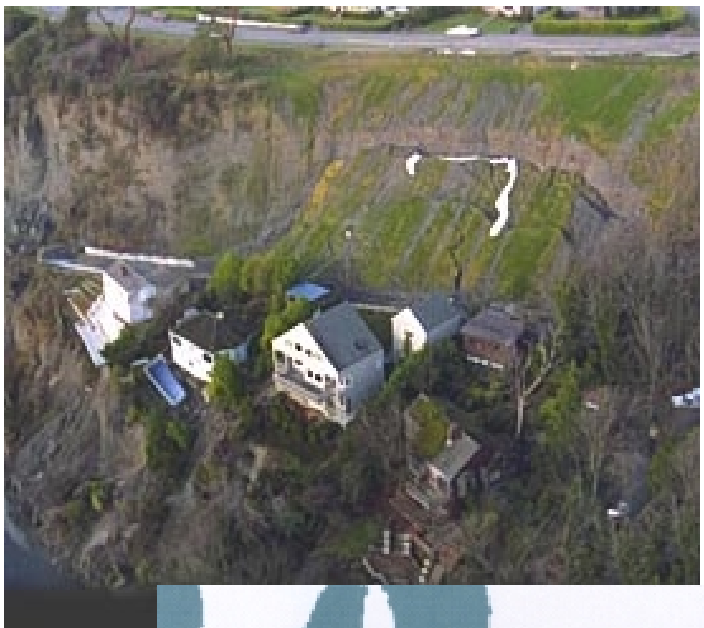
Summary

Puget Sound Tsunami/Landslide Workshop

January 23 and 24, 2001



Organizers

George Crawford
Washington State Military Department
Emergency Management Division

Hal Mofjeld
National Oceanographic and Atmospheric Administration

Craig Weaver
United States Geological Survey

Sponsored by

Washington State Military Department
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NOAA/Pacific Marine Environmental Laboratory
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Contents

Executive Summary

The Washington State Military Department Emergency Management Division (EMD) and the National Oceanic and Atmospheric Administration (NOAA) sponsored a two-day *Puget Sound Tsunami/Landslide Workshop* held at the NOAA/Western Regional Center in Seattle on January 23 through 24, 2001. The workshop is part of ongoing work by the emergency management and scientific communities to forge a partnership to address tsunami and landslide hazards in the Puget Sound region. More than 120 emergency management professionals, scientists, engineers and interested public attended the workshop. The workshop was funded through a Tsunami Mitigation grant to EMD to provide emergency preparedness planning support to Washington state. NOAA provided the facility and technical support, funded in part by the National Tsunami Hazard Mitigation Program.

The organizers' primary goal for the workshop was to provide a forum for discussing the current level of understanding of tsunami and landslide hazards in Puget Sound. Because this understanding has scientific, geotechnical, public policy and emergency response components, the workshop presented these issues in an interdisciplinary forum. The workshop goals were:

- To provide an atmosphere to consider partnerships to address tsunami and landslide hazards in the Puget Sound region.
- To develop an action plan to outline a systematic program to address issues surrounding landslides and tsunamis.

Workshop Conclusions

- Tsunamis and landslides in the greater Puget Sound region pose significant hazards that must be included in local and regional emergency response and development plans.
- Today there is little cross-discipline discussion of the issues, needs or capabilities of various groups concerned with tsunamis and landslides in Puget Sound.
- Emergency managers need more guidance on where and how to apply existing data and maps.
- We need a strategy for integrated tsunami research, community planning, and emergency response. Specifically, we need to:

  -Integrate tsunami research in Puget Sound.

  -Move research results to communities.

  -Educate public and local officials in how to respond.

  -Make products developed by any part of tsunami community widely available

Workshop Structure

The workshop was structured into programmatic sessions (Day 1) and technical sessions (Day 2). Each session served a separate purpose. The programmatic sessions were divided into a morning series of presentations on mitigation planning, including the following:

- State hazard mitigation.
- Growth Management Act.
- Shoreline Management Act.
- Tsunami mitigation.
- Shoreside landslide mitigation.
- Submarine landslide mitigation.
- Flood program.

An afternoon tutorial focused on reducing hazards in Northwest hot spots. It included basics on Puget Sound:

- Ports and harbors.
- Earthquakes.
- Tsunamis.
- Landslides.

The Technical Sessions (Day 2) offered panel discussions delivered by technical experts in several active areas of mitigation product development. The topics covered current research on the following:

- Earthquake faults.
- Landslides.
- Tsunamis.
- Merged bathymetry and topography (bathy/topo) digital electronic maps (DEMs).
- HAZUS/GIS systems.

Day 1: Programmatic Sessions

Introduction - “Preparedness Requires Cooperation”

George Crawford, Washington State Emergency Management division (EMD) Earthquake Program
Eddie Bernard, Director NOAA and Pacific Marine Environmental Laboratory and Chair of National Tsunami Hazard Mitigation Program
Trudy Winterfield, Director of Cowlitz County Emergency Management and Vice Chair Washington State Emergency Management Council

The purpose of the workshop was to bring together the scientific and planning communities to find ways to better defend against tsunami and landslide hazards. We face hazards on a daily basis. Among the lessons we’ve learned—including that of the Aldercrest landslide near Kelso, Washington—is the importance of the inter-relationships among programs. Puget Sound tsunamis will have no warning, making outreach and warning guidance critical. Much work has been done. Tools for emergency managers now include databases on more than a 100 coastal communities, inundation maps, evacuation routes and surveys.

Understanding ongoing research is another tool that emergency managers can use to build disaster-resistant communities.

Mitigation

Moderator: Chuck Hagerhjelm EMD

State Hazard Mitigation

Marty Best (EMD)

All local communities must identify and assess mitigation. Typically, communities do so as part of their normal Capital Improvement Planning (CIP) or Growth Management Planning processes. They don’t, however, recognize CIP or GMA as the mitigation planning tool it is. Every community in the state is required by the GMA to update their comprehensive plans and critical areas ordinances (CAOs). Comprehensive plans and CAOs now require the use of Best Available Science (BAS), a ruling adopted in July 2000.

The state’s mitigation strategy focuses mitigation actions primarily among state agencies and establishes overall mitigation strategy for the state. The need for mitigation planning is critical. Since the eruption of Mount St. Helens, disasters have caused direct damage of $1 billion, monies that could have been spent elsewhere. While state agencies identify hazards and assess risk and vulnerability, mitigation planning is local and will be a requirement to access federal disaster mitigation funds in the future.

