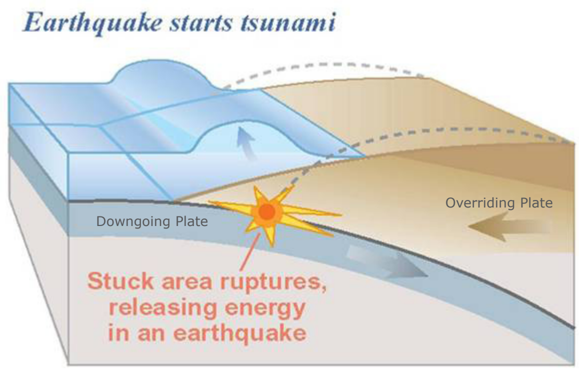
Local Tsunamis

Tsunamis from Earthquakes

Earthquakes are the sudden release of stored energy that normally occurs along a fault. Washington State is located at a boundary between two tectonic plates of the Earth's crust. The Juan de Fuca plate descends beneath North America, this process is known as subduction.



Accumulated energy raises the seafloor (and the water above it) and a tsunami can be created.

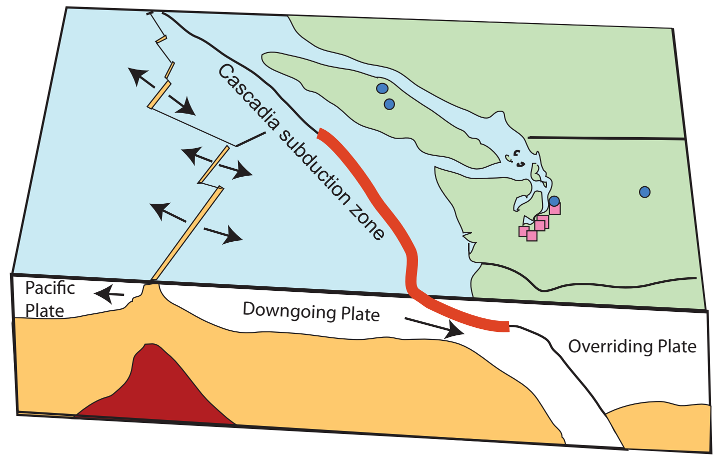
The State is vulnerable to earthquakes originating from three sources:

1. **Within the downgoing plate**.
For instance, 3 days after the 1949 Olympia earthquake a landslide generated a tsunami in the Tacoma Narrows. (*See photo bottom right*).

2. **At the boundary between plates** (Subduction Zone Earthquake). The 1700 Cascadia Subduction Zone Earthquake caused coastal subsidence and generated a tsunami that impacted our coast.

3. **Within the overriding plate**. A Seattle Fault Earthquake between 900 and 930 A.D. raised shores of central Puget Sound by 20 feet between the Duwamish River and Bremerton and generated a tsunami in Puget Sound.

Western Washington's earthquake sources

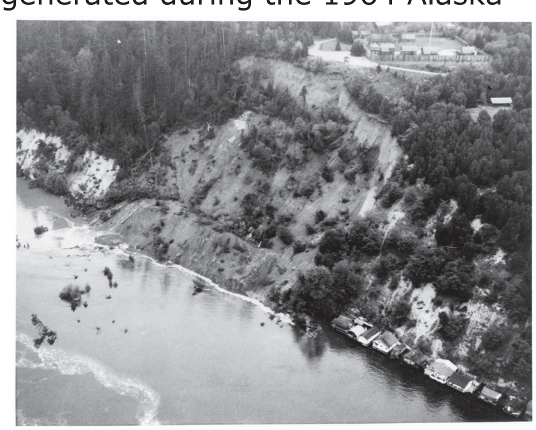


Earthquake Source	Maximum Size	Typical Recurrence Intervals	Examples mapped above
Downgoing plate	7	Decades	1939, 1946, 1949, 1965, 2001
Overriding plate	7	Centuries or millennia	900, 1872, 1918, 1946
Plate Boundary	9	Centuries	1700

Tsunamis from Landslides

Landslides pose a local tsunami threat because they can displace waters of Puget Sound and of the state's lakes, reservoirs, and rivers. Landslides probably set off tsunamis as they dropped forests to the floors of Lakes Washington and Sammamish in AD 900-930. The sliding of a steep bluff into Tacoma Narrows (*see photo below)* generated a wave 8 feet high near Point Defiance in 1949. A rockfall into the Columbia River generated a wave that killed a person near Cathlamet in 1965. Many landslides have made waves in the reservoir behind Grand Coulee Dam, most recently in 2009.

