School Seismic Safety Project

2019–2021 Legislative Report

Engineering and geologic site assessments at 339 Washington public school buildings

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WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES

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Executive Summary

The purpose of this study is to assess the seismic safety of permanent, public, K–12 school buildings in Washington State. This assessment is based on local geology and the engineering and construction of the buildings. This report summarizes the seismic risk at 561 school buildings (274 schools at 245 campuses) across the state and is the culmination of two biennia of work; Phase 1, which was funded by the 2017–2019 capital budget, and Phase 2, which was funded by the 2019–2021 capital budget. This report presents the results of Phase 2 (2019–2021 biennium appropriation), with some high level conclusions from Phases 1 and 2 combined.

Summary of Methods

The project involves both geological and engineering assessments at each school. Geologists collect seismic data to measure how local soils amplify earthquake shaking at school campuses, usually on playing fields. This seismic data greatly improves estimates of potential ground shaking by more accurately evaluating site-specific soil conditions under the school buildings. In addition to this, a group of licensed professional structural engineers collect building data at the schools. The structural and nonstructural adequacy of the school buildings are evaluated and safety ratings and damage estimates for these buildings are developed. Combined, these assessments provide a detailed view of how earthquake shaking might affect each school. A selection of high-risk buildings were studied in more detail to determine what a seismic retrofit design would look like and estimate how much it would cost to complete that upgrade. These are called 'concept-level seismic upgrade designs'.

Major Findings and Conclusions

- Washington State has many older school buildings built prior to the adoption of modern seismic safety codes. Older and more vulnerable construction types are more susceptible to earthquake damage and have a greater percentage of seismically noncompliant structural and non-structural components.
- Unreinforced masonry buildings constructed before the 1940s and non-ductile concrete buildings (without seismic upgrades) constructed before the mid-1970s located in high seismic hazard areas are especially vulnerable to collapse during earthquakes. The risks of these buildings should be mitigated as soon as practical.
- Older school buildings built prior to 1975 and constructed out of reinforced masonry and wood frame materials are vulnerable to collapse.
- Geologic site class measurements showed that 59 campuses of the 245 studied have a measured site-specific site class that differs from the predicted site class based on reconnaissance-scale mapping. The more accurate site-specific measurements help to inform detailed engineering plans and affect building costs.

- In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve more than 10,000 students. Tsunami loads and impacts were not considered in the geologic or engineering assessments. For schools to be safe from a tsunami, they would need to be moved from the tsunami inundation zone or designed to withstand tsunami loads with options for vertical evacuation.
- Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings (This is out of a five-star system. One being the lowest, and most vulnerable, and five being the highest, or safest) based on the information available. Four percent of the school buildings assessed have two-star ratings and 3 percent of the school buildings have three-star ratings.
- The concept-level seismic upgrade design results indicate that for many buildings, the cost to seismically upgrade the structure will cost less than the costs to repair major damage following an earthquake, or significantly less than the cost to replace an irreparably damaged building. For less vulnerable structures, especially structures in low seismicity areas, however, it may not be financially worth implementing seismic upgrades.
- Seismically upgrading a vulnerable structure will generally make the building stronger, stiffer, safer, and more resilient, therefore decreasing the damage costs the building will incur in an earthquake.
- A range of cost estimates were developed for each of the select buildings that received a concept-level designs and estimated costs to retrofit. Phase 1 concept-level design building cost estimates ranged from a median of $63K to $5.01M, where the median represents the range of cost estimates for a single building. Phase 2 median concept level design building cost estimates ranged from $1.24M to $15.26M. Cost estimate methods for Phase 2 were improved from Phase 1 and now include projected soft costs. Phase 1 concept design schools were selected to represent a variety of building construction types and vintages in different seismic hazard areas. Alternatively, Phase 2 concept design schools were selected based on available information to be some of the highest risk buildings based on seismic hazard and engineering design.
- A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations.
- Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Of the 561 buildings studied, 63 percent were high or very high priority, 18 percent were moderate priority, and 19 percent were lower priority.
- The EPAT data show that the median building is expected to be 55 percent damaged in a design-level earthquake (Table 10). EPAT also estimates that the majority of buildings in this study are expected to receive a "Red—Unsafe" post-earthquake building safety placard following a design-level earthquake, meaning that they will be unsafe to occupy. In addition, the EPAT data show that approximately one-half of buildings studied will not be repairable following a design-level

earthquake, and will require demolition. The EPAT results are summarized in Table 10 and results for Phase 1 and 2 building damage estimates are shown in Figure 16 below.

The School Seismic Safety Project (Phases 1 and 2) has been an important opportunity to study and evaluate school buildings across the state and has demonstrated the need for dedicated funding for seismic retrofits. Following the Phase 1 report and project, the Legislature funded the Office of the Superintendent of Public Instruction (OSPI) $13 million in 2019 and $40 million in the 2021–2023 biennium for the School Seismic Safety Retrofit Program (SSSRP). This program is the first of its kind in Washington and is a critical step in repairing the most vulnerable schools. The study team applauds and further encourages the state for continued funding of school seismic safety retrofits.

Recommendations

The cost of inaction on seismic safety is too great for children, parents, teachers, and our communities if we slow down. Washington's legislators, agencies, school districts, and design professionals are actively turning seismic knowledge into action. And although we have learned a great deal about the seismic vulnerabilities to school buildings and now have a SSSRP, there is still a great deal more to be done. The following are recommendations to continue to improve the seismic safety and resiliency of our schools and communities:

- A study to evaluate the feasibility and cost benefit of increasing the seismic performance for the design of new school buildings to enhance the seismic resilience of communities.
- A study to identify which schools in tsunami inundation zones need vertical evacuation structures.
- A study of school sites suspected of having moderate to high risk of liquefiable soils, to determine cost-efficient methods of assessing the risk, and identify mitigation strategies for existing school buildings on liquefiable soils.
- Conduct a statewide inventory of school districts to collect data about which facilities have already had seismic upgrades.
- Continue to update OSPI's database with structural and seismic information about each school building (construction type, year of construction, previous seismic upgrades, site class, seismicity, seismic irregularities).
- Continue doing American Society of Civil Engineers (ASCE) Tier 1 seismic evaluations of school buildings.
- OSPI should develop a panel of experts to advise the SSSRP on spending and how to estimate actual construction costs based on inflation, soft costs, and other factors.
- Develop a policy and provide funding to conduct seismic upgrades when school facilities are undergoing major modernizations. A substantial cost of seismic upgrades is the removal and replacement of architectural, mechanical, electrical and plumbing systems. This study shows that if seismic upgrades are combined with modernizations, the costs of seismic upgrades can be reduced, on average, by 70 percent.

Introduction

This statewide study constitutes a major step taken by Washington State to improve the understanding of seismic risks to public school buildings. These schools are important to local communities, as they house hundreds or even thousands of students and staff on a typical day. Many of these buildings are also historic structures, and they are often culturally or societally important. Additionally, parents are legally required to have their children attend school, making it mandatory for children to spend time in these buildings. In urban and rural communities alike, public schools not only educate the next generation of Washington residents but also serve as gathering spaces for communities to come together over interscholastic athletics, meetings, and other events. Schools often serve as the gathering space or shelter after a natural disaster and are a community staple. Without seismically upgrading buildings, earthquakes will be not only devastating and economically damaging, and will have a significant social impact as well.

This study aims to assess the seismic safety of permanent, public, K–12 school buildings in Washington State. This assessment is based on local geology and the engineering and construction of the buildings. This report summarizes the seismic risk at 561 school buildings (274 schools at 245 campuses) across the state and is the culmination of two biennia of work; Phase 1, which was funded by the 2017–2019 capital budget, and Phase 2, which was funded by the 2019–2021 capital budget. The Department of Natural Resources (DNR) Washington Geological Survey (WGS) was the project lead, with significant contributions from structural engineering contractors led by Reid Middleton, Inc., and the Office of Superintendent of Public Instruction (OSPI).

DNR geologists assessed site-specific geology to determine the National Earthquake Hazard Reduction Program (NEHRP) site class category at each school campus. Geologists also determined if the school campuses are in mapped tsunami inundation zones, and if there are any other mapped geologic hazards on or proximal to the school campuses. Structural engineers performed the following assessments: (1) American Society of Civil Engineers (ASCE) 41-17 Tier 1 seismic screening evaluations, (2) Federal Emergency Management Agency (FEMA) P-154 Rapid Visual Screenings (RVS), (3) earthquake performance rating system (EPRS) developed by the Structural Engineers Association of Northern California (SEAONC), and (4) Earthquake Performance Assessment Tool (EPAT) assessments. These assessments were completed for 561 individual school buildings (339 buildings were assessed in Phase 2 and 222 were assessed in Phase 1) and seven fire stations located within one mile of a school (five in Phase 1 and two in Phase 2). Following the completion of the seismic screening evaluations, a total of 32 school buildings (15 in Phase 1, and 17 in Phase 2) received more detailed concept-level seismic upgrade designs and seismic upgrade cost estimates. All of these assessments provide valuable information on the condition of the school building and can inform school districts about the seismic risk and expected performance of these buildings in an earthquake.

There are also negative economic impacts associated with loss of life, injuries, and the prolonged closure of damaged schools. Prolonged closures can lead to increased costs for school districts, and can require parents to find childcare or alternative educational activities for their children, as we have learned with school closure due to the COVID-19 pandemic. Economic setbacks due to earthquakes (or other natural disasters) can also cause long-term disinvestments that can permanently change the character of a community. The results of this study highlight the critical need for investment in resilience planning, policy updates, and significant funding to seismically upgrade all Washington schools to improve their seismic safety.

The main body of this report presents the results of the school building assessments. The fire station assessments and results are discussed separately at the end of the report in a section titled *Fire Stations*.

Funding and Scope

This project has been funded by the Washington State capital budget with Phase 1 in the 2017–2019 biennium at $1,200,000 and Phase 2 during the 2019–2021 biennium at $2,200,000. These appropriations were largely similar in their scope, however there are differences in school prioritization criteria, among other things. A comparison of the appropriations is provided below (Table 1).

Table 1. Phase 1 (2017–2019) and Phase 2 (2019–2021) appropriation comparison.

Appropriation Conditions	"Phase 1" 2017–2019 Biennium Appropriation Summary	"Phase 2" 2019–2021 Biennium Appropriation Summary
Prioritized seismic risk assessment	DNR, in consultation with OSPI, Emergency Management Division (EMD), and the State Board of Education (SBE), shall develop a prioritized seismic risk assessment that includes seismic safety surveys of public facilities that are subject to high seismic risk as a consequence of high seismic hazard and soils that amplify that hazard.	
Prioritization of the facilities studied	● A minimum of 25 public school facilities that have a capacity of 250 or more persons and are used for the instruction of students in K–12. The Survey must be a representative sample of urban and rural school districts located in different geographical areas of the state. ● Public school facilities that have a capacity of fewer than 250 persons. ● Fire stations located within a one-mile radius of school facilities with 250 person capacity.	● The survey must be a representative sample of public facilities located in high priority areas as determined in the 2017–19 survey of public school seismic safety assessments and tsunami inundation zones as published by DNR. The survey must use the results of the 2017–2019 survey's findings to prioritize school buildings based on geologic and engineering results. ● A portion of public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade and in school districts that have held

		successful bond elections within the previous 3 years. ● A portion of the remaining public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade. ● Fire stations located within a one-mile radius of a public K–12 school facility.
Assessments of facilities shall include	● An on-site assessment, under the supervision of licensed geologists, of the seismic site class of the soils at the facilities. ● An on-site inspection of the facility buildings, including structural systems (using structural plans where available), condition, maintenance, and nonstructural seismic risks following standardized methods by licensed structural engineers. ● An estimate of costs to retrofit a prioritized subset of the school facilities specified above to life safety standards as defined by ASCE. ● An estimate of costs to retrofit a prioritized subset of fire station facilities to immediate occupancy standards as defined by the ASCE.	
Submitting survey data to OSPI	DNR must collect and submit survey data to the superintendent of public instruction in a format compatible with the Information and Condition of Schools (ICOS) database. The department must enter into an agreement with the superintendent of public instruction to make any necessary modifications to the ICOS database to receive and report the survey data.	
Data sharing plan	DNR must share data with: ● The governor and the appropriate legislative committees.	DNR must share data with: ● The school districts and schools where the surveys were conducted. ● The governor and the appropriate legislative committees.
School safety plans	DNR and OSPI must provide technical assistance to the school facilities sampled to incorporate survey information into their school safety plans.	
Reporting	A preliminary report on the progress of the statewide seismic needs assessment shall be submitted to the appropriate committees of the legislature by October 1, 2018. The final report and statewide seismic needs assessment shall be submitted to the Office of Financial Management (OFM) and the appropriate committees of the legislature by June	The statewide seismic needs assessment shall be submitted to the Office of Financial Management (OFM) and the appropriate committees of the legislature by June 30, 2021.

	30, 2019.	
Funding	$1,200,000	$2,200,000

DNR, OSPI, Emergency Management Division (EMD), and SBE, along with help from the United States Geological Survey (USGS) and the University of Washington Civil Engineering Department, developed a committee—the School Seismic Safety Steering Committee (SSSSC)—to determine how to accomplish as much as possible with time and funding allotted in both the 2017–2019, and 2019–2021 biennia. The SSSSC conducted a competitive interview process and ultimately selected Reid Middleton Inc., an Everett, WA-based engineering firm with seismic engineering and evaluation expertise and experience in the design of K–12 schools and statewide resources, to conduct the structural engineering assessments and seismic upgrade design concepts and cost estimates for both phases of this project. As the prime contractor, Reid Middleton partnered with and led teams from three other structural engineering firms to provide DNR, OSPI, and school districts with distributed access to experienced experts and licensed structural engineers throughout the state of Washington – experts invested in the communities and regions around them.

Seismic Hazard

The beautiful mountains, plains, and waterways that are the backdrop for Washington schools are the result of complex geologic processes that have been active for billions of years. Off the coast of western Washington, the Juan de Fuca tectonic plate is being pulled underneath the North American plate in a process known as subduction. This type of geologic action is partly responsible for Washington's tall mountains and volcanoes. This terrain directly affects Washington's climate, which causes heavy snowfall in the mountains and creates the bountiful agricultural region in central and eastern Washington.

Washington's complex plate tectonics have the additional effect of making the state one of the highest seismic risk regions in the United States. When built-up stress from the subduction process is released, it causes the crust of the Earth to vibrate and move—an earthquake. Washington State can experience three major types of tectonic earthquakes (Fig. 1). In the past thousand years or so, Washington State has experienced deep intraplate earthquakes (such as the 2001 Nisqually Earthquake), earthquakes occurring on shallow surface faults (~930 A.D. Seattle Fault Earthquake), and subduction zone earthquakes (1700 Cascadia). Major earthquakes in western Washington in 1946, 1949, 1965, and 2001 cumulatively killed 15 people and caused billions of dollars' worth of property damage (Walsh and others, 2011). In eastern Washington, earthquakes near Chelan in 1872 and near Walla Walla in 1936 also caused significant damage (Walsh and others, 2011). The presence of all three earthquake sources and the relatively high likelihood of having another earthquake in the not too distant future constitutes a significant seismic hazard, and when considered alongside the high population density in areas where these seismic hazards exist, creates a high seismic risk for our state. A large seismic event, such as a magnitude 9 Cascadia event, will have an enormous impact for most of western Washington, where approximately 75% of public school children attend school.

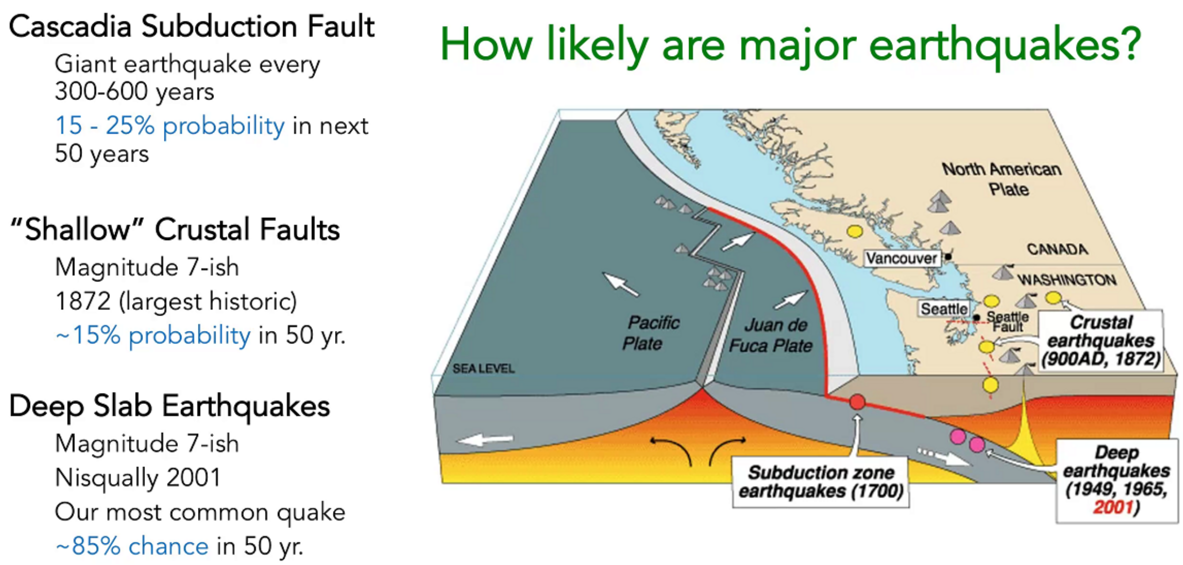


Figure 1. Earthquake sources and probabilities in Washington State. Figure from the Pacific Northwest Seismic Network, adapted from the United States Geological Survey (USGS).

Design-Level Earthquake

Because the range of potential earthquakes varies so greatly, and the worst-case earthquake is not the most likely, engineers use what is called a "design-level earthquake" when engineering new buildings. A "design-level earthquake" is a theoretical earthquake event, which is defined by ASCE 7-16 as being two-thirds of the magnitude of the maximum considered earthquake (MCE_R), and is used in the design of buildings to ensure that the building behaves in a predictable way if that design-level earthquake event should occur. The MCE_R is a risk-adjusted probabilistic event that is based on an earthquake with a 2,475-year return period. The earthquake level is adjusted with the intent that new buildings designed to the current building code will have a 1% probability of collapse in 50 years due to a seismic event (ASCE 41-17, 2017). While not exact, the magnitude of the design-level earthquake event is similar to the magnitude of an earthquake event with a 475-year return period for many locations on the west coast of the United States. Earth scientists expect the average return period of a Cascadia Subduction Zone (CSZ) earthquake to be approximately 500 years. It is possible that a CSZ earthquake could be approximately the magnitude of the design-level earthquake for many parts of Washington State, depending on the particular earthquake characteristics. The design-level earthquake is mandated by the building code to represent the most likely source of earthquake shaking hazard for the region where the building is located; this includes shaking from large earthquakes, such as the Cascadia subduction zone, but also shaking hazard from active crustal faults such as the Seattle fault or the Southern Whidbey Island fault zone.

Tsunami Hazard

Washington is also at risk for tsunamis generated by earthquakes, landslides, and volcanic eruptions. Part of the directive in the 2019–2021 capital budget was to assess the seismic safety of schools in mapped tsunami inundation zones. Schools in tsunami inundation zones are vulnerable to both earthquake and tsunami hazards and thus are some of the highest risk facilities. In Phases 1 and 2 of this project, we assessed 59 buildings at 28 schools in mapped tsunami inundation zones based on mapping conducted and published by DNR (Fig. 2). These schools were assessed solely on seismic risk (as this was the legislative directive) and the schools assessed in this study did not receive an assessment of their buildings' deficiencies in regards to expected tsunami loads. It was outside of the scope of this study to provide any information or recommendations on tsunami vertical evacuation structure necessity for these schools. Additionally, of those schools in the tsunami inundation zone that received concept-level design studies, tsunami hazards and the engineering necessary to withstand a tsunami were not considered in necessary upgrades to the facility.

For many facilities in a mapped tsunami inundation zone, particularly those in southwest Washington, in order for a school facility to be "seismically safe" it is recommended in the *Future Studies* section that future work should also consider the tsunami risk.

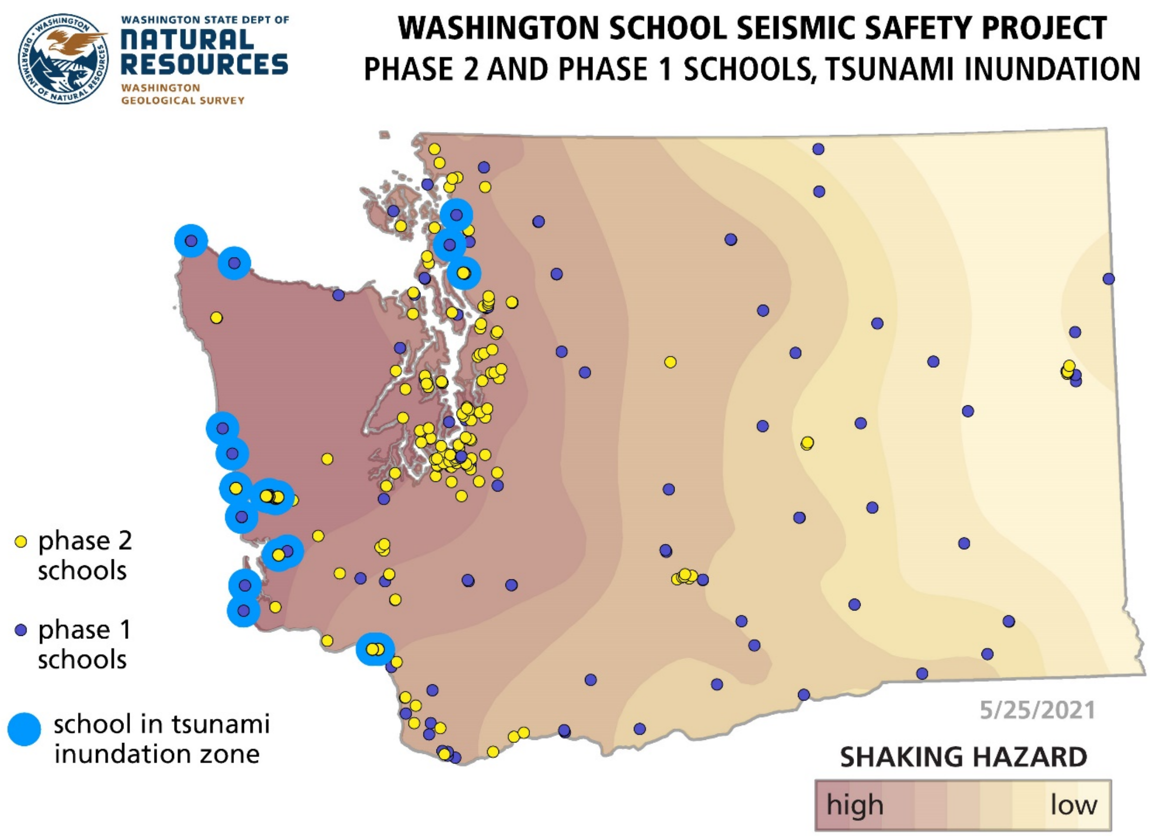


Figure 2. Map showing the location of the schools assessed for Phase 1 (purple dots) and Phase 2 (yellow dots) of this project and highlighting the schools studied that are located in tsunami inundation zones (outlined in blue). The basemap is of the seismic hazard in Washington State, expressed as contours of peak ground acceleration (anticipated ground shaking, or acceleration in bedrock) as a fraction of standard gravity. These values are from the USGS two percent probability of exceedance in 50 years map of peak ground acceleration, which is a proxy for shaking hazard (Petersen and others, 2015). Warmer colors indicate higher hazard areas.

