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Distant Source (Alaska-Aleutian Subduction Zone) Tsunami Inundation Map Toledo, Oregon

2013

Tsunami Inundation Map Linc-08
Tsunami Inundation Maps for Toledo, Lincoln County, Oregon
Plate 2

Introduction

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been identifying and mapping the tsunami inundation hazard along the Oregon coast since 1994. In Oregon, DOGAMI manages the National Tsunami Hazard Mitigation Program, which has been administered by the National Oceanic and Atmospheric Administration (NOAA) since 1995. DOGAMI's work is designed to help cities, counties, and other sites in coastal areas reduce the potential for disastrous tsunami-related consequences by understanding and mitigating this geologic hazard. Using federal funding awarded by NOAA, DOGAMI has developed a new generation of tsunami inundation maps to help residents and visitors along the entire Oregon coast prepare for the next Cascadia Subduction Zone (CSZ) earthquake and tsunami, as well as for far-travelled, or "distant" tsunamis.

The "Ring of Fire", also called the Circum-Pacific belt, is the zone of earthquake activity surrounding the Pacific Ocean. It is an arc stretching from New Zealand, along the eastern edge of Asia, north across the Aleutian Islands of Alaska, and south along the coast of North and South America (Figure 1). The Ring of Fire is located at the borders of the Pacific Plate and other major tectonic plates. The Pacific Plate is colliding with and sliding underneath other plates creating subduction zones that eventually release energy in the form of an earthquake rupture. This rupture causes a vertical displacement of water that creates a tsunami. When these events occur around the Ring of Fire but not directly off the Oregon coast, they take more time to travel the Pacific Ocean and arrive onshore in Oregon (Figure 2). Distant earthquake/tsunami events have affected the Oregon coast: for example, offshore Alaska in 1964 and offshore Japan in March 2011.

Historically, about 28 distant tsunamis have been documented by Oregon tide gauges since 1854. The most severe was generated by the 1964 M9.2 Prince William Sound earthquake in Alaska. Oregon was hit hard by the tsunami, which killed four people and caused an estimated 750,000 to 1 million dollars in damage to bridges, houses, cars, boats, and sea walls. The greatest tsunami damage in Oregon did not occur along the ocean front as one might expect, but in the estuary channels located further inland. Of the communities affected, Seaside was inundated by a 10 foot tsunami wave and was the hardest hit. Tsunami wave heights reached 10 to 11.5 feet in the Nehalem River, 10 to 11.5 feet at Depoe Bay, 11.5 feet at Newport, 10 to 11 feet at Florence, 11 feet at Reedsport, 11 feet at Brookings, and 14 feet at Coos Bay (Witter and others, 2011).

Alaska-Aleutian Model Specifications: DOGAMI modeled two distant earthquake and tsunami scenarios involving M9.2 earthquakes originating near the Gulf of Alaska. The first scenario attempts to replicate the 1964 Prince William Sound event, and the second scenario represents a hypothetical maximum event. This maximum event is the same model used by the U.S. Geological Survey (USGS) in their 2006 tsunami hazard assessment of Seaside (TPSW, 2006). This model uses extreme fault model parameters that result in maximum seafloor uplift, nearly twice as large as in the 1964 earthquake. The selected source location on the Aleutian chain of islands also shows higher energy directed toward the Oregon coast than other Alaskan source locations. For these reasons the hypothetical "Alaska Maximum" scenario is selected as the worst case distant tsunami scenario for Oregon. Detailed information on fault geometries, subsidence, computer models, and the methodology used to create the tsunami scenarios presented on this map can be found in DOGAMI Special Paper 43 (Witter and others, 2011).

