Earthquake damage in Oregon:

Preliminary estimates of future earthquake losses



500 year recurrence interval model (including many earthquakes): Least dangerous areas are yellow, most dangerous are darkest red.



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Earthquakes are a fact of life in Oregon. They come in a variety of sizes, from only measurable by machines to magnitude 9 events that generate tsunamis.

Because Oregon's recorded history is so short, and destructive earthquakes happen so seldom, we have previously underestimated the danger. In fact, Oregon has infrequent large earthquakes, but they can be very dangerous when they happen.

For the first time, we now have estimates of what future damages from earthquakes might be. Using a state of the art computer model, and extensive research about Oregon's geology, the Oregon Department of Geology and Mineral Industries (DOGAMI) estimated future earthquake damage in a number of categories.

Two different studies are included in this report: a M8.5 Cascadia subduction zone earthquake off the coast of Oregon; and statewide earthquakes within a 500 year return interval.

These figures actually underestimate the amount of damage for two important reasons. The default inventory in the computer model did not include old-style brick buildings (called unreinforced masonry buildings, or URMs), which do not fare well in earthquakes. A major source of casualties is the collapse of these buildings.

Earthquake damages will probably be much higher because the computer model did not take into account the tsunami which would follow the earthquake. A tsunami is a series of waves striking the coast over several hours and can be deadly.

Cascadia subduction zone model

Expected losses from the magnitude 8.5 Cascadia earthquake include:

- Almost 8,000 casualties
- Over 30,000 buildings destroyed
- Over \$12 billion of economic damage

Counties at highest risk from this event include:

Lane	Coos	Benton
Lincoln	Josephine	Clatsop
Jackson	Linn	Curry

500 year return interval model

Expected losses from the 500 year model include:

- Over 25,000 casualties
- Over 80,000 buildings destroyed
- Over \$31 billion of economic damage

Counties at highest risk from this event include:

Multnomah	Washington	Lane
Marion	Clackamas	Coos
Benton	Linn	Klamath

1993 Oregon earthquakes

Scotts Mills (the "Spring Break Quake"):

- magnitude (M)5.6
- \$30 million in damage

Klamath Falls:

- M5.9 and M6.0
- \$10 million in damage

Cascadia subduction zone

This offshore fault runs from northern California to Vancouver Island. It's less than 100 miles off the coast of Oregon, and is capable of generating magnitude 9 earthquakes and tsunamis.

500 year return interval

This study uses faults across Oregon and projects an average earthquake on each one. Every county in Oregon is at risk of earthquake damage.



Introduction

Magnitudes

- Each increase in magnitude means 30 times more energy is released.
- A M8 quake releases 30 times as much energy as a M7, which releases 30 times as much as a M6.
- The Loma Prieta earthquake was a M7.1. A M9 Cascadia earthquake would release almost 900 times as much energy as the Loma Prieta event, with strong shaking lasting several minutes instead of 15 seconds.

Earthquakes occur in Oregon every day; every few years an earthquake is large enough for people to feel; and every few decades there is an earthquake that causes damage.

We have not had hugely destructive earthquakes in Oregon's limited written history. But we have seen earthquakes devastate other cities around the world. Large earthquakes in urban areas have produced extensive damage, including:

- \$100 billion in Kobe, Japan (1995, M6.9)
- \$42 billion in Northridge, California (1994, M6.7)
- \$10 billion in Loma Prieta, California (1989, M7.1)

Damage depends on the specific geology, building standards, and preparation of each area. Preparation on state, community, and personal levels can significantly reduce the amount of damage from earthquakes.

This study is an attempt to quantify potential damage and loss to Oregon, and help point out areas of greatest need. Planners and policy makers can use this information to reduce future loss of life and property.

This is a preliminary study, using a newly developed computer model and years of research into Oregon's geology. The figures presented have a large margin of error and should be taken as relative indicators of potential damage, not absolute expected losses.



Molalla High School was condemned after the 1993 Scotts Mills earthquake (M5.6). A new high school was built on another site.

Cascadia subduction zone model

Research at Nestucca Bay suggests there have been at least 12 great (M8–9) Cascadia subduction earthquakes and tsunamis to strike Oregon in the last 5,000 years.

The Cascadia subduction zone is the most dangerous fault in Oregon. On average, it produces an earthquake every 300 to 600 years. However, as with any natural process, the average time between events may be misleading. Some of the earthquakes may have been 150 years apart, some were closer to a 1,000 years apart.

For this fault, the entire coastline is essentially the epicenter. The earthquake might last as long as four minutes, severely testing structures along the coast. Within a few minutes, a tsunami would follow.

Tsunamis are sometimes called tidal waves, but they have nothing to do with tides. They are the result of an undersea earthquake. The waves along the Oregon coast might be 30 feet high, sweeping up anything in their path.

Tsunami damages are not included in the estimates for this earthquake, and would seriously increase losses for coastal counties.

An earthquake of this magnitude is unprecedented in a large, industrialized, urban area and is the single most threatening geologic hazard in Oregon. Part of the danger is in the size of the area affected. If the entire fault ruptures, destruction could occur from northern California to Canada, making it difficult to bring in emergency supplies.

This study uses a magnitude 8.5 earthquake, considered to be an average event.