Phase 2 School Selection

For Phase 1 school survey selection, please refer to the Phase 1 legislative report (Washington Geological Survey, 2019) and Table 1 summarizing the differences in funding and scope. In Phase 2, the survey of schools were selected based on the criteria provided in the 2019–2021 Capital Budget language:

- The survey was a representative sample of public facilities located in high priority areas as determined in the 2017–19 Phase 1 and tsunami inundation zones as published by the department.

The survey used the results of the 2017–19 survey's findings to prioritize school buildings based on geologic and engineering results.

- A portion of public school facilities that are routinely used for the instruction of students in K-12 grade and in school districts that have held successful bond elections within the previous three years.
- A portion of the remaining public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade.
- Fire stations located within a one-mile radius of a public K–12 school facility.

We utilized the results from Phase 1, which indicated that the highest risk schools are: those in high seismic hazard areas, buildings that are older (particularly those built prior to 1975 when the State adopted a building code), and those that are made of vulnerable construction types (URM, and non-ductile concrete being the worst).

DNR worked with OSPI to gather information on school districts that have passed a successful bond election within the previous three years and to select vulnerable buildings in a sample of those districts. Figure 3 shows the schools assessed in Phases 1 and 2 of this project as well as all of the other public K-12 Washington school buildings. The 561 buildings assessed in Phases 1 and 2 are a small sample (~12 percent) of the entire school building stock. Note that in total 561 buildings have been assessed, at 274 schools, on 245 campuses (multiple schools can share the same campus). The engineers performed seismic assessments at each individual building (561 buildings total for Phases 1 and 2), whereas the geologic site assessments are performed at each school campus (245 campuses total for Phases 1 and 2).

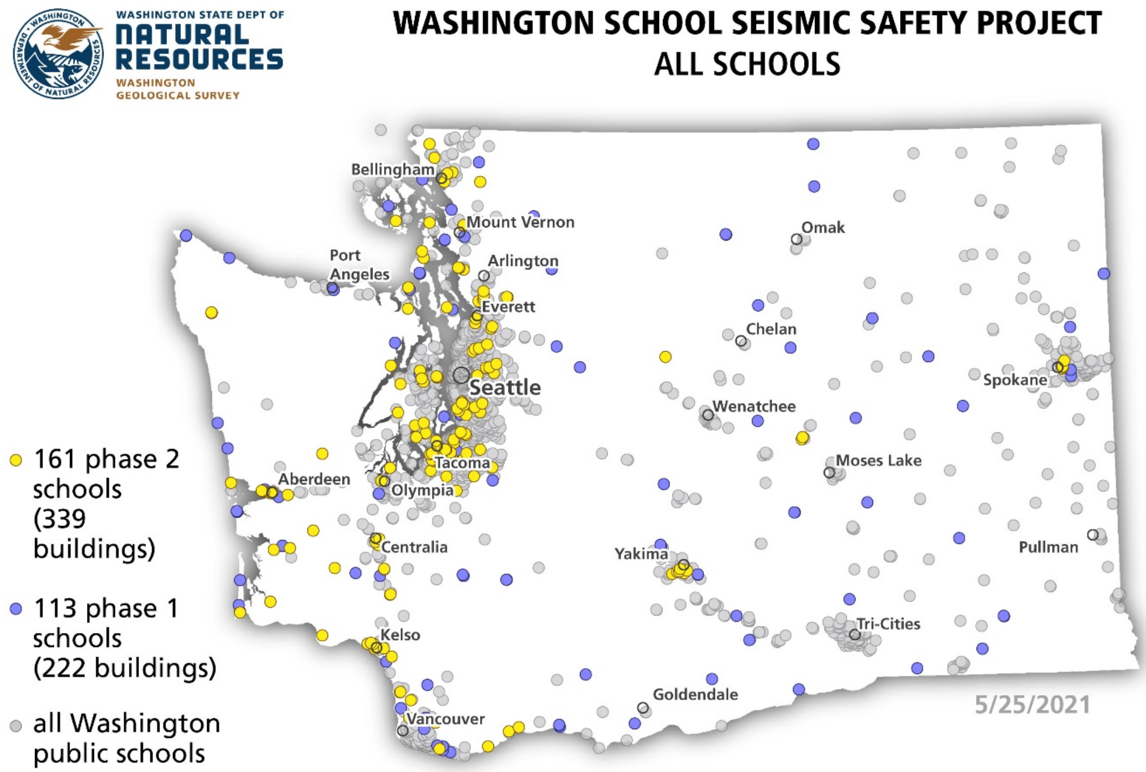


Figure 3. Map showing the schools assessed for Phase 1 and Phase 2 of this project as well as the locations for all other public K–12 Washington schools.

Methods

Geologic Site Assessments

Site Class

Site class is an approximation of how much the soils and rocks at a site will amplify or attenuate ground motion relative to hard rock during an earthquake (Fig. 4). Using the empirical observations of Bordchert (1994), the National Building Safety Council (BSSC, 1997; 2004) developed the site class parameter to categorize the potential for amplification of seismic waves by the local soils, where the relative hardness is proportional to how fast shear waves travel through the soils. The site class parameter also correlates the potential for amplification of seismic waves with the fundamental frequency of a building (i.e. shorter buildings are more affected by short-period or high frequency ground motions, taller buildings are more affected by longer-period or lower frequency shaking). The NEHRP provisions BSSC (2010, 2015), define the standardized site classes (Table 2) and the associated range of the time-averaged shear wave velocity in the upper 100 ft (30 m) of the ground (a value known as Vs30; BSSC, 2004; 2015). Softer soils with a lower Vs30 (site classes E and D) will typically increase the amplification of ground shaking, and have a higher seismic hazard than harder soils or rock, which have a higher Vs30 (site classes A–C).

From a seismic design standpoint, site class is an integral parameter for determining the level of acceleration (and force) that a building needs to be designed for, specific to the underlying soils which the building is built upon. This in turn also determines the Seismic Design Category (SDC) of a structure. The SDC is a categorization scheme that dictates the seismic risk that buildings must be designed to meet. Site class is also incorporated into all the major U.S. and international building codes, including the American Society of Civil Engineers 7-16 (ASCE, 2017b), the International Building Code (IBC, 2017), and the International Residential Code (IRC, 2017), all of which have been adopted in Washington State.

An accurate site class also has direct implications for seismic design and related construction costs. As previously mentioned, seismic ground motions can be amplified depending on the soils the seismic waves travel in. When soil properties are not known in enough detail to classify a site class, site class D is often used as a default, as allowed by the building code or authority having jurisdiction. In shorter buildings that are governed by short-period ground motions, having a site class C can increase seismic accelerations and forces by as much as 20% when compared to a default site class D. In taller buildings governed by long-period ground motions and for buildings in less seismic active areas, site class C can decrease seismic accelerations and forces by as much as 15% and 30% respectively. Furthermore, buildings built on soils classified as site class E are often times associated with soils that are susceptible to liquefaction, the phenomenon where underlying soils liquefy in a seismic event which drastically decreases the strength of the soil that supports the building. Buildings in liquefiable soils require more robust foundation systems, thereby increasing the cost of construction or rehabilitation. Having site-specific

Vs30 measurements to classify the site class at a given site will more accurately define the seismic engineering criteria, risk, and parameters for the structural design and detailing of a building which thereby influences the construction costs of a building. In higher seismic areas, having a defined site class can more accurately estimate costs for buildings for budgetary and programming purposes, as well as for prioritizing seismic upgrades of vulnerable buildings. In less seismic areas, having a defined site class can help to reduce the conservatism in the seismic design and associated construction costs.

At each school campus, WGS geologists and geophysicists used geophysical methods as described in West and others (2019) to measure Vs30. From this measurement, site class was assigned to the school buildings at each campus or fire station. The final results for each campus and fire station are condensed into an individual site class assessment report for that campus (Fig. 5) and distributed to each school, school district, and (or) fire station (*Appendix A*). The results are also entered into OSPI's ICOS statewide database.

The site class assessment reports summarize the key results and observations for each site. The results are in two parts: a non-technical front page and a more technical summary back page (Fig. 5). The non-technical summary provides information about field deployment, methods used, the measured site class, an overview of the soils mapped at the campus, and available information about other mapped geologic hazards. The technical overview expands on the data processing results, briefly discussing the quality of the dispersion images, as well as the methods and the Shear-Velocity Depth Profile (SVDP) used to determine Vs30. This more technical information can be useful for any further geotechnical analysis at the school campus. If there is a change in the site class from a previously published value, or if there is complicated geology mapped at the site, a section is included that summarizes how the velocity model fits into the larger geological context. The technical overview includes a figure of the SVDP, and may also contain a 2D Multi-channel Analysis of Surface Waves (MASW) velocity model or a 2D P-wave velocity model, if relevant.

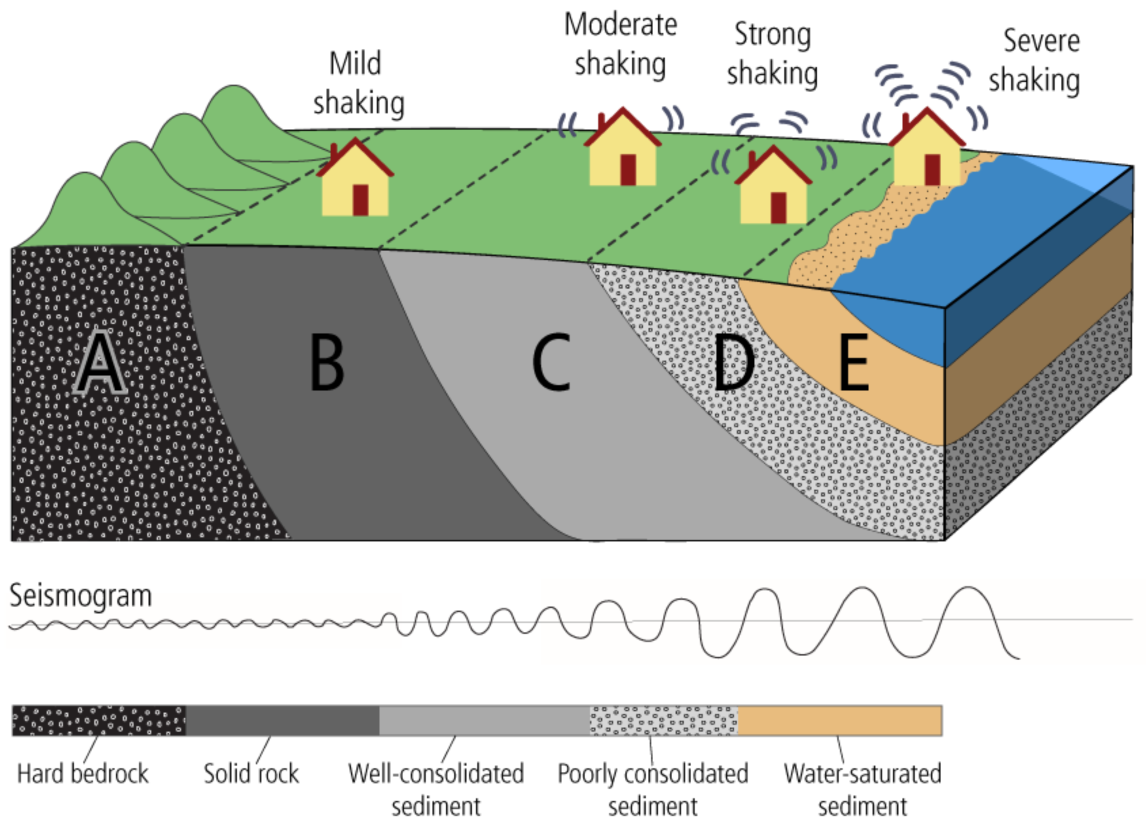


Figure 4. Schematic figure illustrating how seismic waves travel through different rock and soil types and the simplified site class associated with those rock/soil types (site class is labeled A–E). The type of rock or soil beneath a structure greatly affects how a building responds to earthquake shaking. Geologists measure the time it takes seismic waves to travel through the ground at each school campus to determine the rock/soil type and correlate it to a site class value. This value is then incorporated into the engineering assessment. Figure modified from: https://slideplayer.com/slide/6132863

Table 2. NEHRP site class categories. Softer soils typically increase shaking amplification and thus seismic hazard. Under certain circumstances where soils are vulnerable to collapse under seismic loading, such as liquefiable soils like peat, a special site class F may be designated.

NEHRP site class	Description	Vs30 (meters/second)	Ground shaking amplification
A	Hard rock	greater than 1,500	Low
B	Rock	760–1,500	
C	Soft rock/very dense soil	360–760	Moderate
D	Stiff soil	180–360	
E	Soft soil	less than 180	High

Because measuring site class requires either a geophysical survey or boreholes, it can be prohibitively expensive. As a result, state and federal agencies and researchers have developed regional site class maps based on Vs30 proxies. These site class maps are based on topography (Wald and Allen, 2007; Allen and Wald, 2009), geology (Wills and Clahan, 2006; Palmer and others, 2004), or a combination of the two (Thompson and others, 2014). However, these reconnaissance-scale site class maps must make assumptions to account for lateral and vertical changes in geology. These assumptions can significantly over- or under-estimate site class in areas of complex geology. Regional reconnaissance-scale site class maps therefore provide a good approximation for routine building design and seismic screening, but are not intended to replace site-specific testing needed for the design of essential facilities.

In the state of Washington, Palmer and others (2004) utilized surficial geologic mapping and a limited number of Vs30 measurements to construct a 1:100,000-scale predictive statewide site class map. The scale of the geologic mapping is not appropriate for site-specific use. The SSSP site class assessments account for 3D geology and are correlated with newer more accurate 1:24,000-scale geologic mapping and boreholes for ground-truthing where available.

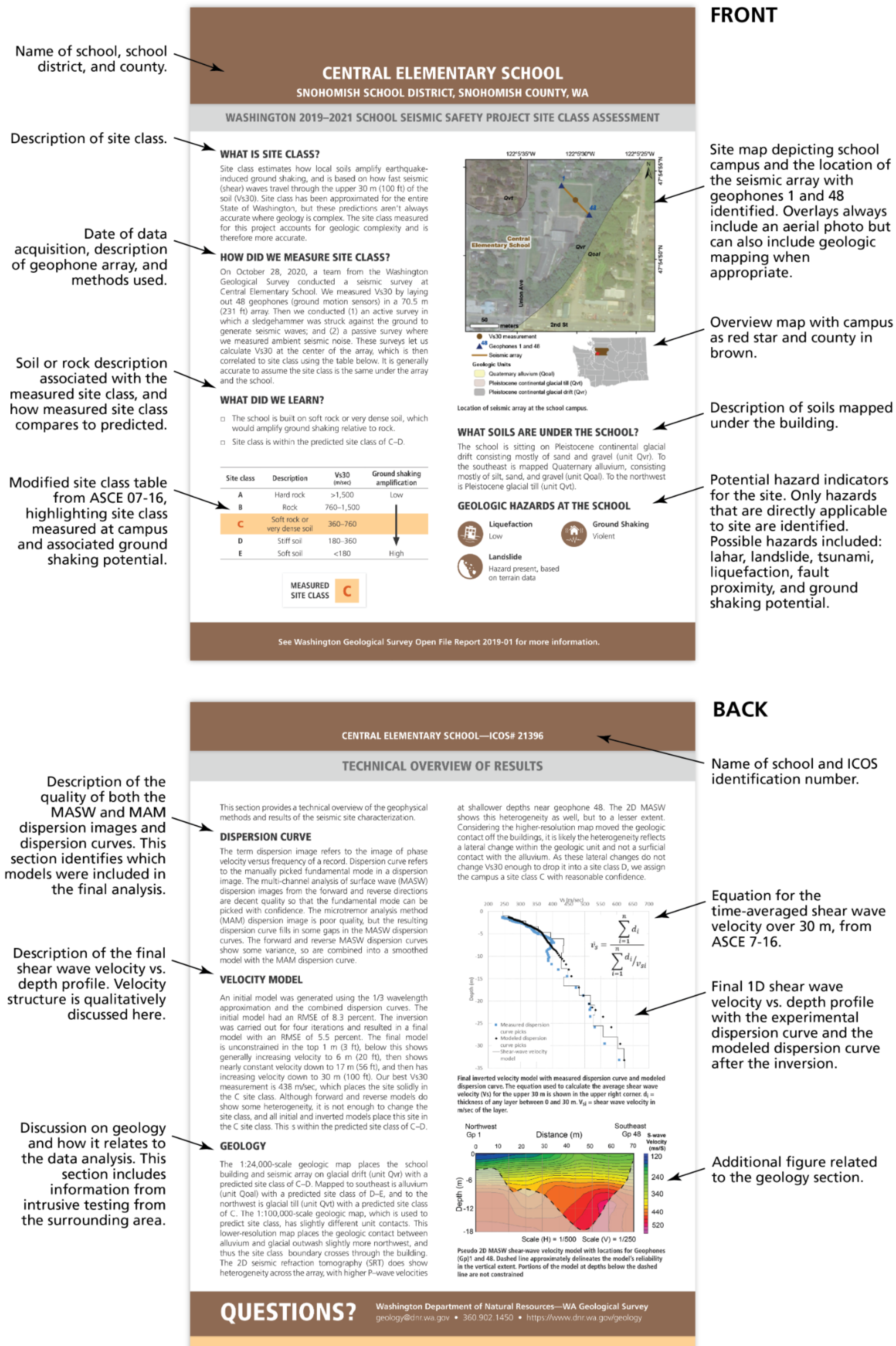


Figure 5. Site class assessment reports, with a non-technical front page shown on top and a technical summary back page shown on bottom. Site class reports for Phase 2 schools are located in *Appendix A*.

Information for Schools on Other Geologic Hazards

Along with our site class assessment, we also reviewed available maps and datasets to screen for other geologic hazards (lahars, landslides, tsunamis, liquefaction, nearby faults, and estimated ground shaking) that could affect the campus. Although these geologic hazards have no direct influence on the measured site class, some are co-seismic (phenomena directly associated with seismic activity) and all pose varying levels of risk to school structures and their occupants. However, an extensive characterization of how each identified hazard could affect the campus is beyond the scope of the site class assessment. Instead, hazard flags are intended simply to notify school authorities and others interested in these reports of the possible geologic risks. If identified, a flag associated with the geologic hazard is placed in the bottom right corner of the front page of the site class assessments (Fig. 5). Below are the short definitions of the hazards and the parameters used to determine if a geologic hazard was flagged:

- **Lahars** are fast-moving destructive mud or debris flows that originate from the flanks of volcanoes and usually travel along river valleys. A school is identified as having a lahar hazard if the campus is in a mapped lahar hazard area (Washington Division of Geology and Earth Resources, 2016).

- **Landslide** hazard was identified by WGS landslide geologists based on high-resolution lidar, orthoimagery, and the landslide activity of an area. The site class assessment reports do not thoroughly assess landslide hazard. If a hazard is suspected and flagged, it should be reviewed by a licensed engineer or engineering geologist.

- **Tsunami** hazard is identified using WGS tsunami inundation modeling (Washington Geological Survey, 2021 b). Not all of Washington is mapped for tsunami hazards. If the school is not flagged as being in a mapped tsunami hazard zone it does not necessarily mean there is not a tsunami hazard present.

- **Liquefaction** hazard is the susceptibility of soils to liquefy during an earthquake. This hazard is identified based on the statewide liquefaction maps by Palmer and others (2004) and expressed as: bedrock, very low, low, moderate, high, very high, or extreme based on the statewide liquefaction mapping. For sites that were mapped as bedrock sites (where liquefaction potential is negligible) but are determined to not actually be a bedrock site though our geologic site assessment, we assign the modified description: unknown, not negligible.

- Mapped **active faults** are derived from the WGS database of Quaternary faults (Bowman and Czajkowski, 2019). If any of these active faults are within a roughly five-mile radius of a school campus, the campus is flagged.

- **Ground Shaking** hazard is estimated by using the Dynamic Conterminous U.S. 2014 (updated) (v. 4.2.0) model of the USGS Earthquake Hazards Program Unified Hazard Tool (UHT) (U.S. Geological Survey, 2021). The measured site class results are incorporated as an input into the UHT to more accurately predict the peak ground acceleration (here we use the model that has a two percent chance of being exceeded in the next 50 years) from the USGS National Seismic Hazard Map (Petersen and others, 2020). The ground shaking intensity (severe, violent, extreme and so on) is then classified based on the classification of Worden and others (2012). Some Schools may have a high ground shaking hazard and yet may be located on hard rock (site class A or B), this is likely due to geologic factors such as their close proximity to an active fault or within a large basin. Conversely, some campuses may have a low ground shaking hazard and be sitting on soils with a measured site class of C, D, or E, in these cases the campus may be located in a low seismic hazard area (likely far away from any mapped faults).