Deltas at the mouths of the Skagit, Snohomish, Duwamish, Puyallup, Nisqually, and Skokomish Rivers probably pose Puget Sound's greatest landslide-tsunami threats. Among the 106 deaths from tsunamis generated during the 1964 Alaska earthquake, 79 resulted from failures of Alaskan deltas that have much in common with deltas of Puget Sound.



Local Tsunamis

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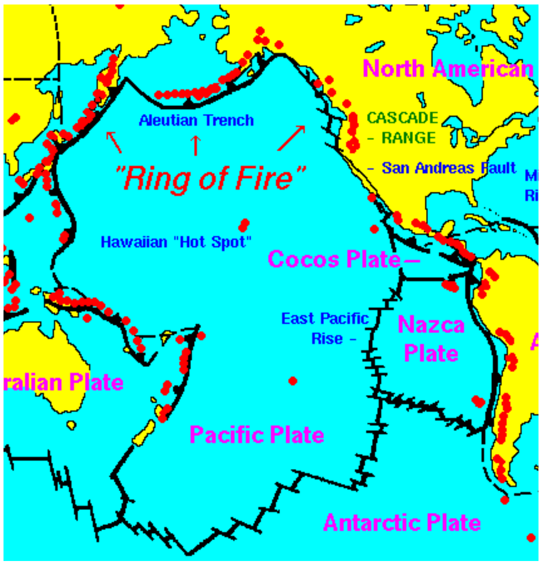
Distant Tsunamis

Probable sources

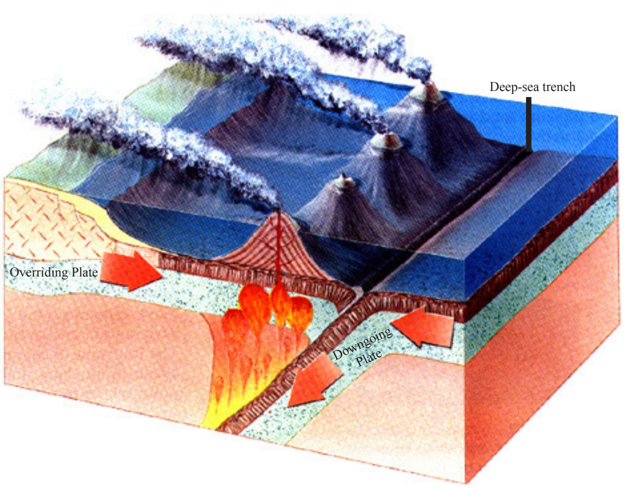
Subduction zones are largely located along the volcanic mountain chains that make up the “Ring of Fire”. They can generate tsunamis that sweep through the entire Pacific basin causing a tsunami risk to Washington coastal communities.

Active Volcanoes, Plate Tectonics, and the "Ring of Fire"



Subduction

Subduction occurs when one plate slides under another plate that usually gets locked together. When the overriding plate breaks free it causes an earthquake.



Upon release the seafloor (and the water above it) is raised, a tsunami is created.

Impact on Washington

While distant tsunamis have caused significant damage, deaths and injuries in Oregon and California, only one significant tsunami struck Washington’s Pacific coast in recent history. The 1964 Alaska earthquake generated a tsunami that resulted in debris deposits throughout the region, minor damage in Ilwaco, damage to two bridges on State Highway 109, a house and smaller buildings being lifted off their foundations in Pacific Beach, and piling damaged at the Moore cannery near Ilwaco.

The 1964 tsunami also was recorded inland in the Strait of Juan de Fuca (Friday Harbor), Puget Sound (Seattle), and the Columbia River (Vancouver). However, recent tsunami modeling indicates that Washington has not yet experienced its worst case distant tsunami event.

