

6.0 EARTHQUAKES

6.1 Introduction

Every location in Washington State has some level of earthquake hazard, but the level of earthquake hazard varies widely by location within the state. Historically, awareness of seismic risk in Washington has generally been high, among both the public and public officials. This awareness is based to a great extent on the significant earthquakes that occurred within the Puget Sound area in 1949 (Olympia earthquake), 1965 (Tacoma earthquake), and 2001 (Nisqually earthquake), as well as on other smaller earthquakes in many locations throughout the state.

The awareness of seismic risk in Washington has also increased in recent years due to the devastating earthquakes and tsunamis in Indonesia in 2004 and Japan in 2011. The geologic settings for the Indonesia and Japan earthquakes are very similar to the Cascadia Subduction Zone along the Washington Coast.

The technical information in the following sections provides a basic understanding of earthquake hazards, which is an essential foundation for making well-informed decisions about earthquake risks and mitigation Action Items for K–12 facilities.

6.2 Washington Earthquakes

Earthquakes are described by their magnitude (M), which is a measure of the total energy released by an earthquake. The most common magnitude is called the “moment magnitude,” which is calculated by seismologists from two factors – 1) the amount of slip (movement) on the fault causing the earthquake and 2) the area of the fault surface that ruptures during the earthquake. Moment magnitudes are similar to the Richter magnitude, which was used for many decades but has now been replaced.

The moment magnitudes for the largest earthquakes recorded worldwide and in Washington are shown below.

Table 6.1
Largest Recorded Earthquakes^{1,2}

| Worldwide | Magnitude | Washington | Magnitude |
|-----------------------------------|-----------|--------------------|------------------|
| 1960 Chile | 9.5 | 1872 Chelan | 6.8 ^a |
| 1964 Prince William Sound, Alaska | 9.2 | 1949 Olympia | 6.8 |
| 2004 Sumatra, Indonesia | 9.1 | 2001 Nisqually | 6.8 |
| 2011 Japan | 9.0 | 1965 Tacoma | 6.7 |
| 1952 Kamchatka, Russia | 9.0 | 1939 Bremerton | 6.2 |
| 2010 Chile | 8.8 | 1936 Walla Walla | 6.1 |
| 1906 Ecuador | 8.8 | 1909 Friday Harbor | 6.0 |

^a Estimated magnitude.

Figure 6.1
Epiconers of Historic Earthquakes in Washington with Magnitudes of 3.0 or Higher³

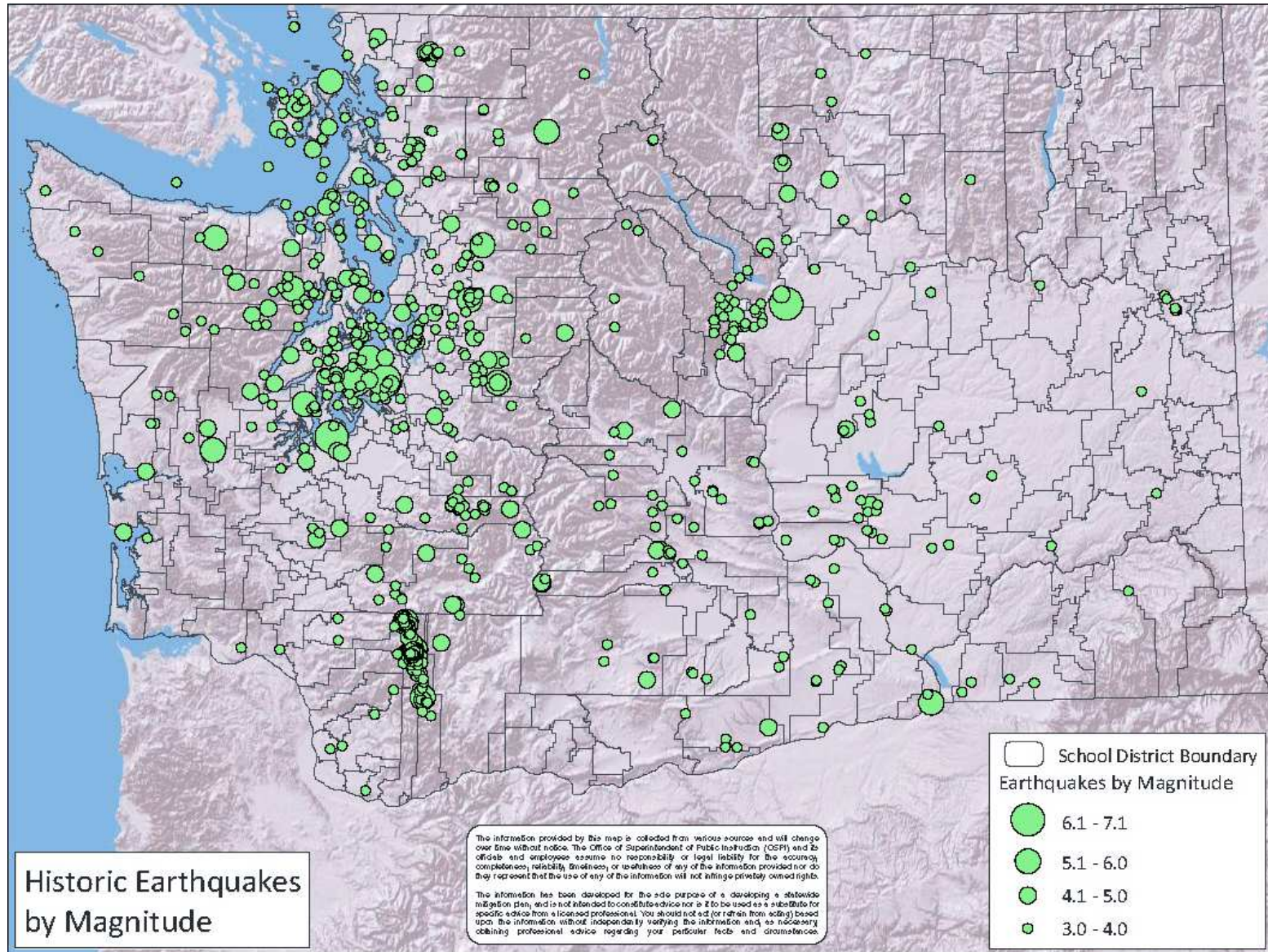


Table 6.1 and Figure 6.1 do not include the January 26, 1700 earthquake on the Cascadia Subduction Zone which has been identified by tsunami records in Japan and paleoseismic investigations along the Washington Coast. The estimated magnitude of the 1700 earthquake is approximately 9.0. This earthquake is not shown in Table 6.1 because it predates modern seismological records. However, this earthquake is among the largest known earthquakes worldwide and the largest earthquake affecting Washington over the past several hundred years. The closest analogy to this earthquake and its effects, including tsunamis, is the 2011 Japan earthquake.

