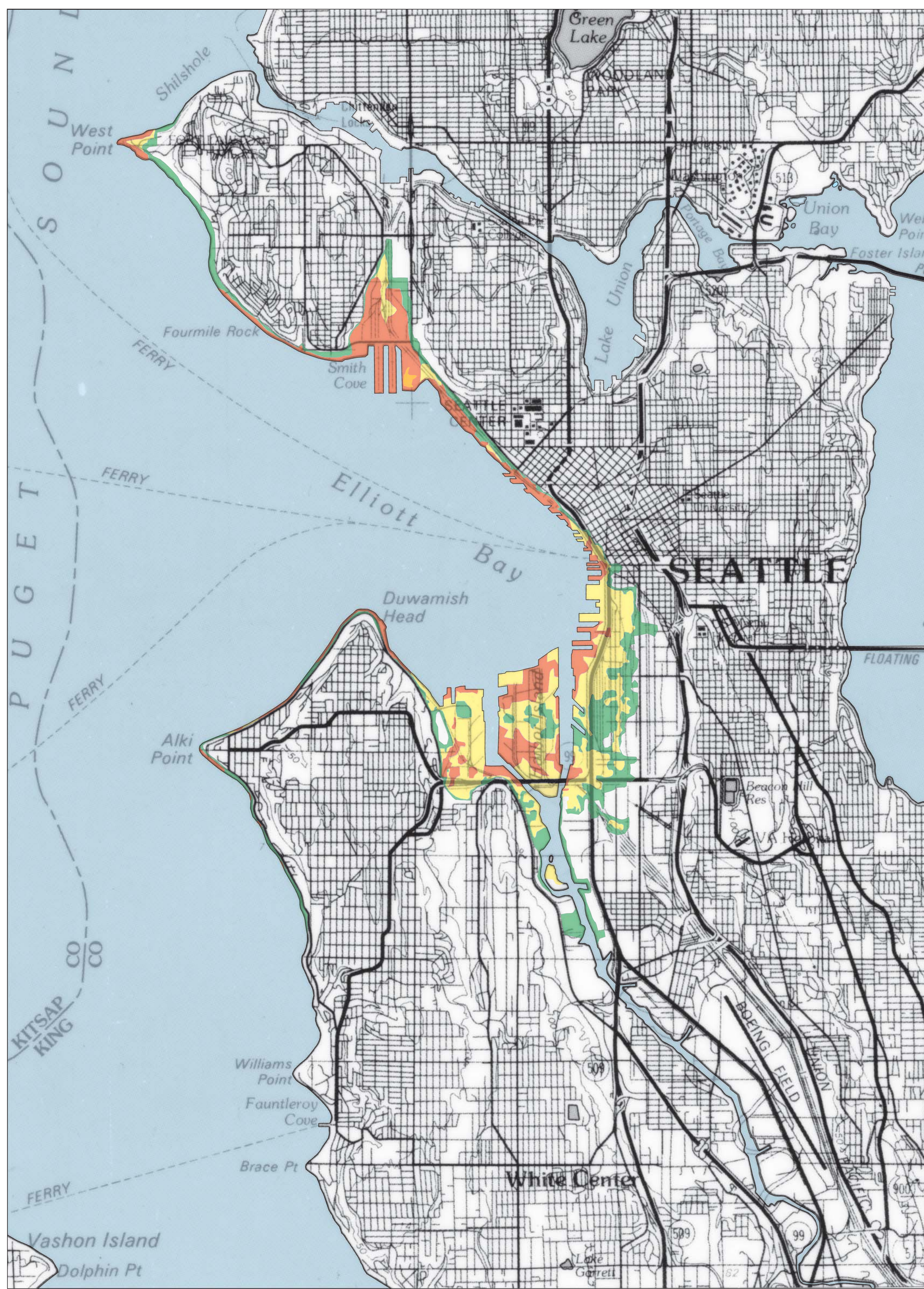


# Tsunami Hazard Map of the Elliott Bay Area, Seattle, Washington: Modeled Tsunami Inundation from a Seattle Fault Earthquake