Growth Management

Chris Parsons (Washington State Office of Community Development)

State emergency managers can now use the Best Available Science (BAS) rule to help identify and plan for geohazards. The BAS rule is required under the Growth Management Act framework for designating and protecting critical areas, such as geologically unstable areas. The new rule provides cities and counties with information about how to recognize valid science and demonstrate how they have included good science when protecting critical areas within their jurisdiction. Local governments are required to update their critical areas to include the best available science ordinances by September 1, 2002.

The BAS rule (WAC 365-195-900 through –925) requires consistency among development regulations for critical areas ordinances (CAOs). Critical areas include wetlands, aquifer recharge zones and areas that are frequently flooded, geologically unstable, or used for fish and wildlife conservation. Under the GMA, you are required to conduct the following 4-step CAO process:

1. Classify: based on CA function or vulnerability to damage from development.
2. Inventory: identify existing conditions and locations in landscape.
3. Designate: apply classification to CA distribution and maps.
4. Protect: Include the BAS in development of regulations and performance standards and in granting exemptions or variances.

The BAS rule provides criteria for determining what is credible, applicable scientific information for making management decisions.

References:

- BAS rule: www.ocd.wa.gov/info/lgd/growth/info/rules/BAS%20rule%20final.html
- Copsey, Alan D. *Including Best Available Science in the Designation and Protection of Critical Areas Under the GMA*, Seattle University Law Review, Volume 23, Summer 1999, Number 1, p. 97-143.
- Chris Parsons, WA Office of Community Development. Email: chrisp@cted.wa.gov (360 725-3058)

Shoreline Management Act

Randy Davis (Washington State Department of Ecology)

The Shoreline Management Act (SMA) and resultant shoreline plans are another mechanism available for implementing tsunami-related policy. These plans strive to protect state shorelines by regulating development. State shorelines include all marine waters, rivers and certain streams and lakes and their adjacent lands.

The Department of Ecology in concert with local governments develops shoreline plans for managing state shorelines. NOAA also approves shoreline plans for coastal jurisdictions as an element of the state's Coastal Zone Management Program.

The Department of Ecology has technical assistance available. Please contact:

Randy Davis, AICP, WA Dept. of Ecology
PO Box 47775
Olympia, WA 98504
360.407.0242
rdav461@ecy.wa.gov

National Flood Insurance Program "V" Zone Requirement

Dan Sokol (Washington State Department of Ecology)

Another mitigation option is the NFIP Velocity or "V" zone designation, a piece of the regulatory framework that covers tsunami risks. FEMA identifies flood areas and local governments that must have flood zone ordinances. These local flood rules are encouraged to be stricter than minimum standards.

Most of these local regulations are more stringent than the 100-year floodplain. Construction standards for velocity, however, are limited to certain areas. Tsunamis could reach "A" zones, which don't have these standards. Further compounding the issue is the lack of licensing for geotechnical engineers. Emergency managers should coordinate tsunami hazard mapping with existing and ongoing flood hazard mapping. State and federal agencies will assist as requested. The new FEMA Coastal Construction manual is now available. Call 1-800-480-2520.

Reference:

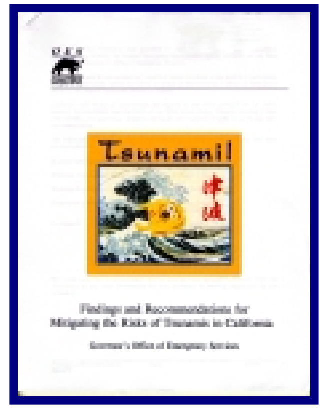
FEMA Coastal Construction manual. Three volumes in CD 1-800-480-2520.

Tsunami Mitigation

Chris Jonientz-Trisler (FEMA)

The National Tsunami Hazard Mitigation Program (NTHMP) was formed to help coastal communities reduce their tsunami risk. The tools the NTHMP has developed are also useful to inland coastal communities at risk to tsunamis generated by local faults and landslides.

Tools include inundation maps, an improved warning system, and a variety of other products. Education materials target a variety of audiences including planners, public officials, tourists, schools and the general public. Tools for emergency managers consist of inundation maps, evacuation routes and warning guidance, and community needs assessment surveys. Future work will include more projects dealing with guides for construction and land-use, infrastructure, vegetation, and vertical evacuation. The *TsuInfo Alert* newsletter facilitates information exchange and is one resource for information about meetings and mitigation



communities assisting them to become more tsunami resistant. Future work will address more long-term mitigation products and recovery planning.

Little tsunami legislation exists. Some is in place in Oregon to address tsunami education and drills for school children and future location of critical facilities on the coast— most of which currently are at risk to severe ground shaking and/or tsunami inundation during a local event based on a 1995 study of 47 communities. A 1994 survey of 11 West Coast U.S. communities showed the level of tsunami disaster resistance there could be improved. Since that finding, the NTHMP has worked to accomplish the following:

- Improve warning procedures and systems.
- Promote regular interaction among states and federal agencies to bring communities a better understanding of local risk.
- Expand a diverse network of information contacts among colleagues to assist communities to become more tsunami resistant. The tsunami resistant community understands the hazard, has the tools it needs, gets information out, and works to change behavior over the long-term by institutionalizing tsunami planning at all levels.

Reference:
www.pmel.noaa.gov/tsunami

Shoreside Landslide Mitigation

Bill Laprade (Shannon & Wilson)

Three basic types of landslides occur in Puget Sound: 1) rapid shallow, 2) block fall, and 3) deep-seated. While large, deep-seated landslides don't occur often, they make for very large disasters. For example, the 1997 deep-seated Woodway landslide dropped the shoreface of the bluff back 50 to 60 feet. The slide plane extended down through hard Lawton Clay, breaking into huge blocks, some as big as automobiles. The force of the event sent rail cars into Puget Sound.

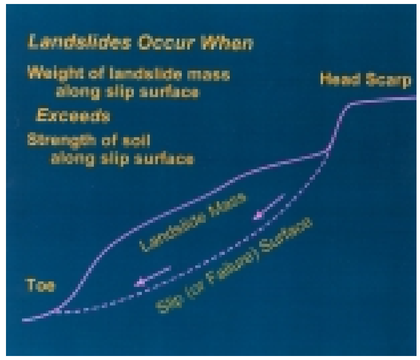
In response to the Holiday storm of 1996/97, Shannon & Wilson recently completed a database of landslides in Seattle, one of the largest in the country. The cataloging, done for Seattle Public Utilities (SPU), goes all the way back to 1890 to record data from 1,326 landslides. Drawn from the Department of Design, Construction and Land Use (DCLU), the Washington State Department of Transportation (WSDOT), and Shannon & Wilson's files, the database is a valuable tool for CIP and maintenance planning. It can be used to define landslide zones, set landslide policy, and educate the public.

