CASCADIA

News & information from the Oregon Department of Geology and Mineral Industries WINTER 2010

Creating a culture of preparedness—

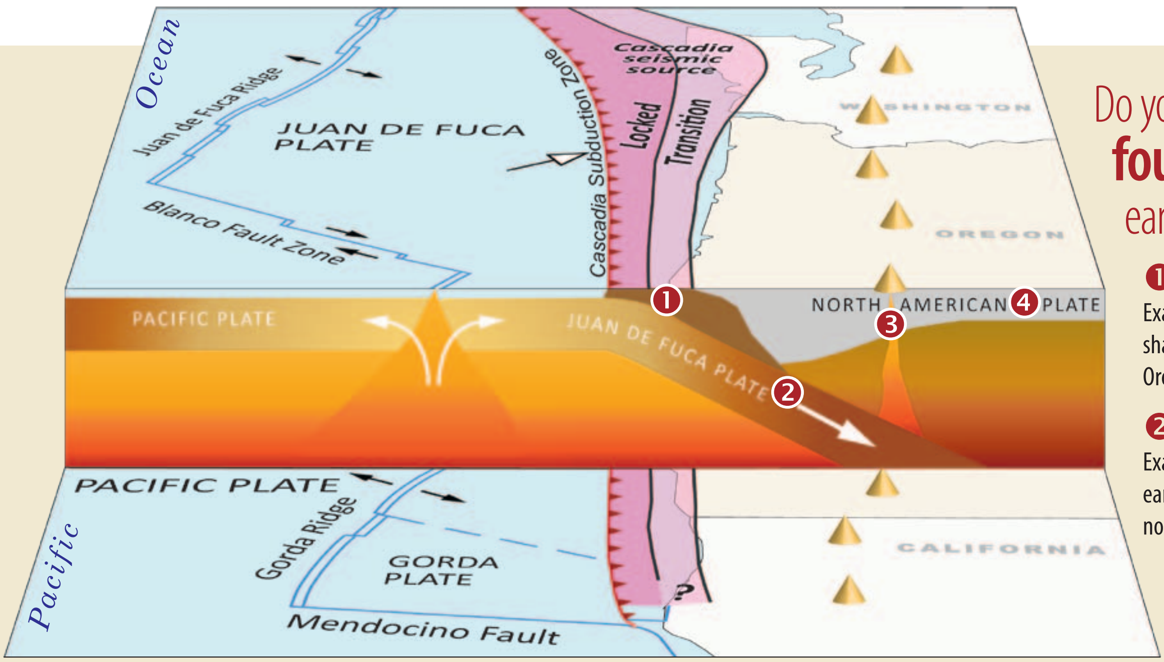
Oregon's earthquake risk and resiliency

With the Cascadia Subduction Zone offshore, Basin and Range faults to the east, and a line of volcanoes in between, Oregon is at risk for earthquakes. Are the state's infrastructure, your community, and your family ready?

Why does the Pacific Northwest have earthquakes?

In the Pacific Northwest, two of the earth's tectonic plates collide, and the boundary between them is a 600-mile-long fault called the Cascadia Subduction Zone (CSZ). Here the Juan de Fuca Plate and the North American plate converge at the rate of 1-2 inches per year (3-4 cm/yr), causing stress to accumulate on the fault (called a megathrust) that extends from Northern California to Vancouver Island. Earthquakes are caused by the abrupt release of this slowly accumulated stress.

The effects of a great (magnitude 9.0) CSZ earthquake will reach far inland. Shaking will be strongest on the coast but also strong in Willamette valley. We can expect up to 5 minutes of shaking. Prolonged shaking can cause structure collapse, landslides, and disruption of lifeline services. If a CSZ earthquake generates a significant tsunami, Oregon can expect an estimated 5,000 fatalities and over $30 billion in damages.



See page 3 for explanation of Cascadia seismic source.

Do you know Oregon's **four** kinds of earthquake sources?

❶ Cascadia Subduction Zone
Example: the 1700 earthquake that caused shaking and a tsunami that inundated the Oregon coast and reached as far as Japan.

❷ Intraplate
Example: the 2001 Nisqually, Washington, earthquake that affected Washington and northwestern Oregon.

❸ Volcanic
Example: the 1980 Mount St. Helens eruption-related earthquakes.

❹ Crustal
Example: the 1993 Scotts Mills and Klamath Falls earthquakes Crustal earthquakes also occur in southeastern Oregon where the crust is pulling apart.

IN THIS ISSUE

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Notes from your State Geologist

— Oregon's take away question: time or money?

by Vicki S. McConnell, Oregon State Geologist

Earthquake and seismological science just keeps getting better and better. In-depth geologic and geophysical study of seismic zones combined with near real-time GPS strain measurements of movement along faults can provide data to pinpoint precisely where the next earthquake along a fault zone may occur and even give us a probable notion of when it might occur. No predictions here, folks; we can only discuss likely activity over years and decades, not the hours, minutes, and seconds that are preferable for human planning and response.

Advances in structural engineering for earthquake and tsunami active areas mean our buildings can be designed to be safer and to be more likely to withstand a geologic process. Contributions from scientists in these areas and others can provide information and tools for communities to survive an earthquake and tsunami with relatively minimal loss of life and infrastructure IF communities can or do respond to the information. In almost every case, time is of the essence. We in the hazard characterization and mitigation business always feel we are struggling to catch up to Mother Nature.

The recent Haiti and Chile earthquakes are prime examples. Haiti, with virtually no building codes and only a very recent understanding of their relative earthquake risk, suffered tremendous loss of life (>200,000) and infrastructure from an earthquake of magnitude 7.0. Chile, on the other hand, has just weathered the fifth largest earthquake recorded (magnitude 8.8, nearly 500 times stronger than the Haiti earthquake) with a loss of about 500 lives and many buildings still standing. What was the difference? Awareness of the magnitude of the risk and willingness to address social issues like enforcing strict building codes and outreach and education of the general public.

Although at the end of the day everyone must take some personal responsibility to be informed, be aware, and be prepared, it is our mission at DOGAMI to provide everyone with as much information about earthquake and tsunami hazards as possible and to provide mitigation tools to reduce the risk — a risk we now know is nearly as high as Chile's.

We have accelerated our tsunami mitigation program by setting forth the goal to have new, expanded inundation maps for the entire Oregon coast by 2013. These will be followed by new evacuation maps designed with input from the Tsunami Advisory Group, whose members represent the end users for our products. Our earthquake and tsunami hazards outreach and education projects are now an equal part of our hazard mitigation program. We are focusing on grass roots projects such as placing tsunami preparedness coordinators in coastal communities to conduct education and outreach. It will still take several years for us to complete the maps and to develop fully the outreach.

With earthquake science and engineering it is a similar story. Over the past decade DOGAMI has worked with dozens of state agencies, emergency responder communities, two Governors' offices, and scores of legislators to implement the Oregon Emergency Management Seismic Rehabilitation Grant Program. This grant program awards state bond funds to public school districts and emergency response facilities that are in need of seismic retrofit and that have successfully applied for funds.