Earthquakes in Washington, and throughout the world, occur predominantly because of plate tectonics – the relative movement of plates of oceanic and continental rocks that make up the rocky surface of the earth. Earthquakes can also occur because of volcanic activity and other geological processes.

The Cascadia Subduction Zone is a geologically complex area off the Pacific Northwest coast that ranges from Northern California to British Columbia. In simple terms, several pieces of oceanic crust (the Juan de Fuca Plate and other smaller pieces) are being subducted (pushed under) the crust of the North American Plate. This subduction process is responsible for most of the earthquakes in the Pacific Northwest and for creating the chain of volcanoes in the Cascade Mountains.

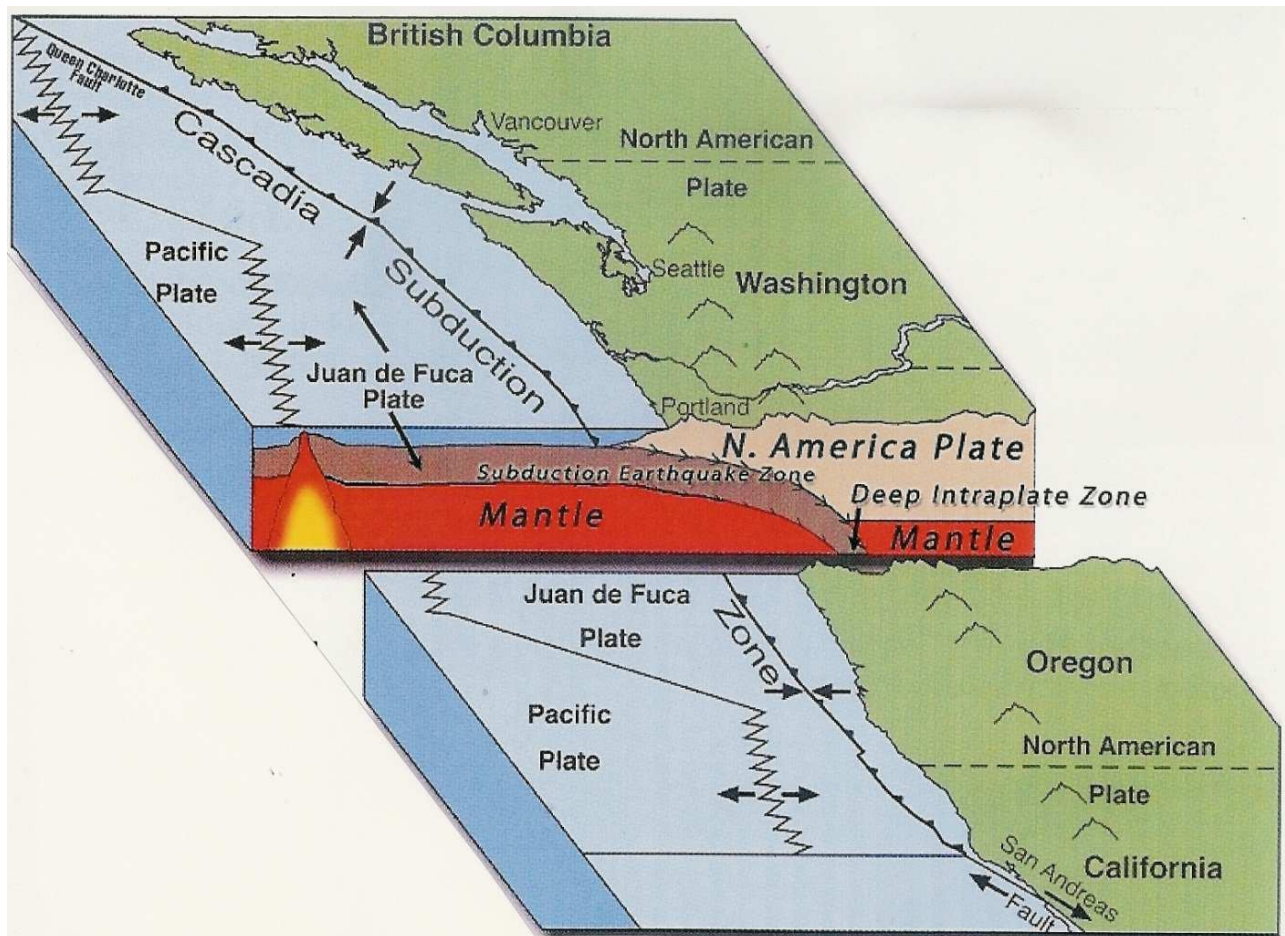
Figure 6.2 on the following page shows the geologic (plate-tectonic) setting of the Cascadia Subduction Zone.

There are three main types of earthquakes that affect Washington State:

- 1) “Interface” earthquakes on the boundary between the subducting Juan de Fuca Plate and the North American Plate,
- 2) “Intraplate” earthquakes within the subducting oceanic plates, and
- 3) “Crustal” earthquakes within the North American Plate.

“Interface” earthquakes on the Cascadia Subduction Zone occur on the boundary between the subducting Juan de Fuca plate and the North American Plate. These earthquakes may have magnitudes up to 9.0 or perhaps 9.2, with average return periods (the time period between earthquakes) of about 250 to 500 years. These are the great Cascadia Subduction Zone earthquake events that have received attention in the popular press. The last major interface earthquake on the Cascadia Subduction Zone occurred on January 26, 1700. These earthquakes occur about 40 miles offshore from the Pacific Ocean coastline. Ground shaking from such earthquakes would be the strongest near the coast and strong ground shaking would be felt throughout much of western Washington, with the level of shaking decreasing further inland from the coast.