A major finding of the work is that landslides in Puget Sound need a large storm and antecedent rainfall to create the conditions for widespread slope instability. The researchers looked first at steep slope (40%) areas. To their surprise, they found "holes" in areas where they thought landslides should occur. Some areas had many landslides where slide-prone zones had not been recognized. By studying concentrations of landslides, researchers were able to judge which ground should be in and which out of a potential landslide zone. These areas of risk are now incorporated in landslide maps. Certain other spots, such as the north end of Queen Anne, were removed as a landslide potential area, because they did not have landslide concentrations and other geologic factors indicative of landsliding.

The City of Seattle is now putting this information to use in several ways. SPU is using it to map engineering improvement and define the right kind of mitigation for a particular area. And because the database includes cost information, it can be used to come up with ballpark estimates for mitigation. DCLU is using the information during screening of building and construction permits.

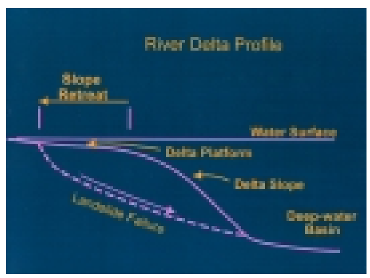
Submarine Landslide Mitigation

Steve Palmer (Washington State Department of Natural Resources)



Puget Sound submarine earthquakes are a significant hazard that requires further study. Historically, these landslides have happened on the deltas of rivers and large streams in the Pacific Northwest. Damage from submarine landslides results from both the movement of the landslide, which can destroy onshore and near-shore structures, and large water waves generated by the moving slide mass. The height of these water waves depends on the volume, geometry, and duration of the slide and the rheologic behavior (how matter deforms when it flows) of the slide mass. Submarine landslides cannot be prevented, and in many instances areas at risk to this hazard must be utilized for port and industrial areas. Consequently, mitigation efforts should be directed at minimizing damage and protecting lives.

Submarine landslides occur when the weight of the landslide mass along a slip surface exceeds the strength of the soil on that surface. They can occur at any time, as submarine slopes are typically at a point of near-instability. The primary triggering mechanisms for static (not caused by earthquake ground shaking) submarine landslides are:



1. Oversteepening: Rapid sedimentation results in a too steep and unstable slope.
2. Tidal Drawdown: Rapid drop in water level at high to low-tide transition results in loss of soil strength due to static liquefaction.
3. Undercutting: Changes in current pattern can erode material from the base of the delta slope.

4. Overloading: Addition of material at the top of the delta slope (e.g. artificial fill) increases downslope weight of soil mass.

The following table lists wave heights and descriptions of damage from static submarine landslides over the last 100 years in the Pacific Northwest.

Static Submarine Landslides – Pacific Northwest Coast (1894 – 1994)

Location	Year	Possible Cause	Wave	Effect
Skagway, AK	1994	• High sedimentation • Low tide • Human activity?	25-30 ft	• 1 dead • Major harbor damage
Fraser Delta, BC	1985	• High sedimentation • Low tide	none	Nearly undermined lighthouse
Seattle, WA	1980s	Previous construction?	none	Undermined sewer outfall
Kitimat, BC	1975	• High sedimentation • Low tide	25-30 ft	Minor damage docks & mill
Howe Sound, BC	1955	• High sedimentation • Low tide	none	Major damage docks & mill
Tacoma, WA	1943	• High sedimentation • Low tide • Toe of slope undercut	none	700 feet of training wall destroyed
Tacoma, WA	1894	• High sedimentation • Low tide • Toe of slope undercut • Human activities?	10-15 ft	• 2 dead • Northern Pacific RR docks destroyed

Strong shaking during an earthquake can trigger submarine landslides by accelerating the landslide mass downslope, consequently increasing its weight, and also by causing liquefaction of soils within the failure. Earthquakes have caused the largest Pacific Northwest submarine landslides. Most of the deaths caused by the 1964 Alaska earthquake were a direct result of submarine landslides. The table below summarizes damage and casualties from earthquake-related submarine landslides in the Pacific Northwest.

Earthquake-Induced Submarine Landslides – Pacific Northwest Coast (1866 – 1964)

Earthquake/yr	Location	Wave	Casualties	Damage
1964 Alaska	Valdez	30-40 ft	31 dead	total destruction shore area
1964 Alaska	Seward	30 ft	13 dead; 5 injured	total destruction shore area
1964 Alaska	Whittier	30-50 ft	13 dead	total destruction shore area
1949 Olympia	Seattle	none	None	none. small slide
1949 Olympia	Olympia (Cooper Spit)	none	None	none. small slide
1946 Vancouver Is	Comox Lake	yes	1 dead	Minor damage to cannery
1866 Olympia	Olympia (Cooper Spit)	10-15 ft	None	Small slide

References:

Coulter, H. W.; Migliaccio, R. R., 1966, Effects of the earthquake of March 27 1964 at Valdez, Alaska: U.S. Geological Survey Professional Paper 542-C, 36 p., 3 plates.

Johns, M. W.; Prior, D. B.; Bornhold, B. D.; Coleman, J. M.; Bryant, W. R., 1986, Geotechnical aspects of a submarine slope failure, Kitimat Fjord, British Columbia: Marine Geotechnology, v. 6, n. 3, p. 243-279.

Kachadoorian, R., 1965, Effects of the earthquake of March 27 1964 at Whittier, Alaska: U.S. Geological Survey Professional Paper 542-B, 21 p., 3 plates.

Kayan, R. E.; Barnhardt, W. A.; Palmer, S. P., in press, Geomorphological and geotechnical issues affecting the seismic slope stability of the Duwamish River delta, Port of Seattle, Washington: pre-print of paper to be presented at the American Society of Civil Engineers 5th Technical Conference on Lifeline Engineering, August 12-15, 1999, Seattle, Washington.

McKenna, G. T.; Luternauer, J. L.; Kostaschuk, R. A., 1992, Large-scale mass-wasting events on the Fraser River delta front near Sand Heads, British Columbia: Canadian Geotechnical Journal, v. 29, n. 1, p. 151-156.

Morrison, K. I., 1984, Case history of very large submarine landslide, Kitimat, British Columbia: *in* IV International Symposium on Landslides, Volume 2, p. 337-342.

