

EARTHQUAKE

Definition of Hazard

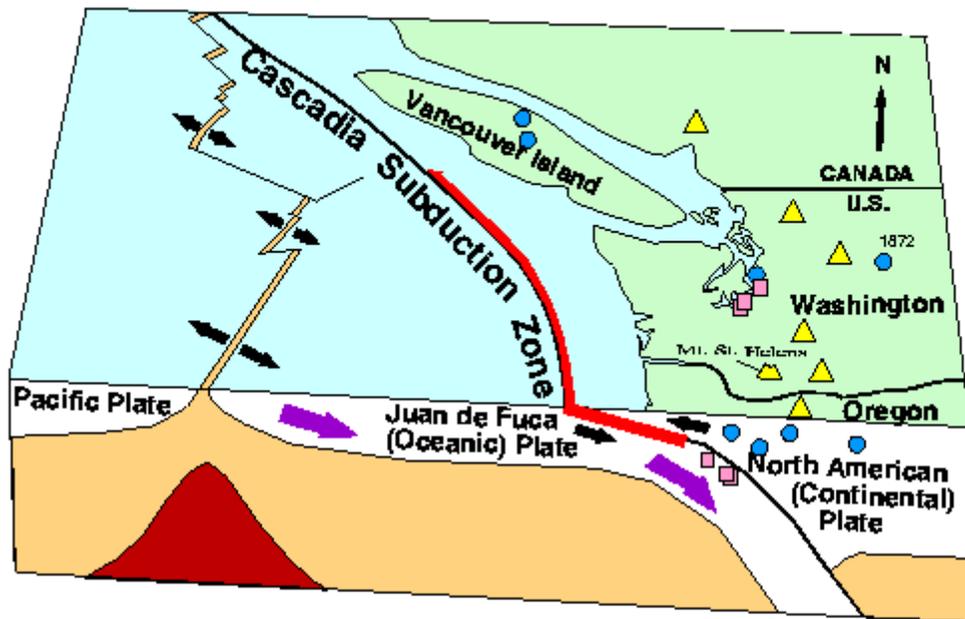
Earthquakes are defined as the sudden release of energy occurring from the collision or shifting of crustal plates on the earth's surface or from the fracture of stressed rock formations in that crust. This release of energy results in the earth shaking, rocking, rolling, jarring and jolting; having the potential to cause minimal to great damage in the Puget Sound area. Earthquakes are measured by units of magnitude, which is a logarithmic measure of earthquake size. This means that at the same distance from the earthquake, the shaking will be 10 times as large during a magnitude 5 earthquake as it would during a magnitude 4 earthquake.

History of Hazard as it Affects the City of Kent

Western Washington and the Kent area have a long history of documented earthquake activity. Kent is geographically located in an area known as the Pacific Ring of Fire. The same geological events that result in the creation of volcanoes and volcanic events may also generate notable earthquakes. Western Washington is framed by the Pacific, North American, and Juan de Fuca plates, with a significant amount of active fault lines identified in the Puget Sound area. All of these have been the cause of earthquakes in history, with the most notable recent earthquakes being the 1949 magnitude 7.1 Olympia earthquake, which caused over \$100 million in damage and killed 8 people; the 1965 magnitude 6.5 Seattle-Tacoma earthquake which caused over \$50 million in damage and killed 7 people; the 1999 magnitude 5.5 Satsop earthquake; and the 2001 magnitude 6.8 Nisqually earthquake. Annually, hundreds of earthquakes occur in Washington, most of which go unnoticed (less than magnitude 2.5).

Hazard Identification

The earth is divided into three main layers -- a hard outer crust, a soft middle layer and a central core. The crust is broken into massive irregular pieces called "plates", which have been moving very slowly over the earth's surface for billions of years, driven by energy deep within the earth. This movement has shaped the physical features of the earth -- its mountains, valleys, plains, and plateaus. As these plates move, stresses are built up and periodically release energy in areas where the plates come into contact with each other.