Engineering Assessments

Field Investigation and Data Collection Process

Engineering field investigations were conducted at each school building to observe existing conditions and collect existing building data. Visual observations were limited to areas and building elements that were safely accessible and observable without requiring the removal of finishes. Significant effort was also spent collecting and scouring through existing building drawings (blueprints) and databases provided by the school districts. Existing building structural drawings are essential for conducting the structural seismic evaluations because most structural elements are not visible during field investigations. For buildings assessed in Phase 2, 63 percent had a full set of structural drawings, 20 percent had partial drawing sets (some with only partial architectural drawings), and 17 percent had no drawings available whatsoever.

Additional building data from OSPI's ICOS database and Study and Survey database were also collected and used in the seismic assessments of the buildings. These data were provided by OSPI and became extremely valuable in the absence of existing drawings. The Study and Survey documents often included previous condition assessment reports, area plans, and area analysis tables that provided floor areas, floor plan layout, and years of construction. Some of the Study and Survey documents provided also included architectural and structural building descriptions and narratives that described the structural systems, lateral force resisting systems, and construction history, including seismic retrofits that occurred over the years. Many older school buildings have undergone multiple additions that are interconnected and contain a variety of structural systems and construction materials. The area plans and Study and Surveys provided by OSPI helped tell the school building's history. See Figure 6 as an example of a building with multiple areas and construction types.

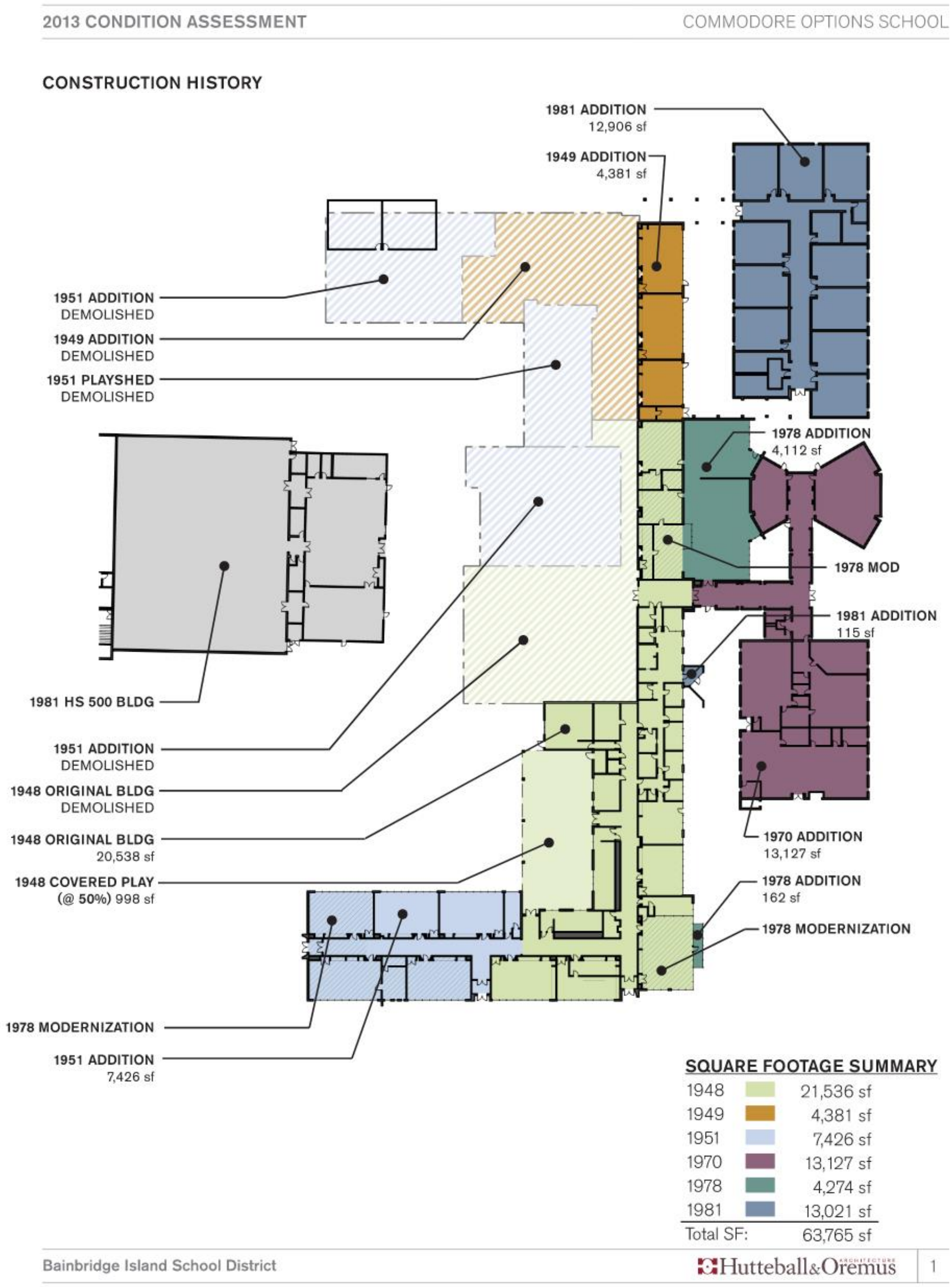


Figure 6. Area plan from ICOS Study and Survey project showing a summary of the years of construction and the square footage of the different building areas at Commodore Options School, Bainbridge Island School District, Washington.

Seismic Performance of Nonstructural Components

For much of the 20th century, little attention was given to designing nonstructural components and their anchorage for forces induced by earthquakes, yet these nonstructural systems can pose a safety risk to building occupants. Nonstructural components of buildings are architectural features, finishes, building envelop and cladding systems, and the various building systems such as mechanical, electrical, plumbing, heating, cooling. These components are essentially everything but the building's structural systems and framing and can comprise of approximately 60% of the construction costs in a new school building.

In addition to the life safety hazards posed by nonstructural components, the cost to repair nonstructural components following an earthquake can be high and significantly delay the reopening of a school. In many cases, the cost to repair or replace nonstructural components can be higher than the cost of repairing structural components following an earthquake.

As was done in Phase 1 of this study, school buildings screened in Phase 2 also include nonstructural seismic evaluations using the ASCE 41 Tier 1 Nonstructural Checklists that evaluates items pertaining to nonstructural systems that can pose a life safety risk to the building's occupants if these systems are inadequately braced, anchored, or fail to operate during or after an earthquake.

The nonstructural checklists can provide immediate guidance on the seismic adequacy of nonstructural elements, some of which may be easily mitigated such as anchoring tall cabinets and bookshelves to backing walls, moving heavy contents to the bottom of shelving, independently supporting light fixtures in suspended ceilings, and adding seismic strapping, bracing, or flexible connections to water tanks and overhead elements (for example, mechanical units, piping, and fire protection systems).

It is often most economical to mitigate nonstructural seismic hazards when the building is already undergoing mechanical, electrical, plumbing, or architectural upgrades or modernizations. Summaries of nonstructural items that require mitigation or further investigation are included in each screening report (*Appendix B*). In addition, school districts are provided with excerpts from the Federal Emergency Management Agency (FEMA) publication E-74 entitled, 'Reducing the Risks of Nonstructural Earthquake Damage' (FEMA E-74) that have helpful illustrations of typical seismic mitigation measures that can potentially be implemented by district facilities and maintenance personnel.

American Society of Civil Engineers 41-17 Tier 1 Screening and Checklists

The seismic evaluation of building structures is based on performance-based earthquake engineering (PBEE) guidelines presented in ASCE 41-17 Seismic Evaluation and Retrofit of Existing Buildings. ASCE 41-17 provides a three-tiered seismic screening and evaluation procedure using performance-based criteria. The evaluation process consists of the following three tiers: Screening Procedure (Tier 1), Deficiency-Based Evaluation Procedure (Tier 2), and Systematic Evaluation Procedure (Tier 3). Only the Tier 1 evaluations were completed as part of this study. For more information and a better understanding of the building's necessary retrofit designs and costs, Tier 2 and 3 screenings are recommended.

The Tier 1 seismic screening procedure was used in this study to seismically evaluate structural and nonstructural building components. The Tier 1 seismic screening is a checklist of evaluation items (building components) designed to identify the seismic safety flaws and weaknesses of a building. The checklist items consist of positively-affirmed (desirable) evaluation statements of various building geometry and structural characteristics that are seismically essential to meeting a stated structural performance objective such as Collapse Prevention, Life Safety, or Immediate Occupancy (Table 3).

The ASCE 41 Tier 1 screening procedure has a checklist for basic structural configuration, different checklists for each common building type, and a checklist for select nonstructural systems. The checklists for each common building type have evaluation items unique to that building type, based on seismic vulnerabilities and past observed failures that are unique to that building type. The common building types classification in ASCE 41 are the same as the building types used in FEMA guideline documents and provide a consistent nomenclature across the pre-disaster and post-disaster earthquake standards.

After reviewing existing drawings and performing field investigations, engineers deem each positively-affirmed evaluation statement of the checklists as either Compliant (C), Noncompliant (NC), Unknown (U), or Not Applicable (N/A). Evaluation items marked as Compliant are those that the engineer deems as acceptable in meeting the positively-affirmed and desirable evaluation statements. Items the engineer marks as Noncompliant are those they assess as not meeting the evaluation statements and require mitigation or further investigation and analysis. Items the engineer marks as Unknown indicate that further investigation and analysis is required, usually as a result of having insufficient existing drawings or field observations to make a C or NC assessment. Where ASCE 41 Tier 1 seismic screening checklist items were unknown due to lack of available information, the checklist items were assessed as Unknown.

Seismic Hazard Levels

Every earthquake is different. An earthquake's intensity and energy magnitude depend on fault type, fault movement, depth to epicenter, and geology of the subsurface. The precise location, intensity, and start time of an earthquake cannot be predicted before an event occurs. However, earthquake hazards for certain geographic areas are relatively well understood based on historical patterns of earthquakes from the geologic record, measured earthquake ground motions, understanding of plate tectonics, and seismological studies.

Geologists, seismologists, and geotechnical engineers have categorized the seismic hazard for particular locations using models based on the probability of a certain magnitude earthquake occurring in a given time period. ASCE 41-17 specifies four different Seismic Hazard Levels at which to seismically screen, evaluate, and (or) upgrade school buildings and other structures. For voluntary seismic evaluations and voluntary seismic upgrades, the owner of a school and the structural engineer can collaborate and decide the seismic hazard level at which it is appropriate to evaluate or upgrade a structure.

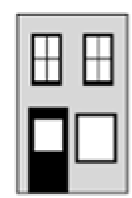
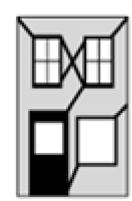
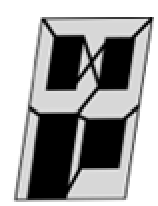
All the school buildings were evaluated as Risk Category III structures as defined by the Washington State Building Code. Generally, schools with more than 250 occupants are classified as Risk Category III and schools with less than 250 occupants are classified as Risk Category II. While it is possible that some school buildings may technically be classified as Risk Category II based on their current occupancy (number of occupants), the study team elected to evaluate all structures as Risk Category III to keep the risk categories consistent for the relatively small sample size.

School Building Performance Levels and Seismic Upgrade Options

A target building performance level must be selected for the seismic design of an upgrade of a school building. The terminology used for target building performance levels is intended to represent goals for design, but not necessarily predict building performance during an earthquake.

The ASCE 41-17 standard identifies the following Structural Performance Levels in a design-level earthquake: Immediate Occupancy (IO), Life Safety (LS), Limited Safety (LTD-S), and Collapse Prevention (CP) (Table 3). The nonstructural Performance Levels identified in the standard are: Operational (OP), Position Retention (PR), and Life Safety (LS). For this study the engineers used the Life Safety performance objective.

Table 3. Structural performance level definitions following ASCE 41-17 and FEMA P-424.

Structural Performance Level	Description of building state following a design-level earthquake	Schematic diagram of building following earthquake
Immediate Occupancy (IO)	Buildings are expected to sustain minimal damage to their structural elements and only minor damage to their nonstructural components. While it is safe to re-occupy a building designed for this performance level immediately following a major earthquake, nonstructural systems may not function due to power outage or damage to fragile equipment.	
Life Safety (LS) and Limited Life Safety (LTD-S)	Buildings may experience extensive damage to structural and nonstructural components. Repairs may be required before re-occupancy, though in some cases extensive restoration or reconstruction may not be cost effective. The risk of casualties at this target performance level is low.	
Collapse Prevention (CP)	Although buildings that meet this building performance level may pose a significant hazard to life safety resulting from failure of nonstructural components, significant loss of life may be avoided by preventing collapse of the entire building. However, many buildings designed to meet this performance level may be complete economic losses.	

Engineering Performance Assessment Tool

The Washington State School Earthquake Performance Assessment Tool (EPAT) is a spreadsheet tool developed for the State of Washington by the Earthquake Engineering Research Institute (EERI). The spreadsheet uses FEMA Hazus fragility curves to calculate expected earthquake performance of schools based on basic school seismic screening characteristics. Hazus is a natural hazards loss estimation tool initially developed by FEMA in the 1990s. Hazus uses basic building information, construction type fragility functions, and expected ground shaking intensity to estimate the probable losses of buildings from a design-level earthquake. These results are displayed as a percentage of the building elements that are expected to be damaged in this earthquake. The EPAT spreadsheet only returns performance values for the building's structural systems, but nonstructural systems are likely to also sustain significant damage in a large earthquake.

Rapid Visual Screening

The standardized tool for performing rapid visual screening of buildings for seismic risks is the 'FEMA P-154: Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards' standard (Applied Technology Council, 2015). Based on extensive data and research on the seismic performance of buildings in previous earthquakes, these standards provide seismic screening criteria specific to each common building archetype, the structural system, configuration, and characteristics of the specific facility, and the seismic risk at each facility site.

This tool uses a scoring system to quantify the potential seismic vulnerability of a structure. A base score is identified based on modeled ground shaking. Other important factors are the buildings' lateral-force-resisting system (for example, wood or concrete shear walls, steel braced or moment frames, and masonry shear walls). This base score is then reduced according to the geological hazards (site class, landslide, and liquefaction hazards) and inherent vulnerabilities in the building's configuration such as vertical and horizontal irregularities. The building score is also adjusted based on the construction year relative to benchmark years in which seismic design code requirements changed significantly.

Scores typically vary between 0.3 and 6.0. Lower scores indicate more hazardous buildings and higher scores indicate buildings that have less risk. There is no official cutoff score that identifies which buildings should receive further evaluation, but, generally, a score of 2.0 or less is used to identify buildings that require further evaluation.

Earthquake Performance Rating System Translation of the ASCE 41 Tier 1 Checklists

A lesson learned from our Phase 1 study is the need to simplify the ASCE 41 Tier 1 checklists for each assessed building to better communicate to people without an engineering background the most important structural seismic deficiencies that need to be mitigated or further investigated. The Phase 2 study attempts to do this by providing both an engineering-based risk rating (described in this section) that characterizes the seismic safety risk of the building in each screening report, and then combining these ratings with other engineering and geologic hazard information to determine prioritization of buildings studied (discussed in the *Results* section *Prioritized Rankings of Phase 1 and 2 School Buildings by Relative Risk*).

The project team used the 'Earthquake Performance Rating System (EPRS) ASCE 41-13 Translation Procedure' developed by the Structural Engineers Association of Northern California (SEAONC) (SEAONC, 2017) and the 'Earthquake Performance Rating System User's Guide' (SEAONC, 2015) to determine a structural safety risk rating to prioritize the seismic evaluation items that need to be addressed. The EPRS procedure and user's guide was published by the Existing Buildings Committee of SEAONC and its methodology has been adopted by the US Resiliency Council (USRC, https://www.usrc.org) in determining their building earthquake ratings.

The EPRS includes guidelines that translate the ASCE 41 Tier 1 seismic evaluation structural checklists into star-ratings that address three focus areas of seismic performance: Safety, Repair Cost, and Recovery. Each of the focus areas have three sub-ratings: Structural, Geologic, and Nonstructural. However, based on the information gathered by the project team in both phases of this study, only a preliminary Structural Safety sub-rating could be determined for each building assessed. See the Engineer's Seismic Assessment Report in *Appendix B* for an in-depth discussion regarding the risk rating translation procedure. Although preliminary, the Structural Safety sub-rating will be helpful in informing school districts of the seismic risks and needs of their buildings, especially when accompanied by a list of seismic evaluation checklist items that can improve the Structural Safety sub-rating if mitigated. See the *Results* and *Recommendations* sections below for additional discussion on how to use the seismic screening reports and EPRS risk rating.

The definitions of the Structural Safety sub-ratings used in this study are based on definitions used in the EPRS User's Guide and by the USRC and have been adapted for use in this study. The EPRS is a five-star rating system, with one star being the lowest, or worst-performing building, and five stars being the highest, or best-performing building. The ratings are communicated in each of the seismic screening reports for each school building assessed in Phase 1 and 2 as follows:

★ **Risk of collapse in multiple or widespread locations**—Expected performance as a whole would lead to multiple or widespread conditions known to be associated with earthquake-related collapse resulting in injury, entrapment, or death.

★★ **Risk of collapse in isolated locations—**Expected performance in certain locations within or adjacent to the building would lead to conditions known to be associated with earthquake-related collapse resulting in injury, entrapment, or death.

★★★ **Loss of life unlikely**—Expected performance results in conditions that are unlikely to cause severe structural damage and loss of life. A three-star rating meets the Tier 1 Life Safety (LS) structural performance objective.

★★★★ **Serious injuries unlikely**—Expected performance results in conditions that are associated with limited structural damage and are unlikely to cause serious injuries.

★★★★★ **Injuries and entrapment unlikely**—Expected performance results in conditions that are associated with minimal structural damage and are unlikely to cause injuries or keep people from exiting the building. A five-star rating meets the Tier 1 Immediate Occupancy (IO) structural performance objective.

Results

Geologic Site Class

The measured site class results were used by the engineers to determine the design ground motions for each of the school buildings and fire stations. The design ground motion is what engineers use when determining if a building will be able to withstand the expected amount of ground shaking for a given seismic event. For new buildings and seismic retrofits this is the design-level earthquake.

By incorporating the measured site class (what is known about the soil beneath the school campus) and the probable earthquake shaking/acceleration, the engineers can more accurately determine how an existing structure is expected to perform and they can better design seismic upgrades for a particular seismic event.

The measured site class results are also entered into the EERI EPAT worksheet (Goettel and others, 2017). The EPAT worksheets can complement more detailed building-specific ASCE 41-17 Tier 1 seismic screenings. These tools can provide school districts with a preliminary assessment of the level of seismic risk (low to very high) at school buildings and can help classify the level of life safety risk and priority for further evaluation.

The Vs30 and EPAT results are inventoried into the OSPI ICOS database, which is integrated into the Pre-disaster Mitigation Program (PDM) module (Goettel and Dengel, 2014). This database and module provide detailed data that school district administrators can use to guide seismic upgrades of buildings and steer future funding strategies.

See *Appendix A* for site class measurements and school 'one-page reports' at the 245 campuses studied (99 for Phase 1 and 146 for Phase 2). For the Vs30 measurements download the WGS shear wave database (Washington Geological Survey, 2021 a). The published Vs30 measurements are identified as single points representing the midpoint of the geophone array.

Of the total 245 school campuses assessed, 59 have measured site classes (*Appendix A)* that differ from those predicted/assigned by the reconnaissance-scale statewide site class map (Palmer and others, 2004) (Table 4). Site classes incorrectly predicted by the reconnaissance-scale map are typically due to one or any combination of three main categories: (1) *subsurface changes from different geologic units,* such as alluvium (river deposits) overlying shallow bedrock (2) *variance within a single geologic unit*, such as lava flows, large boulders, and sediment layers, and (3) *mismapping,* which is any shortcoming of the reconnaissance-scale mapping of the geologic units on which site class is based. For an example of how the predicted site class and geology differ significantly from the measured see Figure 7.

Table 4. Distribution of Phase 1 and 2 predicted site class (gold) versus measured site class (blue), as well as individual totals of measured site class values.

Predicted site class	Measured site class				
	E	D	C	B	Total
F	0	1	0	0	1
D–E	26	29	16	1	73
D	0	21	9	0	29
C–D	0	17	29	1	47
C	0	15	60	0	75
B	0	4	12	4	20
Total	26	87	126	6	**245**

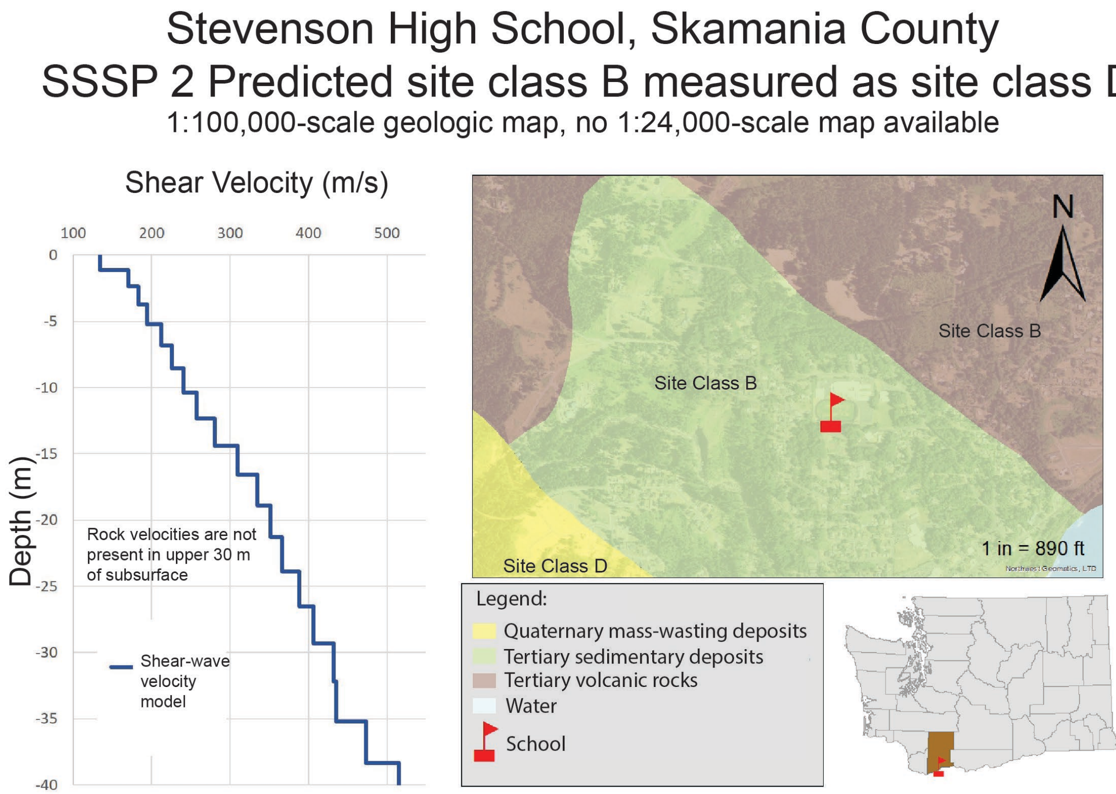


Figure 7. Geologic map of the campus at Stevenson High School in Skamania County, Washington (red flag). The site is mapped on sedimentary rocks (green), and to the north and east are mapped volcanic deposits (brown). According to the reconnaissance-scale mapping both of these have a predicted site class of B. Mapped to the south are mass-wasting deposits (yellow) with a predicted site class of D. The velocity model (the graph in the left of the figure) shows steadily increasing velocity down past 30 m (100 ft), with no sign of hard rock velocities (760 m/sec or above) in the upper 40 m (120 ft). This suggests that the reconnaissance-scale mapping was not accurate at this location, as the measured site class was D, which is more consistent with the mass wasting deposits to the west.