Shannon, W. L.; Hilts, D. E., 1973, Submarine landslide at Seward: The Great Alaska earthquake of 1964, Committee on the Alaska Earthquake of the Division of Earth Sciences, National Research Council, published by the National Academy of Sciences, p. 144-156.

Terzaghi, K., 1956, Varieties of submarine slope failures: *in* Proceedings of the Eighth Texas Conference on Soil Mechanics and Foundation Engineering, published by the University of Texas, Bureau of Engineering Research, Austin, Texas, 41 p.

General Policy Change in the Flood Program

Norman Skjelbreia (U.S. Army Corps of Engineers)

The Corps is the public works arm of the federal government. It can play either a post-disaster or proactive role in studying landslide problems. After a flood disaster is official, the Corps does a damage assessment. Flood “authority” is the key. Once granted that authority, the Corps can act quickly. In ten days the Corps built a million-dollar structure in Snohomish following the 1996 flood. When the 1997 snow melt flooding occurred, the Corps, at the request of the governor, offered technical assistance for a landslide inventory and assessment. As a public works agency, the Corps has geotechnical capabilities and offers structural assessment teams. A CD is available from the Corps.

Reducing Earthquake/Tsunami Hazards in Pacific Northwest Ports and Harbors

Robert F. Goodwin (Washington Sea Grant Program)
Nate Wood (Oregon State University College of Oceanic and Atmospheric Sciences)

A three-year collaboration between researchers, university outreach specialists and community planners is studying how to build Pacific Northwest port and harbor communities that are more resistant to earthquake and tsunami hazards. Work includes the development of a GIS-based hazard and vulnerability model, a community-based planning process, and a regional needs assessment survey.

Sponsored by Washington and Oregon Sea Grant Programs and NOAA’s Coastal Services Center, the project is developing information technology tools coastal communities can use when creating realistic response-recovery options and seeking new mitigation funding.

A primary goal of the project is to determine how well coastal communities are prepared for and understand the effects of tsunami and earthquake risk and to pinpoint harbor-specific data gaps. Data from the project includes natural hazards/vulnerability analyses for subsidence, liquefaction and landslide potential and maximum tsunami elevation. The group’s Web site is a growing forum for public input and a regional educational and training tool for other Pacific Northwest communities.

To date, the study embraces 20 coastal counties and 47 coast towns. Year 1 (1999) was spent designing a model process and testing it in the port and harbor community of Yaquina Bay, Oregon, including the towns of Newport and Toledo. Year 2, now underway, is focused on improving the model and conducting a demonstration project in Washington. Year 3 will concentrate primarily on outreach, training and technical assistance for other Pacific Northwest communities.

Preliminary results from a regional survey suggest that most people believe earthquakes are a greater and more imminent risk to human life and property than tsunamis. Stakeholder input will be merged with technical and scientific input at a "Hazards and Vulnerability Workshop" in Newport, Oregon to be held February 28, 2001. Additional community workshops held in the spring and summer of 2001 will focus on developing mitigation and implementation strategies.

Project investigators recently met with emergency managers and local officials from six mid-sized port and harbor communities in Washington State—Edmonds, Bainbridge Island, Bremerton, Port Orchard, Port Angeles and Port Townsend—in preparation for selecting the Washington demonstration project. You can contact the program through Robert Goodwin, Coastal Resources Specialist, Washington Sea Grant Program, School of Marine Affairs, 3707 Brooklyn Ave. NE, Seattle, WA 98105-6715. Or phone, fax or email at 206.685.2452: 206.543.1417 (Fax), goodrf@u.washington.edu.

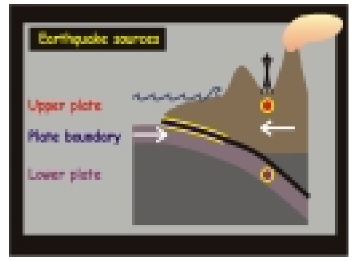
References:

http://www.csc.noaa.gov/products/tsunamis
http://www.wsg.washington.edu

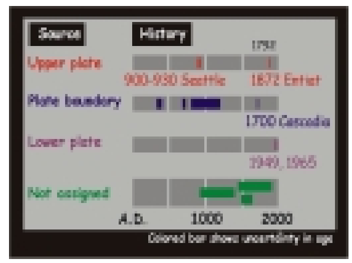
Tutorials

Tsunami Tutorial — Nature of the Threat

Brian Atwater (USGS)



Earthquakes in Puget Sound come from three sources: the lower plate (Juan de Fuca plate), the upper plate (North America plate), and the boundary between those plates. On average, large earthquakes arrive at intervals
of decades in the lower plate, millenia for the best-known fault in the upper plate (Seattle fault), and centuries for events of magnitude 8 or larger on the plate boundary.



Any of these three kinds of earthquakes can produce tsunamis in Puget Sound. A landslide that set off a tsunami in Tacoma Narrows shortly followed the 1949 earthquake in the lower plate. The earthquake of ca. A.D. 900 caused uplift that triggered a tsunami in central Puget Sound and probably also caused landslide-generated waves in Lake Washington. Tsunamis from plate-boundary earthquakes probably account for sand sheets on Whidbey Island and the head of Discovery Bay.

References:
Atwater, B.F., and Moore, A.L., 1992, A tsunami 1000 years ago in Puget Sound, Washington: Science, v. 258, p. 1614-1617.

Noson, L.L., Qamar, A., and Thorsen, G.W., 1988, Washington State earthquake hazards: Washington Division of Geology and Earth Resources Information Circular 85, 77 pp.

Williams, H., and Hutchinson, I., 2000, Stratigraphic and microfossil evidence for late Holocene tsunamis at Swantown marsh, Whidbey Island, Washington: Quaternary Research, v. 54, p. 218-227.

Tsunami Tutorial — Emergency Management Issues

Hal Mofjeld (NOAA)

The study of tsunami hazards naturally divides itself up into two parts: 1) the nature of the threat, discussed by Brian Atwater, and 2) the response to it, addressed in this tutorial. Tsunamis in Puget Sound require understanding the hazard, planning and mitigating for it, and having the warning systems and communication, including education, in place to handle the disaster. Tools for tsunami mitigation currently include (e.g., the NOAA/PMEL/TIME Projects):

- Tsunami inundation maps.
- HAZUS/GIS risk analyses.

- Tsunami model simulations.
- Planning exercises emergency managers use to identify issues and for training.