After seeing the destruction of the 2004 Sumatra earthquake and tsunami we recognize that infrastructure (water mains, bridges, railroad lines, fuel storage, transmission lines, etc.) is very vulnerable, is costly to repair and replace, and frequently is the reason that an area remains uninhabitable long after the hazard has abated. How do we assess the infrastructure vulnerability in Oregon and prioritize retrofits? Will it take us another 10 years to develop a plan to begin the fix?

I end this message with a note from Paul Mann, senior research scientist with the Institute for Geophysics at University of Texas at Austin. In an American Geophysical Union *Eos* magazine interview (January 26, 2010) he cautioned, "Countries with faults threatening dense populations need to approach earthquake 'defense' with the same energy, consistency, and level of scientific spending as devoted to their military defense." I completely agree; we should be defending against hazards now, not after the fact.

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800 NE Oregon Street, #28,
Suite 965, Portland, OR 97232
(971) 673-1555 fax (971) 673-1562

State Geologist – Vicki S. McConnell
Assistant Director – Don Lewis
Cascadia special contributor – Yumei Wang
Cascadia design – Deb Schueller

Mineral Land Regulation and Reclamation Program
229 Broadalbin Street, SW, Albany, OR 97321
(541) 967-2039 fax (541) 967-2075
Gary W. Lynch, Assistant Director

Baker City Field Office
Baker County Courthouse
1995 3rd Street, Suite 130
Baker City, OR 97814
(541) 523-3133 fax (541) 523-5992
Mark L. Ferns, Regional Geologist

Coastal Field Office
313 SW 2nd Street, Suite D
Newport, OR 97365
(541) 574-6642 fax (541) 265-5241
Jonathan C. Allan, Coastal Team Leader

The Nature of the Northwest Information Center
800 NE Oregon Street, #28, Suite 965
Portland, OR 97232-2162
(971) 673-2331 fax (971) 673-1562
Donald J. Haines, Manager
Internet: http://www.NatureNW.org

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Coming to terms with seismicity

Oregon's earthquake hazards come not only from different kinds of earthquakes and from associated tsunamis but from damage that can result from processes triggered by these events. Understanding earthquakes and how damage occurs can help you prepare your home or business. (See pages 4-5 for how to prepare.)

fault *A break in the earth's crust which ruptures during an earthquake, allowing the two sides of the fault to slip past each other. The slippage may range from less than an inch to more than 30 feet in a severe earthquake.*

earthquake *Seismic vibrations produced when a fault in the earth's crust ruptures or breaks, causing movement or slippage of the rocks along the fault.*

seismic waves *Vibrations that travel outward from the earthquake fault at speeds of several miles per second. Although fault slippage directly under a structure can cause considerable damage, seismic waves cause most of the destruction during earthquakes.*

magnitude *The amount of energy released during an earthquake. An increase of one full point on a magnitude scale represents about a 30-fold increase in the energy released. Therefore, an earthquake measuring magnitude 6.0 is about 30 times more powerful than one measuring 5.0.*

intensity *The severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. The intensity for a particular earthquake will vary depending on the distance from the epicenter and the type of soil and rock at the site.*

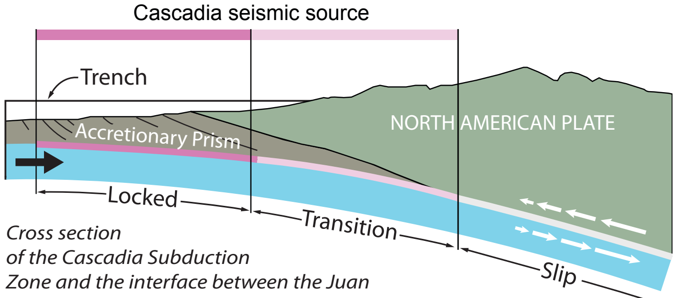
epicenter *The place on the earth's surface directly above the point on the fault where the earthquake rupture begins. Once the rupture begins, it expands along the fault during the earthquake and can extend hundreds of miles before stopping.*

foreshock *An earthquake that precedes the main earthquake.*

main shock *The largest magnitude earthquake in a group of earthquakes.*

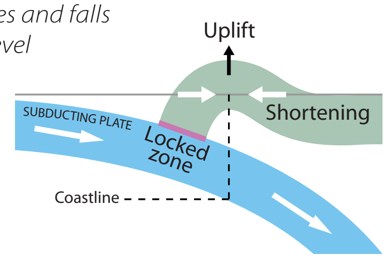
aftershock *An earthquake of similar or lesser intensity that follows the main earthquake.*

Cascadia seismic source, locked zone, transition zone, and rupture zone *The Cascadia subduction zone is locked where the rock is not slipping because frictional resistance on the fault is greater than the stress across the fault. The transition zone separates the locked zone from the zone of continuous sliding to the east. Stored energy is eventually released in an earthquake when frictional resistance is overcome. The rupture zone is the area along which the earthquake can occur; it is equivalent to the pink zones shown in the diagram.*



Cross section of the Cascadia Subduction Zone and the interface between the Juan de Fuca and North American plates. The locked zone (dark pink surface) and transition zone (light pink surface) can be the source of next great earthquake. The gray surface is the deeper slip zone. (image modified from Geological Survey of Canada [http://gsc.nrcan.gc.ca/geodyn/casaction_e.php])

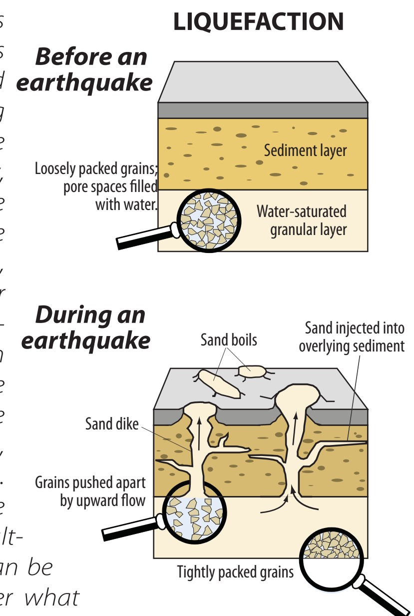
coseismic subsidence *Relative rises and falls in land, sea floor, and sea level caused by the buildup and release of stress associated with great (magnitude 9) underwater earthquakes.*



