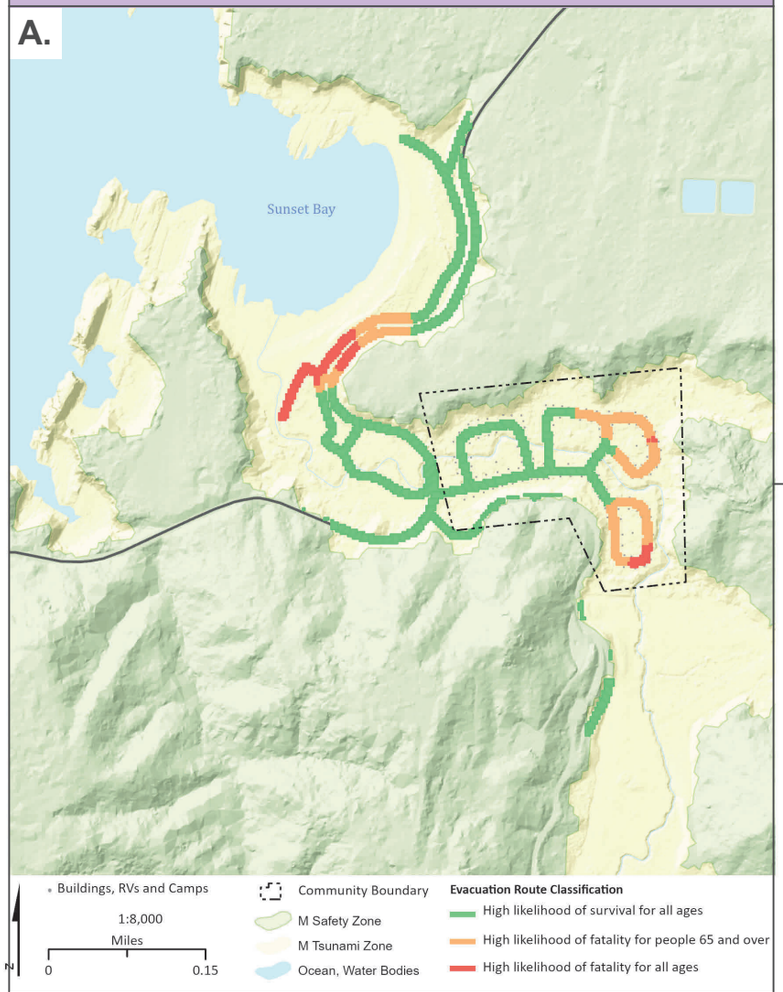


Description	Total
Earthquake Injuries (Entire Community)	14
Tsunami Injuries - Permanent + Temporary	55
Tsunami Fatalities - Permanent	23
Tsunami Fatalities - Temporary @ ~100% occupancy	331
Displaced Population - Permanent	75
Displaced Population - Permanent + Temporary	231

Sunset Bay State Park - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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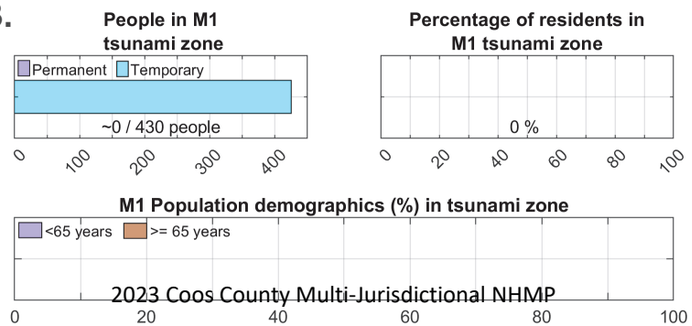

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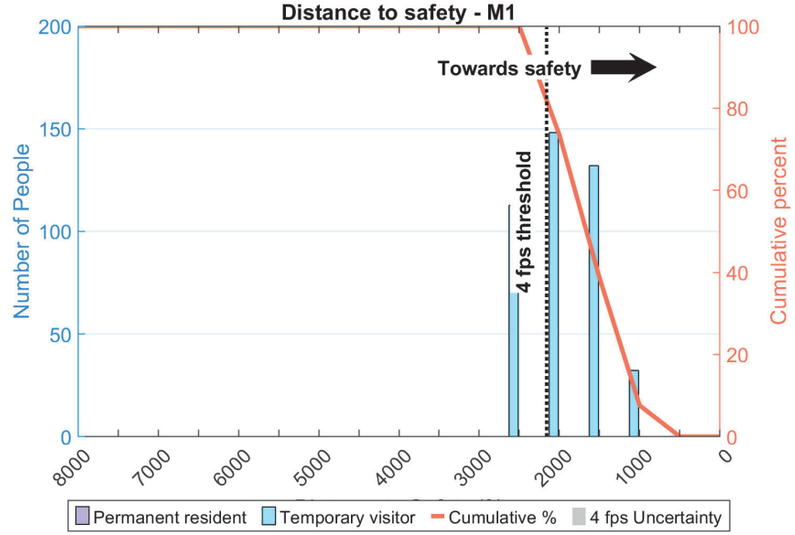

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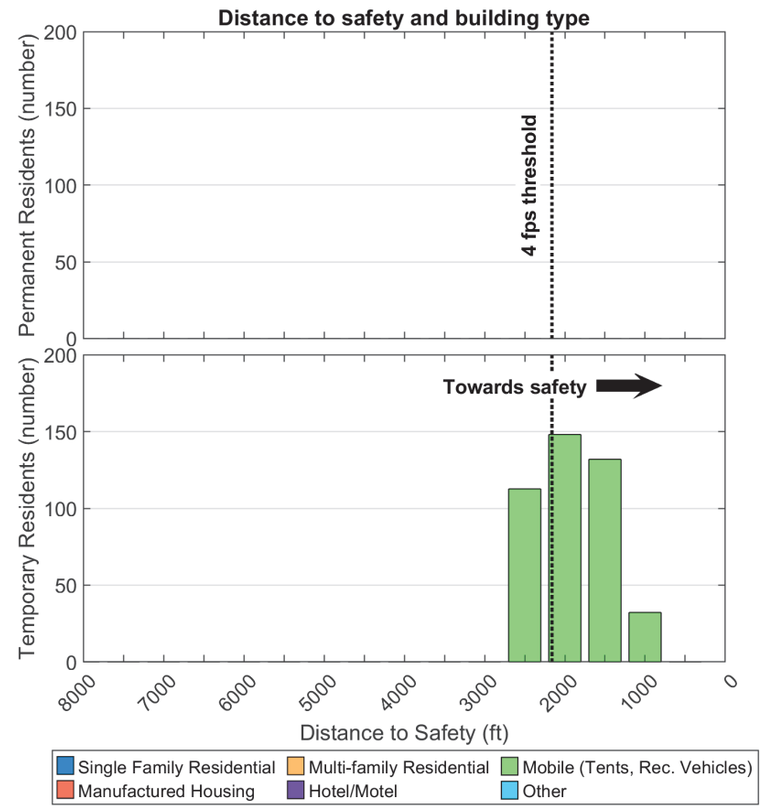

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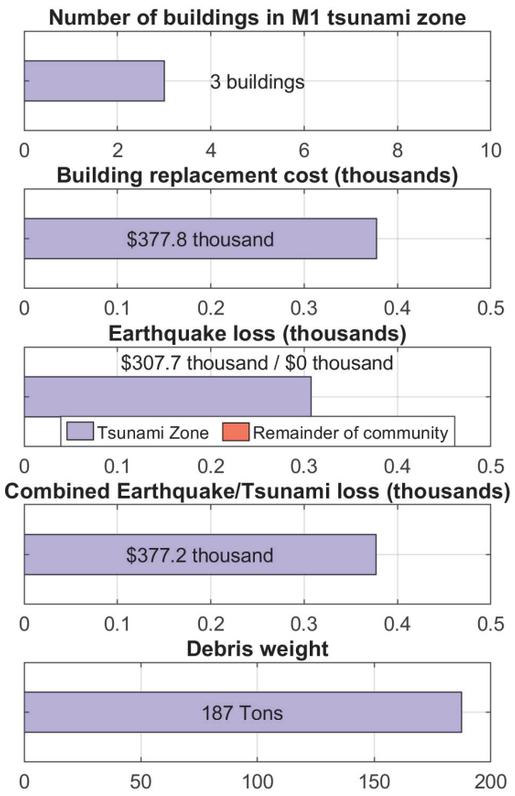

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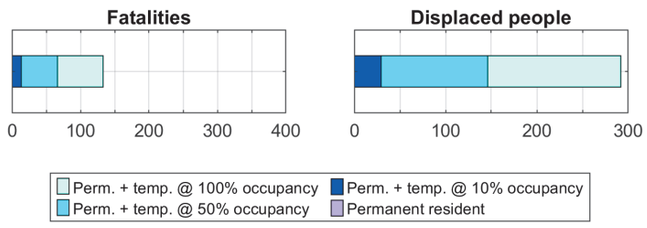
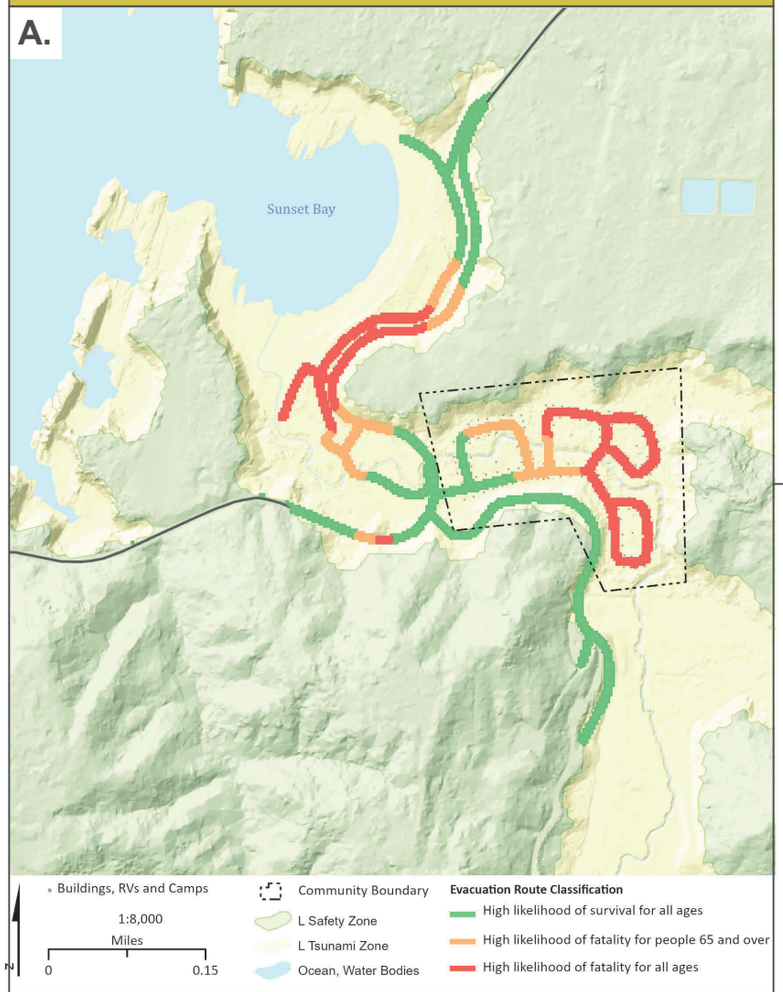


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	11
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	133
Displaced Population - Permanent	0
Displaced Population - Permanent + Temporary	292

Sunset Bay State Park - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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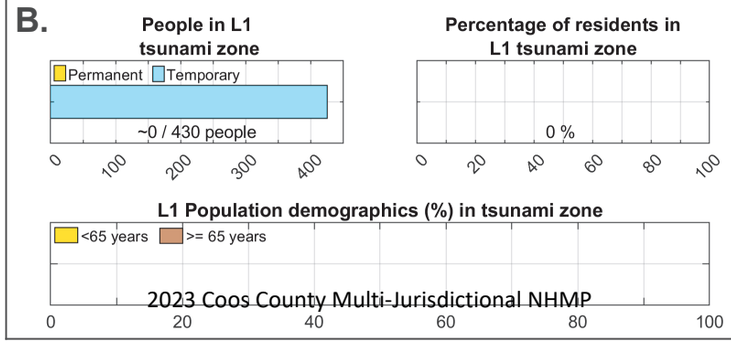

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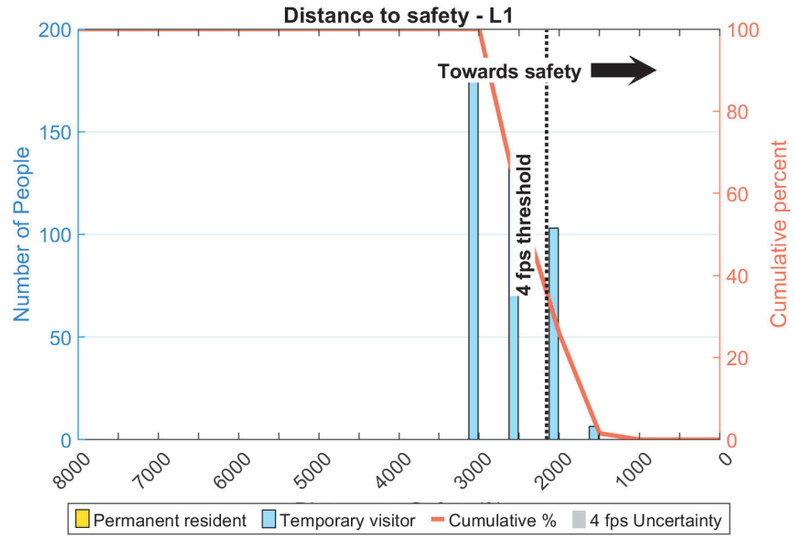

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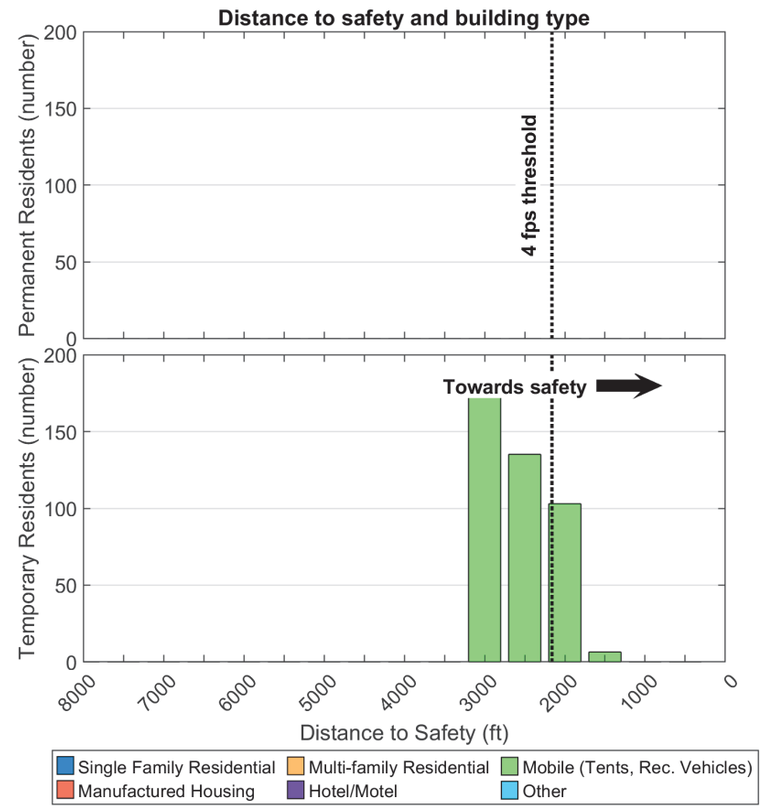

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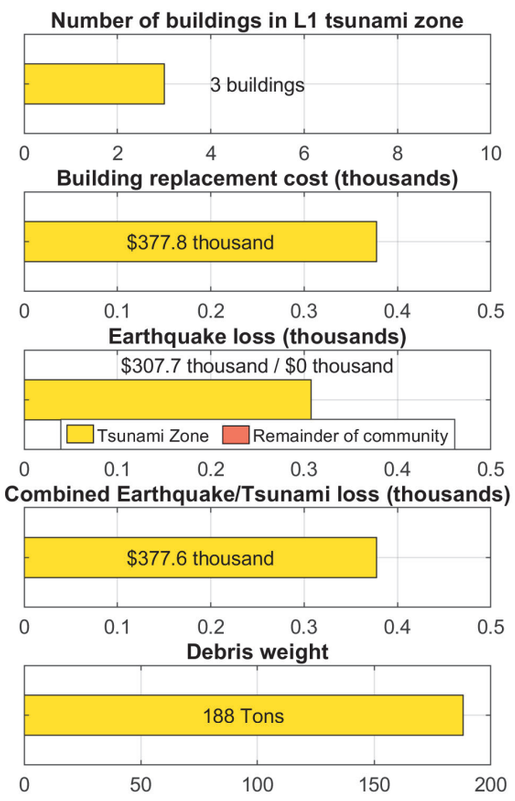

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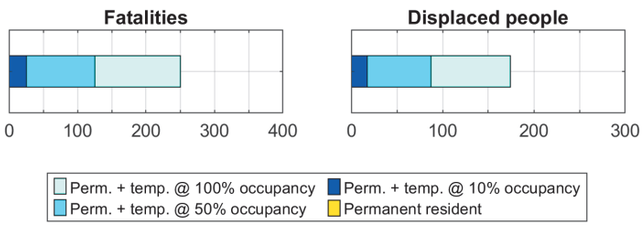
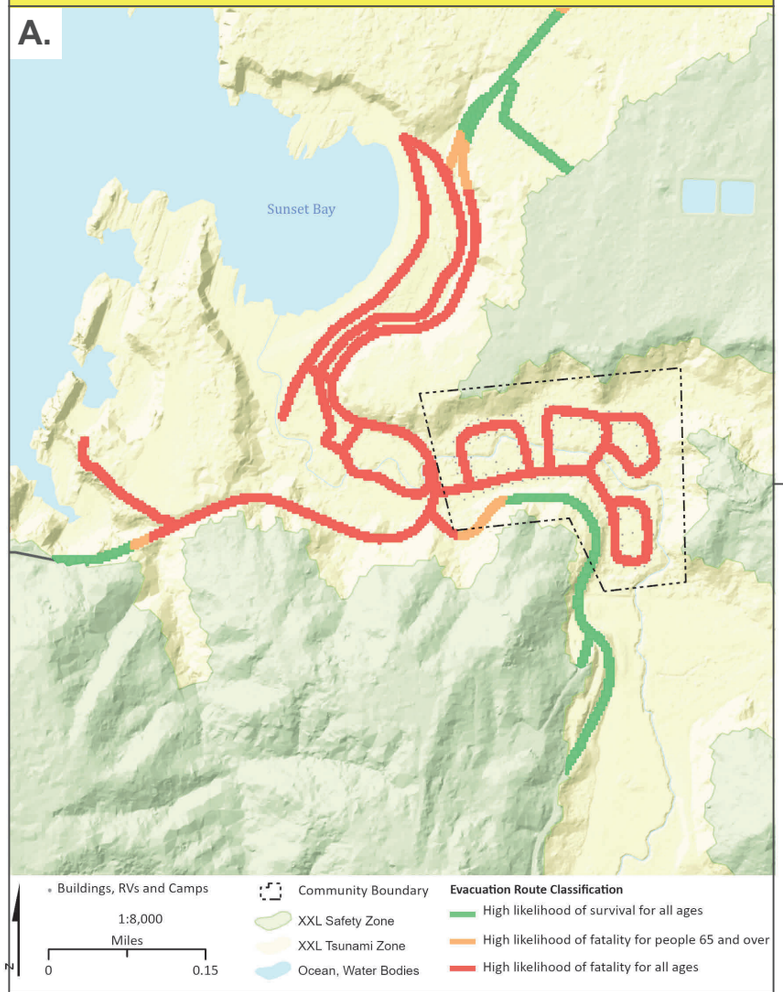


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	40
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	251
Displaced Population - Permanent	0
Displaced Population - Permanent + Temporary	174

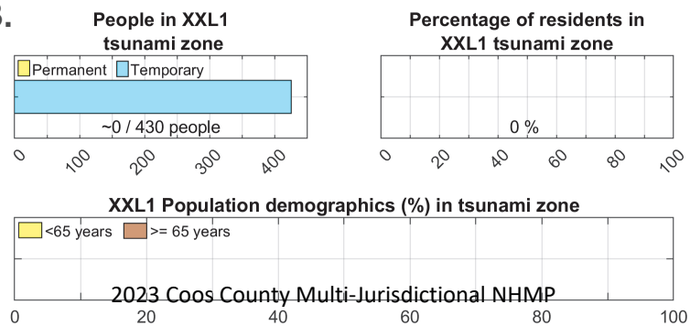
Sunset Bay State Park - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

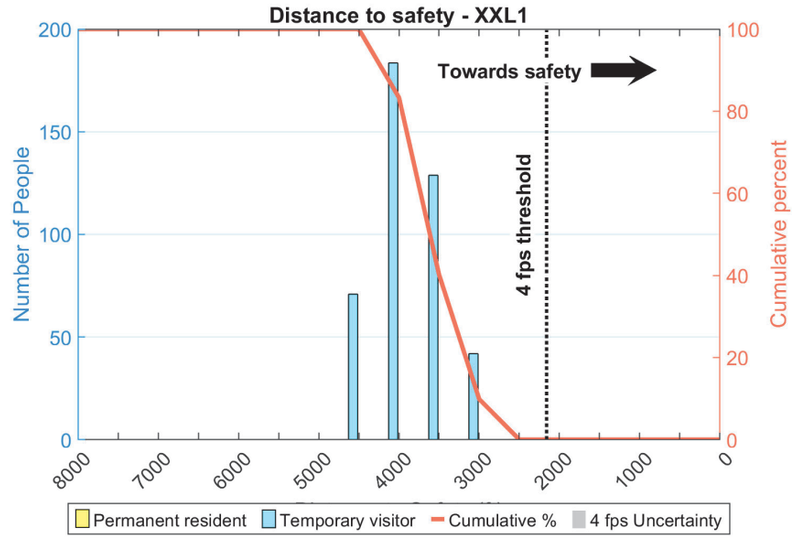
A.



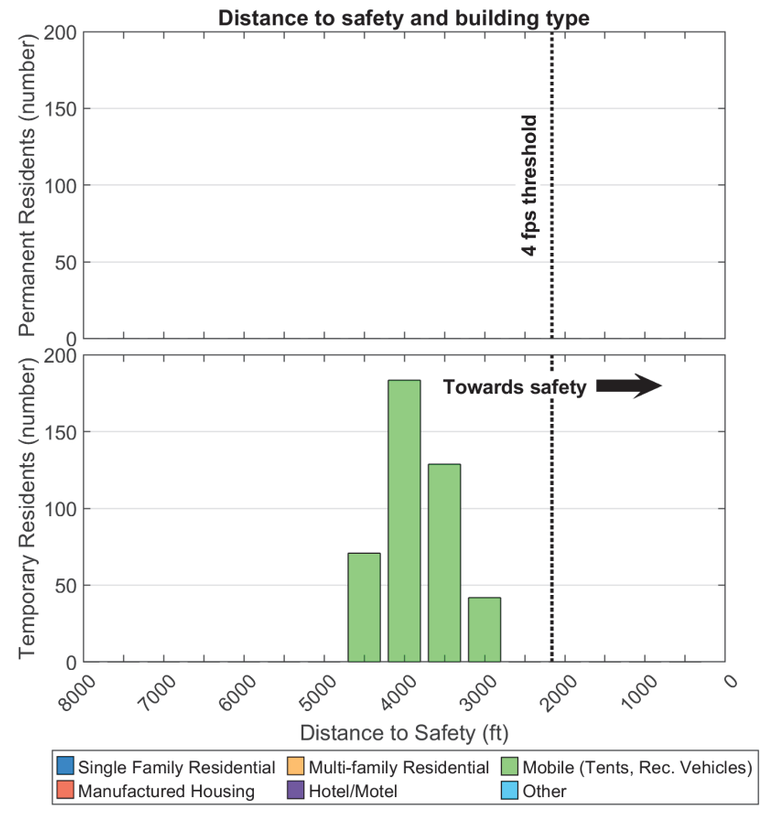
B.



C.



D.



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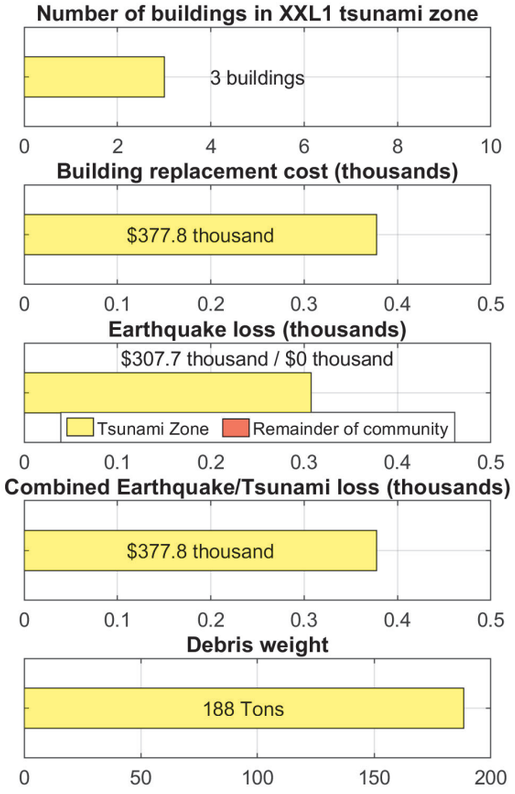

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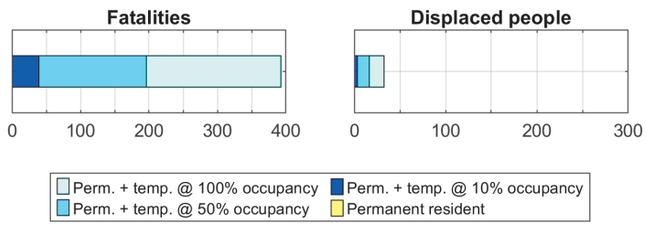
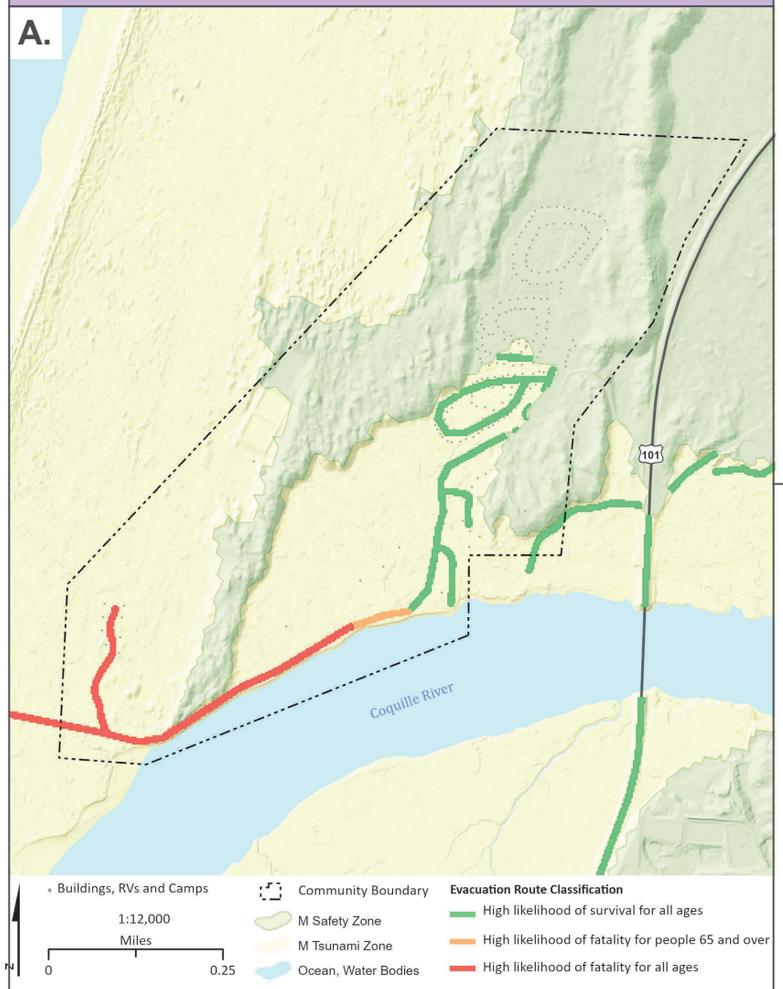


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	30
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	392
Displaced Population - Permanent	0
Displaced Population - Permanent + Temporary	33

Bullards Beach State Park - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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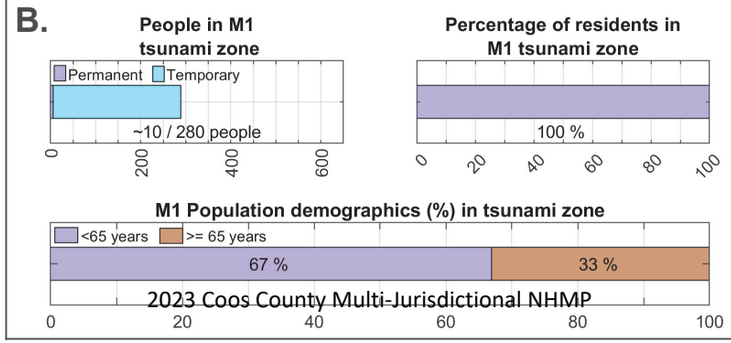
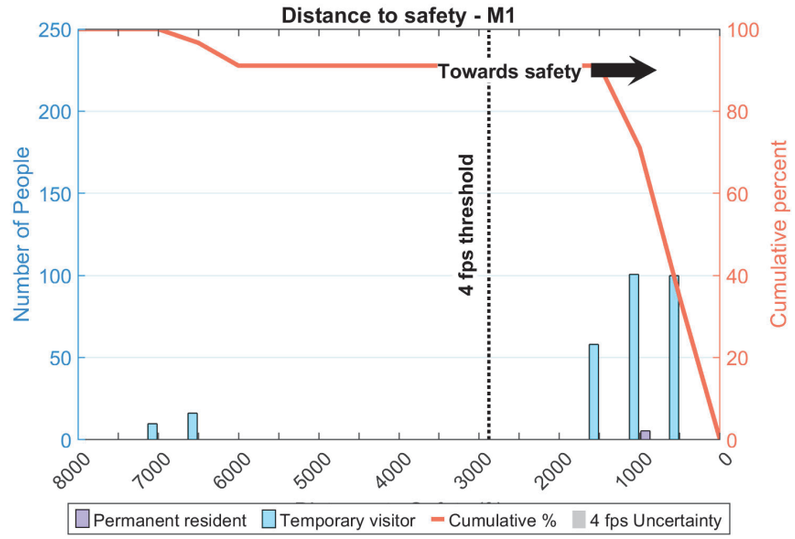
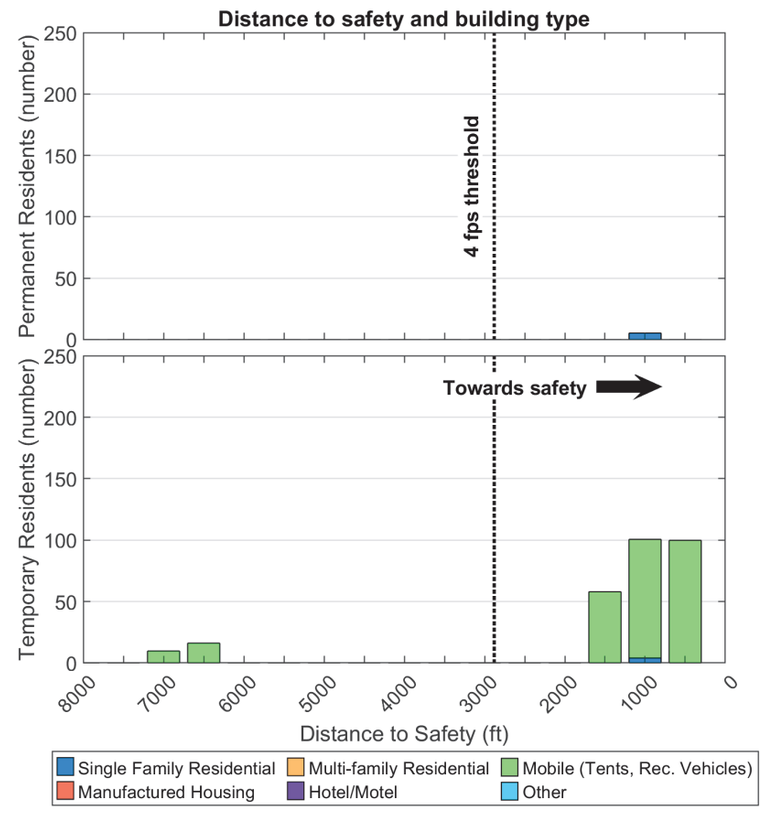


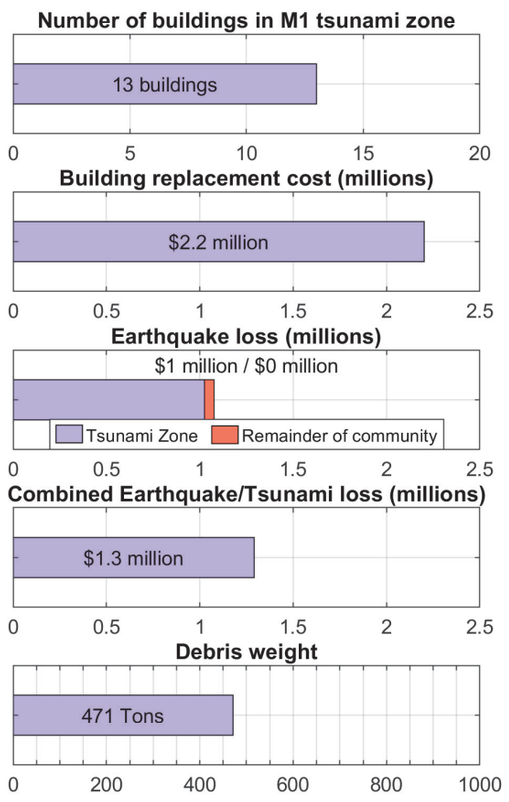
C.



D.



E.



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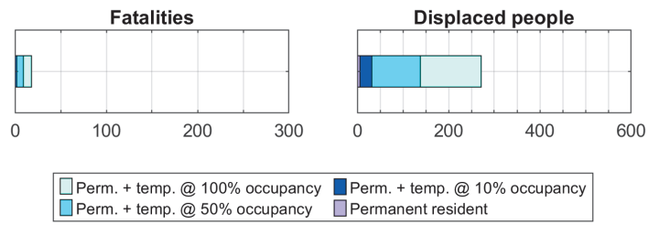
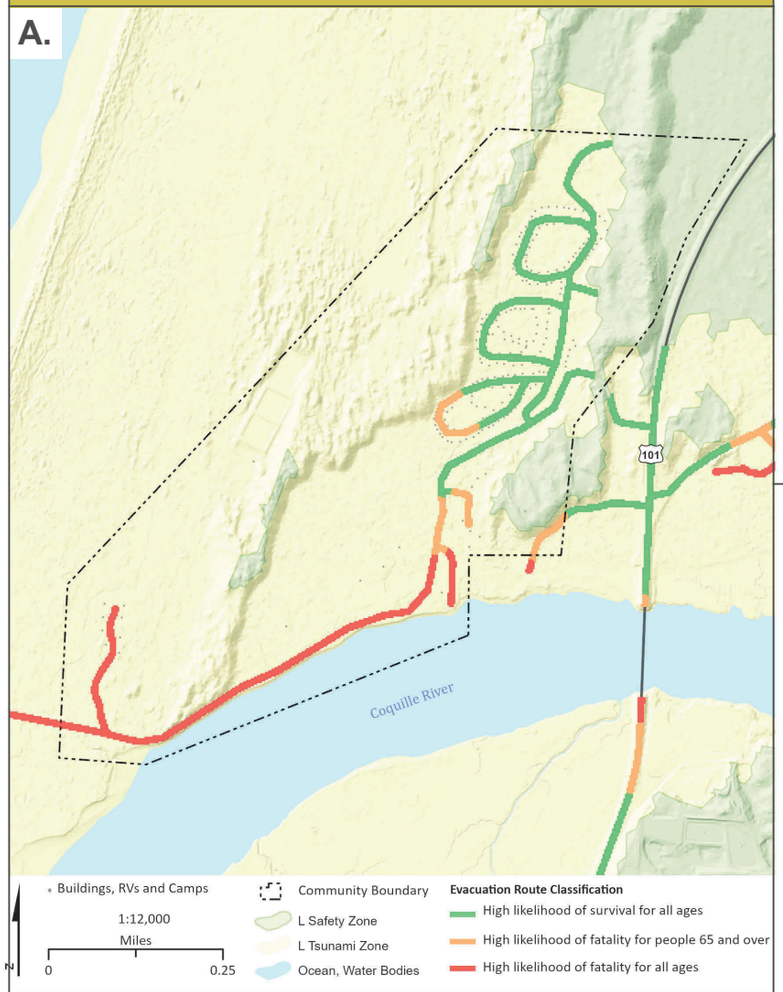


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	14
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	18
Displaced Population - Permanent	5
Displaced Population - Permanent + Temporary	272

Bullards Beach State Park - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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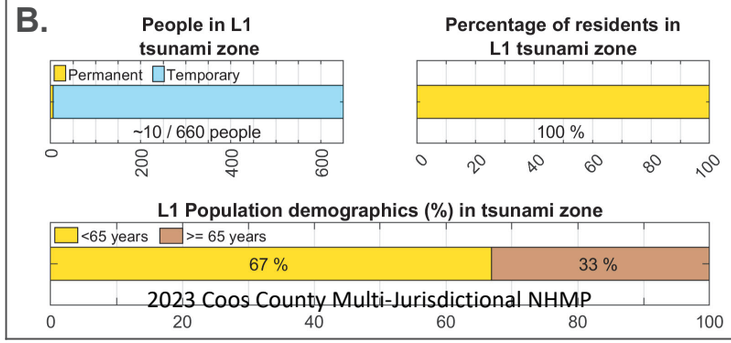

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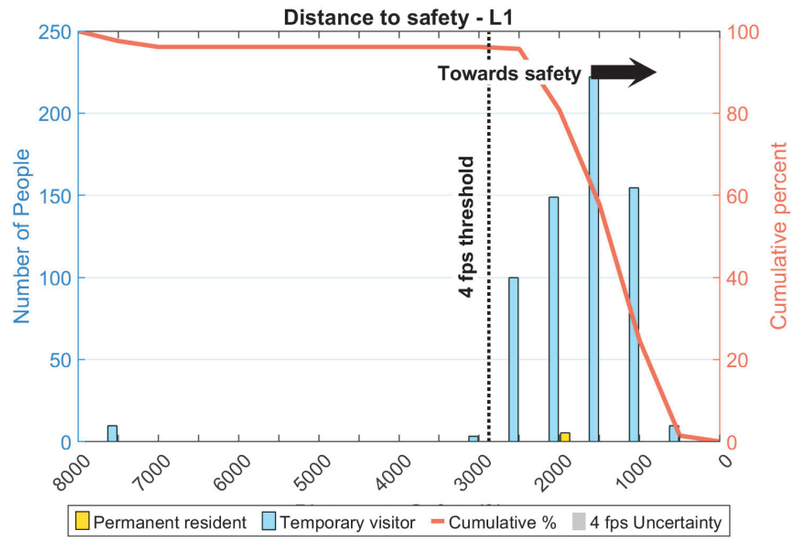
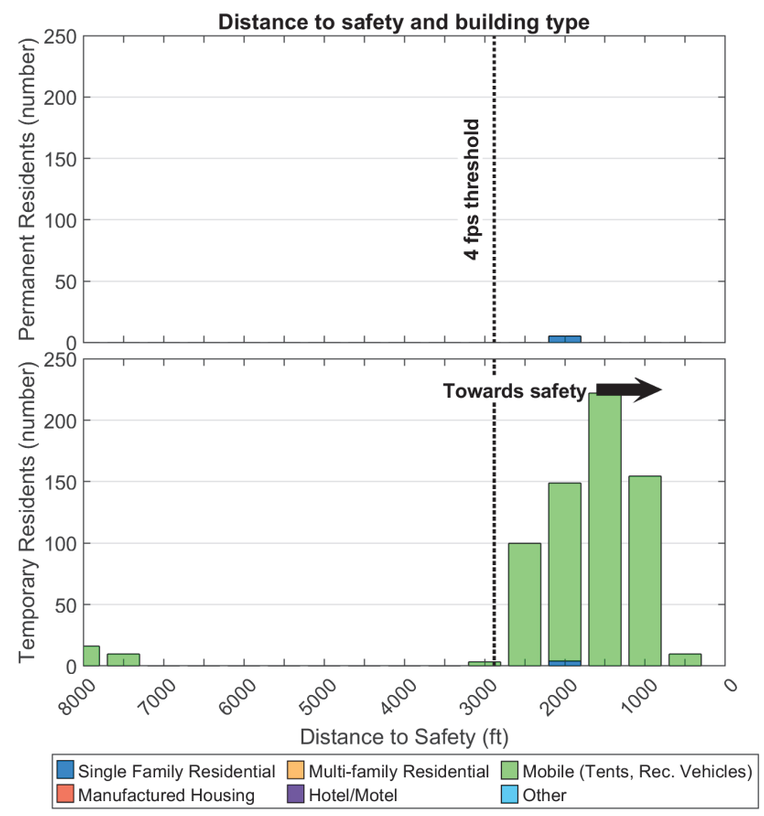
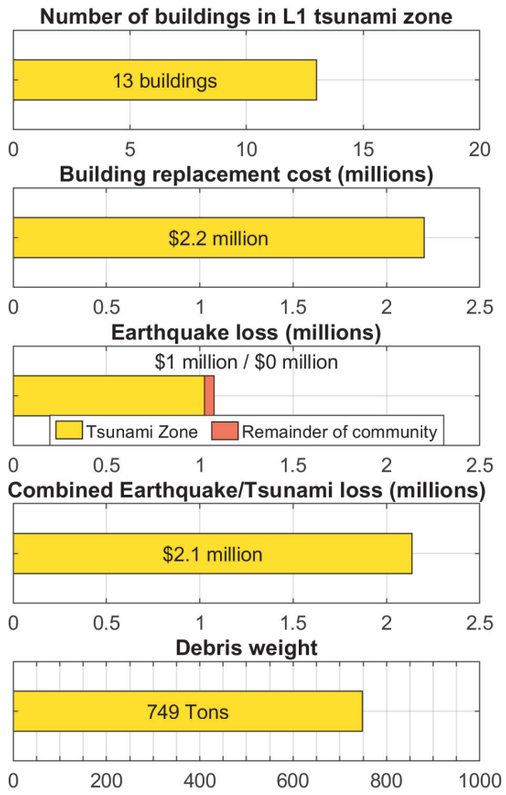


D.



E.



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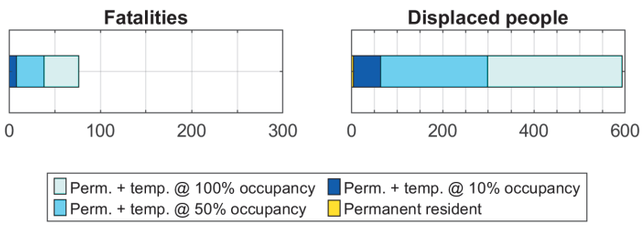
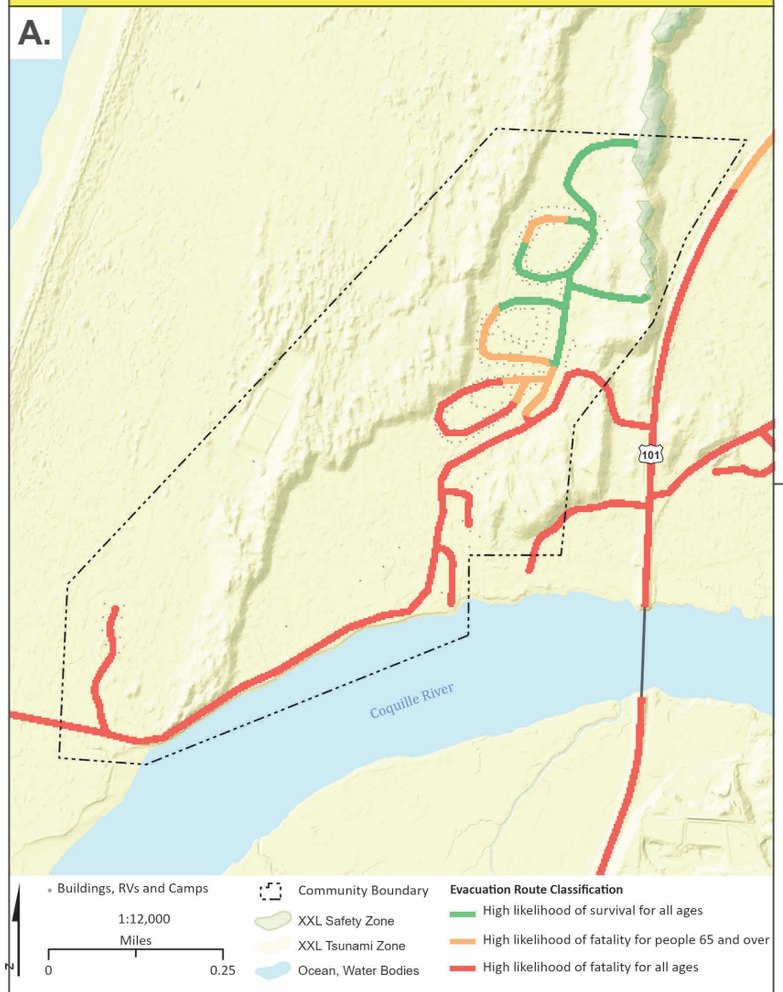


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	35
Tsunami Fatalities - Permanent	0
Tsunami Fatalities - Temporary @ ~100% occupancy	76
Displaced Population - Permanent	5
Displaced Population - Permanent + Temporary	593

Bullards Beach State Park - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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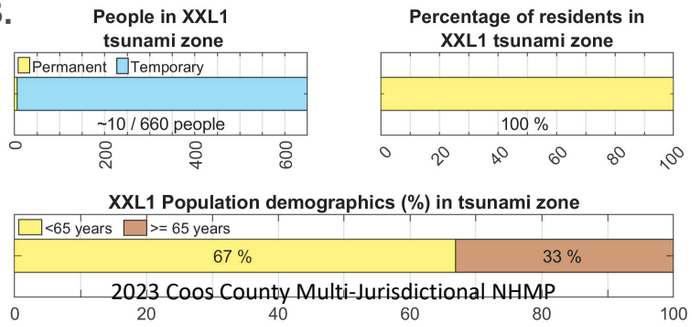

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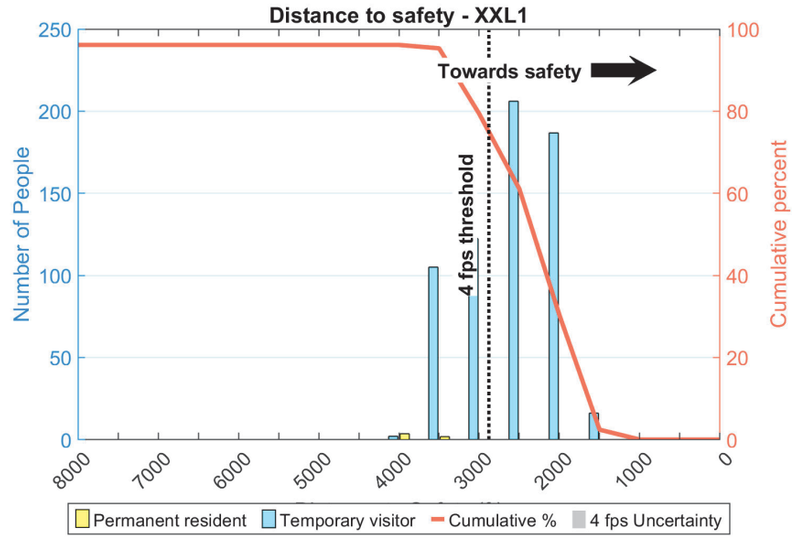
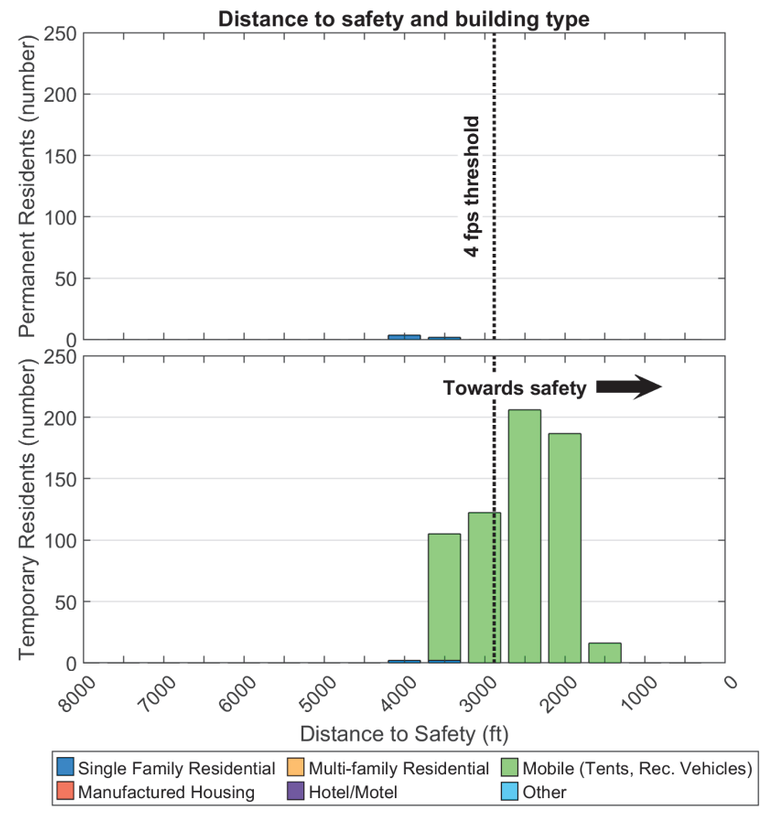


D.



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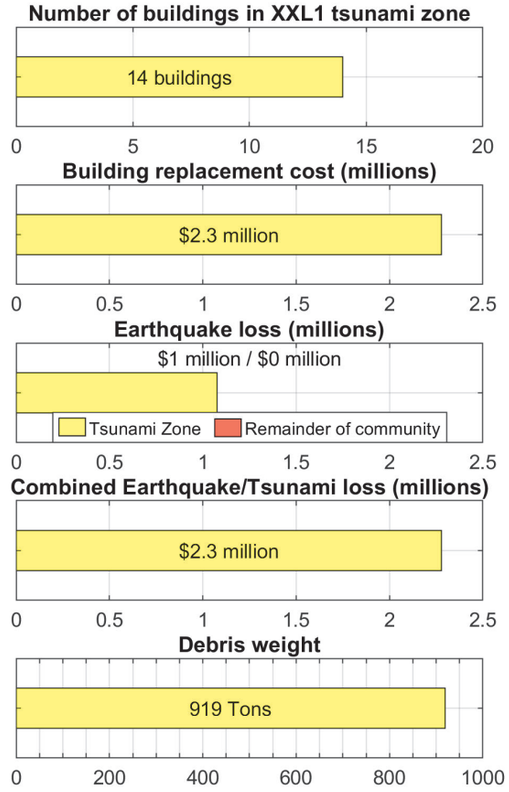

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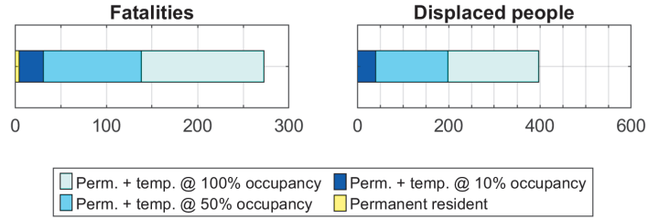
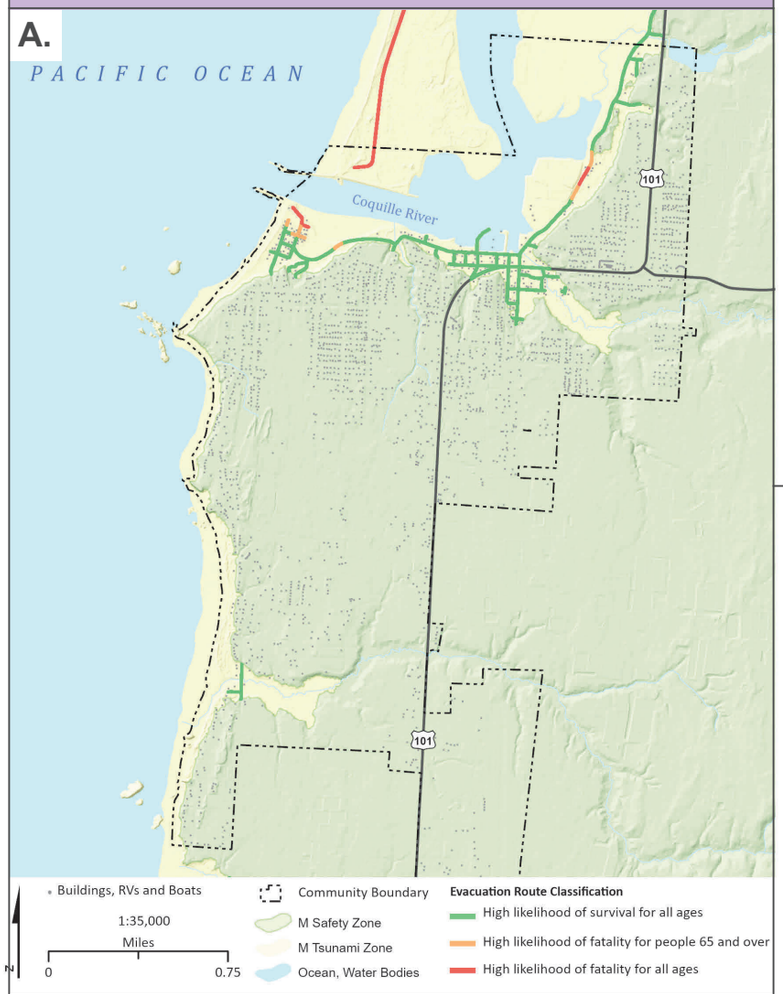


Description	Total
Earthquake Injuries (Entire Community)	0
Tsunami Injuries - Permanent + Temporary	57
Tsunami Fatalities - Permanent	4
Tsunami Fatalities - Temporary @ ~100% occupancy	268
Displaced Population - Permanent	1
Displaced Population - Permanent + Temporary	397

Bandon - M1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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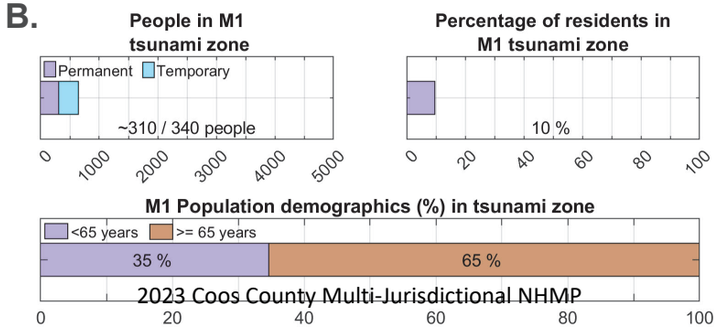

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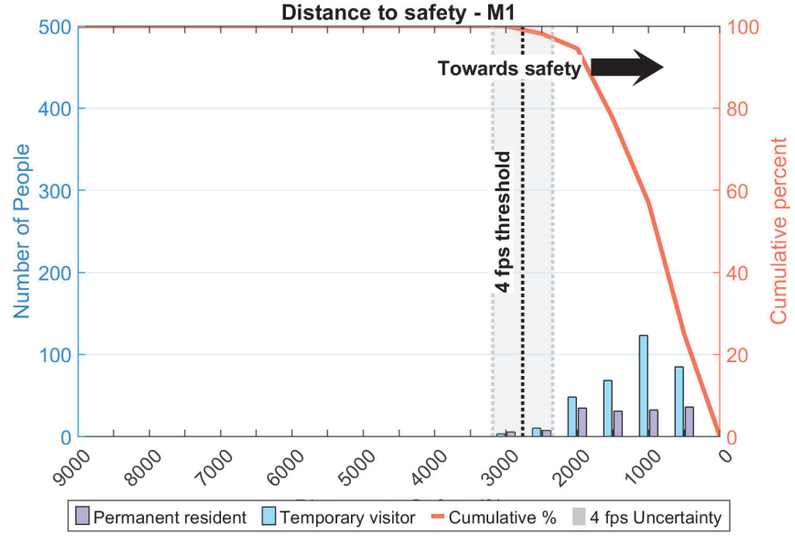
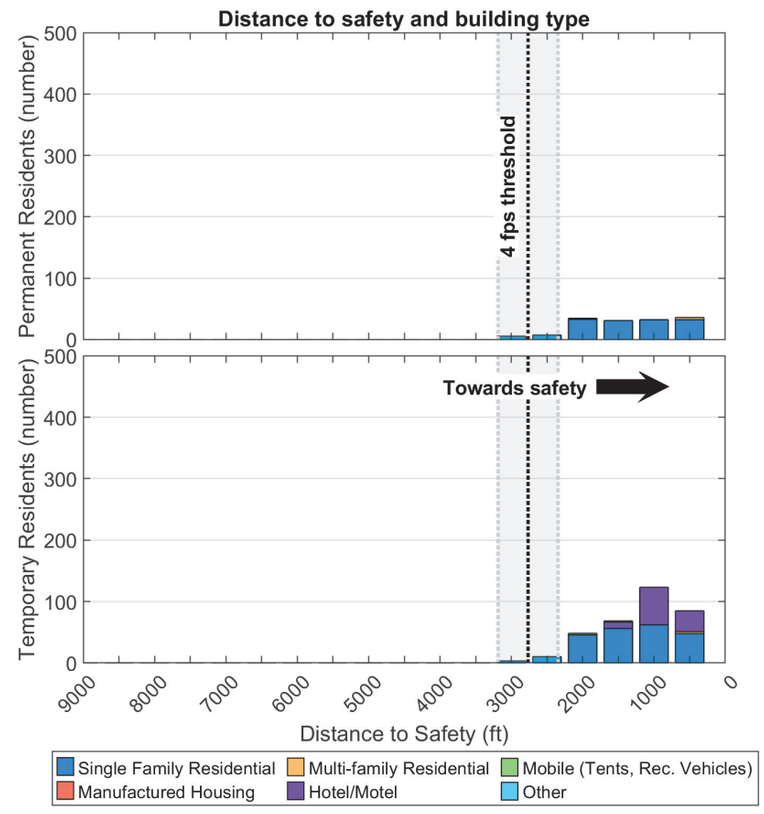


D.