These tools require a basic understanding of tsunamis and where they can happen. Areas at risk are shorelines, ports and harbors, coastal rivers and lakes. Tides, weather, and time of day also determine the size of a tsunami in any of these areas. Tsunamis in Puget Sound come from three sources:

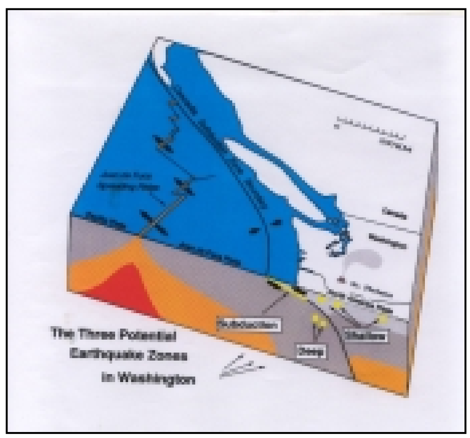
Types of Tsunamis in Puget Sound Region

Type	Source	Warning Time
Local	Local quakes and landslides	1 minute
Regional	Cascadia Subduction Zone	0.5 to 3 hours
Trans- Pacific	Alaska and Asia	4 hours or more

Both NOAA (through its Tsunami Warning Centers and NWS/Seattle Forecast Office) and state, county and local EMDs issue tsunami warnings.

Further management information can be drawn from NOAA's Puget Sound Tsunami Model, which uses a 7.6 earthquake on the Seattle Fault to simulate the results of an earthquake-induced tsunami. The model has shown that a 7.6 quake would unleash a dangerous tsunami that would strike the Seattle Waterfront only 2.5 minutes after the earthquake hit. To address the tsunami threat in Puget Sound, emergency managers need to answer the following questions:

- What information do we need? In what form? Who updates it?
- What happens if we have a tsunami? What are the roles we play?
- How do we prepare for that?



References:
http://www.pmel.noaa.gov/tsunami/
http://www.wa.gov/wsem/
http://www.wrh.noaa.gov/seattle

Earthquake Tutorial

Craig Weaver (USGS)

The three earthquake source zones in Puget Sound can release enough force to cause landslides or underwater slumping. And these disasters may not happen immediately after a quake. Some landslides could produce locally damaging tsunamis. Only shallow crustal events, which are rare, have the potential to generate earth movement.

The UW/USGS Seismic Net is a resource to help emergency managers identify where earthquakes occur in all of western Washington. It may be especially useful to managers following deep quakes, which are unlikely to create a tsunami but could cause landslides in a wide area around the epicenter, as happened in a 1949 ground failure that reached from the Cowlitz river to Seattle.

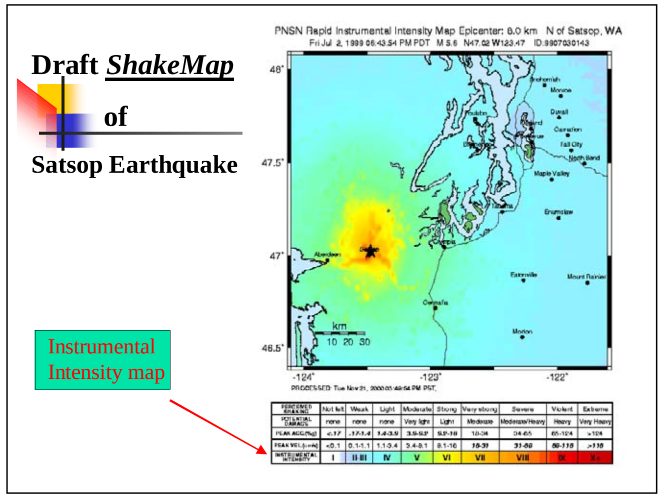
After an earthquake, you can get the following timed sequence of data from the UW/USGS:

- 3 to 60 seconds after event – preliminary location and rough magnitude from RACE.
- 1 to 4 minutes later – Revised hypocenter and more accurate magnitude from RACE and the Web.
- 5 to 20 minutes later – hypocenter checked by seismologists.
- SHAKE MAP (soon to be available within 10 to 20 minutes).
- 20 to 30 minutes – focal mechanism (showing how the fault moved).
- Aftershock activity as it occurs in the same time stream.

SHAKE MAPS are another tool that can be applied as overlay to a map of failure-prone areas. They may be used to identify a subset of slopes with the highest probability of generating a Tsunami. They could also be used as a response template that summarizes ground failure possibilities.

The UW/USGS is developing a real-time data products guide that can show where tsunamis and landslides are expected in Puget Sound.

Reference:
http://www.geophys.washington.edu



Landslide Tutorial

Tim Walsh (Washington State Department of Natural Resources)

Two different methods of mapping landslides—inventory and analytical—are tools now available to local governments. Ideally, the two methods are used in tandem.

1. USGS work by Rex Baum and Ed Harp can give you analytical data that can help predict the likelihood of landslides for Seattle. Look for this information at http://www.landslides.usgs.gov/index.shtml

2. Bill Laprade's (Shannon & Wilson) inventory database for the same area is available from the City of Seattle. Other observational data on landslides along coastal bluffs can be found at:

   http://www.ecy.wa.gov/programs/sea/landslides/index.html
   http: //wa.gov/dnr/htdocs/ger/index.html

Several forces act on a hillslope to cause landslides. Primarily, gravity acts vertically on rocks, making a slope tend to move parallel to the slope or be pinned by forces acting perpendicular to the slope. The Factor of Safety (F_s) is a way scientists measure the resisting and driving forces in a landslide. *Shear stress*, a driving force, pushes soil parallel along a slope. *Shear strength* is a measure of the soil's ability to resist this pushing. In thinking about landslide movement, F_s equals shear strength/shear force.

Sometimes the same materials can act differently because of circumstances, not just the properties of soil. That's one of the reasons landslides are much more common during rainy spells. And it's one of the reasons scientists analyze slope angle and put that kind of information in slope hazard maps to show susceptibility. A mix of heavy rain, rapid snowmelt and saturated soils trigger landslides as shown by both the historical record and recent events, such as the 1997 Perkins Lane and Magnolia Bluff slides.

More than 100 landslides happened in our region after that kind of weather in 1997. The Woodway slide on January 15, 1997 knocked a freight train into the Sound and on January 19, 1997 killed a family of four in the Rolling Bay area of Bainbridge Island. The Rolling Bay area had been mapped as "unstable" by the Coastal Zone Atlas of 1970, which gives a county-by-county readout of landslide hazard along Washington's saltwater coastline areas.