(image modified from Geological Survey of Canada)

liquefaction *A process by which water-saturated sediment temporarily loses strength and acts as a fluid when exposed to strong seismic shaking. The shaking causes the grains to lose grain-to-grain contact, so the sediment tends to flow. Liquefaction is most likely in loose sandy soil with a shallow water table.*

earthquake liquefaction hazards *If an earthquake induces liquefaction, several things can happen: The liquefied layer and everything lying on top of it may move downslope. Alternatively, the layer may vibrate with displacements large enough to rupture pipelines, move bridge abutments, or rupture building foundations. Light objects, such as underground storage tanks, can float toward the surface, and heavy objects, such as buildings, can sink. Thus, if the soil at a site liquefies, the damage resulting from an earthquake can be dramatically increased over what shaking alone might have caused.*



earthquake ground-shaking amplification hazards *Soils and soft sedimentary rocks near the surface can modify bedrock ground shaking caused by an earthquake. This modification can increase (or decrease) the strength of shaking or change the frequency of the shaking. The nature of the modifications is determined by the thickness of the geologic materials and their physical properties, such as stiffness.*

earthquake-induced landslide hazards *Steep and moderate slopes can produce landslides during earthquakes. Not all landslides occur in the first few minutes following an earthquake; some can occur days later. In 1949, a large landslide near Tacoma, Washington, slipped three days after the earthquake. The steep slopes along the edges of the Willamette Valley, often near saturated conditions because of high rainfall, are candidates for earthquake-induced failure. Road cuts and fills can also have slope failures.*

lateral spreading *A kind of landslide that forms on gentle slopes and that has rapid fluid-like flow movement, often associated with liquefaction.*

See animations of earthquake terms and concepts:
http://earthquake.usgs.gov/learn/animations/

What to do BEFORE an earthquake *(from FEMA: http://www.fema.gov/hazard/earthquake/)*

Earthquakes strike suddenly, violently and without warning. Identifying potential hazards ahead of time and advance planning can reduce the dangers of serious injury or loss of life from an earthquake. Here are six ways to plan ahead.

1. Check for Hazards in the Home

- Fasten shelves securely to walls.
- Place large or heavy objects on lower shelves.
- Store breakable items such as bottled foods, glass, and china in low, closed cabinets with latches.
- Hang heavy items such as pictures and mirrors away from beds, couches, and anywhere people sit.
- Brace overhead light fixtures.
- Repair defective electrical wiring and leaky gas connections.
- Secure a water heater by strapping it to the wall studs and bolting it to the floor.
- Repair any deep cracks in ceilings or foundations. Get expert advice if there are signs of structural defects.
- Store weed killers, pesticides, and flammable products securely in closed cabinets with latches and on bottom shelves.

2. Identify Safe Places Indoors and Outdoors

- Under sturdy furniture such as a heavy desk or table.
- Against an inside wall.
- Away from where glass could shatter around windows, mirrors, pictures, or where heavy bookcases or other heavy furniture could fall over.
- In the open, away from buildings, trees, telephone and electrical lines, overpasses, or elevated expressways.

3. Educate Yourself and Family Members

- Contact your local emergency management office or American Red Cross chapter for more information on earthquakes.
- Teach children how and when to call 9-1-1, police, or fire department and which radio station to tune to for emergency information.
- Teach all family members how and when to turn off gas, electricity, and water.

4. Have Disaster Supplies on Hand

- Flashlight and extra batteries.
- Portable battery-operated radio and extra batteries.
- First aid kit and manual.
- Emergency food and water.
- Nonelectric can opener.
- Essential medicines.
- Cash and credit cards.
- Sturdy shoes.

Pack everything in backpacks so you are ready to go.

5. Develop an Emergency Communication Plan

- In case family members are separated from one another during an earthquake (a real possibility during the day when adults are at work and children are at school), develop a plan for reuniting after the disaster.
- Ask an out-of-state relative or friend to serve as the "family contact." After a disaster, it's often easier to call long distance. Make sure everyone in the family knows the name, address, and phone number of the contact person.

6. Help Your Community Get Ready

- Publish a special section in your local newspaper with emergency information on earthquakes. Localize the information by printing the phone numbers of local emergency services offices, the American Red Cross, and hospitals.
- Conduct a week-long series on locating hazards in the home.
- Work with local emergency services and American Red Cross officials to prepare special reports for people with mobility impairments on what to do during an earthquake.
- Provide tips on conducting earthquake drills in the home.
- Interview representatives of the gas, electric, and water companies about shutting off utilities.
- Work together in your community to apply your knowledge to building codes, retrofitting programs, hazard hunts, and neighborhood and family emergency plans.

What to do DURING an earthquake

Stay as safe as possible during an earthquake. Be aware that some earthquakes are actually foreshocks and a larger earthquake might occur. Minimize your movements to a few steps to a nearby safe place and stay indoors until the shaking has stopped and you are sure exiting is safe.

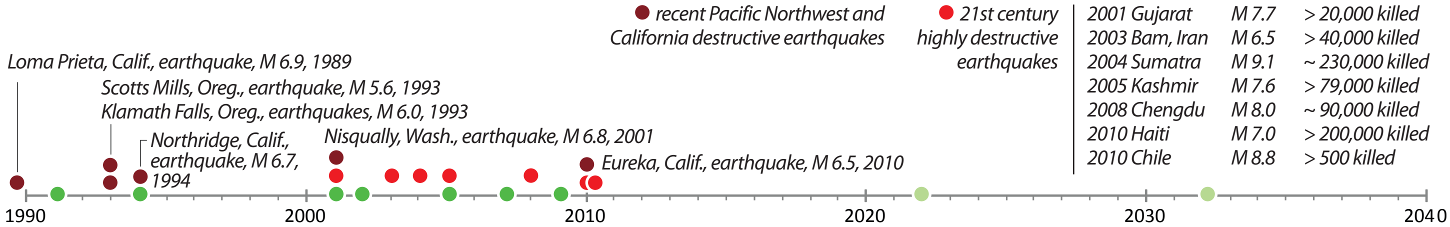
Indoors

- **DROP** to the ground; take **COVER** by getting under a sturdy table or other piece of furniture; and **HOLD ON** on until the shaking stops. If there isn't a table or desk near you, cover your face and head with your arms and crouch in an inside corner of the building.
- Stay away from glass, windows, outside doors and walls, and anything that could fall, such as lighting fixtures or furniture.
- Stay in bed if you are there when the earthquake strikes. Hold on and protect your head with a pillow, unless you are under a heavy light fixture that could fall. In that case, move to the nearest safe place.
- Use a doorway for shelter only if it is in close by and you know it is a strongly supported, load-bearing doorway.
- Stay inside until shaking stops and it is safe to go outside. Research has shown that most injuries occur when people inside buildings attempt to move to a different location inside the building or try to leave.
- Be aware that the electricity may go out or the sprinkler systems or fire alarms may turn on.
- DO NOT use the elevators.

Outdoors

- Stay there.
- Move away from buildings, streetlights, and utility wires.
- Once in the open, stay there until the shaking stops. The greatest danger exists directly outside buildings, at exits, and alongside exterior walls. Ground movement during an earthquake is seldom the direct cause of death or injury. Most earthquake-related casualties result from collapsing walls, flying glass, and falling objects.

Oregon's seismic safety legislative time line



1991
As a result of citizen concern after the 1989 Loma Prieta, Calif., earthquake, Oregon Senate Bill 96 created the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) to increase Oregon's awareness to earthquake hazards by supporting earthquake education, research, mitigation, and legislation.