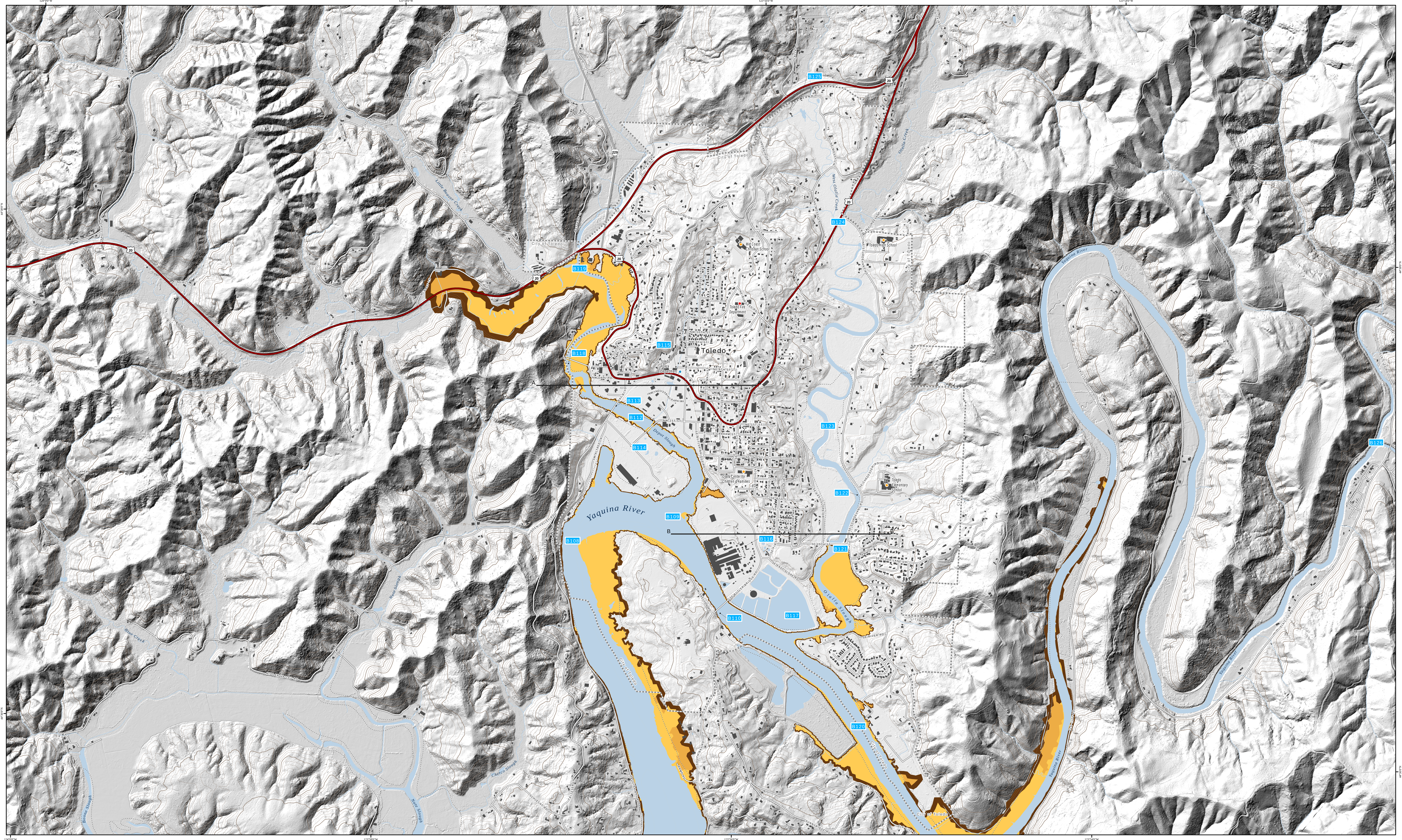
Map Explanation

This tsunami inundation map displays the output of computer models representing the two selected tsunami scenarios: Alaska M9.2 (1964) and the Alaska Maximum. All tsunami simulations were run assuming that prevailing tide was static (no flow) and equal to Mean Higher High Water (MHHW) tide; MHHW is defined as the average height of the higher high tides observed over an 18-year period at the Yaquina Bay (Central Coast Model) tide gauge. The map legend depicts the respective amounts of deformation and the earthquake magnitude for these two scenarios. Figure 3 shows the cumulative number of buildings inundated within the map area.

The computer simulation model output is provided to DOGAMI as millions of points with values that indicate whether the location of each point is wet or dry. These points are converted to wet and dry contour lines that form the extent of inundation. The transition area between the wet and dry contour lines is termed the Wet/Dry Zone, which equates to the amount of error in the model when determining the maximum inundation for each scenario. Only the Alaska Maximum Wet/Dry Zone is shown on this map.

This map also shows the regulatory tsunami inundation line (Oregon Revised Statutes 455.446 and 455.447), commonly known as the Senate Bill 379 line. Senate Bill 379 (1995) instructed DOGAMI to establish the area of expected tsunami inundation based on scientific evidence and tsunami modeling in order to prohibit the construction of new essential and special occupancy structures in this tsunami inundation zone (Priest, 1995).