Researchers mainly rely on winter-storm-related events to study landslides in Puget Sound. But the region also experienced landslides caused by earthquakes as in the 1949 slide at Salmon Beach in the Tacoma Narrows. The landslide, which occurred 3 days after the 1949 Puget Sound earthquake, generated a 6- to 8-foot tsunami that hit Gig Harbor. The photo on the right shows the effects of this massive slide.

Reference:
http://landslides.usgs.gov/index.shtml

Day 2: Technical Sessions

Purpose

Emergency managers want the best available information delivered to them as soon as possible. The task ahead is very practical: to find out just *how* to deliver that information. Technical panels drawn from the earth science and information technology research fields summarized state-of-the-art practice for earthquakes, landslides, tsunamis, merged bathymetry and topography, and HAZUS/GIS products. Panelists were encouraged to explore how their science applies to tsunami and landslide mitigation practice. The following summarizes each panel's major conclusions and the audience's response to the technical discussions.

Earthquakes/Faults

Moderator: Craig Weaver (USGS)
Panelists: Eric Geist (USGS), Tom Brocher (USGS) and Derek Booth (UW)

Conclusions:

- Earthquakes can generate many landslides. But crustal faults in Puget Sound, the region's most frequent source of quakes, are still poorly understood, making earthquake-induced landslides and tsunamis a hazard that is likewise poorly understood.
- Three types of fundamental data are needed to better assess hazards:
    1. Geologic maps—older maps are not prepared with eye toward hazards.
    2. Bathymetry—high resolution, multi-beam data needed to do inventories, potential slump identification, and tsunami models.
    3. Lidar—used to identify faults and potential locations to investigate fault history.
- Emergency planners need improved ground motion estimates to use as inputs to landslide scenarios.
- Scientists and emergency response officials need to discuss the usefulness of probabilistic tsunami hazard maps and deterministic scenarios.
- Improved geologic mapping leads to better discrimination of landslide prone areas.

Audience Discussion:

- ShakeMaps for local earthquakes are now available on the web (www.geophys.washington.edu).
- Hidden (unknown) faults are a problem. There is uncertainty in the relation among geophysical anomalies, surface features, instrumental seismicity, and the paleoseismic record. Based on current understanding, the scientific community does not concur that you can use existing knowledge of crustal faults to limit the number of areas that might generate tsunamis.
- Some in the audience were concerned that building codes in central Puget Sound are too heavily based on Seattle fault and may not reflect the hazards of other, more poorly understood, faults. Engineers and seismologists are working to improve hazard calculations by incorporating crustal deformation rates, measured by sensors on the surface, into current estimates that rely solely on geologic field studies.
- Seismologists and emergency managers need a better structure to communicate results and information. Some counties have detailed discussions with the UW and USGS. Other counties have little or none.

Landslides

Moderator: Tim Walsh (Washington Department of Natural Resources)
Panelists: Connie Manson (WA DNR), Bill Laprade (Shannon & Wilson), Hugh Shipman (Ecology), and Rex Baum (USGS)

Conclusions:

- Coastal Zone Atlas is a good starting point for understanding local landslide hazards (www.ecy.wa.gov/programs/sea.landslides/)
- Washington Department of Natural Resources Library is the best source for geologic information. Their index is on CD*: Digital Bibliography of the Geology and Mineralogy of Washington State*. (contact: Connie Manson 360.902.1472 or connie.manson@wadnr.gov).
- Landslide policy needs to have a scientific basis—can't be based on old data.
- Mitigation has the following hierarchy:
    1. Avoidance.
    2. Get the water out—keep the water flowing through gravity drainage.
    3. Structures are last resort.
- USGS has developed a possible landslide forecasting technique for the City of Seattle.
- Data needs are twofold:

1. Landslide inventories and databases.
2. Lidar imagery to identify old landslides.

Audience Discussion:

- Kitsap County has begun to implement recommendations for USGS landslide databases.
- Need to overcome resistance in some counties to keeping more detailed records.

Other Resources Identified:

- General information: www.ecy.wa.gov/programs/sea

Tsunamis

Moderator: Vasily Titov (NOAA)
Panelists: Brian Atwater (USGS), Shun-ichi Koshimura (JSPS), Ed Meyers (OGI), Sasha Rabinovich (TCM) and Harry Yeh (UW).

Conclusions:

- Puget Sound tsunamis differ from those on the outer coast.
  - Puget Sound tsunamis. Strike shorelines very soon following local earthquakes or landslides—no warning time. Will be over in 30 minutes or so following an earthquake.
  - Outer coast tsunamis. Distant tsunamis allow many hours of response time. May have damaging waves for 12 hours following the earthquake.
- Locally, great devastation will follow a tsunami. Many deaths are possible from debris.
- Scenarios provide guidance for emergency managers. The Seattle fault scenario showed areas of inundation in Puget Sound with strong currents around Harbor Island.
- Source parameters for crustal fault earthquakes are poorly known.
- Landslide-generated tsunamis often have wave heights offshore that are comparable to runup heights.
- Tsunamis will have effects not currently expected, such as the amount of strain on the pontoon cables for floating bridges in Lake Washington.
- Tidal conditions are important for modeling inundation.

<u>Audience Discussion</u>:

- Seismologists and tsunami modelers need to hone fault parameters for more realistic models of the Seattle fault.
- Landslide-generated tsunamis are over quickly and affect limited area—no warnings are possible.

Merged Bathy/Topo Digital Elevation Model (DEM)

Moderator: Ralph Hagerud (USGS)
Panelists: Dave Finlayson (UW), Mike Fisher (USGS) and Cinde Donoghue (NOAA)

<u>Conclusions</u>:

- Merged elevation and bathymetry is useful for a wide range of problems.
- The following three problems occur when merging land and sea elevation/bathymetry data:
    1. The datum (how to calculate?).
    2. Shoreface (how to treat the data? Institutional problem between the USGS and National Oceanographic Service [NOS]).
        - Lack marine data.
        - Lack agreement on the shoreline location.
        - Problems with USGS land DEMs.
        - Many data gaps.
    3. Where are the errors in each data set?
- New surveys in using the three following technologies could improve the match between the land and sea:
    1. <u>Sweep systems</u> drag light beams across and measures close to beach—worked out of a small boat.
    2. <u>Multibeam bathymetry</u> with backscatter—used in deep water.
        - Linked to GPS so position is known.
        - Backscatter measures travel time through water, giving map of physical properties (example showed difference in bathymetry and backscatter).
    3. <u>Lidar</u>—land-sea interface.
        - Physical limitation to what you can do over water because light is poorly returned to sensor.