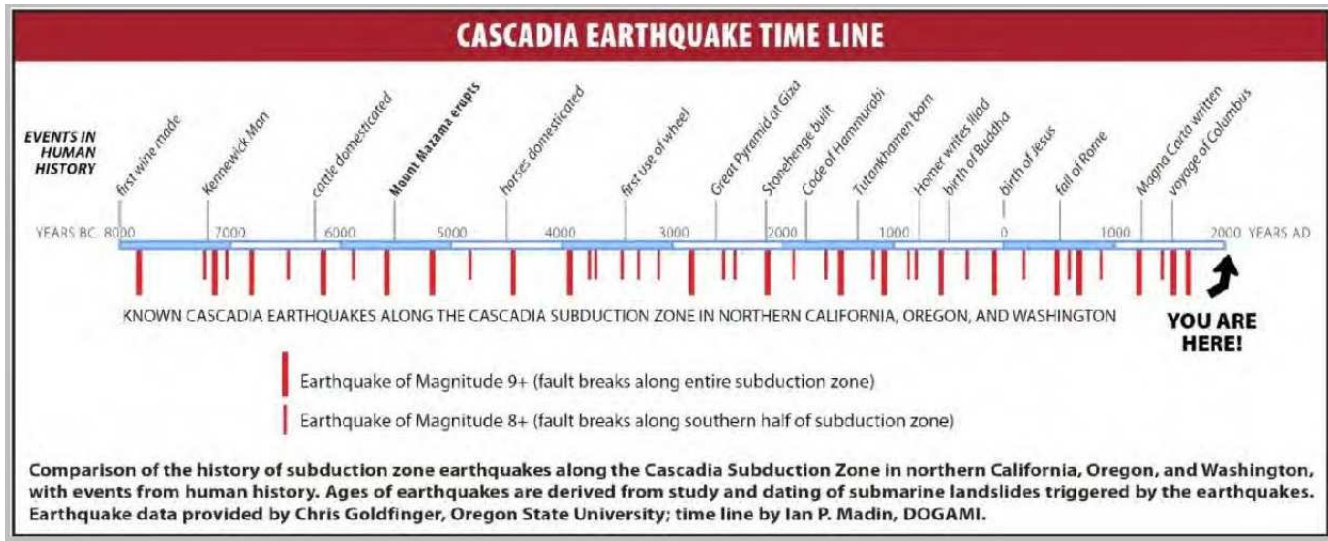
Figure 6.2
Cascadia Subduction Zone⁴



Paleoseismic investigations, which look at geologic sediments and rocks for signs of ancient earthquakes, have identified 41 Cascadia Subduction Zone interface earthquakes over the past 10,000 years, which corresponds to one earthquake about every 250 years. Of these 41 earthquakes, about half are M9.0 or greater earthquakes that represent a full rupture of the fault zone from Northern California to British Columbia. The other half of the interface earthquakes represents M8+ earthquakes that rupture only the southern portion of the subduction zone.

The 300+ years since the last major Cascadia Subduction Zone earthquake is longer than the average timeframe of about 250 years for M8 or greater and is shorter than some of the intervals between M9.0 earthquakes. The time history of these major interface earthquakes is shown in Figure 6.3 on the following page.

Figure 6.3
Time History of Cascadia Subduction Zone Interface Earthquakes⁵



“Intraplate” earthquakes occur within the subducting Juan de Fuca Plate. These earthquakes may have magnitudes up to about 6.5, with probable return periods of about 500 to 1000 years at any given location. These earthquakes can occur anywhere along the Cascadia Subduction Zone. The 1949, 1965, and 2001 earthquakes listed in Table 1 are examples of intraplate earthquakes. These earthquakes occur deep in the earth’s crust, about 20 to 30 miles below the surface. They generate strong ground motions near the epicenter, but have damaging effects over significantly smaller areas than the larger magnitude interface earthquakes discussed above.

“Crustal” earthquakes occur within the North American Plate. Crustal earthquakes are shallow earthquakes, typically within the upper 5 or 10 miles of the earth’s surface, although some ruptures may reach the surface. In Western Washington crustal earthquakes are mostly related to the Cascadia Subduction Zone. Crustal earthquakes are known to occur not only on faults mapped as active or potentially active, but also on unknown faults. Many significant earthquakes in the United States have occurred on previously unknown faults.

Based on the historical seismicity in Washington State and on comparisons to other geologically similar areas, small to moderate crustal earthquakes up to about M5 or M5.5 are possible almost any place in Washington. There is also a possibility of larger crustal earthquakes in the M6+ range on unknown faults, although the probability of such events is likely to be low.

6.3 Earthquake Concepts for Risk Assessments

6.3.1 Earthquake Magnitudes

In evaluating earthquakes, it is important to recognize that the earthquake magnitude scale is not linear, but rather logarithmic (based on intervals corresponding to orders of magnitude). For example, each one step increase in magnitude, such as from M7 to M8, corresponds to an increase in the amount of energy released by the earthquake of a factor of about 30, based on the mathematics of the magnitude scale.

Thus, an M7 earthquake releases about 30 times more energy than an M6, while an M8 releases about 30 times more energy than an M7 and so on. Thus, a great M9 earthquake releases nearly 1,000 times ($30 [M7] \times 30 [M8]$) more energy than a large earthquake of M7 and nearly 30,000 times more energy than an M6 earthquake ($30 [M6] \times 30 [M7] \times 30 [M8]$).

The public often assumes that the larger the magnitude of an earthquake, the “worse” it is. That is, the “big one” is an M9 earthquake, and smaller earthquakes such as M6 or M7 are not the “big one”. However, this is true only in very general terms. Higher magnitude earthquakes do affect larger geographic areas, with much more widespread damage than smaller magnitude earthquakes. However, for a given site, the magnitude of an earthquake is not a good measure of the severity of the earthquake at that site.

For most locations, the best measure of the severity of an earthquake is the intensity of ground shaking. However, for some sites, ground failures and other possible consequences of earthquakes, which are discussed later in this chapter (Section 6.6), may substantially increase the severity.

For any earthquake, the severity and intensity of ground shaking at a given site depends on four main factors:

- Earthquake magnitude,
- Earthquake epicenter, which is the location on the earth’s surface directly above the point of origin of an earthquake,
- Earthquake depth, and
- Soil or rock conditions at the site, which may amplify or deamplify earthquake ground motions.

An earthquake will generally produce the strongest ground motions near the epicenter (the point on the ground above where the earthquake initiated) with the intensity of ground motions diminishing with increasing distance from the epicenter. The intensity of ground shaking at a given location depends on the four factors listed above. Thus, for any given earthquake there will be contours of varying intensity of ground shaking vs. distance from the epicenter. The intensity will generally decrease with distance from the epicenter, and often in an irregular pattern, not simply in

perfectly shaped concentric circles. This irregularity is caused by soil conditions, the complexity of earthquake fault rupture patterns, and possible directionality in the dispersion of earthquake energy.

The amount of earthquake damage and the size of the geographic area affected generally increase with earthquake magnitude. Below are some qualitative examples:

- Earthquakes below about M5 are not likely to cause significant damage, even locally very near the epicenter.
- Earthquakes between about M5 and M6 are likely to cause moderate damage near the epicenter.
- Earthquakes of about M6.5 or greater (e.g., the 2001 Nisqually earthquake) can cause major damage, with damage usually concentrated fairly near the epicenter.
- Larger earthquakes of M7+ cause damage over increasingly wider geographic areas with the potential for very high levels of damage near the epicenter.
- Great earthquakes with M8+ can cause major damage over wide geographic areas.
- A mega-quake M9 earthquake on the Cascadia Subduction Zone could affect the entire Pacific Northwest from British Columbia, through Washington and Oregon, and as far south as Northern California, with the highest levels of damage near the coast.

6.3.2 Intensity of Ground Shaking

There are many measures of the severity or intensity of earthquake ground motions. The Modified Mercalli Intensity scale (MMI) was widely used beginning in the early 1900s. MMI is a descriptive, qualitative scale that relates severity of ground motions to the types of damage experienced. MMIs range from I to XII. More accurate, quantitative measures of the intensity of ground shaking have largely replaced the MMI. These modern intensity scales are used in the Hockinson School District Hazard Mitigation Plan.

