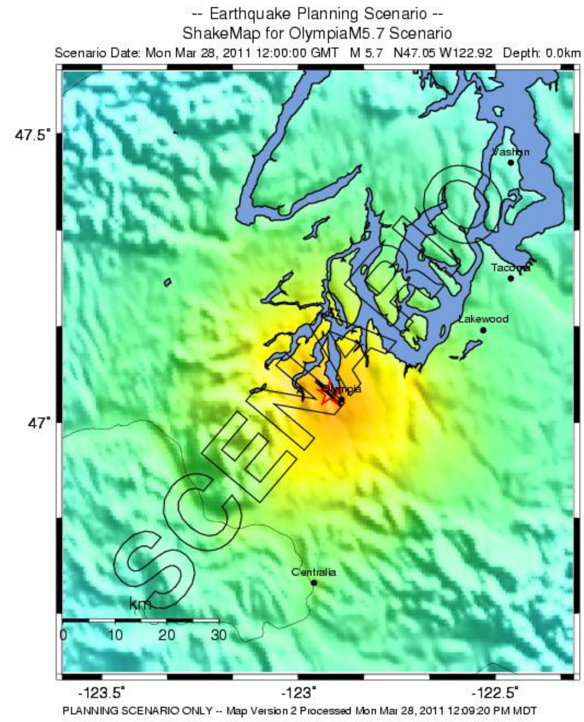
# Modeling a Magnitude 5.7 Earthquake on the Olympia Fault in Thurston County

## Geologic Description

The Olympia fault is a gravitational and aeromagnetic anomaly about 80 kilometers (50 miles) long that separates the sedimentary deposits of the Tacoma basin from the basalt of the Black Hills uplift. This structure is shown in gravitational mapping of 1965, but without comment. In 1985, it was mapped from Shelton (near the Olympic foothills) southeast to Olympia (under the state legislature), directly under the town of Rainier, to a point due east of the Doty fault, and apparently marking the northeastern limit of a band of southeast-striking faults in the Centralia–Chehalis area. It was labeled *structure L* and interpreted it as “simple folds in Eocene bedrock,” though in 1998 a geologist saw enough similarity with the Seattle fault to speculate that it is a thrust fault. Others observed the straight boundaries and interpreted these as evidence of structural control, but refrained from calling it a fault—their model of the Black Hills uplift is analogous with their “wedge” model of the Seattle uplift, but in the opposite direction. (If entirely analogous, then “roof duplex” might also apply, and the Olympia fault would be a reverse fault similar to the Tacoma fault.)




| 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 M5.7 earthquake on the Olympia fault.**

The Olympia fault is identified by high amplitude lineaments on gravity, magnetic, and lidar (light detection and ranging) data. New imaging data across this southeast-striking structure identify faulting of shallow (<60 meters; 197 feet) post-glacial sediments by near-vertical faults, one showing opposite senses of displacement on different beds, suggesting more than one fault is present with some strike-slip motion. The strike of the faults imaged on the seismic profiles aligns with lidar lineations on nearby land. It is not certain that these shallow faults are the surface expression of a deep-seated fault rather than minor bending-moment faults, but the documentation of faults near the structure emphasizes the seismic potential of faults beneath the south Puget Lowland. Regional seismic surveys have not been acquired across this structure, in part because no regional waterways cross the area.

## 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 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 of the ground.

***Deep vs. Shallow:*** The M5.7 scenario earth-quake modeled for the Olympia fault zone is a shallow or crustal earthquake. Shallow quakes tend to be much more damaging than deep quakes of comparable magnitude (such as the deep M6.8 Nisqually earthquake in 2001). This is primarily because the seismic waves generated by deep earthquakes have lost more energy by the time they reach the surface.

***Aftershocks:*** Unlike deep earthquakes, which usually produce few or no aftershocks strong enough to be felt, shallow earthquakes are likely to be followed by many aftershocks, a few of which could be large enough to cause additional damage.

## Other Earthquake Effects

***Tsunamis:*** Some earthquakes may rupture a fault at the surface of the ground. If this offsets the floor of Puget Sound, it could generate a local tsunami. Delta failures and landslides caused by the shaking may also create or amplify tsunamis. Geological and historical evidence shows that landslides and failures of the sediments in river deltas have generated tsunamis within 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 Olympia scenario, the liquefaction susceptibility of the land on either side of the Nisqually, Deschutes, and Chehalis 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.**

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## Hazus Results for the Olympia Fault 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 M5.7 earthquake on the Olympia fault beneath Thurston County. Such a scenario is expected to impact five counties in Washington, with the most significant effects apparent in Thurston, Mason, and Pierce counties.

***Injuries:*** The estimated number of people injured in this scenario is highest if the earthquake occurs during or at the end of the business day (2:00–5:00 pm). The majority of the injuries are expected to occur in Thurston County. While most of these injuries may not require hospitalization, some injuries will be more serious and a few may be life-threatening if not treated promptly. Several fatalities are also likely if the event occurs during the business day or evening commute.

