UNDERSTANDING EARTHQUAKE HAZARDS IN WASHINGTON STATE

Modeling a Magnitude 8.3 Earthquake on the Cascadia Subduction Zone along Washington's Outer Coast

Geologic Description

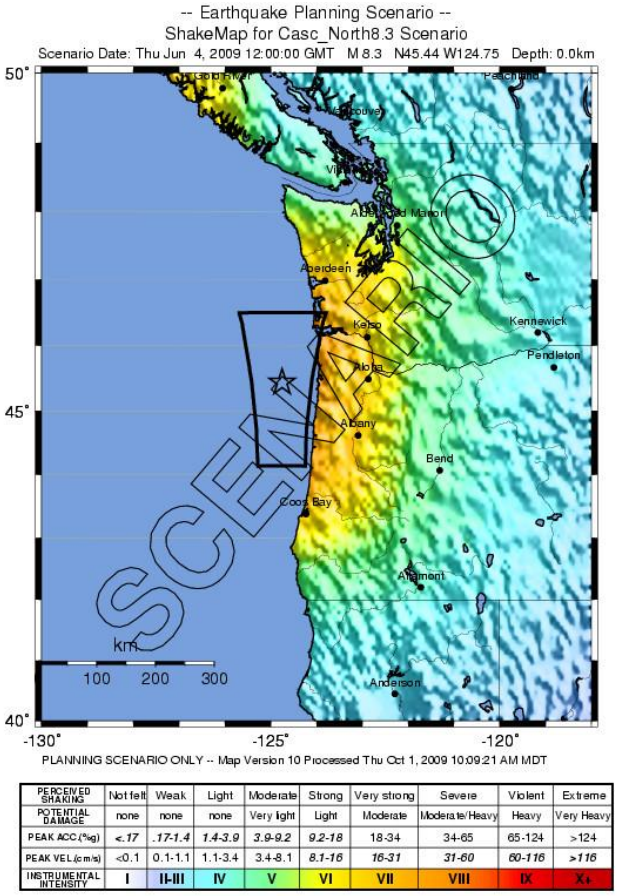
The coastline of the northwestern U.S. and Canada is bordered by an active subduction zone where the Juan de Fuca plate is subducting, or being pushed, beneath the North American plate. The subduction zone is currently considered locked (that is, it is not slipping). Strain is therefore accumulating on the locked interface between the plates. Plate convergence is estimated at between 3 and 4 centimeters per year and possibly as much as 5.8 centimeters per year (the long-term geologically estimated rate).

The M8.3 Cascadia North scenario is based on an approximately 250 kilometer (155 miles)-long rupture of the Cascadia subduction zone megathrust fault. The entire megathrust extends from Cape Mendocino, California, to central Vancouver Island, Canada. This scenario is based on geologic evidence that indicates partial ruptures occur about one-third of the time on the megathrust and that these shorter ruptures are more prevalent south of the Columbia River. The last major earthquake on the megathrust ruptured the entire zone on January 26, 1700. Geologic evidence suggests that the average recurrence of ~M9.0 earthquakes along the Cascadia megathrust is about 500 years, but recurrence intervals vary, ranging from about 250 years to more than 1,000 years.

The effects of these earthquakes include strong ground shaking that goes on for several minutes, subsidence and/or uplift of coastal areas, liquefaction, and tsunamis. Aftershocks will be both strong and numerous (possibly M7 or higher).

Type of Earthquake

Most earthquake hazards result from ground shaking caused by seismic waves that radiate out from a fault when it ruptures. Seismic waves transmit the energy



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1. ShakeMap for a M8.3 earthquake on the Cascadia megathrust. The black polygon offshore is the modeled area of fault rupture for this scenario.

released by the earthquake: The bigger the earthquake, the larger the waves and the longer they last. Several factors affect the strength, duration, and pattern of shaking:

- The type of rock and sediment layers that the waves travel through.
- The dimensions and orientation of the fault and the characteristics of rapid slippage along it during an earthquake.
- How close the rupture is to the surface of the ground.