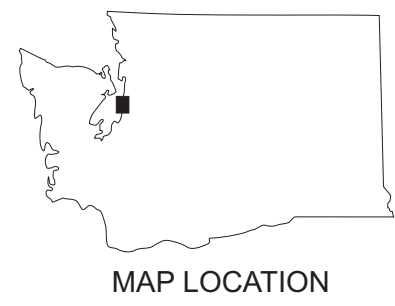
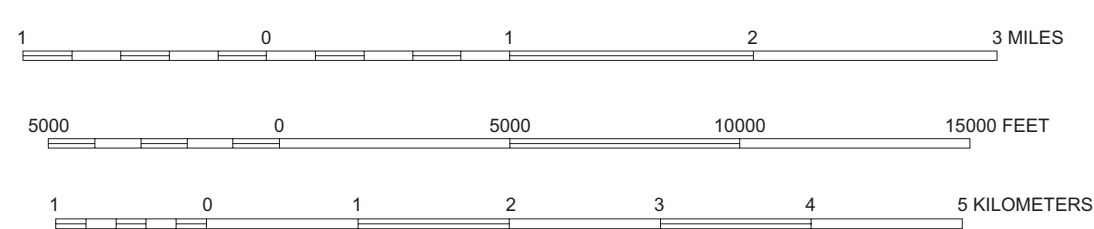
by  
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Depth of inundation: 0-5 meters 5-2 meters 2-5 meters

SCALE 1:50,000



## INTRODUCTION

In 1995, Congress directed the National Oceanic and Atmospheric Administration (NOAA) to develop a plan to protect the West Coast from tsunamis generated locally. A panel of representatives from NOAA, the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS) and the five Pacific coast states wrote the plan and submitted it to Congress, which created the National Tsunami Hazard Mitigation Program (NTHMP) in October of 1996. The National Tsunami Hazard Mitigation Program is designed to reduce the impact of tsunamis through warning guidance, hazard assessment, and mitigation. A key component of the hazard assessment for tsunamis is delineation of areas subject to tsunami inundation. This map is part of a series of tsunami inundation maps produced by the Washington Department of Natural Resources, Division of Geology and Earth Resources, in cooperation with the Washington Emergency Management Division, as a contribution of the National Tsunami Hazard Mitigation Program (Walsh and others, 2003a,b; 2002a,b; 2000). These maps are produced using computer models of earthquake-generated tsunamis from nearby seismic sources. The modeling for this map was done by the Center for the Tsunami Inundation Mapping Efforts (TIME) at NOAA's Pacific Marine Environmental Laboratory in Seattle for a scenario earthquake on the Seattle fault.

## THE SEATTLE FAULT

Geographic features now known to be associated with the Seattle fault have been noted for many years. Vancouver (1798) noted that the fault-uptilted bedrock wavecut platform at Restoration Point (Fig. 1, Location 1) on Bainbridge Island "did not possess that beautiful variety of landscape, being an almost impenetrable wilderness of lofty trees" that characterized the rest of his explorations in Puget Sound. Kimball (1897) described the Newcastle Hills (Fig. 1, Location 2), part of the hanging wall of the fault, as a "postglacial eruption". Danae and others (1965) interpreted the large gravity and magnetic anomalies through central Puget Sound and the associated abrupt change in the sedimentary section thickness as an active fault with about 11 km of displacement. Rogers (1970) collected additional gravity and magnetic data across the structure and named it the Seattle-Bremerton fault. Gower (1978) demonstrated that the uplift at Restoration Point (Fig. 1, Location 1) was Holocene in age and Bucknam and others (1992) showed that there was an uplift of 7 meters produced on the fault about 1,000 years ago.

