WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

Division of Geology and Earth Resources
Ron Teissere - State Geologist

Department of Homeland Security
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Region 10

Washington Military Department
Emergency Management Division

Parapet failures in downtown Olympia from the 1949 Olympia earthquake *(top photo)* and the 2001 Nisqually earthquake *(bottom photo)*. Ground shaking during both events was strongly amplified by the soft soils deposited at the mouth of the Deschutes River that underlie downtown Olympia. *(Top photo by Roger Easton, used by permission of Marie Cameron. Bottom photo by Joe Dragovich, Washington Division of Geology and Earth Resources.)*

Site Class Map of Island County, Washington

by Stephen P. Palmer, Sammantha L. Magsino, Eric L. Bilderback, James L. Poelstra, Derek S. Folger, and Rebecca A. Niggemann

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scale 1:100,000

2 1 0 2 4 6 8 Miles

2 1 0 2 4 6 8 Kilometers

Lambert conformal conic projection
North American Datum of 1983 HARN
Shaded relief generated from U.S. Geological Survey 30-meter Digital Elevation Model, 2x vertical exaggeration
Production by Anne C. Heinitz, Rebecca A. Niggemann, and Jaretta M. Roloff
Editing by Karen D. Meyers

State of Washington
Engineering Geologist
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Licensed Geologist
STEPHEN P. PALMER

Stephen P. Palmer
9/1/04

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EFFECTS OF SOIL CONDITIONS ON GROUND SHAKING DURING AN EARTHQUAKE

The most damaging effect of an earthquake is strong shaking at the ground surface. For more than a century, engineers and seismologists have known that ground shaking during an earthquake is strongest in areas of soft soils, such as in river valleys or along the shorelines of bays and lakes. Measurements of earthquake ground motions made in the last few decades have allowed seismologists to more fully understand the physics of this long-observed phenomenon. Earthquake wave velocity is slower in soils than in the underlying rock of the Earth's crust. It is this difference in wave speed that causes the shaking at the ground surface to be amplified. Generally, the greater the wave velocity difference, the greater the amplification of ground surface shaking. Consequently, ground shaking in areas of soft soils underlain by stiffer soils or rock is generally stronger than in areas where there is little or no variation between the surface and substratum. This has been observed time and again in past earthquakes.

WHAT IS A SITE CLASS?

In the mid-1990s, a simplified method for characterizing the ground-motion amplifying effects of soft soils was developed by Roger Borcherdt of the U.S. Geological Survey, based on data collected from the Loma Prieta and Northridge earthquakes in California (Borcherdt, 1994). His empirical study related the average shear-wave velocity in the upper 100 feet of the soil-rock column to the amplification of shaking at ground surface. Shear waves are the earthquake waves that create the strongest horizontal shaking and are the most damaging to buildings and structures.

Borcherdt's method subdivides the near-surface geology into a number of site classes where each site class is defined by a unique range of average shear wave velocities in the upper 100 feet. A modification of Borcherdt's empirical method was implemented by the Building Seismic Safety Council (BSSC) and the Federal Emergency Management Agency in the 1997 edition of the National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures (BSSC, 1997). Borcherdt's designation of site classes was simplified in BSSC (1997), and the simplified site class groupings are commonly referred to as NEHRP site classes. In 1997, this modified method of accounting for soil-column amplification effects was adopted by the International Code Council in the Uniform Building Code (UBC) (International Code Council, 1997). This method of designating site classes for determination of seismic design ground motions is used in the 2003 version of the International Building Code (International Code Council, 2003), which is the current building code adopted for use in Washington State.

Note that we refer to NEHRP site class simply as site class, which is consistent with the terminology of the 2003 version of the International Building Code.

WHAT IS A SITE CLASS MAP?

This site class map provides some measure of the potential for strong shaking in a particular area during an earthquake, and shows our best judgment to date of the distribution of the various site classes throughout Washington State. This map is based on surficial geology published at a scale of 1:100,000 by the Washington State Department of Natural Resources, Division of Geology and Earth Resources (Washington Division of Geology and Earth Resources staff, 2001). Designation of site classes was based on a large database of shear wave velocity data obtained in many of the geologic units shown in the 1:100,000-scale geologic mapping. For units without velocity measurements, site class was assigned based on similarity to units in the shear wave database.