- Deep Earthquakes (40 miles below the Earth's surface) are within the subducting oceanic plate as it bends beneath the continental plate. The largest deep Northwest earthquakes known were in 1949 (M 7.1), 1965 (M 6.5), and 2001 (M 6.8).
- Shallow earthquakes (less than 15 miles deep) are caused by faults in the North American Continent. The Seattle fault produced a shallow magnitude 7+ earthquake 1,100 years ago. Other magnitude 7+ earthquakes occurred in 1872, 1918, and 1946.
- Subduction Earthquakes are huge quakes that result when the boundary between the oceanic and continental plates ruptures. In 1700, the most recent Cascadia Subduction Zone earthquake sent a tsunami as far as Japan.
- ▲ Mt. St. Helens/Other Cascade Volcanos

There are three technically distinct types of earthquakes that have the ability to generate powerful damaging motion in the greater Puget Sound area

Benioff Zone/Interplate (Deep) earthquakes

These earthquakes occur at depths of 15 to 60 miles from the subducting Juan de Fuca plate. The Olympia, Seattle-Tacoma, Satsop and Nisqually earthquakes are all examples of Benioff Zone earthquakes. They usually do not exceed magnitudes of 7.5, are 15-40 seconds in duration, have normal faulting with no large aftershocks. These earthquakes are more frequent than subduction zone earthquakes, typically occurring every 30 years or so.

Subduction Zone events

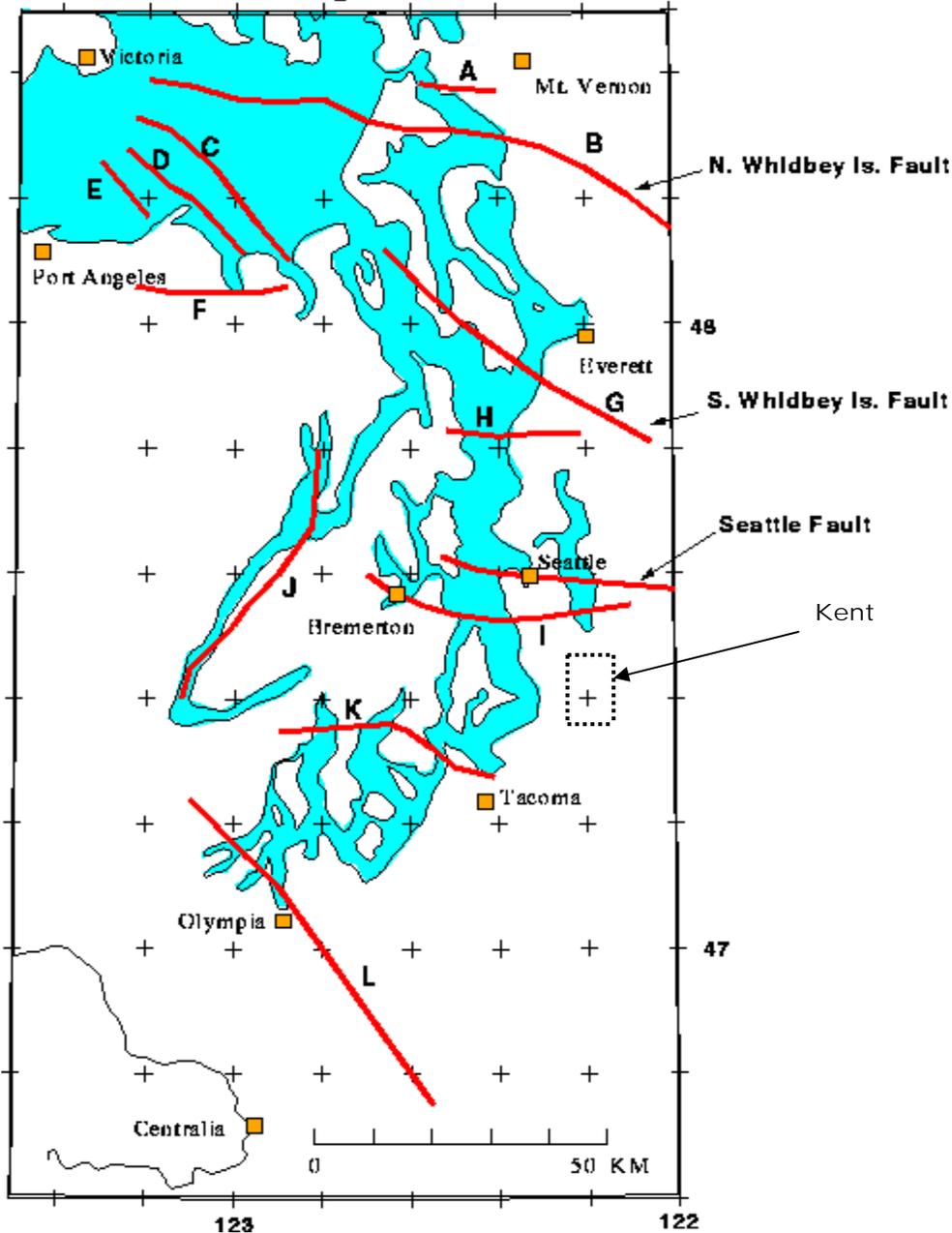
These earthquakes occur along the interface between tectonic plates, generated from the collision of the Juan de Fuca, Pacific, and North American plates. This area is also known as the Cascadia Subduction Zone, and it ranges from southern British Columbia to Northern California. These earthquakes are considered great magnitude events and may reach 8.0-9.0 on the Richter scale. Researchers say the stresses they observe off the coast of Washington could cause an earthquake measuring up to 9.5. **The duration of shaking could last up to 3 minutes.** A subduction zone earthquake may also generate tsunamis. The last known subduction earthquake in the Puget Sound area occurred in 1700. Geological evidence indicates that these great earthquakes may have occurred at least seven times in the last 3,500 years, suggesting a return time of 400-600 years.