1994
Oregon's first statewide seismic building code (Oregon Structural Specialty Code) adopted. New building designs must incorporate seismic provisions. Many buildings built before 1994 will not be able to withstand shaking from earthquakes and are at risk of collapse.

2001
Statute 455.400 required seismic "life-safety" in schools and emergency facilities. Five pieces of legislation introduced at request of Senator Peter Courtney as part of OSSPAC: Senate Bills 13, 14, 15 and Senate Joint Resolutions (SJRs) 21 and 22. All passed. Drills required of large employers (private and public). SJRs created ballot measures. Law (ORS 455.400) required schools and emergency facilities to be seismically safe.

2002
Ballot Measures 21 and 22 passed, allowing for ~$1.2 billion of state bonds for seismic upgrades. These seismic upgrades are for public schools and emergency facilities. (Refer to Constitutional Articles XI-M and XI-N.)

2005
Senate Bills 2, 3, 4, and 5, introduced by Senate President Peter Courtney, required statewide seismic needs assessment, a grant program, and authorized state bonds. First time public universities received seismic mitigation funds. SB 2 directed DOGAMI to conduct statewide risk study. SB 3 directed Oregon Emergency Management (OEM) to start grant program. SB 4 and 5 allowed Dept. of Administrative Services (DAS) and Treasury to issue XI-M and XI-N bonds.

2007
DOGAMI published seismic report (Open-File Report O-07-02) indicating 3,352 educational and emergency facilities buildings are at seismic risk. SB 1 provided Oregon Emergency Management (OEM) funds for four new staff to establish grant program.

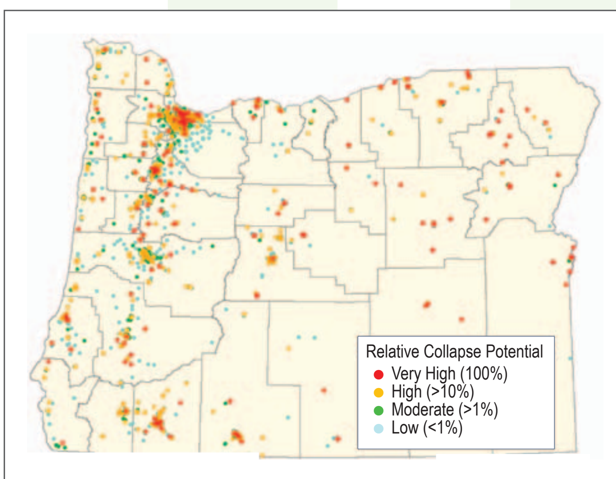
(In 2008 the Oregon Department of Education created the The "Quake Safe Schools" program to share information on the seismic scores and other earthquake preparedness information with the public.)

2009
Seismic Rehabilitation Grant Program provided $30 million in state bond funds ($15 million for public schools and $15 million for fire, police, and hospitals [$1.2 billion authorized by voters]) to begin seismic mitigation of schools and emergency facilities and to improve community preparedness.

(In 2011 more state bond funding is slated to be appropriated for additional seismic upgrades.)

2022
Seismic mitigation to be completed for emergency facilities (fire and police stations, acute care hospitals, and emergency operation centers).

2032
Seismic mitigation to be completed for public high-occupancy schools (K–12, community colleges and universities).



Collapse potential for all educational and emergency sites in DOGAMI's seismic needs assessment study (O-07-02). These sites occur throughout Oregon. Over 1,300 buildings have high to very high seismic collapse potential.

Resources:
Oregon Emergency Management Seismic Rehabilitation Grant Program: http://www.oregon.gov/OMD/OEM/
Oregon Department of Education Quake Safe Schools: http://www.ode.state.or.us/go/quakesafeschools/
DOGAMI seismic needs assessment study (O-07-02): http://www.oregongeology.org/sub/projects/rvs/default.htm
Oregon Seismic Safety Policy Advisory Commission (OSSPAC): http://www.oregon.gov/OMD/OEM/osspac/osspac.shtml
2007 Oregon Structural Specialty Code: http://www2.iccsafe.org/states/oregon/07_Structural/Building07_Frameset.htm

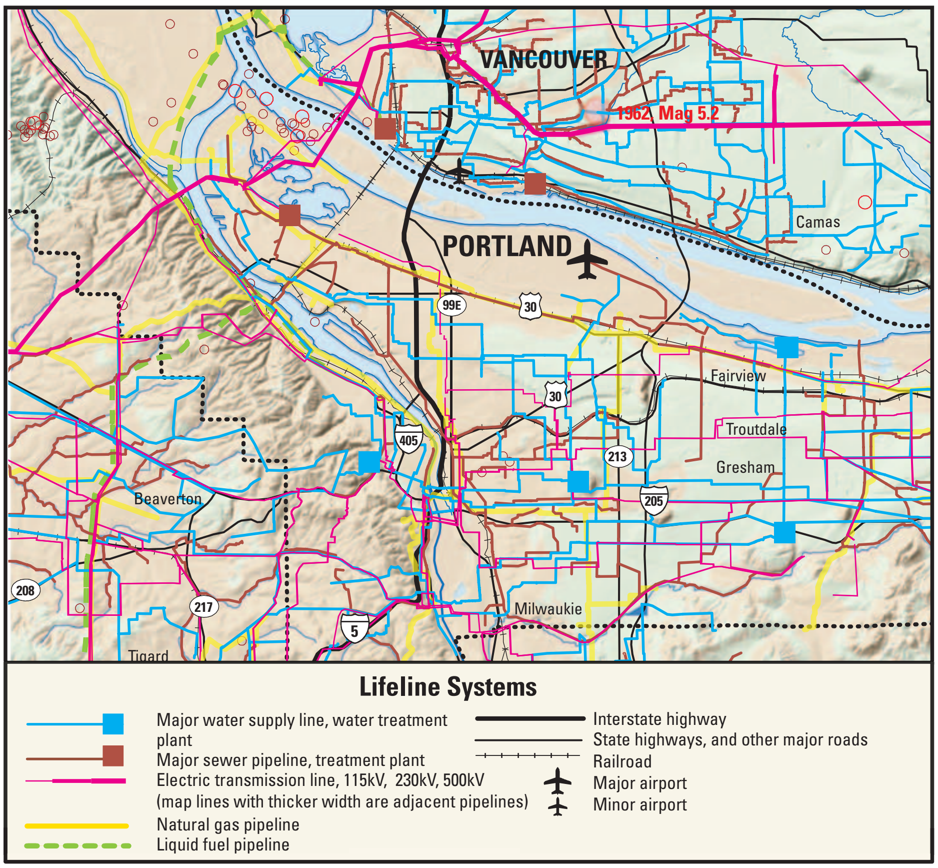
Post-earthquake lifeline damage

Certain infrastructure systems—for example, fuel, electrical, water, highway—are called “lifelines” because our lives depend on them. While the seismic provisions in Oregon’s current building code (Oregon Structural Specialty Code) mean new buildings will be able to withstand most earthquakes, our roads, bridges, and electrical and waterlines might not fare as well. Disruption to these critical services could dramatically slow aid and relief efforts—as happened after the February 2010 Chile earthquake.

