Chapter 4.7
Tsunami Hazard Risk Assessment

Introduction

Tsunamis are rare in Washington, but they have struck throughout the Pacific Northwest in the past. We are reminded of their dangers and their chances of occurring by the tsunami evacuation route signs that are visible throughout Washington's coastal communities.

Tsunamis are among the world's deadliest natural hazards. The United States Geological Survey (USGS) reports that the 2004 Indian Ocean tsunami reached heights of 65 to 100 feet in Sumatra and caused over 200,000 deaths from Indonesia to East Africa.[1] The 1964 Alaska tsunami killed 110 people, with some fatalities occurring as far as Crescent City, California. Although there is scant evidence of a major tsunami inundating Thurston County's shoreline, a computer model simulating a Cascadia Subduction Zone (CSZ) source tsunami shows the South Puget Sound is not risk free.

Tsunami evacuation routes lead people to high ground

Definition

Tsunamis are a series of massive ocean waves triggered by earthquakes. They are generated by a sudden change in the sea floor elevation (uplift or subsidence) which displaces a significant volume of water that travels as waves in all directions. They can travel up to 500 miles per hour in the deep water. Tsunamis can also occur in inland waters and the Puget Sound. Inland tsunamis are initiated by onshore landslides, submarine landslides, and volcanic eruptions where a large land mass of falling debris could generate a hazardous wave.

Subduction zone earthquakes can generate Tsunamis that are tens to thousands of kilometers in length and 10 to 45 meters tall. They can travel across oceans and threaten shoreline communities around the entire Pacific Rim. The movement and behavior of tsunamis is complex. Most tsunamis do not result in giant breaking waves. Rather they behave more like very strong and fast-moving tides. Inundation can last for several hours from multiple wave sets. Tsunamis can travel much farther inland than normal waves. Tsunamis cause damage and destruction by flooding, wave impacts, erosion, strong currents, and floating debris such as logs, vehicles, and structures.

Area of Impact

For the purposes of the risk assessment, the tsunami hazard area for Thurston County is defined by the modeled tsunami inundation zone from a CSZ magnitude 9 earthquake scenario produced by the Washington State Department of Natural Resources (WADNR). [2] This planning level geographical delineation (Map 4.7.1) was then related to Thurston County Assessor parcel data to estimate the region's population and assets that are potentially vulnerable to tsunami risks.

Communities Most Vulnerable to a Tsunami

Low lying areas, estuaries, and the inlets of Thurston County will be subject to inundation. The tidal condition and the level of subsidence a coastline experiences from a major earthquake can also influence the extent of inundation. The WADNR model scenario infers that most of Thurston County's marine shoreline will experience tsunami activity. The risk assessment GIS exposure analysis shows every inlet in Thurston County is potentially at risk for land and property impacts. Unincorporated Thurston County and the City of Olympia have people, homes, and other assets that are in the tsunami inundation zone.

Extent

WADNR describes four types of tsunami risks that threaten Washington's coastal communities. Figure 4.7.1 describes their area of impact and the time needed to evacuate from the hazard area.[3]

Figure 4.7.1 Types of Tsunamis risks in Washington

Tsunami Type	Description	Area of greatest impact	Time to evacuate
Distant	A tsunami is created by a distant earthquake or landslide and travels across the ocean	Pacific coastal communities	Hours
Cascadia subduction zone	Tsunami created by large Magnitude 8–9 earthquake off the Washington, Oregon, or British Columbia coasts	Pacific coastal communities	Tens of minutes*
Local earthquake (for example, the Seattle or Tacoma faults)	Tsunami created in large body of water from an earthquake on local faults	Communities close to the body of water	Minutes to tens of minutes
Landslide-caused tsunami	Large landslide occurs underwater or slides from land into water	Depends on where the landslide occurs	Minutes to tens of minutes

Note: Evacuation time for a Cascadia earthquake tsunami for Puget Sound communities is hours

In 2021, WADNR published a map series and report on tsunami inundation areas from a CSZ earthquake generated tsunami. The scenario focused on modeling maximum tsunami inundation and timing of waves for the Puget Sound and its adjacent waters. Thurston County marine shorelines are included in the study. This section highlights the general findings of the tsunami model scenario results.