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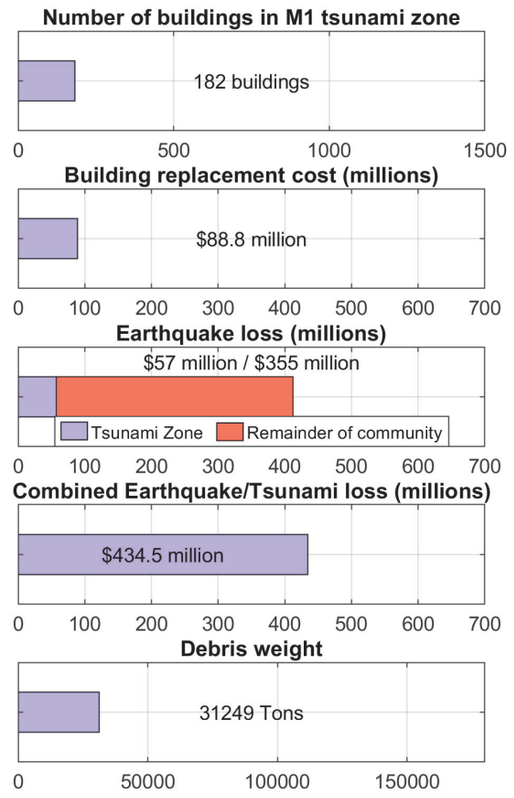
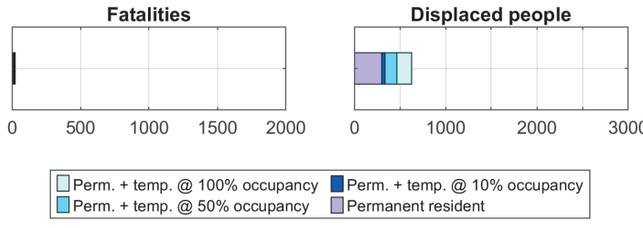


F.

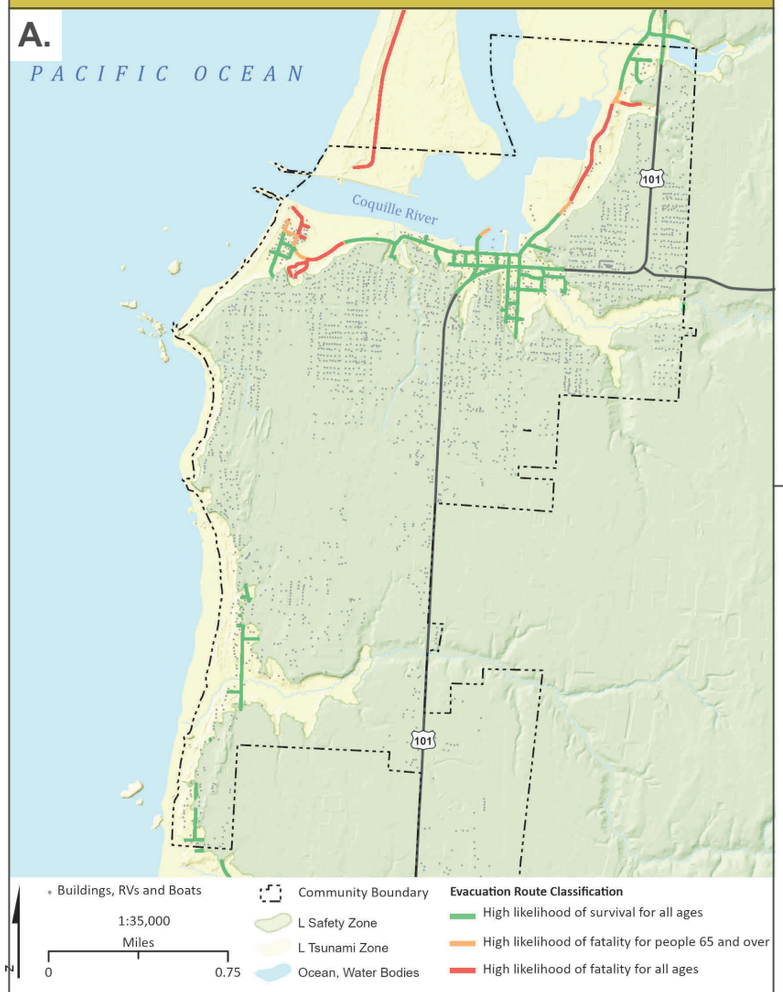


Description	Total
Earthquake Injuries (Entire Community)	215
Tsunami Injuries - Permanent + Temporary	9
Tsunami Fatalities - Permanent	9
Tsunami Fatalities - Temporary @ ~100% occupancy	13
Displaced Population - Permanent	301
Displaced Population - Permanent + Temporary	627

Bandon - L1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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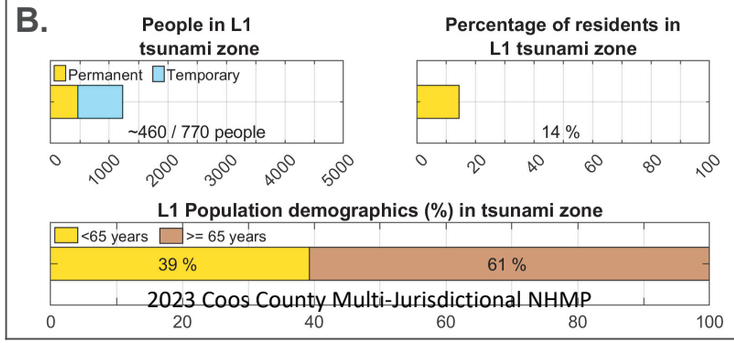

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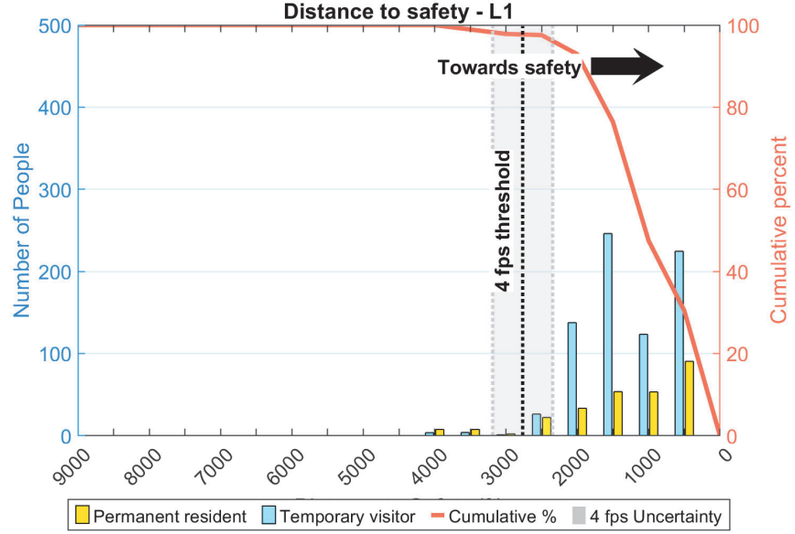
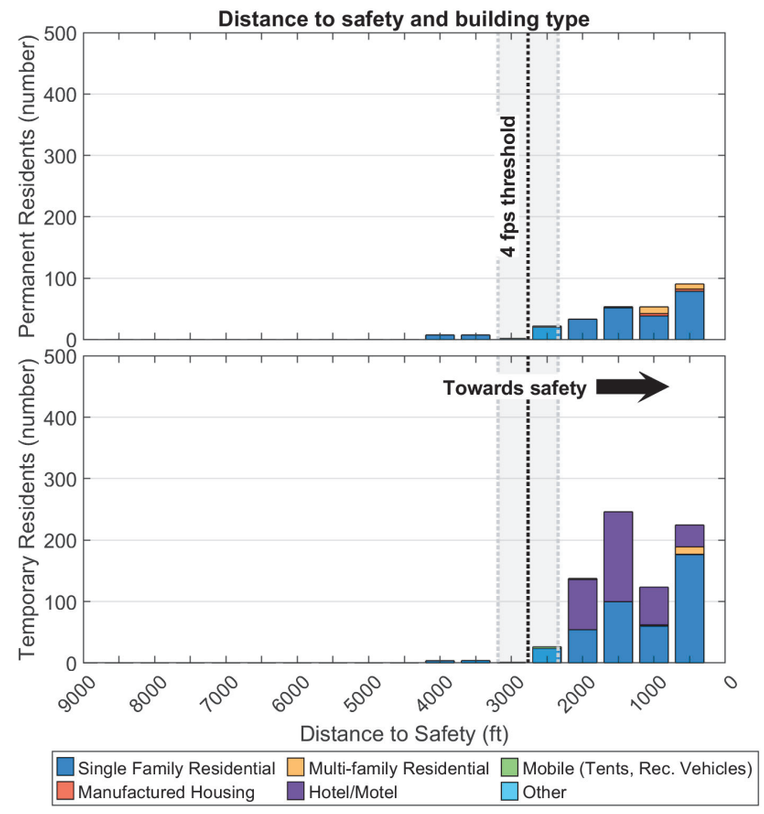
C.



D.



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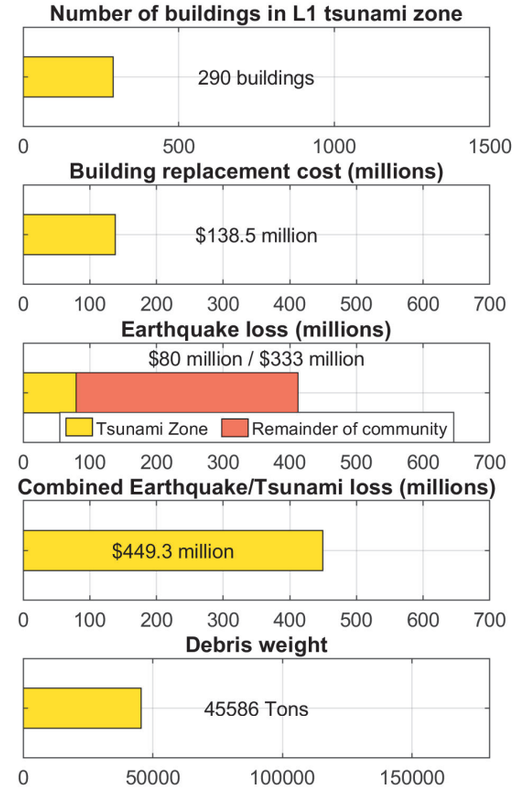

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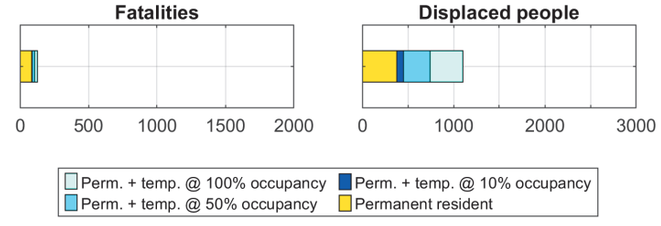
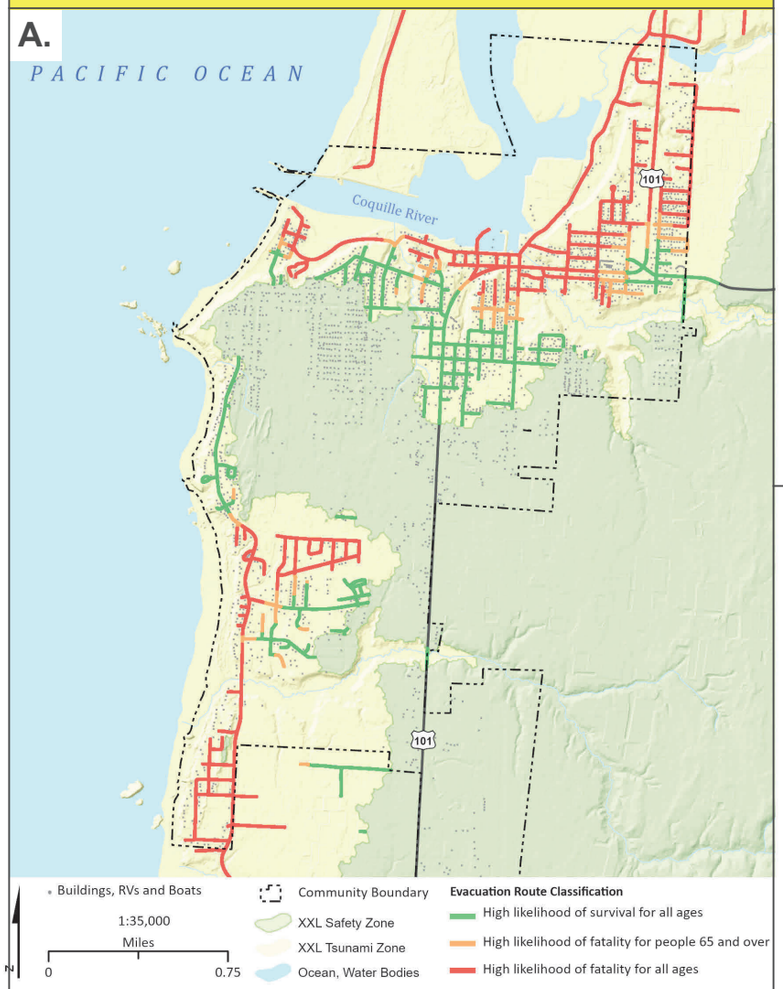


Description	Total
Earthquake Injuries (Entire Community)	215
Tsunami Injuries - Permanent + Temporary	73
Tsunami Fatalities - Permanent	86
Tsunami Fatalities - Temporary @ ~100% occupancy	42
Displaced Population - Permanent	379
Displaced Population - Permanent + Temporary	1,103

Bandon - XXL1

Casualty estimates assume a MODERATE WALK travel speed (4 ft per second)

A.



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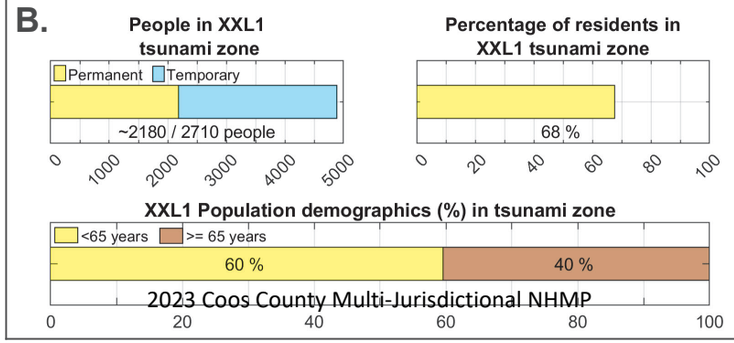

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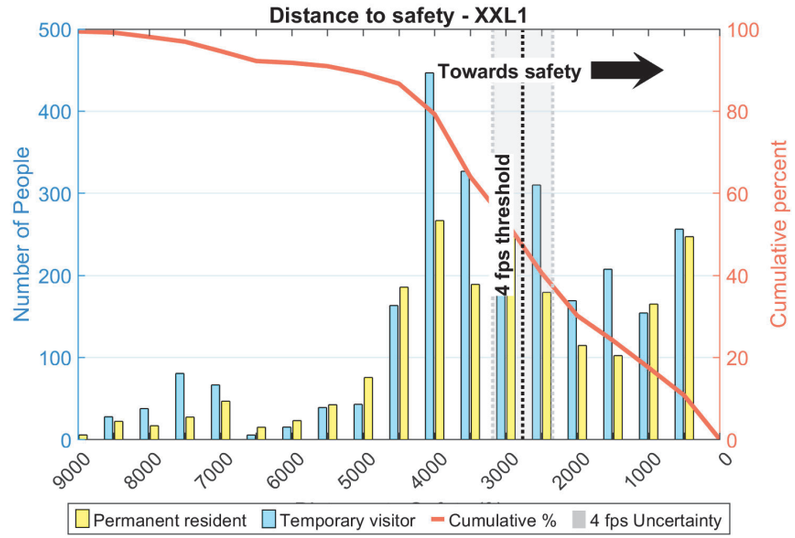

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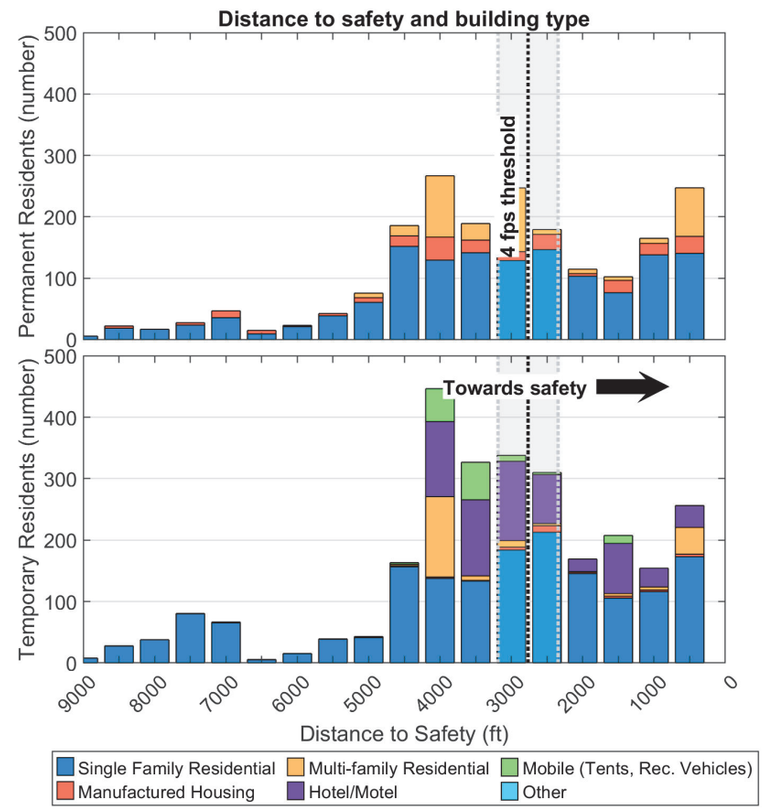

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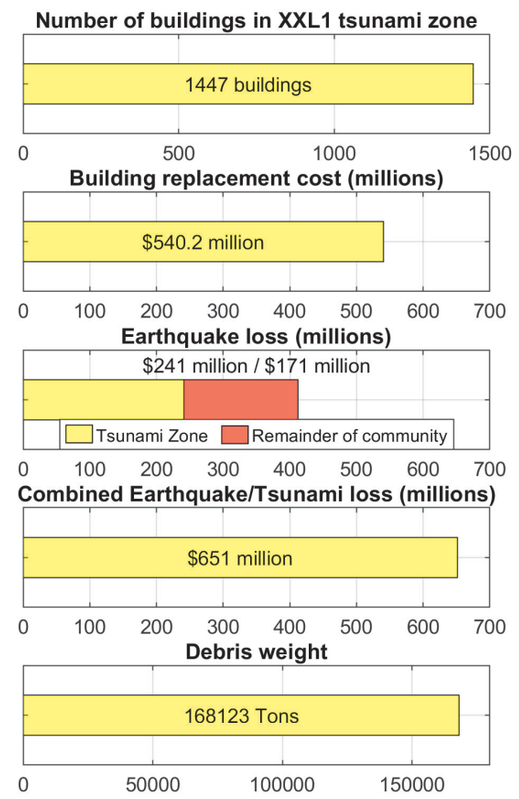

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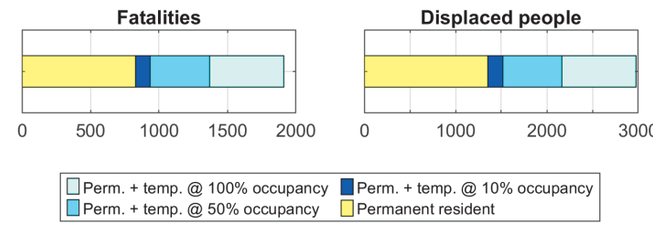

Description	Total
Earthquake Injuries (Entire Community)	215
Tsunami Injuries - Permanent + Temporary	1,047
Tsunami Fatalities - Permanent	828
Tsunami Fatalities - Temporary @ ~100% occupancy	1,085
Displaced Population - Permanent	1,354
Displaced Population - Permanent + Temporary	2,975

B. Appendix B

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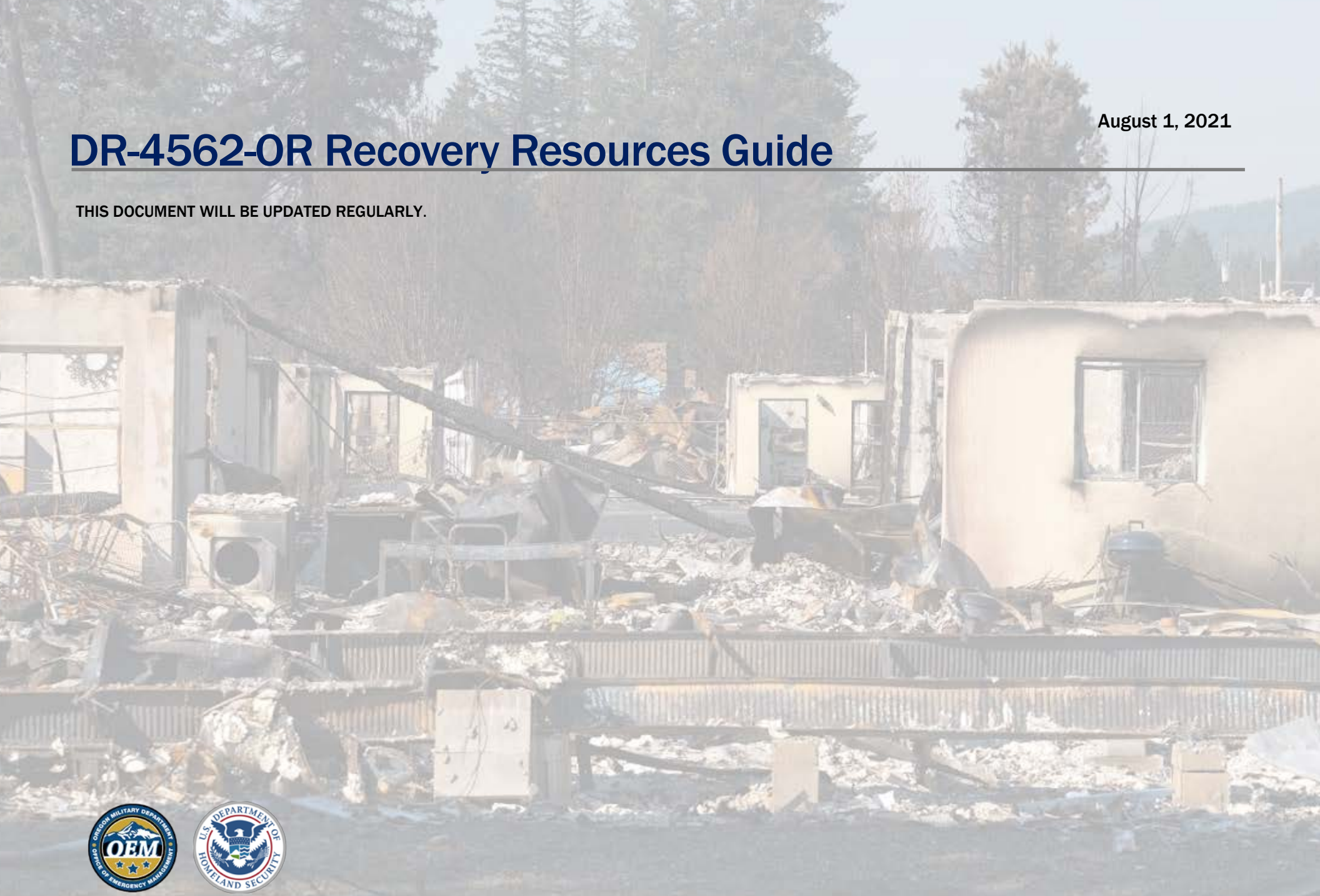
1. Funding: Recovery Resource Guide

August 1, 2021

DR-4562-OR Recovery Resources Guide

THIS DOCUMENT WILL BE UPDATED REGULARLY.



The resources in this report are identified for general informational purposes only and are compiled with publicly available information or with information provided by sources that are publicly obtainable. Please view this document as only a starting point for individual research. Please consult the provider of a potential resource for current program information and to verify the applicability of a particular program

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Agriculture

Arts and Culture

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Redevelopment and Recovery Strategies of Historic Properties Support	Advisory Council on Historic Preservation	In coordination with State Historic Preservation Officers (SHPOs) and Tribal Historic Preservation Officers (THPOs), provides technical expertise to assist Federal, state and local agencies identify programs that fund or support redevelopment and recovery strategies that involve affected historic properties.	Local Government & Authority, State, Territory, Tribe	achp@achp.gov 202-517-0200	None Listed
FY21 Shuttered Venue Operators Grant (SVO)	US Small Business Administration	The SVO Grant program was established by the Economic Aid to Hard-Hit Small Businesses, Nonprofits, and Venues Act, signed into law on December 27, 2020. The program includes $15 billion in grants to shuttered venues, to be administered by the SBA's Office of Disaster Assistance. Eligible applicants may qualify for SVO Grants equal to 45% of their gross earned revenue, with the maximum amount available for a single grant award of $10 million. $2 billion is reserved for eligible applications with up to 50 full-time employees.	Live venue operators or promoters, Theatrical producers, Live performing arts organization operators, museum operators, zoos and aquariums that meet specific criteria, motion picture theater operators, talent representatives, business entities owned by an eligible entity	SVOGrant@sba.gov	Applications accepted continuously.

Broadband / Technology

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY20 Community Development Block Grant Program: Broadband Infrastructure	(USHUD) Dept. of Housing and Urban Development	CDBG funds may be used to install wiring, fiber optic cables, and permanently affixed equipment such as receivers for areas to receive broadband/internet access. Eligible activities include: The acquisition, construction, reconstruction, rehabilitation, or installation of public facilities and improvements. FAQ	Local Government & Authority, State, Territory	Bryan G. Guiney bryan.g.guiney@hud.gov 971-222-2612	None Listed
FY20 Community Planning and Development - Section 108 Loan Guarantee Program (14.248)	(USHUD) Dept. of Housing and Urban Development - Community Planning and Development	Section 108 offers state and local governments the ability to transform a small portion of their CDBG funds into federally guaranteed loans large enough to pursue physical and economic revitalization projects.	Local Government & Authority, Nonprofit Organizations, State, Territory	Bryan G. Guiney bryan.g.guiney@hud.gov 971-222-2612	None Listed
EPA Smart Growth - Cool & Connected	(USEPA) Environmental Protection Agency - Smart Growth	Technical Assistance: Helps community members develop strategies and an action plan for using broadband to create walkable, connected, economically vibrant main streets and small-town neighborhoods that improve human health and the environment.	For-Profit Organizations, Individuals & Households, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education	smartgrowth@epa.gov 202-566-2878	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Broadband USA Appropriations Act, 2021	National Telecommunications and Information Administration (NTIA)	**Tribal Broadband Connectivity Grants**: $1 billion to expand broadband adoption and deployment on tribal lands, as well as to support distance learning, remote work, and telehealth during the COVID-19 pandemic. Grants for Infrastructure (including submarine cable landing stations), affordability programs, digital literacy, telehealth, distance learning	Tribal governments (subgrantees allowed), Tribal organizations, TCUs, the Native Hawaiian Community, and Native Corporations	Chris Tamarin Christopher.tamarin@oregon.gov	A webinar that covered the new grants was held on March 17. A recording of the Grant Programs in the Consolidated Appropriations Act of 2021 can be found here.
		Broadband Infrastructure Deployment Grants: $300 million for state-and-provider partnerships to support broadband infrastructure deployment to areas lacking broadband, especially rural area. Grants for covered broadband projects, defined as competitively and technologically neutral projects for the deployment of fixed broadband service in a census block with at least one household or business that does not have access to 25/3.	Partnerships between a state, or one or more political subdivisions of a state and providers of fixed broadband service. ETC designation is not required.		
		Connecting Minority Communities Pilot Program: $285 million to help students and communities get connected to the internet through affordable broadband service. Grants to eligible recipients in anchor communities for the purchase of broadband internet access service or any eligible equipment, or to hire and train information technology personnel.	Historically Black and Tribal colleges and universities, Minority-serving institutions, and minority business enterprises and nonprofits		
FY20 Neighborhood Networks	(HUD) Dept. of Housing and Urban Development	Grant funding for Public Housing Authorities (PHAs) to establish, expand and/or update community technology centers. Program purpose: Broadband adoption, digital skills training, public computer access	Public/Indian Housing Authorities, Tribe	Dina Lehman-Kim Dina.lehmann-kim@hud.gov 202-402-2430	None Listed
FY20 Public & Indian Housing: Title VI Loan Guarantee	(HUD) Dept. of Housing and Urban Development	Assists Indian Housing Block Grant recipients to finance affordable housing construction and related community development. Tribes and Tribally designated housing entities can utilize the program for broadband access.	Tribes	Dina Lehman-Kim Dina.lehmann-kim@hud.gov 202-402-2430	Ongoing
Realty Program: Utility Right-of-Way (through EO: Accelerating Broadband Infrastructure Deployment 2012)	(DOT) Dept. of Transportation	Program purpose: Non-Highway Use of Federal Aid Rights of Way. There is no direct funding specifically for broadband. However, broadband may be eligible for reimbursement with federal-aid highway funds if it supports a transportation use. Broadband Funding Guide, Dept. of Transportation	Local Government & Authority, State, Territory, Tribe	Maggie Duncan-Augustt Maggie.duncan-augustt@dot.gov 202-366-9901	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
American Rescue Plan – FY21 Public Works & Economic Adjustment Assistance Programs (11.300 &11.307)	(USEDA) Economic Development Administration	Funding for rural & urban areas to provide investments that support construction, non-construction, technical assistance, & revolving loan fund projects under EDA's Public Works and EAA programs. Grants and cooperative agreements are designed to leverage existing regional assets and support the implementation of economic development strategies to advance economic prosperity in distressed communities. Broadband projects in are eligible for funding.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	J. Wesley Cochran jcochran@eda.gov 206-561-6646	Ongoing
Consolidated Appropriations Act: FY21 Broadband Infrastructure Program (11.031)	(DOC) National Telecommunications and Information Administration	Support the deployment of broadband infrastructure; enhance and expand public computer centers; encourage sustainable adoption of broadband service; and promote statewide broadband planning and data collection activities. Grants will be awarded to partnerships between a state, or political subdivisions of a state, and providers of fixed broadband service.	For-Profit Organizations, Local Government & Authority, Public/Private Institutions of Higher Education, State, Territory, Tribe	Jennifer Duane jduane@ntia.gov 202-482-2048	Aug. 17, 2021
Telecom Infrastructure Loan Program (10.851)	(USDA) Dept. of Agriculture- Rural Development	This program provides financing for the construction, maintenance, improvement and expansion of telephone service and broadband in rural areas.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	John Holman John.holman2@usda.gov 503-310-7692	Ongoing

CDBG: Community Development Block Grant

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
CDBG Disaster Recovery Program	(USHUD) Dept. of Housing and Urban Development	CDBG Disaster Recovery grants may be authorized by Congress to rebuild the affected areas and provide crucial seed money to start the recovery process. CDBG-DR funds cannot duplicate funding available from federal, state or local governments, private and nonprofit organizations, insurance proceeds, or any other source of assistance. CDBG-DR funds may be used to match other federal resources and can also be used in combination with the Dept. of Health and Human Services (HHS) Social Services Block Grants (SSBGs).	Local Government & Authority, State, Territory	disaster_recovery@hud.gov 202-708-3587	Ongoing
Community Development Block Grant Program: State Formula (14.228)	(USHUD) Dept. of Housing and Urban Development - Community Planning and Development	States award grants to smaller units of general local government that develop and preserve decent affordable housing, to provide services to the most vulnerable in our communities, and to create and retain jobs.	State, Territory	Bryan G. Guiney bryan.g.guiney@hud.gov 971-222-2612	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Community Development Block Grant Program: Entitlement Communities Funding (14.218)	(USHUD) Dept. of Housing and Urban Development - Community Planning and Development	The CDBG Entitlement Program provides annual grants on a formula basis to entitled cities and counties to develop viable urban communities by providing decent housing and a suitable living environment, and by expanding economic opportunities. Each activity must meet one of the following national objectives for the program: benefit low- and moderate-income persons, prevention or elimination of slums or blight, or address community development needs having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available.	Local Government & Authority	Bryan G. Guiney bryan.g.guiney@hud.gov 971-222-2612	None Listed
Community Development Block Grant Program: Section 108 Loan Guarantee Program Funding (14.248)	(USHUD) Dept. of Housing and Urban Development	Provides CDBG recipients with the ability to leverage their annual grant allocation to access low-cost, flexible financing for economic development, housing, public facility, and infrastructure projects. Communities can use Section 108 guaranteed loans to either finance specific projects or to launch loan funds to finance multiple projects over several years.	Local Government & Authority, State, Territory	Bryan G. Guiney bryan.g.guiney@hud.gov 971-222-2612	None Listed

Children and Youth

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
National School Lunch Afterschool Snack Program (Ongoing)	(USDA) Dept. of Agriculture - Food and Nutrition Service	Funding for schools and residential childcare institutions to provide afterschool snacks to low-income children who participate in the National School Lunch program.	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Education K-12	FNS Regional Office	None Listed
Community Facilities Direct Loan & Grant Program in Oregon **Community Facilities Guaranteed Loan Program in Oregon**	(USDA) Dept. of Agriculture- Rural Development	Funding to construct, rehabilitate, or repair essential community facilities in rural areas including public buildings, schools, hospitals, childcare centers, community centers, etc. May also fund the purchase of equipment for community facilities.	Public bodies, Community-based non-profit corporations, Federally-recognized Tribes with projects in communities of 20,000 or less. Guaranteed loans may be made for projects in communities of 50,000 or less.	Holly Halligan Holly.halligan@usda.gov 541-801-2682	Ongoing
DanPaul Foundation Grants	DanPaul Foundation	The Foundation is interested in providing funding (up to $15,000) to programs that directly serve the health, education, development, and welfare of the world's youth.	Non-profits	danpaulfoundation@gmail.com	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Weyerhaeuser Giving Fund	Weyerhaeuser Company	Provides funding in four areas: affordable housing and shelter, education and youth development, environmental stewardship, and human services, civic, and cultural growth.	Nonprofit Organizations	Anne Leyva Anne.leyva@weyerhaeuser.com 206-539-3000	None Listed

Community Planning and Development

Capacity Building

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
National Dislocated Worker Grants Program	(USDOL) Dept. of Labor	Provides resources to states and other eligible applicants to respond to large, unexpected layoff events causing significant job losses. Funding is intended to temporarily expand capacity to serve dislocated workers and meet the increased demand for WIOA employment and training services, with a purpose to reemploy laid off workers and enhance employability and earnings. It provides funding to create temporary employment opportunities to assist with clean-up and recovery effort	Local Government & Authority, State, Territory, Tribe	McEnery_Jenifer@dol.gov	None Listed
Community Capacity & Land Stewardship Program	National Forest Foundation	The National Forest Foundation Community Capacity and Land Stewardship Program™ (CCLS™) provides funding to increase the capacity of organizations implementing large scale restoration projects that benefit National Forests in Southeast Alaska and Pacific Northwest Region.	501(c)3 nonprofits, universities, and federally recognized Native American tribes are eligible to receive CCLS grants. If an organization does not meet this eligibility requirement, it must utilize an eligible fiscal sponsor, in compliance with the NFF Policy on Fiscal Sponsorship.	grants@nationalforests.org	One time per year. Oct. 15, 2020
Support for Crisis Response	US Digital Response (USDR)	USDR deploys highly qualified professionals to support governments and NGOs in their efforts to deliver critical services to the people who need them. USDR matches professionals to the needs of states, counties, cities, federal agencies, and other organizations. We are committed to partnering directly with governments on the specific issues facing your communities. No issue is too big or too small.	Government and government partners.	www.usdigitalresponse.org/request-help/	

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Indian Environmental General Assistance EFRP Program (GAP) (66.926)	(USEPA) Environmental Protection Agency	Assist tribes and intertribal consortia to develop capacity to manage their own environmental protection programs; develop/implement solid/hazardous waste programs in accordance with individual tribal needs and applicable federal laws & regulations.	Tribes	American Indian Environmental Office	
On-Request Technical Assistance from DOE Office of Indian Energy	(DOE) Office of Indian Energy Policy and Programs	Technical experts from DOE and its national laboratories, along with other partnering organizations, provide support to assist Indian tribes and Alaska Native villages with energy planning, housing and building energy efficiency, project development, policy and regulation, resilience, and village power. For more information, visit the on-request technical assistance description.	Tribes and Alaska Native villages	indianenergy@hq.doe.gov 240-562-1352	
Strategic Project & Initiative Grants	M.J. Murdock Charitable Trust	Provides grants to nonprofits in the Pacific Northwest. Focused giving to nonprofits that serves AK, ID, MT, OR & WA. - Strategic Project Grants: Capacity-building awards for mission-focused projects and infrastructure investment. - Initiative Grants: A variety of grant programs focused on scientific research, education and calling.	Individuals & Households, Nonprofit Organizations	**info@murdocktrust.org** 360-694-8415	Ongoing

Public Spaces

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Community Building Spaces Capital Grants	The Ford Family Foundation (TFFF)	Grants support the development of physical places that are open to the public and have multiple uses. Bricks, mortar and equipment. Bring your community together to build or renovate spaces that foster collaboration, civic participation or community events. Parks, pools and splash pads projects are welcome. Maximum award $250,000. Funds requested may not exceed one-third of the project's total budget. Funds from these grants must serve communities in rural Oregon or Siskiyou County, California, with less than 35,000 in population not adjacent to or part of an urban or metropolitan area .	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, State, Tribe	Rozalyn Mock rmock@tfff.org 541-957-5574	
Main Street America	National Main Street Center, Inc. (NMSC)	Main Street America is a program of the National Main Street Center. We revitalize older and historic commercial districts to build vibrant neighborhoods and thriving economies. Our two signature programs – Main Street America and UrbanMain – provide direct support to local leaders in small towns, mid-sized cities, and urban neighborhoods.		mainstreet@savingplaces.org 312-610-5613 Sheri Stuart Sheri.stuart@oregon.gov Oregon Main Street Coordinator 503-986-0679	

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
T-Mobile-FY21 Hometown Grant	T-Mobile with consulting partners Smart Growth America and Main Street America	The Hometown Grant program invests in small towns by awarding up to 100 towns a year with project funding—up to $50,000 each. They're focusing on revitalizing community spaces in towns with 50,000 people or less. Community Leaders and Civic Officials may submit proposals: https://t-mobile.custhelp.com/app/HTG/HTG_Application	Local Government & Authority, Nonprofit Organizations, Territory, Tribe	None listed	Quarterly: Jan – March April – June July- Sept Oct – Dec

Planning and Project Development

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Hazard Mitigation Grant Program: Post Fire	(DHS) Hazard Mitigation	FEMA makes assistance available through its Hazard Mitigation Grant Program Post Fire (HMGP Post Fire) to help communities implement hazard mitigation measures after wildfire disasters that substantially reduce the risk of future damage, hardship, loss, or suffering. Some examples of eligible projects include erosion control measures, defensible space, slope failure prevention, and flash flooding measures.	State, Territory, Federally-recognized Tribes affected by fires resulting in an Fire Management Assistance Grant	Anna Feigum shmo@mil.state.or.us 503-378-2260	None Listed
EDA FY21-23 Planning Program and Local Technical Assistance	(USDOC) Department of Commerce	EDA assists eligible recipients in creating regional economic development plans designed to build capacity and guide the economic prosperity and resiliency of an area or region. The Planning program also helps support organizations and Tribes with Short Term and State Planning investments designed to guide the creation and retention of high-quality jobs, particularly for the unemployed and underemployed in economically distressed regions. The Local Technical Assistance program strengthens the capacity eligible recipients to undertake and promote effective economic development programs through projects such as feasibility analyses and impact studies. Additional Information.	State, County, local governments, Special district governments, Public and State controlled institutions of higher education, federally recognized Native American tribal governments, Nonprofits other than institutions of higher education, Private institutions of higher education – Others.	Wes Cochran jcohran@eda.gov 206-561-6646 Francis Sakaguchi fsakaguchi@eda.gov	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY 2020 EDA Public Works and Economic Adjustment Assistance Programs	(USDOC) Department of Commerce	A flexible fund that can include assisting state and local interests in designing and implementing strategies to adjust or bring about change to an economy. The program focuses on areas that have experienced or are under threat of serious structural damage to the underlying economic base	State, County, local governments, Special district governments, Public and State controlled institutions of higher education, federally recognized Native American tribal governments, Nonprofits other than institutions of higher education, Private institutions of higher education – Others.	Wes Cochran jcohran@eda.gov 206-561-6646 Francis Sakaguchi fsakaguchi@eda.gov	Ongoing
Community Facilities Direct Loan & Grant Program in Oregon **Community Facilities Guaranteed Loan Program in Oregon**	(USDA) Dept. of Agriculture- Rural Development	Funding to construct, rehabilitate, or repair essential community facilities in rural areas including public buildings, schools, hospitals, childcare centers, community centers, etc. May also fund the purchase of equipment for community facilities.	Public bodies, Community-based non-profit corporations, Federally-recognized Tribes with projects in communities of 20,000 or less. Guaranteed loans may be made for projects in communities of 50,000 or less.	Holly Halligan Holly.halligan@usda.gov 541-801-2682	Ongoing
EPA Smart Growth - Cool & Connected	(USEPA) Environmental Protection Agency - Smart Growth	Technical Assistance: Helps community members develop strategies and an action plan for using broadband to create walkable, connected, economically vibrant main streets and small-town neighborhoods that improve human health and the environment.	For-Profit Organizations, Individuals & Households, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education	smartgrowth@epa.gov 202-566-2878	None Listed
FY19 Disaster Supplemental (11.307)	(USDOC) Dept. of Commerce - Economic Development Administration	Grant funding for non-construction and construction projects, as appropriate, to address economic challenges in areas where a Presidential declaration of a major disaster was issued. Applications must clearly incorporate principles for enhancing the resilience of the relevant community/region or demonstrate the integration of resilience principles into the investment project itself. Inclusion of resilience principles in the project is a necessary step to improve the capacity of the region to recover more quickly from future disaster events.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	Seattle Regional Office 206-220-7660	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
American Planning Association	American Planning Association	The Community Planning Assistance Teams (CPAT) program organizes multidisciplinary teams of planning professionals to work with local stakeholders to create a vision plan and implementation strategy. The program brings planning resources and opportunities to communities with a demonstrated need for assistance. The CPAT provides the time of senior-level planning experts to a community without compensation. However, the community is expected to raise funds to cover travel expenses and accommodations.	Local Government and Authority	CPAT@planning.org 312-786-6359	
Community Facilities Technical Assistance & Training Grant	(USDA) Dept. of Agriculture - Rural Development	Grant funding to public bodies and non-profit organizations to provide technical assistance and/or training to rural communities on identifying and planning for community facility needs; identifying resources to finance community facility construction or repair projects; prepare reports and surveys necessary to request related financial assistance; and prepare applications for Agency financial assistance.	Public bodies and nonprofit institutions assisting communities, Indian Tribes, and nonprofits to identify and plan for community facility needs that exist in rural communities of 20,000 or less.	Charlotte Bentley Charlotte.Bentley@usda.gov 503-414-3362	FY 21 application cycle has closed. Next application window expected after January 1, 2022.
Community Resilience Planning Guide for Buildings and Infrastructure Systems: A Playbook	(USDOC) National Institute of Standards and Technology (NIST)	All communities can improve their resilience and capacity to protect lives, livelihoods, and the quality of life for their residents and businesses. The Planning Guide recognizes that communities must prioritize their limited resources and that improving resilience is a process achieved over time. The Guide's planning process provides a structured yet flexible way to set community-scale goals, align priorities and resources, identify key stakeholders, and develop plans for recovery of community functions. Community resilience planning can inform and integrate other community plans and also reduce conflicting goals between plans.			
Building Blocks for Sustainable Communities	US Environmental Protection Agency	Building Blocks provides quick, targeted technical assistance to selected communities using a variety of tools that have demonstrated results and widespread application. This round of Building Blocks will offer a more flexible approach that leverages EPA staff expertise, facilitates rapid learning and exchange, does not rely on in-person workshops, and focuses on emerging challenges communities face related to land use planning and development. EPA will offer sequential tiers of assistance, starting with staff-led calls only and then selecting some communities for more in-depth, contractor-supported assistance.	Local, county, or tribal governments, or nonprofit organizations that have the support of the local government on whose behalf they are applying	Abby Hall hall.abby@epa.gov	Contact Abby Hall for information

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Recreation Economy for Rural Communities	US Environmental Protection Agency	Recreation Economy for Rural Communities is a planning assistance program to help communities develop strategies and an action plan to revitalize their Main Streets through outdoor recreation.	Local governments, Indian tribes, and nonprofit institutions and organizations representing any community in the United States.	Stephanie Bertaina Bertaina.stephanie@epa.gov	Currently closed but anticipate a call for communities to apply later in 2021
FY21 Real Estate Technical Assistance Grant	Center for Creative Land Recycling (CCLR)	CCLR is partnering with the CRE Foundation of the Counselors of Real Estate (CRE)® to provide select redevelopment projects with the targeted, pro bono strategic guidance of credentialed real estate problem-solvers. The program provides real estate analysis and tailored action plans which address real estate challenges. We are accepting applications now for publicly-owned properties. Technical Assistance can potentially be used for Vision-to-Action (V2A) projects.	Local governments, nonprofits, community groups, and quasi-governmental agencies such as redevelopment agencies or housing authorities.	510-918-3374 info@cclr.org	Currently accepting applications

Economic Development and Recovery

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Community Disaster Loan (CDL) Program (97.030)	DHS	Loans to local governments to help local governments maintain existing functions of a municipal operating character. The local government must demonstrate a need for financial assistance.	Local Government & Authority, Tribe	Martha Castro Martha.castro@fema.dhs.gov	
Shuttered Venue Operators Grant (SVO)	US Small Business Administration	The SVO Grant program was established by the Economic Aid to Hard-Hit Small Businesses, Nonprofits, and Venues Act, signed into law on December 27, 2020. The program includes $15 billion in grants to shuttered venues, to be administered by the SBA's Office of Disaster Assistance. Eligible applicants may qualify for SVO Grants equal to 45% of their gross earned revenue, with the maximum amount available for a single grant award of $10 million. $2 billion is reserved for eligible applications with up to 50 full-time employees.	Live venue operators or promoters, Theatrical producers, Live performing arts organization operators, Relevant museum operators, zoos and aquariums that meet specific criteria, motion picture theater operators, talent representatives, and each business entity owned by an eligible entity that also meets the requirements	SVOGrant@sba.gov	Applications accepted continuously.

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Economic Injury Disaster Loans (EIDL)	US Small Business Administration	EIDL provide working capital to help small businesses, small agricultural cooperatives, small businesses engaged in aquaculture, and most private, nonprofit organizations of all sizes meet their ordinary and necessary financial obligations that cannot be met as a direct result of the disaster. These loans are intended to assist through the disaster recovery period. EIDL loan applications will continue to be accepted through December 2021, pending the availability of funds. Loans are offered at very affordable terms, with a 3.75% interest rate for small businesses and 2.75% interest rate for nonprofit organizations, a 30-year maturity, and an automatic deferment of one year before monthly payments begin. Every eligible small business and nonprofit are encouraged to apply to get the resources they need.	Small businesses, small agricultural cooperatives and most private nonprofit organizations located in a declared disaster area and which have suffered substantial economic injury may be eligible for an SBA Economic Injury Disaster Loan (EIDL)	Richard Jenkins Richard.jenkins@sba.gov 916-735-1500	December 31, 2021
Business and Industry (B&I) Loan Guarantee Program	(USDA) Dept. of Agriculture - Rural Development	USDA Rural Development provides a guarantee on loans made by other lenders to businesses. The purpose is to encourage lending for projects that could not otherwise secure affordable	USDA-approved lenders providing loans for projects that bolster economic opportunity and create jobs in rural communities of 50,000 or less	Mandie Cole Mandie.cole@usda.gov 541-378-3538	Ongoing
FY 2020 EDA Public Works and Economic Adjustment Assistance Programs including CARES Act Funding	(USEDA) Economic Development Administration	EDA solicits applications from applicants in rural and urban areas to provide investments that support construction, non-construction, technical assistance, and revolving loan fund projects under EDA's Public Works and EAA programs. Grants and cooperative agreements made under these programs are designed to leverage existing regional assets and support the implementation of economic development strategies that advance new ideas and creative approaches to advance economic prosperity in distressed communities.	Public and State controlled institutions of higher education Nonprofits having a 501(c)(3) status, other than institutions of higher education County governments Private institutions of higher education Special district governments Native American tribal governments	Wes Cochran jcochran@eda.gov 206-561-6646	Rolling
Intermediary Relending Program: IRP	(USDA) Dept. of Agriculture - Rural Development	This program provides one percent loans to local lenders or "intermediaries" that re-lend to businesses to improve economic conditions and create jobs in rural communities.	Nonprofits, cooperatives, Federally-recognized Indian Tribes, and public agencies.	Mandie Cole Mandie.cole@usda.gov 541-378-3538	Quarterly competitions: March 31, 2021; June 30, 2021

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
NALCAB Rural Capacity Building Program	National Assoc. for Latino Community Asset Builders & HUD	Provide technical assistance and loans to rural nonprofits that are engaged in creating community and economic development opportunities and affordable housing for low income communities in rural areas. Through its past work under the HUD Rural Capacity Building Program, NALCAB has developed a Rural Revolving Loan Fund (RLF) to support eligible rural affordable housing and economic development projects. The Program provides short-term, 0% interest, no-origination-fee lending capital to eligible entities serving LMI rural communities in 15 states and Puerto Rico.	Nonprofit Organizations	Colton Powell cpowell@nalcab.org Info@nalcab.org 202-991-9100	Rolling
Leveraging Development Finance Tools to attract Opportunity Zone Investment	(USEPA) Office of Economic Revitalization	EPA Toolkit created in collaboration with CDFA and Skeo Solutions. This guide provides an overview of various development finance tools and suggestions for how communities could use these tools to finance projects in Opportunity Zones. More Information. Additional resources.		smartgrowth@epa.gov 202-566-2878	NA
Rural Community Assistance Corporation (RCAC)	Rural Community Assistance Corporation (RCAC)	Variety of loans for water and/or wastewater planning, environmental work, and construction. Also offers funding application assistance.	Non-profit organizations, public agencies, tribes, and low-income rural communities with a 50,000 population or less, or 10,000 or less if guaranteed by USDA Rural Development financing.	Jason Carman Rural Development Specialist JCarman@rcac.org 458-221-3473	Ongoing
American Rescue Plan – FY21 Public Works & Economic Adjustment Assistance Programs (11.300 &11.307)	(USEDA) Economic Development Administration	Funding for rural & urban areas to provide investments that support construction, non-construction, technical assistance, & revolving loan fund projects under EDA's Public Works and EAA programs. Grants and cooperative agreements are designed to leverage existing regional assets and support the implementation of economic development strategies to advance economic prosperity in distressed communities. Broadband projects in are eligible for funding.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	J. Wesley Cochran jcochran@eda.gov 206-561-6646	Ongoing
Rural Cooperative Development Grant	Department of Agriculture	The primary objective of the RCDG program is to improve the economic condition of rural areas by assisting individuals or entities in the startup, expansion or operational improvement of rural cooperatives and other business entities.	Nonprofit Organizations, Public/Private Institutions of Higher Education	202-720-1400	August 10, 2021

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Rural Innovation Stronger Economy (RISE) Grants	Department of Agriculture	To create and augment high-wage jobs, accelerate the formation of new businesses, support industry clusters and maximize the use of local productive assets in eligible low-income rural areas.	Agricultural Producers, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	202-720–1400	August 2, 2021

Education

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Community Facilities Direct Loan & Grant Program in Oregon Community Facilities Guaranteed Loan Program in Oregon	(USDA) Dept. of Agriculture- Rural Development	Funding to construct, rehabilitate, or repair essential community facilities in rural areas including public buildings, schools, hospitals, childcare centers, community centers, etc. May also fund the purchase of equipment for community facilities.	Public bodies, Community-based non-profit corporations, Federally-recognized Tribes with projects in communities of 20,000 or less. Guaranteed loans may be made for projects in communities of 50,000 or less.	Holly Halligan Holly.halligan@usda.gov 541-801-2682	Ongoing

Environmental

Conservation

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Plant Materials Program (10.905)	(USDA) U.S. Dept of Agriculture	Program aims to find plant solutions to solve conservation problems. The Plant Materials center delivers needed plants and plant technology throughout the United States. The program is dedicated to developing plants and plant technology to solve conservation problems.	Local Government & Authority, State, Territory, Tribe. See announcement for restrictions.	**John Englert** John.englert@wdc.usda.gov 202-720-0536	None listed
Weyerhaeuser Giving Fund	Weyerhaeuser Company	Provides funding in four areas: affordable housing and shelter, education and youth development, environmental stewardship, and human services, civic, and cultural growth.	Nonprofit Organizations	Anne Leyva Anne.leyva@weyerhaeuser.com 206-539-3000	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 American-Made Solar Prize Round 5: Hardware & Software Tracks	Department of Energy	Designed to support U.S. solar manufacturing and address challenges to rapid, equitable solar energy deployment by incentivizing hardware and software development.	For-Profit Organizations, Individuals & Households, Nonprofit Organizations, Public/Private Institutions of Higher Education		October 5, 2021
FY21 Building Partner Capacity & Promoting Resiliency & Equity Under Clean Water Act: Wetlands, Nonpoint Source, Monitoring, Assessment, & Listing	Environmental Protection Agency	Provides support for training & related activities to build the capacity of agricultural partners, state, territorial and tribal officials and nongovernmental stakeholders in activities to be carried out to support the goals of the Clean Water Act (CWA).	Healthcare Institution, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	202-566-1382	October 8, 2021
New this Month					
FY22 Native American Affairs: Technical Assistance to Tribes	Department of the Interior	Grants and cooperative agreements to provide technical assistance to Indian tribes and tribal organizations for water needs assessments, improved water management studies, water quality data collection and assessments, and water measurement studies.	Tribes		October 20, 2021

Forests

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Community Capacity & Land Stewardship Program	National Forest Foundation	The National Forest Foundation Community Capacity and Land Stewardship Program™ (CCLS™) provides funding to increase the capacity of organizations implementing large scale restoration projects that benefit National Forests in Southeast Alaska and Pacific Northwest Region.	501(c)3 nonprofits, universities, and federally recognized Native American tribes are eligible to receive CCLS grants. If an organization does not meet this eligibility requirement, it must utilize an eligible fiscal sponsor, in compliance with the NFF Policy on Fiscal Sponsorship.	grants@nationalforests.org	One per Year Oct. 15, 2020

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
NFF Grant Programs	National Forest Foundation	Supports action-oriented projects that directly enhance the health and well-being of America's National Forests and Grasslands and that engage the public in stewardship. Nonprofit organizations dedicated to addressing natural resource issues on National Forests and Grasslands can apply for support to complete projects through three distinct grant programs. NOTE: Treasured Landscapes, Unforgettable Experiences is an invitation only	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	ALiljeblad@nationalforests.org	Multiple
Tree Planting Program	National Forest Foundation	The National Forest Foundation is undertaking an effort to plant 50 million trees across our National Forests by 2023. Individuals, businesses, and organizations interested in supporting tree-planting can start their own online fundraiser.		406-542-2805	None Listed
Innovative Finance for National Forests Grant Program	National Forest Foundation	The program supports the development and implementation of innovative finance models that leverage private capital to support the resilience of the National Forest System and surrounding lands. IFNF supports local communities and stakeholders looking for new ways to support healthy forests, project developers working to connect investment capital to forested landscapes, and Forest Service managers and collaborators exploring new ways to support unfunded projects.		Jeff Lerner jalanlerner@gmail.com 202-236-1883	None Listed
Healthy Forests Reserve Program (10.922)	(USDA) Dept. of Agriculture - Natural Resources Conservation Service	One-time payments to landowners in exchange for easements, designed to enhance and protect forestland resources on private lands.	Farm Bill eligible landowners – Agricultural Producers, Individuals & Households, Tribe	Misty Beals Misty.beals@usda.gov 503-320-6953	None Listed
Emergency Forest Restoration Program: EFRP	(USDA) Dept. of Agriculture - Farm Service Agency	Grant funding for owners of non-industrial private forests (NIPF) to restore forest health damaged by natural disasters. Assistance helps landowners carry out emergency measures to restore forest health on land damaged by floods, hurricanes or other natural disasters.	For-Profit Organizations, Individuals & Households, Nonprofit Organizations	FSA County Office	None Listed
Environmental Quality Incentive Program (EQIP) (10.912)	(USDA) Dept. of Agriculture - Natural Resources Conservation Service	Provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land and non-industrial private forestland.	Farm Bill eligible landowners - Agricultural Producers, Individuals & Households, Tribe	Misty Beals Misty.beals@usda.gov 503-320-6953	None Listed
AmeriCorps Student Conservation Association	AmeriCorps	Student Conservation Association is an AmeriCorps partnership that may be a potential resource for labor-intensive conservation-focused projects. Conservation Association could partner with regional communities on urban reforestation and park restoration efforts.		aseda@thesca.org	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
One Tree Planted - Reforestation Funding	One Tree Planted	Fostering tree-planting projects and supporting reforestation through partnerships with US Forest Service, US State Forest & Conservation District, they plant trees across the United States, including California, Colorado, Florida & Oregon.	Agricultural Producers, For-Profit Organizations, Healthcare Institution, Individuals & Households, Local Government & Authority, Nonprofit Organizations, Public/Indian Housing Authorities, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, State, Territory, Tribe	800-408-7850 Online Contact Form	None Listed
FY21 Ford Bronco Wild Fund	Ford Motor Company	This initiative supported by profits from Ford Motor Company in partnership with the National Forest Foundation; Outward Bound, USA; and Sons of Smokey. Help with grants, scholarships, contributions from profits, tree-planting.	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education	Ford Motor Company Customer Relationship Center PO Box 6248 Dearborn MI 48126	