Modern intensity scales use terms that can be physically measured with seismometers (instruments that measure motions of the ground), such as acceleration, velocity, or displacement (movement). The intensity of earthquake ground motions may also be measured in spectral (frequency) terms, as a function of the frequency of earthquake waves propagating through the earth. In the same sense that sound waves contain a mix of low-, moderate-, and high-frequency sound waves, earthquake waves contain ground motions of various frequencies. The behavior of buildings and other structures depends substantially on the vibration frequencies of the building or structure vs. the spectral content of earthquake waves. Earthquake ground motions also include both horizontal and vertical components.

A common physical measure of the intensity of earthquake ground shaking, and the

one used in this mitigation plan, is Peak Ground Acceleration (PGA). PGA is a measure of the intensity of shaking, relative to the acceleration of gravity (g). For example, an acceleration of 1.0 g PGA is an extremely strong ground motion that may occur near the epicenter of large earthquakes. With a vertical acceleration of 1.0 g, objects are thrown into the air. With a horizontal acceleration of 1.0 g, objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10% g PGA means that the ground acceleration is 10% that of gravity, and so on.

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. The following generalized observations provide qualitative statements about the likely extent of damages from earthquakes with various levels of ground shaking (PGA) at a given site:

- Ground motions of only 1% g or 2% g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
- Ground motions below about 10% g usually cause only slight damage.
- Ground motions between about 10% g and 30% g may cause minor to moderate damage in well-designed buildings, with higher levels of damage in more vulnerable buildings. At this level of ground shaking, some poorly designed buildings may be subject to collapse.
- Ground motions above about 30% g may cause significant damage in well-designed buildings and very high levels of damage (including collapse) in poorly designed buildings.
- Ground motions above about 50% g may cause significant damage in many buildings, including some buildings that have been designed to resist seismic forces.

6.4 Earthquake Hazard Maps

The current scientific understanding of earthquakes is incapable of predicting exactly where and when the next earthquake will occur. However, the long term probability of earthquakes is well enough understood to make useful estimates of the probability of various levels of earthquake ground motions at a given location.

The current consensus estimates for earthquake hazards in the United States are incorporated into the 2014 USGS National Seismic Hazard Maps. These maps are the basis of building code design requirements for new construction, per the International Building Code adopted in Washington State. The earthquake ground motions used for building design are set at 2/3rds of the 2% in 50 year ground motion.

The following maps show contours of Peak Ground Acceleration (PGA) with 10% and 2% chances of exceedance over the next 50 years to illustrate the levels of seismic hazard. The ground shaking values on the maps are expressed as a percentage of g, the acceleration of gravity. For example, the 10% in 50 year PGA value means that

over the next 50 years there is a 10% probability of this level of ground shaking or higher.

In very qualitative terms, the 10% in 50 year ground motion represents a likely earthquake while the 2% in 50 year ground motion represents a level of ground shaking close to, but not the absolute, worst case scenario.

Figure 6.4 on the following page, the statewide 2% in 50 year ground motion map, is the best statewide representation of the variation in the level of seismic hazard in Washington State by location:

- The dark red, pink, and orange areas have the highest levels of seismic hazard.
- The tan, yellow, and blue areas have intermediate levels of seismic hazard.
- The bright green and pale green areas have the lowest levels of seismic hazard.

The detailed geographical patterns in the maps reflect the varying contributions to seismic hazard from earthquakes on the Cascadia Subduction Zone and crustal earthquakes within the North American Plate. The differences in geographic pattern between the 2% in 50 year maps and the 10% in 50 year maps reflect different contributions from Cascadia Subduction Zone earthquakes and crustal earthquakes.

These maps are generated by including earthquakes from all known faults, taking into account the expected magnitudes and frequencies of earthquakes for each fault. The maps also include contributions from unknown faults, which are statistically possible anywhere in Washington. The contributions from unknown faults are included via “area” seismicity which is distributed throughout the state.

An important caveat for interpreting these maps is that the 2014 USGS seismic hazard maps show the level of ground motions for rock sites. Ground motions on soil sites, especially soft soil sites, will be significantly higher than for rock sites. Thus, for earthquake hazard analysis at a given site, it is essential to include consideration of the site’s soil conditions.

The ground motions shown in the following figures represent ground motions with the specified probabilities of occurrence. At any given site, earthquakes may be experienced with ground motions over the entire range of levels of ground shaking from just detectible with sensitive seismometers, to higher than the 2% in 50 year ground motion.

Figure 6.4
2014 USGS Seismic Hazard Map: Washington State⁶
PGA value (%g) with a 2% Chance of Exceedance in 50 years