Engineering Assessments Phase 2 Results

American Society of Civil Engineers 41-17 Checklists

ASCE 41 Tier 1 seismic screening evaluations were conducted on all of the 561 Phase 1 and 2 school buildings. This section describes the findings and trends associated with these seismic screening evaluations for Phase 2 buildings. A discussion of Phase 1 and Phase 2 results combined is presented later in this report.

Original building structural drawings were available for review for about 63 percent of the buildings studied. Twenty percent of buildings had partial or incomplete drawings available for review, and 17 percent had no available record drawings for review. Where existing building drawings or other information were not available for review, the engineering data-gathering was limited to visual observations by the project team of licensed structural engineers. Where building component compliance or noncompliance was unknown due to lack of available information, the unknown conditions were indicated on the ASCE 41-17 Tier 1 seismic screening checklists. The findings are as follows:

1. The average year of construction was 1967 and the median year of construction was 1968.
2. The average and median occupied space area is 28,472 square feet, and 17,364 square feet, respectively.
3. Figure 8 illustrates the distribution of building material types represented in the Phase 2 study.

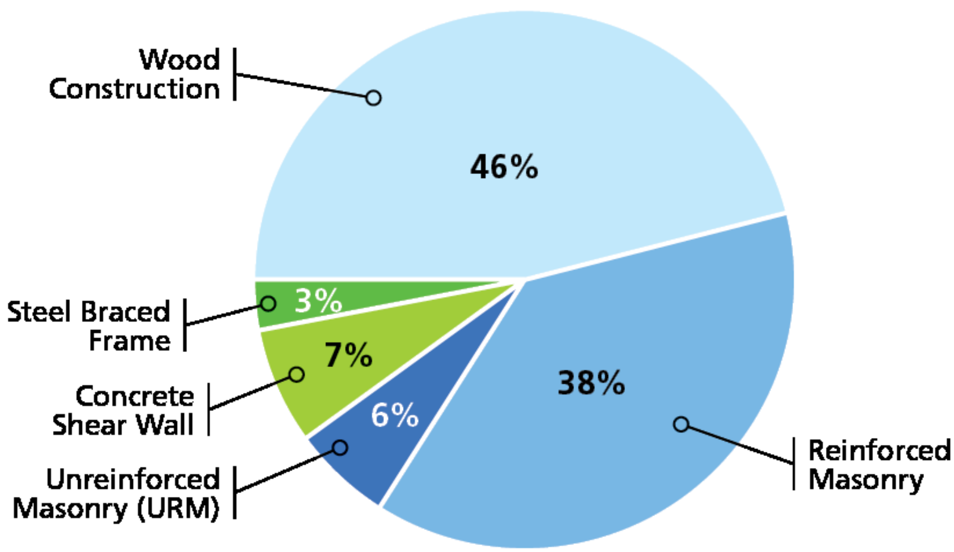


Figure 8. Distribution of Building Material Types of Phase 2 School Buildings Studied.

As was expected, most of the ASCE 41 Tier 1 Screening Evaluation noncompliant features were related to building elements that were likely not strong enough or not interconnected enough to reliably resist seismic loads. Additionally, many of the buildings utilize archaic building materials that do not possess adequate toughness (ductility) or reliable load path for design-level earthquake loads. These seismic weaknesses are typically found in walls, roofs, floors, and where these structural elements are weakly interconnected. These weak structural elements or weak connections are typically not strong enough to reliably transfer (or resist) earthquake loads to the foundations.

Figure 9 shows the percent of items on the checklist that were classified as either noncompliant or unknown (vertical axis), with the horizontal axis showing construction or seismic upgrade date. In general, older buildings, particularly those made of wood, have a higher percentage of seismically noncompliant or unknown items. This relationship is to be expected, as these buildings were built with outdated building codes, or, in some cases, no building code at all. The highest noncompliant or unknown percentage of 71 percent is held by a URM building. There is no building within the sample of Phase 2 school buildings that has zero noncompliant or unknown seismic screening evaluation items.

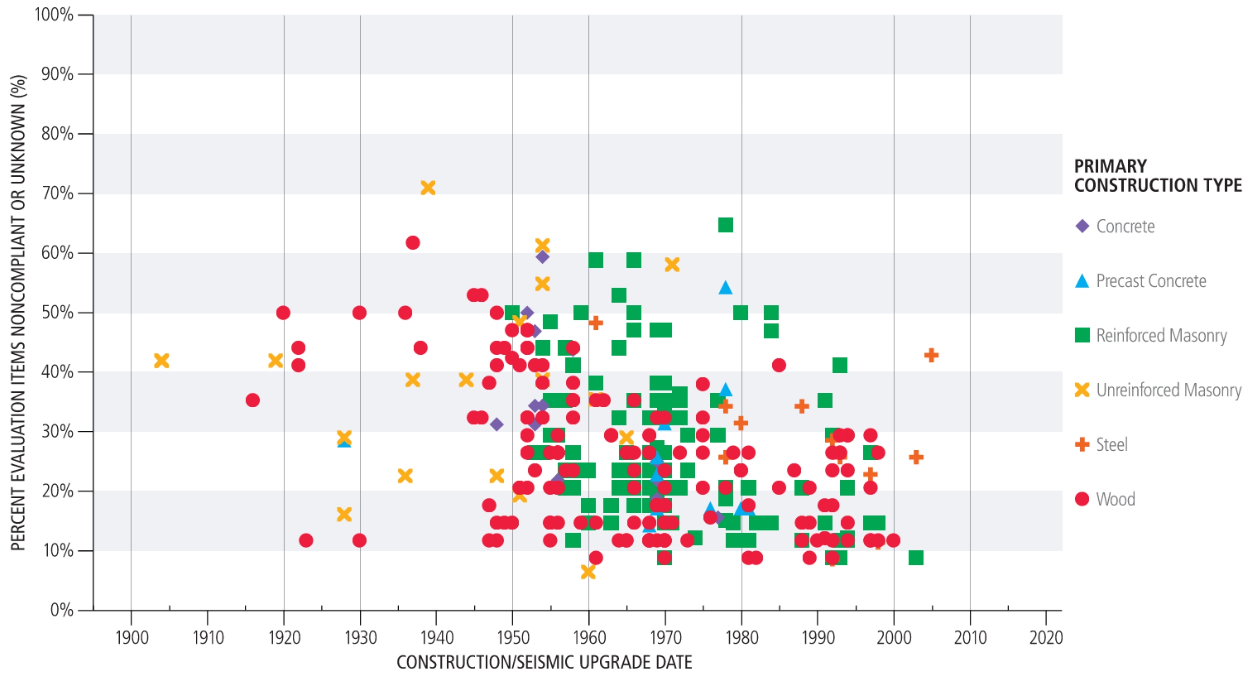


Figure 9. Phase 2 buildings symbolized by primary building construction type. The vertical axis shows the percent of ASCE 41 Tier 1 items identified as noncompliant or unknown and plotted on the horizontal axis are the construction or seismic upgrade dates of the buildings.

Engineering Performance Assessment Tool (EPAT) Results

Table 5 shows the EPAT median, average, maximum, and minimum results for the buildings included in the Phase 2 study. The information displayed in the table is based on each building's existing configuration and estimations of loss, life safety risk level, and post-earthquake tagging as expected for the design earthquake. An EPAT 'scoresheet' for each school building is included in the final engineering report and can be downloaded from the links in *Appendix B*.

Table 5. Washington State schools EPAT summary results for Phase 2 school buildings.

EPAT Calculated Value	Median	Average	Max	Min
Building damage estimate ratio (Amount of building that is damaged)	56%	54%	91%	7%
Probability that building is not repairable	52%	51%	93%	5%
Life safety risk level	High	-	Very High	Very Low
Most likely post-earthquake tagging	Red*	-	Red*	Green*

**Red = Unsafe to Occupy, Yellow = Restricted Building Access, Green = No Restrictions on Building Access*

The primary value calculated for each building from the EPAT spreadsheet is the amount of damage each existing building is expected to sustain in a design-level earthquake event. This value is displayed as a percentage of the building elements that are expected to be damaged. The EPAT spreadsheet only returns performance values for the building's structural systems, but nonstructural systems are likely to also sustain significant damage in a large earthquake.

The EPAT summary results in Table 5 above show that the median building is expected to have more than half its building elements damaged. Similarly, it is expected that about half the buildings included in the study will not be repairable, meaning these buildings will likely need to be demolished. The most likely post-earthquake tagging identified by EPAT is "Red," meaning the majority of school buildings included in the study are expected to not be safe to occupy following the design-level earthquake event.

Building damage estimate ratios are loosely correlated to building type and seismic risk as shown in Figure 10, which depicts building damage estimate ratios against building construction or seismic upgrade date. The figure also includes different symbols for the building lateral system's primary construction material type. As illustrated in the figure, the dominant school construction types prior to the 1940s were unreinforced masonry and wood construction. Starting in the 1950s, many of the school buildings were constructed of reinforced masonry, wood, concrete, and steel. During the 1950s and after, the most prominent building construction types were wood and reinforced masonry.

Figure 10. Phase 2 building EPAT damage estimate ratios in ASCE 7/41 design-level earthquake categorized by primary construction type and year built.

Unreinforced masonry buildings and non-ductile concrete buildings (older concrete buildings) are especially vulnerable to earthquakes due to their weight and brittle nature, and these buildings have well-known seismic risks in high seismic hazard areas. As seen in Figure 10, many of these school buildings possess damage estimate ratios in the range of 70 to 80 percent, or higher. However, the figure also shows that many unreinforced masonry school buildings display damage estimate ratios of between 10 and 30 percent. These buildings are typically located in low or moderate seismic zones. Figure 10 also shows that school buildings built after 1975 have precipitously decreasing damage estimate ratios, with school buildings constructed in the 1990s and the 2000s generally possessing the lowest damage estimate ratios of all the school buildings evaluated.

One significant factor in earthquake performance is the building code standard to which a building was originally designed. The EPAT spreadsheet separates Washington State into zones where the design standards at the time of construction were different. Historically, western Washington and more specifically, the Puget Sound region, has had the strictest seismic code requirements. Buildings in the Puget Sound region were also designed for the highest level of earthquake shaking due to the high seismicity of the region. Buildings in the rest of Washington State were historically designed to lower seismic forces and detailing (toughness) standards.

Rapid Visual Screening Results

Table 6 shows the median, average, maximum, and minimum calculated FEMA P-154 Rapid Visual Screening (RVS) scores for the Phase 2 schools. RVS is a method of assigning a score to a building based on a building's basic features (building type, building age, soil type, seismicity, and structural irregularities). The primary intent of the scoring is to identify potentially hazardous buildings that require further seismic evaluation. There is no official cutoff score, but generally a score of 2.0 or less is used to identify buildings that require further evaluation. Lower scores indicate more hazardous buildings and higher scores indicate buildings that have less risk. Sixty-eight percent of the Phase 2 buildings possess an RVS score that is less-than-or-equal to 2.0, indicating that further evaluation work may be warranted to more accurately determine their seismic risk.

Table 6. Washington State schools RVS summary results for Phase 2 school buildings.

RVS Result	Value
Median Score	1.7
Average Score	2.1
Max Score	5.5
Min Score	0.3

Earthquake Performance Rating System Structural Safety Sub-Ratings (Star-Ratings) Results

Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined using the findings from the ASCE 41 Tier 1 seismic evaluation checklists. The EPRS is a five-star rating system, with one star being the lowest, or worst-performing buildings, and five stars being the highest, or best-performing buildings. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings based on the information available. Four percent of the school buildings assessed have two-star ratings and three percent of the school buildings have three-star ratings. Such a high percentage of one-star ratings was not surprising given that the criteria for selecting school buildings for this study was heavily weighted toward buildings that are older structures and lack the seismic durability and interconnection that more modern buildings have.

Most of the school buildings assessed in Phase 1 and Phase 2 are also considered “pre-benchmark” buildings, many of which were also built before Washington State adopted its first statewide building code in 1975. The buildings assessed were selected in large part because of their older age and need for seismic evaluation. Benchmark buildings are those that are considered compatible with “modern” building code provisions and designed and constructed to relatively recent building codes (typically buildings constructed in 1999 or later). ASCE 41 infers that Benchmark buildings, based on past observed earthquake damage, can be expected to provide Life Safety structural performance at a lower than current code seismic event. Consequently, it was expected that the vast majority of these buildings would have a preliminary one-star Structural Safety sub-rating.

In addition, many buildings assessed did not have existing drawings or limited site observation to confirm critical seismically desirable attributes such as complete load paths, out-of-plane wall anchorage, interconnection of structural components, and diaphragm integrity. This resulted in many ASCE 41 Tier 1 seismic screening checklist items being evaluated as Unknown (U). To be consistent with the EPRS Translation Procedure, the preliminary Structural Safety sub-ratings for this study considered Unknown conditions as Noncompliant (NC). These Unknown conditions being considered as Noncompliant resulted in many Structural Safety sub-ratings of one star, and therefore these Structural Safety star-ratings should not be used as an absolute condemnation of a building but instead as an indication that these buildings need further seismic investigation and analysis.

The overwhelming number of one-star Structural Safety ratings further reinforces the need to voluntarily upgrade or replace older buildings in high seismicity areas. It is highly encouraged and recommended that school districts and structural engineers further study the ratings and assessments of their oldest and most vulnerable buildings and discuss how best to improve the seismic safety of their school facilities. The use of the EPRS results is further discussed in the *Recommendations for Schools on How to Use These Data* section of this report.

Schools Located in Tsunami Inundation Zones

In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve over 10,000 students and while assessment of these buildings to withstand tsunami effects was not part of this study, it is the engineers' opinion that none of these buildings will be able to adequately resist the hydrostatic and hydrodynamic forces; waterborne debris accumulation and impact; and foundation subsidence and scour from a code-level maximum considered tsunami. Of these 67 buildings, 45 percent are wood-framed structures, 37 percent are masonry structures, 13 percent are concrete structures, and 4 percent are steel structures. Of the 30 school campuses located in tsunami inundation zones, only Ocosta Elementary School has a vertical evacuation structure for the safety of the students and school district faculty during a major tsunami event. In order for a school in a tsunami zone to be seismically safe, it is also our opinion that it needs to be designed to withstand the design level tsunami. Additionally, many school campuses in tsunami inundation zones are located in places with no high ground nearby. This means that even if the school building was able to withstand the earthquake shaking and the tsunami loads there would be nowhere for the students and staff to go to evacuate and be safe from the tsunami flooding.

Concept-Level Design and Cost Estimate Summary for Phase 2

Cost estimates were developed for the 17 school buildings selected to receive concept-level seismic upgrade designs as part of Phase 2 (Fig. 11). The buildings were selected from the list of both Phase 1 and Phase 2 schools. Initially, a list of high-risk school buildings was generated by the project team. Then, the school districts who owned those buildings were surveyed to see if they wanted to participate in receiving concept-level seismic upgrade designs. The intent was also to see if any work was already planned to occur on the buildings, to confirm that the buildings had not already received seismic upgrades, and to confirm that the school districts are not planning to replace the buildings in the next 10-15 years. Most school districts replied to the survey, but some did not. From an initial list of approximately 50 high-risk schools, 17 were selected. Additionally, the concept-level upgrade design school buildings were selected prior to the completion of the Phase 2 seismic evaluations, so not all the data from the Phase 2 seismic evaluations were available to review in selecting the buildings.

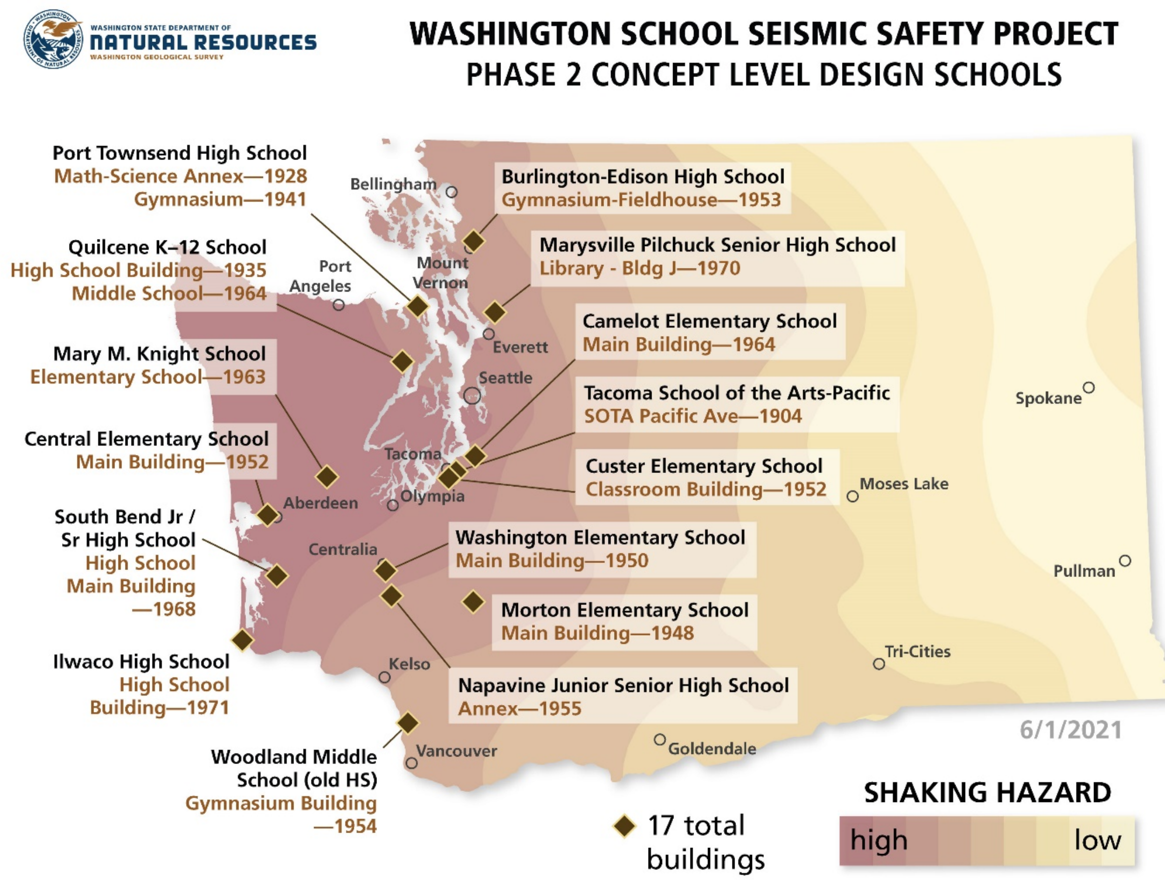


Figure 11. Map showing the location, names, buildings, and year built for the Phase 2 concept-level design school buildings. Basemap shows shaking hazard (modified from Petersen and others, 2015).

When the Phase 1 cost estimates were developed, the OSPI School Seismic Retrofit Program (SSRP) did not yet exist. As such, the Phase 1 cost estimates were not developed with the idea that they would be used as part of that program. The Phase 1 cost estimates only included estimates of the construction costs and did not include any soft cost items such as architecture/engineering design fees, project administration fees, building permitting fees, construction testing fees, or other fees. The Phase 1 cost estimates also did not include any escalation to account for inflation and cost increases over time because it was not known when/if construction would start. Conversely, the Phase 2 cost estimates were developed with the knowledge that the OSPI School Seismic Retrofit Program exists, and the project team worked closely with OSPI to develop cost estimates that could work within that program.

Even so, it is important to emphasize that the estimated costs developed for these buildings are preliminary in nature, as they are based on the results of the Tier 1 seismic screening checklists and engineering design judgment, and have not been substantiated by more detailed analyses. Relative to construction cost estimates that are based upon construction drawings prepared by architecture and engineering firms for a defined scope of work, these concept-level seismic upgrade reports constitute a pre-design level scope of information due to the screening level of engineering and field investigation. Thus, for cost estimating and contingency purposes, these concept-level seismic upgrade designs would be considered as a design that is approximately 1 percent complete. This is in comparison to a 30 percent schematic design cost estimate where a full architecture and engineering design team has spent significantly more time observing existing conditions, performing other assessment studies (such as hazmat abatement, accessibility, energy and so on), and coordinating with school districts to accurately define the scope and phasing considerations in developing a set of construction documents for a renovation project. The concept upgrade designs received some input and review from architects, however, no architectural design has been completed at this time. In addition, there has been no involvement from mechanical, electrical, or fire protection engineers. The estimated costs for the seismic upgrade will change as the designs are further developed.