Land Acquisition

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Hazard Mitigation Grant Program: Post Fire	(DHS) Hazard Mitigation	FEMA makes assistance available through its Hazard Mitigation Grant Program Post Fire (HMGP Post Fire) to help communities implement hazard mitigation measures after wildfire disasters that substantially reduce the risk of future damage, hardship, loss, or suffering. Some examples of eligible projects include erosion control measures, defensible space, slope failure prevention, and flash flooding measures.	State, Territory, Federally-recognized Tribes affected by fires resulting in an Fire Management Assistance Grant	FEMA Hazard Mitigation Region 10 FEMA-R10-MIT@fema.dhs.gov	Ongoing
FY21 Land & Water Conservation Fund/Great American Outdoors Act: Nationally Competitive Funds (15.916)	(USDOI) Dept. of the Interior - National Park Service	The purpose of the competitive funding is to provide grants to acquire and/or develop public lands for outdoor recreation purposes consistent with the purposes of the LWCF.	State, Territory	Ginger Carter Ginger_carter@nps.gov 202-354-6467 Elizabeth Foundriest Elisabeth_foundriest@nps.gov 202-354-6916	Aug. 20, 2021

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
The Clean Water State Revolving Fund (CWSRF): Habitat Protection and Restoration and Silviculture	(USEPA) Environmental Protection Agency	The CWSRF can provide assistance for projects that result in the protection or restoration of surface water. This includes land conservation and restoration. Eligible projects include: Purchase of land, Leasing, Fee-simple purchase, Easement	For-Profit Organizations, Nonprofit Organizations, State, Territory, Tribe	Contact Form https://go.usa.gov/xsBVK	Ongoing
Land and Water Conservation Fund	Oregon Parks and Recreation	The Land and Water Conservation Fund (LWCF) is a Federally funded grant program administrated by the Oregon Parks and Recreation Department. Typically, the program awards about $1.5 million to qualified projects every other year for Oregon recreational areas and facilities. LWCF grants are available to either acquire land for public outdoor recreation or to develop basic outdoor recreation facilities. Can be used to do rehab work in public parks.	Cities, Counties, Park and Recreation Districts, METRO Port District, Indian Tribes, Oregon State Agencies (Parks & Recreation Dept., Dept. of State Lands, Department of Fish and Wildlife and Dept. of Forestry).	Nohemi Enciso Nohemi Enciso 503-480-9092	2021 Not Listed
Agricultural Conservation Easement Program (ACEP)	(USDA) Dept. of Agriculture – Natural Resources Conservation Service	The ACEP program provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits.	Farm Bill eligible landowners – Agricultural Producers, Individuals & Households, Tribes	Misty Beals Misty.beals@usda.gov 503-320-6953	Ongoing
Oregon Brownfields Program	Oregon Business Development Department dba Business Oregon	Oregon's Brownfields Program consists of two Funds which are available to provide financing for a full range of environmental activities – assessment through cleanup – associated with brownfields redevelopment. Environmental actions must be linked to site redevelopment that facilitates economic development or community revitalization. Eligible redevelopment projects include business development projects, industrial lands capacity, community facility and downtown or mixed-use center revitalization projects.	Any individual, business, non-profit organization, prospective purchaser, municipality, special district, port, or tribe.	Karen Homolac karen.homolac@oregon.gov	Rolling

Renewable

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
HDR Foundation Grants	HDR Foundation	Grant funding for education, public health and environmental projects in communities where our employees live and work (Ashland, Bend, Portland, and Salem) Examples of projects we may fund include:- Active transportation modes, such as walking or biking -Water, energy and waste reduction projects •Innovative, small-scale renewable energy and water reuse -Community-led environmental restoration efforts	Nonprofits	HDRFoundation@hdrinc.com	2nd Small Grant Cycle May 12 – June 7, 2021 Large Grant Cycle July 20 – Aug 19, 2021
DOE/EERE – Energy Efficiency & Conservation Block Grant Program	Office of Energy Efficiency & Renewable Energy	Increasing renewable energy capacity, technical knowledge, and deployment of energy efficiency projects at the local level.	Individuals and households, local government and authority, state, territory	877-337-3463	Ongoing

Equity and Inclusion

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Oregon Immigrant and Refugee Funders Collaborative	Collins Foundation, Meyer Memorial Trust, MRG Foundation, Pride Foundation, and The Oregon Community Foundation	A coordinated funding approach to address urgent and emerging issues impacting immigrants and refugees in Oregon, and to support local organizations responding to these issues. Grants fund projects that provide legal information, services, and representation for immigrants and refugees; outreach and education about policies, programs, services, and preparedness; information gathering, research, and analysis on immigration and refugee issues; basic human needs for immigrants and refugees; and community organizing, civic engagement, and advocacy. Application Link.	501(c)(3) organizations exempt or organizations that have a qualified fiscal sponsor.	**Carol Cheney** ccheney@cllinsfoundation.org Sally Yee sally@mmt.org Niyati Desai ndesai@oregoncf.org Kim Sogge kims@pridefoundatin.org	Ongoing

Erosion Control /Floodplain / Watershed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Emergency Watershed Protection Program - Floodplain Easement Option (EWPP-FPE) (10.973)	(USDA) Dept. of Agriculture - Natural Resources Conservation Service (NRCS)	NRCS recommends this option to landowners and others where acquiring an easement is the best approach (more economical and prudent) to reduce threat to life and/or property.	Farm Bill eligible participants – Individuals, Households & Tribes	Molly Dawson Molly.dawson@usda.gov 503-414-3234	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Emergency Watershed Protection (EWP) Program	(USDA) Dept. of Agriculture - Natural Resources Conservation Service (NRCS)	Offers vital recovery options for local communities to help people reduce hazards to life and property caused by floodwaters, droughts, wildfires, earthquakes, windstorms, and other natural disasters. Project funds address erosion related watershed impairments by supporting activities such as removing debris from stream channels, road culverts, and bridges; reshaping and protecting eroded banks; correcting damaged drainage facilities; repairing levees and structures; and reseeding damaged areas	Public and private landowners are eligible but must be represented by a project sponsor. Sponsors include legal subdivisions of the State, such as a city, county, general improvement district, conservation district, or any Native American tribe or tribal.	Molly Dawson Molly.dawson@usda.gov 503-414-3234	None Listed
Watershed Protection and Flood Prevention Program	USDA Natural Resources Conservation Service	The program provides for cooperation between the Federal government and the states and their political subdivisions to work together to prevent erosion; floodwater and sediment damage; to further the conservation development, use and disposal of water; and to further the conservation and proper use of land in authorized watersheds up to 250,000 acres.	Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	Gary Diridoni Gary.diridoni@usda.gov 503-414-3092	None Listed
Watershed Surveys and Planning Program	USDA Natural Resources Conservation Service	The purpose of the program is to assist governments with the protection watersheds from damage caused by erosion, floodwater, and sediment and to conserve and develop water and land resources. Resource concerns addressed by the program include water quality, opportunities for water conservation, wetland and water storage capacity, agricultural drought problems, rural development, municipal and industrial water needs, upstream flood damages, and water needs for fish, wildlife, and forest-based industries. Types of surveys and plans include watershed plans, river basin surveys and studies, flood hazard analyses, and flood plain management assistance.	Local Government & Authority, State, Territory, Tribe	Gary Diridoni Gary.diridoni@usda.gov 503-414-3092	None Listed
Good Neighbor Authority (Ongoing)	(USDA) Dept. of Agriculture - Forest Service	Funding through a cooperative agreement to execute watershed restoration and forest management work on USFS lands.	Local Government & Authority, State, Territory, Tribe		None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Clean Water State Revolving Fund: **Specific Information on Nonpoint Source Implementation Loans**	Oregon Department of Environmental Quality (DEQ)	Below-market rate loans for the planning, design and construction of water pollution control activities to attain and maintain water quality standards, and necessary to protect beneficial uses	Eligible public agencies include tribal nations, cities, counties, sanitary districts, soil and water conservation districts, irrigation districts, various special districts and certain intergovernmental entities. "Public agency" in this program is defined by ORS 468.423. If you are unsure whether your organization qualifies, contact DEQ at 503-229-5622	For general questions: CWSRFinfo@deq.state.or.us 503-229-LOAN Regional Project Officers: https://www.oregon.gov/deq/wq/cwsrf/Pages/CWSRF-Contacts.aspx	Applications are accepted year round with scheduled review and ranking in the first week of January, May, and September.
Drinking Water Source Protection Fund (DWSP)	Oregon Health Authority – Drinking Water Services	Low interest loans up to a maximum of $100,000 per project, and grant funds up to $30,000 per water system. Eligible activities include those that lead to risk reduction within the delineated drinking water source area or would contribute to a reduction in contaminant concentration within the drinking water source	Any Public and Privately-owned Community and Nonprofit Non-Community water systems with a completed Source Water Assessment. Must demonstrate a direct link between the proposed project and maintaining or improving drinking water quality.	Tom Pattee, OHA Drinking Water Services/ Source Water Protection/ Groundwater Coordinator tom.pattee@dhsoha.state.or.us 541-726-2587 ext. 24. Julie Harvey DEQ Water Quality Division Julie.harvey@state.or.us 503-229-5664 Adam DeSemple OHA Drinking Water Services Adam.desemple@dhsoha.state.or.us 971-673-0422	Request for 2021 Letters of Interest closes on March 24, 2021. Year-round application window for Emergency Grant but water quality threat must have occurred within 180 days
Oregon Watershed Enhancement Board – Grant Programs	State of Oregon Watershed Enhancement Board	Providing grants to help protect and restore healthy watersheds and natural habitats that support thriving communities and strong economies in Oregon. Include Restoration, Monitoring, Technical Assistance, Acquisition, See individual grant pages for addition grant opportunities.	Varies by grant. Please reference individual grant pages. www.oregon.gov/oweb/grants/Pages/grant-programs.aspx	Oweb.grant.pgm@oregon.gov 503-986-0178	None listed

Fisheries/Aquaculture

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY20 National Fish Habitat Action Plan (15.608)	(USDOI) Dept. of the Interior - United States Fish and Wildlife Service	Projects must protect, restore, and enhance fish and aquatic habitats. Projects under this program, directly or indirectly, support and promote public access to recreational fishing opportunities.	Individuals & Households, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	Stephanie Long Stephanie_a_long@fws.gov 703-358-1749	Dec 31, 2021
Saltonstall-Kennedy Competition: Fisheries Research & Economic Development	Department of Commerce	For fisheries research and development projects addressing aspects of U.S. fisheries, including, but not limited to, harvesting, processing, marketing, and associated business infrastructures.	For-Profit Organizations, Individuals & Households, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	808-725-5055	November 29, 2021

Food Security and Nutrition

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contacts	Deadline
FY21 Disaster Assistance for State Units on Aging & Tribal Organizations in Major Disasters Declared by the President (93.048)	(USHHS) Dept. of Health and Human Services - Administration for Community Living	Grants awarded under this announcement are to provide disaster reimbursement and assistance funds to those State Units on Aging (SUAs), and federally recognized Tribal Organizations who are currently receiving a grant under Title VI of the OAA.	State, Territory, Tribe	Kathleen Votava Kathleen.votava@acl.hhs.gov 202-765-7603	Sept. 7, 2021
Temporary Assistance for Needy Families: Formula Grant (93.558)	(USHHS) Dept. of Health and Human Services - Administration for Children and Families	The Temporary Assistance for Needy Families (TANF) program is designed to help needy families achieve self-sufficiency. States receive block grants to design and operate programs that accomplish one of the purposes of the TANF program.	State, Territory, Tribe	Robert Shelbourne Robert.shelbourne@acf.hhs.gov 202-401-5150 Info.OFA@acf.hhs.gov	None Listed
National School Lunch Afterschool Snack Program (Ongoing)	(USDA) Dept. of Agriculture - Food and Nutrition Service	Funding for schools and residential childcare institutions to provide afterschool snacks to low-income children who participate in the National School Lunch program.	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Education K-12	Jan Kallio 617-565-6299	None Listed

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contacts	Deadline
FY21 Supplemental Nutrition Assistance Program (SNAP): Online Purchasing Participation Assistance for Farmers & Farmers Markets	Department of Agriculture	The grantee will use resources from this grant to assist FMs and DMFs in becoming SNAP authorized Internet Retailers and supporting the participation of and processing of online transactions by these FMs and DMFs.	Nonprofit Organizations, Public/Private Institutions of Higher Education		August 23, 2021

Health

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 Disaster Assistance for State Units on Aging & Tribal Organizations in Major Disasters Declared by the President (93.048)	(USHHS) Dept. of Health and Human Services - Administration for Community Living	Grants awarded under this announcement are to provide disaster reimbursement and assistance funds to those State Units on Aging (SUAs), and federally recognized Tribal Organizations who are currently receiving a grant under Title VI of the OAA.	State, Territory, Tribe	Kathleen Votava Kathleen.votava@acl.hhs.gov 202-795-7603	Sept. 7,2021
Community Facilities Direct Loan & Grant Program in Oregon **Community Facilities Guaranteed Loan Program in Oregon**	(USDA) Dept. of Agriculture- Rural Development	Funding to construct, rehabilitate, or repair essential community facilities in rural areas including public buildings, schools, hospitals, childcare centers, community centers, etc. May also fund the purchase of equipment for community facilities.	Public bodies, Community-based non-profit corporations, Federally-recognized Tribes with projects in communities of 20,000 or less. Guaranteed loans may be made for projects in communities of 50,000 or less.	Holly Halligan Holly.halligan@usda.gov 541-801-2682	Ongoing
FY22 Ryan White HIV/AIDS Program, Part A: HIV Emergency Relief Grant Program (93.914)	Department of Health and Human Services	Grant recipients must use funds to support, further develop, and/or expand systems of care to meet the needs of people with HIV, who are low-income, and strengthen strategies to reach disproportionately impacted subpopulations.	Local Government & Authority	301-443-1373	October 6, 2021

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Minority Leaders Development Program	Department of Health and Human Services	Establishes a fellowship program at HHS to provide training in health equity issues & leadership to early career individuals to improve the health of racial/ethnic minority & other disadvantaged populations.	Local Government & Authority, Nonprofit Organizations, Public/Indian Housing Authorities, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, State, Territory, Tribe	240-453-6193 240-453-8822	August 17, 2021
FY21 Projects of National Significance: Bridging the Aging and Disabilities Networks	Department of Health and Human Services	Single award to develop a Community of Practice (CoP) designed to build capacity across and within States' aging and disability networks to support futures planning for individuals with intellectual and developmental disabilities (ID/DD).	Local Government & Authority, Nonprofit Organizations, Public/Indian Housing Authorities, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, State, Territory, Tribe		August 24, 2021
FY21 Enhance, Manage, & Promote the Medical Reserve Corps Training & Learning Management System via the TRAIN Learning Network	Department of Health and Human Services	The MRC program office supports the MRC network by providing technical assistance, coordination, communications, strategy and policy development, cooperative agreements, and training opportunities.	Healthcare Institution, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory	617-947-6496	August 25, 2021
FY21 Centers for Independent Living: Operationalizing Independent Living Services to American Indian and Alaska Native Communities	Department of Health and Human Services	Info & referral; skills training; peer counseling; advocacy; & services that facilitate transition from nursing homes/other institutions to the community, to individuals at risk of entering institutions and transition of youth to post-secondary life.	Nonprofit Organizations, Public/Private Institutions of Higher Education		August 27, 2021
FY21 Community Mental Health Services Block Grant (MHBG)	Department of Health and Human Services	The MHBG program makes funds available to support the grantees in carrying out plans for providing comprehensive community mental health services.	State, Territory	240-276-1199	None given
New this Month					

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY22 Service Area Competition Funding for Health Center Program: Round 5	Department of Health and Human Services	The Health Center Program supports public and private nonprofit community-based and patient-directed organizations that provide primary health care services to the Nation's medically underserved populations.	Local Government & Authority, Nonprofit Organizations, Public/Indian Housing Authorities, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, Tribe	301-594-4300	Sept. 7, 2021
FY22 Health & Public Safety Workforce Resiliency: Technical Assistance Center	Department of Health and Human Services	Supports efforts to reduce and address burnout, suicide, mental health conditions and substance use disorders; and promote resiliency among the Health Workforce in rural and underserved communities.	Healthcare Institution, Local Government & Authority, Public/Private Institutions of Higher Education, State, Territory, Tribe	301-443-1728	August 3, 2021
American Rescue Plan: FY21 Section 9813 State Planning Grants for Qualifying Community-Based Mobile Crisis Intervention Services	Department of Health and Human Services	To support the developing of a new state plan option, community-based mobile crisis intervention services for Medicaid recipients in the community who are experiencing a mental health or substance use disorder (MH/SUD) crisis.	State	Linda M Gmeiner: 410-786-9954	August 13, 2021

Housing and Homelessness

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Single Family Housing Guaranteed Loan Program Oregon	(USDA) Dept. of Agriculture - Rural Development	Assists approved lenders in providing low- and moderate-income households the opportunity to own adequate, modest, decent, safe and sanitary dwellings as their primary residence in eligible rural areas.	Individuals & Households	Locate a local lender https://go.usa.gov/xsBVE	Ongoing
Farm Labor Housing Loan and Grant Program	(USDA) Dept. of Agriculture - Rural Development	Provides affordable financing to develop housing for year-round and migrant or seasonal domestic farm laborers. Federal Register Notice of Solicitation	State and local government, Tribes, associations of farmworkers and nonprofit organizations, farmers, associations of farmers and family farm corporations	MFHprocessing2@usda.gov	Round 1– April 1, 2021 Round 2 – November 1, 2021 Round 3 – November 1, 2022

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Section 504 Single Family Housing Repair Loans & Grants	(USDA) Dept. of Agriculture - Rural Development	Section 504 loans and grants are intended to help very low-income make critical repairs or to remove health and safety hazards to their owner-occupied homes. Eligible Rural Areas	Very-low-income homeowners in eligible rural areas; grant available only to applicants 62 years of age or older	866-923-5626 ext. 1	Ongoing, pending availability of funds
Affordable Housing Loans for Low-Income Rural Communities	Housing Assistance Council (HAC)	Short-term loans at below market interest rates to local nonprofits, for-profits, and government entities that are working to develop affordable housing for low-income, rural communities. Loans from these funds are used for a wide variety of housing development purposes, for all types of affordable and mixed income housing projects, and for both rental and ownership units. HAC Loans may be used for: predevelopment; acquisition; construction; self-help housing; and/or preservation.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, Tribe	hac@ruralhome.org 202-842-8600	Ongoing
Federal Housing Administration Multifamily loan programs	(USHUD) Housing and Urban Development	FHA insures multifamily loans originated by FHA approved lenders for the construction, substantial rehabilitation, and acquisition and refinancing of apartments and health care facilities.	For profit or not-for-profit Multifamily housing developers.	Multifamily West Regional Directory https://go.usa.gov/xsBVv	Ongoing
Federal Housing Administration Section 203(h) loan	Housing and Urban Development	The Section 203(h) program allows the Federal Housing Administration (FHA) to insure mortgages made by qualified lenders to victims of a major disaster who have lost their homes and are in the process of rebuilding or buying another home.	Households who lost their homes in a declared natural disaster	FHA Resource Center 1-800-call-FHA	Ongoing
FY19 Disaster Supplemental (11.307)	(USDOC) Dept. of Commerce - Economic Development Administration	Grant funding for non-construction and construction projects, as appropriate, to address economic challenges in areas where a Presidential declaration of a major disaster was issued.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	Seattle Regional Office 206-220-7660	None Listed
NALCAB Rural Capacity Building Program	National Assoc. for Latino Community Asset Builders & HUD	Provide technical assistance and loans to rural nonprofits that are engaged in creating community and economic development opportunities and affordable housing for low income communities in rural areas. Through its past work under the HUD Rural Capacity Building Program, NALCAB has developed a Rural Revolving Loan Fund (RLF) to support eligible rural affordable housing and economic development projects. The Program provides short-term, 0% interest, no-origination-fee lending capital to eligible entities serving LMI rural communities in 15 states and Puerto Rico.	Nonprofit Organizations	Colton Powell cpowell@nalcab.org Info@nalcab.org 202-991-9100	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Rural Capacity Building for Community Development and Affordable Housing Grants (RCB)	(USHUD) Housing and Urban Development	The Rural Capacity Building program enhances the capacity and ability of rural housing development organizations, Community Development Corporations (CDCs), Community Housing Development Organizations (CHDOs), rural local governments, and Indian tribes (eligible beneficiaries) to carry out affordable housing and community development activities in rural areas for the benefit of low- and moderate-income families and persons.	Only National Organizations that are 501(c)(3) nonprofits, other than institutions of higher education	https://www.hudexchange.info/programs/rural-capacity-building/	Varies based on Notice of Funding Availability
Distressed Cities Technical Assistance	(USHUD) Housing and Urban Development	The Distressed Cities Technical Assistance (DCTA) program is designed to improve fiscal health and build administrative capacity of relatively small units of general local government (UGLGs or local governments) that are economically distressed and have been recently impacted by a natural disaster.	Small units of general local government (UGLGs or local governments) that are economically distressed and have been recently impacted by a natural disaster.	distressedcities@hud.gov	Rolling
Low Income Home Energy Assistance Program (LIHEAP)	(USHHS) Dept. of Health and Human Services - Administration for Children and Families	LIHEAP is a federally funded program that helps low-income households with their home energy bills. We may be able to offer help for the following: home energy bills; energy crises; weatherization and minor energy-related home repairs.	Individuals & Households, State	Katina Lawson Katina.lawson@acf.hhs.gov 202-401-6527 202-401-9351	None Listed
Section 502 Single Family Housing Direct Home Loans (Rolling Deadline)	(USDA) Dept. of Agriculture - Rural Development	USDA provides affordable, subsidized direct loans to qualifying low- and very-low-income homebuyers in eligible rural areas. Eligible Rural Areas	Income-qualified home buyers who meet citizenship or eligible non-citizen requirements; have the legal capacity to incur the loan; be unable to secure an affordable loan from other sources; and other requirements	direct.questions@usda.gov (866) 923-5626, extension 1	Ongoing
First Interstate BancSystem Foundation	First Interstate Bank	The majority of the Foundation's grants are focused on alleviating poverty by assisting low- and moderate-income individuals and communities. Specific areas of interest include hunger and homelessness, affordable housing, financial education, youth programs, early childhood development, arts and culture, leadership programs, and healthy living.	Nonprofit organizations in communities served by First Interstate in Idaho, Montana, Oregon, South Dakota, Washington, and Wyoming.	foundation@fib.com 406-255-5393	Ongoing
FY20 Public & Indian Housing: Title VI Loan Guarantee	(HUD) Dept. of Housing and Urban Development	Assists Indian Housing Block Grant recipients to finance affordable housing construction and related community development. Tribes and Tribally designated housing entities can utilize the program for broadband access.	Tribes	Dina Lehman-Kim Dina.lehmann-kim@hud.gov 202-402-2430	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 Indian Housing Block Grant Program (14.867)	Dept. of Housing and Urban Development	Eligible activities for the funds include housing development, operation and maintenance, modernization of existing housing, housing services to eligible families and individuals, housing management services, crime prevention and safety activities, and model activities that provide creative approaches to solving affordable housing problems in Indian Country.	Public/Indian Housing Authorities, Tribe	Hilary Atkin Hilary.c.atkin@hud.gov 202-402-3427	None Listed
American Rescue Plan: FY21 Emergency Rental Assistance Program (ERA2) (21.023)	Dept. of Treasury	The funds are provided directly to states, U.S. territories, local governments, and (in the case of ERA1) Indian tribes. Grantees use the funds to provide assistance to eligible households through existing or newly created rental assistance programs.	Local Government & Authority, State, Territory	SLFRP@treasury.gov	None Listed
Weyerhaeuser Giving Fund	Weyerhaeuser Company	Provides funding in four areas: affordable housing and shelter, education and youth development, environmental stewardship, and human services, civic, and cultural growth.	Nonprofit Organizations	Anne Leyva Anne.leyva@weyerhaeuser.com 206-539-3000	None Listed
Mutual Self-Help Housing Technical Assistance Grants Program	(USDA) Dept. of Agriculture - Rural Development	Provides grants to qualified organizations to help them carry out local self-help housing construction projects. Grant recipients supervise groups of very-low- and low-income individuals and families as they construct their own homes in rural areas.	Government non-profit organizations, Federally-recognized Tribes, and private non-profit organizations	Jill Rees jill.rees@usda.gov 503-414-3302	Ongoing
FY21 Healthy Homes and Weatherization Cooperation Demonstration Grant (14.901)	Department of Housing and Urban Development	To determine if coordination of Healthy Homes & Weatherization Assistance Programs with respect to health remediation & energy conservation achieves cost effectiveness and improves the quality of homes.	Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Tribe		August 17, 2021
FY21 Self-Help Homeownership Opportunity Program	Department of Housing and Urban Development	SHOP funding is used to facilitate and encourage innovative homeownership opportunities on a national, geographically diverse basis through the provision of self-help homeownership housing programs.	Nonprofit Organizations	202-708-2290 / 877-787-2526 (toll-free)	August 23, 2021
NEW THIS MONTH					
FY21 HBCU Cooperative Research in Housing Technologies	Department of Housing and Urban Development	Homebuilding technologies, for HBCUs, that provide the industry innovative construction products/practices for more affordable, energy efficient, resilient (durable, disaster resistant, adaptable, maintainable) and healthier housing.	Public/Private Institutions of Higher Education		August 10, 2021
FY21 Resident Opportunity & Self-Sufficiency Service Coordinator Program	Department of Housing and Urban Development	Designed to assist residents of Public and Indian Housing make progress towards economic and housing self-sufficiency by removing the educational, professional and health barriers they face.	Nonprofit Organizations, Public/Indian Housing Authorities, Tribe	202-708-1112	Sept. 17, 2021

Infrastructure

Public Works

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Special Public Works Fund	Business Oregon	Provides funds for publicly-owned facilities that support economic and community development in Oregon. Funds are available to public entities for: planning; designing, purchasing; improving and constructing publicly-owned facilities; replacing publicly owned essential community facilities; and emergency projects as a result of a disaster. Emergency project assistance is used for reconstruction of essential community facilities that provide or support services vital to public health and safety. Funds can be used to help offset the 25% cost match for HMGP.	Oregon cities, counties, county service districts (organized under ORS Chapter 451), tribal councils; ports; districts as defined in ORS 198.010, airport districts (ORS 838)	Regional Development Officer	None Listed
FY21 American-Made Solar Prize Round 5: Hardware & Software Tracks	**Department of Energy**	**Designed to support U.S. solar manufacturing and address challenges to rapid, equitable solar energy deployment by incentivizing hardware and software development.**	**For-Profit Organizations, Individuals & Households, Nonprofit Organizations, Public/Private Institutions of Higher Education**		October 5, 2021

Water

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Emergency Community Water Assistance Grants Program	(USDA) Dept. of Agriculture - Rural Development	To help rural communities who have experienced a significant decline in quantity or quality of water, due to an emergency event (ex. drought, earthquake, hurricane or tornado), to obtain adequate quantities of clean drinking water.	State and local governmental entities, nonprofit organizations, Federally recognized Tribes	Holly Halligan Holly.halligan@usda.gov 541-801-2682	None
Water & Waste Disposal Loan Guarantees	(USDA) Dept. of Agriculture - Rural Development	USDA guarantees loans made by private lenders; purpose is provide affordable financing to qualified borrowers to improve access to clean, reliable water and waste disposal systems for households and businesses	Federal and State-chartered banks, savings and loans, Farm Credit Banks with direct lending authority, and credit unions making loans to public bodies, Federally-recognized Tribes, non-profit businesses, and others.	Holly Halligan Holly.halligan@usda.gov 541-801-2682	None

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 Water & Waste Disposal Loan & Grant Program	(USDA) Dept. of Agriculture - Rural Development	This program provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and storm water drainage to households and businesses in eligible rural areas.	Most state and local governmental entities, special districts, private nonprofits, and Federally-recognized Tribes	Holly Halligan Holly.halligan@usda.gov 541-801-2682	Ongoing
Water & Waste Disposal Grants to Alleviate Health Risks on Tribal Lands & Colonias	(USDA) Dept. of Agriculture - Rural Development	This program provides low-income communities, which face significant health risks, access to safe, reliable drinking water and waste disposal facilities and service on Federally recognized Tribal lands	Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	Holly Halligan Holly.halligan@usda.gov 541-801-2682	None
Safe Drinking Water on Tribal Lands	(USEPA) Office of Ground Water and Drinking Water	EPA works collaboratively with tribal governments, tribal utilities and tribal members to implement the Safe Drinking Water Act (SDWA). The goal of this collaboration is to improve access to safe drinking water on tribal lands.	Tribe	Manheimer.jennifer@epa.gov 206-553-1189 Online Form	None Listed
Sustainable Infrastructure Planning Project	Oregon Business Development Department dba Business Oregon partnering with Oregon Health Authority	Up to $20k forgivable loan planning awards for feasibility studies, asset management plan, system partnership studies, resilience plan, water rate study, leak detection study, and master plan (systems with less than 300 connections). Emergency projects may receive expedited processing and be processed outside of deadline.	Public Water Systems (non-profit, private, municipality, except federally owned or operated) providing services to at least 25 residents or more than 15 connections	Business Oregon Regional Development Officer www.orinfrastructure.org	March 15, 2021 Sept. 15, 2021 Dec. 15, 2021
Special Public Works Fund	Oregon Business Development Department dba Business Oregon	Loans for planning and construction of Utilities, Emergency projects, Levees, Firm Based Business projects, Telecom, Energy Systems, Transportation, Railroad, Road, Marine & other Public Facilities.	Municipalities: Cities, Counties, Tribal Councils, Ports, Airports, Domestic Water Supply Districts, County Service District, Sanitary Districts and Special Districts	Business Oregon Regional Development Officer www.orinfrastructure.org	Ongoing
Water/Wastewater Financing Program	Oregon Business Development Department dba Business Oregon	Grants and loans for planning and construction of storm water, water source, treatment, distribution, waste water collection and treatment.	Municipalities: Cities, Counties, Tribal Councils, Ports, Airports, Domestic Water Supply Districts, County Service District, Sanitary Districts and Special Districts	Business Oregon Regional Development Officer www.orinfrastructure.org	Ongoing

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Safe Drinking Water Revolving Loan Fund	Oregon Business Development Department dba Business Oregon partnering with Oregon Health Authority	Design and construction of water system infrastructure including but not limited to treatment, transmission/ distribution mains, finished water reservoirs, water sources, pumping, aquifer storage and recovery projects, seismic improvements, redundancy/reliability infrastructure, instrumentation, telemetry, and metering. Emergency projects may receive expedited processing.	Public Water Systems (non-profit, private, municipality, except federally owned or operated) providing services to at least 25 residents or more than 15 connections	Business Oregon Regional Development Officer www.orinfrastructure.org	Letters of Interest accepted quarterly — Applications accepted year round.
Clean Water State Revolving Fund	Oregon Department of Environmental Quality (DEQ)	Below-market rate loans for the planning, design and construction of water pollution control activities to attain and maintain water quality standards, and necessary to protect beneficial uses. Fact sheet: CWSRF Disaster Response	Eligible public agencies include tribal nations, cities, counties, sanitary districts, soil and water conservation districts, irrigation districts, various special districts and certain intergovernmental entities. "Public agency" in this program is defined by ORS 468.423. If you are unsure whether your organization qualifies, contact DEQ at 503-229-5622.	For general questions: CWSRFinfo@deq.state.or.us or 503-229-LOAN Regional Project Officers: https://www.oregon.gov/deq/wq/cwsrf/Pages/CWSRF-Contacts.aspx	Applications are accepted year round with scheduled review and ranking in the first week of January, May and September.
Rural Community Assistance Corporation (RCAC)	Rural Community Assistance Corporation (RCAC)	Variety of loans for water and/or wastewater planning, environmental work, and construction. Also offers funding application assistance.	Non-profit organizations, public agencies, tribes, and low-income rural communities with a 50,000 population or less, or 10,000 or less if guaranteed by USDA Rural Development financing.	Jason Carman Rural Development Specialist JCarman@rcac.org 458-221-3473	Ongoing
FY21 Rural Energy for America (REAP) Renewable Energy Systems & Energy Efficiency Improvements Program	(USDA) Dept. of Agriculture - Rural Development	Program provides guaranteed loan financing and grant funding to agricultural producers and rural small businesses for renewable energy systems or to make energy efficiency improvements. Agricultural producers may also apply for new energy efficient equipment and new system loans for agricultural production and processing.	Agricultural producers who gain 50% or more of their gross income from agricultural operations; small businesses that are located in a rural area or town of 50,000 or less; and rural electric cooperatives.	Jessie Huff Jesie.huff@usda.gov 503-414-3314	Sept. 30, 2021

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Feasibility Study Grants	Oregon Water Resources Department	Feasibility Study Grants fund qualifying costs of studies that evaluate the feasibility of a proposed conservation, reuse, or storage project that appears to have merit but is lacking important details necessary to determine whether or not to proceed with implementation.	Grants require a 50% cost match of the total cost of the feasibility study, up to $500,000. Any local government, Indian tribe, or person may apply for funding.	Becky Williams, 503-986-0869, WRD_DL_feasibilitystudygrants@oregon.gov	NA
Household Water Well System Loan Program [Western States]	Rural Community Assistance Corporation (RCAC)	Low interest loans available to construct, refurbish or replace individual water well systems.	Residence must be in a rural area, town, or community in RCAC's 13 state service area with a population not exceeding 50,000.	Jason Carman Rural Development Specialist JCarman@rcac.org 458-221-3473	None listed
National Water Well Projects	Water Well Trust	Provide long-term, low-interest loans to applicants seeking new or improved water wells. The Water Well Trust limits funding to a maximum of $11,000 per household. Loans have an interest rate of 1% with terms of up to 20 years.	Individuals & Households	info@waterwelltrust.org 202-625-4383	None listed.
New this Month					
FY21 Electric Infrastructure Loan & Loan Guarantee Program	Department of Agriculture	Loans for the construction of electric distribution facilities in rural areas.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	202-720-1422	None listed.
FY22 Clean Vessel Act	Department of the Interior	Funding allows States to construct, renovate, operate, & maintain pump-out stations & waste reception facilities for recreational boaters & to inform boaters about the use, benefits, & availability of pump-out stations & waste reception facilities.	State, Territory	703-785-3829	November 24, 2021

Technology and Renewables

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Special Public Works Fund	Oregon Business Development Department dba Business Oregon	Loans for planning and construction of Utilities, Emergency projects, Levees, Firm Based Business projects, Telecom, Energy Systems, Transportation, Railroad, Road, Marine & other Public Facilities.	Municipalities: Cities, Counties, Tribal Councils, Ports, Airports, Domestic Water Supply Districts, County Service District, Sanitary Districts and Special Districts	Business Oregon Regional Development Officer www.orinfrastructure.org	Ongoing

Transportation

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 Formula Grants for Rural Areas - Section 5311 (20.509)	(USDOT) Dept. of Transportation - Federal Transit Administration	Provides capital, planning, and operating assistance to states to support public transportation in rural areas with populations of less than 50,000, where many residents often rely on public transit to reach their destinations.	Local Government & Authority, State, Territory, Tribe	202-366-2053	None Listed
FY20 Surface Transportation Block Grant Program	(USDOT) Dept. of Transportation - Federal Highway Administration	The Surface Transportation Block Grant program (STBG) provides flexible funding that may be used by States and localities for projects to preserve and improve the conditions and performance on any Federal-aid highway, bridge and tunnel projects on any public road, pedestrian and bicycle infrastructure, and transit capital projects, including intercity bus terminals.	Local Government & Authority, State, Territory, Tribe	David Bartz David.bartz@dot.gov 512-417-5191 Gerald.yakowenko@dot.gov Karen.scurry@dot.gov	None Listed
Special Public Works Fund	Oregon Business Development Department dba Business Oregon	Loans for planning and construction of Utilities, Emergency projects, Levees, Firm Based Business projects, Telecom, Energy Systems, Transportation, Railroad, Road, Marine & other Public Facilities.	Municipalities: Cities, Counties, Tribal Councils, Ports, Airports, Domestic Water Supply Districts, County Service District, Sanitary Districts and Special Districts	Business Oregon Regional Development Officer www.orinfrastructure.org	Ongoing
FY21 National Scenic Byways Program (202.205)	(FHWA) Federal Highway Administration	All National, State, and Tribal Scenic Byways and All-American Roads are eligible for the Program. Eligible activities include: Protection of scenic, historical, recreational, cultural, natural, and archaeological resources in an area adjacent to a scenic byway. • Development and implementation of a corridor management plan to maintain characteristics of a byway corridor while providing for accommodation of increased tourism and development of related amenities. • Construction along a scenic byway of a facility for pedestrians and bicyclists, rest area, turnout, highway shoulder improvement, overlook, or interpretive facility. • Development and implementation of a scenic byway marketing program. • An improvement that will enhance access to an area for the purpose of recreation, including water related recreation.	Local Government & Authority, State, Territory, Tribe	202-366-0660 202-366-4000	Sept. 30, 2024
New this Month					
FY21 Accelerated Innovation Deployment Demonstration Program	Department of Transportation	The AID Demonstration Program provides incentive funding for eligible entities to accelerate the implementation of proven innovation in highway transportation.	State, Territory, Tribe	404-895-6229 / 404-562-3917	Sept. 28, 2021

Mitigation and Resiliency

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Hazard Mitigation Grant Program: Post Fire	(DHS) Hazard Mitigation	FEMA makes assistance available through its Hazard Mitigation Grant Program Post Fire (HMGP Post Fire) to help communities implement hazard mitigation measures after wildfire disasters that substantially reduce the risk of future damage, hardship, loss, or suffering. Some examples of eligible projects include erosion control measures, defensible space, slope failure prevention, and flash flooding measures.	State, Territory, Federally recognized Tribes affected by fires resulting in an Fire Management Assistance Grant	Anna Feigum shmo@mil.state.or.us 503-378-2260	None Listed
Hazard Mitigation Grant Program (97.039)	(USDHS) Dept. of Homeland Security (FEMA specific) - Federal Insurance and Mitigation Administration	Funds provided to state, local, tribal and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses in their communities.	Local Government & Authority, Nonprofit Organizations, State, Territory, Tribe	Anna Feigum shmo@mil.state.or.us 503-378-2260	DR4562: Nov 29, 2021 FM5327: May 28, 2021
Building Resilient Infrastructure and Communities (BRIC)	(USDHS) Dept. of Homeland Security Hazard Mitigation Grant Program	The BRIC program supports communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; and enabling large projects. For more Information. NOFO Opportunities	Local Government & Authority, State, Territory, Tribe	Anna Feigum shmo@mil.state.or.us 503-378-2260	Application period is open.
National Flood Insurance Program (97.022)	(USDHS) Dept. of Homeland Security (FEMA specific) - Federal Insurance and Mitigation Administration	The National Flood Insurance Program provides insurance to help reduce the socio-economic impact of floods.	Individuals & Households, Local Government & Authority, State	Anna Feigum shmo@mil.state.or.us 503-378-2260	None Listed
Wetland Mitigation Banking Program	Department of Agriculture	The Wetland Mitigation Banking Program (WMBP) is a competitive grants program that supports the development and establishment of wetland mitigation banks to make credits available for agricultural producers.	For-Profit Organizations, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribes	800-877-8339	August 16, 2021

Recreation

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY21 Land & Water Conservation Fund/Great American Outdoors Act: Nationally Competitive Funds (15.916)	(USDOI) Dept. of the Interior - National Park Service	The purpose of the competitive funding is to provide grants to acquire and/or develop public lands for outdoor recreation purposes consistent with the purposes of the LWCF.	State, Territory	Ginger Carter Ginger_carter@nps.gov 202-354-6467 Elizabeth Foundriest Elisabeth_foundriest@nps.gov 202-354-6916	Aug-20-2021
FY21 Rivers, Trails, & Conservation Assistance Program	(USDOI) National Park Service	Our national network of conservation and recreation planning professionals partners with community groups, nonprofits, tribes, and state and local governments to design trails and parks, conserve and improve access to rivers, protect special places, and create recreation opportunities.	State and local agencies, tribes, nonprofit organizations, or citizen groups. National Parks and other Federal agencies may apply in partnership with other local organizations.	Barbara Rice Pwr_rtca@nps.gov 202-354-6922	None Listed
Land and Water Conservation Fund	Oregon Parks and Recreation	The Land and Water Conservation Fund (LWCF) is a Federally funded grant program administrated by the Oregon Parks and Recreation Department. Typically, the program awards about $1.5 million to qualified projects every other year for Oregon recreational areas and facilities. LWCF grants are available to either acquire land for public outdoor recreation or to develop basic outdoor recreation facilities.	Cities, Counties Park and Recreation Districts, METRO Port District, Indian Tribes, Oregon State Agencies (Parks & Recreation Dept., Dept. of State Lands, Department of Fish and Wildlife and Dept. of Forestry).	Nohemi Enciso nohemi.enciso@oregon.gov 503-480-9092	2021 Not Listed
Recreational Trails Program - Formula Grants (20.219)	(USDOT) Dept. of Transportation - Federal Highway Administration	The Recreational Trails Program (RTP) provides funds to the States to develop, maintain, or rehabilitate recreational trails and trail-related facilities for both nonmotorized and motorized recreational trail uses.	State, Territory	Christopher Douwes Christopher.douwes@dot.gov 202-366-5013	None Listed
Recreation Economy for Rural Communities	US Environmental Protection Agency	Recreation Economy for Rural Communities is a planning assistance program to help communities develop strategies and an action plan to revitalize their Main Streets through outdoor recreation.	Local governments, Indian tribes, and nonprofit institutions and organizations representing any community in the United States.	Stephanie Bertaina Bertaina.stephanie@epa.gov	Currently closed but anticipate a call for communities to apply later in 2021
New this Month					

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
FY22 Clean Vessel Act	Department of the Interior	Funding allows States to construct, renovate, operate, & maintain pump-out stations & waste reception facilities for recreational boaters & to inform boaters about the use, benefits, & availability of pump-out stations & waste reception facilities.	State, Territory	703-785-3829	November 24, 2021

Volunteers

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
AmeriCorps State & National Grant Programs	Corporation for National and Community Service	AmeriCorps is a federal agency that funds organizations to make positive impact in communities. Grants provide financial assistance to programs that recruit, train, and supervise AmeriCorps members who meet critical community needs in the areas of education, disaster services, health, environmental stewardship, economic opportunity, and veterans and military families.		Mary Greusel or@cns.gov 202-815-4256	None Listed
Senior Corps/Retired & Senior Volunteer Program (RSVP) Competition (94.002)	Corporation for National and Community Service	Funds Retired and Senior Volunteer Program (Senior Corps) projects that support volunteers 55 years and older serving in a diverse range of activities that meet specific local and community needs. The Senior Corps in Oregon provides three major service areas: Foster Grandparents, Senior Companions, and RSVP (safety patrols, home renovation, tutoring, environmental protection, etc.). Oregon has a robust program funded through $12.8 Million in FY 2020 funding.	Local Government & Authority, Nonprofit Organizations, Public /Private Institutions of Higher Education, State, Territory, Tribe	OR@CNS.gov 202-606-5000	None Listed
Engineers Without Borders USA	Engineers Without Borders USA (EWB-USA)	EWB-USA's Community Engineering Corps, in partnership with the American Society of Civil Engineers and the American Water Works Association, lends volunteers' technical expertise to communities that are unable to easily retain or afford engineering services.	Local Government & Authority, State, Territory, Tribe	Lauren Butner info@ewb-usa.org 303-772-2723	None Listed

Workforce: Employment, Labor, and Training

Program Title/Website	Resource Provider	Description	Eligible Applicants	Contact	Deadline
Health Profession Opportunity Grants (HPOG)	(USHHS) Dept. of Health and Human Services - Administration for Children and Families	Provides education and training to TANF recipients and other low-income individuals for occupations in the health care field that pay well and are expected to either experience labor shortages or be in high demand.	Healthcare Institution, Local Government & Authority, Nonprofit Organizations, Public/Private Institutions of Higher Education, State, Territory, Tribe	hpog@acf.hhs.gov	None Listed
National Dislocated Worker Grants Program	(USDOL) Dept. of Labor	Provides resources to states and other eligible applicants to respond to large, unexpected layoff events causing significant job losses. Funding is intended to temporarily expand capacity to serve dislocated workers and meet the increased demand for WIOA employment and training services, with a purpose to reemploy laid off workers and enhance employability and earnings. It provides funding to create temporary employment opportunities to assist with clean-up and recovery effort	Local Government & Authority, State, Territory, Tribe	McEnery_Jenifer@dol.gov	None Listed
Minority Leaders Development Program	Department of Health and Human Services	Establishes a fellowship program at HHS to provide training in health equity issues & leadership to early career individuals to improve the health of racial/ethnic minority & other disadvantaged populations.	Local Government & Authority, Nonprofit Organizations, Public/Indian Housing Authorities, Public/Private Institutions of Education K-12, Public/Private Institutions of Higher Education, State, Territory, Tribe	240-453-6193 240-453-8822	August 17, 2021
New this Month					
FY22 Scientists in Parks Internship Program: Youth & Veteran Organization Conservation Activities	Department of the Interior	Puts America's youth and veterans to work protecting, restoring, and enhancing America's great outdoors.	Nonprofit Organizations		October 1, 2021

2. Policy Framework for Natural Hazards in Oregon

The primary responsibility for the development and implementation of risk reduction strategies and policies lies with local jurisdictions. However, resources exist at the state and federal levels. Some of the key agencies in this area include Oregon Emergency Management (OEM), Oregon Building Codes Division (OBCD), Oregon Department of Forestry (ODF), Oregon Department of Geology and Mineral Industries (DOGAMI), and the Department of Land Conservation and Development (DLCD).

The Disaster Mitigation Act of 2000 (DMA 2000) is the latest federal legislation addressing mitigation planning. It reinforces the importance of mitigation planning and emphasizes planning for natural hazards before they occur. As such, this Act established the Pre-Disaster Mitigation (PDM) grant program and new requirements for the national post-disaster Hazard Mitigation Grant Program (HMGP). Section 322 of the Act specifically addresses mitigation planning at the state and local levels. State and local jurisdictions must have approved mitigation plans in place in order to qualify to receive post-disaster HMGP funds. Mitigation plans must demonstrate that their proposed mitigation measures are based on a sound planning process that accounts for the risk to the individual and their capabilities.

Statewide Land Use Planning Goals

https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Planning for natural hazards is an integral element of Oregon's statewide land use planning program, which began in 1973. All Oregon cities and counties have comprehensive plans and implementing ordinances that are required to comply with the statewide planning goals. The challenge faced by state and local governments is to keep this network of local plans coordinated in response to the changing conditions and needs of Oregon communities.

The comprehensive land use planning system in Oregon begins with a set of 19 Statewide Land Use Planning Goals. These goals address the local process of land use planning, direct the state's resource preservation, give guidance for urban development, and offer direction to cities and counties who need to plan for coastal assets. The outcome of the goals is as unique as each city and county of Oregon – each local government develops a comprehensive plan that addresses the resources, constraints and opportunities specific to the place.

The following land use planning goals are particularly relevant in the management of hazards by local communities. The Department of Land Conservation and Development (DLCD) supports communities in their implementation of these goals.

Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces

Read full text version of Goal 5

Goal 5 is a broad statewide planning goal that covers more than a dozen resources. The resources range from wildlife habitat, to historic places, and gravel mines. To protect and plan for them, local governments are asked to create a number of inventories. The inventories in a local plan may address only a portion of the resources included in Goal 5

Goal 7: Areas Subject to Natural Hazards *Read full text version* of Goal 7

Goal 7 requires local comprehensive plans to address Oregon's natural hazards. Protecting people and property from natural hazards requires knowledge, planning, coordination, and education. Good planning does not put buildings or people in harm's way. Planning, especially for the location of essential services like schools, hospitals, fire and police stations, is done with sensitivity to the potential impact of nearby hazards.

A local government addresses natural hazards in its comprehensive land use plan. They do this by adopting a natural hazard inventory, overlay zones, hazard code, and supporting plans and policies.

DLCD works with the Oregon Department of Geology and Mineral Industries, the Federal Emergency Management Agency, and others to help communities plan for natural hazards. In most 2-year state legislative cycles, a limited amount of planning grant money is available through DLCD to help communities address these planning needs.

Goal 16: Estuarine Resources Read the full text version of Goal 16

Statewide Planning Goal 16 provides the principal guidance for the planning and management of Oregon's estuaries. The overall objective of Goal 16 is to "to recognize and protect the unique environmental, economic and social values of each estuary and associated wetlands; and to protect, maintain, where appropriate develop, and where appropriate restore the long term environmental, economic and social values, diversity and benefits of Oregon's estuaries". To accomplish this, the goal establishes detailed requirements for the preparation of plans and for the review of individual development projects and calls for coordinated management by local, state and federal agencies that regulate or have an interest in activities in Oregon's estuaries.

Goal 17: Coastal Shorelands Read the full text version of Goal 17

Statewide Planning Goal 17 outlines planning and management requirements for the lands bordering estuaries (as well lands bordering the ocean shore and coastal lakes). In general, the requirements of Goal 17 apply in combination with other planning goals to direct the appropriate use of shoreland areas. Provisions in Goal 17 specifically focus on the protection and management of resources unique to shoreland areas; examples of such resources include areas of significant shoreland habitat, lands especially suited for water dependent uses, lands providing public access to coastal waters, and potential restoration or mitigation sites.

The goal focuses on the management of shoreland areas and resources in a manner that is compatible with the characteristics of the adjacent coastal waters. Goal 17 requirements are implemented primarily through local comprehensive plans and zoning.

Water Dependent Shorelands Rule: Goal 17 use requirements direct that shorelands "especially suited for water dependent uses" be protected for such uses, and that local zoning regulations prevent the establishment of uses which would preempt the availability of such lands for water dependent development. In 1999 LCDC adopted an administrative rule to provide additional guidance for implementing this Goal 17 requirement. Known as the water dependent shorelands rule, OAR 660, Division 37 establishes a methodology for calculating the minimum amount of shorelands to be protected for water dependent and also provides more detailed guidance on the qualifications of

shorelands suitable for water dependent uses, as well as suggested land use regulations and standards appropriate for the protection of these shoreland sites.

Goal 18: Beaches and Dunes Read the full text version of Goal 18

Statewide Planning Goal 18 focuses on conserving and protecting Oregon's beach and dune resources, and on recognizing and reducing exposure to hazards in this dynamic, sometime quickly changing environment. Goal 18 is central to the work of coastal communities in addressing the impacts of coastal hazards and climate change in areas along the ocean shore.

Local governments are required to inventory beaches and dunes and describe the stability, movement, groundwater resources, hazards and values of the beach, dune, and interdune areas. Local governments must then apply appropriate beach and dune policies for use in these areas.

Goal 18 includes some requirements are of particular importance:

- Prohibition Areas
- Shoreline Armoring
- Dune Grading
- Ocean Shore Regulation

Goal 19 Ocean Resources *Read full text version of Goal 19*

Goal 19 deals with matters such as dumping dredge spoils and discharge of waste products into the open sea, and prioritizes the protection of renewable marine resources over the development of non-renewable resources. It outlines state interest in conserving resources within the Ocean Stewardship Area, which includes Oregon's territorial sea out to 3 nautical miles as well as the continental margin seaward to the toe of the continental slope, and adjacent ocean areas.

Regulatory Agencies

Oregon Parks and Recreation Department (OPRD)

The Oregon Parks and Recreation Department (OPRD) is responsible for protecting the scenic, recreational, and natural resource values of the Oregon coast. OPRD accomplishes this through an extensive permitting program for shoreline protection under the authority of The Ocean Shores Statutes (ORS 390.605 - 390.770), also known as the Beach Bill. OPRD is the permitting authority for actions affecting the ocean shorelands up to the statutory vegetation line. The Ocean Shores Statutes require that a permit be obtained from the OPRD for all "beach improvements" seaward of the Statutory Vegetation Line or the actual vegetation line, whichever is farther inland. Permits for shoreline protective structures may be issued only for developments that existed prior to January 1, 1977.

OPRD approval is also required for dune management plans and subsequent dune management, resloping or other alterations of bluff slopes below the vegetation line, alteration of stream channels on the ocean shore, and other ocean shore alterations associated with hazard mitigation.

Oregon Department of Forestry

Oregon Department of Forestry was given legislative authority to develop landslide hazard mapping based on historical data and the new Lidar mapping system. New maps were printed in 2007.

Department of State Lands

The Department of State Lands (DSL) regulates removal and filling of the seabed (seaward of the extreme low tide line) and estuaries, including any dredged materials or seabed materials. DSL manages the state-owned seabed within three nautical miles of the low tide line. In some instances, a permit may also be required from the U.S. Army Corps of Engineers. When a Corps permit is required, the Oregon Department of Environmental Quality may also need to issue a water quality certification and the Department of Land Conservation and Development (DLCD) a coastal zone concurrence before the Corps can issue a final permit. The agency recently integrated Local Wetland Inventories (LWIs) into a statewide dataset available at: https://www.oregon.gov/dsl/WW/Pages/SWI.aspx

Oregon Water Resource Department

Oregon Revised Statute (ORS) Chapter 536 identifies authorities available during a drought. To trigger specific actions from the Water Resources Commission and the Governor, a "severe and continuing drought" must exist or be likely to exist. Oregon relies upon two inter-agency groups to evaluate water supply conditions, and to help assess and communicate potential drought-related impacts: Oregon Drought Readiness Council and the Water Supply Availability Committee.

Drought Resources:

Oregon Water Resources Department's *2017 Integrated Water Resources Strategy*:
https://www.oregon.gov/OWRD/wrdpublications1/2017_IWRS_Final.pdf
The *Drought Annex of the State of Oregon Emergency Operations Plan* was updated in January 2016 following the record drought of 2015:
https://www.oregon.gov/owrd/WRDPublications1/2016ORDroughtAnnex.pdf
Monitor the status of drought in Oregon at: https://www.drought.gov/drought/states/oregon

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers is responsible for the protection and development of the nation's water resources to ensure that they are used in the public interest (Figure CE-5). Any person, firm, or agency planning work in the waters of the United States must first obtain a permit from the Corps.

Permits are required even when land next to or under the water is privately owned. Examples of activities in waters that may require a permit include: construction of a pier, placement of intake and outfall pipes, dredging, excavation and depositing of fill. Permits are generally issued only if the activity is found to be in the public interest. DLCD reviews and certifies that Corps permits and other federal activities are consistent with state and local requirements for protecting coastal resources.

C. Appendix C

1. Future Climate Projections Report: Coos County 168
2. Natural Hazard Risk Report for Coos County 247

1. Future Climate Projections Report: Coos County

This report informs the consideration of hazards for the local risk assessment evaluations conducted for the 2023 Coos County Multi-Jurisdictional Natural Hazard Mitigation Plan Update. The production of this report was contracted by the Oregon Department of Land Conservation and Development for the purpose of the plan update. It is cited as Dalton et al, 2022 within the text.

Dalton, M. M., Fleishman, E., & D. Bachelet. (2022, May). Future Climate Projections: Coos County, Oregon. Oregon Climate Change Research Institute. College of Earth, Ocean and Atmospheric Sciences, Oregon State University. https://oregonstate.box.com/s/80o86jyfx5drcup0dvc6qtc9p3f4bhvv

Future Climate Projections
Coos County, Oregon

May 2022

Oregon Climate Change Research Institute

Shore Acres State Park, Coos County, Oregon. Photograph by Rick Obst, CC BY 2.0, via flickr.com.

Future Climate Projections: Coos County, Oregon

Report to the Oregon Department of Land Conservation and Development

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Executive Summary

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

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

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

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

Heat Waves

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

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

In Coos County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 5 days (range 1–11 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Coos County, the temperature on the hottest day of the year is projected to increase by an average of about 5°F (range 2–8°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Cold Waves

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

In Coos County, the temperature on the coldest night of the year is projected to increase by an average of 4.5°F (range 2–8°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Heavy Rains

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

In Coos County, the number of days per year with at least 0.75 inches of precipitation is not projected to change substantially. However, by the 2050s, the amount of precipitation on the wettest day and wettest consecutive five days per year is projected to increase by an average of 12% (range -2–25%) and 9% (range -5–23%), respectively, relative to the1971–2000 historical baselines, under the higher emissions scenario.

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

River Flooding

Winter flood risk in coastal rain-dominated watersheds in Coos County is projected to increase as winter temperatures increase. The temperature increase will lead to an increase in the percentage of precipitation falling as rain rather than snow.

Drought

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

Wildfire

Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase in Coos County by 11 days (range -6–30) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

In Coos County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 30 days (range 9–56) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality

The risk of wildfire smoke in Coos County is projected to increase.

In Coos County, the number of days per year on which the concentration of wildfire-derived fine particulate matter results in poor air quality is projected to decrease by 15%, and the concentration of fine particulate matter is projected to increase by 69%, from 2004–2009 to 2046–2051 under a medium emissions scenario.

Coastal Erosion and Flooding

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

In Coos County, local sea level is projected to rise by 1.2 to 5.3 feet by 2100. This projection is based on the intermediate-low to intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment. Because these local sea level projections account for estimated trends in vertical land movement, they are relative to the future land position.

Given these levels of sea level rise, the multiple-year likelihood of a flood reaching four feet above mean high tide is 4–34% by the 2030s, 25–100% by the 2050s, and 100% by 2100.

At risk within the four-foot inundation zone in Coos County as of the 2010 census are 1062 people, $72 million in property value, 10.9 miles of highways and roads, 9.4 miles of railways, 3 critical facilities, 2 municipal drinking water facilities, 3 potential contaminant sources, and 715 buildings.

Changes in Ocean Temperature and Chemistry

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

Loss of Wetlands

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

Wetland area in the Coos Bay and Coquille River estuaries is projected to decrease with increasing sea levels. Under 4.7 feet of sea level rise, tidal wetland area in these estuaries is projected to decrease by about 50%. Tidal wetland area in the New River Area is projected to increase by more than 2000%, but whether future tides will push into this area is uncertain.

Windstorms

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

Expansion of Pests, Pathogens, and Non-native Invasive Species

In general, invasive and pest species in Coos County are likely to become more prevalent in response to projected increases in temperature, especially minimum winter temperature, and increases in the frequency, duration, and severity of drought. However, many of these responses are uncertain, are likely to vary locally, and may change over time.

Introduction

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

Oregon's Department of Land Conservation and Development (DLCD) contracted with the Oregon Climate Change Research Institute (OCCRI) to analyze the influence of climate change on natural hazards. The scope of the analysis that yielded this report is limited to the geographic area encompassed by Coos, Curry, and Wallowa Counties, Oregon, which are the focus of the Pre-Disaster Mitigation (PDM) 18 grants that DLCD received from the Federal Emergency Management Agency. Products of OCCRI's analysis include county-specific data, graphics, and narrative summaries of climate projections related to ten climate-related natural hazards (Table 2). This information will be integrated into the Natural Hazards Mitigation Plan (NHMP) updates for the three counties, and can be used in other county plans, policies, and programs. In addition to the county reports, OCCRI will share data and provide other technical assistance to the counties. This report covers climate change projections related to natural hazards relevant to Coos County.