Tsunami waves would impact communities from Blaine at the U.S./Canada border to Olympia. After the onset of the earthquake, the tsunami wave would reach Blaine in approximately two hours and five minutes and Olympia in approximately four hours. The model estimates that wave troughs would precede crests in all locations. The leading trough would look similar to a sudden low tide. This would provide visual warning (in addition to strong and extended ground shaking) that a tsunami would be imminent.

Inundation

Inundation is the depth of tsunami-induced flooding over previously dry land. The model forecasts the tsunami will flood many low-lying regions along the Puget Sound. Inundation depths are dependent on the topography and may reach or exceed 10 feet in locations such as Bellingham, Deception Pass State Park, Vashon Island Ferry Terminal, Theler Wetlands near Belfair, and other areas. Inundation could extend well into many other populated areas such as Skagit and Snohomish counties lowlands and the Port of Tacoma. Significant river floodplain inundation could also occur upstream for the Skagit, Stillaguamish, Quilcene, Duckabush, Skokomish, Nisqually, and other rivers. The tsunami model does not account for the influences of tidal changes or projections in sea level rise.

Inundation estimates are noted for the following areas in Thurston County:

- Nisqually Delta North, 11.5 feet
- Nisqually Delta South, 1.4 feet
- Nisqually Delta, End of Boardwalk, at the Billy Frank Jr. National Wildlife Refuge, 2.9 feet
- Port of Olympia Marine Terminal, 0.5 feet
- Eld Inlet, 5 feet
- Oyster Bay, 5.7 feet

Current Speed

The speed of a tsunami depends on the depth of water; the deeper the faster. In the Puget Sound, the current speed could range from 1 to greater than 9 knots (1 knot is approximately 1.15 land miles per hour). Figure 4.7.2 shows ranges of current speed and the approximate hazards to port, ship, and docking facilities. Tsunamis slow as they reach shallow waters near land, however they can maintain speeds of 20 to 30 miles per hour.

Figure 4.7.2 Potential Damage by Current Speed

Speed (knots)	Potential damage
0-3	No expected damage
3-6	Minor/moderate damage possible
6-9	Major damage possible
>9	Extreme damage possible

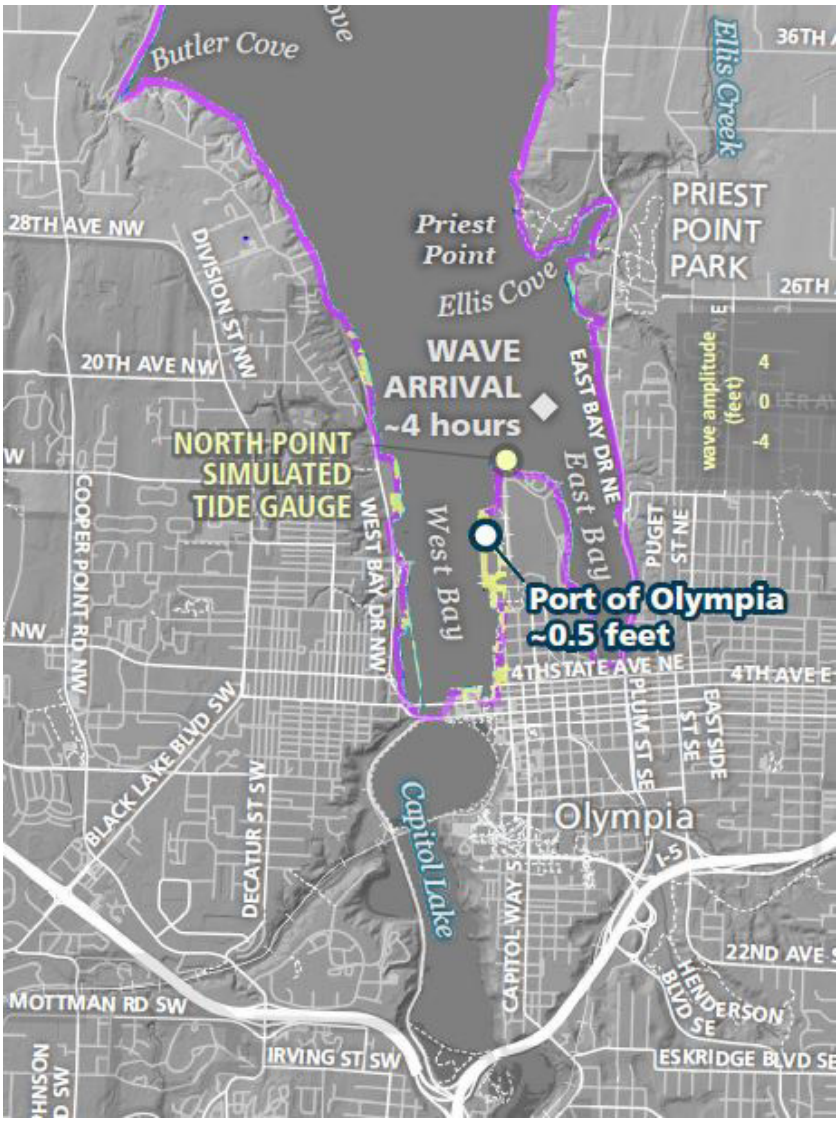
The tsunami model scenario estimates the following areas will experience current speeds of 3 knots or greater:

- Nisqually Delta Boardwalk, 0-3 knots
- Johnson Point, 3-6 knots
- Dana Passage, 10 knots
- Little Fishtrap to Big Fishtrap, 6-9 knots Squaxin Passage, 7 knots
- Port of Olympia Marine Terminal, 0-3 knots
- Edgewater Beach (near Cooper Point), 3-6 knots
- Squaxin Passage, 7 knots
- Oyster Bay, 0-3 knots

Timing of Tsunami Arrival

The estimated time of wave arrival for a given location correspond to the time that has elapsed from the beginning of earthquake shaking to the time when water first rises above the mean high water level. This timing doesn't account for the receding water levels that precede the first incoming wave. The first wave would not be the largest wave. Several minutes or hours could pass between the first wave arrival and the wave that produces the maximum current speed, inundation depth, or inundation extent.

At Olympia's North Point (near KGY Radio station), there will be a gradual drop in sea level by approximately 3 feet approximately three hours after the start of the earthquake. In



Inundation at the Port of Olympia is estimated to be a half-foot and the peak wave will arrive approximately 10 hours after the earthquake.

approximately four hours and 15 minutes after the earthquake, a wave of three feet will arrive. The largest wave is estimated to be the fourth wave (four feet) that arrives approximately 10 hours after the earthquake. Wave activity may last for 14 or more hours following the earthquake.

Effects of Climate Change

In general, tsunami hazards are not a climate change aggravated natural hazard. However, sea level rise, depending on the tide during a tsunami event would influence the depth and extent of tsunami inundation areas. It was beyond the scope of the WADNR study and modeling to account for the effects of sea level rise.

Previous Incidents

Historic Pacific Northwest Tsunamis

Thurston County has never experienced a tsunami event in recorded history. However, there is a history of local and distant tsunamis across the U.S. Pacific Coast.

The March 27, 1964 magnitude 9.2 subduction zone earthquake in Alaska caused ground shaking for three minutes. A tsunami ensued and impacted areas throughout the entire Pacific Ocean. The Tsunami was responsible for 110 deaths. It also caused a large submarine landslide which produced a separate 200-foot tsunami in Valdez Inlet.

Geologic evidence such as sediment deposits, ghost forests in Washington and Oregon, and records from Japan reveal that a large (M8.7-9.0) earthquake occurred off the Washington/Oregon coast. Scientists estimate it occurred in January 1700 and produced nearly a 100-foot tsunami.

Probability of Occurrence

The likelihood of a large tsunami striking Thurston County as described in this risk assessment is tied to the probability for a large Cascadia Subduction Zone earthquake. While estimates vary, there is about a 37 percent chance of a megathrust 7.1+ magnitude earthquake occurring in the next 50 years.[4] This region's earthquake risk assessment categorizes earthquake as a medium probability – a major earthquake occurring within 100 years. For the region and communities with municipal boundaries or service areas that adjoin the Puget Sound shoreline a medium probability for tsunami is assigned. All other jurisdictions are characterized as having a low probability.

Vulnerabilities and Impacts

Impacts to People

Tsunamis are very dangerous due to their speed and volume of water. In the U.S., tsunami warnings are issued through the Emergency Alert System. Communities on Washington's outer coast are at greater risk for tsunami hazards due to the short time available for evacuation.

Tsunamis can kill or injure people and result in mass casualties. A destructive CSZ tsunami will impact and displace people in neighboring coastal communities. Thurston County's

location between I-5 and US 101 makes the region a logical hub for evacuation and recovery support activities for Washington's central coastal communities. Thurston County will likely experience a surge in displaced individuals and families seeking safe refuge from disaster struck coastal areas.