For this preliminary assessment of probable costs, an estimate of the current year (2021) construction costs of the probable scope of work was developed. Then a -20 percent (low) to +50 percent (high) range variance was used to develop the construction cost estimate range for the concept-level scope of work. The -20 percent to +50 percent range variance guidance is from table 1 of the AACE International Recommended Practice 56R-08, *Cost Estimate Classification System for Class 5 Estimates*. The range of a Class 5 construction cost estimate is due to the limited design completeness of 0 percent to 2 percent and is defined as -20 percent to +50 percent as noted. It is unlikely that the actual construction costs will equal the median estimated cost values, but it is the intent that the actual construction costs will fall within the -20 percent to +50 percent ranges.

Cost estimates also factor in when the construction phase of a project will commence to account for escalation in construction costs. Because these cost estimates are used to assist OSPI and school districts with future funding requests or programming needs, it is not known at this time if or when these seismic upgrades will be implemented. To account for some cost escalation however, the cost estimates prepared for this study assume a mid-point of construction occurring at the end of 2022. The cost estimates were developed in the beginning of 2021 and escalated at a rate of 6 percent per year to the end of 2022, effectively adding a 12 percent markup to the 2021 cost estimates.

Soft costs were included in the cost estimates as 40 percent of the estimated construction costs. Soft costs can include things like the owner's general overhead costs, project management costs, financing/bond costs, administration/contract/accounting costs, review of plans, value engineering studies, equipment, fixtures, furnishings and technology, and relocation of the school staff and students during construction. The soft costs used for the projects that total 40 percent are:

A+E Design	10%
QA/QC Testing	2%

Project Administration 2%

Owner Contingency 11%

Average Washington State Sales Tax 9%

Building Permits 6%

It is normal for soft costs to vary from owner to owner. However, based upon the engineering firm's experience in K–12 school projects in Washington, a 40 percent of the probable construction cost was incorporated in the cost estimates as a reasonable and appropriate soft cost allowance for budgeting purposes. Therefore, it is also strongly suggested that each owner develop their own soft costs as part of their budgeting process and not rely solely on the recommended percentage that is stated here.

Table 7 lists the estimated total cost of each seismic upgrade concept design for Phase 2 buildings. The costs listed include both construction costs and soft costs.

Table 7. Seismic upgrade total cost summary grouped by building type (Construction Costs + Soft Costs).

School District, School Building, Bldg. Type	Original Date of Constr.	ASCE 41 Level of Seismicity / Site Class	Perform. Objective	Bldg. Gross Area (SF)	Total Upgrade Cost Range $/SF (Total)			Median Total, $/SF (Total)
Hoquiam, Central Elementary School, Main Building, **Reinforced Concrete**	1952	High / D	Life Safety	38,946	$110 ($4.27M)	-	$205 ($8.01M)	$137 ($5.34M)
Morton, Morton Elementary School, Main Building, **Reinforced Concrete**	1948	High / C	Life Safety	12,360	$182 ($4.60M)	-	$342 ($8.62M)	$228 ($5.75M)
Quilcene, Quilcene K–12 School, High School Building, **Reinforced Concrete**	1935	High / D	Life Safety	7,860	$199 ($1.59M)	-	$373 ($2.99M)	$249 ($1.99M)
Concrete Shear Wall	*1945*			*25,653*	*$164*	-	*$307*	*$205*

Averages								
Burlington-Edison, Burlington-Edison High School, Gym/Fieldhouse Building, **Reinforced Masonry**	1953	High / D	Life Safety	50,133	$100 ($5.00M)	-	$187 ($9.37M)	$124 ($6.25M)
Centralia, Washington Elementary School, Main Building, **Reinforced Masonry**	1950	High / D	Life Safety	51,063	$151 ($7.73M)	-	$284 ($14.49M)	$189 ($9.66M)
Mary M. Knight, Mary M. Knight School, Elementary School Building, **Reinforced Masonry**	1963	High / D	Life Safety	13,333	$91 ($1.22M)	-	$171 ($2.29M)	$114 ($1.53M)
Marysville, Marysville-Pilchuck High School, Library (Building J), **Reinforced Masonry**	1970	High / D	Life Safety	19,772	$131 ($2.59M)	-	$245 ($4.85M)	$163 ($3.23M)
Reinforced Masonry Averages	*1959*			*33,575*	*$118*	-	*$221*	*$148*
Port Townsend, Port Townsend High School, Gym Building, **Unreinforced Masonry**	1941	High / D	Life Safety	34,112	$49 ($1.68M)	-	$92 ($3.15M)	$61 ($2.10M)

Port Townsend, Port Townsend High School, Math-Science Annex, **Unreinforced Masonry**	1928	High / D	Life Safety	13,169	$90 ($1.19M)	-	$169 ($2.24M)	$113 ($1.49M)
Tacoma, Tacoma School of the Arts, Pacific Building, **Unreinforced Masonry**	1904	High / C	Life Safety	21,601	$275 ($5.94M)	-	$516 ($11.14M)	$344 ($7.43M)
Woodland, Woodland Middle School, Gymnasium Building, **Unreinforced Masonry**	1954	High / E	Life Safety	15,202	$193 ($4.47M)	-	$363 ($8.38M)	$242 ($5.58M)
Unreinforced Masonry Averages	*1932*			*21,021*	*$152*	-	*$285*	*$190*
Clover Park, Custer Elementary School, Classroom Building, **Wood Framed**	1952	High / D	Life Safety	40,304	$179 ($7.23M)	-	$336 ($13.55M)	$224 ($9.04M)
Federal Way, Camelot Elementary School, Main Building, **Wood Framed**	1964	High / C	Life Safety	41,111	$112 ($4.61M)	-	$210 ($8.65M)	$140 ($5.76M)
Napavine, Napavine Jr/Sr High School, Annex Building, **Wood Framed**	1955	High / C	Life Safety	11,274	$87 ($988K)	-	$164 ($1.85M)	$109 ($1.24M)

Quilcene, Quilcene K-12 School, Middle School Building, **Wood Framed**	1964	High / C	Life Safety	9,438	$156 ($1.48M)	-	$293 ($2.78M)	$195 ($1.85M)
South Bend, South Bend Jr/Sr High School, HS Main Building, **Wood Framed**	1968	High / E	Life Safety	34,400	$152 ($5.23M)	-	$285 ($9.81M)	$190 ($6.54M)
Ocean Beach, Ilwaco High School, Main Building, **Wood Framed**	1970	High / D	Life Safety	89,249	$131 ($12.20M)	-	$246 ($22.88M)	$164 ($15.26M)
Wood Framed Averages	*1962*			*36,933*	*$136*	-	*$256*	*$170*
OVERALL AVERAGES	**1951**			**30,967**	**$141**	**-**	**$264**	**$176**

A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations. Seismically upgrading a roof diaphragm with a plywood sheathing overlay on older tongue-and-groove roof decking, for example, can be done as part of a future re-roofing project where over 90 percent of the cost would be to remove and replace the nonstructural roofing system.

The median estimated cost to seismically upgrade the 32 school buildings that received the concept level design study ranged from $63,000 to $5,000,000 in Phase 1 and from $1,240,000 to $15,260,000 in Phase 2. It should be noted that the Phase 1 costs do not include soft costs or escalation to the year 2022. The Phase 1 costs are construction costs only. In addition, the Phase 1 concept upgrade schools included several schools in moderate seismicity areas and low seismicity areas. Consequently, the costs from Phase 1 and Phase 2 are not directly comparable.

Extrapolation of Phase 2 Concept-Level Seismic Upgrade Design Costs to Other School Buildings

The State of Washington has over 4,000 permanent K–12 school buildings. Hundreds of school buildings have been built in Washington State every decade starting in the 1950s. Prior to the 1950s, on average, between 25 and 90 school buildings were built each decade. Buildings built in similar time periods tend to have similar construction types and tend to have been built with similar construction methods. It is reasonable to believe that there will be similarities in costs to seismically upgrade buildings of similar construction type that were built in similar eras. Costs can vary and caution should be taken when extrapolating costs from one building to the next. Nonetheless, it is our opinion that the buildings that received concept-level upgrade designs and cost estimates as part of this study have sufficient similarities that this information can be reasonably extrapolated for similar types of school buildings across Washington State. All concept upgrade designs in Phase 2 of this study were developed with the intent of upgrading buildings for the Life Safety Performance Objective (Table 3) and all buildings are located in high seismic zones as defined by ASCE 41. Table 8 indicates the range of features for each building type included in the study to receive concept-level upgrade designs. The costs listed include both construction costs plus soft costs. The low cost listed is the lowest cost value from the study's cost estimates for the building type using the -20 percent variance. The high cost listed is the highest cost value from the study's cost estimates for the building type using the +50 percent variance. There is a high likelihood that other buildings in Washington State whose features match the ranges of the buildings listed in Table 8 will have total seismic upgrade costs that fall within the ranges listed.

In reviewing ICOS data provided by OSPI, over 1,000 recognized and permanent school buildings were built 1960 and earlier, 70 percent of which are west of the Cascade mountains and in relatively higher seismic areas. Of these roughly 700-plus buildings west of the Cascades, over 300 buildings have no record in ICOS of having modernizations done to them since their original construction, totaling approximately 10 million square feet. Applying extrapolated ranges of cost in Table 8 below, retrofitting or replacing the state's oldest and most vulnerable buildings is a multi-billion dollar endeavor that will also need the support of communities in the form of passing capital bonds and levies.

Table 8. Extrapolated range of total seismic upgrade costs for certain building types (Construction Costs + Soft Costs).

Building Type	Date Range of Buildings in Study	ASCE 41 Level of Seismicity	Bldg. Square Footage Range (SF)	Total Upgrade Cost Range (Low-High) $/SF		
Reinforced Concrete	1935–1952	High	7,860–38,946	$110	–	$373
Reinforced Masonry	1950–1970	High	13,333–51,063	$91	–	$284
Unreinforced Masonry	1904–1954	High	13,169–34,112	$49	–	$516
Wood Framed Construction	1952–1970	High	9,438–89,249	$87	–	$336

Prioritized Rankings of Phase 1 and 2 School Buildings by Relative Risk

Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Engineering judgment was used to assign buildings to one of four categories: Very High Priority, High Priority, Moderate Priority, and Lower Priority (Figures 12–15 and for the full lists see *Appendix C*). The prioritization of schools compares buildings to one another by selected parameters using engineering judgment. The parameters for building comparison include: building construction date, construction type, level of site seismicity, extents of previous seismic upgrade work (if any), soil liquefaction potential, EPRS Structural Safety star rating, EPAT expected building damage, FEMA 154 RVS score, and an ASCE 41 Tier 1 checklist percent of "noncompliant" or "unknown". A small adjustment was made for buildings of larger square footage to slightly prioritize larger buildings over smaller ones with the idea that more people may be at risk in buildings of larger area. Finally, the engineers who evaluated each building also used their judgment to adjust the building category, if they felt the scoring system did not accurately capture the building risk. See *Appendix C* for a more detailed description of the prioritized ranking scoring system used and the final prioritized lists.

Table 9 lists the prioritization categories, the definition of the category, and the types of buildings that are typically in each category. Figures 12 through 15 show the spatial distribution of these buildings and those that received concept-level design studies in phases 1 and 2.

Table 9. Prioritized building ranking categories summary.

Prioritization Category	Category Definition	Typical Buildings in Category
Very High Priority	These buildings have the highest seismic risk and have a clear and strong need to receive seismic upgrades. The benefits of seismic performance and structural integrity gained by performing seismic upgrades are likely to significantly exceed the cost of the upgrades by a large margin.	Typically unreinforced masonry buildings and non-ductile concrete buildings built before the 1960s and located in high seismic zones. Some very high risk reinforced masonry buildings are also in this category.
High Priority	These buildings also have a strong need to receive seismic upgrades and would greatly benefit from voluntary seismic upgrades or seismic improvements that are incorporated with other systems upgrade projects or modernizations. The benefits of seismic performance and structural integrity gained by performing seismic upgrades likely	Typically reinforced masonry and wood buildings built in the 1950s, 1960s, and 1970s and located in high seismic zones. Some unreinforced masonry buildings located in moderate and low seismic zones are also included in this category.

	exceed the cost of the upgrades.	
Moderate Priority	These buildings are not as high risk as the buildings in the High and Very High categories. Depending on level of seismicity, some buildings may or may not have a need to receive seismic upgrades. In areas of high seismicity, these buildings would still benefit from voluntary seismic upgrades that may be able to achieve seismic performance similar to modern buildings. However, the financial benefits of seismic upgrades may or may not exceed the costs.	Typically, buildings of various construction types built in the 1960s through the 1990s located in high, moderate, and low seismic zones.
Lower Priority	The benefits of seismic performance and structural integrity gained by performing seismic upgrades would likely not exceed the costs. Some buildings in this category already meet the Life Safety structural performance objective and were built to modern seismic standards where seismic upgrades would not be needed.	Typically buildings of various construction types built in the 1980s through the 2010s located in high, moderate, and low seismic zones.

The following are some notes and caveats about the prioritized rankings.

1. The list of buildings only includes school buildings assessed in Phase 1 and Phase 2 of the Washington State School Seismic Safety Project. This represents approximately 12 percent of recognized school buildings in the ICOS database. Prioritization of the rest of the schools in Washington State requires further study and updates to the information in ICOS.
2. The main seismic evaluation portion of this study evaluated buildings using ASCE 41 Tier 1 procedures. In addition, many buildings had incomplete information, which required the assessment team to make notes where items were unknown. Tier 1 procedures are typically the first step taken in identifying building-specific seismic risks. However, Tier 1 evaluations must be followed up with ASCE 41 Tier 2 or Tier 3 evaluations prior to conducting seismic upgrades. In addition, the buildings have not been evaluated by architects, mechanical engineers, electrical engineers, fire protection engineers, or geotechnical engineers. Further assessments by a structural engineering and architectural/engineering team are required to further determine the extent of seismic upgrades and the building-specific benefits and costs of seismic upgrades.
3. Data used for prioritizing the school buildings assessed in this study were gathered from 2018–2021. Some school buildings listed are undergoing renovations or have subsequently been upgraded, modernized, or seismically improved voluntarily. These buildings should move down

on the priority list once the seismic improvements are implemented and reviewed by a structural engineer.

4. Whether or not a building was located in a tsunami inundation zone was not used as a component of the development of the prioritized rankings. Buildings that are located in tsunami inundation zones may need to be further evaluated to determine the optimum course of action. In many cases, it may be more cost effective to relocate a school outside of a tsunami inundation zone than to upgrade the building. Alternatively, constructing purpose-built tsunami vertical evacuation structures or hardening evacuation routes may be a cost-effective way to improve the survivability of people located in tsunami inundation zones. In these cases, seismically upgrading buildings with the purpose of allowing people to evacuate and reach higher ground may be appropriate. Evaluation of tsunami hazards was outside the scope of this project. It may be appropriate to evaluate structural loads from tsunamis in future studies.
5. The table that lists the prioritized rankings categorizes buildings into one of four categories. Within each category, the school buildings are listed alphabetically. Alphabetization was chosen to provide some amount of organization to the table. The buildings in each category should be construed as possessing approximately equal risk to one another. That is, the buildings within each category are not further prioritized beyond each of the four categories.
6. Some buildings within the study have multiple additions constructed over multiple years. In addition, different portions of the same building may be constructed of multiple structural building types. Generally, the highest risk portion of each building was used to prioritize the buildings. It may be the case that only part of a building is the highest risk portion, with other portions of a building being less at-risk.

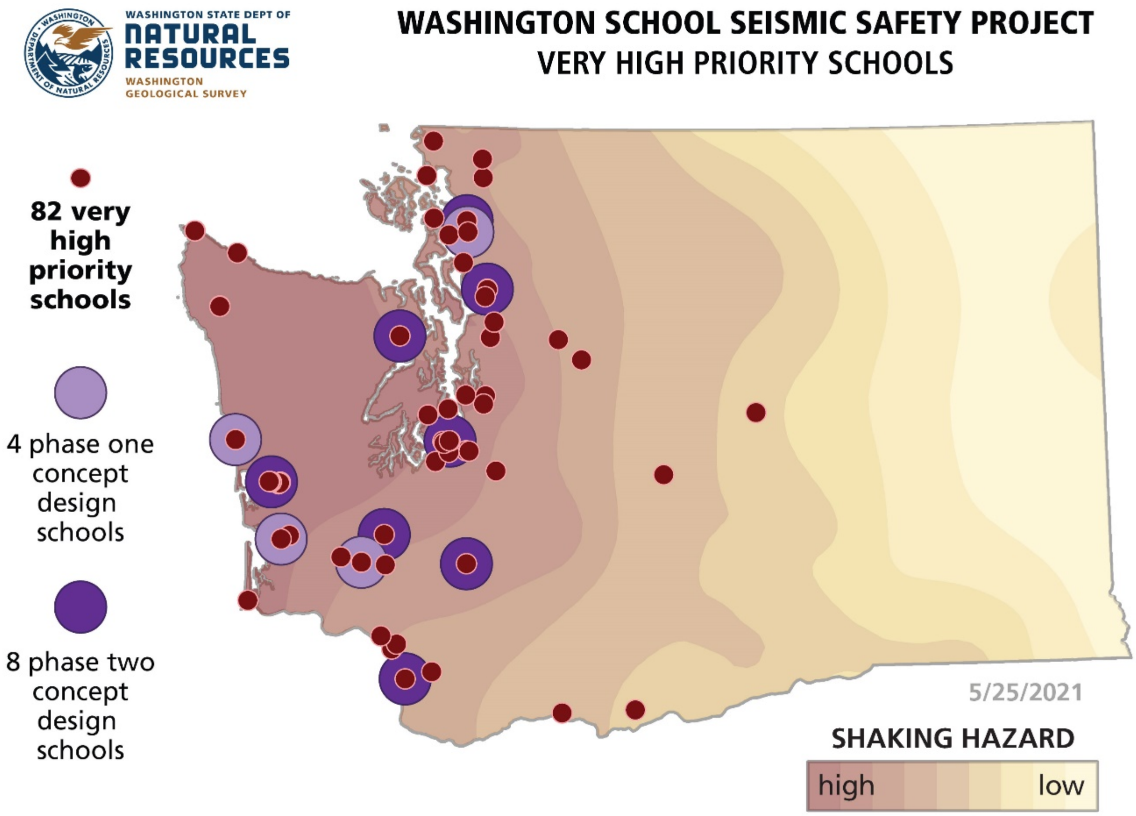


Figure 12. Map showing the very high-priority schools (dark red dots) and those which received concept-level designs in Phase 1 (light purple) and Phase 2 (dark purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).

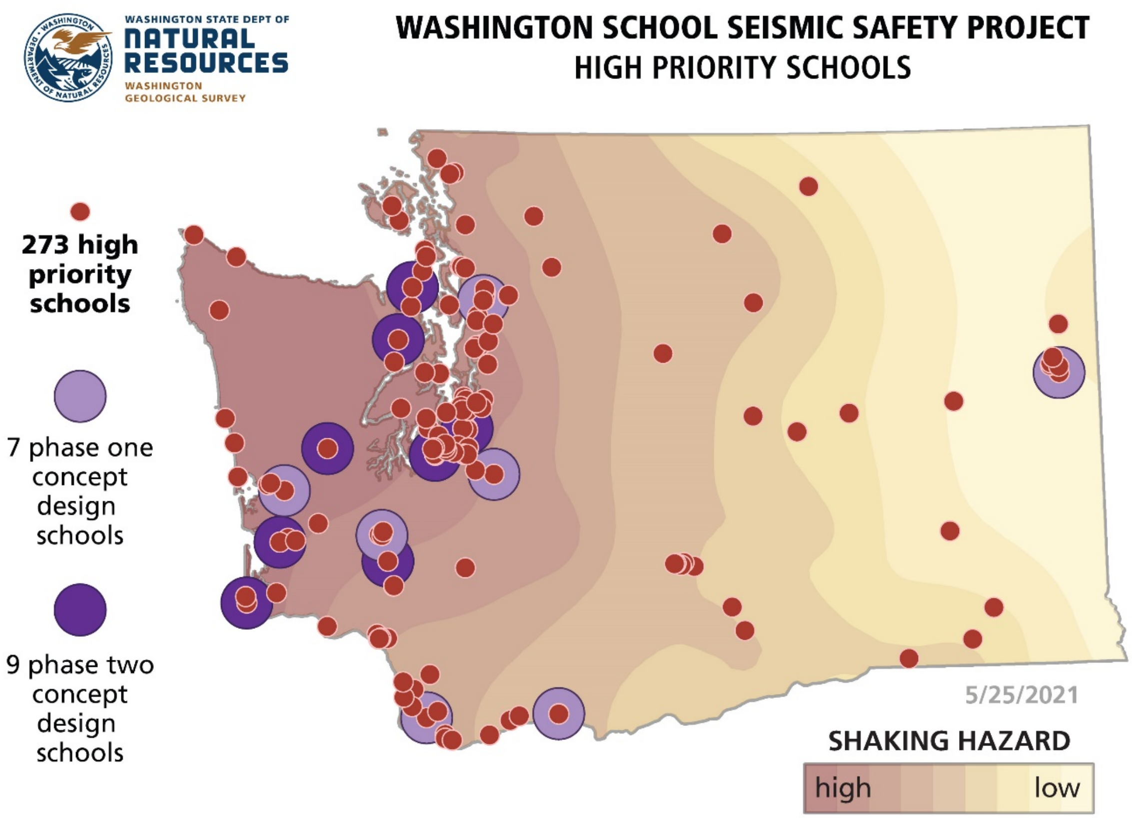


Figure 13. Map showing the high- priority schools (red dots) and those which received concept-level designs in Phase 1 (light purple) and Phase 2 (dark purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).