Highway 109 bridge over Copalis River collapsed and trailers and cars were damaged during the 1964 Alaskan Tsunami.

Frequency in Washington

Due to the various tsunami sources on the “Ring of Fire”, distant source tsunamis are more frequent than local source tsunamis. Historical records (to 1854) and geologic investigations indicate that tsunamis have struck Washington’s shores numerous times. While only one tsunami has caused major damage, strong currents accompanying a tsunami threaten the maritime industry as well as individuals in and around the water. For example, a 1960 earthquake along the coast of Chile generated a tsunami causing non-destructive inundation at Grays Harbor, Tokeland, Ilwaco, Neah Bay, and Friday Harbor.

Distant Tsunamis

References

"Ring of Fire" image. U.S. Geological Survey.

"Subduction" image. University of California, Santa Barbara. Department of Earth Science.

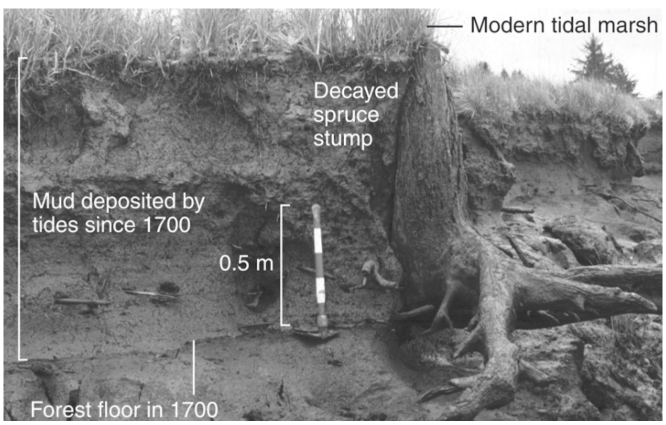
Washington State Hazard Mitigation Plan, Washington State Emergency Management Division, January 2008.

Tsunami Clues

Tsunamis deposits

Many times there are no written records or they are insufficient to accurately assess the tsunami hazard. Tsunami deposits allow geologists to expand the record of tsunamis, improving hazard assessment.

Water from a tsunami can deposit sand, cobbles, boulders and debris from offshore beaches over coastal lowlands. These deposits can be preserved in the geologic record giving evidence of past tsunamis to help assess the tsunami hazard for a community. For example, it is possible to determine frequency, magnitude, tsunami flow direction, and run-up and minimum inundation may be estimated by the inland extent and elevation of tsunami deposits.



The above image is what we find on our coast. This is from the Naselle river which flows into Willapa Bay. You can see the decayed spruce stump, the old forest floor in 1700, and the thick sequence of mud deposited since 1700.

Historical tsunami databases

Internet databases allow communities to access historical tsunami records. These records aid in understanding the tsunami hazard and risk in a coastal community. Also, these online resources may help communities identify the source of a tsunami occurrence identified in written or oral histories. Online tsunami data bases include:

Novosibirsk Tsunami Laboratory

National Geophysical Data Center

Oral history and written records

Oral and written records compliment modern science and technology in identifying hazardous events. Along with modern scientific tsunami numerical modeling, oral and written records provide information for communities to determine their level of risk. Local knowledge can also supplement scientific data and help educate the population about impending hazards. Consequently, lives may be saved by oral history and written records.

Tribal knowledge has valuable information that is passed down to the next generation in the tradition of mythology. Oral traditions of Native American tribes of the Washington Coast describe what is interpreted as a huge earthquake and tsunami destroying coastal villages.

The story describes the Thunderbird as a kind mystical being. The bird soared over the coastal waters and seized the Whale. A struggle ensued first in the water. "The waters receded and rose again. Many canoes came down in trees and were destroyed and numerous lives were lost."

Oral history from the Makah Tribe tells of an earthquake in the middle of the night. Elders tell the young to run for high ground. Those who listen to their warning survive. In the morning they find their village, and all neighboring coastal villages washed away and no survivors. This oral history was also noted in the diary of James Swan on January 12, 1864.