Shallow Crustal Earthquakes

The largest known historic earthquake in Washington or Oregon occurred in 1872 in the North Cascades. This earthquake had an estimated magnitude of 7.4 and was followed by many aftershocks. It was probably at a depth of 10 miles or less within the continental crust. Many other crustal sources in Washington and Oregon could also produce damaging earthquakes. Recent studies have found geologic evidence for large shallow earthquakes 1,100 years ago within the central Puget Basin. Massive block landslides into Lake Washington, marsh subsidence and tsunami deposits at West Point in Seattle, tsunami deposits at Cultus Bay on Whidbey Island, and large rock avalanches on the southeastern Olympic Peninsula have all been dated to approximately 1,100 years ago.

Earthquake energy is released on the earth's surface primarily through faults. A fault is a fracture in the crust of the earth along which rocks on one side have moved relative to those on the other side. Most faults are the result of repeated displacements over a long period of time. A fault trace is the line on the earth's surface defining the fault. Fault rupture almost always follows preexisting faults, which are zones of weakness. Rupture may occur suddenly during an earthquake or slowly in the form of fault creep. Sudden displacements are more damaging to structures because they are accompanied by shaking. The following is a map of major earthquake fault zones in the Puget Sound region.

Major Fault Zones in the Puget Sound



In addition to the different types of earthquakes, geological factors affect how the Kent area will fare during an earthquake. The Kent valley is composed of soft materials such as mud, artificial fill and layers of sand and clay that can amplify ground shaking and make overall damage more intense. Soft soils tend to liquefy during an earthquake creating a condition known as "**liquefaction**". This condition can result in local areas experiencing severe damage, especially where the ground fails (or liquefies) under buildings, pipelines or bridges. Landslides and rock falls may be triggered on steep slopes.



Some effects of liquefaction during the 1964 Niigata earthquake

Liquefaction can cause damage to structures in several ways. Buildings whose foundations bear directly on sand which liquefies will experience a sudden loss of support, which will result in drastic and irregular settlement of the building. Liquefaction causes irregular settlements in the area liquefied, which can damage buildings and break underground utility lines where the differential settlements are large. Pipelines and ducts may float up through the liquefied sand. Sand boils can erupt into buildings through utility openings, and may allow water to damage the structure or electrical systems. Soil liquefaction can also cause slope failures

Vulnerability Analysis



Tom Reese / The Seattle Times

A worker inspects the damage from an earthquake-triggered mudslide that flowed into Cedar River in Renton's Maple Valley. The mudslide caused flooding that moved Paul Patrick's truck and nearly reached his house.

Any building or structure built on land that slides in an earthquake could be destroyed, creating an extreme hazard for those buildings or structures on the hillsides above the valley floor. Landslides could also pose a threat to transportation routes, preventing emergency vehicles from responding in an earthquake disaster.

Additionally disruption of water, sewer, power and communication lines would be likely.



Steve Bloom / The Associated Press

South Puget Sound Community College student Jeff Ennett walks along an Olympia sidewalk made buckled by Wednesday's quake.