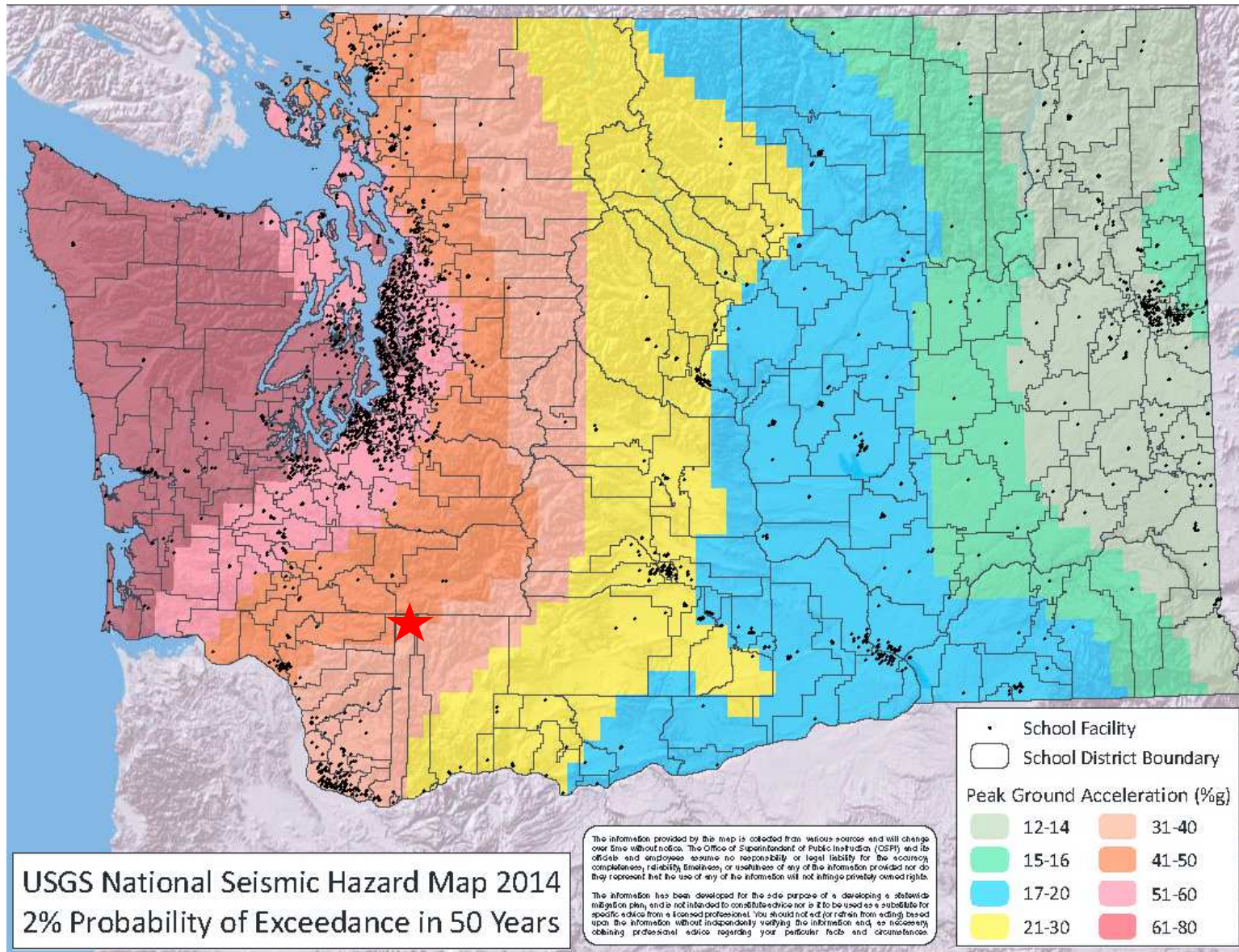
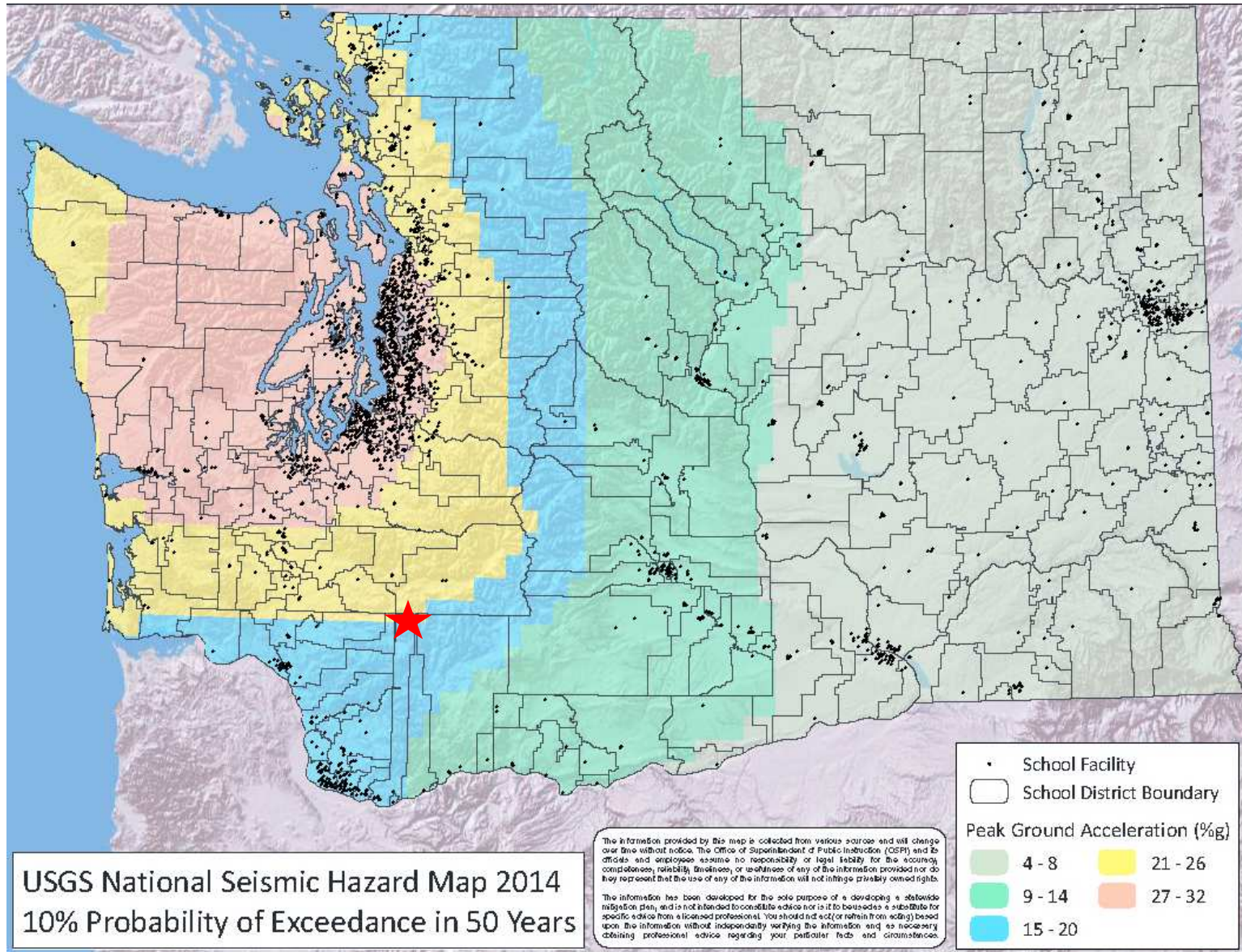


Figure 6.5
2014 USGS Seismic Hazard Map: Washington State⁶
PGA value (%g) with a 10% Chance of Exceedance in 50 years



USGS National Seismic Hazard Map 2014
10% Probability of Exceedance in 50 Years

6.5 Site Class: Soil and Rock Types

As discussed previously, the soil or rock type at a given location substantially affects the level of earthquake hazard because the soil or rock type may amplify or de-amplify ground motions. In general, soil sites, especially soft soil sites amplify ground motions. That is, for a given earthquake, a soil site immediately adjacent to a rock site, will experience higher levels of earthquake ground motions than the rock site.

In simple terms, there are six soil or rock site classes:

- A – Hard Rock
- B – Rock
- C – Very Dense Soil and Soft Rock
- D – Firm Soil
- E – Soft Soil
- F – Very Soft Soil

Site classes for each campus in the Hockinson School District are included in the campus-level report in Section 6.7. These estimates are from DNR or from site-specific determinations if such are entered into the OSPI ICOS PDM database.

6.6 Ground Failures and Other Aspects of Seismic Hazards

Much of the damage in earthquakes occurs from ground shaking that affects buildings and infrastructure. However, there are several other consequences of earthquakes that can result in substantially increased levels of damage in some locations. These consequences include: surface rupture; subsidence or elevation; liquefaction; settlement; lateral spreading; landslides; dam, reservoir, or levee failures; tsunamis and seiches. Any of these consequences can result in very severe damage to buildings, up to, and including, complete destruction and also a high likelihood of casualties.