These oral histories helped identify the source of the January 1700 "Orphan Tsunami" which swept across the Pacific causing destruction along the Pacific coast of Japan.

Corroboration with accurate written records from Japanese samurai, merchants, and villagers allows confident knowledge of the size and time of this great earthquake.

Tsunami Clues

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Novosibirsk Tsunami Laboratory
http://tsun.sscc.ru/

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Quaternary Research, Volume 57, Issue 2, March 2002, Page 285,
Boyd E. Benson, Brian F. Atwater, David K. Yamaguchi, Lorin J. Amidon, Sarah L. Brown, Roger C. Lewis

The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America. 2005. B.F. Atwater, S. Musumi-Rokkaku, K. Satake, Y. Tsuji, K. Ueda, and D.K. Yamaguchi. Published by U.S. Geological Survey, Reston, Virginia and University of Washington Press, Seattle WA and London, UK.

"**Thunderbird and the Whale**" image courtesy of Ruth Ludwin, University of Washington.

Tsunami Hazard Zone

What is the Tsunami Hazard Zone?

A populated and at-risk area determined to have the likeliest probability of being flooded by tsunamis.

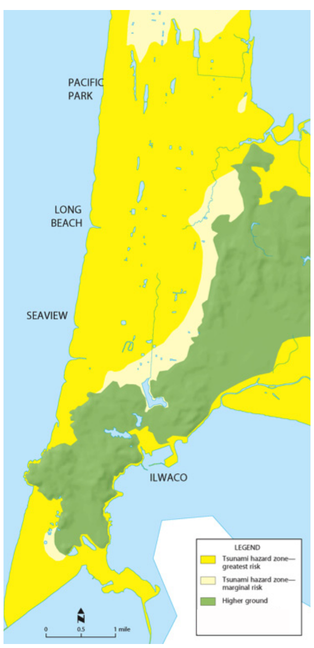
What is needed to determine the Tsunami Hazard Zone?

Components include:

- Inundation map
- Community input
- Geologic evidence
- Local infrastructure
- Oral history

What is an inundation map?

An inundation map displays the areas likeliest to be flooded by a tsunamis.



Example Inundation Map: Long Beach, Washington. Inundation Area in Yellow

How is the inundation area determined?

Tsunami models simulate tsunami generation, propagation of waves to the impact zone and inundation into a community. Inundation studies can be conducted taking a probabilistic approach or a particular "worst case scenario". The results include information about the maximum wave height, maximum current speed and maximum inundation line. Also waves' heights accompanied by arrival times at different locations can be determined.

Inundation Map uses

Awareness initiatives
Examples: Personal preparedness, pollutant anchoring/removal.

Evacuation Planning
Examples: Evacuation routes and evacuation signs.

Land Use
Examples: Open space or low- density zoning.

Designing structures
Examples: Elevated structures.

Isolation identification
Examples: Vertical evacuation plans.
Note: Vertical evacuation should be pursued where vehicular evacuation is unlikely during a tsunamigenic event.

Tsunami hazard zones and inundation maps are not permanent

Once an inundation line is drawn, the line is not permanent. New techniques for tsunami modeling are always improving the capacity to create more effective inundation maps. Also, difficult to detect land changes can effect tsunami inundation mapping. Consequently, inundation maps should be used for guidance in planning not as definitive and permanent maps

Why is inundation mapping and modeling important?

Evacuation maps, routes and assembly areas can be identified once inundation modeling and mapping is developed.

Special needs populations should determine evacuation assembly areas or vertical evacuation refuge sites. Special needs populations must be able to reach safe sites within the expected wave arrival time for safe evacuation.

Tsunami Evacuation Map Brochures should be developed for visiting, or tourist populations. Tsunami evacuation routes should be adequately marked with signage. Official tsunami signage creates pre-event awareness and improves life safety.

References

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http://www.emd.wa.gov/hazards/haz_tsunami.shtml

Tsunami Risk Reduction

www.emd.wa.gov
Washington State
Emergency Management

What is risk?

