WASHINGTON STATE DEPARTMENT OF
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Washington Division of Geology and Earth Resources
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Tsunami Inundation Map of the Neah Bay, Washington, Area

by
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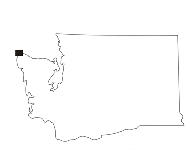
SCALE 1:24,000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
CONTROL ELEVATIONS SHOWN TO THE NEAREST 0.1 FOOT
OTHER ELEVATIONS SHOWN TO THE NEAREST FOOT
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 5 FEET


MAP LOCATION

Landward limit of expected inundation from scenario 1A

Landward limit of expected inundation from scenario 1A with asperity

Introduction

Recent research (Atwater and others, 1995) on the occurrence of great earthquakes (and resulting tsunamis) off Washington, Oregon, and northern California has led to the creation of tsunami hazard maps for potentially affected coastlines. Since tsunami waves may reach nearby coastal communities within minutes of a local earthquake, there will be little or no time to issue formal warnings—evacuation areas and routes will need to be planned well in advance. This map was prepared as part of the National Tsunami Hazard Mitigation Program (NTHMP) to aid local government in designing evacuation plans for areas at risk from potentially damaging tsunamis.

Map Design

The landward limit of tsunami inundation is based on a computer model of waves generated by two different scenario earthquakes, both moment magnitude 9.1, on the Cascadia subduction zone. The model used is a finite element model called ADCIRC, which was modified by Antonio Baptista and Edward P. Myers III of the Oregon Graduate Institute of Science and Technology (OGI) and adapted for modeling earthquake deformation and the resulting tsunami. Figures 1 and 2 show the uplift and subsidence associated with the scenario events that are the initial condition for the tsunami model. The earthquake deformation and tsunami modeling are discussed in detail in Priest and others (1997) and Myers and others (1999) and modified by Walsh and others (2000).

The tsunamis produced by the two scenarios were not distinguishable and are shown as "landward limit of expected inundation". Modeled lines were smoothed to account for resolution limitations and, in some instances, to place the inundation limit at nearby logical topographic boundaries.

The model runs do not include the influences of changes in tides but use a tide height of 4 feet. Tide stage and tidal currents can amplify or reduce the impact of a tsunami on a specific community.

These models do not include potential tsunamis from landslides or nearby crustal faults, which are not well enough understood to be modeled, although Williams and Hutchinson (2000) believe that there is evidence of locally generated tsunamis on Whidbey Island. The frequency of occurrence of Cascadia subduction zone earthquakes ranges from a few centuries to a millennium, averaging about 600 years (Atwater and Hemphill-Haley, 1997). It is believed that the last earthquake on the Cascadia subduction zone, in A.D. 1700, was about the magnitude modeled here (Satake and others, 1996). It is not known, however, if that is a characteristic magnitude for this fault. No damaging tsunamis have struck this area in historic time, although the 1964 Alaskan earthquake generated a tsunami that was 4.7 feet above the expected tide level at the Neah Bay tide gage (Wilson and Torum, 1972). No geologic studies have identified prehistoric tsunami deposits in the Neah Bay area, but Heaton and Snavely (1985) report that Makah stories may reflect a tsunami washing through Waatch Prairie, temporarily isolating Cape Flattery as an island. Ludwin (2002) has found additional stories from peoples up and down the coast that appear to corroborate this and also include apparent references to associated strong ground shaking.

Time Histories

Arrival time and duration of flooding are key factors to be considered for evacuation strategies. We show time histories of the modeled wave elevations and velocities (Figs. 3 and 4) on the open coast near Neah Bay. The elevation time history shows the change in water surface elevation with time for eight hours of modeling. Negative elevations are wave troughs, that is, times when water is flowing out to sea. Positive elevations are wave crests. Note that the first wave crest is predicted to arrive at about 30 minutes after the earthquake, but significant flooding occurs before the crest, rendering available evacuation time even shorter. Actual flooding depth and extent will depend on tide height at the time of tsunami arrival. The velocity is given in feet/second, which is approximately half a knot.