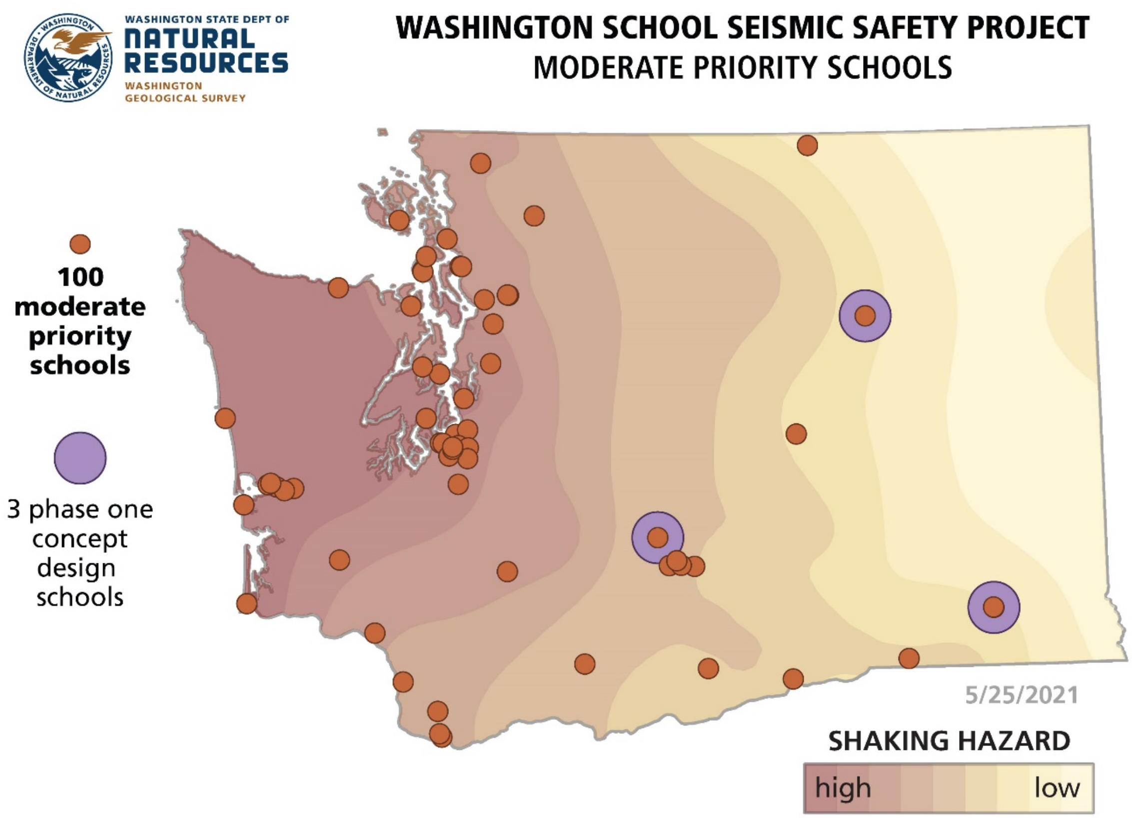


Figure 14. Map showing the moderate-priority schools (orange dots) and those which received concept-level designs in Phase 1 (light purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).

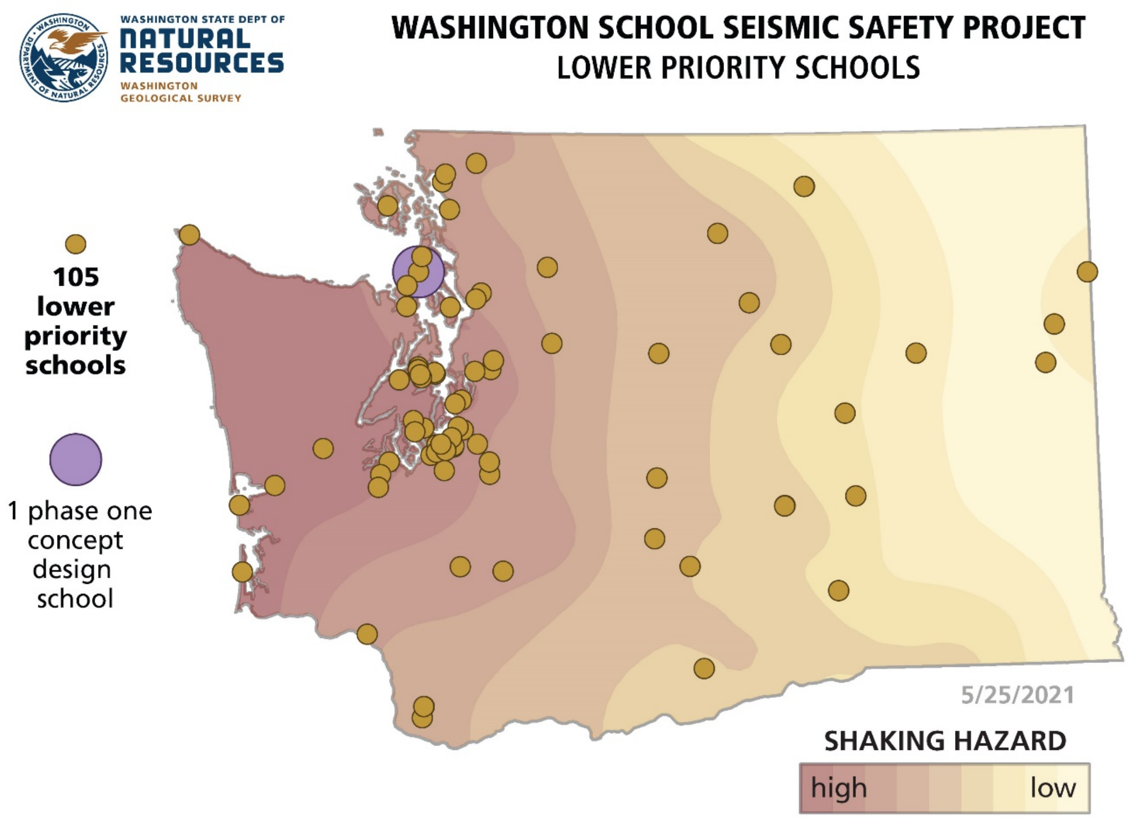


Figure 15. Map showing the lower priority-schools (yellow dots) and those which received concept-level designs in Phase 1 (light purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).

Conclusions

Below is a summary of high-level findings from Phases 1 and 2 combined.

- Washington State has many older school buildings built prior to the adoption of modern seismic safety codes. Older and more vulnerable construction types are more susceptible to earthquake damage and have a greater percentage of seismically noncompliant structural and non-structural components.
- Unreinforced masonry buildings constructed before the 1940s and non-ductile concrete buildings (without seismic upgrades) constructed before the mid-1970s located in high seismic hazard areas are especially vulnerable to collapse during earthquakes. The risks of these buildings should be mitigated as soon as practical.
- Older school buildings built prior to 1975 and constructed out of reinforced masonry and wood frame materials are vulnerable to collapse.
- Geologic site class measurements showed that 59 campuses of the 245 studied have a measured site-specific site class that differs from the predicted site class based on reconnaissance-scale mapping. The more accurate site-specific measurements help to inform detailed engineering plans and affect building costs.
- In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve more than 10,000 students. Tsunami loads and impacts were not considered in the geologic or engineering assessments. For schools to be safe from a tsunami, they would need to be moved from the tsunami inundation zone or designed to withstand tsunami loads with options for vertical evacuation.
- Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined using the findings from the ASCE 41 Tier 1 seismic evaluation checklists. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings based on the information available. Four percent of the school buildings assessed have two-star ratings and 3 percent of the school buildings have three-star ratings.
- The concept-level seismic upgrade design results indicate that for many buildings, the cost to seismically upgrade the structure will cost less than the costs to repair major damage following an earthquake, or significantly less that the cost to replace an irreparably damaged building. For less vulnerable structures, especially structures in low seismicity areas, however, it may not be financially worth implementing seismic upgrades.
- Seismically upgrading a vulnerable structure will generally make the building stronger, stiffer, safer, and more resilient, therefore decreasing the damage costs the building will incur in an earthquake.
- A range of cost estimates were developed for each of the select buildings that received a concept-level designs and estimated costs to retrofit. Phase 1 concept level design building cost estimates ranged from a median of $63K to $5.01M, where the median represents the range of cost estimates for a single building. Phase 2 median concept level design building cost estimates ranged from $1.24M to $15.26M. Cost estimate methods for Phase 2 were improved from Phase

1 and now include projected soft costs. Phase 1 concept design schools were selected to represent a variety of building construction types and vintages in different seismic hazard areas. Alternatively, Phase 2 concept design schools were selected based on available information to be some of the highest risk buildings based on seismic hazard and engineering design.

- A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations.
- Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Of the 561 buildings studied, 63 percent were high or very high priority, 18 percent were moderate priority, and 19 percent were lower priority.
- The EPAT data show that the median building is expected to be 55 percent damaged in a design-level earthquake (Table 10). EPAT also estimates that the majority of buildings in this study are expected to receive a "Red—Unsafe" post-earthquake building safety placard following a design-level earthquake, meaning that they will be unsafe to occupy. In addition, the EPAT data show that approximately one-half of buildings studied will not be repairable following a design-level earthquake, and will require demolition. The EPAT results are summarized in Table 10 and results for Phase 1 and 2 building damage estimates are shown in Figure 16 below.

Table 10. Washington State schools EPAT summary results for Phase 1 and Phase 2 school buildings combined.

EPAT Calculated Value	Median	Average	Max	Min
Building damage estimate ratio (Amount of building that is damaged)	55%	51%	95%	6%
Probability building is not repairable	50%	47%	96%	2%
Life safety risk level	High	-	Very High	Very Low
Most likely post-earthquake tagging	Red*	-	Red*	Green*

**Red = Unsafe to Occupy, Yellow = Restricted Building Access, Green = No Restrictions on Building Access.*

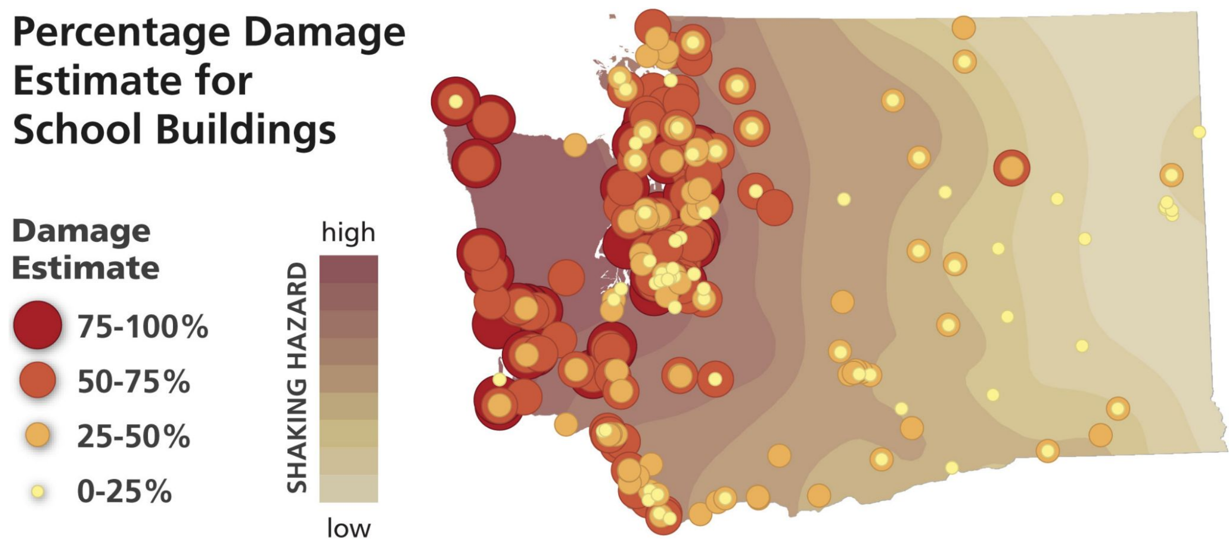


Figure 16. Map of Washington showing school buildings assessed in Phase 1 and 2, symbolized by percent damage estimate using the EPAT tool. Basemap shows shaking hazard (Modified from Petersen and others, 2015).

Information for Schools on How to Use Reports and Data

All of the data generated from these studies were provided to the districts and schools that participated in this project. The following are the major deliverables and a summary of their intended use that were sent to each district and school as part of Phase 2 of this project:

1. A copy of this **legislative report** summarizing the methods and major findings of the project. This report may be useful to get a high-level understanding of the geologic and engineering assessments and how their individual schools fit into the larger study. For schools that participated in Phase 1, the Phase 1 report and appendices were sent to them in June 2019.
2. The final engineering reports summarizing the results of the seismic screenings, available via the following links and also in *Appendix B* of this report:
   a. Volume 1: Seismic Assessment Report—This volume provides an overview of the engineering seismic assessments, which is useful for understanding the process and all of the information included in the school reports.
   b. Volume 2: EPAT & FEMA 154 RVS Summaries—This volume presents the results of the EPAT worksheets and Rapid Visual Screenings.
   c. Volume 3: ASCE 41-17 Screening Reports—This volume presents the results of the ASCE 41-17 assessments at 339 school buildings.
   d. Volume 4: Seismic Upgrades Concept Design Reports, 17 School Buildings—This volume presents the results of the concept-level seismic upgrade designs conducted for 17 school buildings. These reports provide information on the designs, costs, and suggested upgrades that were included in the concept design reports.
3. The individual geologic site class assessment reports for each of the school campuses. These are useful for understanding the local geology at your school campus and for learning about any other potential geologic hazards near the school. These reports are included in *Appendix A* of this report.

Per the state building code, a school district is under no obligation to upgrade its school buildings to the suggested upgrade recommendations presented here unless there is: (1) a change in use or occupancy, (2) an addition that is attached to the existing building and increases the seismic demands on the lateral system, (3) an alteration to a work area exceeding 50 percent of the building area, or (4) an alteration made to the structure's lateral system that would trigger such upgrades. An important thing to also note is that modernizations (that only alter architectural, mechanical and electrical components of a building) often do not count as a significant alteration, therefore, structural seismic upgrades are often not required when nonstructural modernizations occur.

Earthquake Performance Rating System Reporting Recommendations for Use

The goal of this study was to inform school districts of the seismic deficiencies of their buildings and possible ways to mitigate them. As stated earlier, a lesson learned from Phase 1 was that the screening reports were complicated to a non-engineering audience; in this phase the study team attempts to simplify the engineering jargon from the ASCE 41 Tier 1 checklists in order to (1) let school districts know where their buildings stand with regards to seismic safety, and (2) let them know the most important seismic deficiencies that need to be mitigated or further investigated to improve the seismic safety of the school buildings assessed. The 'Earthquake Performance Rating System (EPRS) ASCE 41-13 Translation Procedure' was chosen to help communicate and prioritize the seismic deficiency mitigation in the seismic screening reports. This process extracts evaluation items (building components) from the ASCE 41 Tier 1 checklists that need to be determined as "Compliant" in order to increase a building's structural safety rating from a one-star rating (risk of collapse in multiple or widespread locations) to a two-star rating (risk of collapse in isolated locations) and then to the recommended goal of a three-star rating (the Life Safety structural performance objective). Extracting and categorizing these evaluation items in this manner creates a prioritized list of seismic deficiencies, as shown in Figure 17. This is intended to be used as a mitigation strategy to provide further engineering investigation and analysis, and seismic improvement projects (either done voluntarily or as part of a modernization), to increase the seismic safety of the building and consequently increase its structural safety risk rating. The risk rating and prioritized list of deficiencies are provided to schools in their individual building screening reports.

Table -5. Identified Seismic Evaluation Items to Address for an improved ★★ 2-STAR Rating

Evaluation Item	Tier 1 Screening	Description
Vertical Irregularities	Noncompliant	It does not appear that vertical elements are continuous to the foundation. Further investigation should be performed prior to retrofit. Lateral system strengthening, such as infilling with CMU or adding new shear walls or braced frames may be appropriate to mitigate seismic risk.
Wall Anchorage	Noncompliant	Out-of-plane wall anchoring is not present based on structural drawings provided. Further investigation should be performed prior to retrofit. Diaphragm reinforcement, including tension ties, blocking, strapping, and diaphragm nailing to provide out-of-plane connection at masonry walls may be appropriate to mitigate seismic risk.
Wood Ledgers	Noncompliant	Connections that induce cross-grain bending in wood ledgers are present. Strengthening of connections through the addition of blocking and anchor straps may be appropriate to mitigate seismic risk.
Transfer to Shear Walls	Unknown	Likely noncompliant condition based on year of construction for pre-benchmark building. Further investigation should be performed.
Cross Ties	Noncompliant	There are no continuous cross ties between diaphragm chords. Further investigation should be performed prior to retrofit. The addition of new cross ties between diaphragm chords or the addition of strap plates to connect existing framing members together may be appropriate to mitigate seismic risk.
Diagonally Sheathed and Unblocked Diaphragms	Noncompliant	Diaphragm is unblocked with spans greater than 40 feet in locations. Further investigation should be performed prior to retrofit. Diaphragm strengthening through the addition of blocking or additional diaphragm nailing may be appropriate to mitigate seismic risk.

Table -6. Identified Seismic Evaluation Items to Mitigate or Further Investigate for an improved 3-STAR Rating

Evaluation Item	Tier 1 Evaluation	Description
Adjacent Buildings	Unknown	Limited existing drawings and inadequate access to verify. Further investigation should be performed. Diaphragm reinforcement, shear wall addition, or tying joints together may be appropriate to mitigate seismic risk.
Reinforcing Steel	Noncompliant	The masonry walls are under-reinforced and will likely need to be strengthened for in-plane and out-of-plane seismic loads. FRP or new shear walls may be appropriate to reduce in-plane demand. Steel strongbacks may be appropriate to strengthen out-of-plane capacity.

Figure 17. EPRS output screening reports highlighting an example of a building's evaluation items (building components) that could be retrofitted for the building to increase to either a two-star rating (top) or a three-star rating (bottom).

Incorporating Seismic Data into School Safety Plans

DNR, in coordination with OSPI, delivered all of the engineering and geology results to the participating schools and districts. The information in these documents can be useful for safety planning. Both DNR and OSPI are available for assistance incorporating this information into safety plans as requested. When OSPI meets with districts to help them develop comprehensive safety plans, they encourage them to use geologic hazards in their planning efforts.

Recommendations

Recommendations for Future Studies and Evaluations

The School Seismic Safety Project (Phases 1 and 2) has been an important opportunity to study and evaluate 561 school buildings across the state. These assessments have characterized the seismic risk at ~12 percent of Washington's permanent, public K–12 school buildings and demonstrated the need for dedicated funding for seismic retrofits. We have learned a great deal about different methods for assessing risk, and there is still a great deal more to be done. This section summarizes some of the major recommendations for continuing to assess seismic risk for Washington Schools (Table 11). They are ordered based on our recommendation for greatest impact for life safety of school building occupants and priority for school seismic safety.

Table 11. Recommendations for future studies and evaluations for the school seismic safety of Washington's schools.

Recommendation	Description
A study to evaluate the feasibility and cost benefit of increasing the seismic performance for the design of new school buildings to enhance the seismic resilience of communities.	A well-known trend is that with each building code cycle, new discoveries in geology and lessons learned from recent earthquakes generally result in increases in seismic design forces and more stringent seismic design requirements. It is also understood that incorporating structural enhancements into the design of new buildings has high benefit-to-cost ratios. The first and main benefit is that a building designed and constructed above minimum building code standards will result in better seismic performance. This provides added safety for the building occupants and increases the likelihood that the building can be re-occupied following an earthquake. A second benefit is that enhanced seismic systems above minimum code standards will also better adapt the building to future building codes and seismic design requirements. Both benefits in turn will improve the seismic resiliency of the school buildings themselves and thereby the resiliency of the communities they serve. A simple way to do this is to encourage school buildings, or portions thereof, to be structurally designed to a higher Risk Category IV (similar to that of essential facilities) instead of what buildings codes currently require: Risk Category II for school buildings with 250 or less occupants, or Risk Category III for school buildings with greater than 250 occupants. Additional ways to enhance the seismic performance such as performance-based design and resiliency-based design can also be encouraged at the state and local levels in further protecting some of the most publicly used buildings in the communities.
A study to identify which schools in tsunami	Tens of thousands of Washington students go to school in areas subject to tsunami inundation during a large earthquake. Not only are these

inundation zones need vertical evacuation structures.	structures not designed to withstand tsunami loads, many of these schools are in locations where there are no evacuation options from tsunamis. In addition to seismically upgrading these facilities, it is our recommendation that there be a comprehensive assessment to determine which schools would need vertical evacuation structures to ensure students would have a safe place to evacuate in case of a tsunami.
A study of school sites suspected of having moderate to high risk of liquefiable soils, to determine cost-efficient methods of assessing the risk, and identify mitigation strategies for existing school buildings on liquefiable soils.	More subsurface investigation is required to confirm the presence of liquefiable soils and to anticipate what the liquefaction-induced settlements would be across a site or across a given building. This type of additional investigation typically requires deep exploration borings, soil testing, groundwater determination, liquefaction hazard analyses, and additional geophysics; these are then applied to the design parameters for the seismic design or retrofit of a building. This type of enhanced subsurface investigation can be costly for school districts and the State to incur when applied to existing school sites that are suspected of having moderate to high risk of liquefiable soils. A geologic study that includes licensed geotechnical engineers with expertise in liquefaction hazard analysis and mitigation will help provide the State with: More accurate assessments of liquefaction risks at existing school buildings suspected of having liquefiable soils. Cost-efficient methods and strategies in determining the level of liquefaction risk, leveraging the Vs30 measurements already gathered from previous geologic studies (that include the school sites in Phase 1 and Phase 2 of this study). Strategies and rough order of magnitude costs to mitigate liquefiable soils or to enhance and strengthen existing different types of building foundation systems to attain a Life Safety Performance Objective in considering post-earthquake liquefaction-induced settlements.
Conduct a statewide inventory of school districts to collect data about which facilities have already had seismic upgrades.	Many school districts have already completed seismic retrofits on many of their most vulnerable buildings. These retrofit projects are not necessarily captured in OSPI's ICOS database. In order to fully understand what needs to be done to complete seismically retrofitting our most vulnerable buildings, we need to understand what has already been done. This recommendation would allow OSPI to survey school districts to collect the engineering designs and costs for these upgrades to complete the seismic safety inventory process.
Continue to update OSPI's ICOS database with structural and seismic information about each school building (construction type, year of	Prior condition assessment reports, area plans, and Study and Survey information in OSPI's ICOS database can be used to perform RVS and EPAT as the first step in identifying buildings that could use a further detailed ASCE 41 Tier 1 Seismic Evaluation. This requires trained input of structural building data gathered by architects and engineers through visiting the buildings or reviewing available existing drawings and geotechnical reports. Also, cataloging building description and

construction, previous seismic upgrades, site class, seismicity, seismic irregularities).	construction history narratives, similar to many of the older Study & Survey information, will be extremely valuable to engineers and facility managers in understanding the structural history of the buildings being assessed, a history that often spans multiple generations and school district personnel. These data will be instrumental for future seismic retrofit projects.
Continue doing ASCE 41 Tier 1 seismic evaluations of school buildings.	ASCE 41 Tier 1 Seismic Evaluations continue to be the preferred structural engineering standard to identify seismic deficiencies specific to each building and can be used to provide a seismic mitigation strategy to school districts. RVS and EPAT can be used as an initial metric to prioritize buildings that should get further Tier 1 seismic evaluations, however engineers will need to review existing drawings and perform field investigations to adequately assess the seismic safety of a school building.