Lifelines often depend on each other, so that failure of one can affect other systems. For example, the telecommunications system requires cooling, which requires electricity, gas or liquid fuel, and water. If a water pipeline is located on a bridge and the bridge collapses in an earthquake, then the bridge, the water services, and the telecommunication lines will all be down.

Oregon’s lifelines were constructed to standards well below current seismic safety specifications. In a major earthquake, many of our critical lifelines, such as major highways, fuel ports, electrical transmission, and telecommunication systems will not be able to provide their intended services.

Understanding lifeline locations, their interdependencies, and their locations in relationship to earthquake hazards is only the first step toward making lifeline systems seismically resilient. After risk identification and assessment, stakeholders can be identified and engaged, and risk prioritized and mitigated. Oregon is currently focusing on reliable fuel supply, electricity, and gas service as part of a state energy assurance project.



▲ *Close-up of Portland metro area from* Earthquake Hazards and Lifelines in the Interstate 5 Urban Corridor—Woodburn to Centralia, Washington*, by E. A. Barnett and others (U.S. Geological Survey Scientific Investigations Map 3027 [http://pubs.usgs.gov/sim/3027/]). The I-5 corridor from Cottage Grove to Woodburn, Oregon, has also been studied (U.S. Geological Survey Scientific Investigations Map 3028 [http://pubs.usgs.gov/sim/3028/]).*

The majority of Oregon state-owned bridges built between 1950 and 1980 are seismically vulnerable. An Oregon Department of Transportation 2009 study (http://library.state.or.us/repository/2009/200911171034432/) found that Oregon would face devastating damage to the transportation system from a large Cascadia Subduction Zone earthquake or a crustal earthquake located in the Willamette Valley. Coastal U.S. Highway 101 would have dozens of impassable locations due to bridge failures, and all highways connecting U.S. 101 and I-5 would be impassable due to bridge damage. Vulnerable bridges will need strengthening or replacement to ensure that they survive a large earthquake.

► *Aerial view of collapsed sections of the Cypress viaduct of Interstate Highway 880, Oakland, California, after the 1989 Loma Prieta earthquake (H. G. Wilshire, U.S. Geological Survey).*

DOGAMI geohazards research

Coos County multi-hazard mapping

DOGAMI is conducting Digital Flood Insurance Rate Map (DFIRM) flood-plain redelineation for the Federal Emergency Management Agency (FEMA) using lidar-based data to create the base maps. Once the base maps are created, DOGAMI will use the new base imagery to identify and map channel migration zone hazards; 100-year and 500-year flood hazard loss estimation (using HAZUS, FEMA's risk assessment methodology); landslide hazards; earthquake hazards including liquefaction and ground shaking amplification; tsunami inundation hazards; and coastal erosion hazards. The multi-hazards maps will be available in paper format and in digital format via an interactive web map.

Portland urban area geologic hazard assessment

DOGAMI is partnering with the U.S. Geologic Survey (USGS) to make a new, state-of-the-art digital geologic map and database of the greater Portland urban area, stretching from Estacada to St. Helens, Washougal to Newberg. The map will feature highly detailed geology mapped on new lidar imagery, which allows geologists to see unprecedented detail in the shape of surface. The data from the new map will be used to make detailed landslide and earthquake hazard maps of the area in cooperation with local governments and the USGS.

Multi-hazard risk and vulnerability assessments for Mount Hood

The goal of this USGS-funded, 1½-year project is to assist communities within the Mount Hood, the Highway 26/Sandy River corridor, and the Highway 35/Hood River corridor study area in understanding the risk associated with volcanic, earthquake, landslide, and flooding hazards. DOGAMI is compiling existing hazard and asset data throughout the study as well as creating new data using lidar-based maps.

Pre-Disaster Mitigation (PDM) studies for mid/southern Willamette Valley, mid Columbia River Gorge, and south central Oregon

The purpose of these studies is to help communities prepare pre-disaster mitigation plans, identify potential geologic hazards, help communities perform earthquake damage and loss estimation, and to recommend future action items. Products include digital GIS layers for each community, depicting relative earthquake ground shaking amplification hazards, relative earthquake liquefaction hazards, relative earthquake-induced landslide hazards, and identified landslide areas. Damage and loss estimates for each community were analyzed for two earthquake scenarios. The mid/southern Willamette study is complete (DOGAMI IMS-24); the other two studies will be published in 2010. Funding was provided by FEMA with matching funds from the State of Oregon.

Tsunami hazard modeling and Cascadia paleoseismicity

DOGAMI coastal geologists continue revising tsunami inundation maps that cover the state's entire 362-mile-long coastline using sophisticated computer models coupled with laser-based terrain mapping and field-based geologic investigations. Products include tsunami inundation and evacuation maps and grass-roots outreach and education to coastal communities.

DOGAMI geologist Rob Witter (left) and USGS geologist Brian Atwater (right) present evidence for great Cascadia earthquakes and tsunamis to middle school science teachers participating in the Teachers on the Leading Edge program, supported by the National Science Foundation. Bob Butler, University of Portland earth science educator, is at far right. (Photo: James Roddey, DOGAMI)

Advanced National Seismic System, Pacific Northwest Region

The Advanced National Seismic System (ANSS) is a U.S. Geological Survey effort to coordinate and upgrade seismic-monitoring networks nationwide and to implement rapid distribution of earthquake information. Under the ANSS, the Pacific Northwest Seismic Network (PNSN) has begun installing a new generation of digital earthquake sensors in urban areas that can accurately record ground motions. This information will help improve the design of future buildings to be earthquake resilient. Information on the intensity and distribution of ground shaking can be used by emergency managers to direct rescue service to hard-shaken areas. This information is available on USGS and PNSN web sites. http://pubs.usgs.gov/fs/2004/3073/pdf/Factsheet3073.pdf

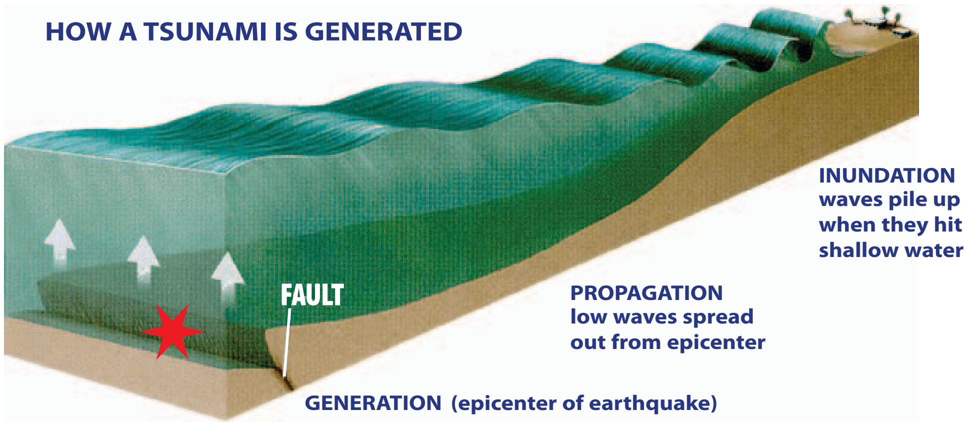
New multi-year tsunami mapping and outreach program