Table 2. Selected natural hazards and related climate metrics.

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

Future Climate Projections Background

Introduction

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

Global Climate Models

Global climate models (GCMs) are computer models of Earth's atmosphere, ocean, and land and their interactions over time and space. The models are grounded in the fundamental laws of physics. Over time the spatial resolution of the models has increased and more biological processes, such as wildfire emissions and dynamic vegetation, have been included (Figure 1). The latest GCMs from the sixth phase of the Coupled Model Intercomparison Project (CMIP6), the climate modeling foundation for the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report, generally have higher resolution, better represent Earth system processes, and improve simulation of recent mean values of climate change indicators relative to older versions of GCMs (IPCC, 2021). However, some CMIP6 models overestimate temperatures in the twentieth century, likely due to the difficulty of accurately simulating cloud dynamics. Consequently, the IPCC ranked climate models on the basis of their ability to reproduce twentieth-century temperatures, and only used the most accurate models to produce its official warming projections given different fossil fuel emissions scenarios (Hausfather *et al.*, 2022). Because downscaled data from CMIP6 are not yet widely available, this report presents projections from GCMs from the fifth phase of the Coupled Model Intercomparison Project (CMIP5).

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

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

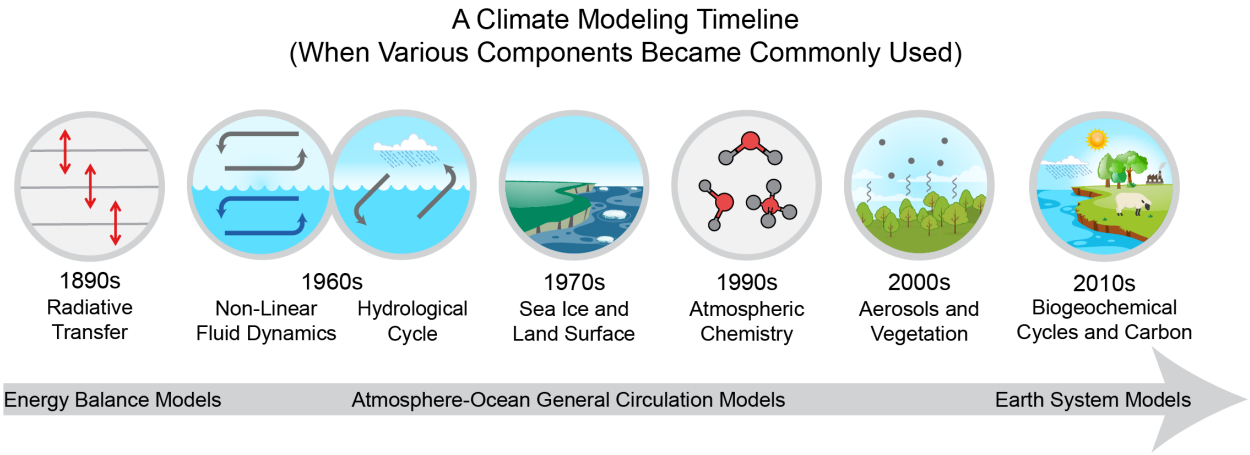


Figure 1. As scientific understanding of climate has evolved over the last 120 years, increasing amounts of physics, chemistry, and biology have been incorporated into calculations and, eventually, models. Various processes and components of the climate system became regularly included in scientific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

Greenhouse Gas Emissions

When scientists use GCMs to project climate, they make assumptions about the quantity of future global emissions of greenhouse gases. The GCMs then simulate the effects of those emissions on the air, ocean, and land over the coming centuries. Because the precise amount of greenhouse gases that will be emitted in the future is unknown, scientists use multiple scenarios of greenhouse gas emissions that correspond to plausible societal trajectories. The future climate projections in this report, which are based on CMIP5 models, use Representative Concentration Pathways (RCPs) that describe different levels of radiative forcing by 2100. A fixed emission trajectory was associated with each pathway. The higher the volume of global emissions, the greater the projected increase in global temperature (Figure 2).

Projections in this report assume a lower emissions pathway (RCP 4.5) and a higher emissions pathway (RCP 8.5). These are the most commonly used pathways in the peer-reviewed literature, and downscaled data representing the effects of these scenarios on local climate are available. RCPs focused on concentrations, instead of emissions, of greenhouse gases, that were consistent with certain socio-economic assumptions. The scenarios for CMIP6 correspond to those for CMIP5. For CMIP6, each RCP was associated with a set of shared socioeconomic pathways that describe various social and economic scenarios (IPCC, 2021). More information about emissions scenarios is in the Appendix.

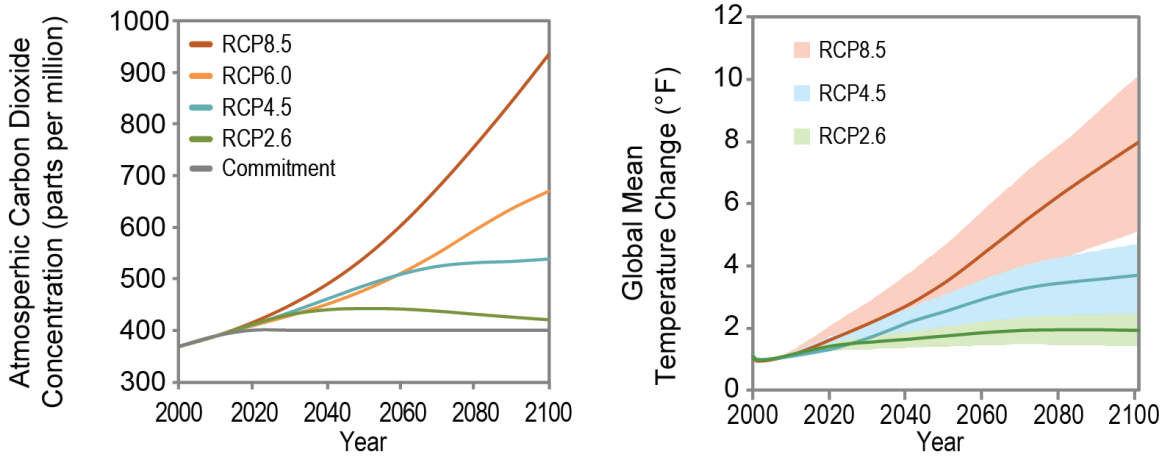


Figure 2. Future scenarios of atmospheric carbon dioxide concentrations (left) and projections of global temperature change (right) resulting from several different emissions pathways, called Representative Concentration Pathways (RCPs), that are considered in the fourth National Climate Assessment. (Source: science2017.globalchange.gov)

Downscaling

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

Future Time Periods

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

Because each of the 20 GCMs is based on slightly different assumptions, each yields a slightly different value for the historical baseline. Therefore, this report presents the average and range of projected *changes* in values of climate variables relative to each model's historical baseline rather than presenting the average and range of projected absolute values of variables. The average of the 20 historical baselines, the *average historical baseline*, is also presented to aid in understanding the relative magnitude of projected changes. The average historical baseline and average projected future change can be used to infer the average projected future absolute value of a given variable. However,

the average historical baseline and range of projected future changes cannot be used to infer the range of projected future absolute values.

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

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

How to Use the Information in this Report

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

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

The information in this report can be used to

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

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

Average Temperature

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

During the twenty-first century, average temperature in Coos County is projected to warm at a rate similar to that of Oregon as a whole (Figure **3**). Projected increases in average temperature in Coos County relative to the 1971–2000 historical baseline in each global climate model (GCM) range from 0.9–3.2°F by the 2020s (2010–2039) and 1.5–6.0°F by the 2050s (2040–2069), depending on emissions scenario and GCM (Table **4**).

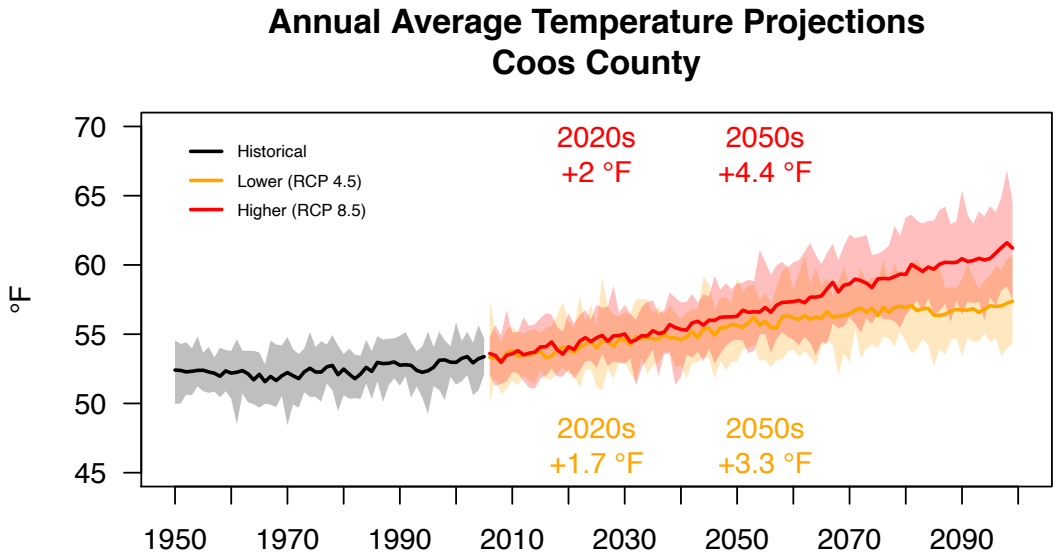


Figure 3. Projected annual average temperature in Coos County as simulated by 20 downscaled global climate models under a lower (RCP 4.5) and a higher (RCP 8.5) greenhouse gas emissions scenario. Solid lines and shading represent the 20-model mean and range, respectively. The multiple-model mean differences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

Table 4. Average (and range) of projected future changes in Coos County's annual temperature relative to the historical baselines (1971–2000 average) of each of 20 global climate models under two emissions scenarios.

Emissions Scenario	2020s (2010–2039 average)	2050s (2040–2069)
Higher (RCP 8.5)	+2.0°F (1.3–3.2)	+4.4°F (2.5–6.0)
Lower (RCP 4.5)	+1.7°F (0.9–2.8)	+3.3°F (1.5–4.5)

Heat Waves

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

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

Table 5. Metrics and definitions of heat extremes.

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

In Coos County, the number of hot days and warm nights, and the temperature on the hottest day and warmest night, are projected to increase by the 2020s (2010–2039) and 2050s (2040–2069) under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios (Table **6**, Figure 4, Figure 5). For example, by the 2050s under the higher emissions scenario, the number of hot days, relative to each GCM's 1971–2000 historical baseline, is projected to increase by 1–11. The average number of hot days per year is projected to be five more than the average historical baseline of one day. The average

number of warm nights per year is projected to be two more than the average historical baseline of virtually zero days.

Similarly, under the higher emissions scenario, the temperature on the hottest day of the year is projected to increase by 2.1–8.3°F by the 2050s relative to the GCMs' historical baselines. The average projected increase in temperature on the hottest day is 5.2°F above the average historical baseline of 86.4°F. The average projected increase in temperature on the warmest night is 5.1°F above the average historical baseline of 59.3°F.

Under the higher emissions scenario, the numbers of daytime and nighttime heat waves are projected to increase by 0.2–1.6 and 0.0–0.7, respectively, by the 2050s relative to the GCMs' historical baselines. The average number of daytime and nighttime heat waves is projected to increase by 0.8 and 0.2, respectively, above the average historical baseline of 0.1 and zero (Table 6, Figure 6).

Table 6. Mean (and range) of projected future changes in extreme heat metrics in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average) of each of 20 global climate models (GCMs), under a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario. The average historical baseline across the 20 GCMs and the average projected future change can be used to infer the average projected future absolute value of a given variable. However, the average historical baseline and the range of projected future changes cannot be used to infer the range of projected future absolute values.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Hot Days	0.8 days	0.8 days (0.2-1.8)	1.1 days (0.2-2.1)	2.9 days (0.9-5.7)	5 days (1-10.8)
Warm Nights	0.1 days	0.1 days (0-0.3)	0.2 days (0-0.8)	0.7 days (0.1-2.4)	1.6 days (0.2-5.7)
Hottest Day	86.4°F	1.7°F (0.1-2.7)	2.2°F (0.4-3.9)	4.1°F (2-7)	5.2°F (2.1-8.3)
Warmest Night	59.3°F	1.8°F (0.4-3.2)	2.2°F (0.6-3.5)	3.9°F (1.9-6.3)	5.1°F (2.8-8.1)
Daytime Heat Waves	0.1 events	0.1 events (0-0.2)	0.2 events (0-0.3)	0.4 events (0.1-0.9)	0.8 events (0.2-1.6)
Nighttime Heat Waves	0 events	0 events (0-0)	0 events (0-0.1)	0.1 events (0-0.3)	0.2 events (0-0.7)

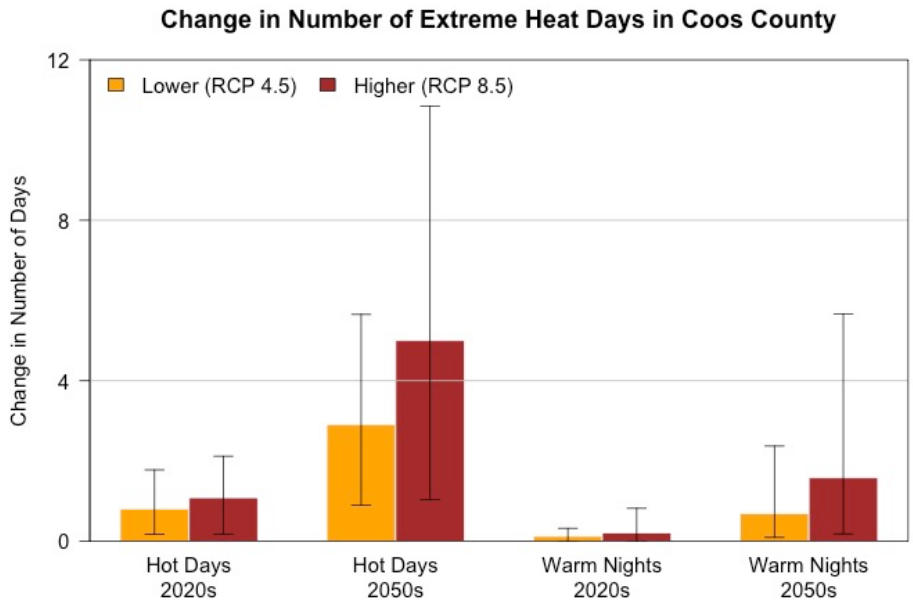


Figure 4. Projected changes in the number of hot days (left two sets of bars) and warm nights (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. The bars and whiskers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

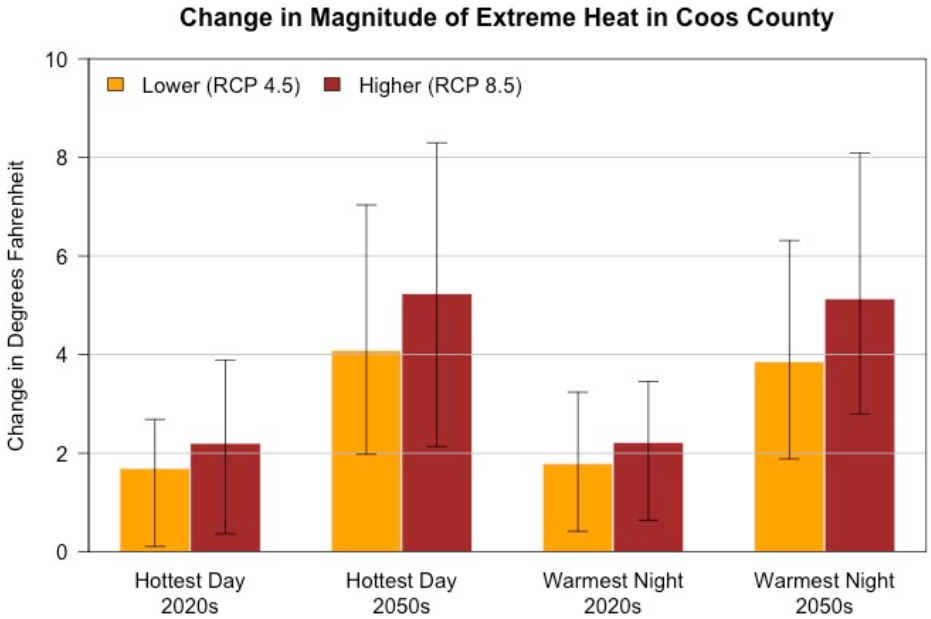


Figure 5. Projected changes in the temperature on the hottest day of the year (left two sets of bars) and warmest night of the year (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two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

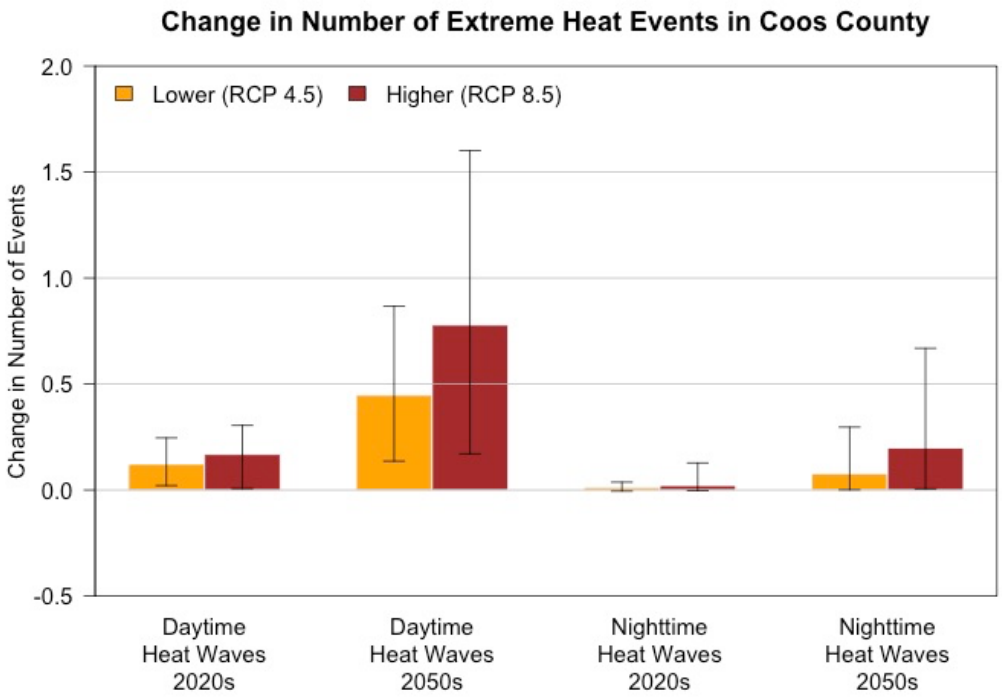


Figure 6. Projected changes in the number of daytime heat waves (left two sets of bars) and nighttime heat waves (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios.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

Key Messages

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

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

⇒ In Coos County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 5 days (range 1–11 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

⇒ In Coos County, the temperature on the hottest day of the year is projected to increase by an average of about 5°F (range 2–8°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Cold Waves

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

Table 7. Metrics and definitions of cold extremes.

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

In Coos County, the temperatures on the coldest day and night are projected to increase by the 2020s and 2050s under both emissions scenarios (Table 8, Figure 8). For example, by the 2050s under the higher emissions scenario, the temperature on the coldest night of the year is projected to increase by 1.5–8.4°F relative to the GCMs' historical baselines. The average projected increase in the temperature on the coldest night is 4.5°F above the average historical baseline of 23.8°F. The average projected increase in the temperature on the coldest day is 4.2°F above the average historical baseline of 39.0°F. However, cold days and nights and daytime and nighttime cold waves are rare in Coos County (Table 8, Figure 7, Figure 9).

Table 8. Mean (and range) of projected future changes in extreme cold metrics in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average) of each of 20 global climate models (GCMs), under a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario. The average historical baseline across the 20 GCMs and the average projected future change can be used to infer the average projected future absolute value of a given variable. However, the average historical baseline and the range of projected future changes cannot be used to infer the range of projected future absolute values.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Cold Days	0.2 days	0 days (-0.1 - 0.4)	0 days (-0.2 - 0.3)	-0.1 days (-0.2 - 0.1)	-0.1 days (-0.2 - 0.1)
Cold Nights	0 days	0 days (0 - 0)	0 days (0 - 0)	0 days (0 - 0)	0 days (0 - 0)
Coldest Day	39°F	1°F (-2.1 - 3.1)	1.9°F (-0.9 - 3.3)	3.1°F (0.3 - 5)	4.2°F (0.8 - 6.6)
Coldest Night	23.8°F	1.1°F (-1.4 - 3.4)	2.2°F (-0.1 - 4.2)	3.5°F (1.3 - 6.4)	4.5°F (1.5 - 8.4)
Daytime Cold Waves	0 events	0 events (0 - 0.1)	0 events (0 - 0.1)	0 events (0 - 0)	0 events (0 - 0)
Nighttime Cold Waves	0 events	0 events (0 - 0)	0 events (0 - 0)	0 events (0 - 0)	0 events (0 - 0)

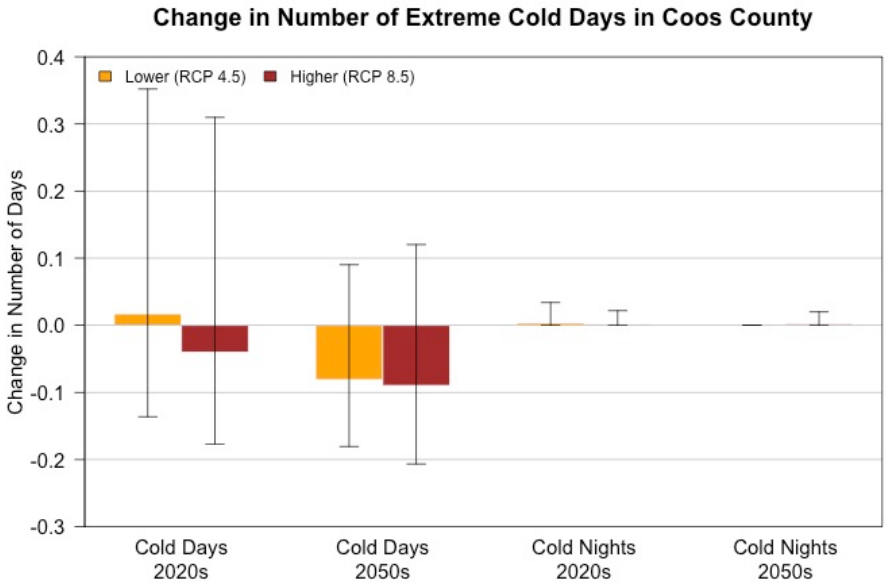


Figure 7. Projected changes in the number of cold days (left two sets of bars) and cold nights (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. The bars and whiskers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

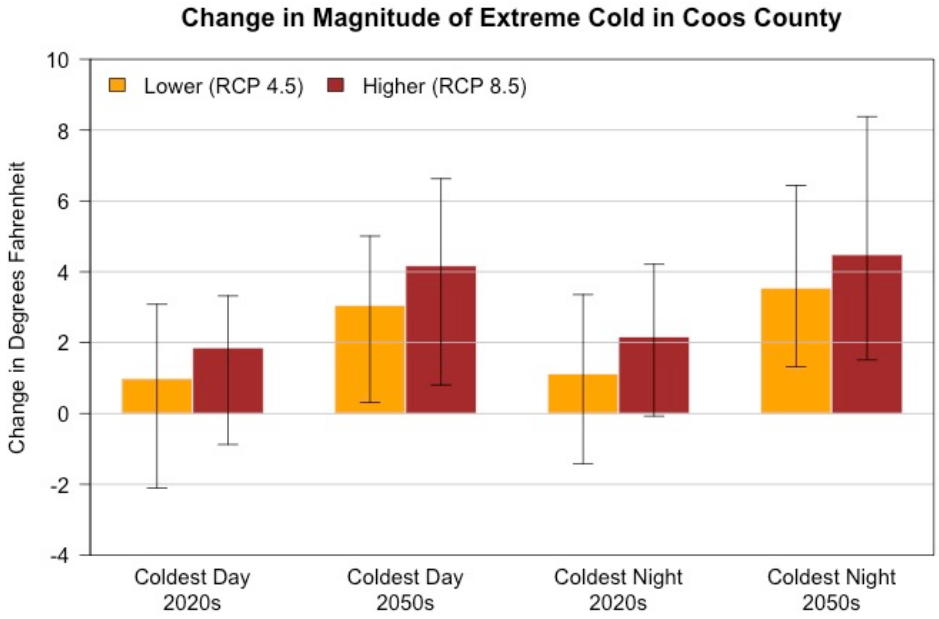


Figure 8. Projected changes in the temperature on the coldest day of the year (left two sets of bars) and coldest night of the year (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two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

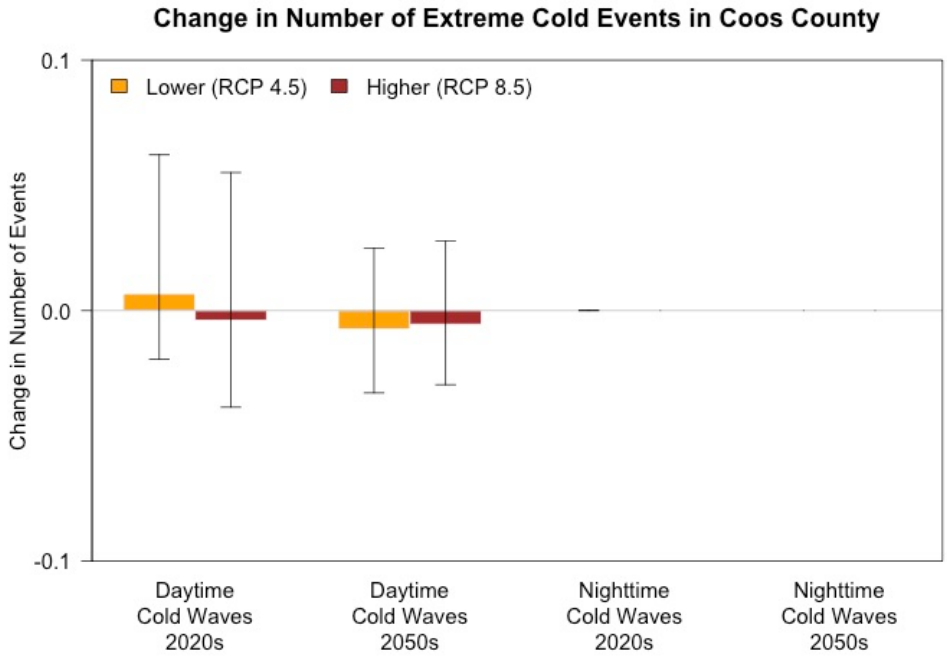


Figure 9. Projected changes in the number of daytime cold waves (left two sets of bars) and nighttime cold waves (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios.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

Key Messages

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

⇒ In Coos County, the temperature on the coldest night of the year is projected to increase by an average of 4.5°F (range 2–8°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Heavy Rains

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

Observed annual precipitation in Oregon has high year-to-year variability and has not changed significantly; future trends in annual precipitation are expected to be dominated by natural variability (Dalton *et al.*, 2017; Dalton and Fleishman, 2021). On average, summers in Oregon are projected to become drier and other seasons to become wetter, resulting in a slight increase in annual precipitation by the 2050s. However, some models project increases and others decreases in each season (Dalton *et al.*, 2017).

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

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

Table 9. Metrics and definitions of precipitation extremes.

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

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

Climate models project that by the 2050s under the higher emissions scenario, the amount of precipitation on the wettest day of the year, relative to each GCM's 1971–2000 historical baseline, will change by -2.3–25.4% (Figure 10). The average projected amount of precipitation on the wettest day of the year is 12.3% greater than the average historical baseline of about 3 inches.

Climate models project that by the 2050s under the higher emissions scenario, the amount of precipitation on the wettest consecutive five days of the year will change by - 5.3–22.5% (Figure 10). The average projected amount of precipitation on the wettest consecutive five days is 9.1% above the average historical baseline of 7.4 inches.

The average number of days per year on which precipitation exceeds 0.75 inches is not projected to change substantially (Figure 11). For example, by the 2050s under the higher emissions scenario, the number of wet days per year is projected to change by 0.2 (range -4.4–4.1). The historical baseline is an average of 30 days per year.

Landslides are often triggered by rainfall when the soil becomes saturated. As a surrogate measure of landslide risk, this report presents a threshold based on recent rainfall (cumulative precipitation over the previous 3 days) and antecedent precipitation (cumulative precipitation on the 15 days prior to the previous 3 days). In Coos County, by the 2050s under the higher emissions scenario, the average number of days per year on which the landslide risk threshold is exceeded is projected to remain about the same, with a change of -0.5 days (range -4.6–4.4 days) (Figure 11). The historical baseline is an average of 31 days per year. Landslide risk depends on multiple site-specific factors, and

this metric does not reflect all aspects of the hazard. The landslide risk threshold was developed for Seattle, Washington, and may be less applicable to other locations.

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

Table 10. Mean (and range) of projected changes in extreme precipitation in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average) of each of 20 global climate models (GCMs), under a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario. The average historical baseline across the 20 GCMs and the average projected future change can be used to infer the average projected future absolute value of a given variable. However, the average historical baseline and the range of projected future changes cannot be used to infer the range of projected future absolute values.

	Average Historical Baseline	2020s		2050s	
		Lower	Higher	Lower	Higher
Wettest Day	3 inches	6.2% (-8.8-19.6)	6.1% (-9.6-27.4)	10.5% (-6.1-24.3)	12.3% (-2.3-25.4)
Wettest Five-Days	7.4 inches	3.4% (-8.7-13.9)	3.2% (-5.6-15.9)	7.8% (-2.6-24)	9.1% (-5.3-22.5)
Wet Days	29.6 days	0.1 days (-2.4-3)	-0.3 days (-4-2.2)	0.3 days (-3.5-3)	0.2 days (-4.4-4.1)
Landslide Risk Days	30.8 days	-0.5 days (-4.9-3.8)	-0.6 days (-3.5-3.7)	-1.6 days (-4.9-2)	-0.5 days (-4.6-4.4)

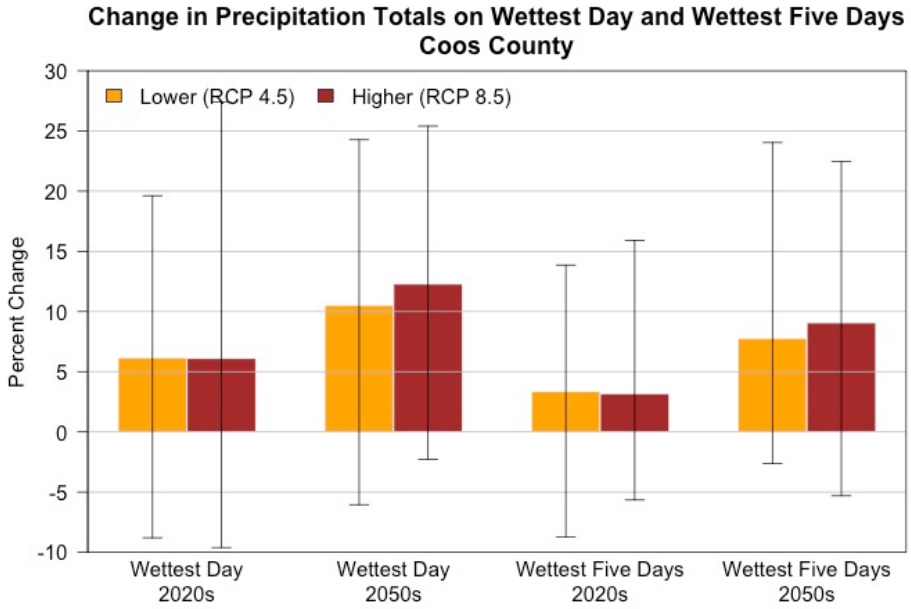


Figure 10. Projected percent changes in the amount of precipitation on the wettest day of the year (left two sets of bars) and wettest consecutive five days of the year (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline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

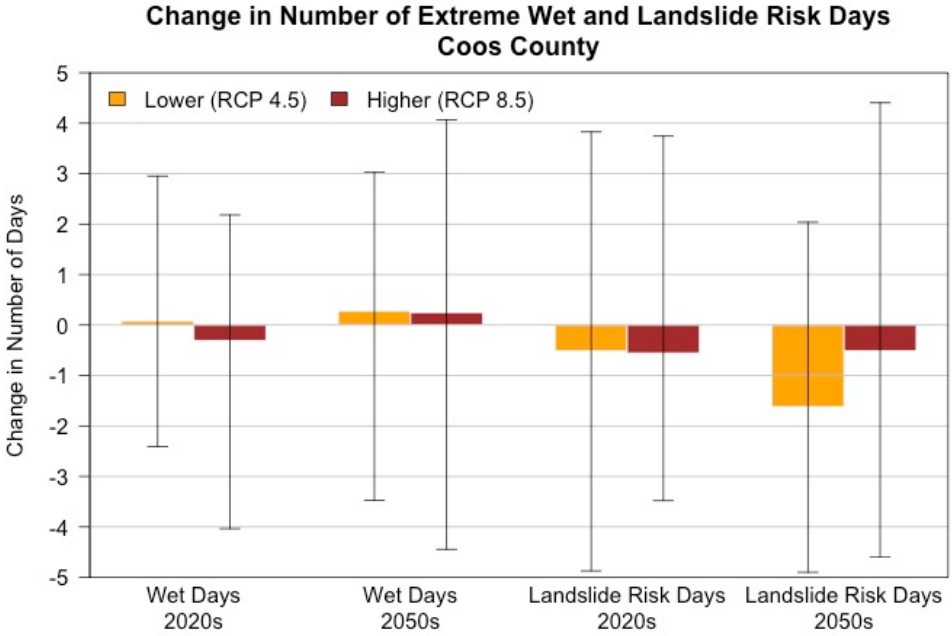


Figure 11. Projected changes in the number of wet days (left two sets of bars) and landslide risk days (right two sets of bars) in Coos County by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the historical baseline (1971–2000 average), under two emissions scenarios. The bars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

Key Messages

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

⇒ In Coos County, the number of days per year with at least 0.75 inches of precipitation is not projected to change substantially. However, by the 2050s, the amount of precipitation on the wettest day and wettest consecutive five days per year is projected to increase by an average of 12% (range -2–25%) and 9% (range -5–23%), respectively, relative to the1971–2000 historical baselines, under the higher emissions scenario.

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

River Flooding

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

Warming temperatures and increasing winter precipitation are expected to increase flood risk in many basins in the Northwest, particularly mid- to low-elevation mixed rain-and-snow basins in which winter temperatures are near freezing (Tohver *et al.*, 2014). The greatest projected changes in peak streamflow magnitudes are at intermediate elevations in the Cascade Range and Blue Mountains (Safeeq *et al.*, 2015). Recent regional hydroclimate models project increases in extreme high flows throughout most of the Northwest, especially west of the Cascade crest (Salathé *et al.*, 2014; Najafi and Moradkhani, 2015; Naz *et al.*, 2016). One study, which used a single climate model, projected an increase in flood risk in fall due to earlier, more extreme storms, including atmospheric rivers; and an increase in the proportion of precipitation falling as rain rather than snow (Salathé *et al.*, 2014). Rainfall-driven floods are more sensitive to increases in precipitation than snowmelt-driven floods. Therefore, the projected increases in total precipitation, and in rain relative to snow, likely will increase flood magnitudes in the region (Chegwidden *et al.*, 2020). Streamflow in rain-dominant watersheds reflects the seasonal pattern of precipitation, with peak flows occurring during winter and low flows occurring during summer. Few peer-reviewed publications have addressed potential future changes in streamflow in coastal rain-dominated watersheds, such as those in Coos County. Generally, future changes in rain-dominant basins are expected to be similar to changes in seasonal precipitation, with increases in winter peak flows and decreases in summer low flows.

Across much of the western United States, major floods—peak flow magnitudes associated with 100-year and 25-year return periods (1% and 4% probability that this daily flow magnitude would be exceeded in a given year)—are projected to increase by 2070–2099, compared to the 1971–2000 historical baseline, under the higher emissions scenario (Maurer *et al.*, 2018). Peak flow magnitudes with 25-year and 100-year return periods along the South Fork Coquille River at Powers are projected to increase by 15% and 14%, respectively, by 2070–2099 relative to the historical baseline. In effect, the magnitudes of floods currently corresponding to 25-year and 100-year peak flow events will become magnitudes corresponding to 15-year and 48-year events, respectively (Maurer *et al.*, 2018).

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

Dettinger, 2017).

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

Key Messages

⇒ Winter flood risk in coastal rain-dominated watersheds in Coos County is projected to increase as winter temperatures increase. The temperature increase will lead to an increase in the percentage of precipitation falling as rain rather than snow.

Drought

Drought is common in the Northwest. The incidence, extent, and severity of drought has increased over the last 20 years relative to the twentieth century, and this trend is expected to continue under future climate change (Dalton and Fleishman, 2021). Drought can be defined in many ways (Table 11), but most fundamentally is insufficient water to meet needs (Redmond, 2002; Dalton and Fleishman, 2021).

Table 11. Definitions and characteristics of various drought classes. (Source: Dalton and Fleishman, 2021; Fleishman *et al*., unpublished)

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

Summers in Oregon are expected to become warmer and drier, and mountain snowpack is projected to decline due to warmer winter temperatures (Dalton and Fleishman, 2021). Across the western United States, the decline in mountain snowpack is projected to reduce summer soil moisture in the mountains (Gergel *et al.*, 2017). Climate change is expected to result in lower summer streamflows in snow-dominated basins across the Northwest as snowpack melts earlier due to warmer temperatures and decreases in summer precipitation (Dalton *et al.*, 2017; Mote *et al.*, 2019). As mountain snowpack declines, seasonal drought will become less predictable and snow droughts will increase the likelihood of meteorological and hydrological drought in subsequent seasons (Dalton and Fleishman, 2021).

Because watersheds in Coos County are largely rain-dominated, the drivers of drought and water scarcity are different than across much of the western United States, where mountain snowpack contributes to streamflow (Dalton *et al.*, 2017; Mote *et al.*, 2019). In Coos County, like much of the Pacific Northwest, winters are wet and summers are dry. Severe drought is rare during the rainy winters on the Oregon coast, but the region is prone to periods of summertime water scarcity, especially when precipitation is lower than average in spring and fall. This scarcity is exacerbated by the lack of natural storage in the snowpack) and built storage in reservoirs. Changes in landcover due to forest management practices that affect shading and water demand, climate-driven shifts in vegetation, and wildfires will likely exacerbate the effects of drought.

This report presents projected changes in four variables indicative of drought: low spring snowpack (snow drought), low summer soil moisture from the surface to 55 inches below the surface (agricultural drought), low summer runoff (hydrological drought), and low summer precipitation (meteorological drought). Drought is presented in terms of a change in the probability of exceeding the magnitude of seasonal drought conditions for which the historical annual probability of exceedance was 20% (5-year return period) (Figure 12).

In Coos County, summer (June–August) soil moisture, summer runoff, and summer precipitation are projected to decline by the 2050s under both lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios. Therefore, seasonal drought conditions will occur more frequently by the 2050s under both emissions scenarios (Figure 12). By the 2050s under the higher emissions scenario, the annual probability of low summer soil moisture and low summer runoff is projected to be about 45% (2.2-year return period). The annual probability of low summer precipitation is projected to be 32% (3.1-year return interval). Spring snowpack is not a major determinant of drought conditions in low-elevation coastal watersheds, such as those in Coos County. Drought projections for the 2020s were not evaluated due to data limitations, but drought magnitudes in the 2020s likely will be smaller than those in the 2050s.

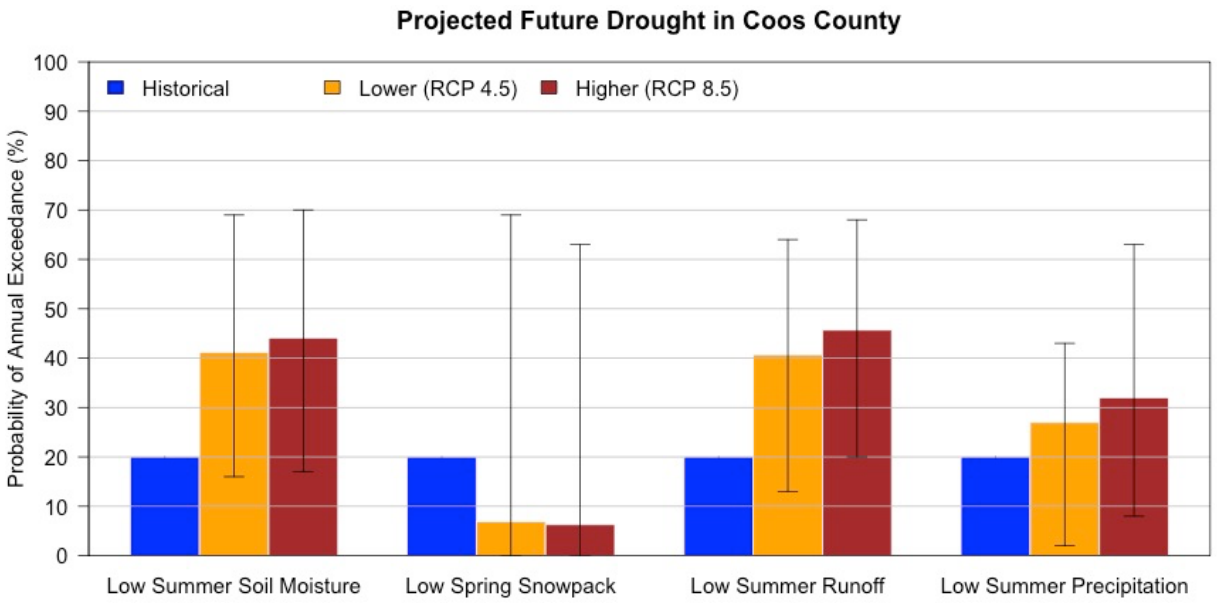


Figure 12. Projected probability of exceeding the magnitude of seasonal drought conditions for which the historical annual probability of exceedance was 20%. Projections are for the 2050s (2040–2069), relative to the historical baseline (1971–2000), under two emissions scenarios. Seasonal drought conditions include low summer soil moisture (average from June through August), low spring snowpack (April 1 snow water equivalent), low summer runoff (total from June through August), and low summer precipitation (total from June through August). The bars and whiskers represent the mean and range across ten global climate models. (Data Source: Integrated Scenarios of the Future Northwest Environment, https://climate.northwestknowledge.net/IntegratedScenarios/)

Key Messages

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

Wildfire

Human activities have modified fire dynamics in the western United States through clearance of native vegetation for agriculture and urbanization, fragmentation and exploitation of forests and other natural land-cover types, human population growth and increased recreational activities, introduction of highly flammable, non-native annual grasses, and replacement of indigenous or natural fires by extensive fire suppression and vegetation management. From 1985 through 2017, the annual area burned by high-severity fires across forests in the western United States increased eightfold (Parks and Abatzoglou, 2020), although not along the Pacific Northwest coastlines that support naturally cool moist rainforests which, undisturbed under recent past conditions, would only support wildfires every few centuries.

Over the last several decades, warmer and drier summers have contributed to an increase in vegetation dryness and promoted pest outbreaks causing widespread mortality that enabled more-frequent large wildfires exacerbated by longer wildfire seasons across the western United States (Dennison *et al.*, 2014; Jolly *et al.*, 2015; Westerling, 2016; Williams and Abatzoglou, 2016). The lengthening of the wildfire season has been largely due to warmer springs causing earlier spring snowmelt and an overall decline in mountain snowpack mostly due to warmer winters (Westerling, 2016).

Vegetation drought stress is also often caused by air dryness. Records of high values of vapor pressure deficit (VPD) corresponds to the difference, in terms of pressure, between the water vapor in the air, and the air's saturation point, which is the maximum amount the air can carry at its current temperature (dew point). This pressure difference is what drives transpiration from the plants' stomata. VPD, or evaporative demand, is more strongly associated with forest area burned than precipitation, drought indices, or temperature (Sedano and Randerson, 2014; Williams *et al.*, 2014; Seager *et al.*, 2015; Rao *et al.*, 2022). The area of forests burned annually is expected to increase exponentially with increases in VPD across the western United States (Zhuang *et al.*, 2021; Juang *et al.*, 2022). Futhermore, fires often generate their own weather patterns with extremely hot and dry air that can kill plants without consuming them creating more fuel for future fires.

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

Fire danger is generally evaluated on the basis of daytime conditions that may cause wildfires to spread. Historically, wildfires were less active overnight. However, nights have become hotter and drier, and the temperature and duration of wildfires is expected to increase as a result (Balch *et al.*, 2022). In the western United States, the number of nights during which atmospheric conditions are conducive to burning has increased by 45% since 1979 (Balch *et al.*, 2022). Vegetation can also amplify or dampen the effect of aridity on wildfires. The geographic co-occurrence of plants with high water sensitivity (e.g., plants that do not close their stomata, shallow-rooted plants on porous soils) and high VPD

suggests that the distribution of vegetation in the western United States has amplified the effect of climate change on wildfire hazard (Rao *et al.*, 2022).

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

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

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

In this report, the future change in wildfire risk is expressed as the increase in the average annual number of days on which fire danger is very high and VPD is extreme. Projections

are presented for two future periods under two emissions scenarios compared to the historical baseline. A day on which fire danger is very high is defined as a day on which FM100 is lower (i.e., vegetation is drier) than the historical 10th percentile value. Historically, fire danger was very high on 36.5 days per year. A day on which VPD is extreme is defined as a day on which VPD exceeds the historical warm season (March–November) 90th percentile value.

In Coos County, the average number of days per year on which fire danger is very high is projected to increase by 11 days (range -6–30) by the 2050s, compared to the historical baseline, under the higher emissions scenario (Figure 13). The average number of days per year on which VPD is extreme is projected to increase by 30 days (range 9–56) by the 2050s, compared to the historical baseline, under the higher emissions scenario (Figure 14). The impacts of wildfire on air quality are discussed in the following section, Reduced Air Quality.

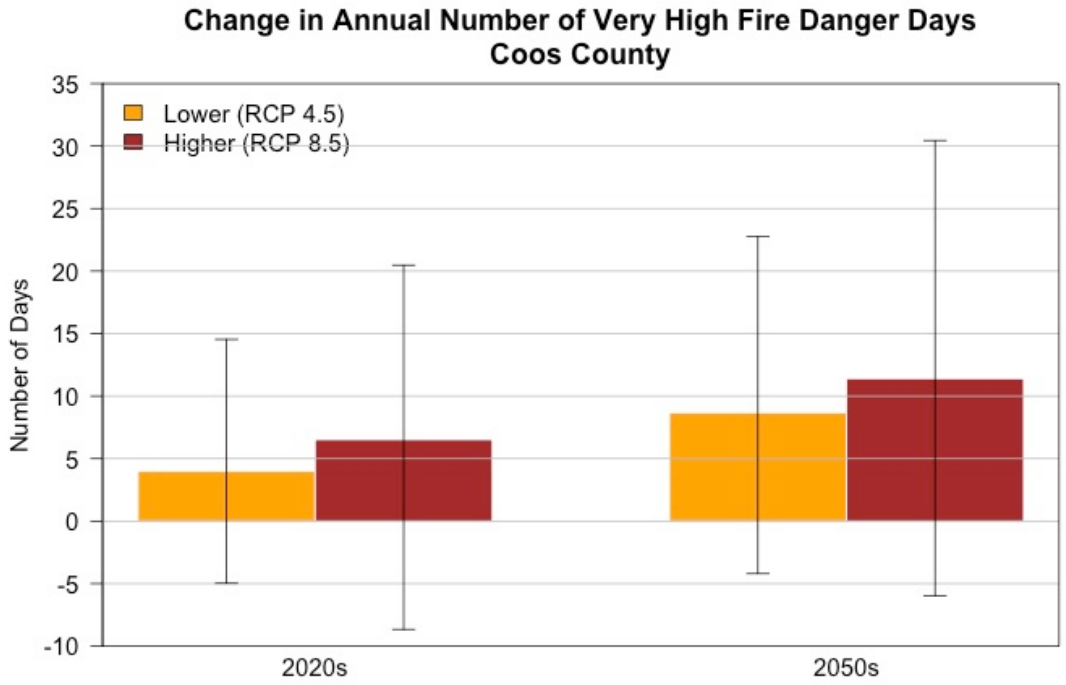


Figure 13. Projected changes by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the 1971–2000 historical baseline and under two emissions scenarios, in the number of days on which fire danger in Coos County is very high. The bars and whiskers represent the mean and range, respectively, of changes across 18 global climate models. (Data Source: Climate Toolbox, climatetoolbox.org/tool/Climate-Mapper)

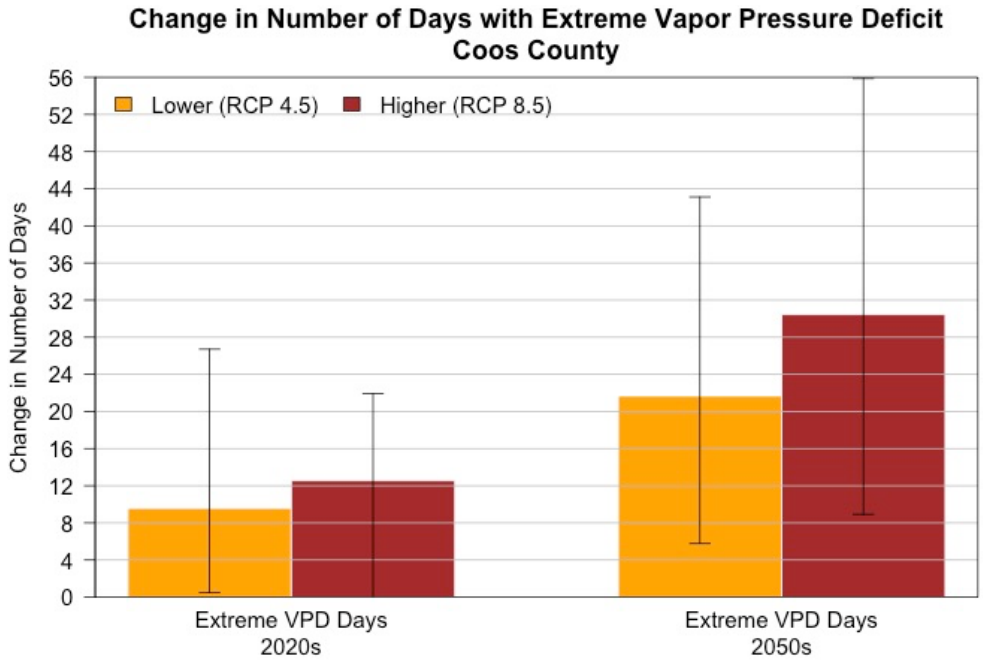


Figure 14. Projected changes by the 2020s (2010–2039 average) and 2050s (2040–2069 average), relative to the 1971–2000 historical baseline and under two emissions scenarios, in the number of days on which vapor pressure deficit in Coos County is extreme. The bars and whiskers represent the mean and range, respectively, of changes across 20 global climate models. (Data Source: Climate Toolbox, climatetoolbox.org/tool/Climate-Mapper)

Key Messages

⇒ Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase in Coos County by 11 days (range -6–30) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

⇒ In Coos County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 30 days (range 9–56) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality

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

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

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

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

This report presents projections of future air quality that are based on $PM_{2.5}$ from wildfire smoke. Smoke wave days are defined as two or more consecutive days on which simulated, county-averaged, wildfire-derived $PM_{2.5}$ values are in the highest 2% of simulated daily values from 2004 through 2009 (Liu *et al.*, 2016). Smoke wave intensity is defined as the

concentration of $PM_{2.5}$ on smoke wave days. Mean number of smoke wave days and mean smoke wave intensity are projected for two six-year periods, 2004–2009 and 2046–2051, under a medium emissions scenario. More information about the methods underlying these projections of future air quality is in the Appendix. In Coos County, the number of smoke wave days is projected to decrease by 15%, whereas the intensity of smoke wave days is projected to increase by 69% (Figure 15).

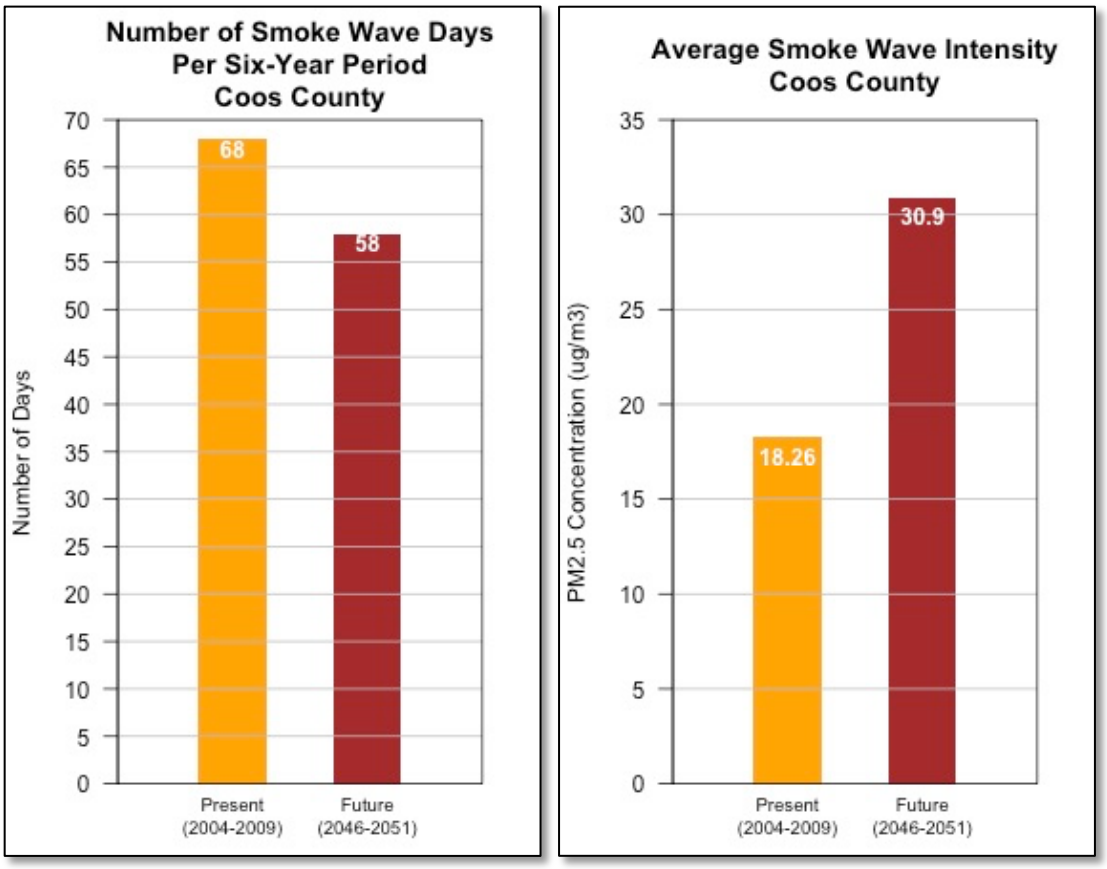


Figure 12. Simulated present (2004–2009) and future (2046–2051) number (left) and intensity (right) of smoke wave days in Coos County under a medium emissions scenario. Values represent the mean among 15 global climate models. (Data source: Liu et al. 2016, https://khanotations.github.io/smoke-map/)

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

Fungal spores also could become more abundant following extreme floods or droughts, which are expected to become more common with climate change. The period during

which outdoor airborne mold spores are detectable increased in the last 20 years as a result of increasing concentrations of carbon dioxide and changes in climate and land use (Paudel *et al.*, 2021). Furthermore, because both ozone and particulates affect the sensitivity of respiratory systems to airborne allergens, the combined effects of climate change, air pollution, and changes in vegetation phenology will likely increase the severity of respiratory diseases and allergies (D'Amato *et al.*, 2020).

Key Messages

- ⇒ The risk of wildfire smoke in Coos County is projected to increase.
- ⇒ In Coos County, the number of days per year on which the concentration of wildfire-derived fine particulate matter results in poor air quality is projected to decrease by 15%, and the concentration of fine particulate matter is projected to increase by 69%, from 2004–2009 to 2046–2051 under a medium emissions scenario.

Coastal Erosion and Flooding

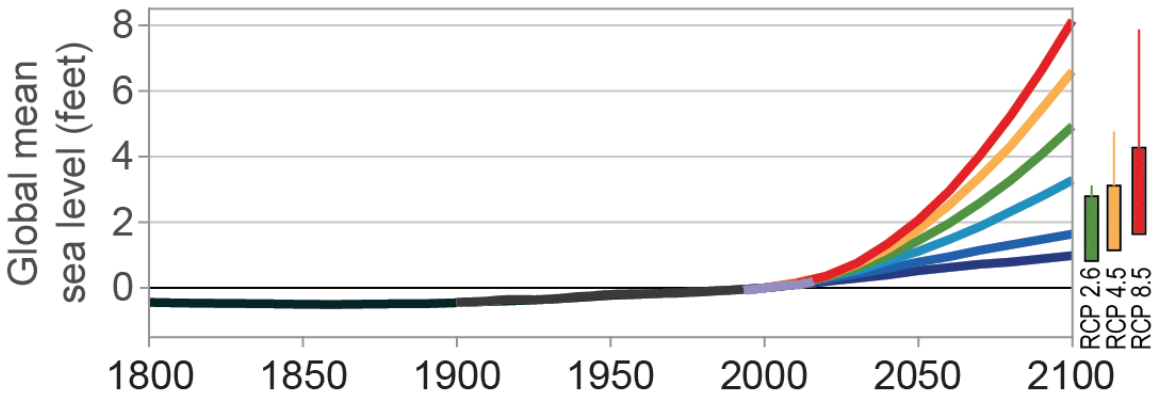
Variability in water levels associated with the El Niño–Southern Oscillation, tides, storm surges, and waves, especially in conjunction with relative sea level rise, can result in flooding and erosion along the Oregon coast. Projected changes in these processes and phenomena may increase their risks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

Observed and Projected Trends in Sea Level

Global mean sea level has risen by about 7–8 inches since 1900, and recent observations suggest that rates of sea level rise have accelerated since 1993 (Nerem *et al.*, 2018). Global mean sea level is very likely to continue to rise by another 1–4 feet, relative to the year 2000, by the year 2100 (Sweet *et al.*, 2017a; Hayhoe *et al.*, 2018). Instabilities in Antarctic ice sheets that are plausible, but have low probability, could result in much higher (~8 feet) global sea level rise (Hayhoe *et al.*, 2018) (Figure 16).