Limitations of the Map

Sources of error are discussed in detail in Priest and others (1997). Because the nature of the tsunami depends on the initial deformation of the earthquake, which is poorly understood, the largest source of uncertainty is the input earthquake. The earthquake scenarios used in this modeling appear to reasonably honor the paleoseismic constraints, but the next Cascadia subduction zone earthquake may be substantially different from these. Scenario 1A (with asperity) is considering a worst case scenario (at least for the Washington coast), but some scenarios tested by Priest and others (1997) locally showed larger tsunamis.

Another significant limitation is that the resolution of the modeling is no greater or more accurate than the bathymetric and topographic data used. This can be up to 50 meters horizontally. The vertical resolution is not well known but is probably on the order of 2 to 6 meters. This means that, while the modeling can be a useful tool to guide evacuation planning, it is not of sufficient resolution to be useful for land-use planning.

Acknowledgments

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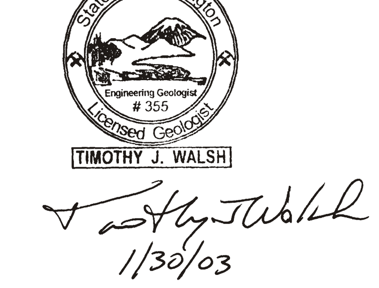

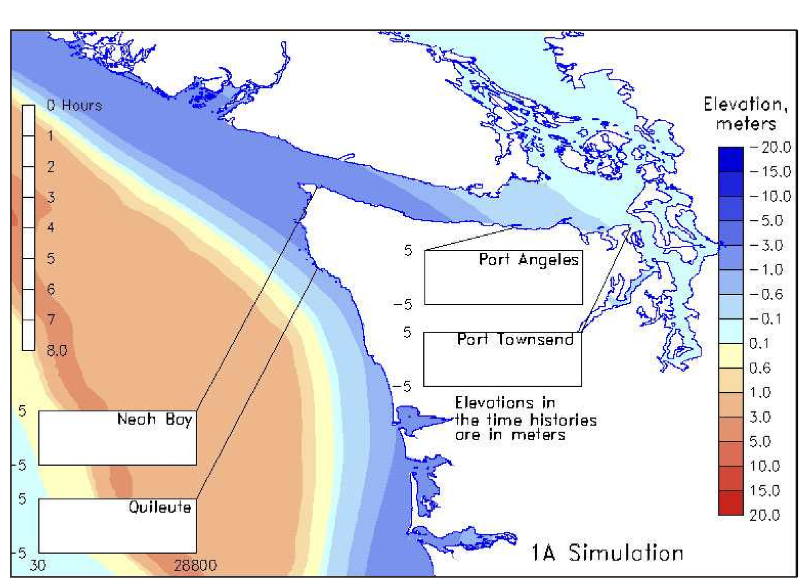

Figure 1. Initial deformation model for scenario 1A. Warmer colors denote areas of uplift and cooler colors denote areas of subsidence.