Time Series Graphs and Wave Elevation Profiles: In addition to the tsunami scenarios, the computer model produces time series data for "gauge" locations in the area. These points are simulated gauge stations that record the time, in seconds, of the tsunami wave arrival and the wave height observed. It is especially noteworthy that the greatest wave height and velocity observed are not necessarily associated with the first tsunami wave to arrive onshore. Therefore evacuees should not assume that the tsunami event is over until the proper authorities have sounded the all-clear at the end of the evacuation. Figure 4 depicts the tsunami waves as they arrive at a simulated gauge station. Figure 5 depicts the overall wave height and inundation extent for the two scenarios at the profile locations shown on this map.



Ring of Fire

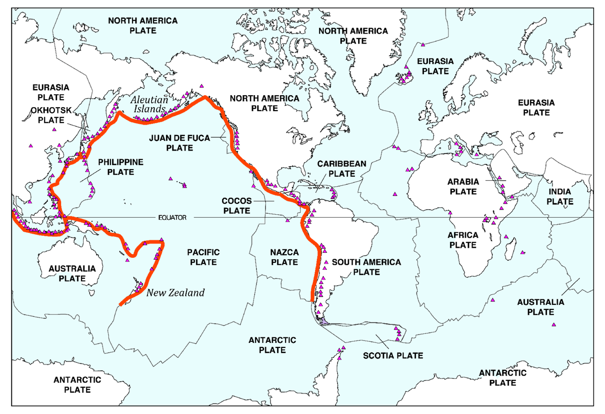


Figure 1: The "Ring of Fire" is a zone of active earthquakes and volcanoes that rings much of the Pacific Ocean, including the Oregon coast. Volcanoes and earthquakes on this ring are caused by the movements of tectonic plates. One type of movement is called subduction — when thin, oceanic plates, such as those that compose the rock beneath the Pacific Ocean, sink beneath thicker, lighter plates that make up continental plates. Earthquakes that occur as a result of subduction can trigger tsunamis.

Prince William Sound 1964 M9.2 Earthquake and Tsunami Travel Time Map

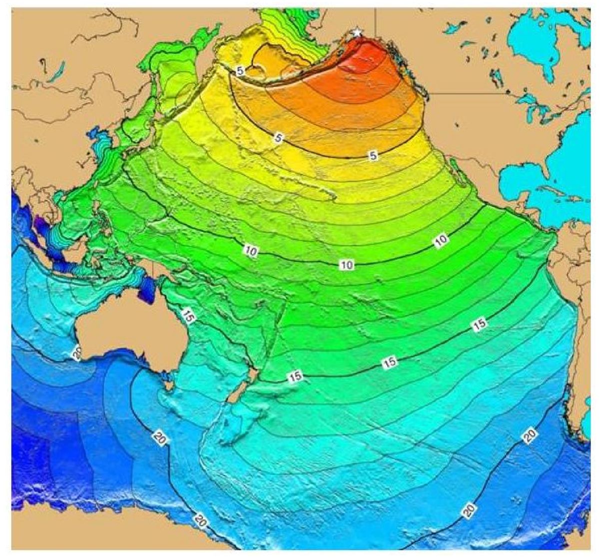


Figure 2: This image depicts the actual initial tsunami arrival times, in hours, around the Pacific Rim from the 1964 Prince William Sound earthquake. This magnitude 9.2 earthquake and resulting tsunami caused 125 deaths and $311 million in property loss, $84 million and 106 deaths in Alaska (NGDC/WDC). The tsunami devastated many towns along the Gulf of Alaska, left serious damage in British Columbia, Hawaii, and along the west coast of the United States, and was recorded on tide gauges in Cuba and Puerto Rico.

Buildings within Tsunami Inundation Zones

	Entire Map Area	Toledo	Unincorporated Areas
Total Buildings	2,810	2,051	759
Buildings within Tsunami Zones*			
Alaska M9.2 (1964)	9	8	1
Alaska Maximum	20	14	6
Percent of Buildings within Tsunami Zones			
Alaska M9.2 (1964)	0.3%	0.4%	0.1%
Alaska Maximum	0.7%	0.7%	0.8%

*Building counts shown are based on polygon centroids and are cumulative within the map area.

Figure 3: The table and chart show the number of buildings inundated for the Alaska M9.2 (1964) and the Alaska Maximum tsunami scenarios for cities and unincorporated portions of the map.