An estimated 109 people in Unincorporated Thurston County and 52 people in Olympia are in the mapped tsunami inundation area and are potentially at risk for tsunami hazards (Table 4.7.1).

Table 4.7.1 Thurston County Population Residing in the Tsunami Inundation Areas

Jurisdiction	Population	Population Exposed	% Population Exposed
Bucoda	610	0	0%
Lacey	58,180	0	0%
Olympia	56,370	52	0.1%
Rainier	2,510	0	0%
Tenino	2,030	0	0%
Tumwater	26,360	0	0%
Yelm	10,680	0	0%
Unincorporated Thurston County	143,760	109	0.1%
Total Planning Area	**300,500**	**161**	**0.1%**

Impacts to Structures and Systems

Earthquake generated tsunami damage will likely be secondary to impacts from the direct ground shaking effects of an earthquake. Tsunamis can cause damage and destruction of homes, businesses, ports and harbors, boats, utilities, and critical infrastructure and facilities such as roads, bridges, power transmission, and water and wastewater systems. Communications, ground and marine transportation, and health and public safety services may be disrupted. A substantial volume of debris could overwhelm existing waste disposal and debris management systems.

Crescent City, California experienced damage from the 2011 Japan tsunami, about 10 hours after the initial earthquake. Courtesy of NOAA

Impacts from tsunamis can cause other hazards such as structural fires, transportation accidents, and hazardous materials release.

There are an estimated 54 residential, 28 commercial, and 2 industrial buildings located in Thurston County's tsunami inundation zone. In total, there are 84 buildings valued over $94 million that are exposed to a large tsunami event (Tables 4.7.2 and 4.7.3). There are an estimated four community lifeline assets located in the tsunami inundation area (Table 4.7.4). Exposed assets include a wastewater pump station and three state highway bridges.

Table 4.7.2 Number of Structures in the Tsunami Inundation Area

	Number of Structures in Tsunami Inundation Areas							
Jurisdiction	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Bucoda	0	0	0	0	0	0	0	0
Lacey	0	0	0	0	0	0	0	0
Olympia	15	18	2	0	0	3	0	35
Rainier	0	0	0	0	0	0	0	0
Tenino	0	0	0	0	0	0	0	0
Tumwater	0	0	0	0	0	0	0	0
Yelm	0	0	0	0	0	0	0	0
Unincorporated Thurston County	39	10	0	0	0	0	0	49
Total	**54**	**28**	**2**	**0**	**0**	**0**	**0**	**84**

Table 4.7.3 Value of Structures and Contents in the Potential Tsunami Inundation Area

Jurisdiction	Total Buildings	Total Residential Buildings	Total Building & Contents Value	Buildings Exposed	Total Building & Contents Exposed	% Total Value
Bucoda	245	237	$63,726,655	0	$0	0.0%
Lacey	18,985	17,637	$17,357,526,547	0	$0	0.0%
Olympia	18,242	16,257	$19,116,213,011	35	$72,696,331	0.4%
Rainier	875	814	$393,003,023	0	$0	0.0%
Tenino	751	651	$404,778,123	0	$0	0.0%
Tumwater	9,513	8,408	$9,362,171,728	0	$0	0.0%
Yelm	3,139	2,827	$2,077,637,133	0	$0	0.0%
Unincorporated	53,104	817	$24,765,596,428	49	$22,215,710	0.1%
Total Planning Area	**104,854**	**817**	**$73,540,652,648**	**84**	**$94,912,042**	**0.1%**

Table 4.7.4 Thurston County Community Lifelines located in the Tsunami Inundation Area

Location in Planning Area	Comm-unications	Energy	Food, Water, Shelter	Hazardous Material	Health & Medical	Safety & Security	Trans-portation	Total
Bucoda	0	0	0	0	0	0	0	0
Lacey	0	0	0	0	0	0	0	0
Olympia	0	0	1	0	0	0	0	0
Rainier	0	0	0	0	0	0	0	0
Tenino	0	0	0	0	0	0	0	0
Tumwater	0	0	0	0	0	0	0	0
Yelm	0	0	0	0	0	0	0	0
Unincorporated Thurston County	0	0	0	0	0	0	3	3
Total Planning Area	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**4**

Impacts to Natural, Cultural, and Historic Resources

Tsunami induced erosional forces, pollutants and toxic substances, sediment deposition, and marine debris can create near-term or permanent adverse impacts to agricultural lands and on and offshore natural resources. There could be loss of wildlife habitat and changes to the quality and availability of fresh water due to inundation by salt water. Changes to these resources can be detrimental to areas that are valued by communities and tribes for their economic, ecological, and recreational benefits. The Nisqually River Delta and portions of the Billy Frank Jr. Nisqually National Wildlife Refuge are estimated to receive 1.4 feet of inundation.