In 1996, the first of a series of lidar (Light Detection And Ranging) surveys was flown over Bainbridge Island. This and subsequent lidar missions have enabled scientists to locate splays of the fault in a number of places accurately enough to dig trenches (Bucknam and others, 1999; Nelson and others, 2002). Lidar mapping and trenching have enabled scientists to accurately map the amount of uplift on the fault in some places. Also in 1996, the U.S. Geological Survey began several large-scale geophysical studies. An aeromagnetic study of the Puget Sound (Blakely and others, 1999, 2002) enabled more accurate location of the fault along its entire length. Seismic reflection and tomographic studies, such as SHIPS (Seismic Hazards Investigations in Puget Sound) and other geophysical studies in Puget Sound have greatly increased the understanding of the fault characteristics at depth (Pratt and others, 1997; Johnson and others, 1999; Brocher and others, 2001; ten Brink and others, 2002; Van Wagoner and others, 2002), although considerable uncertainties and controversy remain.

There also is substantial evidence that earthquakes on the Seattle fault can generate tsunamis. Atwater and Moore (1992) showed that tsunamis inundated part of Whidbey Island (Fig. 1, Location 5) and West Point (Fig. 1, Location 4) about 1000 years ago, and Jacoby and others (1992) showed that a tree in the tsunami deposit at West Point died in the same season of the same year as a drowned forest carried into Lake Washington by a huge landslide from Mercer Island, strongly implicating the A.D. 900-930 event. A discontinuous sand layer along Snohomish delta distributaries—Ebay Slough, Steamboat Slough, Union Slough, and Snohomish River (Fig. 1, Location 6)—also probably was deposited by the tsunami from the large A.D. 900-930 earthquake on the Seattle fault (Bourgeois and Johnson, 2001).

## MODELING

Tsunami inundation shown on the map is based on a computer model of waves generated by the Seattle fault (Titov and others, in press). The model uses the finite difference model of Titov and Synolakis (1998), also known as the Method of Splitting Tsunami (MOST) model (Titov and Gonzalez, 1997). It uses a grid of topographic and bathymetric elevations and calculates a wave elevation and velocity at each gridpoint at specified time intervals to simulate the generation, propagation and inundation of tsunamis in the Elliott Bay area. In this MOST model study, the tsunami is generated by a Seattle fault deformation model that simulates the A.D. 900-930 event as a credible worst-case scenario of magnitude 7.3. The magnitude was chosen to be consistent with the 2002 USGS update of the National Seismic Hazard Maps (Frankel and others, 2002). Parameter values are based on Brocher and others (2001), Calvert and Fisher (2001), and ten Brink and others (2002).

Table 1. Segment (west to east) parameters for magnitude 7.3 Seattle fault earthquake models. The vertical deformation pattern is shown in Figure 1.

Segment	Depth (km)	Length (km)	Width (km)	Strike (°)	Dip (°)	Slip (m)
1	0.5	15.2	20	87.9	60	1
2	0.5	6.3	20	86.6	60	1
3	0.5	8.9	20	96.0	60	12
4	0.5	3.2	20	128.8	60	11
5	0.5	11.5	20	99.3	60	4
6	0.5	14.9	20	81.0	60	1

