Modeling a Magnitude 7.2 Earthquake on the Nisqually Fault Zone near Olympia, Washington

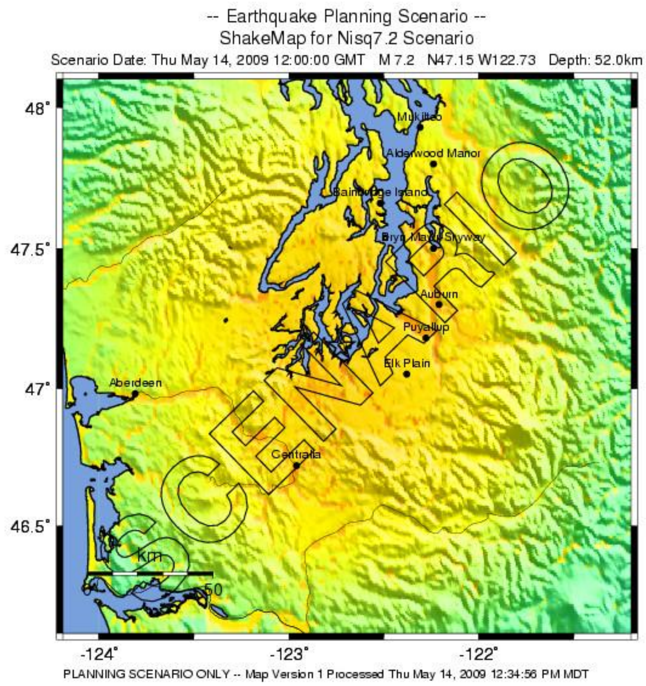
Geologic Description

This scenario is based on a M7.2 deep earthquake centered below the Nisqually delta. Deep earthquakes—also called intraplate or Wadati-Benioff zone earthquakes—are common in western Washington. Over the last 65 years, the largest of these deep earthquakes occurred between Olympia and Seattle in 1949 (M7.0), 1965 (M6.5), and 2001 (M6.8).

Intraplate earthquakes usually are the result of normal faulting within the upper part of a subducting oceanic plate and typically are not followed by large aftershocks. Beneath western Washington, the depth range of deep earthquakes begins near 30 kilometers (19 miles) and continues downward to about 60 kilometers (37 miles). This range is where all of the damaging deep earthquakes have been located. In some places, notably central and northern Puget Sound, a few events have been located much deeper, but their magnitudes tend to be small. The distribution of deep earthquake allows seismologists to map the surface of the subducting Juan de Fuca plate as it descends into the mantle below western Washington.

Two mechanisms are often cited as the cause of these earthquakes:

1. The subducting plate is bent by gravity as it descends into the mantle, and bending-moment forces cause normal faults to rupture in the upper part of the down-going slab
2. Dehydration and metamorphism of minerals in the down-going slab cause the plate to shrink and become denser, in turn causing stresses to build up that pull the plate apart.



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 M7.2 deep earthquake on the Nisqually fault zone near Olympia, Washington.

Worldwide, deep earthquakes can reach M7.5 or greater. For example, a M7.5 deep earthquake beneath Oaxaca, Mexico, occurred on Sept. 30, 1999. Our historical record of these earthquakes in northwestern Washington suggests an average recurrence of 30 years for a magnitude 6.5 or greater deep earthquake.

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

Washington Military Department
Emergency Management Division
Washington State Department of Natural Resources
USGS science for a changing world
FEMA

released by the earthquake: The bigger the quake, 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.

Deep vs. Shallow: Like the M6.8 Nisqually earthquake in 2001, the magnitude 7.2 earthquake modeled in this scenario is a deep earthquake. In relative terms, deep quakes tend to be less damaging than shallow quakes of comparable magnitude; this is primarily because in deeper quakes, the seismic waves have lost more energy by the time they reach the surface. Nevertheless, a deep earthquake of this magnitude will cause damage. The shaking from a deep earthquake is also likely to be felt over a much larger area than shaking caused by a shallow quake.

Aftershocks: Unlike shallow earthquakes, which usually produce numerous aftershocks, a M7.2 deep earthquake like the one in this scenario is not likely to be followed by aftershocks strong enough to be felt.