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

Local sea level at the National Oceanic and Atmospheric Administration (NOAA) water-level station at Charleston, Oregon rose about one inch from 1978–2013. Climate change is expected to accelerate sea level rise along the southern Oregon coast during the twenty-first century. Local sea level is projected to rise by 1.2–5.3 feet by 2100 (Climate Central, 2022) given the intermediate-low and intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment (Sweet *et al.*, 2017a) (Table 12). This range of sea level rise scenarios is similar to the *very likely* range projected under the higher emissions scenario (RCP 8.5) by 2100 (Figure 16). Additionally, median local sea level rise at Charleston, Oregon, was projected for each decade from 2030–2100, relative to the 1992 mean high tide line, given six scenarios of global sea level rise. These projections incorporated estimates of trends in vertical land movement derived from GPS measurements and tide gauge platforms (Sweet *et al.*, 2017b) (Table 12). Accordingly, the projections are relative to the future land position as opposed to the existing land position.



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

Figure 13. (Top) Global mean sea level rise from 1800 to 2100, based on tide gauge-based reconstruction (black), satellite-based reconstruction (purple), and six future scenarios (navy blue, royal blue, cyan, green, orange, red) used in the 2018 U.S. National Climate Assessment (NCA4). Colored boxes indicate the *very likely* ranges in 2100 given different RCPs. Lines augmenting the very likely ranges account for estimates of accelerated Antarctic ice-sheet melt. (Bottom) Probability of exceeding each NCA4 global mean sea level scenario in 2100 under three RCPs. (Source: Sweet et al., 2017a, https://science2017.globalchange.gov/chapter/12/)

Table 12. Median local sea level rise projections at the NOAA water level station at Charleston, Oregon, based on scenarios used in the 2018 U.S. National Climate Assessment. Sea level rise is feet above the 1992 baseline. Each scenario also has an associated likely range of sea level rise (not shown). Projections account for estimated trends in vertical land movement. (Source: Climate Central Surging Seas Risk Finder, https://riskfinder.climatecentral.org/county/coos-county.or.us?comparisonType=county&forecastType=NOAA2017_int_p50&level=4&unit=ft&zillowPlaceType=postal-code)

Scenario	2030	2040	2050	2060	2070	2080	2090	2100
Low	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.7
Intermediate-Low	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2
Intermediate	0.5	0.8	1.0	1.3	1.7	2.1	2.6	3.1
Intermediate-High	0.7	1.1	1.5	2.1	2.8	3.5	4.4	5.3
High	1.0	1.5	2.3	3.1	4.0	5.2	6.5	8.0
Extreme	1.2	1.8	2.7	3.8	5.1	6.5	8.1	10.0

Anticipated Effects of Climate Change on Ocean Wave Climate

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

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

advance understanding of the impacts of alterations to the wave climate and will examine extreme and average conditions separately.

Coastal Erosion

Over the past 100 years (late 1800s through 2002), trends in beach erosion were statistically significant in only three of Oregon's 18 littoral cells (coastal compartments within which sediment movement is self-contained), Humbug, Heceta, and Netarts (Ruggiero *et al.*, 2013). However, in the shorter term (1967–2002), 10 of Oregon's littoral cells eroded at a statistically significant rate of 1–3.6 feet per year (Ruggiero *et al.*, 2013). This increase in rates of erosion along much of Oregon's coastline may be related to the effects of sea level rise and changes in storm patterns (Ruggiero *et al.*, 2013). In the Bandon littoral cell, which is along the coastline of Coos County between Cape Blanco and Cape Arago, the average annual rate of accretion across the shoreline was a statistically significant 0.7 feet, although 39% of the shoreline is eroding (Ruggiero *et al.*, 2013).

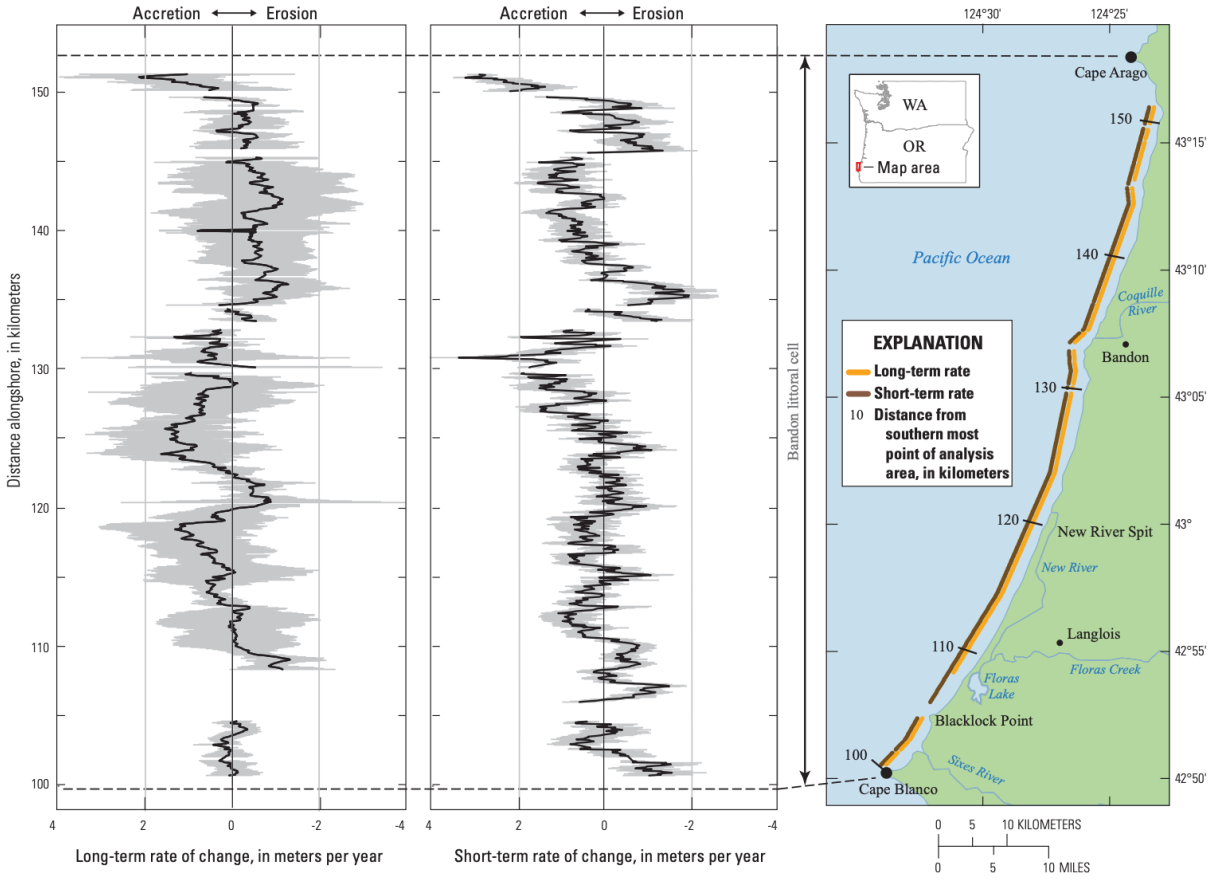


Figure 14. Long-term (1800s through 2002) and short-term (1960s through 2002) shoreline change rates (black lines on plots) in the Bandon littoral cell along the coastline of Coos County, Oregon. Shaded gray area behind long- and short-term rate lines represents uncertainty associated with rate calculation. (Source: Ruggiero et al., 2013)

Coastal Flooding

The projected increase in relative sea levels along the Oregon coast raises the starting point (still water level) for waves, storm surges, and high tides that can impinge on beaches and backshore areas. Possible changes to waves, storm surges, and tides have the potential to make coastal flooding in Oregon (which is associated with total water levels) more severe and more frequent in the future. A simple estimate of coastal flood risk combined projections of relative sea level rise and historic flood frequencies to estimate the multiple-year risk of flooding above a certain threshold (Climate Central, 2022). For example, one can project the likelihood that at least one coastal flood will exceed four feet above mean high tide by a given year (Table 13).

Assuming the intermediate-low to intermediate-high sea level scenarios for Charleston, Oregon (Table 12), the projected likelihood that at least one flood will exceed four feet above mean high tide was 4–34% by 2030, 25–100% by 2050, and 100% by 2100 (Climate Central, 2022) (Table 13). For historical perspective, the highest observed flood in the area from 1970 through 2015 was 3.56 feet above mean high tide in 1983, and the statistical 1-in-100 year flood height is 3.6 feet (Climate Central, 2022). As of 2010, 1062 people, 592 buildings, and $72 million in property value in Coos County are within zero to four feet above mean high tide and are not protected by levees or other features (Climate Central, 2022). These flood risk projections did not incorporate changes to wave dynamics or storm surges, which could result in a given coastal flood level occurring sooner.

Table 13. Percent likelihood that at least one flood will exceed four feet above mean high tide from 2016 through each year. Likelihoods are based on median projections of local sea level rise at Charleston, Oregon (Table 12). (Source: Climate Central Surging Seas Risk Finder, https://riskfinder.climatecentral.org/county/coos-county.or.us?comparisonType=county&forecastName=Basic&forecastType=NOAA2017_extreme_p50&level=4&unit=ft&zillowPlaceType=postal-code)

Scenario	2030	2040	2050	2060	2070	2080	2090	2100
Low	2	4	9	16	30	48	67	81
Intermediate-Low	4	11	25	47	73	92	99	100
Intermediate	14	45	85	99	100	100	100	100
Intermediate-High	34	85	100	100	100	100	100	100
High	64	100	100	100	100	100	100	100
Extreme	83	100	100	100	100	100	100	100

Relative sea level rise narrows the gap in elevations between commonly occurring high tides and the thresholds above which flooding begins. Coastal communities were developed with an understanding of this gap and the flooding that could occur under extreme conditions. When considering only long-term sea level trends (still water levels), the gap between high tide and flooding may be filled on the order of decades. When considering

sea-level variability associated with waves (total water levels), flooding and its effects on the built and natural environment may become frequent much sooner, on the order of years (Mills *et al.*, 2018; Hamlington *et al.*, 2020). Incremental increases in relative sea level rise can produce exponential increases in coastal flood frequency (Taherkhani *et al.*, 2020). For example, on the west coast of the United States, approximately 2.1 inches of sea level rise doubles the odds of exceeding the present-day, 50-year water-level event (a flood level with a 2% annual probability of exceedance) (Taherkhani *et al.*, 2020). The odds of such extreme flooding double about every five years (Taherkhani *et al.*, 2020).

The Oregon Coastal Management Program (OCMP) estimated the exposure to sea level rise of Oregon's estuaries, including the Coquille River and Coos Bay estuaries in Coos County (Sepanik *et al.*, 2017). The OCMP sea level rise scenarios are taken from the upper range of projections for Newport, Oregon in *Sea-Level Rise for Coasts of California, Oregon, and Washington* (National Research Council, 2012). In this report for Coos County, OCCRI summarized the sea level rise and flooding scenarios considered by OCMP for Coos County and compared them to the sea level rise and flooding scenarios from the 2018 U.S. National Climate Assessment (2018 NCA) and Climate Central (Table 14) to place the OCMP analysis in the context of more-recent sea level rise scenarios (Table 12).

OCMP's scenarios for the 2030s and 2050s most closely align with the 2018 NCA's median intermediate-high scenario. OCMP's sea level rise scenario for 2100 most closely aligns with the lower end of the likely range of 2018 NCA's intermediate-high scenario (Table 14). The OCMP estimated that across the two major estuaries in Coos County, the mean flood levels coinciding with a 1% and 50% probability of exceedance in a given year were 3.72 feet and 2.45 feet, respectively (Sepanik *et al.*, 2017). These levels are similar to Climate Central's estimates for Charleston, Oregon's mild flood level (2.4 feet) and major flood level (3.6 feet) (Table 14).

Climate Central's projections of water levels resulting from combined effects of sea level rise and flooding, and associated likelihoods of flood risk, can be compared to OCMP's water-level scenarios (Table 14, Table 15). For example, the likelihood that flood levels will exceed four feet above mean high tide in any single year by 2050, similar to OCMP's 2050 + 50% scenario, is 56%, but the likelihood that four feet will be exceeded at some point between 2016 and 2050 is 100% (Table 15). The likelihood that flood levels will exceed seven feet above mean high tide in any single year by 2100, similar to OCMP's extreme scenario, 2100 + 1%, is 33%, whereas the likelihood that seven feet will be exceeded at some point between 2016 and 2100 is 82% (Table 15). The likelihood of exceeding seven feet by 2110, just a decade later, is 100% (Climate Central, 2022).

Table 14. Sea level rise (SLR) and flooding scenarios for a given year that were generated by the Oregon Coastal Management Program (OCMP), Climate Central, and 2018 U.S. National Climate Assessment (NCA). (Source: Sepanik et al., 2017; Climate Central Surging Seas Risk Finder for Coos County, Oregon, https://riskfinder.climatecentral.org)

OCMP SLR Scenario[2]	2018 NCA SLR Scenario[3]
2030: 0.75 feet	2030: 0.7 feet
2050: 1.57 feet	2050: 1.5 feet
2100: 4.66 feet	2100: 4.3 feet
OCMP Flood Scenario[4]	Climate Central Flood Scenario[5]
1% probability: 3.72 feet	major flood: 3.6 feet
50% probability: 2.45 feet	mild flood: 2.4 feet

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

OCMP SLR + Flood Scenarios	OCMP SLR + Flood Water Level (feet)	Climate Central Equivalent SLR + Flood Water Level (feet)	Climate Central Estimated Single Year Flood Risk (%)	Climate Central Estimated Multiple-Year Flood Risk (%)
2030 + 50%	3.2	3.1	70	100
2030 + 1%	4.5	4.3	6	34
2050 + 50%	4.0	4.0	56	100
2050 + 1%	5.3	5.1	2	7
2100 + 50%	7.1	6.7	95	100
2100 + 1%	8.4	7.8	33	82

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

[3] The 2018 NCA sea level rise scenario for Charleston, Oregon that most closely aligns with the OCMP 2030 and 2050 sea level rise scenarios is the median of the intermediate-high scenario. The NCA 2018 sea level scenario that most closely aligns with the OCMP 2100 scenario is the 17th percentile of the intermediate-high scenario.

[4] The OCMP analysis used NOAA's estimates of extreme water levels to calculate the 1% and 50% probability of exceedance in a given year. Values are averaged over two estuaries in Coos County.

[5] Extreme water levels at the NOAA water level station at Charleston, Oregon

Under the 2050 + 50% scenario, which is virtually certain to occur at least once by 2050, exposed assets in the Coos Bay and Coquille Rivers estuaries in Coos County include 4.3 miles of state highways, 6.6 miles of state, county and local roads, 9.4 miles of railways, 3 critical facilities, 2 municipal use drinking water facilities, 3 potential contaminant sources, and 715 buildings (Table 16). Under the 2100 + 1% scenario, which has an 82% likelihood of occurring at least once by 2100 and is virtually certain to occur at least once by 2110, exposed assets include 19.2 miles of state highways, 109.8 miles of state, county and local roads, 1 airport, 19.4 miles of railways, 6 critical facilities, 2 municipal use drinking water facilities, 2 waste water treatment plants, 7 potential contaminant sources, and 1894 buildings (Table 16). No electrical substations are exposed under either scenario.

Table 16. Assets exposed under OCMP's 2050 + 50% and 2100 + 1% sea level and flooding scenarios for two estuaries in Coos County. The exposure of the built infrastructure within the footprints of these estuaries to future flooding, relative to all estuaries along the Oregon coast, is moderately high for the Coos Bay estuary and low for the Coquille River estuary. (Source: Sepanik et al., 2017)

	2050 SLR + 50% Probability Flood (~4.0 feet)			2100 SLR + 1% Probability Flood (~8.4 feet)		
Assets	Coos Bay	Coquille River	Total	Coos Bay	Coquille River	Total
State Highways (miles)	4	0.3	4.3	18.1	1.1	19.2
State, County, and Local Roads (miles)	43	2.3	6.6	93.6	16.2	109.8
Airports (number)	0	0	0	1	0	1
Railways (miles)	9.4	0	9.4	18.3	1.1	19.4
Critical Facilities (number)	3	0	3	6	0	6
Municipal Use Drinking Water (number)	1	1	2	1	1	2
Wastewater Treatment Plants (number)	0	0	0	2	0	2
Electrical Substations (number)	0	0	0	0	0	0
Potential Contaminant Sources (number)	2	1	3	4	3	7
Buildings (number)	697	18	715	1722	172	1894

Key Messages

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

⇒ In Coos County, local sea level is projected to rise by 1.2 to 5.3 feet by 2100. This projection is based on the intermediate-low to intermediate-high global sea level scenarios used in the 2018 U.S. National Climate Assessment. Because these local sea level projections account for estimated trends in vertical land movement, they are relative to the future land position.

⇒ Given these levels of sea level rise, the multiple-year likelihood of a flood reaching four feet above mean high tide is 4–34% by the 2030s, 25–100% by the 2050s, and 100% by 2100.

⇒ At risk within the four-foot inundation zone in Coos County as of the 2010 census are 1062 people, $72 million in property value, 10.9 miles of highways and roads, 9.4 miles of railways, 3 critical facilities, 2 municipal drinking water facilities, 3 potential contaminant sources, and 715 buildings.

Changes in Ocean Temperature and Chemistry

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

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

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

Warming ocean temperatures have profound effects on other aspects of ocean physics, particularly water density and stratification in the upper part of the water column, which in turn reduces transfer of oxygen among surface and deeper layers (Pershing *et al.*, 2018). Additionally, warm water holds less oxygen than cool water, so increasing water temperature directly decreases the concentration of dissolved oxygen. Trends in dissolved oxygen are difficult to detect given that oxygen concentration varies considerably due to periodic circulation patterns and interdecadal oscillations (e.g., seasonal coastal upwelling, seasonal coastal storm mixing, El Niño-Southern Oscillation, Pacific Decadal Oscillation) (Pierce *et al.*, 2012). Local coastal processes of decomposition further can lead to temporally and spatially variable low-oxygen or hypoxia events (oxygen concentration less than 1400 ppm of ocean water). On the shelf and adjacent slope, changes are already noticeable; oxygen levels off Newport, Oregon, decreased by 40% at 197–230 feet below the surface from 1960–1971 to 1998–2009 (Pierce *et al.*, 2012). These changes have led to

an increasingly recognizable and severe late-summer hypoxia season in Oregon and throughout the Pacific Northwest (Chan *et al.*, 2008, 2019), that can cause extensive mortality and changes in the distribution of marine species (Chan *et al.*, 2019). The risk of an increasing number of hypoxia events is high given that average oxygen levels were projected to decline by 17% throughout the north Pacific Ocean by 2100, assuming RCP 8.5 (Jewett and Romanou, 2017; Pershing *et al.*, 2018).

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

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

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

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

Key Messages

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

Loss of Wetlands

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

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

Under scenarios of sea level rise of up to 2.5 feet, wetland area in 23 estuaries in Oregon is projected to increase slightly as tides inundate slightly higher land surfaces (Brophy *et al.*, 2017). However, projected tidal wetland area begins to decline sharply as sea level continues to rise, with a 21% reduction in area at 4.7 feet of sea level rise, 45% reduction at 8.2 feet, and 60% reduction at 11.5 feet (Brophy *et al.*, 2017). The 2.5 and 4.7 feet of sea level rise correspond to the upper end of the range of sea level rise projected by 2050 and 2100, respectively, for Newport, Oregon (National Research Council, 2012). The 2.5 feet sea level rise scenario corresponds to the level expected by the 2090s, 2070s, and 2050s under the 2018 NCA's intermediate, intermediate-high, and high sea level rise scenarios, respectively (Table 12). The 4.7 feet sea level rise scenario is similar to that projected by the 2090s under the 2018 NCA's intermediate-high sea level rise scenario and by the 2070s to 2080s under the high sea level rise scenario (Table 12).

Projected changes in tidal wetland area of three estuaries in Coos County (Coos Bay, Coquille River, and New River Area) were inconsistent with the general pattern of increases in potential tidal wetland area with relatively low levels of sea level rise followed by decreases with high levels of sea level rise. Potential tidal wetland area in the Coos Bay and Coquille estuaries is projected to decrease early and continuously under all sea level rise scenarios. Assuming 4.7 feet of sea level rise, tidal wetland area in the Coos Bay (Figure 18, Figure 19) and Coquille River (Figure 20) estuaries is projected to decrease by about 50% (Brophy *et al.*, 2017) (Table 17).

Tidal wetland area in the New River Area, which includes Twomile Creek South, Fourmile Creek, New River, and Floras Creek, is projected to increase by more than 2000%, from 81 to 1861 acres, with 4.7 feet of sea level rise (Table 17, Figure 21). However, in this area, the inland extent of tides is currently limited by a long sand spit on which waves consistently deposit sand. Whether future tides will push into the New River area is uncertain and depends on whether and how deposition of sediment and sand changes (Brophy *et al.*, 2017).

Table 17. Present-day baseline and potential future tidal wetland area (acres) of three estuaries in Coos County, and projected changes in area under two sea level rise (SLR) scenarios. (Source: Brophy et al. 2017).

Estuary	Present-Day Tidal Wetland Area (acres)	Future Tidal Wetland Area with 2.5 feet of SLR (acres)	Future Tidal Wetland Area with 4.7 feet of SLR (acres)	Change in Tidal Wetland Area with 2.5 feet of SLR (%)	Change in Tidal Wetland Area with 4.7 feet of SLR (%)
Coos Bay	6422	4740	3103	-26	-52
Coquille River	7758	6251	3946	-19	-49
New River Area	81	907	1861	1019	2196

Key Messages

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

⇒ Wetland area in the Coos Bay and Coquille River estuaries is projected to decrease with increasing sea levels. Under 4.7 feet of sea level rise, tidal wetland area in these estuaries is projected to decrease by about 50%. Tidal wetland area in the New River Area is projected to increase by more than 2000%, but whether future tides will push into this area is uncertain.

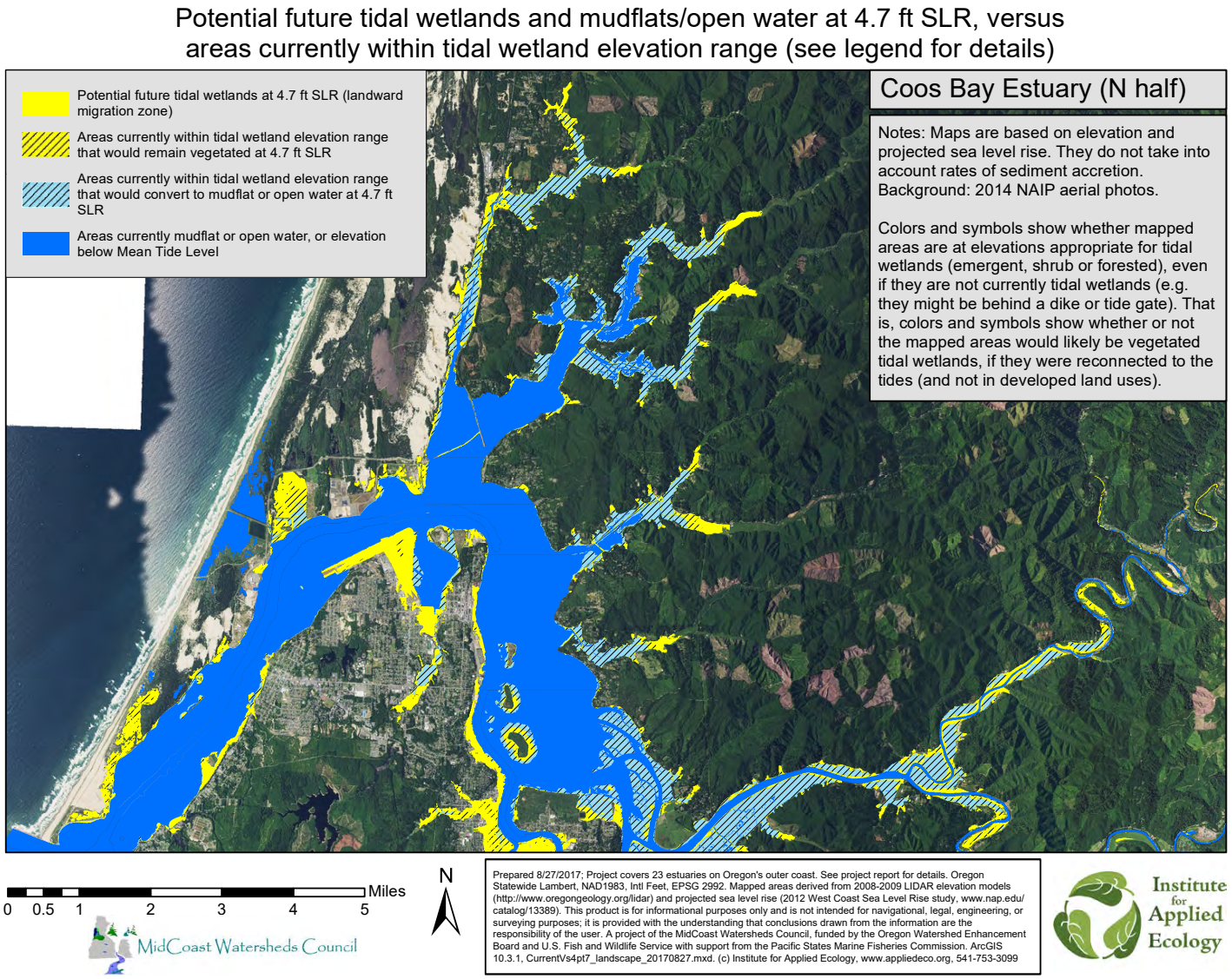


Figure 15. Potential tidal wetlands, mudflats, and open water at 4.7 feet sea level rise, versus areas currently within the elevation range of tidal wetlands, within the north half of the Coos Bay Estuary. (Source: Brophy et al., 2017)

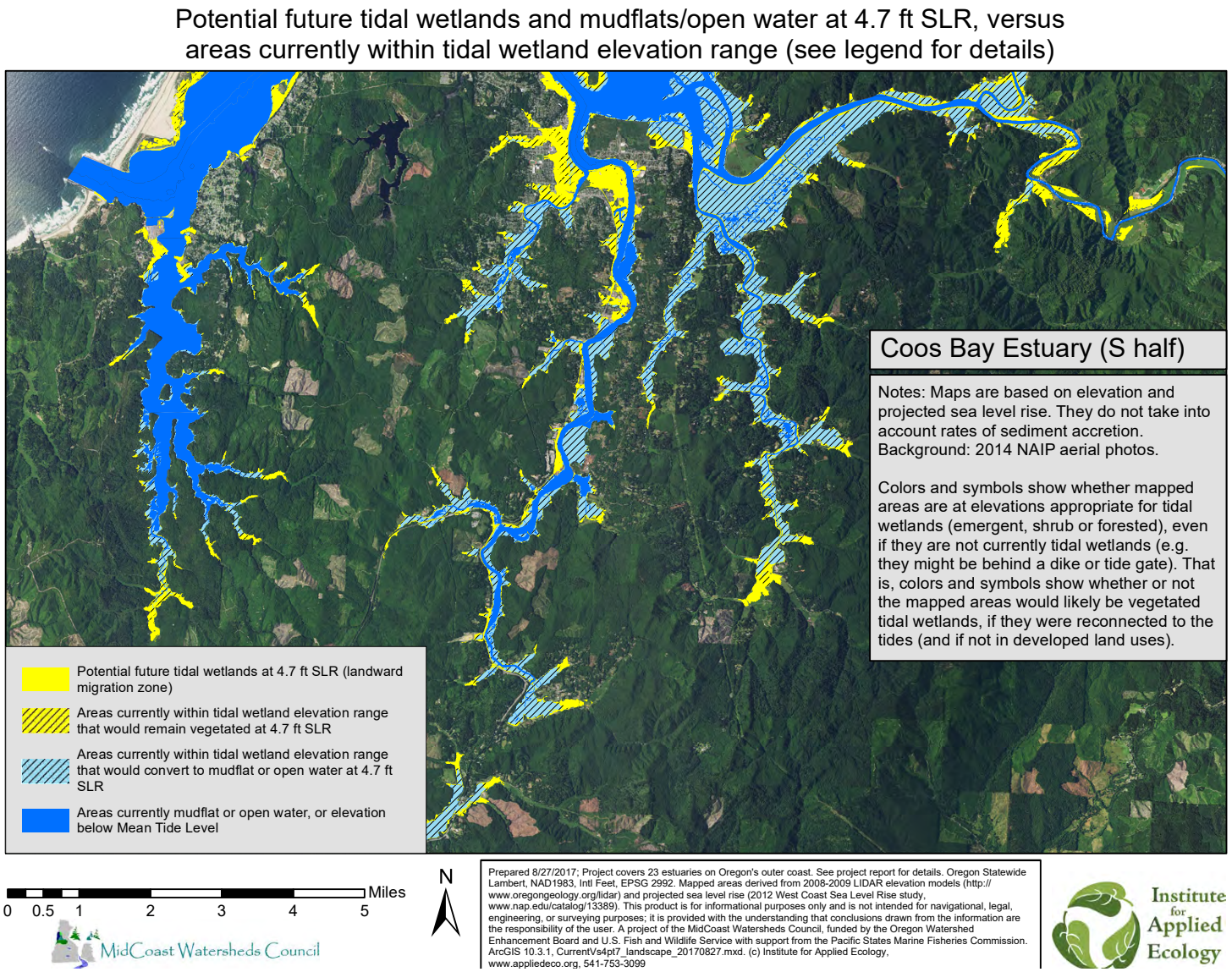


Figure 16. Potential tidal wetlands, mudflats, and open water at 4.7 feet sea level rise, versus areas currently within the elevation range of tidal wetlands, within the south half of the Coos Bay Estuary. (Source: Brophy et al., 2017)

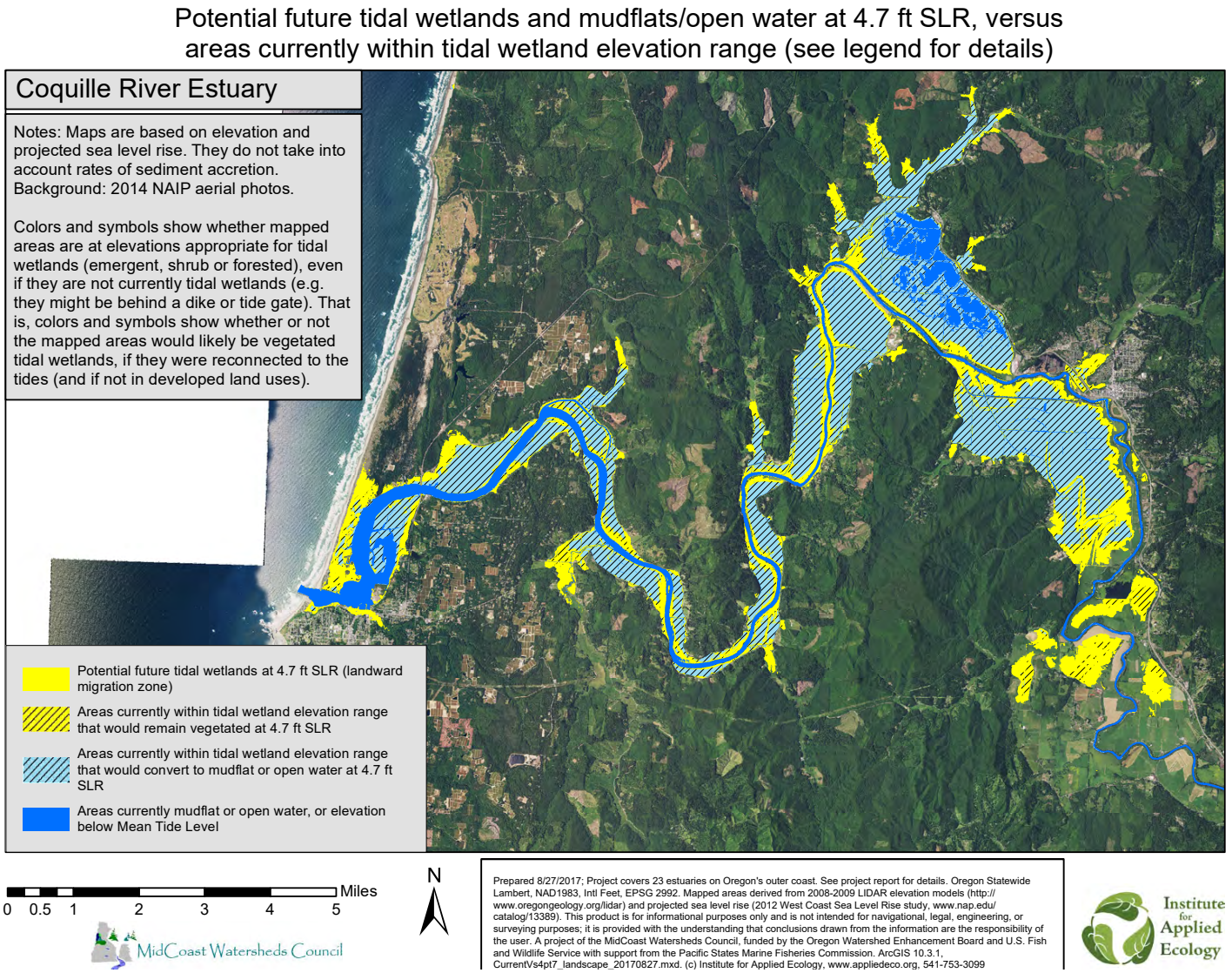


Figure 17. Potential tidal wetlands, mudflats, and open water at 4.7 feet sea level rise, versus areas currently within the elevation range of tidal wetlands, within the Coquille River Estuary. (Source: Brophy et al., 2017)

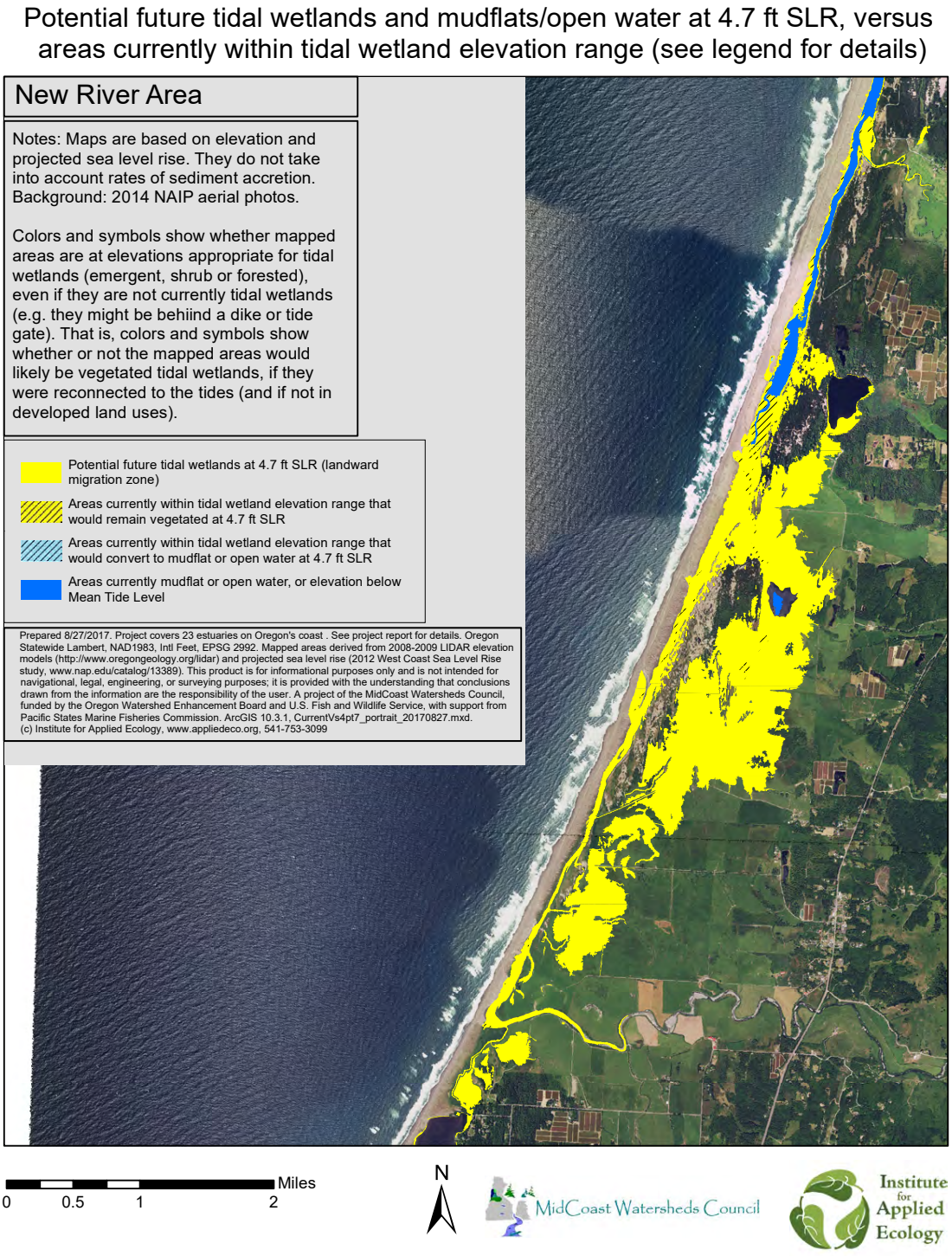


Figure 18. Potential tidal wetlands, mudflats, and open water at 4.7 feet sea level rise, versus areas currently within the elevation range of tidal wetlands, within the New River Area. (Source: Brophy et al., 2017)

Windstorms

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

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

Key Messages

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

Expansion of Pests, Pathogens, and Non-native Invasive Species

Changes in climate and atmospheric concentrations of carbon dioxide can affect the distribution and population dynamics of native and non-native species of plants and animals that are considered to be invasive or pests in natural and agricultural systems. Increasing concentrations of carbon dioxide not only lead to increases in global temperature, but affect plants' primary productivity, water-use efficiency, and nutrient content. Changes in climate, ongoing human additions of nitrogen to the environment, and their interactions also affect the growth and competitive relations among plant and animal species (Greaver *et al.*, 2016). In general, invasive and pest species in Coos County are likely to become more prevalent in response to projected increases in temperature, especially minimum winter temperature, and increases in the frequency, duration, and severity of drought. However, many of these responses are uncertain, and are likely to vary locally. Moreover, the responses may change over time.

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

Sudden oak death (*Phytophthora ramorum*), which primarily affects tanoak (*Notholithocarpus densiflorus*), may colonize Coos County by the late 2020s, with negative effects on economic returns from the timber industry, recreation and tourism revenue, and property values (Buhl *et al.*, 2020). In 2021, a new genetic variant of sudden oak death was detected in tanoaks north of Port Orford, more than 20 miles north of the previously known northern extent of the pathogen. Sudden oak death generally is associated with warm, wet microclimates, and it is difficult to project how interactions between changes in temperature, trends in total water-year precipitation, and trends in drought will affect its incidence and virulence.

The Coos County Noxious Weed Control Advisory Board targets 15 of the species or taxa that it designates as weeds for prevention and control within the county. Although little is known about how several of these species may to respond to climate change, some evidence suggests how others may be affected. For example, biddy biddy (*Acaena novae-zelandiae*; a perennial forb), which generally is sensitive to frost (Gynn and Richards, 1985), and Japanese knotweed (*Fallopia japonica*; an herbaceous shrub), in which photosynthesis is reduced by freezing (Baxendale and Tessier, 2015), may become more

widespread or abundant as autumn and winter temperatures increase. Given that biddy biddy is transported readily by humans, often on socks (Pickering *et al.*, 2011), increases in recreational activity could interact with climate change to facilitate its expansion. Much like biddy biddy, Scotch broom (*Cytisus scoparius*; a shrub) and English and Atlantic ivy (*Hedera helix* and *H. hibernica*; evergreen vines) usually are not highly tolerant of frost in autumn, although populations can become more frost-tolerant over time (Strelau *et al.*, 2018; Winde *et al.*, 2020). Increases in temperature throughout the year may lead to expansion of diffuse knapweed (*Centaurea diffusa*) (Li *et al.*, 2018).

There is some evidence that heat stress impairs photosynthesis and therefore growth of English and Atlantic ivy (Strelau *et al.*, 2018). Nevertheless, English and Atlantic ivy can benefit from increases in carbon dioxide concentrations, especially when temperatures are relatively warm (Manzanedo *et al.*, 2018). Experiments suggested that the photosynthetic rate and biomass of Canada thistle (*Cirsium arvense*), the number and length of the species' spines also are likely to increase as ambient concentrations of carbon dioxide increase throughout the twenty-first century, and may have increased during the previous century (Ziska, 2002). Whether the root biomass of Canada thistle also responds positively to increases in carbon dioxide concentrations, especially independent of increases in temperature, is unclear (Ziska *et al.*, 2004; Tørresen *et al.*, 2020), and may vary in space. Furthermore, both bull thistle (*Cirsium vulgare*) and Canada thistle can establish readily in soils that have been disturbed by high-severity wildfires, which may become more common as climate changes, or by logging (Reilly *et al.*, 2020).

Changes in the amount and timing of precipitation may contribute to expansion or contraction of different non-native invasive plants in Coos County. In forests in western Oregon, cover of *H. helix* was associated negatively with summer precipitation, and occurrence of bull thistle and Canada thistle was associated negatively with annual precipitation (Gray, 2005). Gorse (*Ulex europaeus*; an evergreen shrub) can spread after wildfire and generally is highly flammable. However, extreme precipitation following wildfire directly or indirectly may reduce seedling survival via movement of soil and litter, which can either expose or bury the small plants (Luís *et al.*, 2005). By contrast, increases in annual precipitation may facilitate expansion of French broom (*Genista monspessulana*; an evergreen shrub) (García *et al.*, 2014) and diffuse knapweed (*Centaurea diffusa*) (Blumenthal *et al.*, 2008).

Following experimental drought treatment in a seasonally flooded area, percent cover of bull thistle increased five to 13 times (Hogenbirk and Wein, 1991). Evidence of drought tolerance in Scotch broom is equivocal, especially in the field rather than in greenhouse experiments (Potter *et al.*, 2009; Hogg and Moran, 2020). The species' growth and survival may increase as snow depths decrease, especially during the winter after germination (Stevens and Latimer, 2015).

As tropospheric concentrations of ozone continue to increase, productivity of native and agricultural plants generally is expected to decrease. However, ozone tolerance in weedy, vegetatively reproducing species such as yellow nutsedge (*Cyperus esculentus*) may increase relatively quickly, allowing them to gain a competitive advantage over some crops (Grantz and Shrestha, 2006).

Key Messages

⇒ In general, invasive and pest species in Coos County are likely to become more prevalent in response to projected increases in temperature, especially minimum winter temperature, and increases in the frequency, duration, and severity of drought. However, many of these responses are uncertain, are likely to vary locally, and may change over time.

Appendix

Future Climate Projections Background

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

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

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

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

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

Climate and Hydrological Data

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

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

Simulations of daily maximum temperature, minimum temperature, and precipitation from 1950 through 2099 for 20 GCMs (Table 18) and two emissions scenarios (RCP 4.5 and RCP 8.5) are available. Hydrological simulations of snow water equivalent (SWE) are available for the 10 GCMs used as input to VIC. All available modeled outputs were obtained from the Integrated Scenarios data archives and included in this report to represent the mean and range of projections among the largest possible ensemble of GCMs.

Table 18. The 20 CMIP5 GCMs represented in this report. Asterisks indicate the ten GCMs used as inputs to the Variable Infiltration Capacity hydrological model.

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

All simulated climate data and the streamflow data, with the exception of snow water equivalent, were bias-corrected with quantile mapping by the Integrated Scenarios project. Quantile mapping adjusts simulated values by comparing the cumulative probability distributions of simulated and observed values. In practice, the simulated and observed values of a variable (e.g., daily streamflow) over the historical time period are sorted and ranked, and each value is assigned a probability of exceedance. The bias-corrected value of

a given simulated value is assigned the observed value that has the same probability of exceedance as the simulated value. The historical bias in the simulations is assumed to be constant. Therefore, the relations between simulated and observed values in the historical period were applied to the future scenarios. Climate data in the MACA data reflect quantile mapping relations for each non-overlapping 15-day window in the calendar year. Streamflow data reflect quantile mapping relations for each calendar month.

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

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

Smoke Wave Data

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

Sea Level Rise and Coastal Flooding Data

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

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2. Natural Hazard Risk Report for Coos County

This report forms the basis of the risk assessment for the 2023 Coos County Multi-Jurisdictional Natural Hazard Mitigation Plan Update. It is cited as Williams et al, 2021 within this document.

Williams, M. C., Anthony, L. H., and Fletcher E. O'Brien. (2021). *Natural hazard risk report for Coos County, Oregon, including the Cities of Bandon, Coos Bay, Coquille, Lakeside, Myrtle Point, North Bend, and Powers, and Tribal Lands of the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians and the Coquille Indian Tribe, and the unincorporated communities of Bunker Hill, Charleston, Glasgow, Green Acres, Hauser, and Millington. Portland, OR.*

What's in this report?

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

Executive Summary (excerpt):

This report describes the methods and results of the natural hazard risk assessments performed in 2018 by the Oregon Department of Geology and Mineral Industries (DOGAMI) for the communities of Coos County. The purpose of this project is to provide communities in Coos County detailed risk assessments of natural hazards that affect them and to enable communities to compare hazards and act to reduce their risk. The risk assessments contained in this project quantify the impacts of natural hazards to these communities and enhance the decision-making process in planning for disaster

State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

OPEN-FILE REPORT O-21-04

NATURAL HAZARD RISK REPORT FOR COOS COUNTY, OREGON

INCLUDING THE CITIES OF BANDON, COOS BAY, COQUILLE, LAKESIDE, MYRTLE POINT, NORTH BEND AND POWERS, AND TRIBAL LANDS OF THE CONFEDERATED TRIBES OF COOS, LOWER UMPQUA, AND SIUSLAW INDIANS AND THE COQUILLE INDIAN TRIBE, AND THE UNINCORPORATED COMMUNITIES OF BUNKER HILL, CHARLESTON, GLASGOW, GREEN ACRES, HAUSER, AND MILLINGTON

by Matt C. Williams[1], Ian Madin[1], Lowell H. Anthony[1], and Fletcher O'Brien[1]

2021

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Cover photo: Mouth of the Coos River and North Spit near the City of Coos Bay, Oregon.
Credit: Oregon ShoreZone, made available under a Creative Commons "CC-BY-SA" license.

WHAT'S IN THIS REPORT?

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

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GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.2 format. Metadata are embedded in the geodatabase and are also provided as separate .xml format files.

Coos_County_Risk_Report_Data.gdb

Feature dataset: Asset_Data
feature classes:
Building_footprints (polygons)
UDF_points (points)
Communities (polygons)

Raster data: Hazard_Data
FL_Depth_10
FL_Depth_50
FL_Depth_100
FL_Depth_500

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 Coos County, Oregon, with funding provided by the Federal Emergency Management Agency (FEMA). It describes the methods and results of the natural hazard risk assessment performed in 2018 by the Oregon Department of Geology and Mineral Industries (DOGAMI) within the study area. The purpose of this project was to provide communities with a detailed understanding of their risk from natural hazards, to give communities the ability to compare their risk across multiple hazards, and to prioritize and take actions that will reduce risk. The results of this study can also inform the natural hazard mitigation planning process.

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

To complete 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 this dataset, we were able to represent an accurate spatial location and vulnerability 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 some were produced using high-resolution lidar topographic data. While not all the data sources used in the report are countywide, each hazard dataset was the best available at the time the analysis was performed.

In the third task, we performed the risk assessment using Esri® ArcGIS Desktop® software. We used two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using Hazus-MH methodology; and (2) calculated the number of buildings, their value, and associated populations exposed to earthquake, tsunami, flood, landslide, and wildfire hazards.

The findings and conclusions of this report show the potential impacts of hazards in communities within Coos 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 from a CSZ event. We also found that the hazards with the highest potential of population displacement are earthquake, tsunami, and landslide hazards. We demonstrate the potential for the reduction in damages and losses from seismic retrofits through building code simulations in the Hazus-MH earthquake model. 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 new landslide mapping based on improved methods and lidar information will increase the accuracy of future risk assessments. During the time of writing, the best available data show that wildfire risk is high for the upstream portions of the Coos River watershed. Lastly, we demonstrate that this risk assessment can be a valuable tool to local decisionmakers.

Results were broken out for the following geographic areas:

- Unincorporated Coos County (rural)
- Community of Charleston
- Community of Green Acres
- Community of Millington
- Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians
- City of Coquille
- City of Lakeside
- City of North Bend
- Community of Bunker Hill
- Community of Glasgow
- Community of Hauser
- City of Bandon
- City of Coos Bay
- Coquille Indian Tribe
- City of Myrtle Point
- City of Powers

Selected countywide results

Total buildings: 42,550

Total estimated building value: $11.5 billion

Cascadia Subduction Zone (CSZ) Magnitude (Mw) 9.0 Earthquake[a]

Red-tagged buildings[b]: 9,689

Yellow-tagged buildings[c]: 3,659

Loss estimate: $3.5 billion

100-year Flood Scenario

Number of buildings damaged: 1,870

Loss estimate: $125 million

Wildfire Exposure (High Risk)

Number of buildings exposed: 1,050

Exposed building value: $217 million

CSZ Tsunami Inundation

Number of buildings exposed: 1,286

Exposed building value: $612 million

Landslide Exposure (High and Very High Susceptibility)

Number of buildings exposed: 7,123

Exposed building value: $1.6 billion

[a]Results reflect damages caused by earthquake to buildings outside of the tsunami zone. Earthquake and tsunami results combined estimate the total damages from a CSZ Mw 9.0 event.

[b]Red-tagged buildings are considered to be uninhabitable due to complete damage.

[c]Yellow-tagged buildings are considered to be of limited habitability due to extensive damage.

1.0 INTRODUCTION

A natural hazard is a naturally occurring phenomenon that can negatively impact humans, which is typically characterized as risk. A natural hazard risk assessment analyzes how a hazard could affect the built environment, population, the cost of recovery, and identifies potential risk. In natural hazard mitigation planning, risk assessments are the basis for developing mitigation strategies and actions. A risk assessment informs the decision-making process, 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 is the first natural hazard risk assessment analyzing individual buildings and resident populations in Coos County. It is the most detailed and comprehensive analysis of natural hazard risk to date and provides a new, comparative perspective across hazards. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Coos County communities.

The Oregon Coast, including its estuaries, and Oregon Coast Range are subject to several significant natural hazards, including riverine and coastal flooding, earthquake, tsunami, landslide, and wildfire. This region of the state is moderately developed, mostly in cities and unincorporated communities within the estuary of Coos Bay and along the Coos River. Natural hazards that pose a potential threat to development results in risk. The primary goal of the risk assessment is to inform communities of their vulnerability and risk to natural hazards and to be a resource for risk reduction actions.

1.1 Purpose

The purpose of this project is to help communities in the study area better understand their risk and increase resilience to natural hazards that are present in their community. This is accomplished by providing accurate, detailed, and up-to-date information about these hazards and by measuring 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 the methods and results for these objectives. We describe the methods for creating the building and population information used in this project. 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** provides 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 county-wide hazard maps.

1.2 Study Area

The study area for this project is the entirety of Coos County, Oregon. Coos County is located in the south coast part of the state and is bordered by Curry County on the south, Douglas County on the east and south, and the Pacific Ocean on the west. The total area of Coos County is 1,626 square miles (4,211 square kilometers). A large percentage of the eastern part of Coos County is managed as industrial forest land.

Coastal geography consists of rocky and irregular shores and dune-backed beaches, estuarine areas, and coastal lowlands. The heavily timbered interior of the county is very rugged and is comprised of portions of the Oregon Coast Range which transitions to the Klamath Mountains in the southern half of the county.

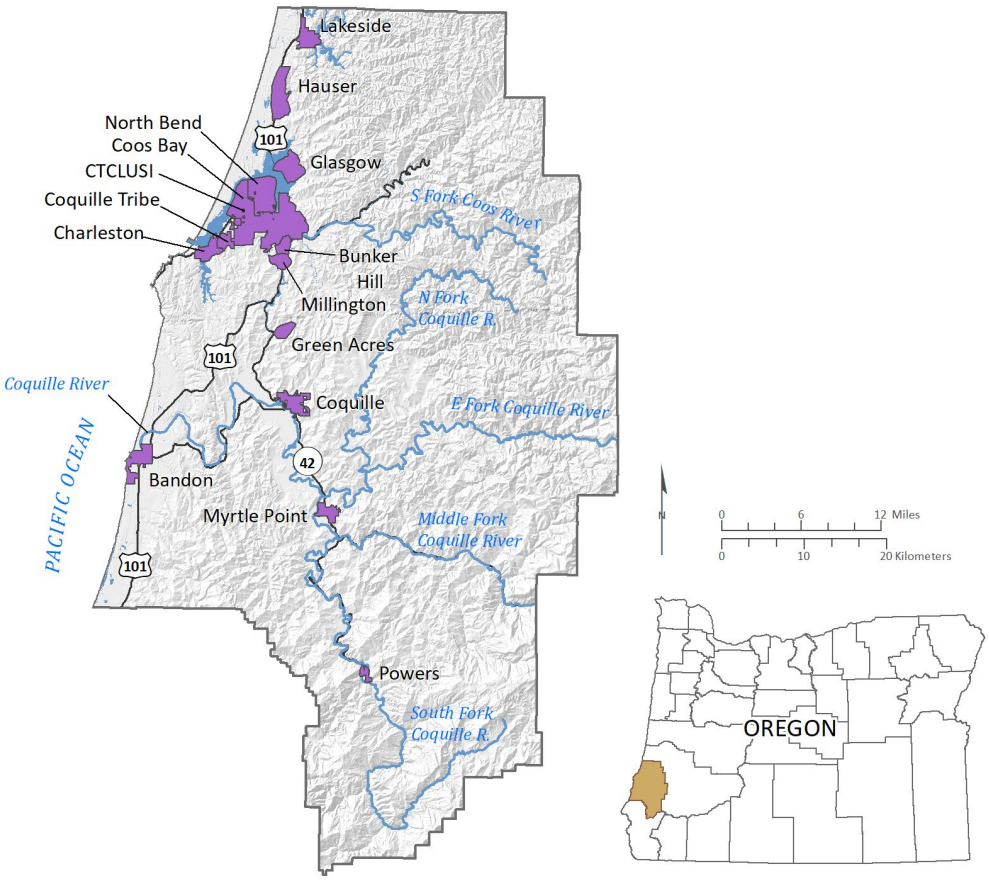
The population of Coos County is 63,043 according to the 2010 U.S. Census Bureau (2010a). The county seat is the City of Coos Bay, which is the largest city on the Oregon Coast. All the communities in the study,

incorporated and unincorporated, are located near the Pacific Ocean or the Coos or Coquille rivers. The incorporated communities are Bandon, Coos Bay, Coquille, Lakeside, Myrtle Point, North Bend, and Powers (**Figure 1-1**). The unincorporated communities are Bunker Hill, Charleston, Glasgow, Green Acres, Hauser, and Millington.

The Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians ("CTCLUSI") and the Coquille Indian Tribe are two federally recognized tribes and communities within the study area. The areas that comprise the tribal lands used in the analyses are made up of several noncontiguous areas within Coos County. The cities of Coos Bay and North Bend have tribal lands adjacent to and within them (**Figure 1-1)**. It is for this reason that areas within the cities of Coos Bay and North Bend that are tribal lands are included in total counts for buildings and population for either the CTCLUSI or the Coquille Indian Tribe communities. No buildings or permanent residents are double counted in any of the individual hazard analyses. Results and analyses for either the CTCLUSI or the Coquille Indian Tribe are for all areas considered tribal lands, including those within the incorporated boundaries of the cities of Coos Bay or North Bend.

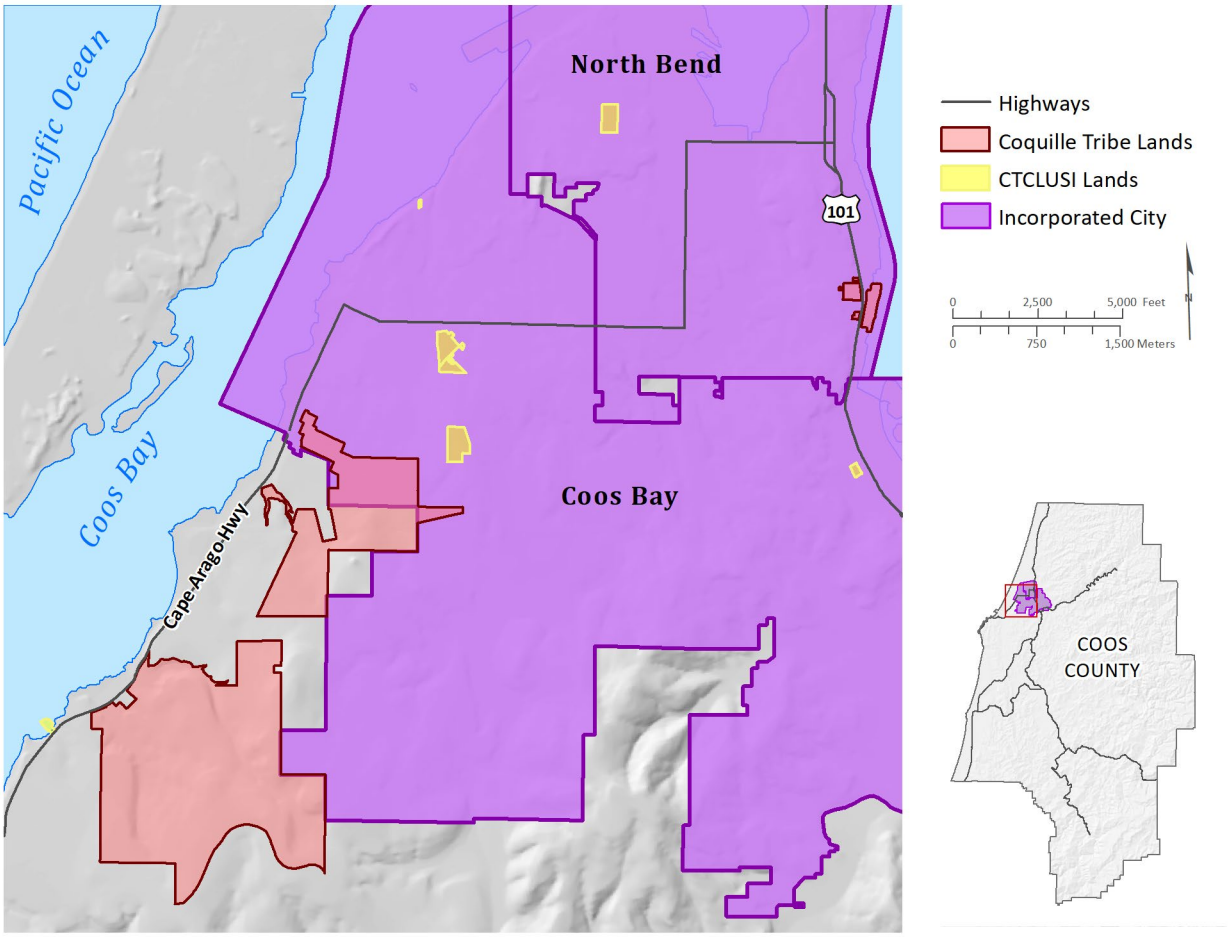
We selected these unincorporated communities on the basis of population size and density, which makes them distinct from the overall unincorporated county jurisdiction. We based the boundaries of these unincorporated communities primarily on the 2010 census block areas.