    - Relatively fast to acquire data (aircraft along shoreline).
    - Survey can extend on both sides of water line.
    - Disadvantages:
        - Large footprint compared to sonar.
        - No backscatter for sediment type.
        - Max and min water depths of about 30 meters, 1 meter.
        - Weather can be a factor for data collection.

- Data problems such as repository, archiving and distribution must be resolved before data collected.

Audience Discussion:

- Interest in Tsunami modeling is highest in developed areas with sharp water interface. Has anyone gauged the effort needed to merge these areas into the regional data set maintained by PRISM at the UW? Difficult to merge these data sets. The panel felt that money might be better spent on a new survey.
- USGS estimated a full survey with multi-beam bathymetry and backscatter would be about $2 million.
- Jetski and ATV with GPS are being used to collect near-shore lidar along a segment of the beach in southwest Washington.

HAZUS/GIS Systems

Moderator: Ron Langhelm (FEMA)
Panelists: George Graettinger (NOAA), Chris Wayne (ERSI) and Tiffany Vance (NOAA).

Conclusions:

- GIS is the tool to deal with all types of data.
    - GIS is a data integration tool.
    - GIS is a data dissemination tool.
    - GIS is a data visualization tool.
- GIS community needs to understand what emergency managers need.
- HAZUS (Hazard U.S.) is a loss estimation tool originally designed for earthquakes but now expanded to include floods.
    - HAZUS stresses reporting functions and options.
    - Private-public network required to maximize usefulness.
    - HAZUS can house tsunami data.
    - Example outputs.
        - Risk maps.
        - Highway and bridge databases and state of system during restoration.
        - Power outage.

Audience Discussion:

- Need a Web page that serves as a point to all of the issues, data sets, and models discussed in this meeting.
- Interest in customizing HAZUS and incorporating 2000 census data.
- Scientific inputs to HAZUS still needed.
- Desire better access to information before that information is needed to make a decision.

List of Acronyms

BAS	Best Available Science
BATHY	Bathymetry
CAO	Critical Area Ordinance
CIP	Capital Improvement Project or Program
DCLU	Department of Construction and Land Use
DEM	Digital Electronic Mapping
EMD	Emergency Management Division (Washington State Military Department) Or Emergency Management Districts
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System
GMA	Growth Management Act
GPS	Global Positioning System
HAZUS	Hazard U.S.
JSPS	Japan Society for the Promotion of Science
NFPI	National Flood Insurance Program
NOS	National Oceanographic Service
NOAA	National Oceanographic and Atmospheric Administration
NTHMP	National Tsunami Hazard Mitigation Program
OGI	Oregon Graduate Institute
PMEL	Pacific Marine Environmental Laboratory (a division of NOAA)
PRISM	Puget Sound Integrated System Model
RACE	Rapid Alert of Cascadia Earthquakes
SMP	Shoreline Management Plan
SPU	Seattle Public Utility
TCM	Tsunami Center, Moscow
TIME	Center for Tsunami Inundation Modeling Efforts at NOAA/PMEL
TOPO	Topography
TsuInfo	*TsuInfo* newsletter produced by FEMA
USGS	United States Geological Survey
UW	University of Washington
WSDOT	Washington Department of Transportation

Attendee List

Puget Sound Tsunami/Landslide Workshop January 23-24, 2001

First	Last Name	Title	Organization
Allen	Alston	Emergency Planner	King County Office of Emergency Management
Brian	Anderson	Teacher Education Supervisor	Pacific Science Center
Brian	Atwater	Geologist	USGS/Quaternary Geology and Earthquake Hazards
Eric	Baer	Professor	Highline Community College
Steve	Bailey	Director	Pierce County Dept. of Emergency Management
Cathleen	Barry	Cartographer	NOAA/Pacific Hydrographic Branch
Rex	Baum	Geologist	USGS/National Landslide Hazards Program
James	Bela	President	Oregon Earthquake Awareness
Boyd	Benson	Geologist	GeoEngineers
Eddie	Bernard	Director	NOAA/Pacific Marine Environmental Laboratory
Matthew	Bernard	CDR Planner	US Coast Guard
Marty	Best	Mitigation Officer	WA Emergency Management Division
Derek	Booth	Director	UW/ Center for Urban Water Resources Management
Tom	Brocher	Geophysicist	USGS/Western Earthquake Hazards Team
Eric	Brose	Intern	Kitsap County Dept. of Emergency Management

Attendee List

First	Last Name	Title	Organization
Steve	Brown	Recovery & Mitigation Coordinator	City of Seattle Emergency Management
Ted	Buehner	Warning & Coordination Meteorologist	NOAA/National Weather Service
Det. Steve	Cain	Detective	City of Bainbridge Island Dept. of Public Safety
Sharon	Christopherson	Scientific Support Coordinator	NOAA/ORR/Hazardous Materials Response Division
Joe	Ciarlo	Emergency Coordinator	Clallam County Emergency Management Division
Mitch	Cline	Major Incidence & Response Coordinator	Thirteenth Coast Guard District
George	Crawford	Earthquake Program Manager	WA Emergency Management Division
Feruccio	Crocetti	Plans Section Supervisor	WA Emergency Management Division
Randy	Davis	Shorelands Planner	WA State Dept. of Ecology
Cinde	Donoghue	Bathymetry Expert	NOAA/Coastal Services Center
John	Ege	Engineering Geologist	City of Seattle Public Utilities
Claudia	Ellsworth	Project Consultant	Project Impact
Richard	Fife	Emergency Management Coordinator	WA St. Dept. of Transportation
Dave	Findley	Principal	Golder Associates
Dave	Finlayson	Graduate Student	UW/Geology/Puget Sound Regional Synthesis Model

Attendee List

First	Last Name	Title	Organization
Mike	Fisher	Marine Geophysicist	USGS/Coastal and Marine Geology
Bob	Freitag	Director	UW/Institute for Hazard Maintenance & Research
Eric	Geist	Geophysicist/Earthquake &Tsunami Hazards	USGS/Coastal and Marine Geology
Frank	Gonzalez	Supervisory Oceanographer	NOAA/PMEL/Tsunami Research Program
Roberto	Gonzalez	Regional Director	Emergency Preparedness Canada
Bob	Goodwin	Coastal Resource Specialist	UW/Washington Sea Grant
George	Graettinger	GIS Coordinator	NOAA/NOS/ORR/Coastal Protection and Restoration Div.
Barb	Graff	Emergency Preparedness Manager	City of Bellevue Fire Department
Lyn	Gross	Director	Emergency Services Coordinating Agency
Chuck	Hagerhjelm	Recovery Section Supervisor	WA Emergency Management Division
TJ	Harmon	Director	Island County Emergency Management Division
Ralph	Haugerud	Geologist	USGS/Puget Sound Landform Studies
Roger	Hieb	Training Section Supervisor	WA Emergency Management Division
Eric	Holdeman	Manager	King County Office of Emergency Management
Steve	Hou	Senior Civil Engineer	City of Seattle Transportation