6.6.1 Surface Rupture

Surface rupture occurs when the fault plane along which rupture occurs in an earthquake reaches the surface. Surface rupture may be horizontal and/or vertical displacement between the sides of the rupture plane. For a building subject to surface rupture the level of damage is typically very high and often results in the destruction of the building.

Surface rupture does not occur with interface or intraplate earthquakes on the Cascadia Subduction Zone and does not occur with all crustal earthquakes. Faults in Washington State where surface rupture is likely, include the Seattle Fault System and the Tacoma Fault System.

6.6.2 Subsidence

Large interface earthquakes on the Cascadia Subduction Zone are expected to result in subsidence of up to several feet or more along Washington's Pacific Coast. For facilities located very near sea level, co-seismic subsidence may result in the facilities being below sea level or low enough so that flooding becomes very frequent. Subsidence may also impede egress by blocking some routes and thus increase the likelihood of casualties from tsunamis.

6.6.3 Liquefaction, Settlement, and Lateral Spreading

Liquefaction is a process where loose, wet sediments lose bearing strength during an earthquake and behave similar to a liquid. Once a soil liquefies, it tends to settle vertically and/or spread laterally. With even very slight slopes, liquefied soils tend to move sideways downhill (lateral spreading). Settling or lateral spreading can cause major damage to buildings and to buried infrastructure such as pipes and cables.

Estimates of liquefaction potential for each campus in the Hockinson School District are included in the campus-level report in Section 6.7. These estimates are from DNR or from site-specific determinations, if such determinations were entered into the OSPI ICOS PDM database by the District.

6.6.4 Dam, Levee and Reservoir Failures

Earthquakes can also cause failure of dams, levees, and reservoirs. Campuses downslope from dams or water reservoirs or behind levees may be subject to flooding if the dams, reservoirs, or levees fail as a result of an earthquake. Further information about the District's flood risk is included in the flood chapter in this mitigation plan.

6.7 Seismic Risk Assessment for the Hockinson School District's Facilities

The potential impacts of future earthquakes on the Hockinson District include damage to buildings and contents, disruption of educational services, displacement costs for temporary quarters if some buildings have enough damage to require moving out while repairs are made, and possible deaths and injuries for people in the buildings. The magnitude of potential impacts in future earthquakes can vary enormously from none in earthquakes that are felt but result in neither damages nor casualties, to very substantial for larger magnitude earthquakes with epicenters near a given campus.

The vulnerability of the Hockinson District's facilities varies markedly from building to building, depending on each building's structural system and date of construction (which governs the seismic design provisions). The level of risk on a building by building level is summarized in the building-level earthquake risk tables later in this chapter.

The initial seismic risk assessment for the District's facilities at both the campus level and the building-level is largely automated from the data in the OSPI ICOS PDM database. The data used include GIS data for the location of each campus and district-specific data entered into the OSPI ICOS PDM database.

The three step hazard and risk assessment approach, outlined below, uses data in the OSPI ICOS PDM database for screening and prioritization of more detailed evaluations which usually require inputs from an engineer experienced with seismic assessments of buildings. The auto-generated reports help to minimize the level of effort required by districts and to reduce costs by prioritizing more detailed seismic evaluations, enabling the District to focus on the buildings most likely to have the most substantial seismic deficiencies. The three steps include:

1. An auto-generated campus-level earthquake report that summarizes earthquake hazard data including ground shaking, site class, and liquefaction potential and classifies the combined earthquake hazard level from these data. The campus-level report also includes priorities for building-level risk assessments and geotechnical evaluations of site conditions.
2. An auto-generated building-level earthquake report that is based on the ASCE 41-13 seismic evaluation methodology. The building-level report contains the data necessary to determine whether a building is pre- or post-benchmark year for life safety. If a building is post-benchmark, it is generally deemed to provide adequate life safety and no further evaluation is necessary. If not, completing an ASCE 41-13 Tier 1 evaluation is recommended. The auto-generated report includes suggested priorities for Tier 1 evaluations.
3. The third step includes completion and interpretation of the ASCE 41-13 Tier 1 evaluations and:
 - a. More detailed evaluation of one or more buildings that are determined to have the highest priority for retrofit or replacement from the previous step.
 - b. Design of seismic retrofits for buildings for which a retrofit is the preferred alternative.
 - c. Implementation of retrofits or replacement of buildings, as funding becomes available.

The OSPI ICOS PDM database campus-level and building-level reports are shown on the following pages.

**Table 6.2
Campus-Level Earthquake Report**

| Campus | Earthquake Ground Shaking 2% in 50 Years ² (% g) | Site Class ^o | Earthquake Ground Shaking Hazard Level | Liquefaction Potential | Combined Earthquake Hazard Level | Recommendations | | | |
|--|---|-------------------------|--|------------------------|----------------------------------|--------------------------------|----------|-------------------------|----------|
| | | | | | | Building Level Risk Assessment | | Geotechnical Evaluation | |
| | | | | | | Yes/No ³ | Priority | Yes/No | Priority |
| HOCKINSON SCHOOL DISTRICT – Earthquake Campus – Level Hazard and Risk Report: Preliminary (1) | | | | | | | | | |
| District Maintenance Shop | 37.23% | B-C | Moderate to High | None | Moderate to High | No | N/A | No | N/A |
| Hockinson Heights Elementary School | 36.94% | B-C | Moderate to High | None | Moderate to High | Yes | Moderate | No | N/A |
| Hockinson High School | 39.75% | C-D | High | Low to Moderate | High | No | N/A | Yes | Moderate |
| Hockinson Middle School | 37.23% | B-C | Moderate to High | None | Moderate to High | No | N/A | No | N/A |
| School District Administration | 37.25% | B-C | Moderate to High | None | Moderate to High | No | N/A | No | N/A |

¹ Campus level risk is generally proportional to the combined earthquake hazard, but depends very strongly on the seismic vulnerability of buildings which must be evaluated at the building level. Thus, earthquake risk cannot be defined meaningfully at the campus level, except by doing building-level evaluations and then aggregating building results to provide campus-level risk.

² Earthquake ground motion measured as peak ground acceleration (PGA) relative to the "g", the acceleration of gravity.

³ "Limited" applies only to campuses with low ground shaking hazard level (2% in 50 year PGA less than 20% g) and means building-level risk assessments are recommended only for the most vulnerable building types.

^o The six site classes are identified as follows: A-Hard Rock, B-Rock, C-Very Dense Soil and Soft Rock, D-Firm Soil, E-Soft Soil and F-Very Soft Soil. Estimates by DNR also include intermediate classes such as D-E, where the data is not sufficient to distinguish between D and E, as well as G-Unknown, when data is missing

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The information has been developed and presented for the sole purpose of developing school district mitigation plans and to assist in determining where to focus resources for additional evaluations of natural hazard risks. The reports are not intended to constitute in-depth analysis or advice, nor are they to be used as a substitute for specific advice obtained from a licensed professional regarding the particular facts and circumstances of the natural hazard risks to a particular campus or building.