Impacts to Activities

Earthquake and tsunami losses will impact the region's economy. Communities throughout the Pacific Northwest will be challenged with recovery and rebuilding activity due to transportation disruptions, critical shortages of construction materials, contractors, skilled labor, and equipment.

Risk Ratings

Social Vulnerability Rating and National Risk Index

Social vulnerability is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. As a

consequence enhancing risk component of the National Risk Index, a Social Vulnerability score and rating represent the relative level of a community's social vulnerability compared to all other communities at the same level. A community's Social Vulnerability score measures its national rank or percentile. A higher Social Vulnerability score results in a higher Risk Index score. Map 4.7.2 shows assets and structures in Thurston County that are located in the tsunami inundation areas by census tract social vulnerability ratings. Most areas affected by tsunami have a rating that ranges from very low to relatively moderate.

The Federal Emergency Management Agency National Risk Index (NRI) reports Thurston County's tsunami Index score as zero. The rating represents a community's relative risk for tsunami when compared to the rest of the United States. For comparison, Pierce County's NRI tsunami score is 86.5, a relatively moderate ranking. The NRI reports an estimated tsunami hazard annual loss of $0.

Community Hazard Risk Ratings for the Tsunami Inundation Areas

The countywide tsunami risk ranking score is 12, and Olympia's score is 6, both are low risk. Tsunami risk ranking scores are zero for most other communities. Tables 4.7.5 and 4.7.6 show community and special purpose tsunami hazard risk ratings). The details of the tsunami hazard risk assessment calculations are shown in Appendix C.

Table 4.7.5 Community Tsunami Hazard Risk Ratings

Municipal Plan Participants	Tsunami Hazard Risk Ranking Score	Risk Rating
Bucoda	0	Low
Lacey	0	Low
Olympia	12	Low
Rainier	0	Low
Tenino	0	Low
Tumwater	0	Low
Yelm	0	Low
Unincorporated Thurston County	12	Low
Total Planning Area	**12**	**Low**