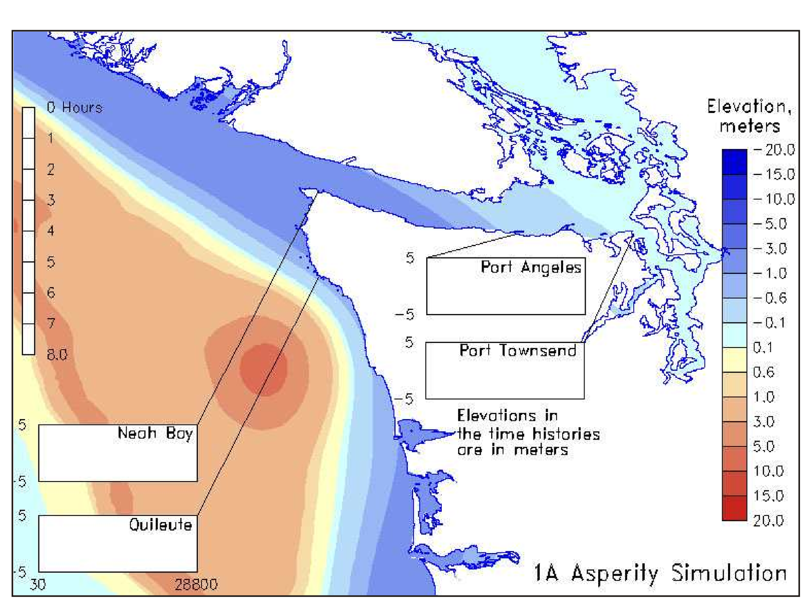

Figure 2. Initial deformation model for scenario 1A with an asperity or area of additional uplift, located west of the core of the Olympics. Warmer colors denote areas of uplift and cooler colors denote areas of subsidence.

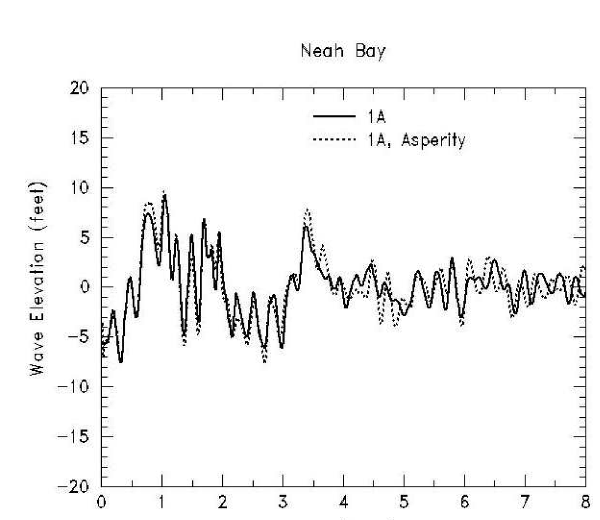

Figure 3. Elevation time history of tsunami waves in open water near Neah Bay. Negative numbers indicate water moving out and positive numbers indicate water moving in.

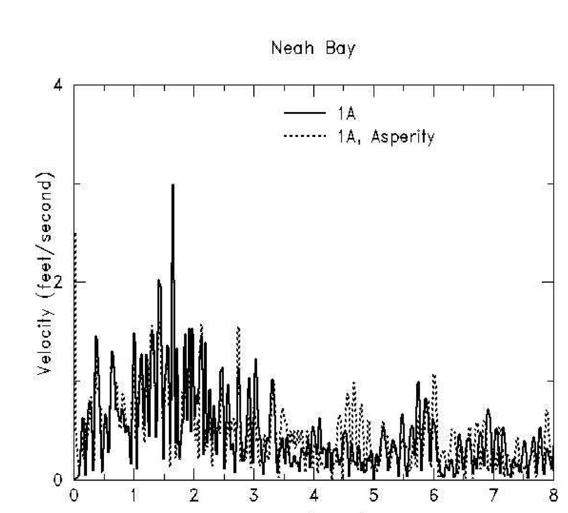

Figure 4. Current velocity with time in open water off Neah Bay, in feet per second, which is about half a knot.

The phenomenon we call "tsunami" (soo-NAH-mee) is a series of traveling ocean waves of extremely long length generated by disturbances associated primarily with earthquakes occurring below or near the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunamis. In the deep ocean, their length from wave crest to wave crest may be a hundred miles or more but with a wave height of only a few feet or less. They cannot be felt aboard ships nor can they be seen from the air in the open ocean. In deep water, the waves may reach speeds exceeding 500 miles per hour.

Tsunamis are a threat to life and property to anyone living near the ocean. For example, in 1992 and 1993 over 2,000 people were killed by tsunamis occurring in Nicaragua, Indonesia and Japan. Property damage was nearly one billion dollars. The 1960 Chile Earthquake generated a Pacific-wide tsunami that caused widespread death and destruction in Chile, Hawaii, Japan and other areas in the Pacific. Large tsunamis have been known to rise over 100 feet, while tsunamis 10 to 20 feet high can be very destructive and cause many deaths and injuries.

From *Tsunamis—The Great Waves*
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National Oceanic and Atmospheric Administration,
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