At the campus-level evaluation most schools have a ground shaking hazard of moderate to high, with exception of Hockinson High School which has a high ground shaking hazard level. The result of this difference is that the High School site has softer site soils (Site Class C-D) and a low to moderate liquefaction potential. All other campuses have firmer site soils (Site Class B-C) and no liquefaction potential identified.

**Table 6.3
Building-Level Earthquake Report**

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|---|--------------------------------|-------------------|------------------|--------------------------------|----------------------|----------------------------------|---|--|---|--------------------------------------|-----------------------------|------------------------------------|------------------------|-------------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended¹ | | ASCE 41-13 Tier 1 Evaluation² | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| Hockinson Heights Elementary School Facility | | | | | | | | | | | | | | |
| Building 100 A - 10 | 1992 | | | N | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| - 10 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 4 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 5-6 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 7 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 8 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 8 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - 9 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - Area 1 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| - Areas 2-3 | 1992 | | | N | RM1L | Moderate | Y | Low - N/A | N/A | | | | | |
| - New | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| Building 200 C - Area 15 | 1975 | | | N | W1 | Low | Y | Low - Moderate | N | | | | | |
| - Area 16 | 1975 | | | N | W1 | Low | Y | Low - Moderate | N | | | | | |
| - Areas 13, 14-17 | 1975 | | | N | W1 | Low | Y | Low - Moderate | N | | | | | |
| - Areas 15 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| | | | | | | | | | | | | | | |

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|--|-------------------------|------------|-----------|-------------------------|---------------|---------------------------|---|--|---|-------------------------------|----------------------|-----------------------------|-----------------|------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended ¹ | | ASCE 41-13 Tier 1 Evaluation ^a | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority ^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| Building 300 D - Areas 18 & 19 | 1975 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - Areas 20 & 21 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| Building 400 B - Areas 11-12 | 1992 | | | N | W1 | Moderate | Y | Low - N/A | N/A | | | | | |
| Building 500 E - 1 | 1980 | | | N | W2 | Low | Y | Low to Moderate | N | | | | | |
| - 2 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 3 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 4,5 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| Building 600 F - 6,7,11,12 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 8,10 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 9 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| Building 700 G - 13,14,18,19 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 15,17 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 16 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|--|-------------------------|------------|-----------|-------------------------|---------------|---------------------------|---|--|---|-------------------------------|----------------------|-----------------------------|-----------------|------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended ¹ | | ASCE 41-13 Tier 1 Evaluation ^a | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority ^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| Building 800 H - 20,21,26,27 | 1975 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 22,25 | 1975 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 23 | 1975 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| - 28 | 1975 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |
| Play Shed - CP | 1974 | | | N | W1 | Pre | Y | Low to Moderate | N | | | | | |
| Portable 901/902 - Area 1 | 2000 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable 903/904 - Area 1 | 2001 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable 905/906 - Area 1 | 2000 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable 907/908 - Area 1 | 2000 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable 909/910 - Area 1 | 1980 | | | N | W1 | Moderate | Y | Low | N | | | | | |
| Portable 911/912 - Area 1 | 2003 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable 913/914 - Area 1 | 2003 | | | Y | W1 | Moderate | N | Low - N/A | N/A | | | | | |
| Portable One - P-1 | 1980 | | | N | W1 | Low | Y | Low to Moderate | N | | | | | |

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|---|-------------------------|------------|-----------|-------------------------|---------------|---------------------------|---|--|---|-------------------------------|----------------------|-----------------------------|-----------------|------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended ¹ | | ASCE 41-13 Tier 1 Evaluation ^a | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority ^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| Hockinson High School Facility | | | | | | | | | | | | | | |
| Athletic Storage Building - Area 1 | 2003 | | | Y | RM1L | High | N | Low – N/A | N/A | | | | | |
| - Concession 1st Flr | 2005 | | | Y | | | N | Low | N/A | | | | | |
| - Press Booth 3rd Flr | 2005 | | | Y | | | N | Low | N/A | | | | | |
| Main Building - 2nd Flr U1,12,13 | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| - 2nd Flr U1,7-11,14 | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| - 2nd Flr U2-6 | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| - Main Flr M1,2,3,4,5, | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| - Main Flr M7,8,10-14, | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| - Main Flr M9,15,16&20 | 2003 | | | Y | RM1L | High | N | Low | N/A | | | | | |
| Northwest Baseball Field Storage and Dugout - Dugout area 1 | 2005 | | | Y | | | N | Low | N/A | | | | | |
| - Storage area 2 | 2005 | | | Y | | | N | Low | N/A | | | | | |
| South Baseball Field Storage and Dugout - Dugout area 1 | 2005 | | | Y | | | N | Low | N/A | | | | | |

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|--|-------------------------|------------|-----------|-------------------------|---------------|---------------------------|---|--|---|-------------------------------|----------------------|-----------------------------|-----------------|------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended ¹ | | ASCE 41-13 Tier 1 Evaluation ^a | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority ^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| Hockinson Middle School Facility | | | | | | | | | | | | | | |
| Building A - 1st flr A-1a,2 | 1953 | | | N | W1 | Pre | N | Low to Moderate | N | | | | | |
| - 1st flr A-1b | 2001 | | | Y | W1 | High | N | Low to Moderate | N | | | | | |
| - 1st flr A-3,4 | 1953 | | | N | W1 | Pre | N | Low to Moderate | N | | | | | |
| - 1st flr A-5 | 1963 | | | N | W1 | Low | N | Low –N/A | N/A | | | | | |
| Building B - A-6-10 | 1989 | | | N | W1 | Low | N | Low –N/A | N/A | | | | | |
| Building C - 1st flr A 11 | 2001 | | | Y | W1 | High | N | Low –N/A | N/A | | | | | |
| - 1st flr A 12-15 | 1989 | | | N | W2 | Low | N | Low –N/A | N/A | | | | | |
| Building D - A 16,17 | 2001 | | | Y | W1 | High | N | Low –N/A | N/A | | | | | |
| Covered Playshed - A 18 | 2001 | | | Y | W1 | High | N | Low –N/A | N/A | | | | | |
| Portable 113/114 - Area 1 | 2003 | | | Y | W1 | Moderate | N | Low –N/A | N/A | | | | | |
| Portable 116/117 - Area 1 | 2001 | | | Y | W1 | Moderate | N | Low –N/A | N/A | | | | | |
| Portable 222/223 - Area 1 | 1991 | | | N | W1 | Moderate | N | Low –N/A | N/A | | | | | |
| Portable 224/225 - Area 1 | 2001 | | | Y | W1 | Moderate | N | Low –N/A | N/A | | | | | |