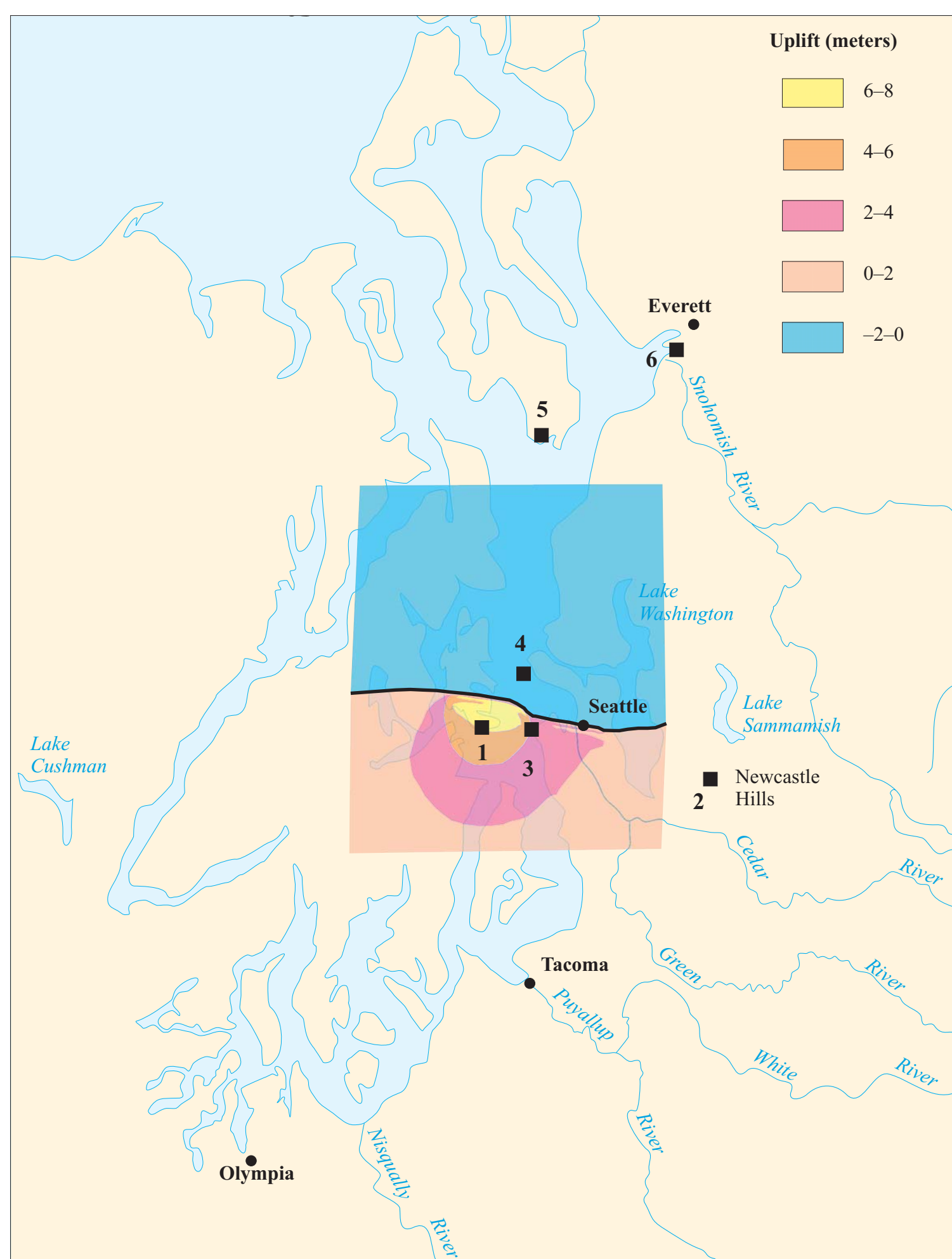


Figure 1. (left) Map showing Seattle fault and associated ground deformation model used in this study. Numbered locations are localities mentioned in text. 1, Restoration Point; 2, Newcastle Hills; 3, Alki Point; 4, West Point; 5, Cultus Bay; 6, Snohomish Delta.