Other Earthquake Effects

Seiches & Local Tsunamis: Large earthquakes like the one in this scenario may create waves (known as seiches) in enclosed or partially enclosed bodies of water. The effect is similar to water sloshing up the sides of a bathtub. Delta failures and landslides caused by the shaking could create local tsunamis. Geological and historical evidence shows that landslides and failures of the sediments in river deltas have generated tsunamis in Puget Sound in the past.

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. For example, in the Nisqually scenario, the liquefaction susceptibility of the land on either side of the Nisqually, Deschutes, and Puyallup rivers is rated moderate to high.

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.

Photo: Steven Kramer, University of Washington

Figure 2. The M6.8 Nisqually earthquake in 2001 caused this road failure at Sunset Lake in Tumwater, Washington.

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.**

LEARN MORE ABOUT WHAT YOU CAN DO:
www.emd.wa.gov

Hazus Results for the Nisqually (Olympia) 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 M7.2 earthquake on the Nisqually fault zone beneath Pierce and Thurston counties. Such a scenario is expected to impact seventeen counties in Washington, with the most significant effects apparent in King, Pierce, and Thurston counties.

Injuries: The number of people injured in this scenario is likely to be high, particularly if the earthquake occurs during or at the end of the business day. King County is expected to have the highest number of injured people, followed by Pierce and Thurston counties. Many of the injuries will be serious enough to require hospitalization, and some may be life-threatening if not treated promptly. Numerous fatalities are likely if the event occurs during the afternoon or early evening.

Damage: The earthquake will damage buildings in all of the affected counties, but King, Pierce, and Thurston account for the highest number (over 200,000). Of these buildings, more than 1,900 in King County will be extensively damaged, 1,633 in Pierce County, and 1,140 in Thurston. In addition, several hundred buildings will collapse or be in imminent danger of collapse (complete damage). Most of the damaged buildings will be residential, but commercial and industrial structures also account for a large part of the total.

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. King County accounts for the largest portion of the capital stock loss estimate (over $3.7 billion), followed by Pierce (over $1.5 billion), and Thurston (about $811 million).

NISQUALLY SCENARIO EARTHQUAKE	
End-to-end length of fault (kilometers)	38
Magnitude (M) of scenario earthquake	7.2
Number of counties impacted	17
Total injuries (*severity 1, 2, 3, 4) at 2:00 PM	1,750
Total number of buildings extensively damaged	6,026
Total number of buildings completely damaged	547
Income losses in millions	$1,015
Displaced households	3,258
People requiring shelter (individuals)	2,015
Capital stock losses in millions	$5,325
Debris total in millions of tons	1.43
Truckloads of debris (25 tons per truckload)	57,040
People without potable water (Day 1)	45,916

Table 1. Summary of significant losses in the M7.2 Nisqually earthquake scenario. Among the most affected counties are Cowlitz, King, Pierce, Snohomish, Thurston, Wahkiakum, and Lewis.

***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**

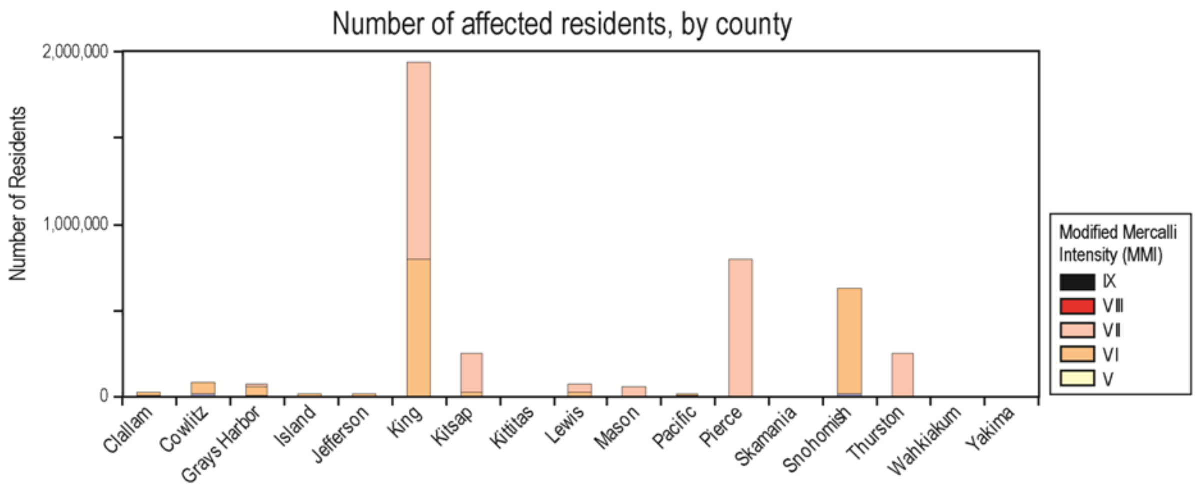
Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in King County ($726 million), Pierce County ($292 million), and Thurston County (over $154 million).