Table 4.7.6 Special Purpose District Tsunami Hazard Risk Ratings

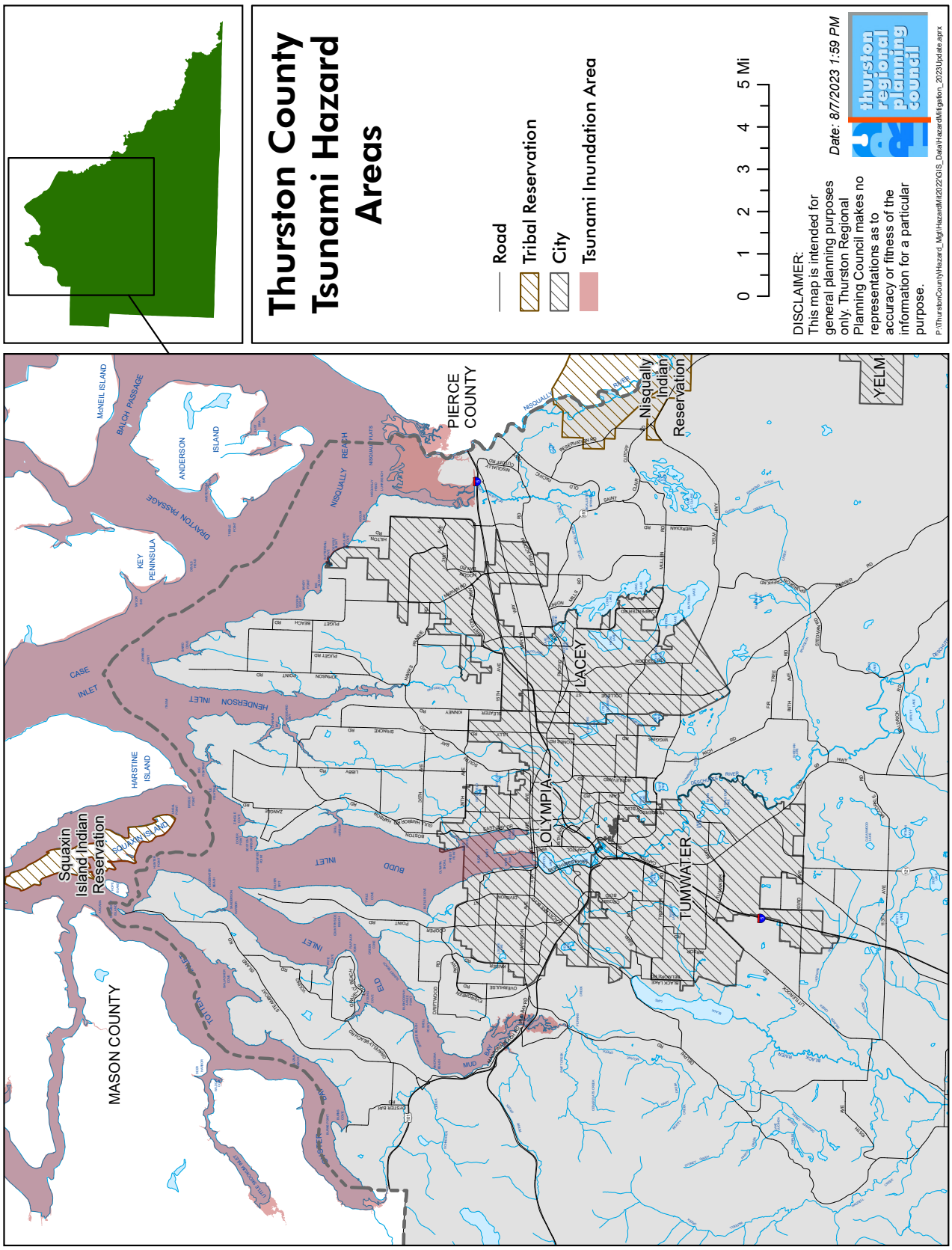
	Tsunami Hazard	
Special Purpose District Plan Participants	Risk Ranking Score	Risk Rating
East Olympia Fire District	0	Low
Intercity Transit	0	Low
Lacey Fire District	0	Low
McLane Black Lake Fire District	6	Low
Olympia School District	6	Low
SE Thurston Fire Authority	0	Low
South Bay Fire District	6	Low
The Evergreen State College	0	Low
Thurston PUD	6	Low
West Thurston Regional Fire Authority	0	Low

Changes in Tsunami Hazard Risks Since Last Plan Update

Tsunami inundation maps were unavailable to perform a vulnerability analysis and risk assessment during the development of the 2017 Hazard Mitigation Plan. The 2023 plan update process identified that approximately 0.1 percent of the population, 0.1 percent of assessed value of structures, and four community lifeline assets are potentially at risk for tsunami hazards. This provides a baseline tsunami hazard assessment for future evaluation of the region's tsunami vulnerabilities and risk.