Subduction Zone Earthquakes: In the Pacific Northwest, subduction zone earthquakes occur where the Juan de Fuca oceanic plate is being forced under the continental plate. An earthquake is produced when pressure that has built up along this zone causes the plates to slip suddenly and rapidly past each other. Shaking from the M8.3 earthquake modeled in this scenario will be felt over a very large area and may last for several minutes.

Aftershocks: Unlike other deep earthquakes (such as the M6.8 Nisqually earthquake in 2001), which usually produce few or no aftershocks strong enough to be felt, a M8.3 subduction zone earthquake will be followed by many aftershocks, a few of which could be large enough to cause additional damage.

Other Earthquake Effects

Tsunamis: A M8.3 Cascadia subduction zone earthquake is expected to generate a tsunami. Tsunami waves will reach the Pacific coast of Washington within 25 to 40 minutes of the earthquake and may continue for the next 12 to 24 hours. (Tsunami waves will also travel across the Pacific Ocean.) Delta failures and landslides caused by the shaking may also create or amplify tsunami waves.

Liquefaction: If sediments (loose soils consisting of silt, sand, or gravel) are water-saturated, strong shaking can disrupt the grain-to-grain contacts, causing the sediment to lose its strength. Increased pressure on the water between the grains can sometimes produce small geyser-like eruptions of water and sediment called *sand blows*. Sediment in this condition is liquefied and behaves as a fluid. Buildings on such soils can sink and topple, and foundations can lose strength, resulting in severe damage or structural collapse. Pipes, tanks, and other structures that are buried in liquefied soils will float upwards to the surface.

Artificial fills, tidal flats, and stream sediments are often poorly consolidated and tend to have high liquefaction potential.

Landslides: Earthquake shaking may cause landslides on slopes, particularly where the ground is water-saturated or has been modified (for example, by the removal of stabilizing vegetation). Steeper slopes are most susceptible, but old, deep-seated landslides may be reactivated, even where gradients are as low as 15%. Catastrophic debris flows can move water-saturated materials rapidly and for long distances, mostly in mountainous regions. Underwater slides are also possible, such as around river deltas.

Figure 2. Tsunami damage along the waterfront in Kodiak, Alaska, following a M9.2 earthquake in Prince William Sound on March 27, 1964. (Photo: U.S. Geological Survey, Circular 491)

BE PREPARED WHEREVER YOU ARE: **Develop a plan and a disaster supply kit. When you're prepared, you feel more in control and better able to keep yourself and your family safe.**

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Hazus Results for the Cascadia Subduction Zone (North) Scenario

Hazus is a nationally applicable standardized methodology developed by FEMA to help planners estimate potential losses from earthquakes. Local, state, and regional officials can use such estimates to plan risk-reduction efforts and prepare for emergency response and recovery.

Hazus was used to estimate the losses that could result from a M8.3 earthquake on the northern part of the Cascadia subduction zone. Such an event is expected to impact 23 counties in Washington. Among the most affected by the earthquake are Clark, Cowlitz, Grays Harbor, Lewis, Pacific, and Thurston. *(Note: These estimates do not include losses due to tsunami.)*

Injuries: Many people will be injured in this earthquake. Estimates vary by location—from less than 100 in Thurston County to nearly 400 in Clark County. Although many of the injuries will not be life-threatening, they will require medical attention and, in dozens of cases, hospitalization. Potentially life-threatening injuries and fatalities are expected; these will be more numerous if the earthquake happens during the afternoon or early evening.

Damage: Clark and Thurston counties may have the greatest number of damaged buildings (over 48,000) in this scenario. The totals for other counties are lower, but still amount to thousands of buildings (for example, over 17,000 in Grays Harbor). Most of the damaged buildings will be residential, but the totals include many commercial and industrial structures as well as other occupancy classes. The degree of damage will vary. In many counties, extensive damage to thousands of buildings is expected (with the highest numbers in Pacific, Grays Harbor, and Clark counties). Structural collapse of buildings is also expected (more than 1,200 in Pacific County alone). Many unreinforced masonry buildings will experience partial to full collapse.