Transportation and communication would be limited or inaccessible. Major transportation lifelines are built on liquefaction prone soils and hillsides, both of which could be destroyed as a result of an earthquake. Bridges may be damaged or need structural assessment resulting in road closures. Assessment of bridges, overpasses and roadways may be delayed, creating a potential continuum of harm. Downed utility lines could cause more problems for transportation as well as the loss of communication and power.



Fire as a result of the 1994 Northridge California Earthquake

Fire, a disaster in itself, frequently accompanies earthquakes. Fire usually occurs as a result of damaged electrical equipment, broken gas lines, fuel spills, disrupted heating equipment or any combination thereof. These fires can break out in multiple locations in a short period of time following an earthquake, quickly causing firefighting resources to be overextended. Additional strain on firefighting capabilities could be caused by transportation route interruptions and broken water lines, which would make firefighting impossible.



Masonry Damage in Seattle after the 2001 Nisqually earthquake

Damage to existing structures in the area could be great, with older brick buildings and tilt-up warehouses potentially being the most susceptible. Because the Kent valley contains the largest concentration of older buildings and lies on soil prone to liquefaction, it is likely that this area would be the most heavily damaged in the event of an earthquake.

Another concern is the potential for destruction and damage of tilt-up buildings in the industrial area of Kent. As well as being located on the liquefaction soil, many of these structures have hazardous materials stored on site, which when released have a high potential for being life threatening. High populated facilities, such as schools and community buildings are of concern as well, due to the potential high loss of life.

Howard Hanson Dam, and to a lesser degree the Mud Mountain Dam, have more than a significant effect on the flow of the Green and White Rivers, making flooding of the Kent valley an added concern. The Green River flows through the Kent area and the White River flows through south Auburn. An earthquake of significant magnitude could cause enough damage to these dams to create a serious flood hazard.

The time that an earthquake occurs significantly determines the impact of the quake. The most significant effect of time relates to the potential for human casualties. Experts believe that casualties would be greatest during hours of heavy vehicular traffic and when large numbers of people are in concentrated areas such as business, and government districts, places of commerce and schools. **Thus the highest potential for human casualties in Kent resulting from an earthquake exists during the 12-hour period from 6 a.m. to 6 p.m. Monday thru Friday.**

Conclusions

The effects of a major earthquake in the Kent area have the potential to be catastrophic. Hundreds of people could be killed with thousands left homeless. Damage to buildings and structures could be in the millions of dollars. Transportation and communication could be disrupted from flooding, landslides, structure damage, and downed lines.

Since an earthquake's potential for catastrophic human and economic consequences, it is incumbent upon local government to take appropriate actions now to mitigate against its severity with conscientious enforcement of codes and improved building standards, and to educate our citizens as best we can to be ready for a great quake. This education includes; public awareness programs, school staff and student community "Drop, Cover and Hold" training and drills. Community Emergency Response Team (C.E.R.T) education and training, and community outreach on what to do before, during and after an earthquake are just part of the answer.

RICHTER MAGNITUDE SCALE

The measure of strength of an earthquake is indicated by a number called its magnitude. Magnitude is calculated from a measurement of either the amplitude or the duration of specific types of recorded seismic waves. In general, the different magnitude scales (for example, local or Richter magnitude and surface wave magnitude) give similar numerical estimates of the size of an earthquake, and all display a logarithmic relation to recorded ground motion. That means each unit increase in magnitude represents an increase in the size of the recorded signal by a factor 10.

Seismologists sometimes refer to the size of an earthquake as moderate (magnitude 5), large (magnitude 6), major (magnitude 7), or great (magnitude 8).

The intensity of an earthquake is a measure of the amount of ground shaking at a particulate site, and it is determined from reports of human reaction to shaking, damage done to structures, and other effects. The Modified Mercalli Intensity Scale (Table 1) is now the scale most commonly used to rank earthquakes felt in the United States.

Modified Mercalli Intensity Scale.

Taken from a pamphlet "The severity of an earthquake" prepared by the U.S. Geological Survey in 1986. See Wood and Neuman (1931) for complete details.

- I. Not felt except by a very few under especially favorable circumstances.
- II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake, standing motor cars may rock slightly with vibration similar to the passing of truck. Duration estimated.
- IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound: sensation like heavy truck striking building. Standing motor cars rocked noticeably.
- V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
- VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster; damage slight.
- VII. Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken; noticed by persons driving motor cars.
- VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
- IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
- X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
- XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
- XII. Damage total. Lines of sight and level distorted; objects thrown into the air.

Table 1.