Estimated Tsunami Wave Height through Time for Simulated Gauge Station

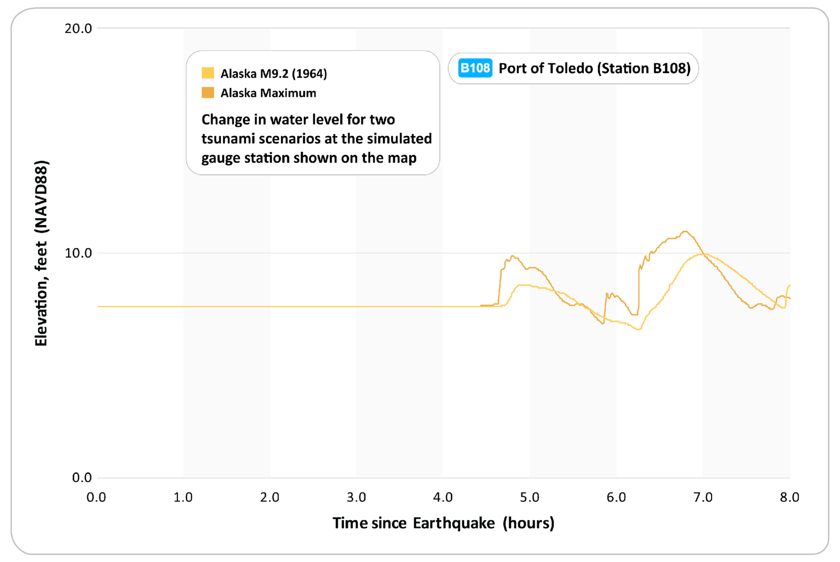


Figure 4: This chart depicts the tsunami waves as they arrive at the selected reference point (simulated gauge station). It shows the change in wave heights for the two Alaska tsunami scenarios over an 8-hour period. Wave heights vary through time, and the first wave will not necessarily be the largest as waves interfere and reflect off local topography and bathymetry. Any absence of data indicates periods for which tsunami inundation has not yet reached or has receded from the station location and dry land is exposed.

Maximum Wave Elevation Profiles

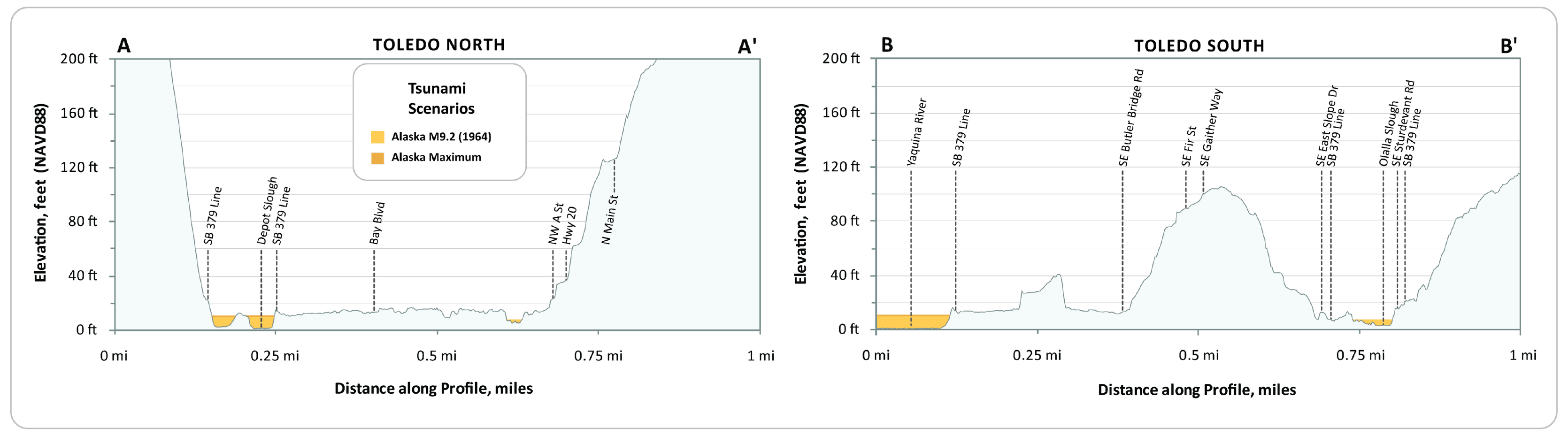


Figure 5: These profiles depict the expected maximum tsunami wave elevation for the two Alaska tsunami scenarios along lines A-A' and B-B'. The tsunami scenarios are modeled to occur at a static (no flow) tide and equal to the Mean Higher High Water (MHHW) high tide.