Economic Losses Due to Damage: Capital stock losses are the direct economic losses associated with damage to buildings, including the cost of structural and non-structural damage, damage to contents, and loss of inventory. The estimates for this scenario are high, ranging from about $197 million in Lewis County to nearly $565 million in Clark County.

CASCADIA SUBDUCTION ZONE (NORTH) SCENARIO	
End-to-end length of fault (kilometers)	275
Magnitude (M) of scenario earthquake	8.3
Number of counties impacted (WA only)	23
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	1,443
Total number of buildings extensively damaged	12,233
Total number of buildings completely damaged	1,940
Income losses in millions	$989
Displaced households	3,692
People requiring shelter (individuals)	2,452
Capital stock losses in millions	$2,708
Debris total in millions of tons	1.40
Truckloads of debris (25 tons per truckload)	55,920
People without potable water (Day 1)	2,858

Table 1. Summary of significant losses in the M8.5 Cascadia subduction zone (north) earthquake scenario. Among the most affected counties are Clark, Cowlitz, Grays Harbor, Lewis, Pacific, and Thurston.

***Injury severity levels: 1—requires medical attention, but not hospitalization; 2—not life-threatening, but does require hospitalization; 3—hospitalization required; may be life-threatening if not treated promptly; 4—victims are killed by the earthquake**

Income losses, including wage losses and loss of rental income due to damaged buildings, are also high: Clark County accounts for over $268 million.

Impact on Households and Schools: The number of households without water will be highest in Pacific County (over 2,500). Clark County is estimated to have the highest number of displaced households and individuals in need of shelter. The functionality of many schools will also be affected: On Day 1 in Pacific County, functionality may be as low as 32%.

Debris Removal: Following this earthquake, debris (brick, wood, concrete, and steel) will have to be removed and disposed of. Clark County alone accounts for nearly 350,000 tons, Grays Harbor for 210,000 tons, and Cowlitz for 209,000 tons.

Estimates vs. Actual Damage: Although this M8.3 earthquake scenario was modeled using the best scientific information available, it represents a simplified version of expected ground motions. The damage resulting from an actual earthquake of

similar magnitude is likely to be even more variable and will depend on the specific characteristics and environment of each affected structure.

Other Tools: Community planners can also look at how a large earthquake may impact local resources and people's lives and livelihoods. The following graphs illustrate variations in such impacts: The first shows the levels of shaking that residents are likely to experience; the second shows possible impacts on services and business sectors. Note that in King County, a greater number of residents will be exposed to strong shaking; Cowlitz, Grays Harbor, Lewis, and Thurston counties, although less populated, will experience more intense ground motions.