Recommendations to Enhance School Seismic Safety and Resiliency

Following the Phase 1 study and report that was published in 2019, the 2020 Supplemental Capital Budget appropriated $13.24M to OSPI for the School Seismic Safety Retrofit Program (SSSRP) signed into law by the Governor on April 2, 2020. We commend the State on taking action in creating the SSSRP and for publicly funding the design and construction for the seismic upgrades of the selected school buildings. The assessment team further commends the State's effort in further funding this program in the 2021–2023 capital budget for an additional $40M to continue providing funding to seismically upgrade some of the state's more seismically vulnerable buildings. Additionally, state funding was allocated to DNR for conducting site class assessments at school campuses that are participating in OSPI's Study and Survey program. These site class assessments in conjunction with the enhanced Study and Survey funding for RVS and EPAT assessments will help to further our understanding of school seismic risk.

The SSSRP and DNR's recent work is already paying off. Based on Phase 1 results and the 2020 Supplemental Budget for OSPI's SSSRP funding, Centralia School District's Edison Elementary School is expected to begin the installation of its seismic retrofit in June, 2021. Edison Elementary School will be the first school in the state to install a seismic retrofit under the SSSRP. North Beach School District's Pacific Beach Elementary Gym Building is expected to begin the installation of their seismic retrofit shortly after. In addition, there are many schools ready to begin their seismic retrofits in the near future, as funding permits.

Despite some progress, there are still many more buildings that need seismic improvements, and a lot of school districts in need of state-level funding. OSPI's new SSSRP is a tremendous push toward a long-term program in providing seismically safe public school buildings. The results of this study are very useful in determining which buildings are the highest priority and provide valuable guidance for how the

SSSRP could begin prioritizing other similar schools that did not receive an assessment as part of this project. Additionally, the costs that are presented as estimates in the concept level design studies are valuable for estimating the amount it may take to seismically retrofit the selected school buildings. However, it is our recommendation that the SSSRP develop a panel of experts to advise the program on spending and how to estimate actual construction costs based on inflation, soft costs, and other factors. It is our recommendation for OSPI to continue to consult with other states or educational agencies such as Oregon, California, and Alaska (Anchorage School District in particular), to enhance the way the SSSRP is administered and awarded. And, it is our recommendation that the SSSRP eventually includes an application process by which school districts can submit seismic upgrade designs and objectives, and potentially qualify to receive seismic upgrade funding from the State based on a benefit-costs determination.

Washington State spends millions of dollars in each biennium to modernize schools. For the most part, these modernization projects do not (and are not required to) include seismic upgrades. A substantial cost of seismic upgrades is the removal and replacement of architectural, mechanical, electrical and plumbing systems. This study shows that if seismic upgrades are combined with modernizations, the costs of seismic upgrades can be reduced, on average, by 70 percent. Combining seismic upgrades with modernizations has the potential to save Washington State millions of dollars each biennium and allows for much more efficient spending of funds while improving the seismic safety and resilience of communities. For example, the federal government requires all buildings in high seismic zones that are undergoing renovations/modernizations that exceed 30 percent of the building's value to receive seismic upgrades; Washington State could consider developing similar policies for school buildings. Performing seismic retrofits during a school modernization project would require additional funding from the Legislature to ensure that all school districts can participate in the SSSRP, regardless of their ability to pass a capital bond or levy.

Fire Stations

Fire Stations Studied

In Phase 1 of this study, five fire stations located within a mile of a public school were seismically screened to an Immediate Occupancy structural performance objective. In Phase 2, two more fire stations within a mile of a public school were similarly assessed. See Figure 18 for Phase 1 and 2 fire station locations. The selection criteria for these two Phase 2 fire stations were based on seismic hazard, availability of existing drawings, tsunami risk, and construction type. In Phase 2, these two fire stations also received a conceptual seismic upgrade design report and cost estimate to determine possible upgrade solutions and probable cost to seismically upgrade these buildings to meet an Immediate Occupancy structural performance objective.

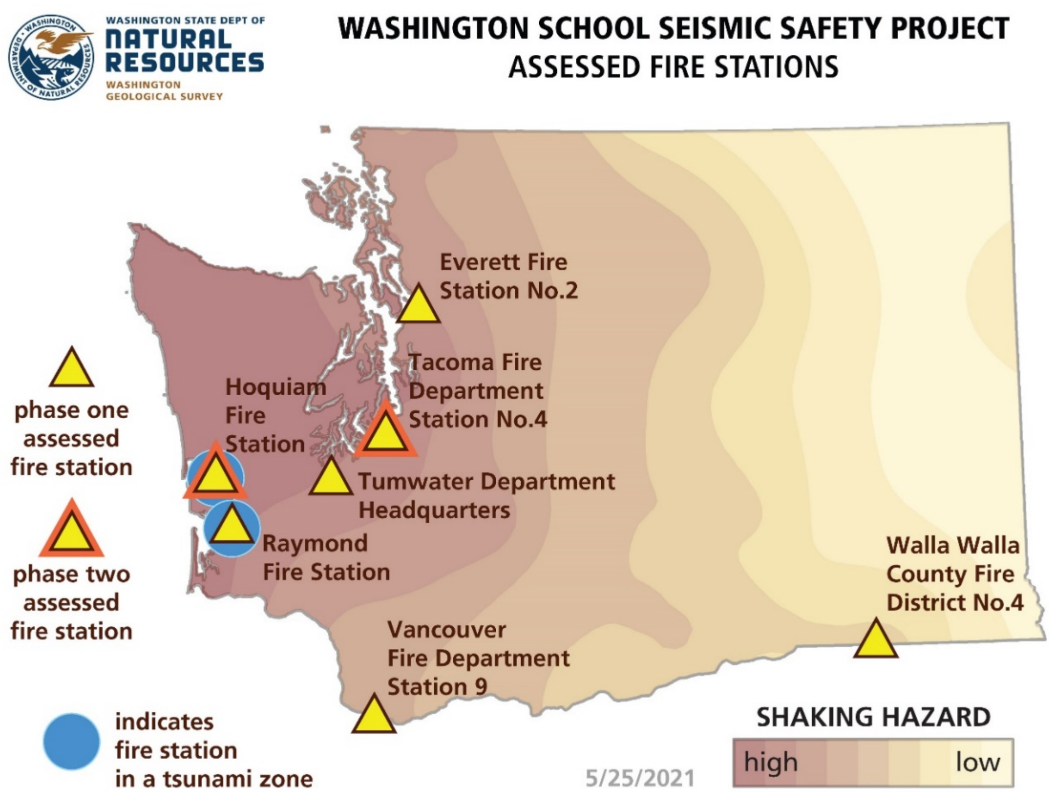


Figure 18. Map showing the five fire stations assessed for Phase 1 (yellow triangle) and Phase 2 (yellow triangle with an orange outline) of this project and highlighting (in blue) those in a mapped tsunami inundation zone. Basemap shows shaking hazard (Modified from Petersen and others, 2015).

Methods

Similar to the seismic screenings of the school buildings, structural engineers reviewed available existing drawings, performed site investigations, and seismically evaluated the fire stations using the Tier 1 checklists of the ASCE 41-17 'Seismic Evaluation and Retrofit of Existing Buildings' standard. Different from the school buildings however, these fire stations were seismically evaluated to the Immediate Occupancy structural performance objective compared to the Life Safety and Collapse Prevention structural performance objectives. The Immediate Occupancy structural performance objective is intended to result in a very low overall risk of life-threatening injury, and though there may be some minor structural repairs required, these repairs would generally not be necessary to allow for re-occupancy following an earthquake.

Following the Tier 1 seismic screenings, a conceptual seismic upgrade design report and cost estimate was prepared for each fire station to upgrade to an Immediate Occupancy structural performance objective (*Appendix D*).

For each fire station (except Tacoma Fire Station, No. 4) WGS personnel deployed to a nearby location and measured site class using the same techniques and methodologies employed at school campuses. From this measurement we assigned site class to each fire station. The final results are condensed into a site class assessment report (Fig. 5) and distributed to each fire station (*Appendix D*). The Vs30 measurements are also included in the WGS shear wave database (Washington Geological Survey, 2021 a). For the Tacoma fire station, WGS personnel could not deploy to the area to conduct a survey measurement, due to travel restrictions from COVID-19; therefore the site class used for the engineering analysis is based on the default D site class.

Results and Recommendations for Fire Stations

This study's seismic assessments of seven fire stations resulted in similar observations to the school buildings that were assessed. Older fire stations (pre-1975) and fire stations constructed of heavier materials (URM, reinforced masonry, non-ductile concrete) are significantly more vulnerable than more modern wood or steel-framed fire stations. Fire stations are considered essential facilities that need to be functioning and occupant-ready to perform essential community services following an earthquake. As a result, older fire station buildings should be highly prioritized for seismic retrofit or replacement by State, City, and County agencies as funding becomes available.

The seven fire stations assessed in Phase 1 and Phase 2 of this study are a very small sampling of the fire stations throughout the state. Based upon the structural engineers' experience in working with fire districts and city agencies in and around the greater Puget Sound area, there are many other fire stations in operation that were built prior to 1975 and have vulnerable URM, reinforced masonry, and non-ductile concrete structural systems. There are a number of fire districts and communities that have successfully passed capital bonds and levies over the past couple of decades, to replace or retrofit their older fire stations. However, similar to schools, there are many other fire districts and communities statewide that have not had the economic means or support to upgrade or replace their aging fire stations and may need state assistance to do so.

Assessments of probable construction costs for the two Phase 2 fire stations have been prepared as part of this study. The estimated upgrade costs range from approximately $82 per square foot to $192 per square foot for the reinforced masonry and unreinforced masonry fire stations, respectively. These are merely two data points of approximate renovation costs needed to bring these fire stations to an Immediate Occupancy structural performance objective, but can be used with other planning level estimates of fire stations to help quantify the financial need at a higher overview level. Past studies of fire station seismic upgrades that the structural engineers have worked on had similar ranges of probable costs per square foot. However, like any other fire station or school building, these costs are highly variable depending on building age, construction type, historic significance, area, seismicity, and site conditions. Specific seismic upgrade costs for a given fire station will require further study by a structural engineer and architect team.

This study recommends consideration of a state-funded grant program similar to the SSSRP that will assist in seismically upgrading the most seismically vulnerable fire stations, and ideally other public essential and critical facilities (Table 12). Further study of the state's inventory of fire stations could be performed by structural engineers and architects to help the State administer and prioritize which fire stations receive assistance. Alternatively, an application program could be administered where fire districts apply and demonstrate their need for seismic upgrade funding assistance through fire district-funded seismic evaluation reports, seismic upgrade designs, and benefit-cost analysis.

Table 12. Recommendations for future studies and retrofits of fire stations.

Recommendation	Description
Develop a long-term program to seismically upgrade or replace all vulnerable Washington State fire stations.	Washington State has many older fire station buildings that are highly vulnerable to earthquakes. This is an issue shared by fire districts all across the state. As essential facilities, these buildings will be called upon to provide emergency services following an earthquake and should be prioritized for retrofit projects. There are organizations that could be used as models for a long-term program with the goal of improving seismic safety and resiliency. For example, Seattle Public Utilities has developed seismic resilience goals they plan to achieve for their drinking water system by the years 2045 and 2075. Due to the extent of the seismic vulnerability of fire stations, it is not financially feasible to seismically upgrade all vulnerable facilities in a short period of time. Therefore, developing a long-term program to systematically improve seismic safety and resiliency is essential to ensure the future well-being of our fire stations and the communities they serve.

Conduct an inventory of all Washington fire stations and develop a plan to conduct seismic safety assessments to prioritize seismic resilience efforts.	To our knowledge there is no comprehensive inventory of Washington fire stations that captures the building construction information and any seismic retrofits that have been conducted. It is our recommendation that a comprehensive inventory of fire station building information be conducted to prioritize seismic retrofits of these critical facilities.

Acknowledgments

We would like to extend our sincere gratitude to all the school employees and facility managers who provided access to their school campuses and facilitated all our information requests. This project would not have been as successful without the participation of these dedicated and committed personnel. We would also like to thank the Washington State Legislature and the Governor for funding this project and supporting the seismic assessment of schools and the School Seismic Safety Retrofit Program. Continued funding and prioritization of these efforts will help to keep Washington's children and teachers safe from earthquakes.

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Appendices

Appendix A: Site Class One-Page Reports

The results of the geological seismic site class assessments are provided in the form of one-page reports. The front side of each report is directed at a general audience and provides a brief explanation of the work done at each school, the final site class determination, and flags for any geologic hazards that might affect the school. The back side of each report is a technical explanation of the geophysical analysis used to determine site class, as well as a discussion of any geologic complexity encountered at each site.

- The one-page reports can be downloaded at the following link. Note that all of the site class reports developed for Phase 2 are combined into a single PDF file for ease of download.

  https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_Site_Class_Assessment_Reports_2021.pdf

- You can also download combined Phase 1 and Phase 2 one-page site class assessment reports bundled by school district from our website:

  https://www.dnr.wa.gov/school-seismic-safety

Table A1. Phase 1 and 2 school districts, school names, phase participation (SSSP1 or SSSP2 for phases 1 and 2 respectively) and measured site classes. The asterisk (*) Denotes schools with buildings that have been assessed in both Phase 1 and Phase 2.

District Name	Site Name	SSSP Phase	Measured site class
Aberdeen	A.J. West Elementary School	SSSP2	E
Aberdeen	Central Park Elementary School	SSSP2	D
Aberdeen	Hopkins Building (Harbor High School)	SSSP2	E

Aberdeen	J. M. Weatherwax High School	SSSP2	E
Aberdeen	McDermoth Elementary School	SSSP2	D
Anacortes	Mount Erie Elementary School	SSSP2	C
Bainbridge Island	Bainbridge High School	SSSP2	D
Bainbridge Island	Commodore Options School	SSSP2	D
Bainbridge Island	Ordway Elementary School	SSSP2	D
Bainbridge Island	Woodward Middle School	SSSP2	C
Battle Ground	Maple Grove K-8	SSSP1	D
Battle Ground	Prairie High School	SSSP1	D
Battle Ground	River Homelink	SSSP1	D
Bellingham	Fairhaven Middle School	SSSP2	C
Bellingham	Roosevelt Elementary School	SSSP2	D
Bellingham	Whatcom Middle School	SSSP2	D

Bethel	Camas Prairie Elementary School	SSSP2	C
Bethel	Rocky Ridge Elementary School	SSSP2	C
Bickleton	Bickleton Elementary and High School	SSSP1	B
Boistfort	Boistfort Elementary	SSSP1	D
Brinnon	Brinnon Elementary School	SSSP2	C
Burlington-Edison	Edison Elementary School	SSSP1	E
Burlington-Edison	Burlington-Edison High School	SSSP2	D
Burlington-Edison	West View Elementary School	SSSP2	D
Camas	Lacamas Heights Elementary School	SSSP1	C
Camas	Liberty Middle School	SSSP1	C
Camas	Skyridge Middle School	SSSP1	D
Camas	Dorothy Fox Elementary School	SSSP2	C

Cape Flattery	Clallam Bay High and Elementary School	SSSP1	D
Cape Flattery	Neah Bay Elementary School	SSSP1	D
Cape Flattery	Neah Bay Junior/ Senior High School	SSSP1	D
Carbonado	Carbonado Historical School 19	SSSP1	C
Cascade	Beaver Valley School	SSSP2	C
Centerville	Centerville Elementary School	SSSP1	C
Central Kitsap	Ridgetop Junior High	SSSP1	C
Central Kitsap	Silver Ridge Elementary	SSSP1	C
Central Kitsap	Cottonwood Elementary School	SSSP2	C
Central Kitsap	Emerald Heights Elementary	SSSP2	C
Central Kitsap	Green Mountain Elementary	SSSP2	C
Central Kitsap	Pinecrest Elementary	SSSP2	C
Central Kitsap	Woodlands Elementary	SSSP2	D

Centralia	Edison Elementary School	SSSP1	C
Centralia	Centralia Middle School	SSSP2	C
Centralia	Oakview Elementary School	SSSP2	C
Centralia	Washington Elementary School	SSSP2	D
Chimacum	Chimacum High School	SSSP2	D
Chimacum	Chimacum Middle School	SSSP2	D
Clover Park	Custer Elementary School	SSSP2	D
Clover Park	Oakbrook Elementary School	SSSP2	C
Clover Park	Tillicum Elementary School	SSSP2	C
Concrete	Concrete High School	SSSP1	C
Concrete	Concrete K-6 School	SSSP1	C
Cosmopolis	Cosmopolis Elementary School	SSSP1	D
Coupeville	Coupeville Elementary School	SSSP1	C

Coupeville	Coupeville High School	SSSP1	D
Coupeville	Coupeville Middle School	SSSP1	D
Creston	Creston Junior Senior High School	SSSP1	D
Darrington	Darrington Elementary School	SSSP1	D
Darrington	Darrington Senior High School	SSSP1	D
Dayton	Dayton High School	SSSP1	B
Dayton	Dayton K-8 School	SSSP1	B
Dieringer	North Tapps Middle School	SSSP2	C
Dixie	Dixie Elementary School	SSSP1	D
East Valley (Yakima)	East Valley Central Middle School	SSSP1	C
East Valley (Yakima)	East Valley Elementary School	SSSP1	C
Ephrata	Ephrata High School	SSSP2	D
Ephrata	Grant Elementary School	SSSP2	D

Ephrata	Parkway School	SSSP2	C
Evaline	Evaline Elementary School	SSSP1	D
Everett	Jackson Elementary School	SSSP2	D
Everett	Madison Elementary School	SSSP2	C
Federal Way	Brigadoon Elementary School	SSSP2	C
Federal Way	Camelot Elementary School	SSSP2	C
Federal Way	Kilo Middle School	SSSP2	C
Federal Way	Nautilus K-8 School	SSSP2	C
Federal Way	Sacajawea Middle School	SSSP2	C
Ferndale	Beach Elementary	SSSP1	C
Ferndale	Central Elementary School	SSSP2	E
Ferndale	Custer Elementary	SSSP2	D
Fife	Columbia Junior High School	SSSP1	E

Fife	Fife High School	SSSP1	E
Glenwood	Glenwood School	SSSP1	C
Grand Coulee Dam	Lake Roosevelt K-12	SSSP1	D
Granite Falls	Crossroads High School (form. MS)	SSSP2	D
Granite Falls	Granite Falls Middle School (form. HS)	SSSP2	C
Granite Falls	Mountain Way Elementary School	SSSP2	C
Green Mountain	Green Mountain School	SSSP1	D
Harrington	Harrington Elementary & High School	SSSP1	C
Highline	Woodside Site	SSSP1	D
Highline	Beverly Park @ Glendale Elementary School	SSSP2	C
Highline	Chinook Middle School	SSSP2	C
Highline	Hilltop Elementary School	SSSP2	D
Highline	Seahurst Elementary School	SSSP2	C

Highline	Southern Heights Elementary School	SSSP2	D
Highline	Sylvester Middle School	SSSP2	D
Hockinson	Hockinson Heights Elementary School (East)	SSSP2	D
Hoquiam	Lincoln Elementary School	SSSP1	E
Hoquiam	Hoquiam High School	SSSP1*	D
Hoquiam	Central Elementary School	SSSP2	E
Hoquiam	Emerson Elementary School	SSSP2	E
Index	Index Elementary School	SSSP1	C
Kelso	Carrolls Elementary School	SSSP1	B
Kelso	Coweeman Middle School	SSSP2	E
Kelso	Rose Valley Elementary School	SSSP2	C
La Center	La Center Elementary & Middle Schools	SSSP2	D
La Conner	La Conner High School	SSSP1	D

La Conner	La Conner Middle School (form. Elem.)	SSSP1	D
Lake Washington	Dickinson Elementary School	SSSP2	C
Lake Washington	Einstein Elementary School	SSSP2	C
Lake Washington	Emerson Campus	SSSP2	D
Lake Washington	Rockwell Elementary School	SSSP2	D
Lake Washington	Wilder Elementary School	SSSP2	C
Longview	R. A. Long High School	SSSP1	E
Longview	Mint Valley Elementary School	SSSP2	E
Longview	Mt. Solo Middle School	SSSP2	E
Longview	Northlake Elementary School	SSSP2	D
Longview	Olympic Elementary School	SSSP2	E
Longview	Robert Gray Elementary School	SSSP2	E
Lopez Island	Lopez Elementary School	SSSP2	C

Lopez Island	Lopez Middle High School	SSSP2	C
Mabton	Mabton Jr/Sr High School	SSSP1	D
Mansfield	Mansfield Elem and High School	SSSP1	B
Mary M Knight	Mary M. Knight School	SSSP2	C
Marysville	Liberty Elementary School	SSSP1	D
Marysville	Marysville Middle School	SSSP1	D
Marysville	Totem Middle School	SSSP1	D
Marysville	Cascade Elementary School	SSSP2	D
Marysville	Marysville Pilchuck Senior High School	SSSP2	D
Marysville	Pinewood Elementary School	SSSP2	D
Marysville	Quil Ceda Tulalip Elementary School	SSSP2	D
Marysville	Shoultes Elementary School	SSSP2	D

Methow Valley	Liberty Bell Junior Senior High School	SSSP1	D
Methow Valley	Methow Valley Elementary School	SSSP1	D
Morton	Morton Elementary School	SSSP1	C
Morton	Morton Junior Senior High School	SSSP1	E
Mount Baker	Mount Baker Junior High School	SSSP1	D
Mount Baker	Mount Baker Senior High School	SSSP1	D
Mount Baker	Acme Elementary School	SSSP2	D
Mount Vernon	Lincoln Elementary School	SSSP1	C
Naches Valley	Naches Valley High School	SSSP1	D
Naches Valley	Naches Valley Middle School	SSSP1	C
Napavine	Napavine Elementary School	SSSP2	C
Napavine	Napavine Junior Senior High School	SSSP2	C
Naselle-Grays River Valley	Naselle K-12 School	SSSP2	D