Impact on Households and Schools: The number of people without water will be highest in King, Pierce, and Thurston counties. These counties also account for most of the displaced households and individuals in need of shelter. The functionality of schools will be most affected in Thurston and Pierce counties.

Debris Removal: Following an earthquake, debris consisting of brick, wood, concrete, and steel must be removed and disposed of. Much of this will come from King County (about 681,000 tons), with a significant portion from Pierce, Thurston, Lewis, and Snohomish counties (about 628,000 tons).

Estimates vs. Actual Damage: Although the M6.8 earthquake scenario for the Nisqually fault zone 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 the possible impact on different services and business sectors. Note that even where structural damage to buildings is slight, the shaking may be strong enough to damage furnishings and inventories.



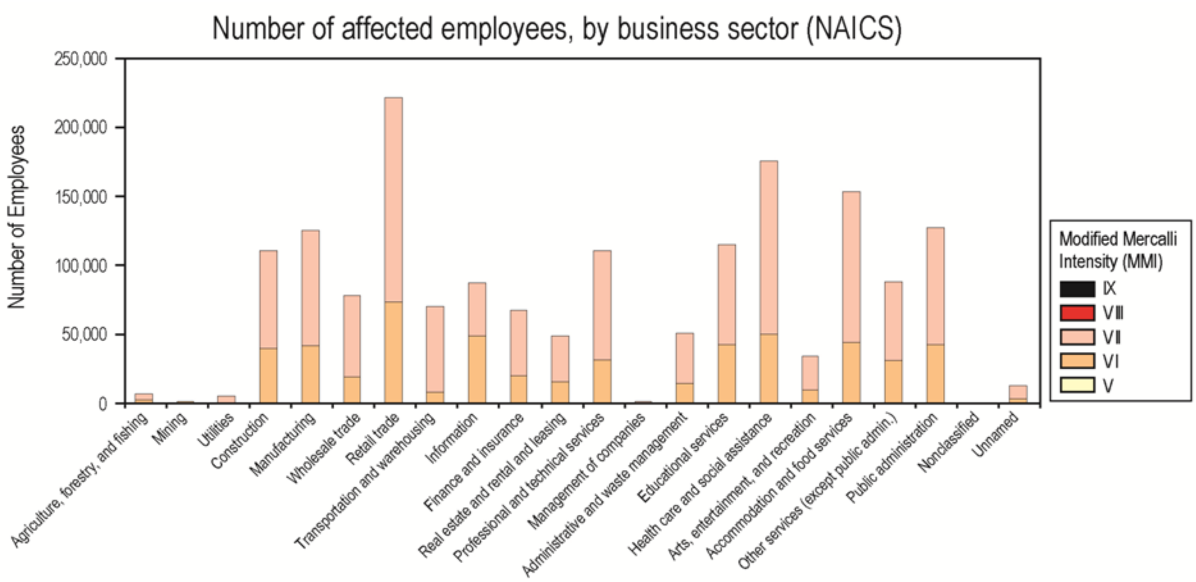


Figure 3. Number of residents and employees affected by the M7.2 earthquake projected for the Nisqually fault zone. The Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.

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.