In the methodology presented by BSSC (1997), site class B represents a soft rock condition, where earthquake shaking is neither amplified or reduced by the near-surface geology. Site classes C, D, and E represent increasingly softer soil conditions which result in a progressively increasing amplification of ground shaking. Site class F is reserved for unusual soil conditions where prediction of the amplification of earthquake shaking can only be determined by a site-specific evaluation. On this map we delineate areas of peat soil as site class F. Liquefiable soils also fall into site class F, but we have not included them on this map; please refer to the liquefaction susceptibility maps in this series for more information.

OTHER FACTORS CONTRIBUTING TO GROUND SHAKING

This map provides only a general guide to areas where shaking will be the strongest and where the potential damage to buildings and other structures may be elevated because of soil effects. This map does not incorporate other factors affecting the actual severity of ground shaking. The two most important of these factors are the size of the earthquake and the distance of the area in question from the earthquake's focus (location of the fault rupture that caused the earthquake).

The amount of energy released during a fault rupture, expressed as the earthquake magnitude, can vary tremendously from earthquake to earthquake. The earthquake magnitude scale is exponential to accommodate this range in earthquake size. An increase of one on the scale represents a thirty to forty times increase in the amount of energy released by the fault rupture. For example, a magnitude 7 earthquake releases about 35,000 times the energy of a magnitude 4 tremor.

As one might expect, the intensity of ground shaking will generally decrease with increasing distance from the focus. Comparison of the strength of ground shaking between the 2001 Nisqually earthquake (magnitude 6.8) and the 1995 Kobe, Japan earthquake (magnitude 6.9) demonstrates this point. Ground shaking from the Nisqually earthquake was not particularly violent because the fault rupture was at a depth of 30 miles, so that even the point on the ground surface directly above the earthquake focus was 30 miles away. However, during the Kobe earthquake, the fault rupture was only a mile or two beneath the city; shaking was violent and the damage severe, with the loss of over 5000 lives in a country experienced with and prepared for earthquakes.

HOW CAN THIS MAP BE USED?

Site class maps such as this can be used for many different purposes by a variety of users. For example:

- Emergency managers can determine which critical facilities and lifelines are located in hazardous areas.
- Building officials and engineers can select areas where detailed geotechnical studies should be performed before new construction or retrofitting of older structures.
- Facilities managers can assess the vulnerability of corporate and public facilities, including schools, and recommend actions required to maximize public safety and minimize earthquake damage and loss.
- Insurance providers can determine relative seismic risk to aid in the calculation of insurance ratings and premiums.
- Land-use planners can reduce vulnerability by recommending appropriate zoning and land use in high hazard areas to promote long-term mitigation of earthquake losses.
- Private property owners can guide their decisions on purchasing, retrofitting, and upgrading their properties.

This map is meant only as a general guide to delineate areas based on their potential for enhanced ground shaking. It is not a substitute for site-specific investigation to assess the actual ground conditions and potential for amplified ground shaking, as measured by the site class or other more quantitative analyses. Because the data used in producing this site class map is based on regional geologic mapping, this map cannot be used to make a final determination at any specific locality. This determination requires a site-specific evaluation performed by a qualified practitioner.

This map is intended to be printed at a scale of 1:100,000 and was generated using 1:100,000-scale digital coverages of the geologic mapping; therefore, the digital data reflect the original 1:100,000-scale of the hazard mapping. As with all maps, it is recommended that the user does not apply this map, either digitally or on paper, at scales greater than the source data.

EXPLANATION

- Site class F — Requires site-specific investigation
- Site class E
- Site class D to E
- Site class D
- Site class C to D
- Site class C
- Site class B to C
- Site class B
- Water
- Ice

Increasing amplification of ground shaking

This explanation is standardized for this series of county-based site class maps; some categories may not appear on this map.

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