Oregon coastal communities will be TsunamiReady, TsunamiPrepared

Scientific research looking 10,000 years into the geologic past indicates great earthquakes and tsunamis generated by a rupture of the Cascadia Subduction Zone have occurred with alarming frequency (see time line below). The last great earthquake happened just over 300 years ago, and we can expect another of these great earthquakes and tsunamis at any time. An earthquake could result in a tsunami inundating the Oregon coast within 15 to 30 minutes. Before that, ground shaking could cause liquefaction, landslides, and coastal subsidence.

TsunamiReady™, TsunamiPrepared, a multi-year, multi-million dollar program funded by the National Tsunami Hazard Mitigation Program and overseen by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), has the goal of reaching every resident and visitor at the Oregon coast with a message of how to prepare for and respond to an earthquake and tsunami generated by a rupture of the Cascadia Subduction Zone.

The program will build on the work coastal communities have already accomplished or assist in work they are ready to begin by supporting a grass roots program of awareness and preparedness. TsunamiReady, TsunamiPrepared will also provide much needed resources to help these communities create or maintain a sustained effort of education and preparation.



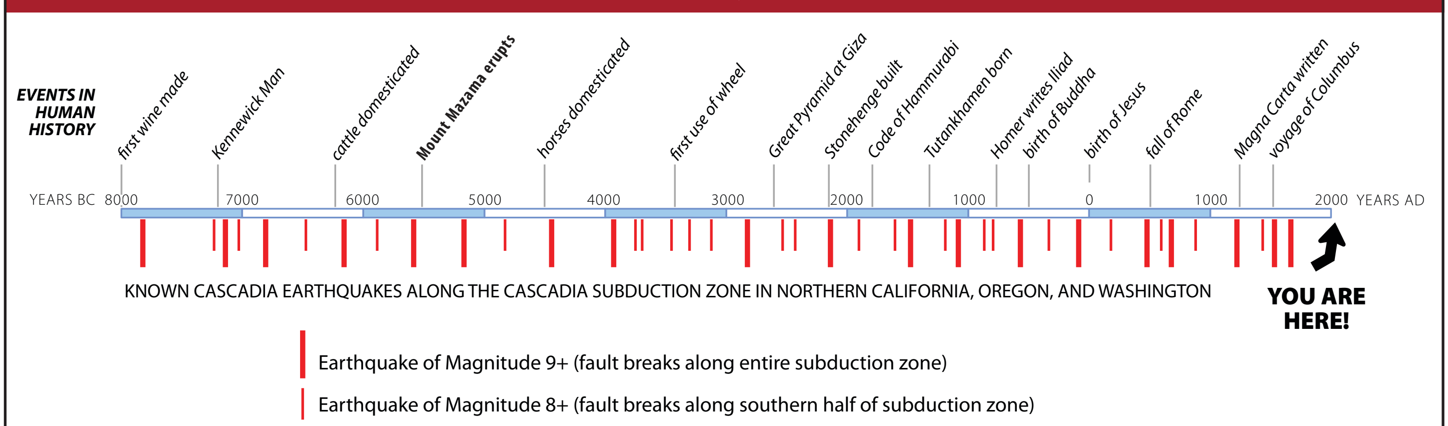
(image modified from Geoscience Australia [http://www.ga.gov.au/hazards/tsunami/] where the image appears courtesy of the Russian Academy of Sciences)

TsunamiReady, TsunamiPrepared will also accelerate the remapping of the Oregon coast for tsunami inundation using state of the art computer modeling and laser based terrain mapping (lidar). The outcome will be the creation of new, more accurate tsunami evacuation maps for the entire 362-mile length of the Oregon coast.

Communities chosen for the first year of accelerated funding of the TsunamiReady, TsunamiPrepared program include **Rockaway Beach**, **Manzanita**, **Nehalem**, and **Wheeler** on the north coast, **Yachats**, **Waldport**, and **Seal Rock** on the central coast, and **Bandon** on the south coast. State parks adjacent to these communities will also participate.

TsunamiReady™, TsunamiPrepared is administered by DOGAMI in collaboration with Oregon Emergency Management, the Oregon Coastal Zone Management Association, and the National Weather Service. For more information contact James Roddey, Oregon Department of Geology and Mineral Industries, (971) 673-1543.

CASCADIA EARTHQUAKE TIME LINE



Comparison of the history of subduction zone earthquakes along the Cascadia Subduction Zone in northern California, Oregon, and Washington, with events from human history. Ages of earthquakes are derived from study and dating of submarine landslides triggered by the earthquakes. Earthquake data provided by Chris Goldfinger, Oregon State University; time line by Ian P. Madin, DOGAMI.

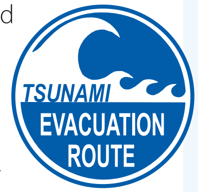
Tsunami evacuation maps and information available online

Will you know where to go if a tsunami hits?

A tsunami caused by an undersea earthquake near the Oregon coast is called a **local tsunami.** An undersea earthquake in the Pacific Ocean far away from the coast may cause a **distant tsunami**.

A distant tsunami will take 4 hours or more to come ashore. No earthquake will be felt at the coast, and the tsunami will generally be smaller than that from a local earthquake. Typically, there is time for an official warning and evacuation to safety.

A local tsunami can come onshore within 15 to 20 minutes after the earthquake—before there is time for an official warning from the national warning system. Ground shaking from the earthquake may be the only warning you have. After the ground stops shaking, evacuate on foot, if possible. Follow evacuation signs and arrows.



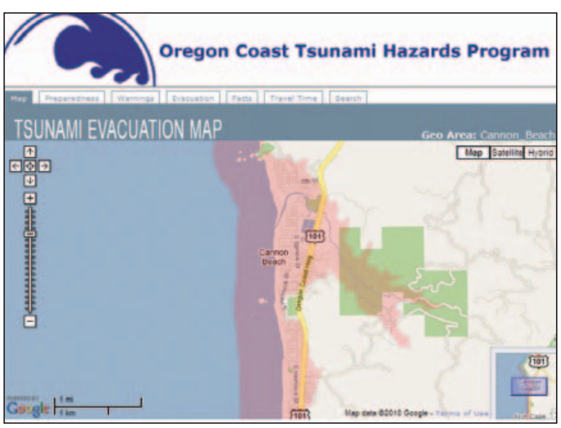
Coastal residents and visitors can prepare for the possibility of a tsunami by becoming familiar with the tsunami hazard zones and evacuation routes in their communities. Oregon tsunami evacuation zone maps for some communities are online, and more are planned. See your local emergency preparedness agency for specific information on tsunami shelters and other specific evacuation instructions for your community.