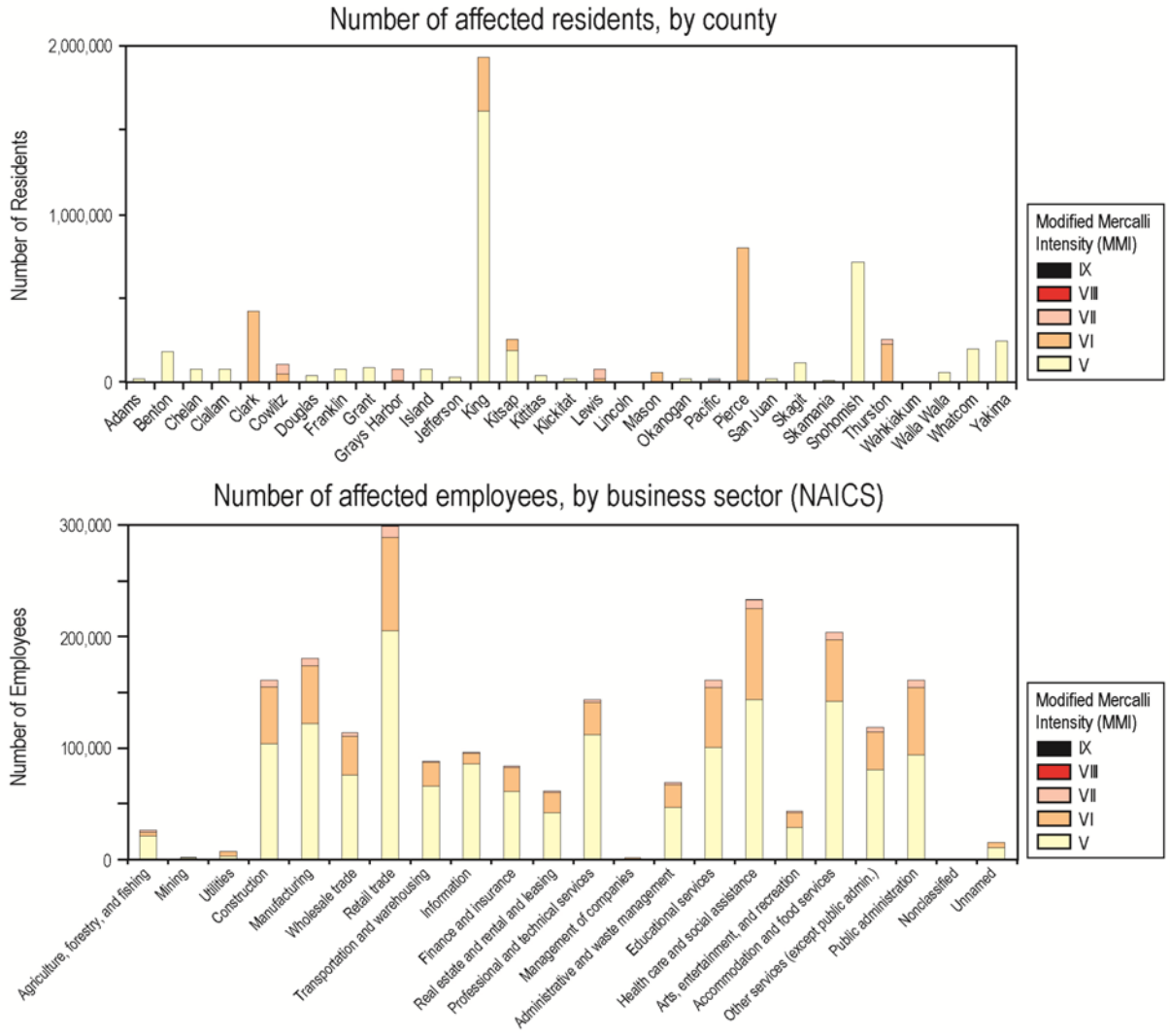

Figure 3. Number of residents and employees affected by the M8.3 earthquake projected for the Cascadia (North) scenario. Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

V. Rather Strong (PGA 3.9–9.2 *g*)	Felt outside by most. Dishes and windows may break. Large bells ring. Vibrations like large train passing close to house.
VI. Strong (PGA 9.2–18 *g*)	Felt by all; people walk unsteadily. Many frightened and run outdoors. Windows, dishes, glassware broken. Books fall off shelves. Some heavy furniture moved or overturned. Cases of fallen plaster. Damage slight.
VII. Very Strong (PGA 18–34 *g*)	Difficult to stand. Furniture broken. Damage negligible in buildings of good design & construction; slight-moderate in other well-built structures; considerable in poorly built/badly designed structures. Some chimneys broken.
VIII. Destructive (PGA 34–65 *g*)	Damage slight in specially designed structures; considerable in ordinary substantial buildings (partial collapse); great in poorly built structures. Fall of chimneys, factory stacks, columns, walls. Heavy furniture moved.
IX. Violent (PGA 65–124 *g*)	General panic; damage considerable in specially designed structures; well designed frame structures thrown out of plumb. Damage great in substantial buildings: partial collapse. Buildings shifted off foundations.