January 26, 1700

The last great Cascadia earthquake happened in 1700. This event was confirmed by several lines of evidence, including:

- Native American
 legends;
- Liquefaction features;
- Carbon dating;
- Tree-ring dating;
- Japanese records of a tsunami generated from a large earthquake across the Pacific.

Individual county estimates A summary of statewide and individual county losses is in the Appendix.

The Cascadia subduction zone runs along the Pacific Northwest coast. It is the result of the Juan de Fuca plate sliding, or subducting, under the North American plate. Subduction zone earthquakes are usually very large and produce tsunamis.

Copies of this interpretive sign are being placed along the Oregon coast to warn residents and tourists.

Earthquake damage in Oregon

Injuries and time of day

The number of deaths and injuries depends on the time of day, building type, occupancy class, and traffic pattern.

- Highest injuries are at 2 PM, mostly because of damages to commercial and industrial buildings.
- At 2 AM and 5 PM, casualties are higher in residential buildings.

Deaths and injuries

Deaths and injuries are estimated at 7,800, including:

- 6,300 injuries needing first aid
- 1,200 injuries needing hospitalization
- 200 life-threatening injuries
- 100 immediate deaths

Displaced households

Displaced households are estimated at 17,300.

Short-term shelter needs

Short-term shelter needs are estimated at 12,400.



In Kobe, 48,000 of these prefab units were needed for shelter for months after the earthquake.



Building damage

Building damage can be assessed only after a qualified inspector has surveyed the structure. The following categories of damage are expected:

- 885,000 green-tagged (no restrictions)
- 55,000 yellow-tagged (need permission to enter)
- 37,000 red-tagged (cannot be used)



Properties along rivers, like port facilities, are especially vulnerable in an earthquake.

Direct economic losses

The total direct economic losses to buildings are estimated at \$12 billion. These losses include both capital stock losses and income losses:

- Structural damage\$2.0 billion
- Nonstructural damage
 \$4.3 billion
- Contents \$1.0 billion
- Inventory damage\$0.1 billion
- Relocation\$1.2 billion
- Capital-related loss\$1.4 billion
- Wages\$1.2 billion
- Rental income\$0.7 billion



Residential, commercial, and industrial buildings are damaged in earthquakes. Losses include not only rebuilding costs, but also lost wages and income.

Essential facilities and schools

Essential facilities are police stations, fire stations, and emergency operation centers. These are facilities that provide services to the community and need to be functional after an earthquake.Only an estimated 65 percent of essential facilities and 66 percent of schools will be usable the day after the earthquake.

This high school chemistry lab was damaged in an earthquake. Chemical spills from hospitals, industrial facilities, and schools can be an additional hazard for cleanup crews.



Earthquake damage in Oregon



The Oregon Department of Transportation is on a 100-year schedule to upgrade stateowned bridges.

Transportation

It is important to have usable highways and airports after an earthquake, to allow rescue, recovery, and rebuilding efforts. Damage estimates include:

- \$370 million in highways, including major and urban roadways and bridges
- \$120 million in airports, including control towers, runways, terminal buildings, parking structures, fuel facilities, and maintenance and hangar facilities

Bridges are a vital transportation link. Damage to bridges can make some areas inaccessible. An estimated 18 percent of highway bridges will not be usable the day of the earthquake.

Broadcasting stations

An estimated 29 percent of broadcasting stations would not be functioning the day after an earthquake. Total expected losses are \$100 million.

Debris

An estimated 9.3 million tons of debris is expected to be generated. This includes brick, wood, glass, building contents, steel members or reinforced concrete elements, and other materials.



Oregon has over 4,000 bridges. This Costa Rican bridge failed during an earthquake.

Earthquake damage in Oregon

Bridge damage			
No damage	67%		
■ Slight	21%		
Moderate	9%		
Extensive	1%		
Complete	7%		

County Rankings

Oregon's 36 counties have been ranked in a variety of ways to better understand the relative risks.

There is a level of uncertainty in all results of the study. However, the uncertainty is so high in counties with losses less than \$20 million and loss ratios of less than 1 percent, that for them the results have limited application. Baker, Crook, Deschutes, Gilliam, Grant, Harney, Hood River, Jefferson, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, Wasco, and Wheeler Counties are in this group.

"Highest" loss can be calculated in several ways. The table below shows the counties with the largest economic base, the greatest absolute losses, and the highest ratio of losses to base. The counties with the highest loss ratios have the highest "relative" impact to the county.

A combination of absolute loss and relative loss (shown in the sidebar) is one way of determining the most vulnerable counties.

The listing of coastal counties as having the highest loss ratios indicated their relative closeness to the Cascadia subduction zone. However, their losses would probably be substantially higher with the inclusion of tsunami damages.

Highest combined economic loss and loss ratio

Lane Coos Benton Lincoln Josephine Clatsop Jackson Linn Curry

Largest economic base	Highest economic losses	Highest loss ratio
Multnomah	Multnomah	Coos
Washington	Lane	Curry
Lane	Coos	Clatsop
Clackamas	Washington	Lincoln
Marion	Marion	Josephine
Jackson	Benton	Benton
Linn	Lincoln	Tillamook
Deschutes	Josephine	Polk
Douglas	Clatsop	Lane
Benton	Jackson	Linn



Small businesses in older unreinforced brick or masonry buildings are among the hardest hit in an earthquake.

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