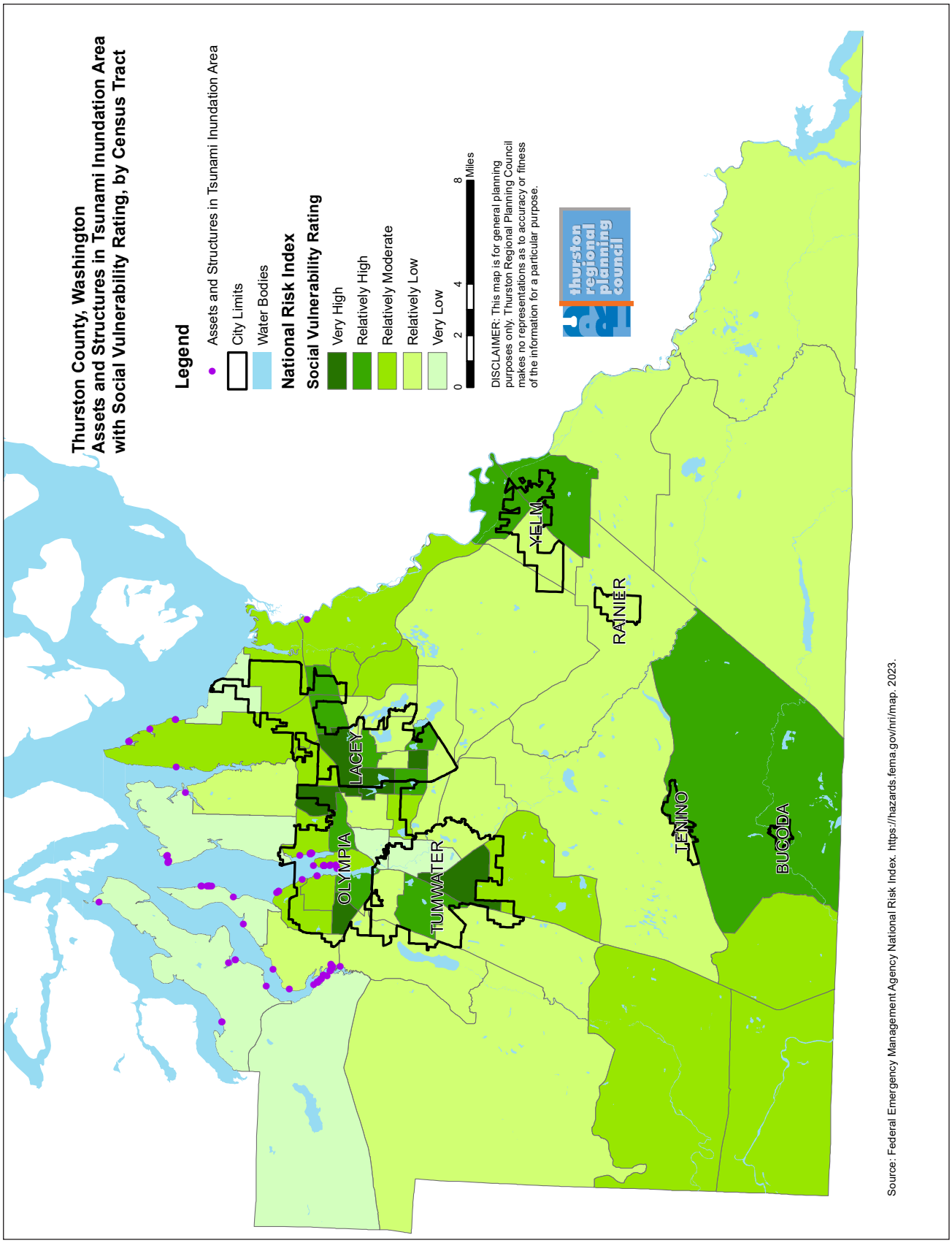
Connection to the Regional Mitigation Strategy

The 2022 "Thurston County Communities Natural Hazards and Resiliency Survey" results show that City of Olympia and Unincorporated Thurston County residents ranked tsunami as the lowest rated hazard of concern. This is expected considering the region has never experienced a tsunami and the probability of occurrence is low. Nonetheless, tsunami hazard education and preparedness for community residents is useful, both for its applicability to mitigation measures but also awareness to promote preparedness for residents who visit coastal communities. Tsunami hazard information will be included through the Regional Hazard Mitigation Public Outreach Strategy initiative.



Map 4.7.1 Tsunami Inundation Areas of Thurston County

Map 4.7.2 Exposed Assets and Structures in Tsunami Inundation Area and Thurston County Social Vulnerability Index Rating by Census Tract



Source: Federal Emergency Management Agency National Risk Index. https://hazards.fema.gov/nri/map. 2023.

Endnotes

[1]USGS. 2023. Tsunami Hazards Fact Sheet: https://pubs.usgs.gov/fs/2006/3023/2006-3023.pdf

[2]Dolcimascolo, Alexander, et. al. 2022. Tsunami hazard maps of the Puget Sound and adjacent waters – Model results from an extended L1 Mw 9.0 Cascadia subduction zone megathrust earthquake scenario: Washington Geological Survey Map Series 2021-01, originally published 2021. https://fortress.wa.gov/dnr/geologydata/tsunami_hazard_maps/ger_ms2021-01_tsunami_hazard_puget_sound.zip

[3]Washington State Department of Natural Resources. 2023. Geological Hazards Website: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis#tsunamis-in-washington.

[4]Oregon Office of Emergency Management. 2023. Hazards Website: https://www.oregon.gov/oem/hazardsprep/pages/cascadia-subduction-zone.aspx#:~:text=Currently%2C%20scientists%20are%20predicting%20that,in%20the%20next%2050%20years.