***Damage:*** The earthquake will damage buildings in all of the affected counties, but the highest number by far will be in Thurston County (20,838). For most counties, the damage will be slight to moderate, but in Thurston County, nearly 400 buildings will be extensively damaged and at least 28 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. Thurston County accounts for the largest portion of the capital stock loss estimate (over $400 million), followed by Pierce County (about $12.5 million), and Mason County (more than $5 million).

| *OLYMPIA FAULT SCENARIO EARTHQUAKE* | |
|---|---|
| End-to-end length of fault (kilometers) | 7 |
| Magnitude (M) of scenario earthquake | 5.7 |
| Number of counties impacted | 5 |
| Total injuries (*severity 1, 2, 3, 4) at 2:00 PM | 94 |
| Total number of buildings extensively damaged | 388 |
| Total number of buildings completely damaged | 29 |
| Income losses in millions | $70 |
| Displaced households | 242 |
| People requiring shelter (individuals) | 139 |
| Capital stock losses in millions | $426 |
| Debris total in millions of tons | 0.09 |
| Truckloads of debris (25 tons per truckload) | 3,480 |
| People without potable water (Day 1) | 274 |

**Table 1. Summary of significant losses in the M5.7 Olympia fault earthquake scenario. The counties most likely to be affected are Grays Harbor, Lewis, Mason, Pierce, Snohomish, 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**

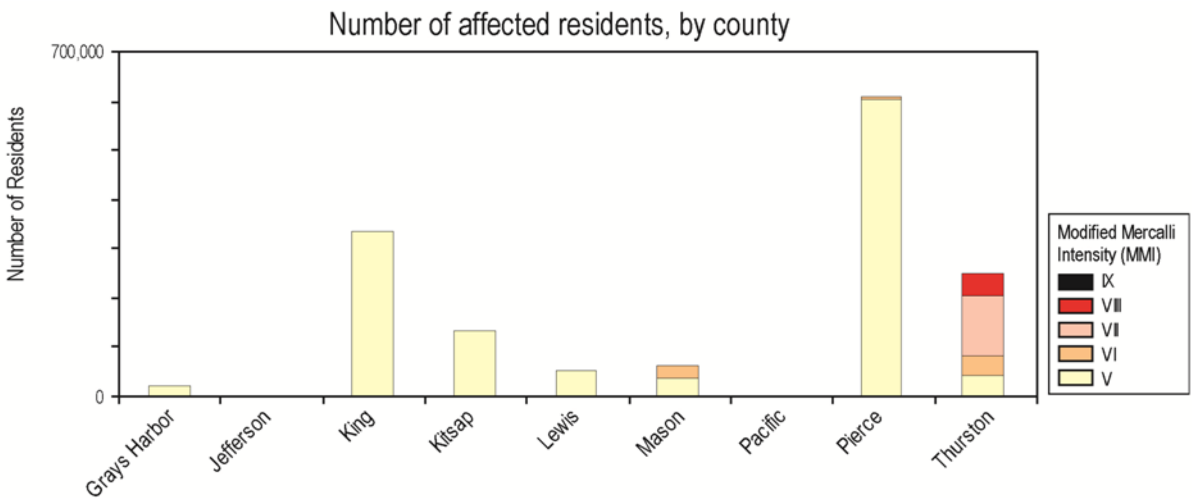
Income losses, including wage losses and loss of rental income due to damaged buildings, are also highest in Thurston County (over $68.7 million) and Pierce County (about $4.4 million).

***Impact on Households and Schools:*** The number of people without water will be highest in Thurston County. This county also accounts for all of the displaced households and individuals in need of shelter. The functionality of schools is likely to be affected only in Thurston County.

***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 Thurston County (about 85,000 tons), with Pierce and Mason contributing only 1,000 tons each.

***Estimates vs. Actual Damage:*** Although this M5.7 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 different services and business sectors. Note that a greater number of residents in King and Pierce counties will be exposed to less severe shaking, whereas Thurston County, although less populated, will experience more intense ground motions.



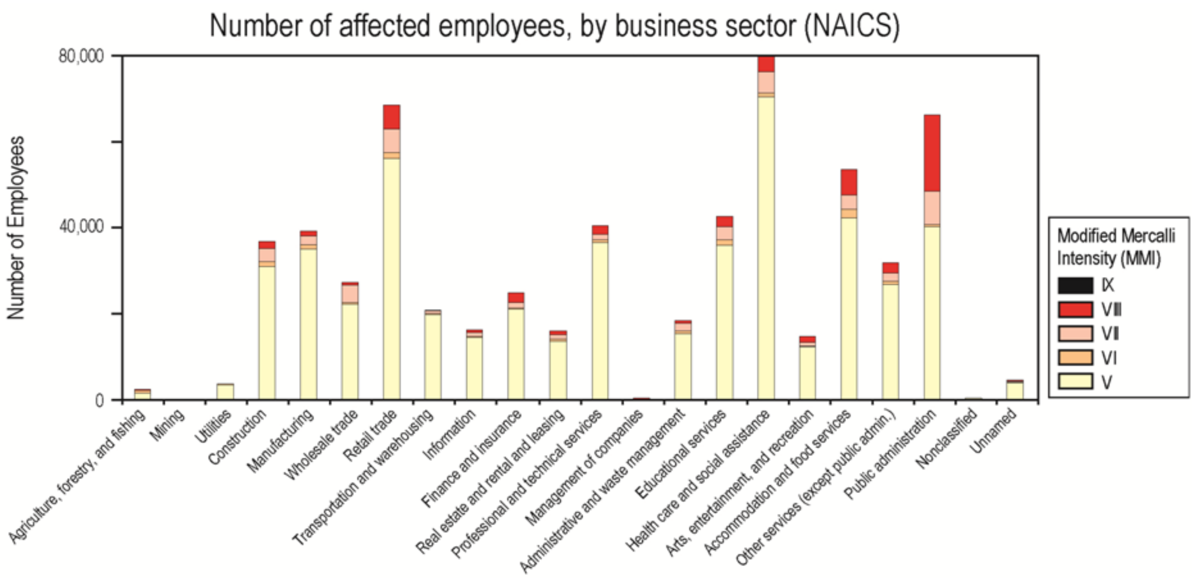




**Figure 3. Number of residents and employees affected by the M5.7 earthquake projected for the Olympia fault. Modified Mercalli Intensity (MMI) classes indicate peak ground acceleration (PGA) values and the impact of the shaking.**

| | |
|---|---|
| **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. |