Figure 1-1. Study area: Coos County with communities in the study identified.



Note that "CTCLUSI" is the tribal community of the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians.

Figure 1-2. Cities of Coos Bay and North Bend with overlapping tribal lands.



Note that "CTCLUSI" is the tribal community of the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians.

1.3 Project Scope

For this risk assessment, we took a quantitative approach and applied it to buildings and population. We limited the project scope to buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, or the environment. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (Hazards U.S., Multi-Hazard), 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), 2010 U.S. census data (U.S. Census Bureau, 2010a) were associated with residential buildings.

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

Cascadia Subduction Zone (CSZ) Earthquake and Tsunami Risk Assessment

- Hazus-MH loss estimation from a CSZ earthquake magnitude (Mw) 9.0 event (includes liquefaction and coseismic landslides)
- Exposure to five potential CSZ tsunami scenarios

Flood Risk Assessment

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

Landslide Risk Assessment

- Exposure based on landslide susceptibility (low to very high)

Wildfire Risk Assessment

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

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

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake (includes liquefaction and coseismic landslides)	CSZ Mw 9.0	Statewide	DOGAMI (Madin and Burns, 2013)
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 (2014) data, included in GIS data for this report
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016)
Wildfire	Risk (Low, Moderate, High)	Regional (Western United States)	Oregon Department of Forestry (Sanborn Map Company, Inc., 2013)

CSZ Mw 9.0 is Cascadia Subduction Zone magnitude 9.0 earthquake.

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.4.1 or the report by Burns and others (2016) for more information.

1.4 Previous Studies

One previous earthquake risk assessment has been conducted that included Coos County by DOGAMI. Wang and Clark (1999: DOGAMI Special Paper 29) 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 Coos County had a very high loss ratio relative to most counties in the state.

In 2010, DOGAMI updated FEMA's Flood Insurance Rate Maps (FIRM)s for Coos County. During this map update process, DOGAMI also produced a series of flood maps of the communities of Coos County that showed parcels and building exposure to the depth of flooding from a 1% annual-chance flood (Tilman, 2010: O-10-05, O-10-06, O-10-07, O-10-08, O-10-09, O-10-10, O-10-11). Exposure results were quantified by land value and real market value provided by the county assessor.

We did not compare the results of this project with the results of the previous studies because of limited time and funding and differences in methodologies.

2.0 METHODS

2.1 Hazus-MH Loss Estimation

Key Terms:

- *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

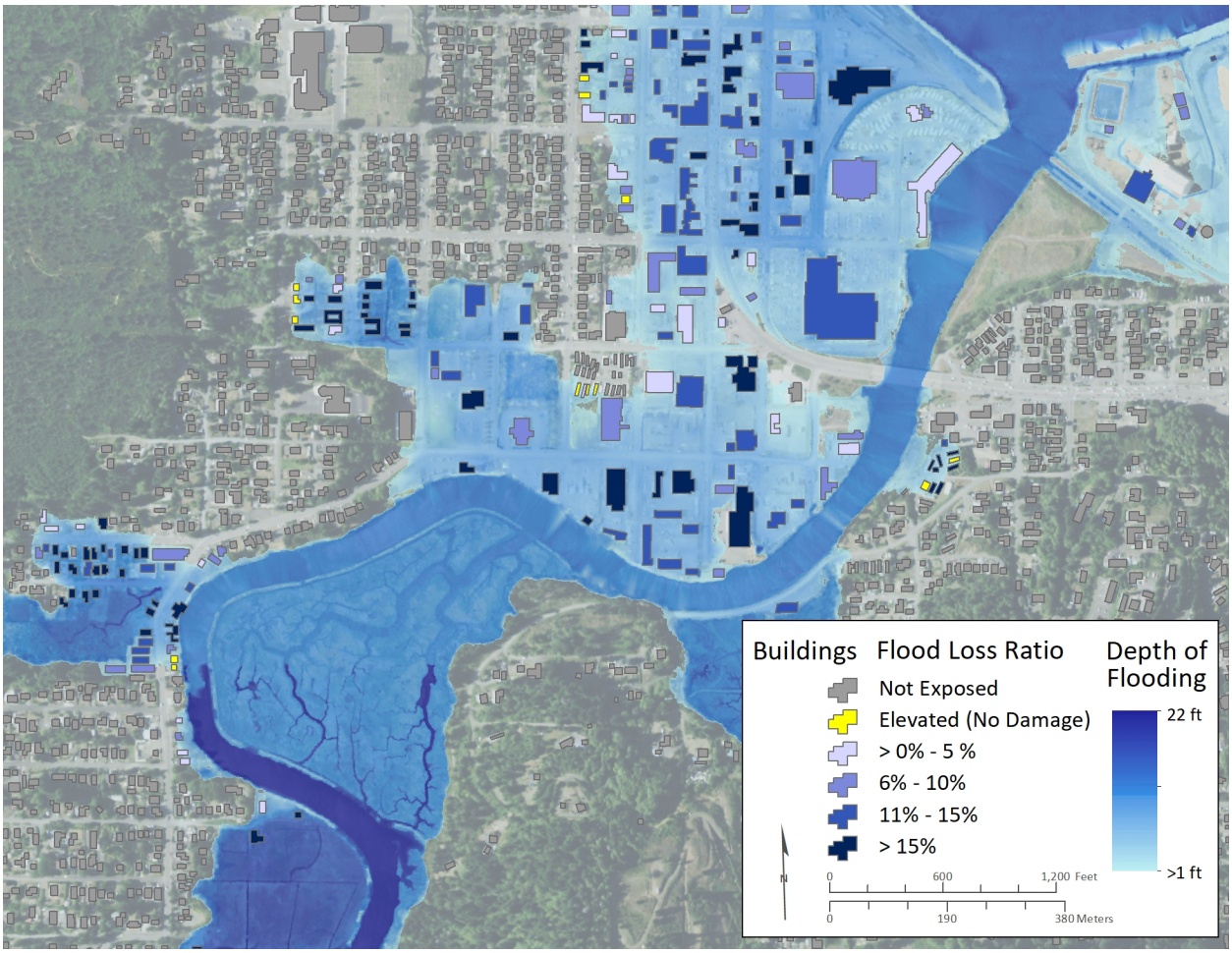
"Hazus provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis. Hazus can be used to conduct loss estimation for floods and earthquakes […]. The multi-hazard Hazus is intended for use by local, state, and regional officials 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" (FEMA, 2012a, p. 1-1).

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 DOGAMI then aggregates to the community level to report loss ratios. Cost used in general building stock mode is 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 square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus-MH database.

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

DOGAMI used Hazus-MH version 3.0 (FEMA, 2015), 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 Coos Bay.



2.2 Exposure

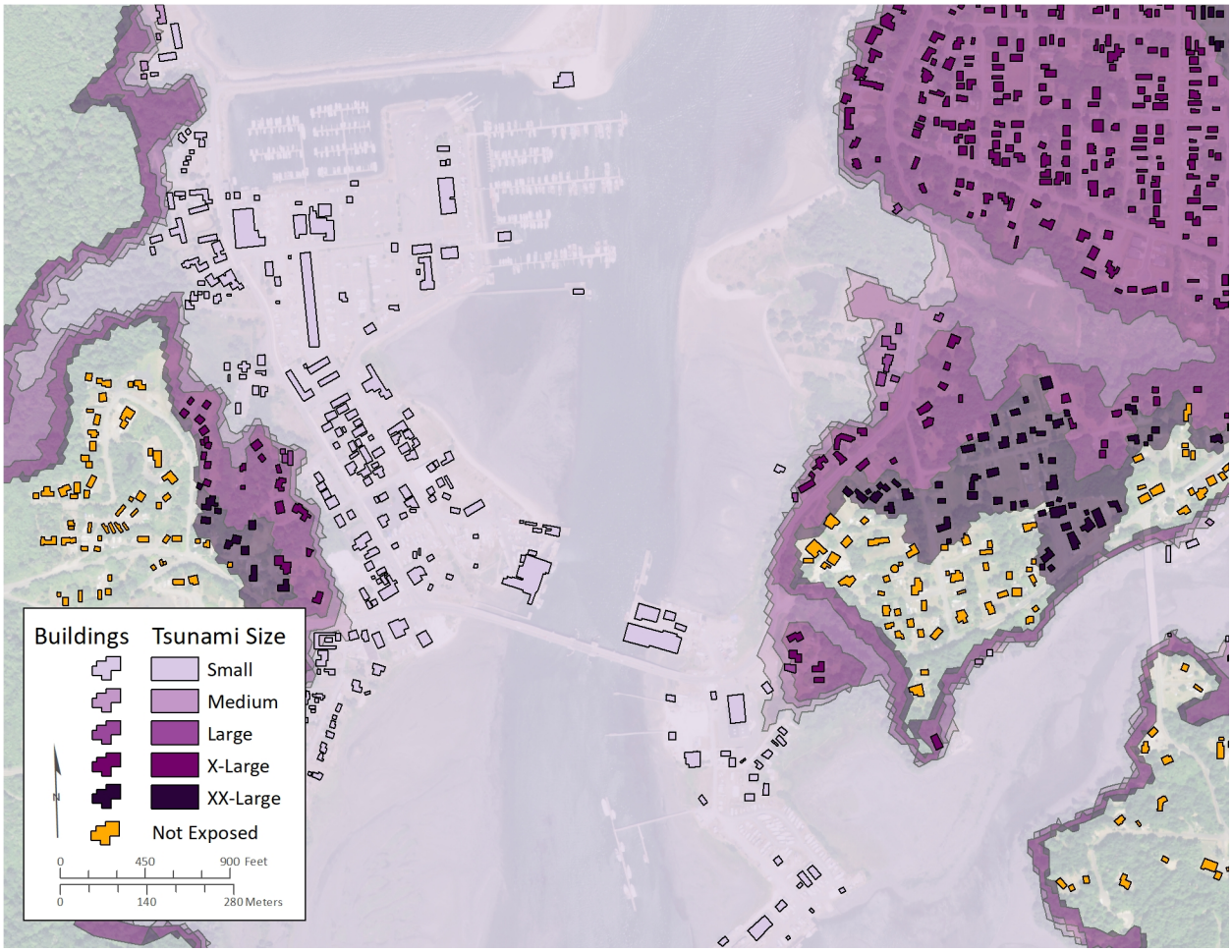
Exposure methodology is calculating the buildings and population that are within a natural hazard zone. This is an alternative for natural hazards that do not have readily available damage functions and, therefore, loss estimation is not possible. It provides a way to easily quantify what is and what is not threatened. Exposure results are communicated in terms of total building value exposed, rather than loss estimate because the loss ratio is unknown. For example, **Figure 2-2** shows buildings that are exposed to different tsunami scenarios.

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.

Exposure is used for tsunami, landslide, and wildfire to quantify buildings and residents at risk. For comparison with loss estimates, exposure is also used for the 1% annual chance flood.

Figure 2-2. Tsunami inundation scenarios and building exposure example in the community of Charleston.



Note that larger scenarios include the buildings of the smaller scenarios.

2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 500 square feet (152 square meters), as determined from existing building footprints or tax assessor data. **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Coos County. See also **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, 2012b, c) 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 **C.2.2**.

Figure 2-3. Building occupancy types, portion of City of Bandon.

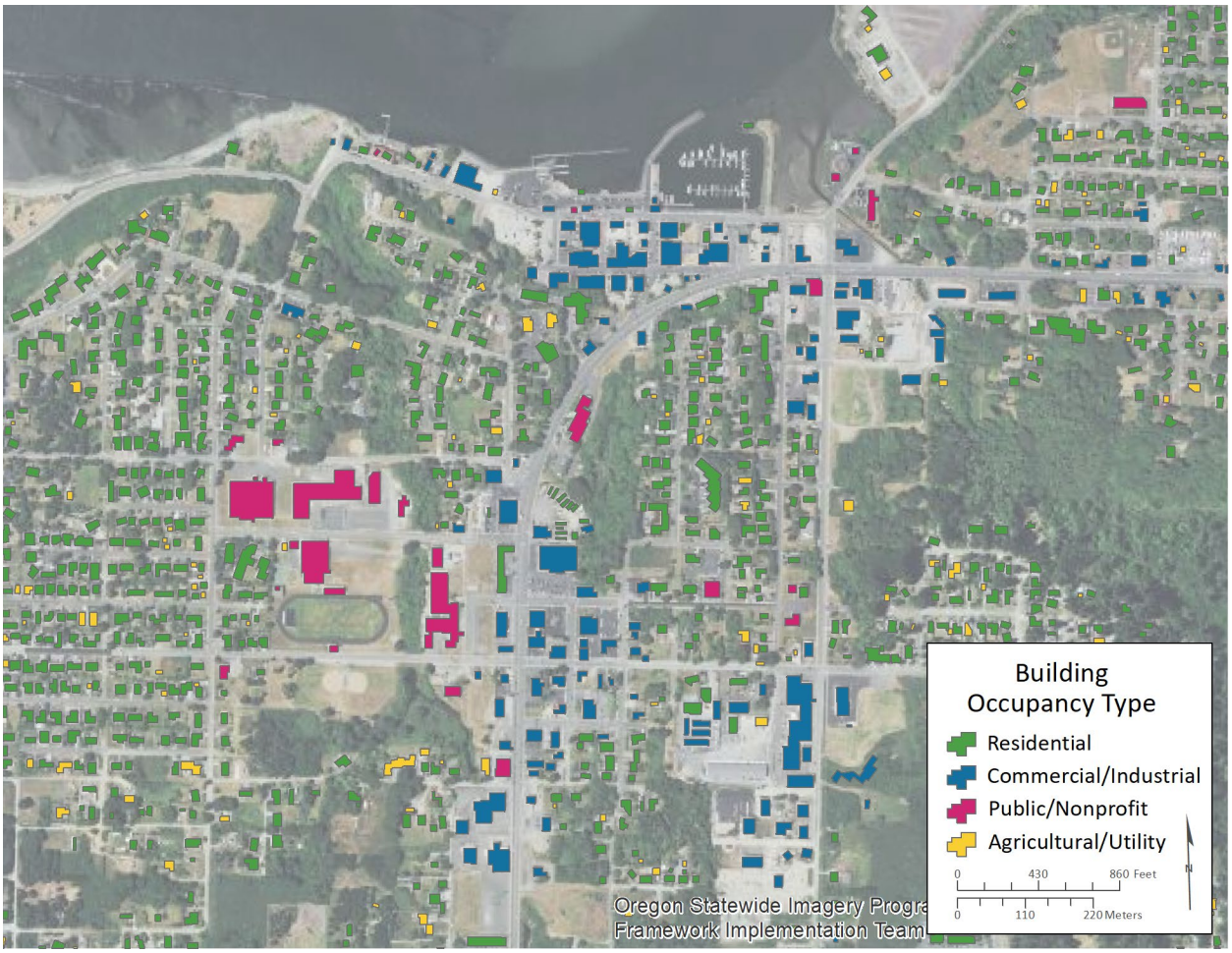


Table 2-1 shows the distribution of building count and value within the UDF database for Coos County. A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

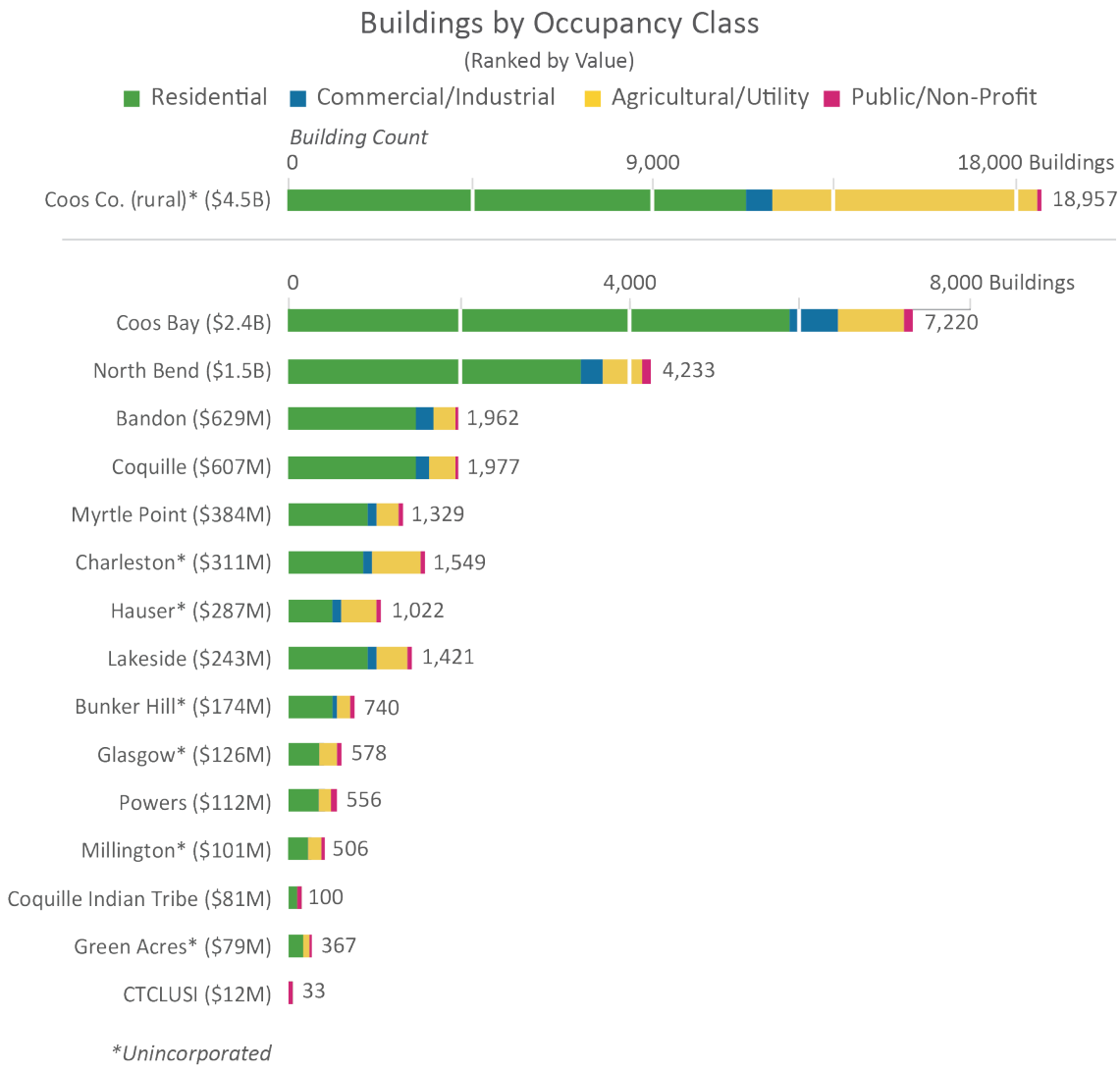
Table 2-1. Coos County building inventory.

Community	Total Number of Buildings	Percentage of Buildings of Coos County	Total Estimated Building Value ($)	Percentage of Building Value of Coos County
Unincorp. County (rural)	18,957	45%	4,476,885,000	39%
Bunker Hill	740	1.7%	173,872,000	1.5%
Charleston	1,549	3.6%	310,927,000	2.7%
Glasgow	578	1.4%	125,629,000	1.1%
Green Acres	367	0.9%	79,090,000	0.7%
Hauser	1,022	2.4%	286,877,000	2.5%
Millington	506	1.2%	100,571,000	0.9%
Total Unincorp. County	23,719	56%	5,553,851,000	48%
Bandon	1,962	4.6%	629,445,000	5.5%
CTCLUSI	33	0.1%	12,470,000	0.1%
Coos Bay	7,220	17%	2,420,579,000	21%
Coquille	1,977	4.6%	606,670,000	5.3%
Coquille Indian Tribe	100	0.2%	80,721,000	0.7%
Lakeside	1,421	3.3%	242,768,000	2.1%
Myrtle Point	1,329	3.1%	383,743,000	3.3%
North Bend	4,233	9.9%	1,494,790,000	13%
Powers	556	1.3%	111,516,000	1.0%
Total Coos County	42,550	100%	11,536,553,000	100%

The building inventory was developed from several data sources and was refined for use in loss estimation and exposure analyses. A database of building footprints for a significant portion of Coos County was already available from a previous DOGAMI project (Priest and others, 2013). Building footprints in the database were digitized from high-resolution lidar collected in 2009 (South Coast project, Oregon Lidar Consortium; see http://www.oregongeology.org/lidar/collectinglidar.htm). The building footprints provide a spatial location and 2D representation of a structure. The total number of buildings within the study area was 42,550.

Coos County supplied assessor data that 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 variation of building value and occupancy across the communities of Coos County.

Figure 2-4. Community building value in Coos County by occupancy class.



Note that "Coos Co. (rural)" excludes incorporated communities, tribal lands, Bunker Hill, Charleston, Glasgow, Green Acres, Hauser, and Millington.

We attributed critical facilities in the UDF database so that 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 attributed include hospitals, schools, fire stations, police stations, emergency operations, and military facilities. In addition to these standard building types, we considered other building types based on local input or special considerations that are specific to the study area that would be essential during a natural hazard event, such as public works and water treatment facilities. Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. 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. **Table 2-2** shows the critical facilities on a community basis. Critical facilities are listed for each community (see **Community Risk Profiles**).

Table 2-2. Coos 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)	0	0	0	0	14	17,574	0	0	0	0	7	49,986	21	67,560
Bunker Hill	0	0	1	9,335	0	0	0	0	0	0	0	0	1	9,335
Charleston	0	0	0	0	1	783	0	0	1	3,551	0	0	2	4,333
Glasgow	0	0	0	0	1	1,754	0	0	0	0	0	0	1	1,754
Green Acres	0	0	0	0	1	815	0	0	0	0	0	0	1	815
Hauser	0	0	1	17,261	1	1,886	0	0	0	0	0	0	2	19,147
Millington	0	0	0	0	1	1,099	0	0	0	0	0	0	1	1,099
Total Unincorp. County	0	0	2	26,596	19	23,911	0	0	1	3,551	7	49,986	29	104,043
Bandon	1	7,414	3	38,553	2	3,813	0	0	0	0	2	1,024	8	50,804
CTCLUSI	0	0	0	0	0	0	0	0	0	0	1	3,164	1	3,164
Coos Bay	1	32,309	8	104,239	5	16,535	0	0	2	4,846	6	23,977	22	181,906
Coquille	1	7,858	3	44,644	2	3,300	1	2,647	0	0	1	6,424	8	64,872
Coquille Indian Tribe	0	0	0	0	0	0	0	0	0	0	1	3,315	1	3,315
Lakeside	0	0	0	0	1	1,628	0	0	0	0	2	2,476	3	4,103
Myrtle Point	0	0	2	29,743	1	1,882	0	0	0	0	3	3,650	6	35,275
North Bend	0	0	4	75,399	5	9,657	0	0	1	8,782	2	28,906	12	122,745
Powers	0	0	2	9,355	2	1,782	0	0	0	0	0	0	4	11,136
Total Coos County	3	47,581	24	328,529	37	62,508	1	2,647	4	17,179	25	122,922	94	581,363

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

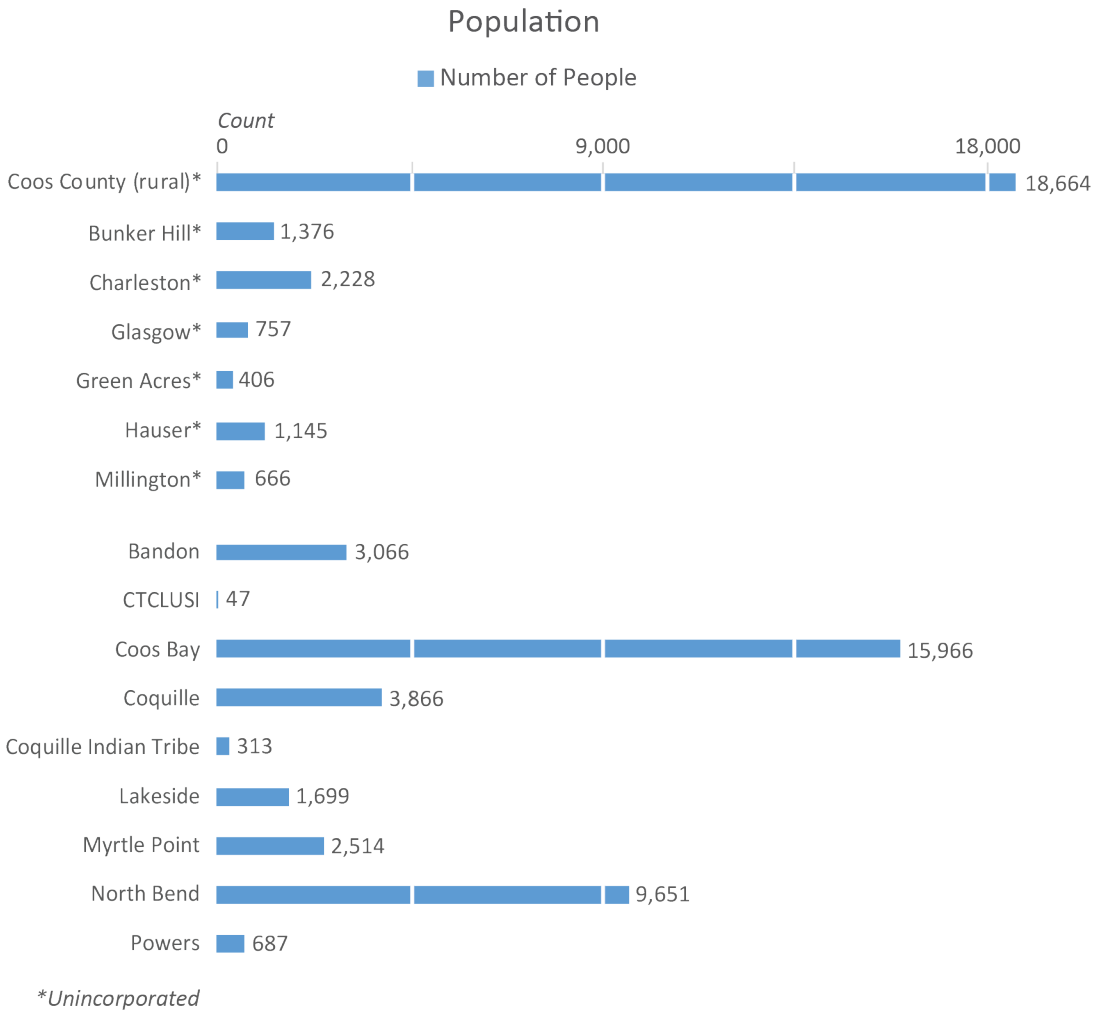
*Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g. water treatment facilities or airports).

2.4 Population

Within the UDF database, the population of permanent residents reported per census block was distributed among residential buildings and pro-rated based on square footage (**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 assessor and census databases, the distribution includes vacation homes, which in many coastal communities make up some of the total residential building stock. From information reported in the 2010 U.S. Census, American FactFinder regarding vacation rentals within the county and coastal communities, it is estimated that approximately 4% of residential buildings are vacation rentals in Coos County (U. S. Census Bureau, 2010b).

From the census data, DOGAMI analyzed the 63,043 residents within the study area who could be affected by a natural hazard scenario. For each natural hazard, with the exception of the CSZ Mw 9.0 earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the CSZ Mw 9.0 earthquake scenario the potentially displaced residents were based on a combination of residents exposed to tsunami and those in buildings estimated to be significantly damaged by the earthquake.

Figure 2-5. Population by Coos County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers five natural hazards (earthquake, tsunami, flood, landslide, and wildfire) that pose a risk to Coos County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. 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 disasters. Communities can use the results to update plans as part of the work toward becoming more resilient to future disasters.

3.1 Hazards and Countywide Results

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

3.2 Cascadia Subduction Zone Earthquake

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

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.

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. Earthquakes as large as Mw 8-9 occur along the CSZ on average every 230-540 years (Goldfinger and others, 2012, 2017).

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

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.

3.2.1 Data sources

Most of the hazard data inputs for our Hazus-MH earthquake analysis were originally created for the 2012 Oregon Resilience Plan (ORP) for Cascadia Subduction Zone Earthquakes (Madin and Burns, 2013). In conducting their vulnerability assessment, the ORP seismic workgroup chose an earthquake scenario of Mw 9.0 off the coast of Oregon along the subduction zone.

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

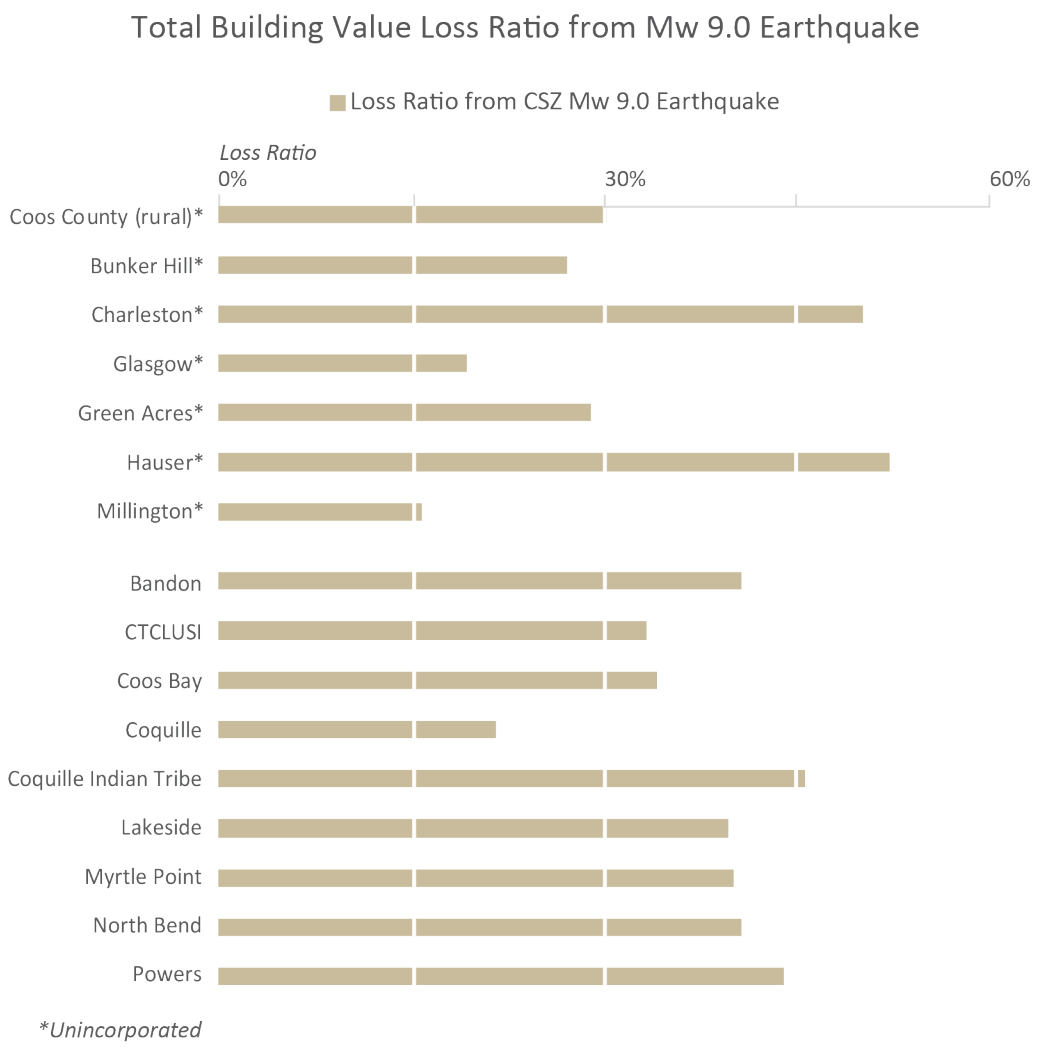
The following hazard layers used for our loss estimation are derived from work conducted by Madin and Burns (2013): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). 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 equates 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 Arthur Frankel of the USGS (personal communication, 2012) and then modified to include site class soil factors (Madin and Burns, 2013). 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. Irrespective of these differences, the two scenarios represent similar levels of severity and was a determining factor for their use in this report.

3.2.2 Countywide results

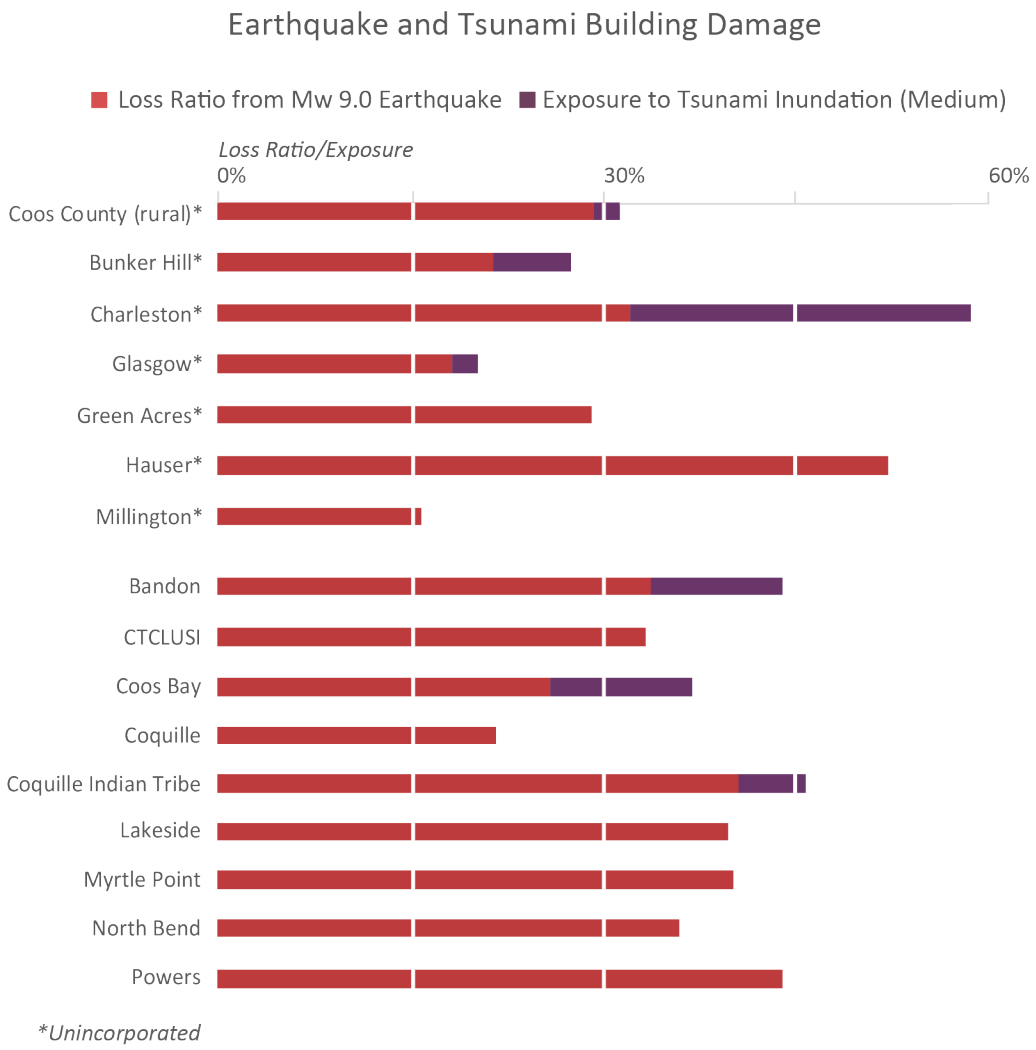
The CSZ event will produce severe ground shaking and ground failure, as well as a large and swift moving tsunami (Madin and Burns, 2013). Due to the nearly simultaneous timing of these two natural hazards, we have parsed loss estimate results to avoid double counting. That is, buildings within the (Medium-sized) 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. Based on recent tsunami events in Japan, Sumatra, and Chile, we assumed that tsunami losses to buildings are complete within the 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 Coos County from a CSZ Mw 9.0 event without the effects from tsunami.

Figure 3-1. Earthquake loss ratio by Coos County community.



Because an earthquake can affect a wide area, it is unlike other hazards in this report—every building in Coos County, to some degree, will be shaken by a CSZ Mw 9.0 earthquake (see Appendix E, **Plate 3**). Hazus-MH loss estimates (see **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). Loss estimates reported for earthquake are for buildings *outside* the (Medium-sized) tsunami inundation zone. **Figure 3-2** shows loss ratios from the CSZ event (both tsunami and earthquake) for the communities of Coos County.

Figure 3-2. CSZ Mw 9.0 event loss ratio in Coos 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 tsunami 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.

In keeping with earthquake damage reporting conventions, we used the 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 in each community is based on an aggregation of probabilities and does not represent individual buildings (FEMA, 2012b).

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

number reported for nonfunctioning critical facilities is only for buildings outside the (Medium-sized) tsunami inundation zone.

The number of potentially displaced residents from the CSZ Mw 9.0 earthquake is based on the number of red-tagged and 90% of yellow-tagged residences that were determined in the Hazus-MH earthquake analysis results (FEMA, 2012b). The number reported for potentially displaced residents is only for residences outside the (Medium-sized) tsunami inundation zone. Displaced residents due to a tsunami are discussed in the CSZ tsunami hazard section.

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

- Number of red-tagged buildings: 9,689
- Number of yellow-tagged buildings: 3,659
- Loss estimate: $3,516,968,000
- Loss ratio: 30%
- Nonfunctioning critical facilities: 70
- Potentially displaced population: 11,999

The results indicate that Coos County would incur significant losses (30%) due to a CSZ Mw 9.0 earthquake. These results are strongly influenced by the overall average age of the building stock, which is an important factor in earthquake vulnerability. The first seismic building codes were implemented in Oregon in the 1970s (Judson, 2012). By the 1990's modern seismic building codes were being enforced; more than 80% of Coos County's buildings were built before this time. Communities within Coos County that are composed of older buildings are expected to experience more damage from earthquake than newer ones.

Moderate to high susceptibility liquefaction zones exist throughout the county and in the densest populated areas, which increases the risk from earthquake. Liquefaction could also present difficulties for evacuation from the subsequent tsunami, since liquefaction areas correspond closely with the most likely tsunami inundation zone (Priest and others, 2015). This factor, as well as the overall age of the building stock, along with the proximity of Coos County to the CSZ, results in high levels of damage.

While damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a significant amount of the estimated damage from the earthquake hazard in Coos County. Landslide exposure results show that 14% of buildings in Coos County are within a very high or high susceptibility zone. This indicates that a similar percentage of the loss estimate calculated in this study may be due to coseismic landslide rather than earthquake shaking alone.

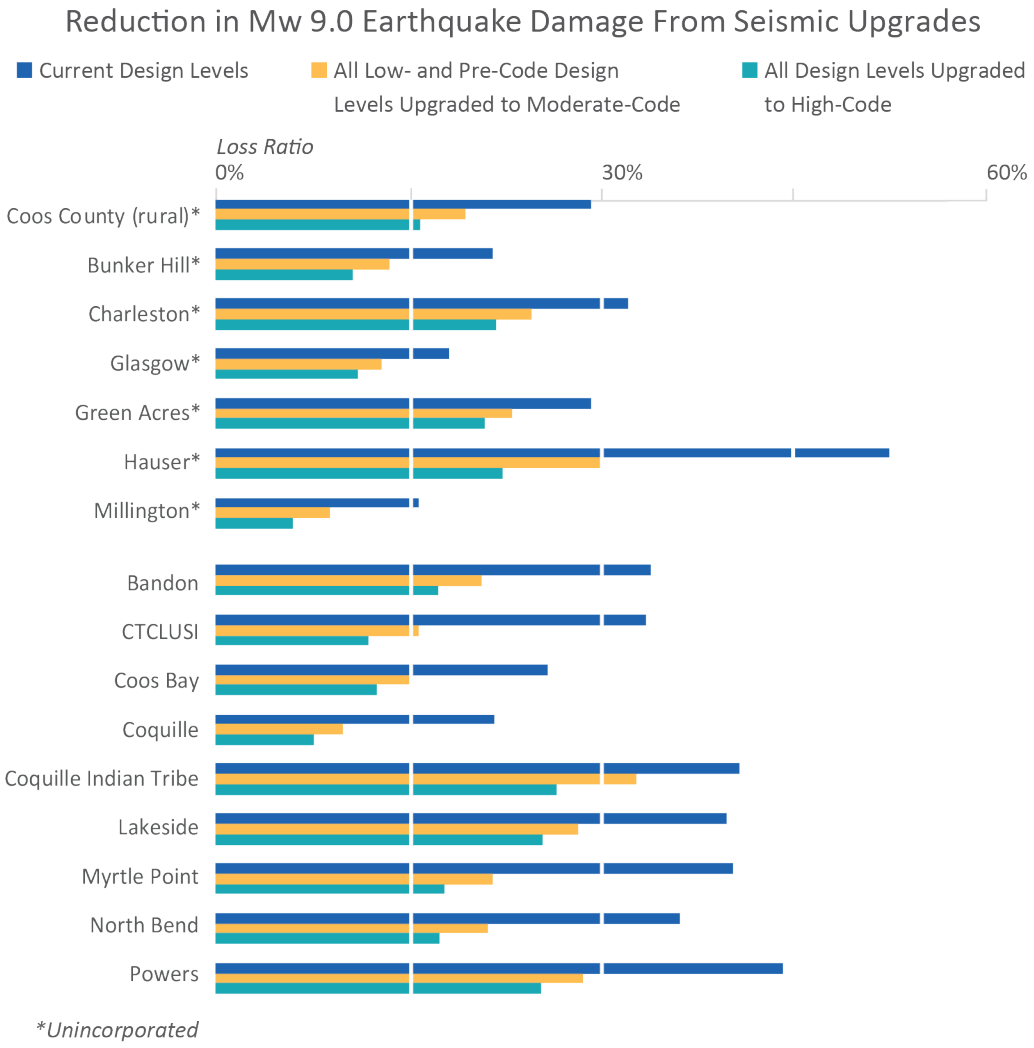
If buildings could be seismically retrofitted to moderate or high code standards, the impact of this event would be greatly reduced. In a simulation by DOGAMI, Hazus-MH earthquake analysis shows that loss ratios drop from 30% to 19%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, for areas of high landslide or liquefaction, additional geotechnical mitigation may be necessary to have an effect on losses. **Figure 3-3** illustrates the reduction in loss estimates from a CSZ Mw 9.0 earthquake through two simulations where all buildings are upgraded to at least moderate code standards and then all buildings to high code standards.

Key Terms:

- *Seismic retrofit:* Structural modification to a building that improves its resilience to earthquake.
- *Design level:* Hazus-MH terminology referring to the quality of a building's seismic building code (i. e. pre, low, moderate, and high). Refer to Error! Reference source not found. for

Communities that are mostly within the tsunami hazard zone may need additional tsunami mitigation to reduce vulnerability.

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



Note: Loss ratios 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.

3.2.3 Areas of vulnerability or risk

We identified locations within the study area that are comparatively more vulnerable or at greater risk to CSZ Mw 9.0 earthquake hazard:

- Very high liquefaction soils are found throughout most of the populated estuarine portions of Coos County, which include the communities of Bandon, Bunker Hill, Charleston, Coos Bay, Millington, and North Bend.
- Building inventory for the cities of Coquille and Myrtle Point are relatively older than other communities in Coos County, which implies lower seismic building design codes and are more

vulnerable to damage during an earthquake. Myrtle Point's estimated loss ratio from a CSZ earthquake alone is 40%. Building code upgrade simulations show that Myrtle Point would benefit the most from seismic retrofits, loss estimates go from 40% to 22% when pre- and low-code buildings are upgraded to moderate code.

- Because of the liquefaction and landslides, communities will likely be "islands" disconnected from other communities by severed transportation routes. With losses up to 52%, it is very important for a community to be able to respond to emergencies with its own resources.
- Nearly all of the critical facilities (87%) in the communities of Coos County could be nonfunctioning due to a CSZ earthquake.

3.3 Cascadia Subduction Zone Tsunami

Tsunamis are a natural hazard threat that exists for many of the communities along the Oregon coast. The tsunami 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 are the most likely to occur from a CSZ event.

3.3.1 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 slip deficit time intervals for each local source tsunami scenario is 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 recurrence rates are from Witter and others (2013) 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 for the Medium scenario only (see **Table B-3** 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 to tsunami hazard. See **Appendix B: Detailed Risk Assessment Tables** for cumulative multi-scenario analysis results.

3.3.2 Countywide results

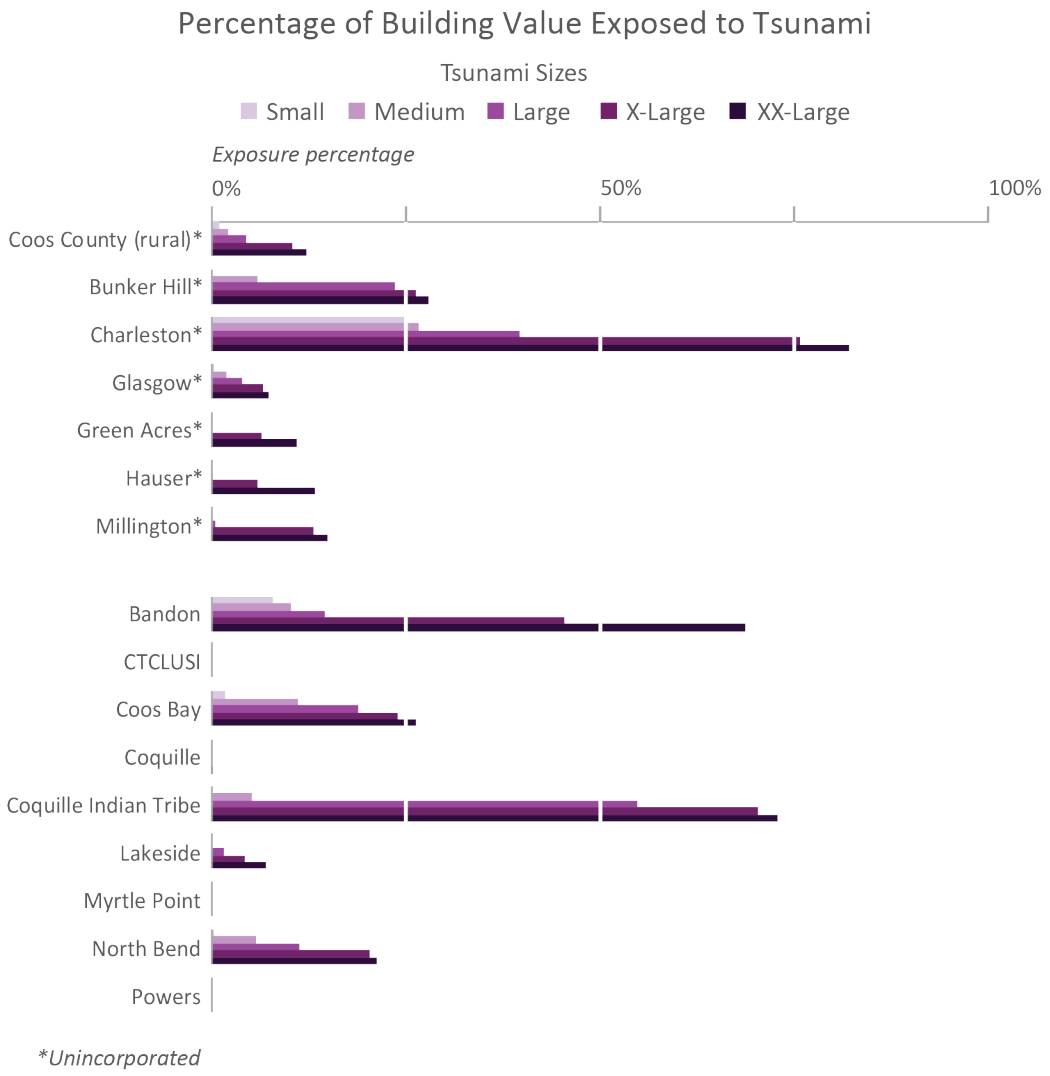
Most of the inhabited areas in Coos County are relatively near the Pacific Ocean and nearly all communities of the study area would be affected by the largest of the DOGAMI calculated tsunami scenarios. However, the Medium-sized tsunami was chosen as the primary scenario to describe the level of risk because that category represents the most likely to occur. Coos County's communities built along the open coast are at a higher risk to tsunami hazard than communities along the Coos River and Coquille River estuaries.

Coos countywide CSZ tsunami exposure (Medium tsunami scenario):

- Number of buildings exposed: 1,286
- Exposure value: $611,536,000
- Percentage of exposure value: 5.3%
- Critical facilities exposed: 13
- Potentially displaced population: 1,274

Many areas of development along Coos Bay and near the mouth of the Coquille River will be inundated by a tsunami. These areas could see exposure to the Medium-sized scenario as high as 25%. More than 1,200 permanent residents could be impacted from a CSZ tsunami event and require medical and shelter services. Because there is high risk of tsunami along the entire coast and estuarine areas of Coos County, awareness is important for the emergency response immediately after the event and for future planning and mitigation efforts in these areas (**Figure 3-4**).

Figure 3-4. Tsunami inundation exposure by Coos County community.



3.3.3 Areas of vulnerability or risk

We identified locations within the study area that are comparatively more vulnerable or at greater risk to CSZ Mw 9.0 tsunami hazard:

- The City of Bandon is expected to be impacted by a tsunami originating from a CSZ event. Exposure percentage is as high as 10% for the Medium tsunami scenario.
- Developments all along Coos Bay are exposed to tsunami hazard, with Charleston being the most exposed to this hazard.
- The developed area around the Highway 101 bridge near Lakeside is expected to be inundated by a tsunami.

3.4 Flooding

In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Floods are a frequently occurring natural hazard in Coos County, and have the potential to create public health hazards, 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 looked at in this report.

A typical method for determining flood risk is to identify the probability of flooding and the impacts 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, a greater understanding of flood hazard, and longer periods of record for the stream or water body in question.

The major rivers within the county are the Coos, Coquille, East Fork Coquille, Middle Fork Coquille, North Fork Coquille, South Fork Coos, and South Fork Coquille rivers. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain. In addition to riverine flooding, there are lakes within the coastal margin that are subject to flooding, including North Tenmile Lake, Saunders Lake, and Tenmile Lake. Other flooding effects for low-lying coastal developments are due to coastal flooding from the Pacific Ocean and the Coos River and Coquille River estuaries.

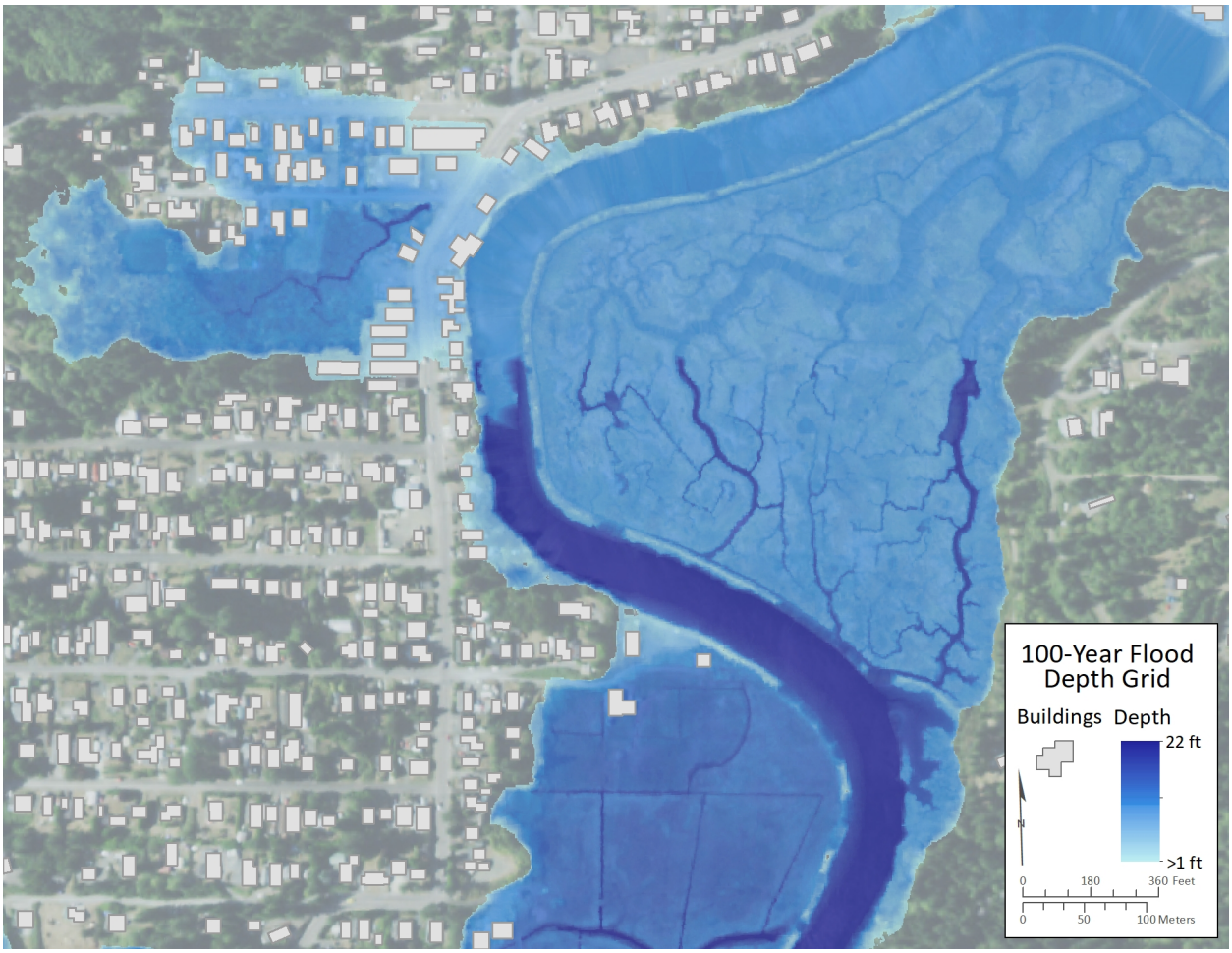
The impacts of flooding are determined by adverse effects to human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are to elevate structures above the expected level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

3.4.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs) for Coos County were updated in 2012 (FEMA, 2014) and included a recently completed study of coastal flooding (Allan and others, 2012); these were the primary data sources for the flood risk assessment in this report. These studies were adopted as effective flood maps for the communities of Coos County in 2014. Further information regarding the National Flood Insurance Program (NFIP) can be found on the FEMA website: https://www.fema.gov/flood-insurance. These were the only flood data sources that DOGAMI used in the analysis, but flooding does occur in areas outside of the detailed mapped areas.

Depth grids, developed by DOGAMI in 2018 and based on the effective map data, were used in this risk assessment to determine the level to which buildings are impacted by flooding. Depth grids are raster GIS datasets where each digital pixel value represents the depth of flooding at that location within the flood zone **(Figure 3-5)**. Though considered draft at the time of this analysis, the depth grid data are the best available flood hazard data. Depth grids for four flooding scenarios (10-, 50-, 100-, and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis. The 100-year depth grid included coastal flood modeling that was not available for the other scenarios.

Figure 3-5. Flood depth grid example, portion of the City of Coos Bay.



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

For Coos 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 properly 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, please see the **Exposure analysis** section below.

3.4.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for each of the 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 5**). 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 (FEMA, 2013). See **Table B-4** for multi-scenario cumulative results.

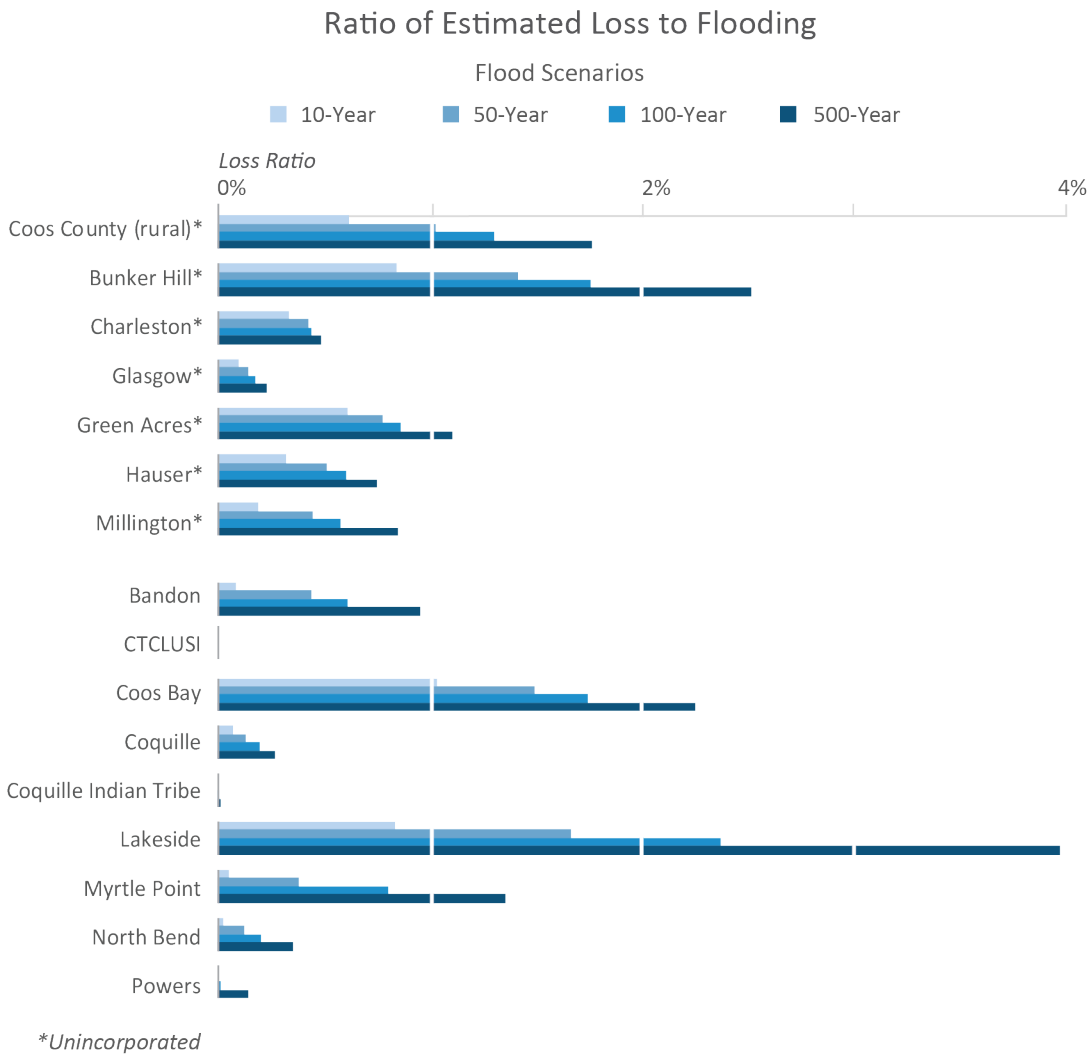
Coos countywide 100-year flood losses:

- Number of buildings damaged: 1,870
- Loss estimate: $125,349,000
- Loss ratio: 1.1%
- Damaged critical facilities: 13
- Potentially displaced population: 2,116

3.4.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is approximately $125 million. Flooding in riverine and estuarine areas has the potential to significantly impact communities in Coos County. Most of the built environment along Coos Bay is potentially at risk to flooding hazard. A large concentration of buildings at risk to flooding is in the downtown portion of the City of Coos Bay. Flooding from coastal sources is limited to a few areas, like the low-laying coastal area south of Bandon (**Figure 3-6**). 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.