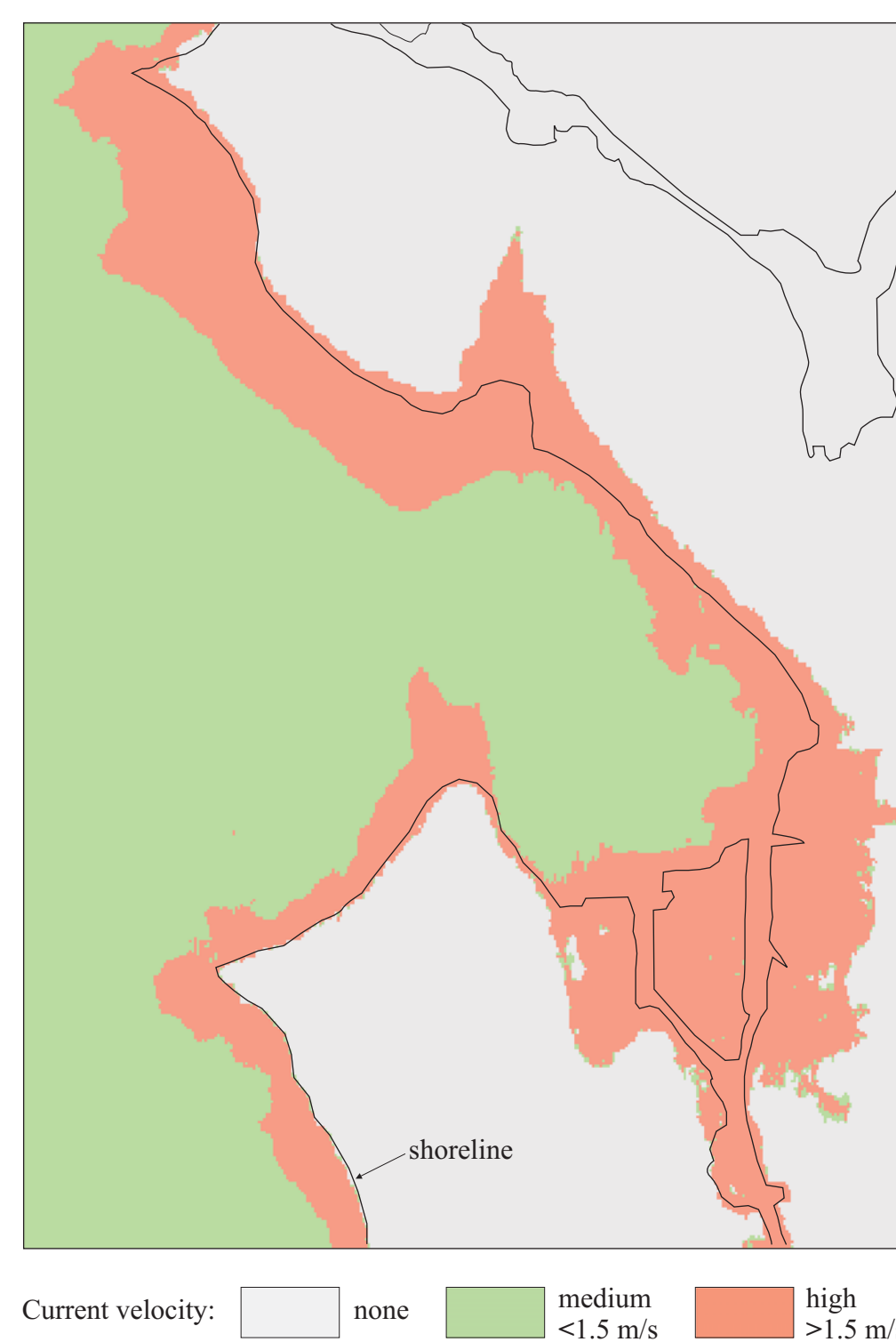
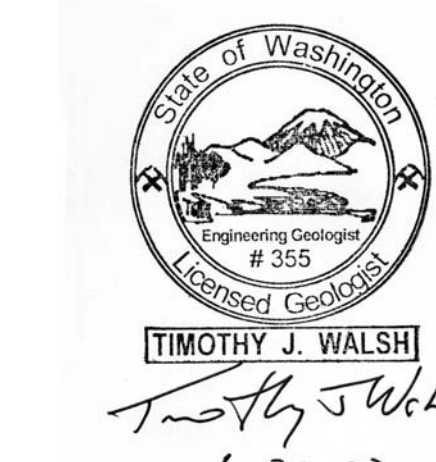


Figure 2. Computed current velocity zones. Note that velocities are highest along the shoreline and in narrow channels. One meter/second is ~2.2 mph.



Figure 3. Freeze frames of animation of modeled tsunami at 30-second intervals (from left to right). The wave crest is colored pale blue. Note that because Harbor Island is uplifted by the earthquake, the Duwamish Waterway initially drains rapidly before the wave reflects off the north side of the bay and then inundates the Harbor Island area.



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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* by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Intergovernmental Oceanographic Commission, and International Tsunami Information Center. Accessed at <http://www.nws.noaa.gov/om/brochures/tsunami.htm> on 8/27/02