Existing definitions include:

$$\text{Risk} = \text{Hazard} * \text{Exposure}$$

$$\text{Risk} = \frac{(\text{Vulnerability} * \text{Hazard})}{\text{Capability}}$$

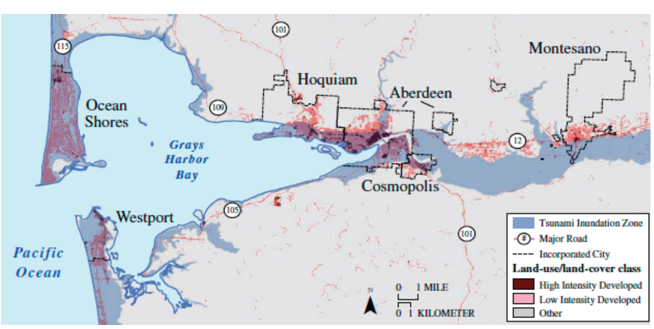
Why understand your risk?

Identifying and understanding a community's risk allows appropriate time and effort and effective use of resources for reducing that risk. A community needs to identify assets with high vulnerability and low capability to recover from a tsunami and start appropriate preparedness and response activities.

Hazard & vulnerability

By understanding a community's hazard exposure, physical vulnerability, and social vulnerability, evacuation planning, public education, and other preparedness and response programs can be developed. For instance:

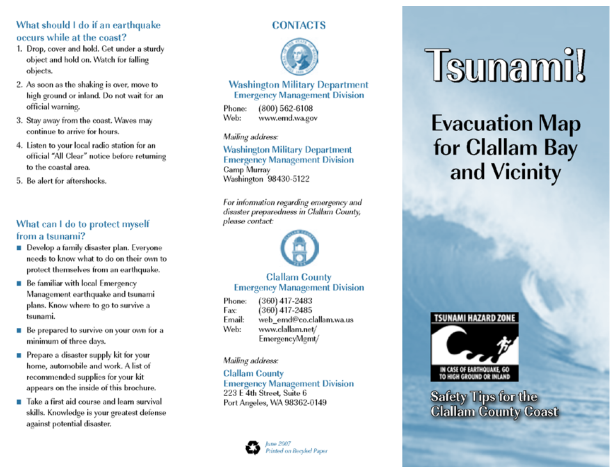
- *Exposure*. Assets and resources in the tsunami hazard zone. (People, businesses, cultural and natural resources, roads, bridges, utilities)
- *Sensitivity*. Asset characteristics and implications of a tsunami. (What conditions will complicate evacuation?)
- *Resilience*. Ability to manage risk, adapt during crises and recover from tsunami. (How prepared is the community to respond? How will individuals receive and react to warnings?)



Gray's Harbor Bay land-cover and tsunami-inundation area.

Increasing capability through preparedness

At-risk populations in the community have their own perceptions of risk. Social science suggests people are more inclined to act on hazard education information when they believe present actions can mitigate future losses (Paton et al., 2008). Therefore, public education must not focus on uncontrollable (and infrequent) tsunami hazards. Instead, focus should be on individual actions that can reduce the impacts of typical tsunamis. A good example of this is our tsunami brochures that identify evacuation routes, natural warning signs, official warning protocols and steps to take to prepare for a tsunami event.


What should I do if an earthquake occurs while at the coast?

1. Drop, cover and hold. Get under a sturdy object and hold on. Watch for falling objects.
2. As soon as the shaking is over, move to high ground or inland. Do not wait for an official warning.
3. Stay away from the coast. Waves may continue to arrive for hours.
4. Listen to your local radio station for an official "All Clear" notice before returning to the coastal area.
5. Be alert for aftershocks.

What can I do to protect myself from a tsunami?

- Develop a family disaster plan. Everyone needs to know what to do on their own to protect themselves from an earthquake.
- Be familiar with local Emergency Management earthquake and tsunami plans. Know where to go to survive a tsunami.
- Be prepared to survive on your own for a minimum of three days.
- Prepare a disaster supply kit for your home, automobile and work. A list of recommended supplies for your kit appears on the inside of this brochure.
- Take a first aid course and learn survival skills. Knowledge is your greatest defense against potential disaster.