Oregon Coast Local Emergency Preparedness Agencies

Clatsop County Sheriff's Office, Emergency Services: http://www.co.clatsop.or.us/default.asp?pageid=391&deptid=5
Coos County Emergency Services: http://www.cooscountysheriff.com/tsunami.htm
Curry County Emergency Services: http://www.co.curry.or.us/Emergency%20Services/emergency_Services.htm
Douglas County Emergency Services: http://www.dcso.com/tsunami_maps.asp
Lane County Emergency Management: http://www.lanecounty.org/EmerMgmt/default.htm
Lincoln County Emergency Services: http://www.lincolncoemergencyservices.us/home.cfm?dir_cat=34589
Tillamook County Emergency Management: http://www.co.tillamook.or.us/gov/EMGMGNT/

NOAA West Coast and Alaska Tsunami Warning Center: http://wcatwc.arh.noaa.gov/

American Red Cross, Oregon Chapters: http://www.oregonredcross.org/index.asp?IDCapitulo=663B0ID44V
Oregon State Police: http://www.oregon.gov/OSP/
Oregon Emergency Management: http://www.oregon.gov/OMD/OEM/



Online interactive maps and evacuation brochure maps show tsunami inundation zones for Oregon coastal communities such as the Cannon Beach area shown above.

- ***Online interactive evacuation maps:*** *http://www.nanoos.org/data/products/oregon_tsunami_evacuation_zones/index.php.*
- ***Evacuation brochures:*** *http://www.oregongeology.org/sub/earthquakes/Coastal/Tsumaps.htm*

Tsunami vertical refuges

Conceptual illustration by Jay Raskin, president of Ecola Architects and former mayor of Cannon Beach, of a proposed new Cannon Beach City Hall. The elevated building could double as a tsunami evacuation shelter for people who do not have time to reach higher ground as well as ensure that city government services continue to function during all but the largest tsunamis.

On September 28-29, 2009, the Cascadia Region Earthquake Workgroup (CREW) held the Pacific Northwest region's first workshop on tsunami vertical evacuation buildings (TEBs) as a way to protect people and to improve community recovery in the event of a tsunami.

TEBs, reinforced concrete buildings on robust deep foundations that allow water to flow through the first floor, could be strategically located in low-lying coastal communities. Elevated platforms designed to withstand earthquake and tsunami forces could be erected in state parks.

Cannon Beach, Oregon, may become the first community in the United States to erect a TEB. Several designs for a new city hall building were showcased and discussed at the CREW workshop. The designs feature wave-dissipation structures in the front and back, and refuge for about a 1,000 people. With about 50% of residents and 75% of businesses in the tsunami zone, the City of Cannon Beach is exploring options on how to fund a new state-of-the art, sustainable TEB. Depending on the features, a TEB structure would add $1-2 million to the cost of a new city hall.

The CREW workshop minutes are available as DOGAMI Open-File Report O-10-02. For more information on TEBs, contact Yumei Wang, DOGAMI Geotechnical Engineer, at (971) 673-1551 or email yumei.wang@dogami.state.or.us.

Earthquake educational resources

Earthquake Preparedness

American Red Cross
http://www.redcross.org/

Federal Emergency Management Agency (FEMA)
http://www.fema.gov/

NOAA West Coast and Alaska Tsunami Warning Center
http://wcatwc.arh.noaa.gov/

Are You Ready? An In-depth Guide to Citizen Preparedness by FEMA
http://www.fema.gov/areyouready/

Quake Safe Schools (Oregon Department of Education)
http://www.ode.state.or.us/go/quakesafeschools/

FEMA 395, Incremental Seismic Rehabilitation of School Buildings (K-12)
http://www.fema.gov/library/viewRecord.do?id=1980

Oregon Emergency Management (OEM) Seismic Rehabilitation Grant Program
http://www.oregon.gov/OMD/OEM/plans_train/SRGP.shtml

Oregon Building Codes Division
http://www.cbs.state.or.us/bcd/

Earthquake Science

Pacific Northwest Seismic Network (PNSN)
http://www.pnsn.org/

U.S. Geological Survey Oregon Earthquake Information
http://earthquake.usgs.gov/earthquakes/states/?region=Oregon

National Earthquake Hazards Reduction Program (NEHRP)
http://www.nehrp.gov/

Earthquake Organizations

Oregon Seismic Safety Policy Advisory Commission (OSSPAC)
http://www.oregon.gov/OMD/OEM/osspac/osspac.shtml

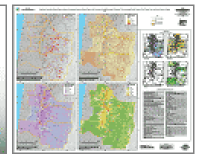
Western States Seismic Policy Council (WSSPC)
http://www.wsspc.org/

Oregon Partnership for Disaster Resilience
http://opdr.uoregon.edu/

Cascadia Region Earthquake Workgroup (CREW)
http://www.crew.org/index.html

DOGAMI Earthquake and Tsunami Publications

DOGAMI earthquake hazard maps (IMS series) online
http://www.oregongeology.org/sub/publications/IMS/ims.htm

Geologic hazards, earthquake and landslide hazard maps, and future earthquake damage estimates for six counties in the Mid/Southern Willamette Valley including Yamhill, Marion, Polk, Benton, Linn, and Lane Counties, and the City of Albany, Oregon (Interpretive Map 24), by W. J. Burns, R. J. Hofmeister, and Y. Wang, 2008, 121 p., map scale 1:422,400.

Oregon Public Utilities Commission--Oregon Department of Geology and Mineral Industries Leadership Forum and Seismic Critical Energy Infrastructures Workshop, April 2, 2008 (Open-File Report 08-10), by Y. Wang and J. R. Gonzalez, 2008, 13 p.

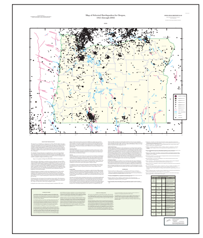
Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings (Open-File Report 07-02), by D. Lewis, 2007, 140 p. plus app.
http://www.oregongeology.org/sub/projects/rvs/default.htm

Enhanced rapid visual screening (E-RVS) for prioritization of seismic retrofits in Oregon, (Special Paper 39), by Y. Wang and K. A. Goettel, 2007, 27 p.

Portland State University Ondine Residence Hall seismic rehabilitation demonstration project (Special Paper 38), by Y. Wang and C. J. Heathman, 2007, 23 p.

Portland State University Montgomery Court seismic rehabilitation project (Open-File Report 07-04), by Y. Wang, and C. J. Heathman, 2007, 16 p.