Figure 3-6. Ratio of flood loss estimates by Coos County community.



Note: In addition to the four riverine flood scenarios, coastal flooding information is available for the 100-year flood scenario for areas near of the mouth of the Coos and Coquille rivers.

3.4.4 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 non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. We counted 2,055 of Coos County's buildings to be within designated flood zones, which was about 5% of the county's buildings. Of these buildings, 185 buildings were elevated above the height of the 100-year flood. Elevating more of these exposed structures would further reduce the potential damages sustained from flooding. This evaluation also estimates that 2,116 residents might have mobility or access issues due to surrounding water. See appendix **Table B-5** for community-based results of flood exposure.

3.4.5 Areas of vulnerability or risk

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

- A large portion of the downtown area of the City of Coos Bay is prone to flooding. A large estimated loss ($42 million) could result from 100-year flooding in the City of Coos Bay.
- 100-year flooding from Tenmile Creek and Tenmile Lake would damage many buildings in the City of Lakeside. This community has the highest loss ratios from flooding of any community in the study area.
- The commercial area by the marina in the City of Bandon is at risk to flooding.
- Several buildings in the communities of Coquille and Myrtle Point along the Coquille River are at risk to flooding.

3.5 Landslide Susceptibility

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

3.5.1 Data sources

The Statewide Landslide Information Layer for Oregon [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. Modern methodology and lidar-based elevation data were used to map areas in the developed western half of the county in 2011. The eastern and mostly uninhabited part of the county was mapped in the 1970s.

Burns and others (2016) used SLIDO inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016). Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) 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 **Table B-6**). The total dollar value of exposed buildings was calculated for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides were not examined for this report, in addition to potentially hazardous unmapped areas that may pose real risk to communities.

3.5.2 Countywide results

Many Coos County communities have some exposure to landslide hazard. Communities that developed in terrain with moderate to steep slopes or at the base of steep hillsides may be at risk to landslides. The Coast Range and Klamath Mountains run through eastern and central Coos County, so much of the area is steep and landslide prone. The combination of rugged terrain, historically active landslides, large amounts of rainfall, and frequent large earthquakes make landslides a serious threat.

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 6**). It was useful to combine

exposure for both susceptibility zones to best communicate the level of landslide risk to communities. The high and very high susceptibility zones represent areas most prone to landslides and with the highest impact to the community.

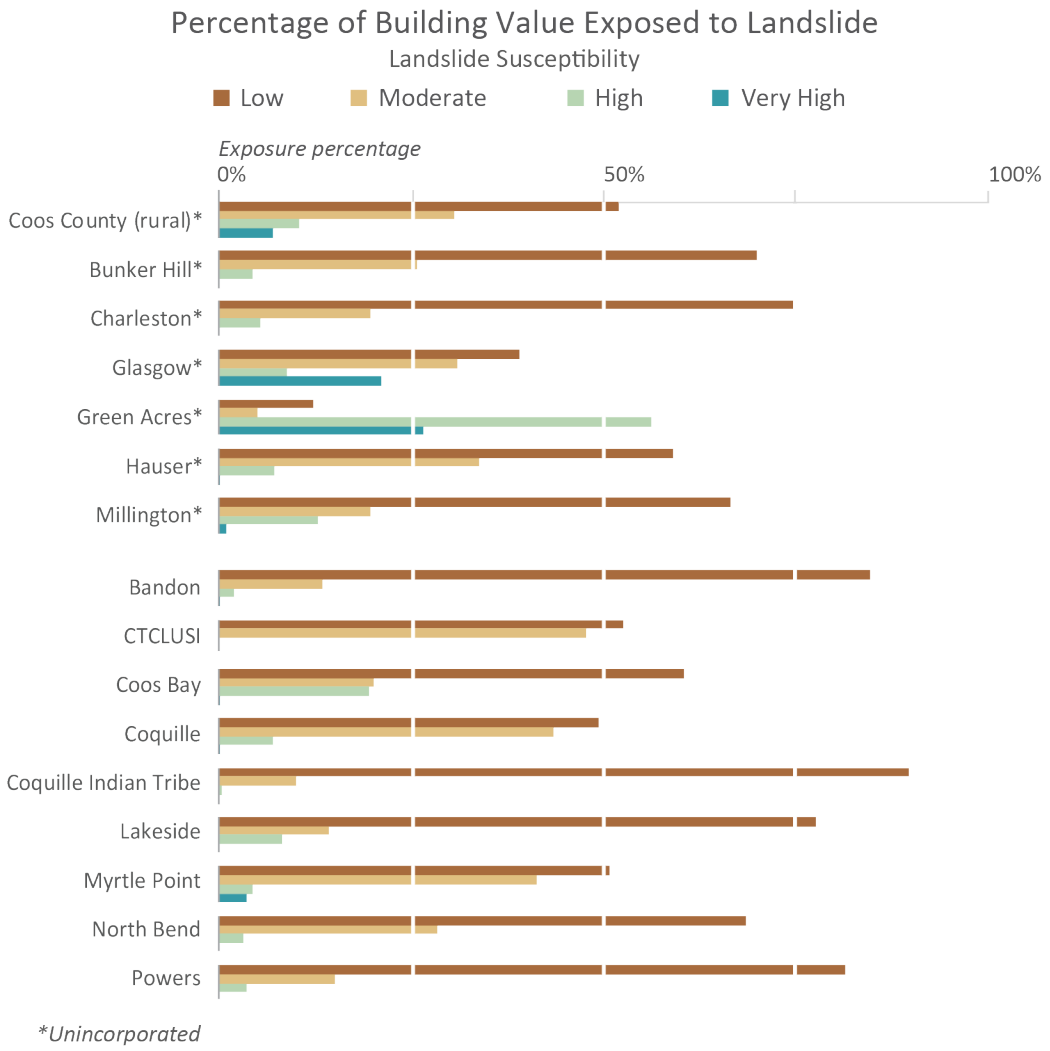
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-7**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

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

- Number of buildings: 7,123
- Exposure value: $1,583,583,000
- Percentage of exposure value: 14%
- Critical facilities exposed: 16
- Potentially displaced population: 9,550

The majority of buildings in Coos County are located on estuaries and floodplains, which are flatter than the surrounding landscape and are low-susceptibility landslide zones. Still, approximately 14% of the county's buildings have exposure to high or very high susceptibility to landslides. Landslide hazard is ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of the county.

Figure 3-7. Landslide susceptibility exposure by Coos County community.



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 landslide hazard:

- Several inhabited areas in the community of Glasgow are exposed to very high landslide susceptibility.
- The community of Green Acres has a significant amount of exposure (83%) to high and very high landslide susceptibility.
- Exposure to landslide hazard is present for buildings throughout the unincorporated county. Additionally, a large portion of undeveloped land in the unincorporated county is deemed high or very high landslide susceptibility, which can be a factor when determining future developments.

3.6 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property, because communities often grow into the transition areas between developed areas and undeveloped areas, commonly called the wildland-urban interface (WUI) (Sanborn Map Company, Inc., 2013). The most common wildfire conditions include: hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development (Sanborn Map Company, Inc., 2013). Post-wildfire geologic hazards can also present risk. These usually include flooding, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

There is potential for losses due to WUI fires in Coos County. Forests cover most of the undeveloped land in Coos County. According to the Coos County Community Wildfire Protection Plan, forests play an important role in the local economy but also surround homes and businesses (OPDR, 2011). In an effort to limit exposure to wildfire, The Coos County Comprehensive Plan provides guidance on reducing risk to wildfire (CCDP, 1985). Contact the Coos County Department of Planning for specific requirements related to the county's comprehensive plan.

3.6.1 Data sources

The West Wide Wildfire Risk Assessment (WWA; Sanborn Map Company, Inc., 2013) is a comprehensive report that includes a database developed over the course of several years for 17 Western states and some Pacific Islands. The steward of this database in Oregon is the Oregon Department of Forestry (ODF). The database was created to assess the level of risk residents and structures have to wildfire. For this project, the Fire Risk Index (FRI) dataset, a dataset included in the WWA database, was used to measure the level of risk to communities in Coos County.

Using guidance from ODF, we categorized the FRI into low, moderate, and high hazard zones for the wildfire exposure analysis. The FRI hazard zones are based on a combination of the impacts of wildfire (Fire Effects Index) and the probability of wildfire (Fire Threat Index). Both indices are the result of an integration of several input datasets. Broadly, the Fire Effects Index is based on potentially impacted assets and the difficulty of suppression. The components that make up the Fire Threat Index are fire occurrence, fire behavior, and fire suppression effectiveness (Sanborn Map Company, Inc., 2013).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. In certain areas no wildfire data are present which indicates areas that have minimal risk to wildfire hazard (see **Table B-7**). The total dollar value of exposed buildings in the study area is reported below. We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.6.2 Countywide results

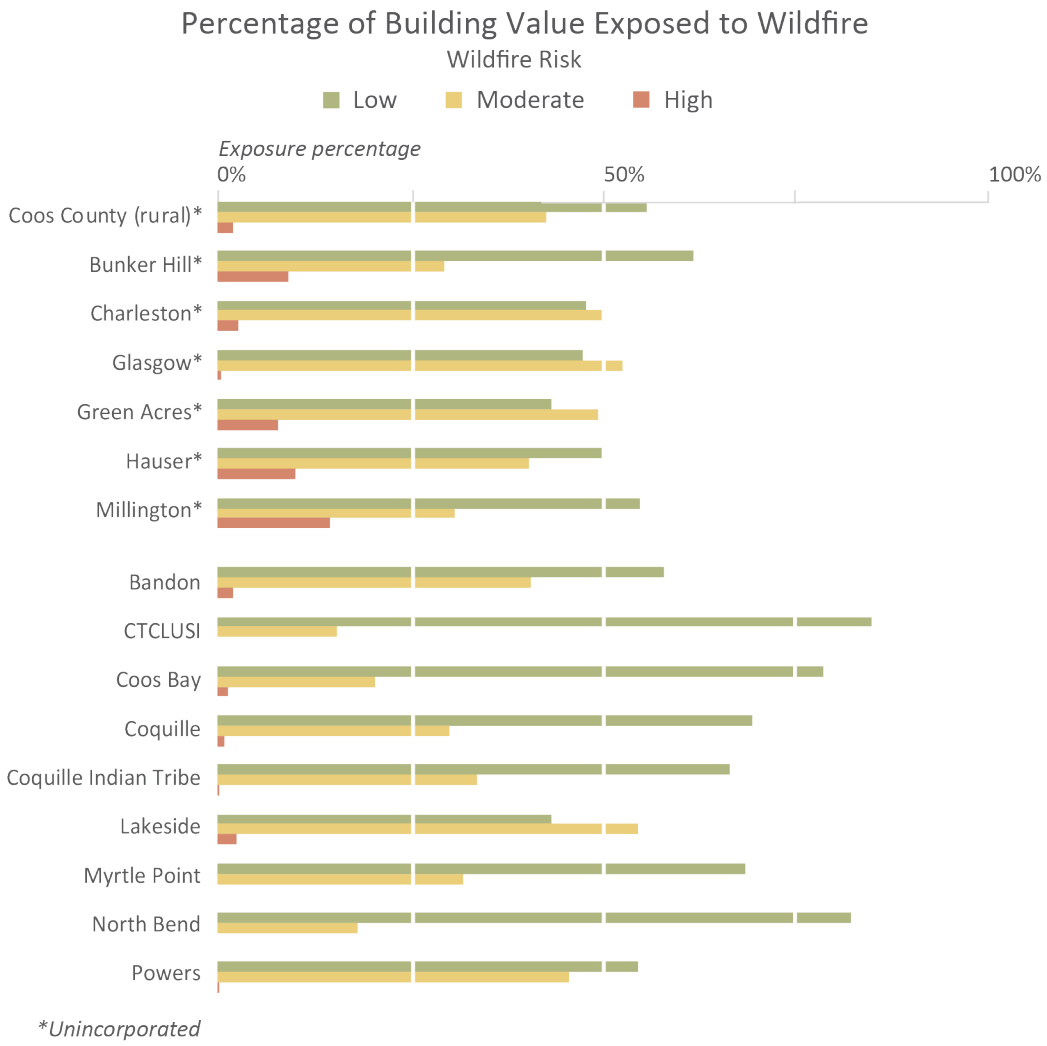
The high hazard category was chosen as the primary scenario for this report because that category represents areas that have the highest potential for losses. However, a large amount of loss would occur if the moderate hazard areas were to burn, as almost every community has ~30–50% of exposure to moderate wildfire hazard. Still, the focus of this section is on high hazard areas within Coos County to emphasize the areas where lives and property are most at risk.

Coos countywide wildfire exposure (high hazard):

- Number of buildings: 1,050
- Exposure value: $216,525,000
- Percentage of exposure value: 1.9%
- Critical facilities exposed: 1
- Potentially displaced population: 1,375

For this risk assessment, building locations were compared to the geographic extent of the wildfire hazard categories. We found that some of the communities in Coos County are exposed to wildfire hazard. The primary areas of exposure to this hazard are in the estuarine areas of the South Slough of the Coos River and some of the dunal areas in the north part of the county (see Appendix E, **Plate 7**). The communities of Bunker Hill, Hauser, Millington, and, to a certain degree, Green Acres are at a higher risk to wildfire than other communities in the county. **Figure 3-8** illustrates the level of risk from wildfire for the different communities of Coos County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-8. Wildfire hazard exposure by Coos County community.



3.6.3 Areas of vulnerability or risk

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

- Wildfire risk is high for hundreds of homes in the low-laying forested areas of the floodplains south of the City of Coos Bay. This area includes Unincorporated Coos County (rural), Bunker Hill, Green Acres, and Millington.
- Many residential buildings in the dunal areas within the community of Hauser are exposed to high wildfire hazard.

4.0 CONCLUSIONS

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

- **Extensive overall damage and losses are expected from a Cascadia Mw 9.0 earthquake and tsunami** - Due to its proximity to the CSZ, every community in Coos County will experience significant impact and disruption from a CSZ Mw 9.0 earthquake event. We limited our analysis to the impacts of an Mw 9.0 earthquake (including liquefaction and coseismic landslides) and an accompanying tsunami. Results show that a CSZ Mw 9.0 event will cause approximately 35% to 50% in building value losses for most communities. The unincorporated community of Charleston can expect a very high percentage of losses (27%) due to tsunami hazard. Other communities like Lakeside, Myrtle Point, North Bend, Powers, and Hauser have little to no tsunami exposure, but still will have high losses from the earthquake alone. The high loss levels estimated in the study area are due to the highly vulnerable building inventory (primarily because of the age of construction), the proximity to the CSZ event, and the amount of development within tsunami zones.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake -** Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We examined potential loss reduction from seismic retrofits (modifications that improve building's seismic resilience) in simulations by using Hazus-MH building code "design level" attributes of pre, low, moderate, and high codes (FEMA, 2012b) in CSZ earthquake scenarios. The simulations were accomplished by upgrading every pre (non-existent) and low seismic code building to moderate seismic code levels in one scenario, and then further by upgrading all buildings to high (current) code in another scenario. We found that retrofitting to at least moderate code was the most cost-effective 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 earthquake building value loss for the entire study area was reduced from 30% to 19%. We found further reduction in estimated loss in our simulation to 16% only by upgrading all buildings to high code. Some communities would see greater loss reduction than the study area as a whole due to older building stock constructed at pre or low code seismic building code standards. Some examples are the cities of Myrtle Point and North Bend, which would see a significant loss reduction (from 40% to 22% and 36% to 21%, respectively) 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 tsunami, landslide, and liquefaction hazards will also be present in some areas, and these hazards require different geotechnical mitigation strategies. Future research focused on tsunami, landslide, and liquefaction hazard specific risk assessments are needed for a clear understanding of the hazard to inform local decisionmakers.
- **Flooding is a threat for some communities in Coos County** – Most of the communities in the study area are estimated to experience less than 1% of total building value loss from the 100-year flood. However, a few communities are estimated to experience higher levels of damage from

flood than other communities in the study area. Unincorporated Coos County (rural), Bunker Hill, Coos Bay, and Lakeside all are estimated to have 2% of building value losses due to 100-year flooding. At first glance, Hazus-MH flood loss estimates may give a false impression of risk because they show fairly low damages for a community relative to other hazards we examined. This is due to the difference between loss estimation and exposure results, as well as the limited area impacted from flooding. An average of 14% loss was calculated for buildings within the 100-year flood zone. Residents and buildings located near the riverine and estuarine portions of the Coos and the Coquille rivers are at a greater risk from flood than other locations within the study area. The highest concentrations of flood damage in the study area are downtown Coos Bay, the commercial area near the marina in the City of Bandon, and in the City of Lakeside near Tenmile Creek and Tenmile Lake.

- **Elevating structures in the flood zone reduces vulnerability -** Flood exposure analysis was used in addition to Hazus-MH loss estimation to identify buildings that were not damaged but that were within the area expected to experience a 100-year flood. By using both analyses in this way, the number of elevated structures within the flood zone could be quantified. This showed possible mitigation needs in flood loss prevention or the effectiveness of past activities. The City of Coos Bay has a high percentage (95%) of flood exposed buildings that are not elevated above the level of flooding, providing an opportunity to greatly reduce the estimated damages from a 100-year flood event. The exposure analysis also estimates the number of people that have limited mobility due to surrounding floodwaters. Many residents in the cities of Coos Bay (773), Lakeside (253), and Myrtle Point (119) may need evacuation assistance during a flood event.
- **New landslide mapping would increase the accuracy of future risk assessments -** Exposure analysis was used to assess the threat from landslides. Landslides are a widespread hazard and are present for some communities within the county. The communities of Glasgow and Green Acres have high levels of exposure to landslides. Landslide hazard is a very significant risk throughout the unincorporated rural parts of Coos County. The landslide hazard data for most of the areas used in this risk assessment were created before modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results.
- **Wildfire risk is high for upstream portions of the Coos River watershed** - Exposure analysis shows that buildings south of Coos Bay are at risk to wildfires, especially around the communities of Bunker Hill and Millington. The western portion of the community of Hauser also has areas of higher risk to wildfires relative to the study area. Moderate wildfire hazard is present throughout the county, especially along transportation corridors. and is a potential threat for most communities. We estimate that most communities in Coos County have approximately 30–50% of exposure to moderate or higher wildfire hazard.
- **Most of the study area's critical facilities are at high risk from a CSZ earthquake and tsunami -** Critical facilities were identified and were specifically examined within this report. We have estimated that 88% (83) of Coos County's 94 critical facilities will be non-functioning after a CSZ event, with 13 of those located with the medium tsunami zone. For comparative purposes, 17% (16) of critical facilities are at risk to landslide, 14% (13) are exposed to flood hazard, and 1% (1) are exposed to wildfire.
- **The biggest causes of displacement to population are earthquake, tsunami, and landslide** - Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that 20% of the population in the county would be displaced due to a

combined earthquake and tsunami. Landslide hazard is a potential threat to 15% of permanent residents, flood hazard puts 3% at risk to displacement, and 2% are exposed to wildfire hazard.

- **The results allow communities the ability to compare across hazards and prioritize their needs -** Each community within the study area was assessed for natural hazard exposure and loss. This allowed 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 those individual communities.

5.0 LIMITATIONS

There are several limitations associated with interpreting the results of this risk assessment.

- **Spatial and temporal variability of natural hazard occurrence** – Flood, landslide, coastal erosion, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones. For example, areas mapped in the 1% annual chance 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, the losses from a single hazard event probably will not be as severe and widespread. Exceptions to this are earthquake ground-shaking and tsunami inundation, which are expected to impact the entire study area, and loss estimates for this hazard are based on a single event.
- **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. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged. We note the tsunami hazard as a possible exception, given the extreme and widespread damage to buildings in recent events in Japan, Sumatra, and Chile.
- **Population variability** – Many coastal communities in Coos County are popular vacation destinations, particularly during the summer. Our estimates of potentially displaced people rely on permanent populations published in the 2010 U.S. Census (U.S. Census Bureau, 2010b). As a result, we are underestimating the number of people that may be at risk to hazards, especially during periods of high temporary population.
- **Data accuracy and completeness** – Some datasets in our risk assessment had incomplete coverage or lacked high-resolution data within the study area. We used lower resolution data to fill gaps where there was incomplete coverage or where high resolution was not available. Assumptions to amend areas of incomplete data coverage were made based on reasonable

methods described within this report. However, we are aware that some uncertainty has been introduced from these data amendments at an individual building scale. At community-wide scales the effects of the uncertainties are slight. We made certain assumptions regarding data layers to fill in data gaps for building footprints, population, some attributes derived from the assessor database, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors. Identifying or repairing these problems was beyond the scope of the project and require additional research.

6.0 RECOMMENDATIONS

The following areas of implementation are needed to better understand hazards and reduce risk to natural hazards 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 in general is a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the amount of time for a community to recover from a disaster—this ability is commonly referred to as "resilience."

This report is intended to provide local officials 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/sub/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 partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

Information presented here are available for local decisionmakers in developing their local plans and help identify geohazards and associated risks to the community. The primary framework for accomplishing this is through the comprehensive planning process. The comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

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

While there are many similarities between this report and an NHMP, the 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 will 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 reevaluate evacuation routes and identify vulnerable populations to target for early warning. At the time of writing, DOGAMI is producing a series of tsunami evacuation maps for recommended pedestrian travel speeds to reach tsunami evacuation zones. The product is called "Beat the Wave" and is available at https://www.oregongeology.org/tsuclearinghouse/beatthewave.htm.

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

6.4 Mitigation Funding Opportunities

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

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

- 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 88% of critical facilities (**Appendix A: Community Risk Profiles**) will be damaged by the CSZ event, 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.
- Improve the mapping of liquefaction and NEHRP datasets within the county.

6.5.2 CSZ Mw 9.0 Tsunami

- Use approved guides on preparing for tsunamis (e.g., Oregon Department of Land Conservation and Development (DLCD) guide on preparing for the CSZ tsunami) https://www.oregon.gov/LCD/OCMP/Pages/Tsunami-Planning.aspx
- Evaluate the community evacuation plan, including consideration for viable vertical evacuation options.

6.5.3 Flood

- Map areas of potential floodwater storage areas.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.
- Map channel migration zones along rivers identified as having moderate or high susceptibility to channel migration (Roberts and Anthony, 2017).

6.5.4 Landslide

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

6.5.5 Wildfire

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

7.0 ACKNOWLEDGMENTS

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9.0 APPENDICES

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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 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.

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A.1 Unincorporated Coos County (Rural)

Table A-1. Unincorporated Coos County hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Unincorporated Coos County		18,664	18,957		21	4,476,885,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	763	4.1%	890	0	58,390,000	1.3%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	3,149	17%	5,862	16	1,310,768,000	29%
Earthquake (within Tsunami Zone)		136	0.7%	196	3	44,178,000	1.0%
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*	365	2.0%	418	3	94,049,000	2.1%
Tsunami	Senate Bill 379 Regulatory Line	230	1.2%	264	3	62,355,000	1.4%
Landslide	High and Very High Susceptibility	3,411	18%	3,749	3	782,675,000	18%
Wildfire	High Hazard	457	2.4%	402	1	86,157,000	1.9%

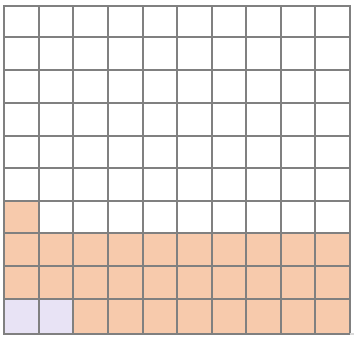
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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 Coos 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 Coos County critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Bandon RFPD	—	X	—	—	—
Bandon State Airport	—	X	—	—	—
Benham Airstrip	—	—	—	—	—
Bridge Rural Fire Department	—	X	—	—	—
Charleston RFPD	—	X	—	—	—
Charleston RFPD - 2	—	X	—	—	—
Coos RFD Station	—	X	—	—	—
Coquille RFD 1	—	X	—	—	—
Coquille RFD 2	—	X	—	X	—
Coquille RFD 3	—	X	—	X	—
Dora-Sitkum RFPD	—	X	—	—	—
Fairview RFPD	—	X	—	—	—
Millington RFD No. 5	—	X	—	—	—
Myrtle Point Fire 1	—	X	—	—	—
Myrtle Point RFPD Gravelford Station 3	—	X	—	—	—
ODOT - Davis Slough Maintenance	—	X	—	—	—
Port of Coos Bay 1	—	X	X	—	—
Port of Coos Bay 2	—	X	X	—	—
Port of Coos Bay 3	—	X	X	X	X
Powers Airstrip	—	X	—	—	—
Sumner RFPD	—	—	—	—	—

A.2 Unincorporated Community of Bunker Hill

Table A-3. Unincorporated community of Bunker Hill hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Bunker Hill		1,376	740		1	173,872,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	22	1.6%	50	0	3,061,000	1.8%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	45	3.3%	146	1	37,528,000	22%
Earthquake (within Tsunami Zone)		0	0.0%	5	0	9,733,000	5.6%
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*	9	0.7%	6	0	10,370,000	6.0%
Tsunami	Senate Bill 379 Regulatory Line	3	0.2%	2	0	508,000	0.3%
Landslide	High and Very High Susceptibility	84	6.1%	42	0	7,681,000	4.4%
Wildfire	High Hazard	185	14%	92	0	15,762,000	9.1%

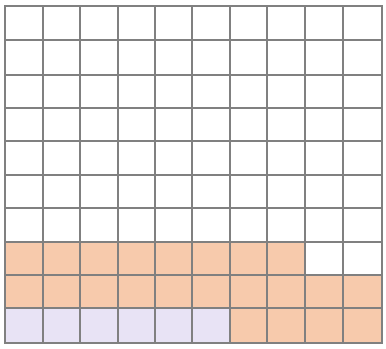
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-2.

[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 Bunker Hill 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 Bunker Hill critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Bunker Hill Elementary	—	X	—	—	—

A.3 Unincorporated Community of Charleston

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

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Charleston		2,228	1,549		2	310,927,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	37	1.7%	18	1	1,381,000	0.4%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	916	41%	686	0	99,432,000	32%
Earthquake (within Tsunami Zone)		91	4.1%	176	1	56,162,000	18%
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*	255	11%	267	2	82,989,000	27%
Tsunami	Senate Bill 379 Regulatory Line	217	9.7%	220	2	72,984,000	24%
Landslide	High and Very High Susceptibility	112	5.0%	85	0	16,793,000	5.4%
Wildfire	High Hazard	57	2.6%	39	0	8,259,000	2.7%

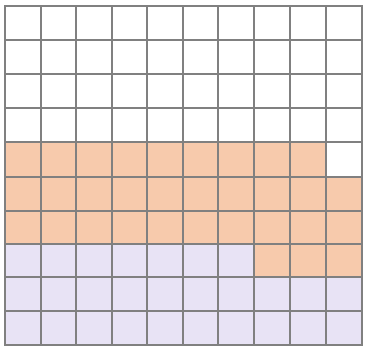
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-3.

[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 Charleston 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-6. Unincorporated community of Charleston critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Charleston RFPD - 3	—	—	X	—	—
Coos Bay Coast Guard Station	X	X	X	—	—

A.4 Unincorporated Community of Glasgow

Table A-7. Unincorporated community of Glasgow hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Glasgow		757	578		1	125,629,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	6	0.7%	9	0	227,000	0.2%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	92	12%	165	0	22,865,000	18%
Earthquake (within Tsunami Zone)		2	0.3%	9	0	1,542,000	1.2%
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*	7	1.0%	13	0	2,537,000	2.0%
Tsunami	Senate Bill 379 Regulatory Line	3	0.4%	6	0	2,878,000	2.3%
Landslide	High and Very High Susceptibility	227	30%	194	0	37,475,000	30%
Wildfire	High Hazard	3	0.4%	2	0	550,000	0.4%

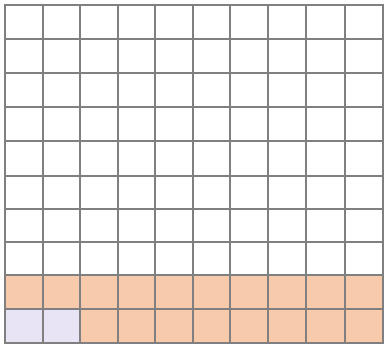
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-4.

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

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

Figure A-4. Unincorporated community of Glasgow 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-8. Unincorporated community of Glasgow critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
North Bay RFPD	—	—	—	—	—

A.5 Unincorporated Community of Green Acres

Table A-9. Unincorporated community of Green Acres hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Green Acres		406	367		1	79,090,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	15	3.6%	16	0	681,000	0.9%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	83	21%	112	0	23,040,000	29%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	342	84%	306	1	65,380,000	83%
Wildfire	High Hazard	33	8.2%	27	0	6,098,000	7.7%

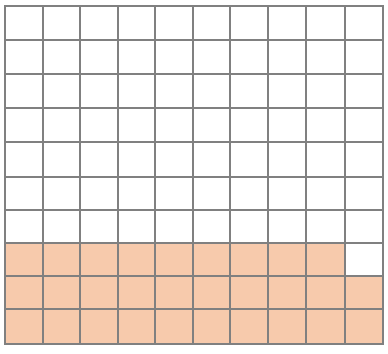
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-4.

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

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

Figure A-5. Unincorporated community of Green Acres 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-10. Unincorporated community of Green Acres critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Greenacres RFPD	—	—	—	X	—

A.6 Unincorporated Community of Hauser

Table A-11. Community of Hauser hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Hauser	1,145	1,022	2	286,877,000	

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	1.0%	8	0	1,738,000	0.6%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	422	37%	521	2	149,929,000	52%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%

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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	1	0	4,555,000	1.6%
Landslide	High and Very High Susceptibility	114	10%	102	0	20,917,000	7.3%
Wildfire	High Hazard	104	9.1%	123	0	29,007,000	10%

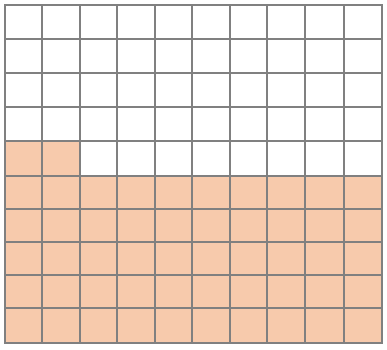
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-6.

[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. Community of Hauser 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-12. Community of Hauser critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Hauser RFPD	—	X	—	—	—
North Bay Light House Elementary School	—	X	—	—	—

A.7 Unincorporated Community of Millington

Table A-13. Community of Millington hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Millington		666	506		1	100,571,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	13	1.9%	13	1	586,000	0.6%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	28	4.2%	108	1	15,917,000	16%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	5	0	779,000	0.8%
Landslide	High and Very High Susceptibility	112	17%	67	0	13,834,000	14%
Wildfire	High Hazard	89	13%	90	0	14,703,000	15%

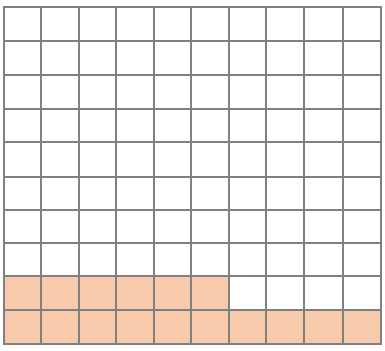
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-7.

[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. Community of Millington 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-14. Community of Millington critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Tsunami CSZ Mw 9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
Millington RFPD	X	X	—	—	—

A.8 City of Bandon

Table A-15. City of Bandon hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Bandon		3,066	1,962		8	629,445,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	60	2.0%	94	1	3,855,000	0.6%
*Earthquake**	CSZ Mw 9.0 Deterministic	837	27%	693	5	213,771,000	34%
Earthquake *(within Tsunami Zone)*		27	0.9%	116	2	43,296,000	6.9%
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*	102	3.3%	185	2	64,742,000	10%
Tsunami	Senate Bill 379 Regulatory Line	82	2.7%	158	2	54,088,000	8.6%
Landslide	High and Very High Susceptibility	57	1.9%	51	0	13,379,000	2.1%
Wildfire	High Hazard	51	1.7%	45	0	11,825,000	1.9%

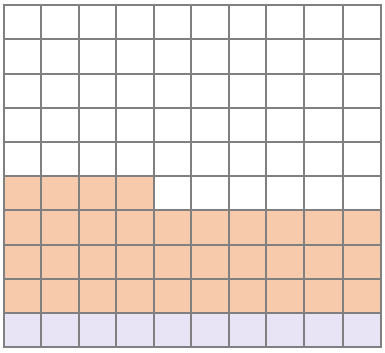
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-8.

[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 Bandon 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-16. City of Bandon critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Bandon Fire Department	—	X	—	—	—
Bandon Police Department	—	X	—	—	—
Bandon Senior High School	—	X	—	—	—
Bandon Water Plant	X	X	X	—	—
Harbor Lights Middle School	—	X	—	—	—
Ocean Crest Elementary School	—	X	—	—	—
Port of Bandon - Office	—	X	X	—	—
Southern Coos Hospital	—	—	—	—	—

A.9 Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians

Table A-17. Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians		47	33		1		12,470,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0%	0	0	0	0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	16	35%	15	1	4,271,000	34%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	0	0%	0	0	0	0%
Wildfire	High Hazard	0	0%	0	0	0	0%

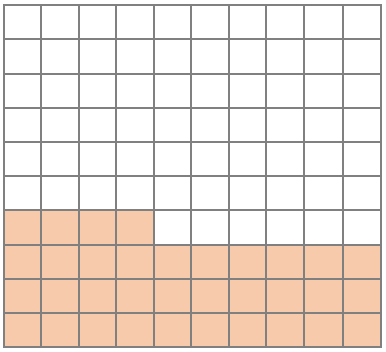
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-9.

[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. Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians 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-18. Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians critical facilities.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Tsunami CSZ Mw 9.0 – Medium	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**	**Exposed**
CTCLUSI Admin	—	X	—	—	—

A.10 City of Coos Bay

Table A-19. City of Coos Bay hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Coos Bay		15,966	7,220		22	2,420,579,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	773	4.8%	468	7	42,299,000	1.7%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	2,732	17%	2,027	16	632,247,000	26%
Earthquake (within Tsunami Zone)		181	1.1%	226	3	203,853,000	8.4%
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*	421	2.6%	319	3	267,595,000	11%
Tsunami	Senate Bill 379 Regulatory Line	53	0.3%	84	2	41,966,000	1.7%
Landslide	High and Very High Susceptibility	3,978	25%	1,890	6	477,292,000	20%
Wildfire	High Hazard	294	1.8%	163	0	32,642,000	1.3%

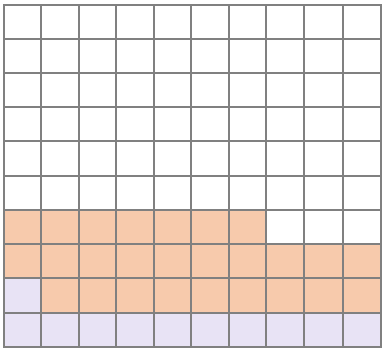
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-10.

[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 Coos Bay 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 (tsunami damage negligible for this community).

= Estimated losses due to earthquake (outside of tsunami zone).

Table A-20. City of Coos Bay critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Bay Area Hospital	—	—	—	—	—
Blossom Gulch Elementary School	X	X	—	—	—
Coos Bay - North Bend Water Board	—	X	—	—	—
Coos Bay City Shop	X	X	—	—	—
Coos Bay Fire Station - Central	—	—	—	X	—
Coos Bay Fire Station - Eastside	—	X	—	X	—
Coos Bay Fire Station - Empire	—	X	—	—	—
Coos Bay Police Department	X	X	X	—	—
Coos Bay Wastewater Department	X	X	—	—	—
Coos Bay Wastewater Treatment	—	X	X	—	—
Eastside Elementary School	—	X	—	X	—
Harding Learning Center	—	X	—	X	—
Madison Elementary School	—	X	—	—	—
Marshfield Senior High School	—	X	—	X	—
Millicoma Intermediate School	—	X	—	X	—
Oregon Coast Technology School 2	—	X	—	—	—
Oregon International Port of Coos Bay - Port Office	X	X	—	—	—
Oregon State Police	—	—	—	—	—
Pacific Power	X	X	—	—	—
Sunset Middle School	—	X	—	—	—
U.S. Coast Guard Station - Cutter Orcas	X	X	X	—	—
U.S. Oregon Army National Guard	—	X	—	—	—

A.11 City of Coquille

Table A-21. City of Coquille hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Coquille		3,866	1,977		8	606,670,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	24	0.6%	23	1	1,207,000	0.2%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	259	6.7%	357	6	131,036,000	22%
Earthquake (within Tsunami Zone)		0	0.0%	0	0	0	0.0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	323	8.4%	202	0	43,926,000	7.2%
Wildfire	High Hazard	51	1.3%	22	0	5,181,000	0.9%

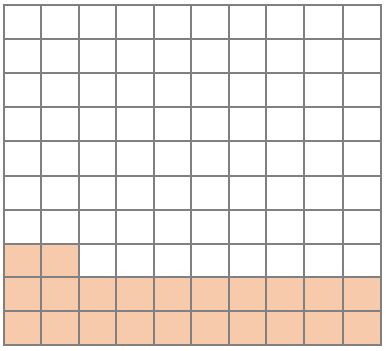
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-10.

[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 Coquille 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 (tsunami damage negligible for this community).

= Estimated losses due to earthquake (outside of tsunami zone).

Table A-22. City of Coquille critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Coos County Sheriff's Office and EOC	—	X	—	—	—
Coos Couny Road Department	—	X	—	—	—
Coquille City Police Department	—	—	—	—	—
Coquille Fire and Rescue Station No. 1	—	X	—	—	—
Coquille High School	X	X	—	—	—
Coquille Valley Hospital	—	—	—	—	—
Coquille Valley Middle School	—	X	—	—	—
Lincoln Elementary School	—	X	—	—	—

A.12 Coquille Indian Tribe

Table A-23. Coquille Indian Tribe hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Coquille Indian Tribe		313	100		1	80,721,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	0	0%	1	0	2,000	0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	44	14%	31	1	32,707,000	41%
Earthquake (within Tsunami Zone)		59	19%	2	0	4,080,000	5.1%
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*	59	19%	3	0	4,147,000	5.1%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	5	0	33,438,000	41%
Landslide	High and Very High Susceptibility	3	0.8%	1	0	291,000	0.4%
Wildfire	High Hazard	0	0%	1	0	61,000	0.1%

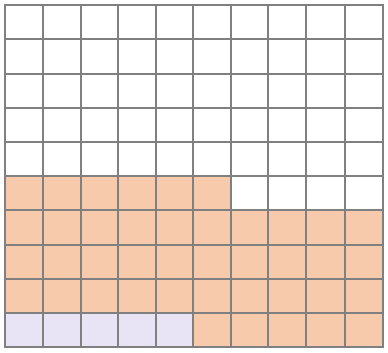
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-12.

[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. Coquille Indian Tribe 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-24. Coquille Indian Tribe critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Coquille Indian Tribe Admin Building	—	X	—	—	—

A.13 City of Lakeside

Table A-25. City of Lakeside hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Lakeside		1,699	1,421		3	242,768,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	253	15%	171	1	5,768,000	2.4%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	572	34%	666	3	96,156,000	40%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	12	0.7%	18	1	4,912,000	2.0%
Landslide	High and Very High Susceptibility	113	6.6%	105	0	20,042,000	8.3%
Wildfire	High Hazard	50	2.9%	43	0	6,144,000	2.5%

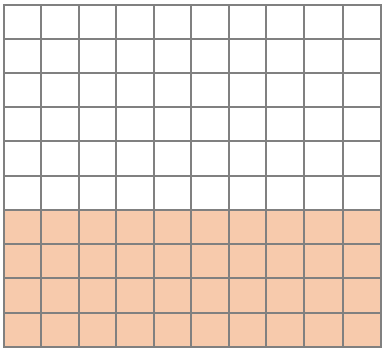
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-10.

[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-13. City of Lakeside 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 (tsunami damage negligible for this community).

= Estimated losses due to earthquake (outside of tsunami zone).

Table A-26. City of Lakeside critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Lakeside Airstrip	—	X	—	—	—
Lakeside RFPD	—	X	—	—	—
Lakeside Water Treatment	X	X	X	—	—

A.14 City of Myrtle Point

Table A-27. City of Myrtle Point hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Myrtle Point		2,514	1,329		6	383,743,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	119	4.7%	80	1	3,081,000	0.8%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	455	18%	468	6	154,830,000	40%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	239	9.5%	131	2	30,609,000	8.0%
Wildfire	High Hazard	0	0%	0	0	0	0%

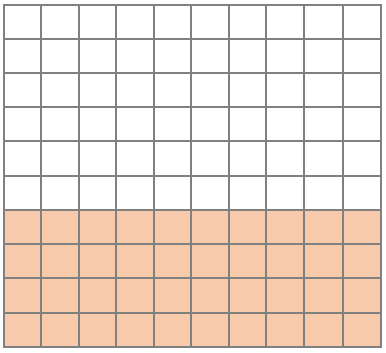
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-10.

[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-14. City of Myrtle Point 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 (tsunami damage negligible for this community).

= Estimated losses due to earthquake (outside of tsunami zone).

Table A-28. City of Myrtle Point critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Myrtle Crest School	—	X	—	X	—
Myrtle Point City Hall	—	X	—	—	—
Myrtle Point Fire Department	—	X	—	—	—
Myrtle Point High School	—	X	—	X	—
Myrtle Point Water Plant	X	X	—	—	—
Myrtle Point Water Plant 2	—	X	—	—	—

A.15 City of North Bend

Table A-29. City of North Bend hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
North Bend		9,651	4,233		12	1,494,790,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	18	0.2%	27	0	3,063,000	0.2%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	1,576	16%	1,225	9	542,929,000	36%
Earthquake (within Tsunami Zone)		25	0.3%	55	2	71,271,000	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*	55	0.6%	75	2	85,107,000	5.7%
Tsunami	Senate Bill 379 Regulatory Line	29	0.3%	51	2	72,394,000	4.8%
Landslide	High and Very High Susceptibility	408	4.2%	179	3	49,187,000	3.3%
Wildfire	High Hazard	0	0%	0	0	0	0%

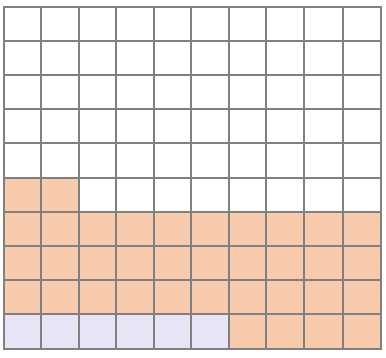
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-15.

[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-15. City of North Bend 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-30. City of North Bend critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Airport Water Treatment Facility	—	X	X	X	—
Hillcrest Elementary School	—	X	—	—	—
North Bend Fire - Airport	—	X	—	—	—
North Bend Fire and Rescue	—	X	—	—	—
North Bend Fire Station 3	—	—	—	X	—
North Bend Middle School	—	X	—	—	—
North Bend Police Department	—	X	—	—	—
North Bend Senior High School	—	X	X	X	—
Oregon Coast Technology School	—	X	—	—	—
Oregon State Trooper Office	—	X	—	—	—
Southwest Oregon Regional Airport	—	X	—	—	—
U.S. Coast Guard Sector North Bend	—	X	—	—	—

A.16 City of Powers

Table A-31. City of Powers hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]	Total Building Value ($)	
Powers		687	556		4	111,516,000	
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	4	0.6%	2	0	11,000	0%
*Earthquake**	*CSZ Mw 9.0 Deterministic*	252	37%	267	4	49,542,000	44%
Earthquake (within Tsunami Zone)		0	0%	0	0	0	0%
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	0	0	0%
Tsunami	Senate Bill 379 Regulatory Line	0	0%	0	0	0	0%
Landslide	High and Very High Susceptibility	26	3.7%	19	1	4,102,000	3.7%
Wildfire	High Hazard	0	0%	1	0	135,000	0.1%

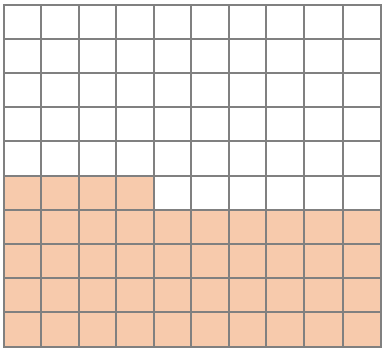
*Earthquake losses were calculated for buildings outside of Medium tsunami zone.

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-15.

[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-16. City of Powers 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-32. City of Powers critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Tsunami CSZ Mw 9.0 – Medium Exposed	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Powers Elementary School	—	X	—	—	—
Powers High School	—	X	—	X	—
Powers Police Department	—	X	—	—	—
Powers Volunteer Fire Department	—	X	—	—	—

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

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Table B-1. Coos County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Nonprofit			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)	11,513	2,443,296	55%	706	378,565	8.5%	6,655	1,594,035	36%	83	60,989	1.4%	18,957	45%	4,476,885	39%
Bunker Hill	501	91,415	53%	87	52,807	30%	146	19,028	11%	6	10,622	6.1%	740	1.7%	173,872	1.5%
Charleston	889	183,211	59%	107	45,254	15%	545	77,684	25%	8	4,777	1.5%	1,549	3.6%	310,927	2.7%
Glasgow	366	94,263	75%	10	3,624	2.9%	201	25,987	21%	1	1,754	1.4%	578	1.4%	125,629	1.1%
Green Acres	265	58,361	74%	2	2,386	3.0%	98	16,574	21%	2	1,769	2.2%	367	0.9%	79,090	0.7%
Hauser	507	116,877	41%	102	82,673	29%	409	62,173	22%	4	25,154	8.8%	1,022	2.4%	286,877	2.4%
Millington	292	59,020	59%	42	17,903	18%	170	22,548	22%	2	1,099	1.1%	506	1.2%	100,571	0.9%
Total Unincorp. County	14,333	3,046,443	55%	1,056	583,212	11%	8,224	1,818,029	33%	106	106,164	1.9%	23,719	56%	5,553,851	48%
Bandon	1,480	417,147	66%	188	109,241	17%	256	36,430	5.8%	38	66,627	11%	1,962	4.6%	629,445	5.5%
CTCLUSI	19	5,333	43%	6	2,171	17%	5	1,802	14%	3	3,164	25%	33	0.1%	12,470	0.1%
Coos Bay	5,817	1,440,007	59%	557	619,017	26%	728	100,335	4.1%	118	261,220	11%	7,220	17%	2,420,579	21%
Coquille	1,485	345,664	57%	151	129,958	21%	303	38,388	6.3%	38	92,661	15%	1,977	4.6%	606,670	5.3%
Coquille Indian Tribe	88	30,570	38%	5	38,992	48%	1	61	0.1%	6	11,098	14%	100	0.2%	80,721	0.7%
Lakeside	942	164,648	68%	68	20,309	8.4%	391	46,906	19%	20	10,905	4.5%	1,421	3.3%	242,768	2.1%
Myrtle Point	941	223,699	58%	102	67,707	18%	258	44,084	11%	28	48,254	13%	1,329	3.1%	383,743	3.3%
North Bend	3,398	950,809	64%	285	291,672	20%	451	58,263	3.9%	99	194,046	13%	4,233	10%	1,494,790	13%
Powers	352	66,890	60%	13	6,149	5.5%	176	24,443	22%	15	14,033	13%	556	1.3%	111,516	1%
Total Coos County	28,855	6,691,210	58%	2,431	1,868,428	16%	10,793	2,168,741	19%	471	808,172	7.0%	42,550	100%	11,536,553	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)	18,957	4,476,885	1,354,946	30%	1,606	4,256	1,310,768	29%	1,273	2,752	873,272	20%
Bunker Hill	740	173,872	47,261	27%	86	61	37,528	22%	29	35	23,631	14%
Charleston	1,549	310,927	155,594	50%	124	561	99,432	32%	140	417	76,008	24%
Glasgow	578	125,629	24,408	19%	71	94	22,865	18%	21	71	16,247	13%
Green Acres	367	79,090	23,040	29%	25	87	23,040	29%	11	76	18,263	23%
Hauser	1,022	286,877	149,929	52%	91	429	149,929	52%	177	217	85,514	30%
Millington	506	100,571	15,917	16%	73	34	15,917	16%	18	19	8,930	9%
Total Unincorp. County	23,719	5,553,851	1,771,095	32%	2,076	5,522	1,659,479	30%	1,669	3,587	1,101,865	20%
Bandon	1,962	629,445	257,067	41%	142	551	213,771	34%	171	347	131,333	21%
CTCLUSI	33	12,470	4,271	34%	5	10	4,271	34%	3	5	2,026	16%
Coos Bay	7,220	2,420,579	836,100	35%	604	1,423	632,247	26%	464	886	375,844	16%
Coquille	1,977	606,670	131,036	22%	162	195	131,036	22%	62	113	59,419	10%
Coquille Indian Tribe	100	80,721	36,787	46%	10	21	32,707	41%	4	16	26,245	33%
Lakeside	1,421	242,768	96,156	40%	155	511	96,156	40%	186	327	68,136	28%
Myrtle Point	1,329	383,743	154,830	40%	129	339	154,830	40%	105	209	83,263	22%
North Bend	4,233	1,494,790	614,201	41%	328	898	542,929	36%	193	609	319,391	21%
Powers	556	111,516	49,542	44%	48	219	49,542	44%	68	140	32,084	29%
Total Coos County	42,550	11,536,552	3,951,085	34%	3,659	9,689	3,516,968	30%	2,925	6,239	2,199,606	19%

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

Table B-3. 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)	18,957	4,476,885	234	46,762	1.0%	418	94,049	2.1%	918	200,079	4.5%	2,015	464,241	10%	2,337	544,997	12%
Bunker Hill	740	173,872	1	418	0.2%	6	10,370	6.0%	71	40,907	24%	96	45,748	26%	107	48,463	28%
Charleston	1,549	310,927	247	78,239	25%	267	82,989	27%	465	123,141	40%	1,122	235,075	76%	1,238	254,901	82%
Glasgow	578	125,629	5	407	0.3%	13	2,537	2.0%	24	4,838	3.9%	37	8,339	7%	42	9,270	7.4%
Green Acres	367	79,090	0	0	0%	0	0	0%	0	0	0%	32	5,177	6.5%	45	8,693	11%
Hauser	1,022	286,877	0	0	0%	0	0	0%	1	11	0%	19	16,933	5.9%	52	38,178	13%
Millington	506	100,571	0	0	0%	0	0	0%	3	506	0.5%	44	13,191	13%	54	14,961	15%
Total Unincorp. County	23,719	5,553,851	487	125,826	2.3%	704	189,945	3.4%	1,482	369,482	6.7%	3,365	788,704	14%	3,875	919,463	17%
Bandon	1,962	629,445	145	49,200	7.8%	185	64,742	10%	276	91,553	15%	925	285,412	45%	1,374	431,860	69%
CTCLUSI	33	12,470	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Coos Bay	7,220	2,420,579	79	43,133	1.8%	319	267,595	11%	624	455,071	19%	1,018	578,485	24%	1,238	634,178	26%
Coquille	1,977	606,670	0	0	0%	0	0	0%	0	0	0%	0	0	0%	1	447	0.1%
Coquille Indian Tribe	100	80,721	0	0	0%	3	4,147	5.1%	6	44,153	55%	37	56,737	70%	44	58,670	73%
Lakeside	1,421	242,768	0	0	0%	0	0	0%	7	4,044	1.7%	43	10,543	4.3%	76	16,944	7.0%
Myrtle Point	1,329	383,743	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
North Bend	4,233	1,494,790	23	6,110	0.4%	75	85,107	5.7%	263	168,526	11%	558	304,613	20%	608	316,952	21%
Powers	556	111,516	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Total Coos County	42,550	11,536,553	734	224,269	1.9%	1,286	611,536	5.3%	2,658	1,132,829	9.8%	5,946	2,024,494	18%	7,216	2,378,514	21%

Table B-4. Flood loss estimates.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	10% (10-yr)			2% (50-yr)			1% (100-yr)*			0.2% (500-yr)		
			Number of Buildings	Loss Estimate	Loss Ratio	Number of Buildings	Loss Estimate	Loss Ratio	Number of Buildings	Loss Estimate	Loss Ratio	Number of Buildings	Loss Estimate	Loss Ratio
Unincorp. County (rural)	18,957	4,476,885	602	27,673	0.6%	825	45,993	1.0%	890	58,390	1.3%	948	79,270	1.8%
Bunker Hill	740	173,872	33	1,463	0.8%	41	2,465	1.4%	50	3,061	1.8%	52	4,379	2.5%
Charleston	1,549	310,927	14	1,050	0.3%	17	1,324	0.4%	18	1,381	0.4%	20	1,517	0.5%
Glasgow	578	125,629	7	120	0.1%	9	183	0.1%	9	227	0.2%	10	292	0.2%
Green Acres	367	79,090	12	485	0.6%	15	613	0.8%	16	681	0.9%	22	877	1.1%
Hauser	1,022	286,877	6	931	0.3%	7	1,475	0.5%	8	1,738	0.6%	8	2,148	0.7%
Millington	506	100,571	6	191	0.2%	11	449	0.4%	13	586	0.6%	18	853	0.8%
Total Unincorp. County	23,719	5,553,851	680	31,913	0.6%	925	52,502	0.9%	1,004	66,064	1.2%	1,078	89,336	1.6%
Bandon	1,962	629,445	21	544	0.1%	74	2,774	0.4%	94	3,855	0.6%	110	6,028	1.0%
CTCLUSI	33	12,470	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Coos Bay	7,220	2,420,579	344	25,021	1.0%	436	36,201	1.5%	468	42,299	1.7%	490	54,591	2.3%
Coquille	1,977	606,670	8	415	0.1%	19	799	0.1%	23	1,207	0.2%	23	1,619	0.3%
Coquille Indian Tribe	100	80,721	0	0	0%	0	0	0%	1	2	0%	1	9	0%
Lakeside	1,421	242,768	49	2,033	0.8%	119	4,044	1.7%	171	5,768	2.4%	248	9,661	4.0%
Myrtle Point	1,329	383,743	17	197	0.1%	60	1,474	0.4%	80	3,081	0.8%	88	5,224	1.4%
North Bend	4,233	1,494,790	12	385	0%	24	1,852	0.1%	27	3,063	0.2%	32	5,360	0.4%
Powers	556	111,516	0	0	0%	0	0	0%	2	11	0%	4	157	0.1%
Total Coos County	42,550	11,536,553	1,131	60,508	0.5%	1,657	99,646	0.9%	1,870	125,350	1.1%	2,074	171,985	1.5%

*1% results include coastal flooding source.

Table B-5. 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)	18,957	18,664	763	4.1%	938	4.9%	48
Bunker Hill	740	1,376	22	1.6%	53	7.2%	3
Charleston	1,549	2,228	37	1.7%	20	1.3%	2
Glasgow	578	757	6	0.7%	10	1.7%	1
Green Acres	367	406	15	3.6%	21	5.7%	5
Hauser	1,022	1,145	11	1.0%	8	0.8%	0
Millington	506	666	13	1.9%	14	2.8%	1
Total Unincorp. County	23,719	25,242	867	3.4%	1,064	4.5%	60
Bandon	1,962	3,066	60	2.0%	123	6.3%	29
CTCLUSI	33	47	0	0%	0	0%	0
Coos Bay	7,220	15,966	773	4.8%	493	6.8%	25
Coquille	1,977	3,866	24	0.6%	23	1.2%	0
Coquille Indian Tribe	100	313	0	0.0%	1	1.0%	0
Lakeside	1,421	1,699	253	15%	233	16%	62
Myrtle Point	1,329	2,514	119	4.7%	85	6.4%	5
North Bend	4,233	9,651	18	0.2%	29	0.7%	2
Powers	556	687	4	0.6%	4	0.7%	2
Total Coos County	42,550	63,051	2,118	3.4%	2,055	4.8%	185

*1% results include coastal flooding source.

Table B-6. Landslide exposure.