Note: Building A – A- 4 and A-5 are being demolished in 2016

| Hockinson Building-Level Earthquake Report | | | | | | | | | | | | | | |
|---|--------------------------------|-------------------|------------------|--------------------------------|----------------------|----------------------------------|---|--|---|--------------------------------------|-----------------------------|------------------------------------|------------------------|-------------------------------------|
| Building-Area | Seismic Design Criteria | | | | Building Type | Seismic Design Basis Code | ASCE 41-13 Tier 1 Evaluation Recommended¹ | | ASCE 41-13 Tier 1 Evaluation^a | | | Mitigation Desired (yes/no) | Mitigation Type | Mitigation Complete (yes/no) |
| | Year Built | UBC or IBC | Code Year | Post-Benchmark (yes/no) | | | Yes/No | Risk Level and Priority^{2,3} | Complete (yes/no) | ASCE 41-13 Compliant (yes/no) | Further Eval Desired | | | |
| District Maintenance Shop Facility | | | | | | | | | | | | | | |
| District Maintenance - Administration 2 | 2001 | | | Y | S3 | High | N | Low | N/A | | | | | |
| - Covered storage 3 | 2001 | | | Y | S3 | High | N | Low | N/A | | | | | |
| - Mezzanine 4 | 2001 | | | Y | S3 | High | N | Low | N/A | | | | | |
| - Service & storage 1 | 2001 | | | Y | S3 | High | N | Low | N/A | | | | | |
| School District Administration Facility | | | | | | | | | | | | | | |
| School District Administration - Area 1 | 2001 | | | Y | W1 | High | N | Low | N/A | | | | | |
| - Area 2 | 2001 | | | Y | W1 | High | N | Low | N/A | | | | | |

¹ ASCE 41-13 seismic evaluations are recommended for buildings that were not designed to a "benchmark" seismic code deemed adequate to provide life safety. However, ASCE 41-13 recommends that post-benchmark code buildings be evaluated by an engineer to verify that the as-built seismic details conform to the design drawings. Most such buildings should be compliant, unless poor construction quality degrades the expected seismic performance of the building.

² The priority for 41-13 evaluations is based on the building type, the combined earthquake hazard level (ground shaking and liquefaction potential), the seismic design basis, and whether a building has been identified as having substantial vertical or horizontal irregularities. These priorities recognize that many districts have limited funding for 41-13 evaluations. Districts with adequate funding may wish to complete 41-13 evaluations on all pre-benchmark year buildings.

³ The earthquake risk level is low for all buildings for which an ASCE 41-13 evaluation is not recommended as necessary. For other buildings, the preliminary risk level and the priority for 41-13 evaluation are based on the earthquake hazard level, the building structural type, the seismic design level and whether a building has vertical and horizontal irregularities.

⁴ The final determination of priorities for retrofit are based on whether a building is compliant with the 41-13 life safety criteria. If not, the priorities should be set in close consultation with the engineer who completed the 41-13 evaluation.

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The level of risk for each building depends on the level of earthquake hazard and on each building's seismic design characteristics. Most of the district's buildings have low or low to moderate levels of seismic risk. Buildings that may have significant seismic vulnerabilities and thus warrant further evaluations include:

- Hockinson Heights Elementary School – 1975 and 1980 parts of the school,
- Hockinson Middle School – 1953 parts of the school, and
- All district portables – evaluations of the foundation systems

6.8 Previous Earthquake Events

The district has not experienced any damage in previous earthquakes.

6.9 Earthquake Hazard Mitigation Measures for K–12 Facilities

6.9.1 Typical Seismic Mitigation Measures

There are several possible earthquake mitigation Action Items for the District's facilities, including:

- Replacement of seismically vulnerable buildings with new buildings that meet or exceed the seismic provisions in the current building code,
- Structural retrofits for buildings,
- Nonstructural retrofits for buildings and contents,
- Installation of emergency generators for buildings with critical functions, including designated emergency shelters, and
- Enhanced emergency planning, including earthquake exercises and drills.

Of these potential earthquake Action Items, FEMA mitigation grants, which typically provide 75% of total project costs, may be available for structural or nonstructural retrofits and for emergency generators.

Earthquake Action Items for the Hockinson School District are given in Table 6.4 on the following page.

**Table 6.4
Hockinson School District: Earthquake Action Items**

| Hazard | Action Item | Timeline | Source of Funds | Responsible Party | Plan Goals Addressed | | | |
|---|---|-----------|--------------------|------------------------|----------------------|--------------------|----------------------------|---------------------------------|
| | | | | | Life Safety | Protect Facilities | Enhance Emergency Planning | Enhance Awareness and Education |
| Earthquake Mitigation Action Items | | | | | | | | |
| Short-Term #1 | Evaluate nonstructural seismic vulnerabilities in the District's buildings from building elements and contents that pose significant life safety risk (falling hazards) and mitigate by bracing, anchoring or replacing identified high risk items. | 1-2 Years | District or Grants | Maintenance Supervisor | X | X | | X |
| Short-Term #2 | Have a structural engineer make a preliminary assessment of the 1975 and 1980 parts of the Elementary School and the foundations of the district's portables to determine whether further seismic evaluations are recommended. | 1-2 Years | District or Grants | Maintenance Supervisor | X | X | | X |
| Short-Term #3 | If necessary, based on the results of the preliminary assessment, complete ASCE 41-13 Tier 1 evaluations for some or all parts of the Elementary and Middle Schools. | 1-2 Years | District or Grants | Maintenance Supervisor | X | X | | X |
| Long-Term #1 | Prioritize and implement structural seismic retrofits or replacements based on the results of the seismic evaluations completed under the Short-Term Action Items #2 and #3 listed above, as funding becomes available. | Ongoing | District or Grants | Maintenance Supervisor | X | X | | X |
| Long-Term #2 | Maintain and update building data for seismic risk assessments in the OSPI ICOS PDM database. | Ongoing | District or Grants | Maintenance Supervisor | X | | X | X |
| Long-Term #3 | Enhance emergency planning for earthquakes including duck and cover and evacuation drills. | Ongoing | District or Grants | Principals | X | | X | X |

6.10 References

1. United States Geological Survey (2013). Largest Earthquakes in the World Since 1900.

http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php

2. University of Washington (2002). Map and List of Significant Quakes in WA and OR, The Pacific Northwest Seismograph Network. University of Washington Department of Earth Sciences.

3. Washington State Department of Natural Resources (2013).

<https://fortress.wa.gov/geology?Theme-wigm>

4. Cascadia Region Earthquake Working Group (2005): Cascadia Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario.

5. Oregon Seismic Safety Policy Advisory Commission (2013). The Oregon Resilience Plan.

6. Washington State Department of Natural Resources (2004). Liquefaction Susceptibility and Site Class Maps of Grays Harbor County, Washington. Open File Report 2004-20.