Cascadia Subduction Zone earthquakes: A magnitude 9.0 earthquake scenario (Open-File Report 05-05), by Cascadia Region Earthquake Workgroup, J. Roddey, and L. Clark, 2005, 21 p.
http://www.crew.org/PDFs/CREWSubductionZoneSmall.pdf



Map of selected earthquakes for Oregon, 1841-2002 (Open-File Report 03-02), by C. A. Niewendorp and M. E. Neuhaus, 2003.
http://www.oregongeology.org/sub/earthquakes/images/EpicenterMap.pdf

Earthquake damage in Oregon: Preliminary estimates of future earthquake losses, (Special Paper 29), by Y. Wang, and J. L. Clark, 1999, 59 p.

Tsunami hazard zone and evacuation maps online
http://www.oregongeology.org/sub/earthquakes/Coastal/Tsumaps.HTM

Tsunami hazard assessment of the northern Oregon coast: A multi-deterministic approach tested at Cannon Beach, Clatsop County, Oregon (Special Paper 41), by G. R. Priest, C. Goldfinger, K. Wang, R. C. Witter, Y. Zhang, and A. M. Baptista, 2009, 87 p. plus app., GIS data files, time histories, and animations.

Tsunami Evacuation Building Workshop, September 28-29, 2009, Cannon Beach, Seaside, and Portland, Oregon (Open-File Report 10-02), Y. Wang, complier, 2010, 35 p.

Prehistoric Cascadia tsunami inundation and runup at Cannon Beach, Clatsop County, Oregon (Open-File Report 08-12), by R. C. Witter, 2008, 36 p. and 3 app.

Fact Sheet: Tsunami hazards in Oregon, 2008, 4 p.
http://www.oregongeology.org/pubs/fs/tsunami-factsheet_onscreen.pdf

Fact Sheet: TsunamiReady, TsunamiPrepared: Oregon Coast-Wide National Tsunami Hazard Mitigation Program, 2010, 2 p.
http://www.oregongeology.org/pubs/fs/TsunamiPreparedFactSheetAlt-12-28-09.pdf

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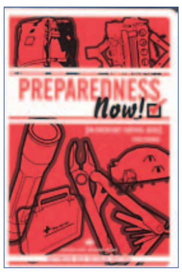
Portland, OR 97232-2162
phone (971) 673-2331, fax (971) 673-1562

The Orphan Tsunami of 1700—Japanese Clues to a Parent Earthquake in North America, U.S. Geological Survey Professional Paper 1707, by Brian Atwater and others, 2005, 144 p., 325 illus, paperback, $24.95.

Tells the scientific detective story of the tsunami through clues from both sides of the Pacific. Also available as a PDF file: http://pubs.usgs.gov/pp/pp1707/pp1707.pdf

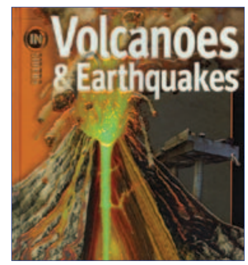


Preparedness Now! An Emergency Survival Guide, revised ed., by Aton Edwards, Process Media, Self-Reliance Series, Port Townsend, Wash., 2009, 343 p., $16.95.

Guide for those who want to live more self-sufficiently and learn how to prepare for emergencies and disasters.

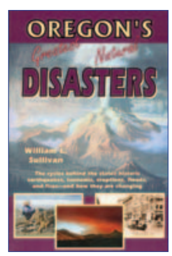
Volcanoes and Earthquakes, by Ken Rubin, Simon and Schuster, New York, 2007, 64 p., $16.95.

Brings volcanoes and earthquakes to life, with the most up-to-date information and state-of-the-art 3-D illustrations that practically leap off every page, stimulating minds and imaginations in a whole new way.



Living With Earthquakes in the Pacific Northwest: A Survivor's Guide, 2nd ed., by Robert S. Yeats, Oregon State University Press, Corvallis, 2004, 390 p., $22.95.

Describes the threat posed by the Cascadia Subduction Zone fault.



Oregon's Greatest Natural Disasters, by William L. Sullivan, Navillus Press, Eugene, Oregon, 2008, 263 p., $18.95.

The cycles behind the state's historic earthquakes, tsunamis, eruptions, floods, and fires — and how they are changing.

A complete list of DOGAMI publications can be found online at www.OregonGeology.org.
Use the order form below or log on to www.NatureNW.org to order.

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Please charge to Visa __ Mastercard __ Account number: ____________________

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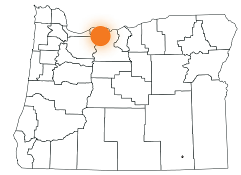
Places to see: University building seismic mitigation

Cross-bracing (far left) and, steel plate wall floor-to-floor connections (left) are some visible results of the PSU Ondine residence hall seismic mitigation effort.



Portland area places to see:
Ondine Residence Hall, PSU;
TriMet Washington
Park/Zoo station

Oregon is at risk for a major earthquake. In addition to the Cascadia Subduction Zone threat, many communities have active crustal faults nearby. One major success of the 2001 laws to better prepare and protect Oregonians from future earthquake losses (see p. 5) is requiring life-safety in public university buildings.

The state's goal is to increase awareness and promote preparedness through demonstration projects such as the one at Ondine Hall, Portland State University (PSU). Demonstration projects create momentum in earthquake preparedness throughout the state by providing an impetus for individual owners and communities to conduct similar seismic retrofit projects.

As part of a long-term, 7-campus-wide, seismic mitigation plan, DOGAMI developed a 6-step method for evaluating buildings for seismic risk. Out of about 1,000 buildings evaluated using this method, the Oregon University System (OUS) and DOGAMI identified five demonstration projects as part of the initial Seismic Risk Management Program, which began in 2005: Montgomery Court and Ondine Residence Hall, Portland State University; Snell Hall Administration Building, Oregon Institute of Technology; Humanities and Social Sciences, Western Oregon University; and Nash Hall, Oregon State University. Many other university buildings have serious seismic deficiencies and are slated to be seismically strengthened via the long-term comprehensive mitigation plan. The plan is driven by the seismic life-safety risk index coupled with deferred maintenance needs and energy efficiency improvements.

Related DOGAMI publications: SP-39, Enhanced rapid visual screening (E-RVS) for prioritization of seismic retrofits in Oregon; SP-38, Portland State University Ondine Residence Hall seismic rehabilitation demonstration project; O-07-04, Portland State University Montgomery Court seismic rehabilitation project.

Places to see: Geologic time line at Portland TriMet station

Portland's TriMet Washington Park/Zoo light-rail (MAX) station (Red/Blue lines) is the deepest tunnel station in North America at 260 feet. The public art on the station platform includes a geologic time line and drill core from one of the many geotechnical borings made along the tunnel route. This is the most accessible and complete "exposure" of Portland geology in existence. Visitors can walk along the core as it traverses Columbia River Basalt, Boring Lava, and loess.

To learn more about Portland's geology, including faults, see the field trip guide "Portland, Oregon, geology by tram, train, and foot" by Ian P. Madin (http://www.oregongeology.org/pubs/og/OGv69n01-PDXtram.pdf).