Attendee List

First	Last Name	Title	Organization
Sheryl	Jardine	Program Assistant	WA Emergency Management Division
Jeff	Jensen	Deputy Chief	City Tacoma Fire Department
Jerry	Jenson	Exercise Training Officer	WA Emergency Management Division
Bill	Johnson	Inspector	Kent Dept. of Fire & Life Safety
Bob	Johnson	Chief	City of Auburn Fire Department
Chris	Jonientz-Trisler	Earthquake Program Manager	FEMA Region X
Rob	Kayen	Civil Engineer/ Earthquake & Landslide Hazards	USGS/Coastal and Marine Geology
Gordon	Kelsey	Civil Engineer	Thurston County Roads & Transportation Services
Shun-ichi	Koshimura	Tsunami Scientist	NOAA/Pacific Marine Environmental Laboratory
Don	Krupp	Director	Thurston County Development Services Division
Ron	Langhelm	GIS Coordinator	FEMA Region X/Response & Recovery
Bill	Laprade	Engineering Geologist	Shannon & Wilson, Inc.
Peter	Leon	Policy Analyst	NOAA/Office of Response & Recovery
Michael	Lienau	Television Producer	Global Net Productions
Jeff	Loewen	GIS Technician	FEMA Region X/Response & Recovery

Attendee List

First	Last Name	Title	Organization
Erika	Lund	Recovery Coordinator	City of Seattle Emergency Management
Phyllis	Mann	Director	Kitsap County Dept. of Emergency Management
Connie	Manson	Senior Librarian	WA Dept of Natural Resources
Steve	Marten	Operations and Training Coordinator	City of Seattle Emergency Management
Peter	May	Professor	UW/Political Science
Mike	McCallister	Coordinator	Snohomish County Emergency Management
TJ	McDonald	Information Technology Coordinator	City of Seattle Emergency Management
Bob	Mead	Hydrologist	Thurston County Environmental Health
Max	Messman	Southest Regional Coordinator	WA Emergency Management Division
Bob	Minty	Assistant Director / Coordinator	Jefferson County Dept. of Emergency Management
Hal	Mofjeld	Tsunami Scientist	NOAA/Pacific Marine Environmental Laboratory
Jim	Mullen	Director	City of Seattle Emergency Management
Ed	Myers	Tsunami Scientist	Oregon Graduate Institute
Ken	Olsen	Student	UW/Geophysics Program
Lester	Olson	Director	Thurston County Emergency Management
Steve	Palmer	Geologist	WA Dept of Natural Resources

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First	Last Name	Title	Organization
Steve	Palmer	Geologist	WA Dept of Natural Resources
Chris	Parsons	Senior Planner	Community Trade & Economic Development
Cheryl	Paston	Contract Administration Manager	City of Seattle Public Utilities
Catherine	Petroff	Assistant Professor	UW/Civil & Environmental Engineering
Jane	Preuss	Principal	GeoEngineers
Sasha	Rabinovich	Tsunami Scientist	Tsunami Center, Moscow, Russia
Frank	Reynolds	Inspector	U.S. Dept. of Transportation
Stanley	Roe	Personal Secretary to the County Assessor	King County Dept. of Assessment
Keith	Ronnholm	President	Remote Measurement Systems, Inc.
Robert	Schneider	Emergency Preparedness Manager	City of Redmond Fire Dept.
Dave	Schneidler	Manager, Emergency Planning	Port of Seattle Seaport Planning Services
Richard	Schroedel	Coordinator	Pierce County Dept. of Emergency Management
Roger	Serra	Director	Snohomish County Dept. of Emergency Management
Hugh	Shipman	Coastal Geologist	WA Department of Ecology
Kristi	Silver	Water Quality Planner	King County Dept. of Natural Resources

Attendee List

First	Last Name	Title	Organization
Terry	Simmonds	Emergency Response Coordinator	Wash. St. Department of Transportation
Norman	Skjelbreia	Engineer	U.S. Army Corps of Engineers
Randy	Sleight	Chief Engineering Officer	Snohomish County Planning & Development Services
Dan	Sokol	Environmental Planner	WA Department of Ecology
Colleen	Srull	Private Citizen	
Bill	Steele	Seismology Lab Coordinator	UW/Geophysics Program
Ron	Stephens	Assistant Chief, Prevention & Education	City of Tacoma Fire Department
Don	Summers	Section Supervisor	Snohomish County Planning & Development Services
Genie	Thompson	Vice President	Bank of America
Vasily	Titov	Co-Director	Center for Tsunami Inundation Modeling Efforts
Joe	Toland	GIS Specialist	FEMA Region X/Response & Recovery
Dee	Totten	Emergency Management Coordinator	City of Mercer Island
Kathy	Troost	Research Scientist	UW/Dept. of Geological Sciences
Maillian	Uphaus	Programs & Recovery Unit Manager	WA Emergency Management Division
Teffany	Vance	GIS Specialist	NOAA/Pacific Marine Environmental Laboratory

Attendee List

First	Last Name	Title	Organization
John	Vollmer	Individual Asst. Program Manager	WA Emergency Management Division
Lee	Walkling	Librarian	WA Dept of Natural Resources
Tim	Walsh	Chief Geologist	WA Dept of Natural Resources
Chris	Wayne	GIS Expert	Environmental Systems Research Institute, Inc.
Craig	Weaver	Pacific Northwest Coordinator	USGS Earthquake Hazard Program
Kate	Wheatley	Science Education Associate	Pacific Science Center
Carla	Whittington	Instructor	Highline Community College
John	Willits	Lieutenant	Kent Dept. of Fire & Life Safety
David B.	Winandy	Facilities Engineer	NOAA/Western Regional Center
Trudy	Winterfeld	Vice Chair	WA St. Emergency Management Council
Nate	Wood	Graduate Student	OSU/Oregon Sea Grant
Patrick	Yamashita	City Engineer	City of Mercer Island
Harry	Yeh	Professor	UW/Civil & Environmental Engineering
Jon	Zerby	Director	San Juan County Emergency Management