APPROXIMATE MEAN MAGNETIC DECLINATION JANUARY 1, 2012

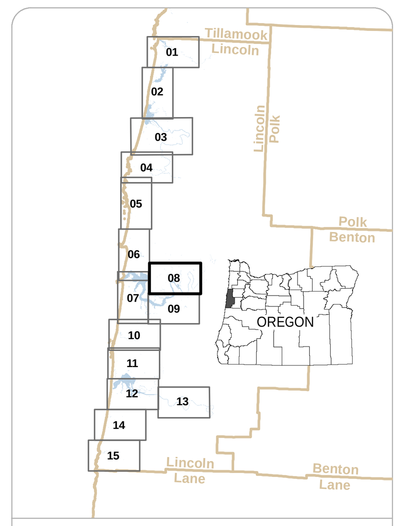
Scale 1:10,000

Legend

Earthquake Size	Slip / Deformation	Earthquake Magnitude
Alaska M9.2 (1964)	Vertical seafloor deformation estimate.	~9.2
Alaska Maximum	Uniform slip on 12 subfaults with each assigned values ranging from 49 to 98 feet.	~9.2
Alaska Maximum Wet/Dry Zone		

Urban Growth Boundary
Building Footprint
Simulated Gauge Station
Profile Location
Senate Bill 379 Line
State Park
Elevation Contour (25 ft intervals up to 200 ft)
Fire Station
Police Station
School
Hospital/Urgent Care Clinic
U.S. Highway
State Highway
Improved Road

Tsunami Inundation Map Index



Linc-01 Lincoln City North
Linc-02 Lincoln City South
Linc-03 Gleneden Beach - Siletz River
Linc-04 Depoe Bay
Linc-05 Otter Rock - Beverly Beach
Linc-06 Newport North
Linc-07 Newport South
Linc-08 Toledo
Linc-09 Yaquina River
Linc-10 Seal Rock
Linc-11 Driftwood Beach
Linc-12 Waldport
Linc-13 Tidewater
Linc-14 Ocean Shores
Linc-15 Yachats

Data References

Source Data:
This map is based on hydrodynamic tsunami modeling by Joseph Zhang, Oregon Health and Science University, Portland, Oregon. Model data input were created by John T. English and George R. Priest, Department of Geology and Mineral Industries (DOGAMI), Portland, Oregon.

Hydrology data, contours, critical facilities, and building footprints were created by DOGAMI. Senate Bill 379 line data were redigitized by Rachel L. Smith and Sean G. Pickner, DOGAMI, in 2011 (GIS file set, in press, 2012).

Urban growth boundaries (2011) were provided by the Oregon Department of Land Conservation and Development (DLCD).

Transportation data (2007) provided by Lincoln County were edited by DOGAMI to improve the spatial accuracy of the features or to add newly constructed roads not present in the original data layer.

Lidar data are from DOGAMI Lidar Data Quadrangles LDQ-2011-44123-E7-Elk City, LDQ-2011-44123-E8-Toledo South, LDQ-2011-44123-F7-Eddyville, LDQ-2011-44123-F8-Toledo North, LDQ-2011-44124-E1-Newport South, and LDQ-2011-44124-F1-Newport North; additional unpublished lidar data flown 2011.

Coordinate System: Oregon Statewide Lambert Conformal Conic, Unit: International Feet, Horizontal Datum: NAD 1983 HARN, Vertical Datum: NAVD 1988.

Software: Esri ArcGIS® 10.1, Microsoft® Excel®, and Adobe® Illustrator®

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References:
National Geophysical Data Center / World Data Center (NGDC/WDC) Global Historical Tsunami Database, Boulder, CO, USA. [http://www.ngdc.noaa.gov/hazard/tsu_db.shtml].

Priest, G. R., 1995, Explanation of mapping methods and use of the tsunami hazard maps of the Oregon coast, Oregon Department of Geology and Mineral Industries Open-File Report O-95-67, 95 p.

Tsunami Pilot Study Working Group (TPSW), 2006, Seaside, Oregon tsunami pilot study — modernization of FEMA flood hazard maps: U.S. Geological Survey Open-File Report 2006-1234, 90 p. + 7 app. [http://pubs.usgs.gov/of/2006/1234/].

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

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