(all dollar amounts in thousands)

Community	Total Number of Buildings	Total Estimated Building Value ($)	Very High Susceptibility			High Susceptibility			Moderate Susceptibility		
			Number of Buildings	Building Value ($)	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)	18,957	4,476,885	1,406	314,141	7.0%	2,343	468,534	11%	6,435	1,372,990	31%
Bunker Hill	740	173,872	0	0	0%	42	7,681	4.4%	255	44,854	26%
Charleston	1,549	310,927	0	0	0%	85	16,793	5.4%	304	61,103	20%
Glasgow	578	125,629	131	26,504	21%	63	10,971	8.7%	198	39,009	31%
Green Acres	367	79,090	100	21,050	27%	206	44,330	56%	24	4,008	5.1%
Hauser	1,022	286,877	3	415	0%	99	20,502	7.1%	452	96,894	34%
Millington	506	100,571	4	942	0.9%	63	12,892	13%	110	19,876	20%
Total Unincorp. County	23,719	5,553,851	1,644	363,052	6.5%	2,901	581,703	11%	7,778	1,638,734	30%
Bandon	1,962	629,445	4	672	0.1%	47	12,707	2.0%	285	84,494	13%
CTCLUSI	33	12,470	0	0	0%	0	0	0%	20	5,935	48%
Coos Bay	7,220	2,420,579	15	4,255	0.2%	1,875	473,037	20%	1,701	484,382	20%
Coquille	1,977	606,670	4	1,179	0.2%	198	42,747	7.0%	982	263,510	43%
Coquille Indian Tribe	100	80,721	0	0	0%	1	291	0.4%	32	8,147	10%
Lakeside	1,421	242,768	0	0	0%	105	20,042	8.3%	192	34,725	14%
Myrtle Point	1,329	383,743	64	14,091	3.7%	67	16,518	4.3%	622	158,591	41%
North Bend	4,233	1,494,790	0	0	0%	179	49,187	3.3%	1,401	422,578	28%
Powers	556	111,516	0	0	0%	19	4,102	3.7%	85	16,701	15%
Total Coos County	42,550	11,536,553	1,731	383,249	3.3%	5,392	1,200,334	10%	13,098	3,117,797	27%

Table B-7. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Hazard			**Moderate Hazard**		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**	**Number of Buildings**	**Building Value ($)**	**Percent of Building Value Exposed**
Unincorp. County (rural)	18,957	4,476,885	402	86,157	1.9%	8,603	1,904,749	43%
Bunker Hill	740	173,872	92	15,762	9.1%	257	50,895	29%
Charleston	1,549	310,927	39	8,259	2.7%	858	154,453	50%
Glasgow	578	125,629	2	550	0.4%	286	65,751	52%
Green Acres	367	79,090	27	6,098	7.7%	189	38,881	49%
Hauser	1,022	286,877	123	29,007	10%	591	115,620	40%
Millington	506	100,571	90	14,703	15%	177	30,871	31%
Total Unincorp. County	23,719	5,553,851	775	160,536	2.9%	10,961	2,361,220	43%
Bandon	1,962	629,445	45	11,825	1.9%	892	254,314	40%
CTCLUSI	33	12,470	0	0	0%	7	1,921	15%
Coos Bay	7,220	2,420,579	163	32,642	1.3%	1,649	493,509	20%
Coquille	1,977	606,670	22	5,181	0.9%	681	181,451	30%
Coquille Indian Tribe	100	80,721	1	61	0.1%	78	27,107	34%
Lakeside	1,421	242,768	43	6,144	2.5%	792	131,891	54%
Myrtle Point	1,329	383,743	0	0	0%	532	121,994	32%
North Bend	4,233	1,494,790	0	0	0%	805	269,076	18%
Powers	556	111,516	1	135	0.1%	293	50,668	45%
Total Coos County	42,550	11,536,553	1,050	216,524	1.9%	16,690	3,893,151	34%

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

We compiled a UDF database for all buildings in Coos County for use in both flood and earthquake modules of Hazus-MH. We used the Coos County assessor database (acquired in 2015) to determine which tax lots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

We used the existing DOGAMI dataset of building footprints (unpublished) to help precisely locate the centroid of each building. Where the building footprint dataset lacked coverage in the eastern portion of the county, we used the centroid of the tax lot; for tax lots larger than 10 acres the building centroid was corrected by using orthoimagery. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. For buildings partially within the inundation zone, we moved the building point to the centroid of the portion of the building within the inundation zone. We used an iterative approach 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

We populated the required attributes for Hazus-MH through a variety of approaches. We used the Coos County assessor database wherever 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 positions 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 = nonprofit/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 Coos County assessor database. Where data were not available, the default value of RES1 was applied throughout.
- **Cost** – The cost of an individual UDF. Loss ratio is derived from this value. The value was obtained from the Coos County assessor database. Where not available, cost was based on the square footage of the building footprint or from the square footage found in the Coos County assessor

database. When multiple UDFs occupied a single tax lot, the overall cost of the tax lot was distributed to the UDFs based on square footage.

- **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 Coos County assessor database. Where not available the year of "1900" was applied (12% of the UDFs).
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for tax lots with multiple UDFs. The value distribution method will ensure that UDFs with the highest square footage will be the most expensive on a given tax lot. This value is also used to pro-rate the **Number of people** field for Residential UDFs within a census block. The value was obtained from DOGAMI's building footprints; where (RES) footprints were not available, we used the Coos 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 Coos County assessor database where available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using the Google Street View™ mapping service 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, 2012c]). 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 Coos County assessor database where available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ mapping service or available oblique imagery was used to ascertain basement presence.
- **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: Hazus-MH overlays a UDF location on a depth grid and by using the **First floor height** determines the level of flooding occurring to a building. The **First floor height** is derived from the **Foundation type** attribute (Coos County assessor data) or observation via oblique imagery or the 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 to estimate earthquake losses by determining which damage function will be applied. This information was not in the Coos County assessor data, so instead Building type 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. (see "Seismic building codes" section below for more information). This information is derived from the **Year built** attribute (Coos Assessor) and state 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 number of people affected by a given hazard. This attribute is derived from the default Hazus-MH database (United States Census Bureau, 2010a) of population per census block and distributed across residential UDFs.

- **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 Coos County. **Table C-1** outlines the benchmark years that apply to buildings within Coos County.

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

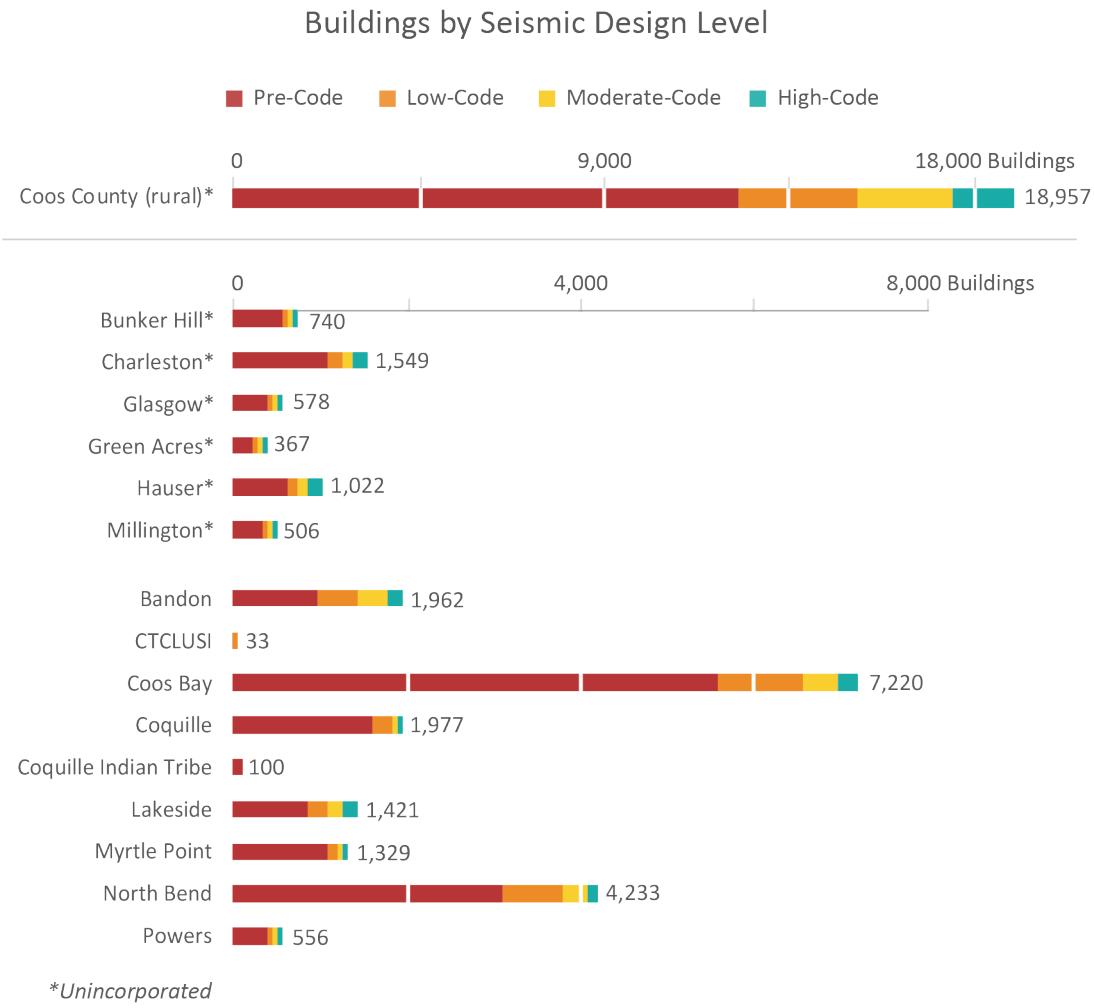
Building Type	Year Built	Design Level	Basis
Single Family Dwelling (includes Duplexes)	prior to 1976	Pre-Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low-Code	
	1992–2003	Moderate-Code	
	2004–2016	High-Code	
Manufactured Housing	prior to 2003	Pre-Code	Interpretation of OR BCD 2002 Manufactured 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	
	1991–2018	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 Coos 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)	18,957	12,240	65%	2,906	15%	2,284	12%	1,527	8.1%
Bunker Hill	740	593	80%	77	10%	35	4.7%	35	4.7%
Charleston	1,549	1,094	71%	164	11%	152	10%	139	9.0%
Glasgow	578	422	73%	55	10%	63	11%	38	6.6%
Green Acres	367	268	73%	39	11%	38	10%	22	6.0%
Hauser	1,022	657	64%	127	12%	98	10%	140	14%
Millington	506	386	76%	31	6.1%	44	8.7%	45	8.9%
Total Unincorp. County	23,719	15,660	66%	3,399	14%	2,714	11%	1,946	8.2%
Bandon	1,962	991	51%	478	24%	297	15%	196	10%
CTCLUSI	33	22	67%	11	33%	0	0%	0	0%
Coos Bay	7,220	5,611	78%	952	13%	396	5.5%	261	3.6%
Coquille	1,977	1,624	82%	212	11%	86	4.4%	55	2.8%
Coquille Indian Tribe	100	100	100%	0	0%	0	0%	0	0%
Lakeside	1,421	870	61%	215	15%	183	13%	153	11%
Myrtle Point	1,329	1,081	81%	154	12%	55	4.1%	39	2.9%
North Bend	4,233	3,124	74%	664	16%	296	7.0%	149	3.5%
Powers	556	433	78%	63	11%	38	6.8%	22	4.0%
Total Coos County	42,550	29,516	69%	6,148	14%	4,065	10%	2,821	6.6%

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



C.3 Flood Hazard Data

DOGAMI developed flood hazard data in 2012 for a revision of the Coos County FEMA FIS (FEMA, 2014). The hazard data were based on a combination of previous flood studies and new riverine and coastal hydrologic and hydraulic analyses. For riverine areas, flood elevations for the 10-, 50-, 100-, and 500-year events for each stream cross-section were used to develop depth of flooding raster datasets or "depth grids." For coastal zones and other stillwater flood areas, a 100-year stillwater elevation was used to create the depth grid.

A countywide, 2-meter (~6.5 foot), lidar-based depth grid was developed for each of the 10-, 50-, 100-, and 500-year annual chance flood events. The depth grids were imported into Hazus-MH for determining the depth of flooding for areas within the FEMA flood zones.

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

which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

Several data layers were used for the deterministic analysis conducted for this report. Data layers created for the ORP (Madin and Burns, 2013) provided most of the earthquake inputs for the CSZ magnitude 9.0 event modeled in Hazus-MH. Liquefaction susceptibility data came directly from the ORP, but site ground motion data (PGA: peak ground acceleration; PGV: peak ground velocity; SA10 and SA03: spectral acceleration at 1.0 second period and 0.3 second period) were derived from NEHRP site class soil data. The GIS procedure used to amplify the site ground motion data from NEHRP soil data are described in Appendix B of Bauer and others (2018): Site Ground Motion and Ground Deformation Map Development. The landslide susceptibility data from the ORP were replaced with newer and more accurate data (Burns and others, 2016).

The hazard layers were formatted for use in a Python script developed by DOGAMI to apply the Hazus-MH methodology. The earthquake hazard datasets used in the analysis were: ground motion data (PGA, PGV, SA03, and SA10), a landslide susceptibility map, and liquefaction susceptibility map. Permanent ground deformation (PGD) for landslide and liquefaction were both calculated using Hazus-MH methodology for each of the susceptibility maps. In addition to the earthquake data layers, Hazus-MH requires a water table parameter for PGD due to liquefaction. As water table data were unavailable, we set the water table value to a depth of 5 feet (1.5 meters).

A deterministic method for a CSZ Mw 9.0 event was deemed the most likely and impactful earthquake scenario for Coos County. Past work has shown that probabilistic models of a 500-year event for this area are roughly the same as the CSZ Mw 9.0 event.

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

C.5 Post-Analysis Quality Control

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

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

Finding anomalies and investigating possible sources of error are crucial in making corrections to the data. A wide range of corrections might be required to produce a better outcome. For example, floating homes may need to have a first-floor height adjustment or a UDF point position might need to be moved

due to issues with the depth grid. Incorrect basement or occupancy type attribution could be the cause of a problem. Commonly, inconsistencies between assessor data and tax lot geometry can be the source of an error. These are just a few of the many types of problems addressed in the quality control process.

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

CPAC	Community Planning Advisory Committee
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
RFPD	Rural Fire Protection District
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
SLR	Sea level rise
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% 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% chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1%-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 Special Flood Hazard Areas (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.

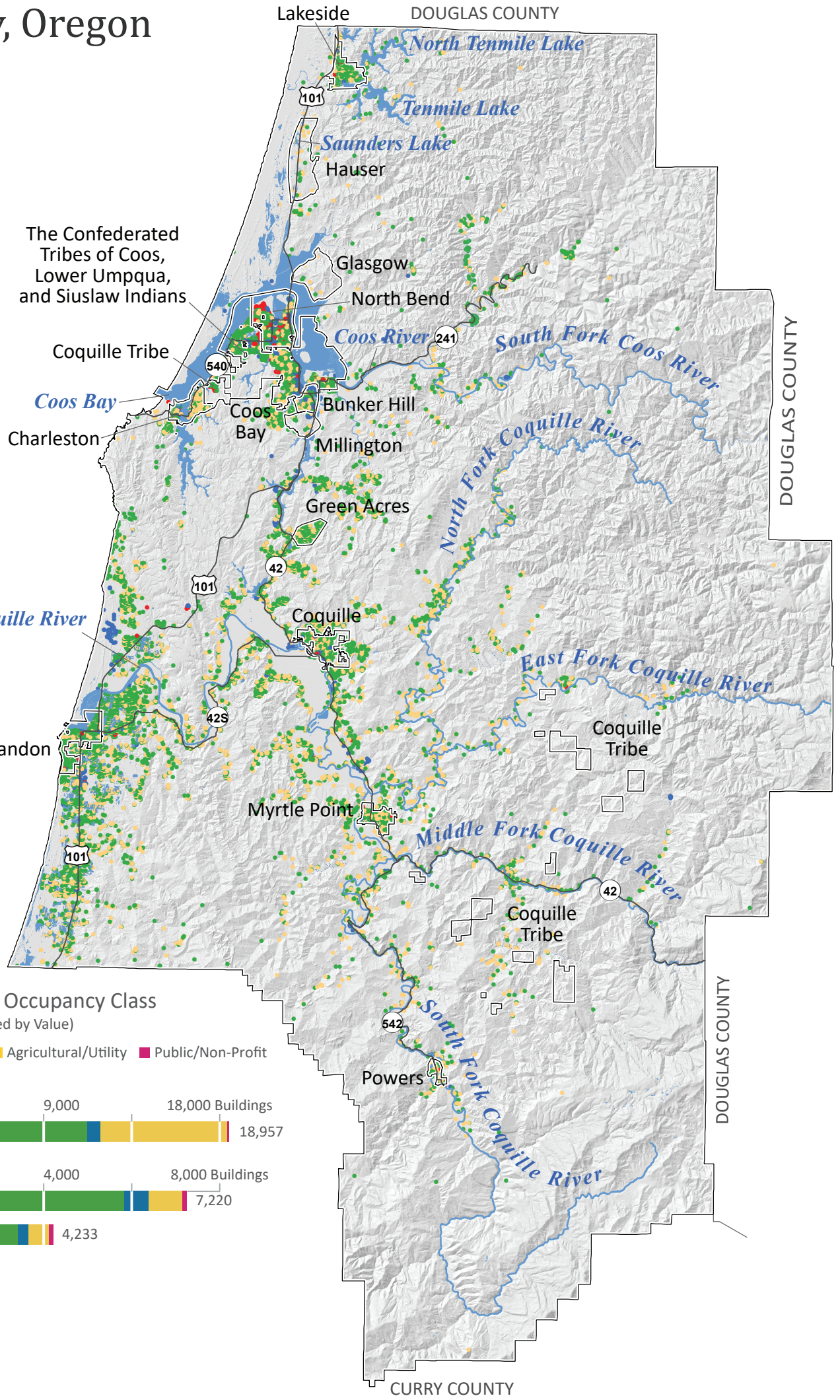
Plate 1. Building Distribution Map of Coos County, Oregon 98
Plate 2. Population Density Map of Coos County, Oregon 99
Plate 3. CSZ Mw 9.0 Peak Ground Acceleration Map of Coos County, Oregon 100
Plate 4. Tsunami Inundation Map of Coos County, Oregon 101
Plate 5. Flood Hazard Map of Coos County, Oregon 102
Plate 6. Landslide Susceptibility Map of Coos County, Oregon 103
Plate 7. Wildfire Risk Map of Coos County, Oregon 104

Building Distribution Map of Coos County, Oregon

Building Occupancy

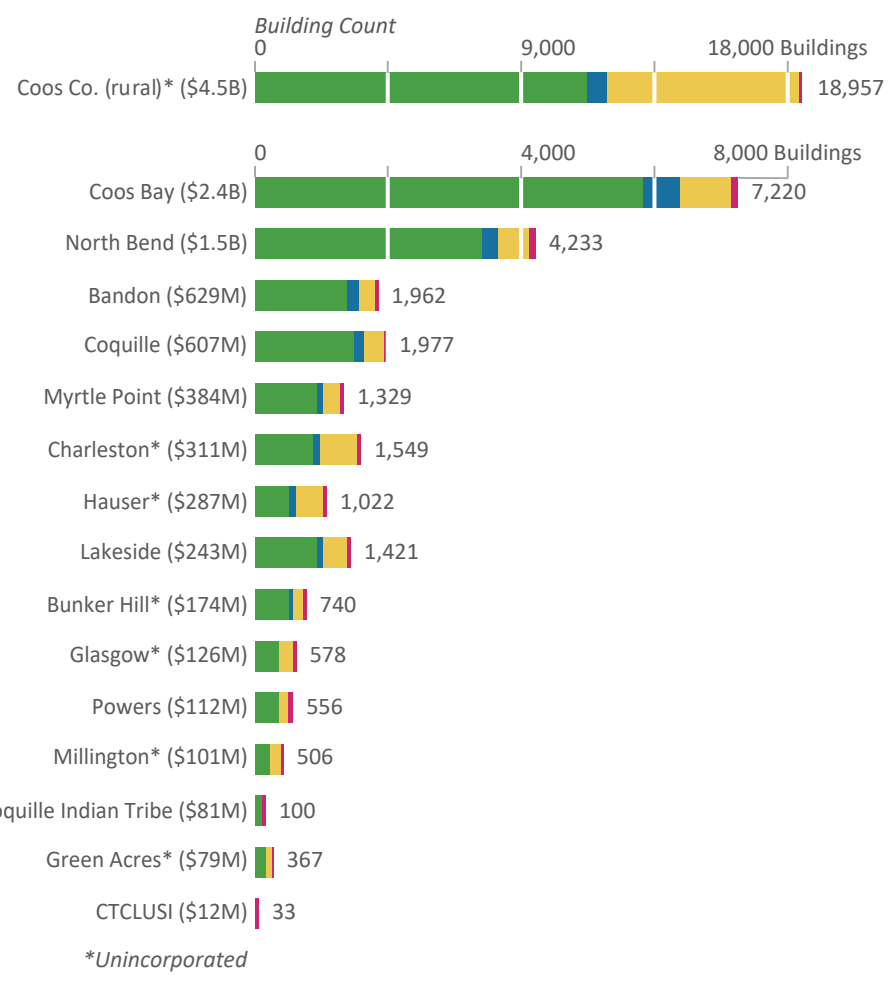
- Agricultural / Utility
- Commercial & Industrial
- Public & Non Profit
- Residential

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



Buildings by Occupancy Class

(Ranked by Value)

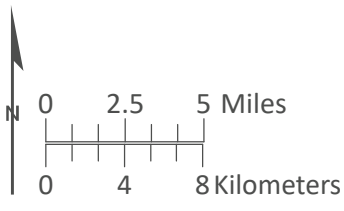


Data Sources:
Building footprints: Oregon Department of Geology (2010)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

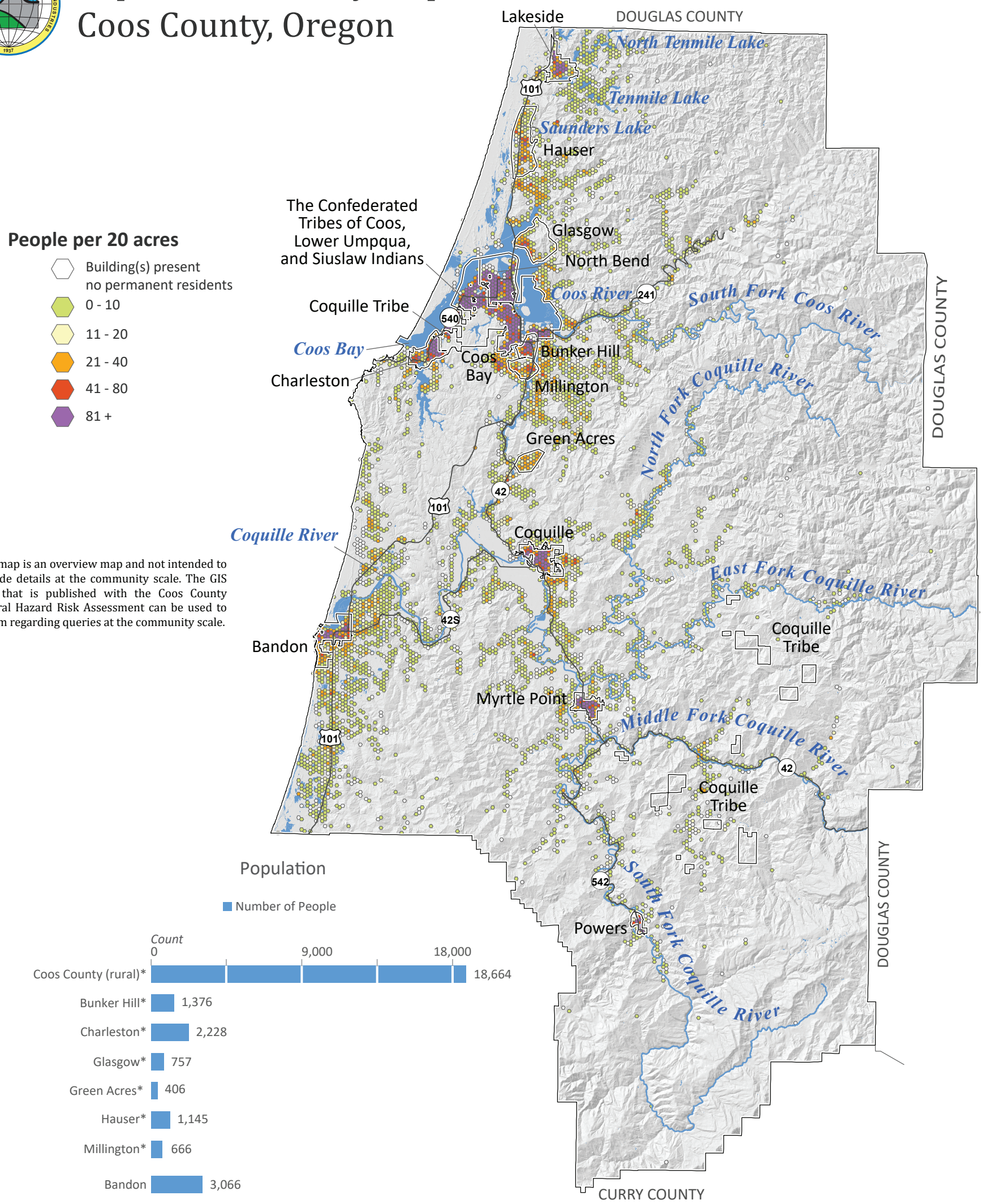
Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell H. Anthony, 2018

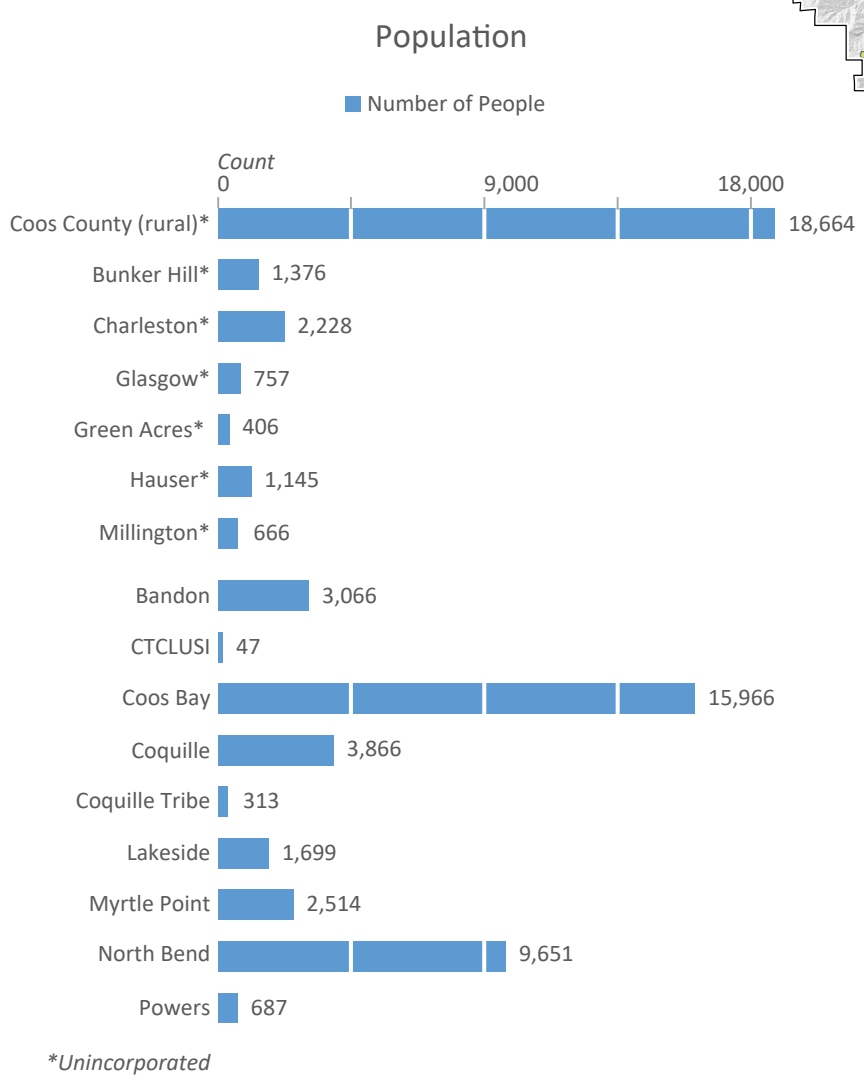
Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication 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.



Population Density Map of Coos County, Oregon



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

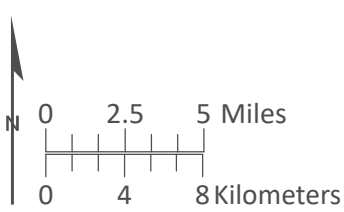


Data Sources:
Population data: U.S. Census (2010)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell H. Anthony, 2018

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.



Mw 9.0 CSZ Earthquake Shaking Map of Coos County, Oregon

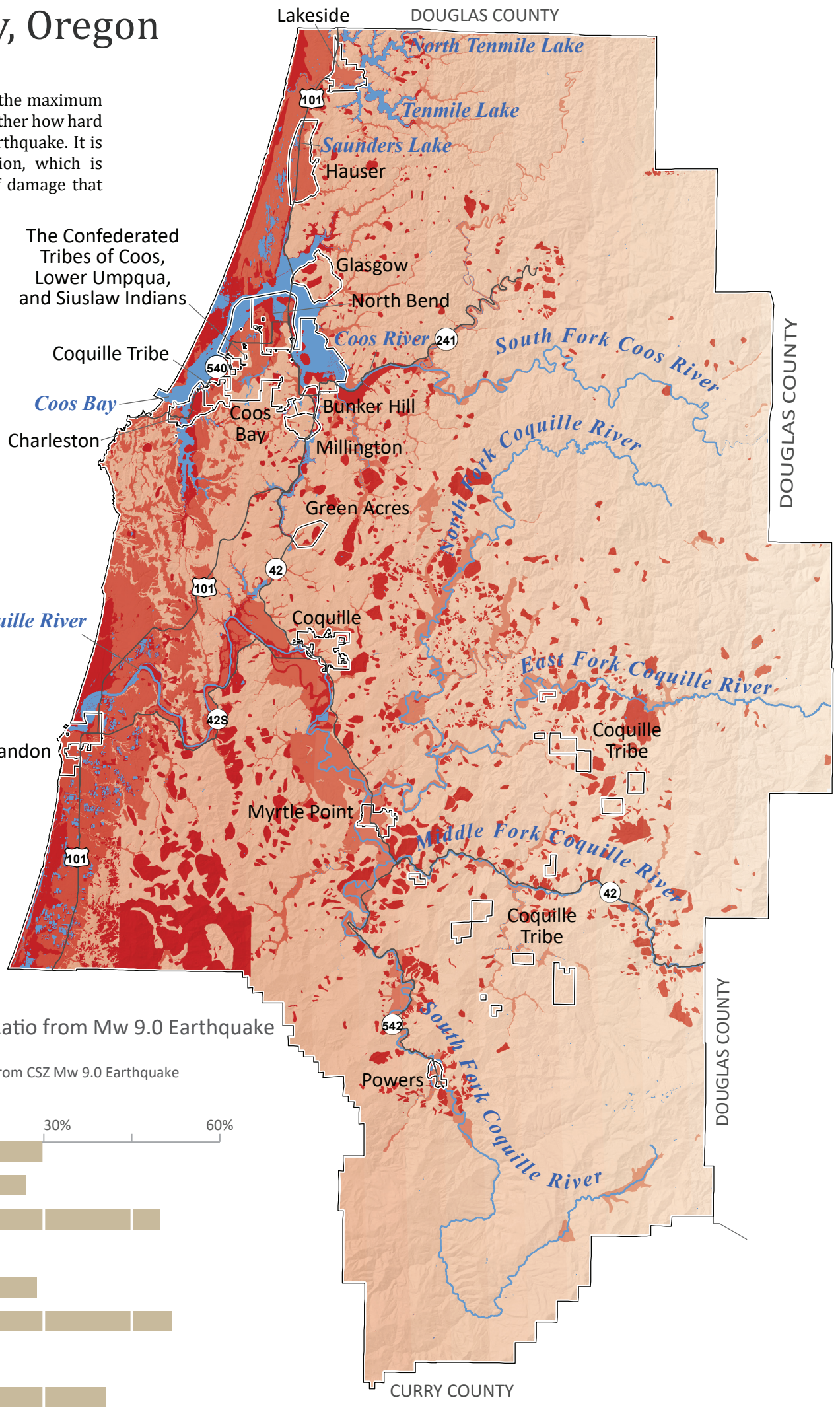
Peak Ground Acceleration (PGA) is the maximum acceleration in a given location or rather how hard the ground is shaking during an earthquake. It is one measurement of ground motion, which is closely associated with the level of damage that occurs from an earthquake.

Earthquake Peak Ground Acceleration

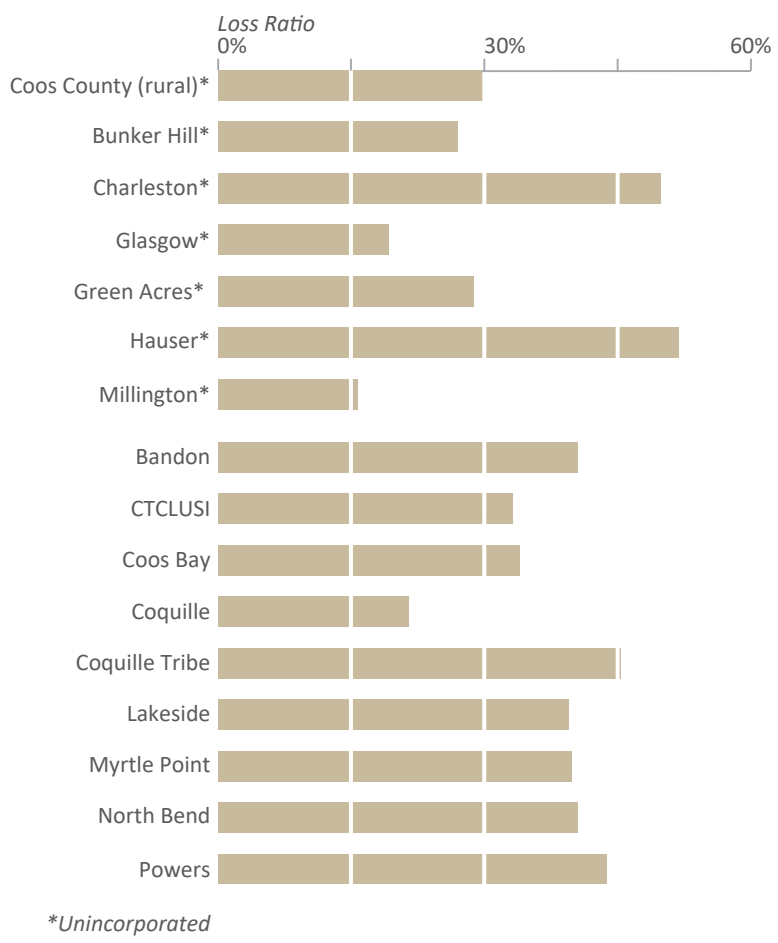
(Correlated Modified Mercalli Scale)

Very Strong — Severe

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



Total Building Value Loss Ratio from Mw 9.0 Earthquake



Study Location Map

Data Sources:
Earthquake peak ground acceleration: Oregon Department of Geology, Appleby and Bauer, unpub. data (2018)
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 CS6

Cartography by: Lowell H. Anthony, 2018

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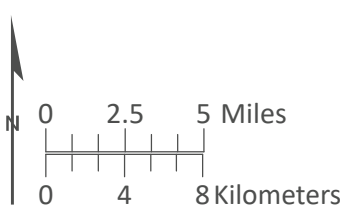

Tsunami Inundation Map of Coos County, Oregon

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

Tsunami Hazard Zone

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

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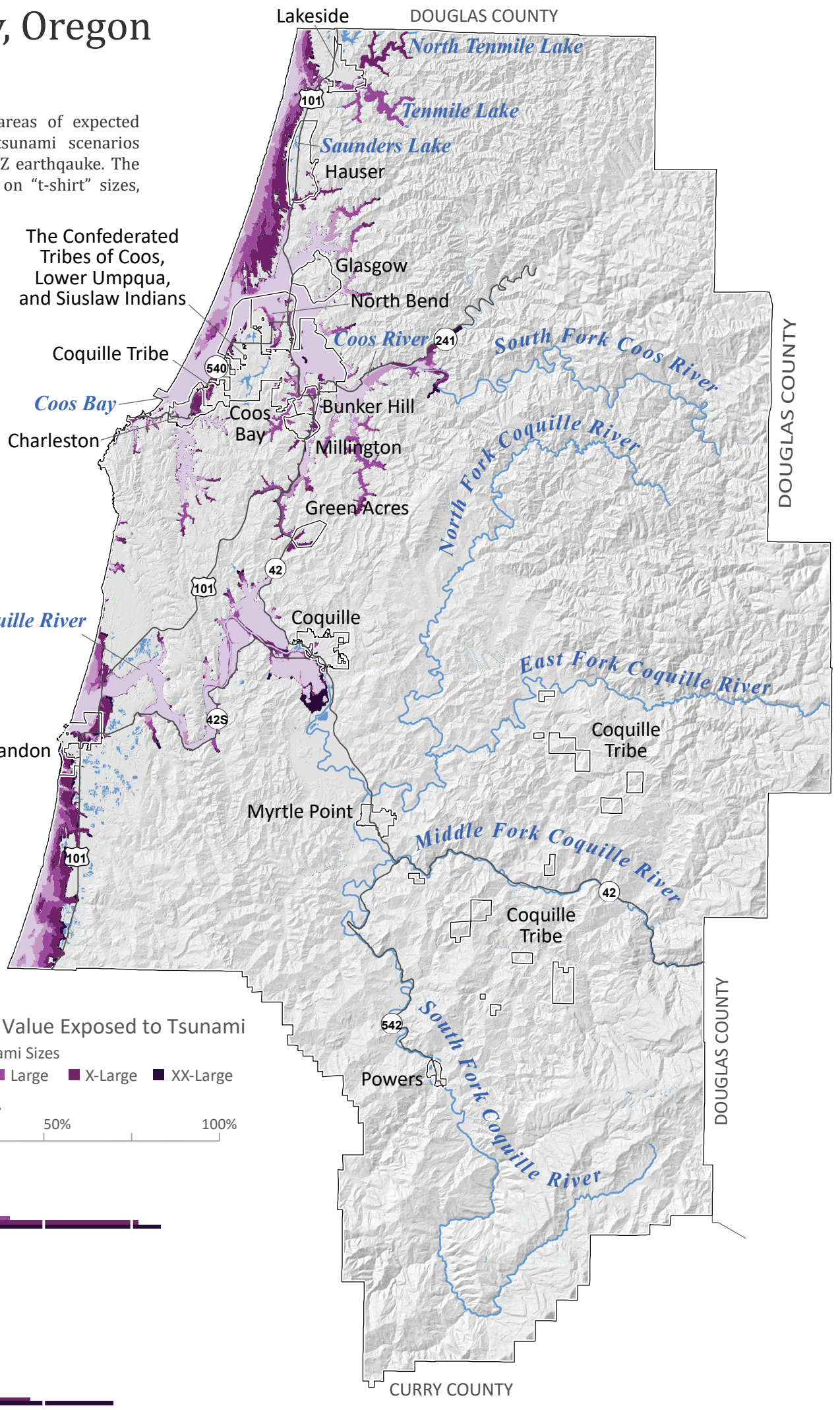

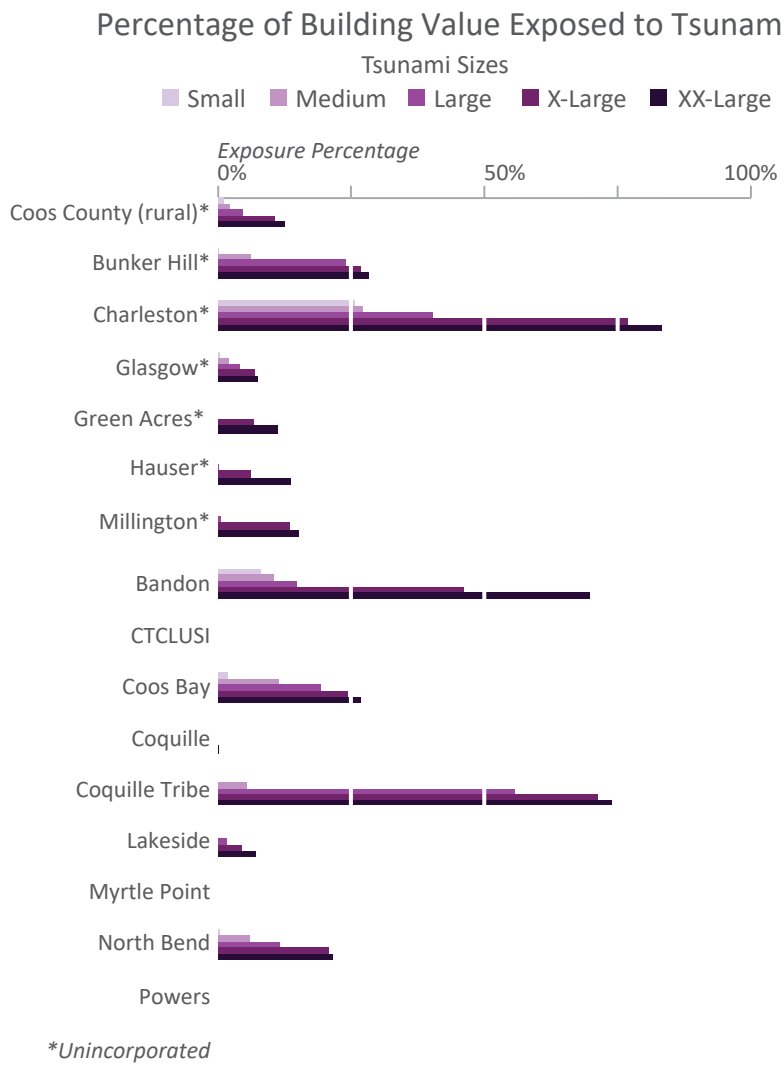

Data Sources:
Tsunami hazard zones: Oregon Department of Geology, Priest and others (2013)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey 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 CS6

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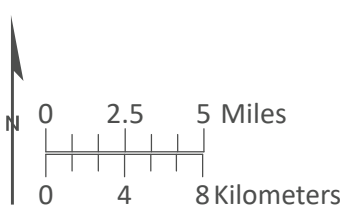

Flood Hazard Map of Coos County, Oregon

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 Coos County's Digital Flood Insurance Rate Maps.

Flood Hazard Zone

100-Year Flood
(1% annual chance)

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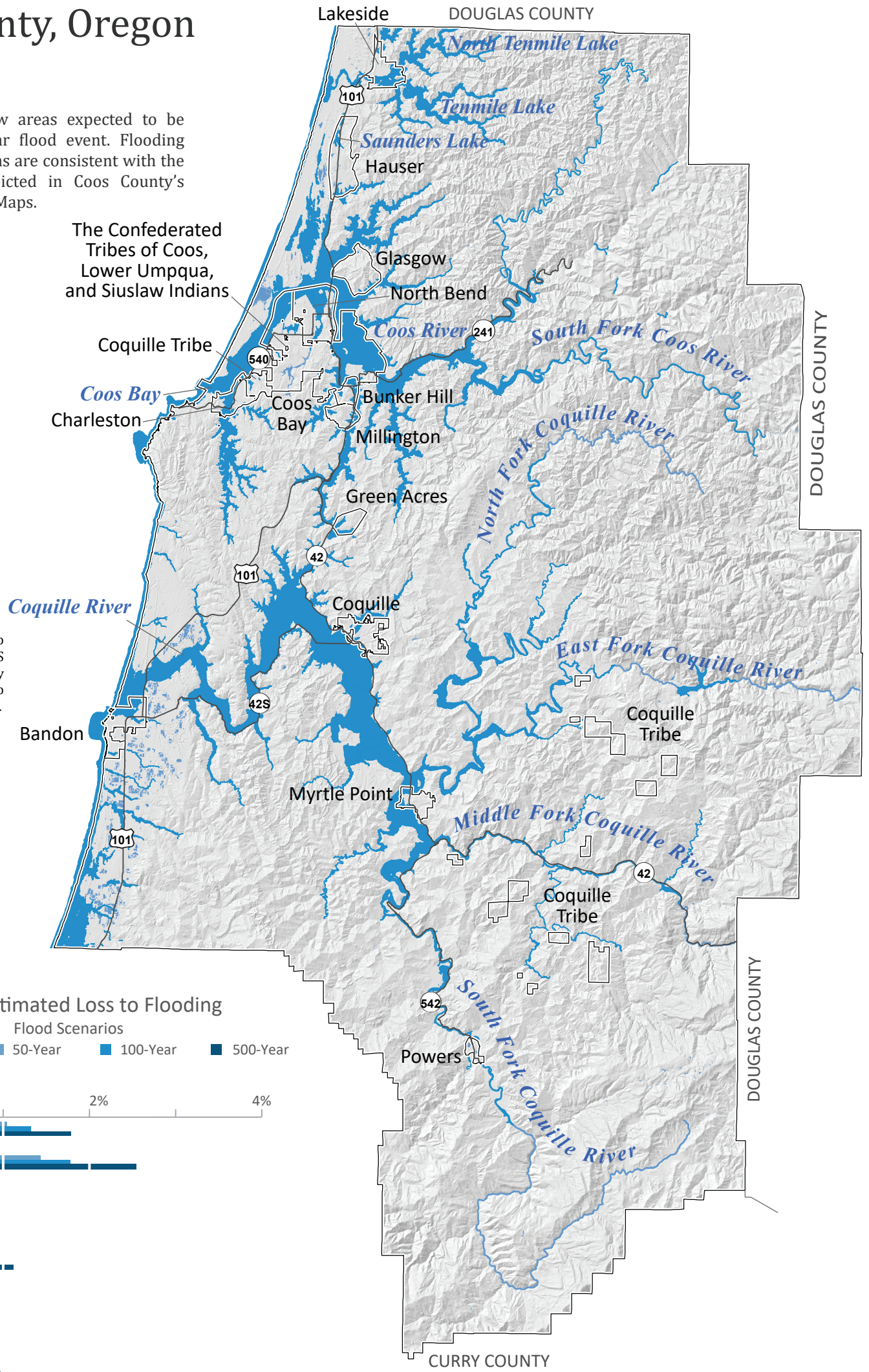

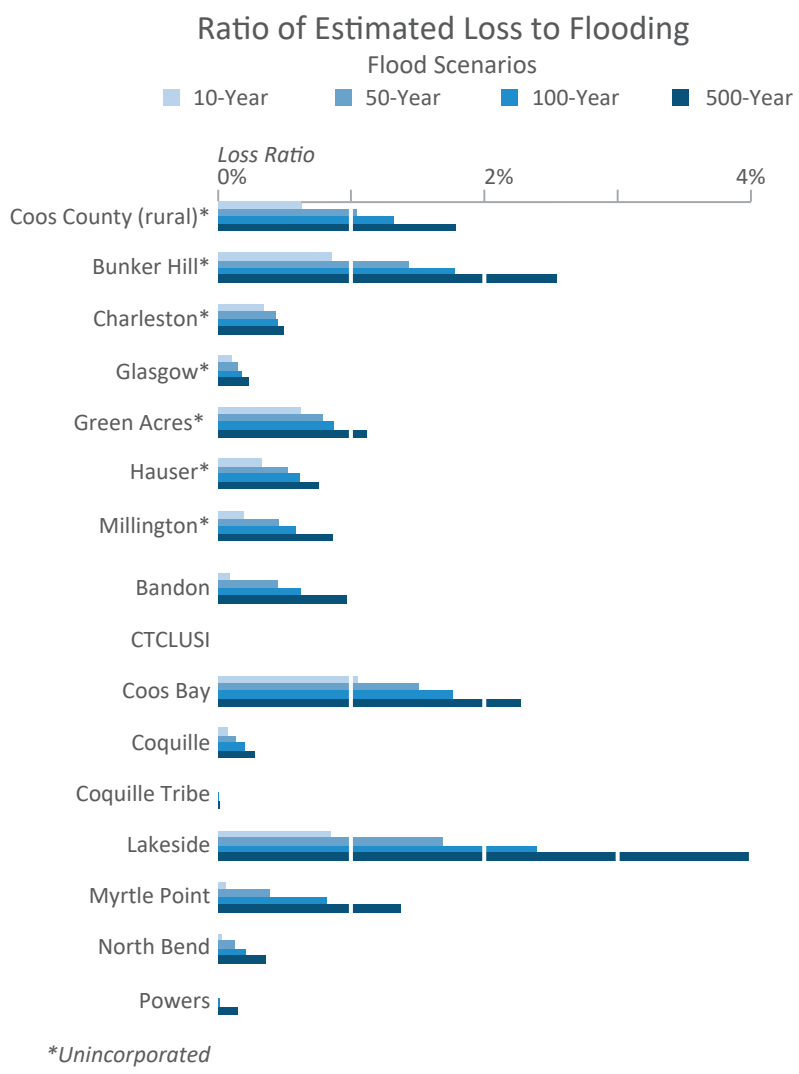

Data Sources:
Flood hazard zone (100-year): Coos County Flood Insurance Rate Map (2018)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey 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 CS6

Cartography by: Lowell H. Anthony, 2018

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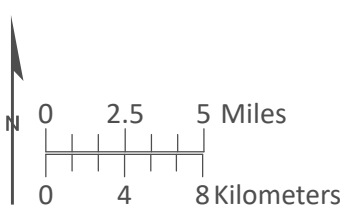

Landslide Susceptibility Map of Coos County, Oregon

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.

Landslide Susceptibility

- Low
- Moderate
- High
- Very High

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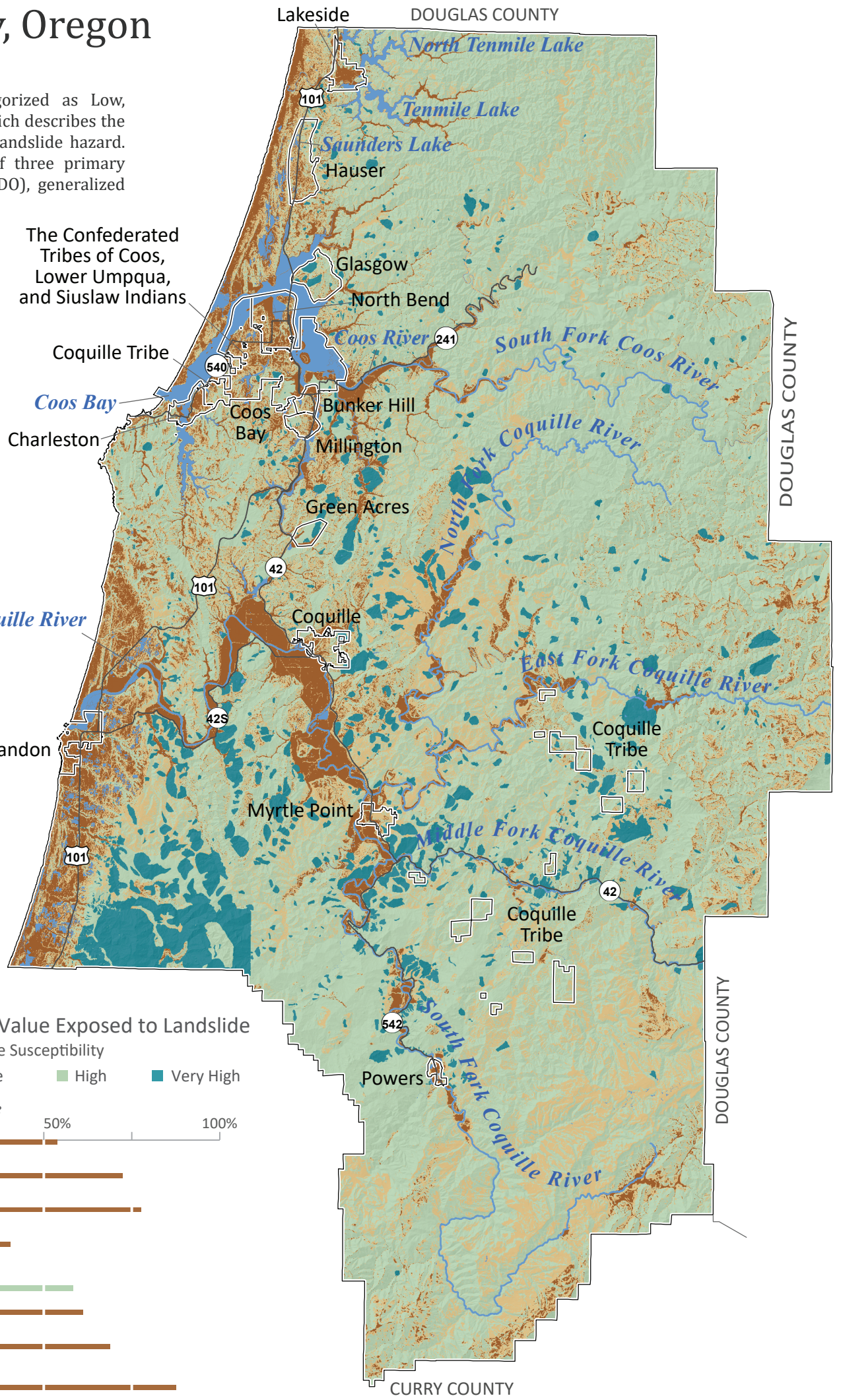

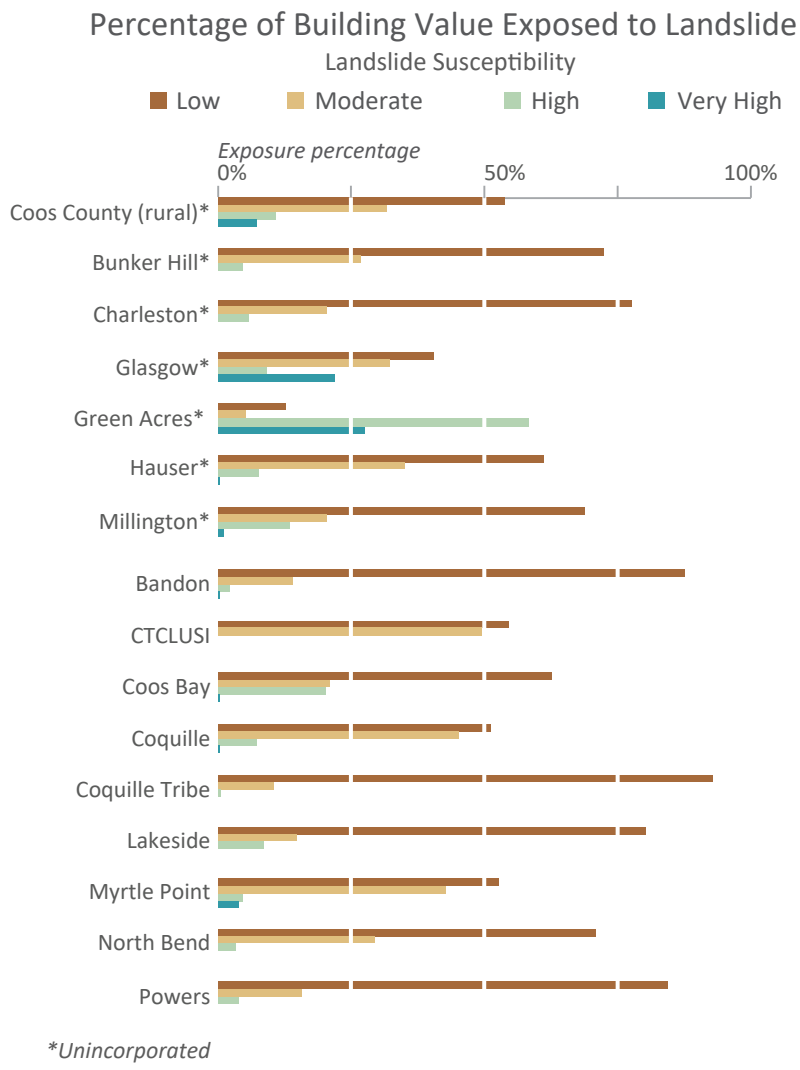

Data Sources:
Landslide susceptibility: Oregon Department of Geology, Burns and others (2016)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)
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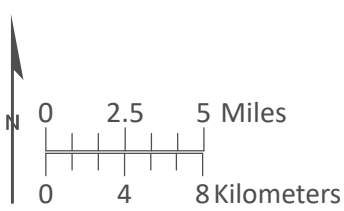

Wildfire Risk Map of Coos County, Oregon

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 (Fire Risk Index) is derived from a combination of the Fire Threat Index (fire history and behavior) and the Fire Effects Index (infrastructure and assets).

Wildfire Risk

- Low
- Moderate
- High

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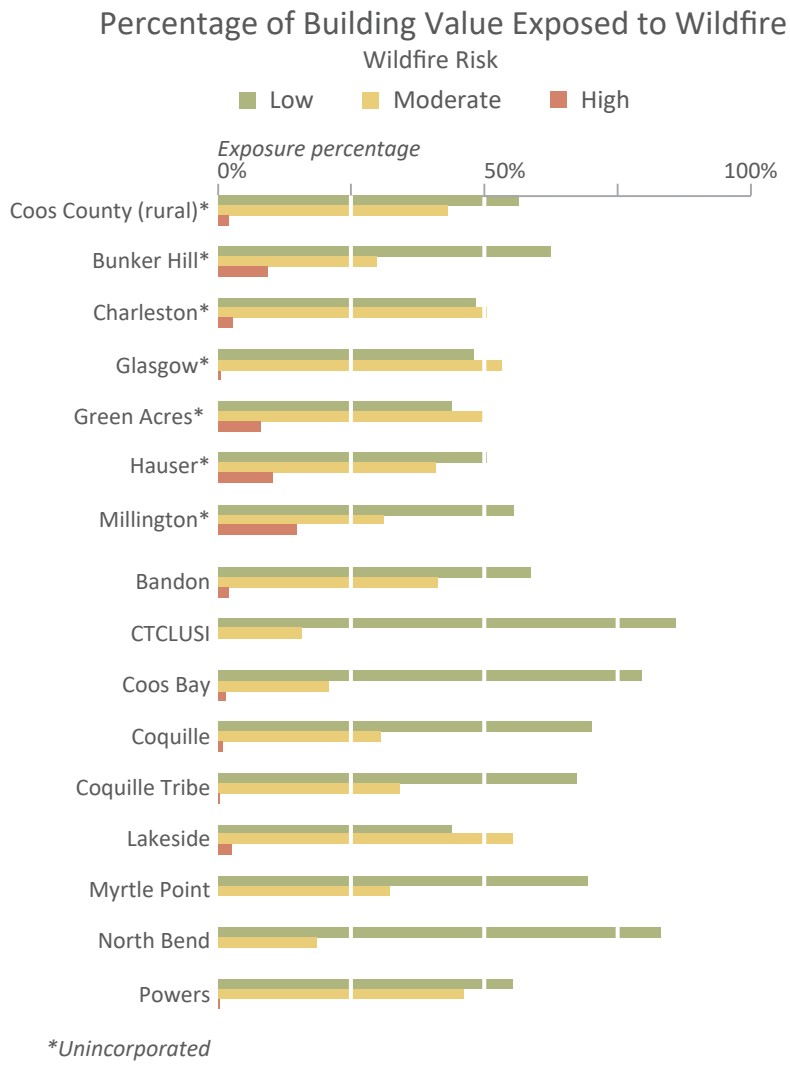

Data Sources:
Wildfire risk data: Oregon Department of Forestry, Sanborn Map Company, Inc. (2013)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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