CONTACTS

Washington Military Department
Emergency Management Division
Phone: (800) 562-6108
Web: www.emd.wa.gov

Mailing address:
Washington Military Department
Emergency Management Division
Camp Murray
Washington 98430-5122

For information regarding emergency and disaster preparedness in Clallam County, please contact:

Clallam County
Emergency Management Division
Phone: (360) 417-2483
Fax: (360) 417-2485
Email: web_emd@co.clallam.wa.us
Web: www.clallam.net/EmergencyMgmt/

Mailing address:
Clallam County
Emergency Management Division
223 E 4th Street, Suite 6
Port Angeles, WA 98362-0149

June 2007
Printed on Recyled Paper

Tsunami!

Evacuation Map for Clallam Bay and Vicinity

TSUNAMI HAZARD ZONE
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

Safety Tips for the Clallam County Coast

Community-specific tsunami brochures provide valuable life-saving information. *Example from Clallam Bay.*

Evacuation plans reduce risk

When planning and developing tsunami evacuation routes, we must identify special population groups lacking the ability to anticipate, cope with, resist and recover from the impacts of a tsunami.

Those that are in need of help to evacuate, should talk to neighbors and community support groups to pre-arrange evacuation to high ground. Remember that special populations in the community will require additional time to arrive to an evacuation assembly area. It is recommended that you time how long it takes these groups to get to an assembly area, and compare to expected wave arrival time.

During a local-source event, evacuation on foot may be your only option. Debris from the earthquake and flooding may increase the time it takes to get to high ground.

References

Paton, D., Houghton, B. F., Gregg, C. E., Gill, D. A., Ritchie, L. A., McIvor, D., Larin, P., Meinhold, S., Horan, J., & Johnston, D. M. (2008) '**Managing tsunami risk in coastal communities: Identifying predictors of preparedness**,' The Australian Journal of Emergency Management, 23(1): 4-9

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Tsunami Response

Tsunami arrival times vary

Washington coastal communities need to be prepared for either a local tsunami such as the one generated by the Cascadia Subduction Zone in 1700 striking the coast within minutes of the earthquake; or, a distant tsunami that allows several hours of warning before the tsunami reaches our coastline, such as the 1964 Alaskan event.

Local tsunami response

A local earthquake event has potential to cause damage to the built environment leaving the public and government officials to deal with destruction of the earthquake and a potential destructive tsunami within tens of minutes after the earthquake. The public needs to understand the natural warning signs of an impending tsunami and be prepared to respond to the event on their own by taking immediate action to move to high ground.

Natural Warning Signs:

Strong coastal earthquake
Rapid sea level changes
Roaring sound

Do not wait for all three natural warning signs. If you notice any natural warning signs, run to high ground immediately!

Self-evacuation

Steps public can take to manage a self-evacuation:

- Develop a family plan.
- Identify the nearest assemby areas and evacuation routes.
- Prepare disaster kit. Food and water may not be available for an extended period of time at the assembly areas.

Distant tsunami response

Distant tsunamis give the federal, state, and local/tribal governments time to assess the tsunami risk and make evacuation decisions. The tsunami warning center in Alaska provides information to decision makers that implement evacuation plans. A tsunami warning and evacuation order will be disseminated over community communication systems. Response personnel and volunteers support the evacuation effort of the tsunami hazard zone.

Examples of key official warning communication systems in Washington's communities

- Emergency Alert System: Radio, Television and NOAA Weather Radio
- All Hazard Alert Broadcasting (AHAB) Radio

AHAB Radios (*left*) are placed throughout Washington in at-risk communities. NOAA Weather Radios (*right*) should be placed in homes, schools, and businesses to provide critical information to everyone.

How to improve tsunami response

Community-based education helps the public respond correctly to local or distant tsunamis. Pre-event public education, workshops, town hall meetings, focus groups and other outreach efforts need to be consistent and continuous.

Important public outreach messages include:

- Recognize natural warning signs for a local event
- Identify systems that will provide tsunami warning and evacuation messages in their community (during a distant event)
- Obtain an evacuation map
- Get to know evacuation routes and evacuation assembly areas
- Develop a community support network
- Develop a family plan and preparedness kit
- Understand how local government will respond to a tsunami event

Tsunami Response

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