Newport	Newport High School	SSSP1	C
North Beach	Pacific Beach Elementary School	SSSP1	D
North Beach	North Beach Junior/Senior High School	SSSP2	D
North Mason	Belfair Elementary School	SSSP2	C
North River	North River School	SSSP2	D
Northshore	Canyon Creek Elementary School	SSSP2	C
Northshore	Crystal Springs Elementary School	SSSP2	D
Northshore	Shelton View Elementary School	SSSP2	C
Oak Harbor	Clover Valley School (new name is HomeConnection)	SSSP2	D
Oak Harbor	Oak Harbor Middle School	SSSP2	C
Ocean Beach	Ilwaco (Hilltop) Middle School	SSSP1	D
Ocean Beach	Ilwaco High School	SSSP1	D

Ocean Beach	Long Beach Elementary School	SSSP1	D
Ocean Beach	Ocean Park Elementary School	SSSP1	D
Ocean Beach	Kaino Gym	SSSP1**	D
Ocosta	Ocosta Elementary School	SSSP1	D
Ocosta	Ocosta Junior Senior High School	SSSP1	D
Olympia	Boston Harbor Elementary School	SSSP2	C
Olympia	Thurgood Marshall Middle School	SSSP2	C
Oroville	Oroville Elementary School	SSSP1	D
Orting	Orting Primary School	SSSP2	D
Palisades	Palisades Elementary School	SSSP1	D
Pasco	Edwin Markham Elementary School	SSSP1	D
Pateros	Pateros K-12 School	SSSP1	D
Paterson	Paterson Elementary School	SSSP1	B

Pe Ell	Pe Ell School	SSSP2	C
Peninsula	Discovery Elementary School	SSSP2	C
Peninsula	Gig Harbor High School	SSSP2	C
Peninsula	Minter Creek Elementary School	SSSP2	C
Peninsula	Peninsula High School	SSSP2	C
Peninsula	Voyager Elementary School	SSSP2	D
Port Angeles	Roosevelt Elementary School	SSSP1	C
Port Townsend	Port Townsend High School	SSSP1	D
Port Townsend	Blue Heron Middle School	SSSP2	D
Puyallup	Maplewood Elementary School	SSSP1	E
Puyallup	Puyallup High School	SSSP1	E
Puyallup	Spinning Elementary School	SSSP1	D
Puyallup	Meeker Elementary School	SSSP2	E
Puyallup	Mt View Elementary School	SSSP2	C

Puyallup	Waller Road Elementary School	SSSP2	C
Puyallup	Wildwood Elementary	SSSP2	C
Quilcene	Quilcene High And Elementary School	SSSP1	C
Quillayute Valley	Forks Elementary School	SSSP2	C
Quillayute Valley	Forks Intermediate School	SSSP2	C
Quillayute Valley	Forks Junior-Senior High School	SSSP2	C
Raymond	Raymond Elementary School	SSSP1	D
Raymond	Raymond Junior Senior High School	SSSP1	D
Renton	Hazen Senior High School	SSSP2	C
Renton	Lindbergh Senior High School	SSSP2	C
Renton	Renton Senior High School	SSSP2	D
Ridgefield	Union Ridge Elementary School	SSSP1	D

Ridgefield	South Ridge Elementary School	SSSP2	D
Riverside	Chattaroy Elementary School	SSSP1	D
Royal	Red Rock Elementary School	SSSP1	C
Royal	Royal High School	SSSP1	C
Royal	Royal Middle School	SSSP1	C
Shaw Island	Shaw Island School	SSSP1	B
Skamania	Skamania Elementary School	SSSP2	D
Skykomish	Skykomish School	SSSP1	D
Snohomish	Cathcart Elementary School	SSSP2	C
Snohomish	Central Elementary School	SSSP2	C
Snohomish	Emerson Elementary School	SSSP2	C
South Bend	South Bend Jr/Sr High School	SSSP1*	E

South Whidbey	South Whidbey Grades K-4	SSSP1	C
South Whidbey	South Whidbey Grades 5 & 6 - (Formerly S. Whid. Primary)	SSSP2	C
Spokane	Adams Elementary School	SSSP1	C
Spokane	Audubon Elementary School	SSSP1	C
Spokane	Libby Center	SSSP1	C
Spokane	Bancroft (The Community School)	SSSP2	C
Spokane	Bryant Center	SSSP2	C
Spokane	Havermale (Montessori)	SSSP2	C
Spokane	Madison Elementary School	SSSP2	D
Stanwood-Camano	Stanwood Elementary School	SSSP2	E
Stanwood-Camano	Stanwood Middle School	SSSP2	E
Stanwood-Camano	Twin City Elementary School	SSSP2	D
Stevenson-Carson	Carson Elementary School	SSSP2	C

Stevenson-Carson	Stevenson High School	SSSP2	D
Stevenson-Carson	Wind River Education Center	SSSP2	C
Sunnyside	Outlook Elementary School	SSSP1	D
Tacoma	Fern Hill Elementary School	SSSP1	C
Tacoma	Oakland High School	SSSP1	C
Tacoma	DeLong Elementary School	SSSP2	C
Tacoma	Edison Elementary School	SSSP2	C
Tacoma	Foss High School	SSSP2	C
Tacoma	Franklin Elementary School	SSSP2	C
Tacoma	Larchmont Elementary School	SSSP2	C
Tacoma	Lister Elementary School	SSSP2	C
Tacoma	Manitou Park Elementary School	SSSP2	C
Tacoma	Mann Elementary School	SSSP2	C

Tacoma	Northeast Tacoma Elementary School	SSSP2	C
Tacoma	Point Defiance Elementary School	SSSP2	C
Tacoma	Reed Elementary School	SSSP2	C
Tacoma	Roosevelt Elementary School	SSSP2	C
Tacoma	Sheridan Elementary School	SSSP2	C
Tacoma	Stanley Elementary School	SSSP2	C
Tacoma	Tacoma School of the Arts-Pacific	SSSP2	C
Tacoma	Willie Stewart Academy	SSSP2	C
Taholah	Taholah School	SSSP1	D
Thorp	Thorp Elementary and Junior Senior High School	SSSP1	C
Toledo	Toledo Elementary School	SSSP2	D
Toledo	Toledo Middle School	SSSP2	C
Tonasket	Tonasket Elementary School	SSSP1	D

Tonasket	Tonasket Middle-High School	SSSP1	D
Touchet	Touchet Elementary and High School	SSSP1	C
Tumwater	Black Lake Elementary School	SSSP1	C
University Place	Curtis Senior High School	SSSP2	D
University Place	Sunset Primary School	SSSP2	C
Vashon Island	Vashon Island High School	SSSP1	C
Wahkiakum	Julius A. Wendt Elementary/John C. Thomas Middle School	SSSP2	C
Warden	Warden K-12	SSSP1	C
Washougal	Hathaway Elementary School	SSSP1	C
Washtucna	Washtucna Elementary High School	SSSP1	C
West Valley (Yakima)	West Valley Junior High School	SSSP2	C
White Pass	White Pass Elementary School	SSSP1	D
White Pass	White Pass Junior Senior High School	SSSP1	D

White River	Mountain Meadow Elementary School	SSSP2	C
White Salmon Valley	Columbia High School	SSSP1	C
White Salmon Valley	Hulan L. Whitson Elementary School	SSSP1	C
White Salmon Valley	Wayne M. Henkle Middle School	SSSP1	C
Willapa Valley	Willapa Elementary School	SSSP2	D
Wilson Creek	Wilson Creek K-12	SSSP1	C
Woodland	Woodland Middle School (old HS)	SSSP2	E
Woodland	Woodland Primary School	SSSP2	E
Yakima	Adams Elementary School	SSSP2	C
Yakima	Hoover Elementary School	SSSP2	C
Yakima	Nob Hill Elementary School	SSSP2	C
Yakima	Robertson Elementary School	SSSP2	C
Yakima	Wilson Middle School	SSSP2	C

Appendix B: Engineering School Seismic Assessment Reports

All of the data generated from the engineering assessments as part of Phase 2 have been bundled into four volumes. Download these volumes by clicking the blue links below. A link to our website is also provided below. There you can access all downloadable material for both Phase 1 and Phase 2.

- **Volume 1: Seismic Assessment Report**—This volume provides an overview of the engineering seismic assessments, which is useful for understanding the process and all of the information included in the school reports.

  https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol1_Seismic_Assessment_Report.pdf

- **Volume 2: EPAT & FEMA 154 RVS Summaries**—This volume presents the results of the EPAT worksheets and Rapid Visual Screenings.

  https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol2_EPAT_RVS_Forms.pdf

- **Volume 3: ASCE 41-17 Screening Reports**—This volume presents the results of the ASCE 41-17 assessments at 339 school buildings.

  https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol3_ASCE41_Screening_Reports.pdf

- **Volume 4: Seismic Upgrades Concept Design Reports, 17 School Buildings**—This volume presents the results of the concept-level seismic upgrade designs conducted for 17 school buildings. These reports provide information on the designs, costs, and suggested upgrades that were included in the concept design reports.

  https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol4_Concept_Level_Design_Reports_17_Schools.pdf

- **Washington Geological Survey School Seismic Safety Project website**—Contains overview information about this project and a map where you can download the seismic screening reports for each school district.

  https://www.dnr.wa.gov/school-seismic-safety

Appendix C: Prioritized Rankings of Phase 1 and 2 School Buildings

Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Engineering judgment was used to assign buildings to one of four categories: Very High Priority, High Priority, Moderate Priority and Lower Priority (Appendix Tables C1–C4). The prioritization of schools was done by comparing buildings to one another by selected parameters using engineering judgment. The parameters used for comparison include: building construction date, construction type, level of site seismicity, extents of previous seismic upgrade work (if any), soil liquefaction potential, SEAONC EPRS structural star rating, EPAT expected building damage, FEMA 154 RVS score, and an ASCE 41 Tier 1 checklist percent of "noncompliant" or "unknown". A small adjustment was made for buildings of larger square footage to slightly prioritize larger buildings over smaller ones with the idea that more people may be at risk in buildings of larger area. Finally, the engineers who evaluated each building also used their judgment to adjust the building category if they felt the scoring system did not accurately capture the building risk. Within each priority grouping the buildings are listed in alphabetical order by district. The buildings in each group are considered equally at risk.

Table C1. List of schools labeled as very high priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

VERY HIGH PRIORITY SCHOOL BUILDINGS

District Name	Facility Name	Building Name	ICOS#
Aberdeen	Hopkins Building (Harbor High School)	Hopkins Building	57394
Aberdeen	J. M. Weatherwax High School	1964 Gymnasium Building	57378
Aberdeen	McDermoth Elementary School	Main Building	57397

Anacortes	Mount Erie Elementary School	1955 Original Main Building	54084
Boistfort	Boistfort Elementary	Gymnasium Building	57720
Boistfort	Boistfort Elementary	Main Building	57717
Burlington-Edison	Burlington-Edison High School	Art/Tiger TUB Building	50119
Burlington-Edison	Burlington-Edison High School	Cafeteria and 400 Wing	50117
Burlington-Edison	Burlington-Edison High School	CTE	50110
Burlington-Edison	Burlington-Edison High School	Fieldhouse 1953 and 1975	50109
Burlington-Edison	West View Elementary School	Main Building	50095
Cape Flattery	Clallam Bay High and Elementary School	High School Building	57823
Cape Flattery	Neah Bay Elementary School	Elementary School	57829
Cape Flattery	Neah Bay Junior/ Senior High School	Neah Bay High School Gym	57832
Carbonado	Carbonado Historical School 19	A - Main Building	57837

Centerville	Centerville Elementary School	Main Building	51688
Centralia	Washington Elementary School	Main Building	57962
Clover Park	Tillicum Elementary School	Classroom Building - TL1	50186
Evaline	Evaline Elementary School	Main Building	58128
Ferndale	Beach Elementary	Main Building	55002
Ferndale	Custer Elementary	Main Building	54976
Green Mountain	Green Mountain School	Main Building	58305
Highline	Southern Heights Elementary School	Building C - Admin/Multi Purpose	55188
Hoquiam	Central Elementary School	Main Building	58356
Hoquiam	Emerson Elementary School	Main Building	58357
Hoquiam	Hoquiam High School	A-Administration	58350
Hoquiam	Hoquiam High School	B-Science	58341

Hoquiam	Hoquiam High School	H-Gymnasium	58342
Index	Index Elementary School	Main Building	55232
Kelso	Carrolls Elementary School	Main Building	58401
Kelso	Rose Valley Elementary School	Main Building	58396
La Conner	La Conner High School	High School Auditorium	55667
La Conner	La Conner Middle School (form. Elem.)	Old Auditorium/Cafeteria Bldg	55672
Longview	R. A. Long High School	Gym	58425
Longview	R. A. Long High School	Main Building	58427
Longview	R. A. Long High School	Shop Bldg	58428
Marysville	Marysville Pilchuck Sr High School	Auditorium - Bldg K	56248
Marysville	Marysville Pilchuck Sr High School	Library - Bldg J	56244
Marysville	Marysville Pilchuck Sr High School	Pool Building - Bldg L	56233

Marysville	Totem Middle School	Cafeteria Gym Building	56224
Morton	Morton Elementary School	Main Building	58501
Mount Baker	Acme Elementary School	Main Building	56410
Mount Baker	Mount Baker Senior High School	Field House	56426
Mount Vernon	Lincoln Elementary School	Main Building	50960
North Beach	Pacific Beach Elementary School	Gym/Lunchroom	58523
Ocean Beach	Ilwaco (Hilltop) Middle School	Auditorium	58642
Ocean Beach	Ilwaco (Hilltop) Middle School	Main Building	58643
Palisades	Palisades Elementary School	Main Building	52634
Pe Ell	Pe Ell School	Main Building	51321
Peninsula	Peninsula High School	Main Building (100	58796
Puyallup	Puyallup High School	Main Building	58962

Puyallup	Spinning Elementary School	Main Building	59065
Quilcene	Quilcene High And Elementary School	Elementary	59185
Quilcene	Quilcene High And Elementary School	High School	59184
Quillayute Valley	Forks Intermediate School	Main Building - 1952 Portion	59203
Quillayute Valley	Forks Jr-Sr High School	Main Jr High Building - 1949 Portion	59193
Raymond	Raymond Junior Senior High School	Main Building	59223
Renton	Hazen Senior High School	Bldg 1 Main Building	56888
Renton	Hazen Senior High School	Bldg 1 Music	56888
Renton	Lindbergh Senior High School	Main Building - North	56945
Renton	Lindbergh Senior High School	Main Building - South	56945
Skykomish	Skykomish School	Main Building	57083
Snohomish	Cathcart Elementary School	100 Building	57090

Snohomish	Central Elementary School	Main Building - Gym	57085
Snohomish	Central Elementary School	Main Building	57085
South Bend	South Bend Jr/Sr High School	Koplitz Field House	51399
South Bend	South Bend Jr/Sr High School	Vocational Building	51398
Stanwood-Camano	Stanwood Middle School	Main Building (Bldg 1) Units E and F	51448
Tacoma	Fern Hill Elementary School	Main Building	59748
Tacoma	Foss High School	Gym-Pool-Cafeteria	59802
Tacoma	Foss High School	Main Building - South	59802
Tacoma	Oakland High School	Main Building	59698
Tacoma	Tacoma School of the Arts-Pacific	SOTA Pacific Ave	59768
Tacoma	Willie Stewart Academy	Main Bldg	59727
Thorp	Thorp Elementary and Junior Senior High School	Brick Building	53670

Vashon Island	Vashon Island High School	Building D - Gymnasium	57368
White Salmon Valley	Hulan L. Whitson Elementary School	Main Building	51619
Woodland	Woodland Middle School	Gymnasium Building	60193
Woodland	Woodland Middle School	Main Building	60193
Woodland	Woodland Middle School	Performing Arts	60193
Woodland	Woodland Middle School	Shared High School /Middle School	60192
Woodland	Woodland Middle School	Vocational Building	60193

Table C2. List of schools labeled as high priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

HIGH PRIORITY SCHOOL BUILDINGS

District Name	Facility Name	Building Name	ICOS#
Bainbridge Island	Bainbridge High School	500 Building	57410
Bainbridge Island	Commodore Options School	Commodore Options School	57422
Bainbridge Island	Ordway Elementary School	Education Pod	57416
Bainbridge Island	Ordway Elementary School	K-4 Building	57416
Bainbridge Island	Ordway Elementary School	Main Building	57416
Battle Ground	Praire High School	500 Building	50021
Battle Ground	Praire High School	600 Building	50024
Bellingham	Roosevelt Elementary School	Main Building	54493
Bellingham	Whatcom Middle School	Industrial Arts Building	54467

Brinnon	Brinnon Elementary School	Main Building	57777
Burlington-Edison	Burlington-Edison High School	500 Wing	50112
Burlington-Edison	Burlington-Edison High School	Admin/Classroom Building	50118
Camas	Lacamas Heights Elementary School	100 Pod	57802
Camas	Lacamas Heights Elementary School	Multipurpose	57803
Camas	Liberty Middle School	Main Building	57790
Camas	Liberty Middle School	Music Building	57791
Cape Flattery	Clallam Bay High and Elementary School	Big Gym	57827
Cape Flattery	Clallam Bay High and Elementary School	Elementary Building	57824
Cape Flattery	Clallam Bay High and Elementary School	Elementary Gym	57822
Cape Flattery	Clallam Bay High and Elementary School	Shop and Art Building	57825
Cape Flattery	Neah Bay Jr/ Sr High School	Neah Bay High School Classroom Building	57833

Cape Flattery	Neah Bay Jr/ Sr High School	Neah Bay High School Shop Building	57835
Carbonado	Carbonado Historical School 19	B - Community Gym	57838
Cascade	Beaver Valley School	Old Winton School House	51677
Central Kitsap	Cottonwood Elementary School	Gym	57901
Centralia	Centralia Middle School	Classroom Wings	57953
Centralia	Centralia Middle School	Gym Wing	57953
Centralia	Centralia Middle School	Main Building	57953
Centralia	Edison Elementary School	Main Building	57958
Centralia	Oakview Elementary School	Main Building	57970
Chimacum	Chimacum Middle School	Middle School Bldg 100 B	58032
Clover Park	Custer Elementary School	Second Classroom Building	50240
Clover Park	Oakbrook Elementary School	First Classroom Building	50244

Clover Park	Oakbrook Elementary School	Gym / MPR	50245
Concrete	Concrete High School	Main Building	54519
Concrete	Concrete High School	Tech Building	54518
Cosmopolis	Cosmopolis Elementary School	Auditorium Building	58041
Cosmopolis	Cosmopolis Elementary School	Main Building	58038
Cosmopolis	Cosmopolis Elementary School	Multipurpose Building	58037
Coupeville	Coupeville Elementary School	Cedar Pod	54538
Darrington	Darrington Senior High School	Darrington High School	54547
Darrington	Darrington Senior High School	Woodshop	54546
Dayton	Dayton High School	Ag Shop	51839
Dayton	Dayton High School	High School Building	51838
Dayton	Dayton High School	Wood Shop	51840
Dixie	Dixie Elementary School	Main Building	51843

East Valley (Yakima)	East Valley Central Middle School	Gymnasium Building	50350
Ephrata	Ephrata High School	1937 Annex (Former Beezley Springs ES)	51934
Ephrata	Ephrata High School	Performing Arts Center PAC	51932
Ephrata	Grant Elementary School	Main Building	51927
Everett	Jackson Elementary School	Main Building	54780
Everett	Madison Elementary School	Main Building	54831
Federal Way	Camelot Elementary School	Main Building	50675
Federal Way	Kilo Middle School	Building E Little Theater	50809
Federal Way	Kilo Middle School	Building G	50805
Federal Way	Sacajawea Middle School	100 Building	50706
Federal Way	Sacajawea Middle School	300 Building/Cafeteria	50704
Federal Way	Sacajawea Middle School	400 Building	50702

Federal Way	Sacajawea Middle School	600/700/800 Building	50703
Federal Way	Sacajawea Middle School	900 Building	50699
Federal Way	Sacajawea Middle School	Gym (500) Building	50705
Federal Way	Sacajawea Middle School	Main Office Building	50700
Ferndale	Central Elementary School	Main Building	54971
Fife	Fife High School	Building IV 400 Library	58147
Fife	Fife High School	Building V 500 Main	58144
Fife	Fife High School	Building VIII 800 Shop	58145
Granite Falls	Crossroads High School (form. MS)	Main Building	55015
Granite Falls	Granite Falls Middle School (form. HS)	Main Building - Gym	55028
Granite Falls	Granite Falls Middle School (form. HS)	Main Building (Excl. Gym)	55028
Green Mountain	Green Mountain School	Gymnasium	58303
Harrington	Harrington Elementary & High School	Main Building	52039

Highline	Beverly Park @ Glendale Elementary School	Main Building A	55096
Highline	Beverly Park @ Glendale Elementary School	Multi-Purpose Building B	55097
Highline	Chinook Middle School	100 Building	55065
Highline	Chinook Middle School	200 Building	55067
Highline	Chinook Middle School	300 Building - Gymnasium	55063
Highline	Chinook Middle School	400 Building - Cafeteria	55066
Highline	Chinook Middle School	800 Building	55064
Highline	Hilltop Elementary School	100 Building - Bldg A	55177
Highline	Hilltop Elementary School	200 Building - Bldg B	55176
Highline	Hilltop Elementary School	300 Building - Bldg C	55178
Highline	Sylvester Middle School	100 Building	55128
Highline	Sylvester Middle School	200 Building	55131

Highline	Sylvester Middle School	300 Building - Gymnasium/Cafeteria	55134
Highline	Sylvester Middle School	400 Building	55130
Highline	Sylvester Middle School	500 Building - Library	55133
Highline	Sylvester Middle School	600 Building	55129
Highline	Sylvester Middle School	700 Building - Band/Drama	55132
Highline	Woodside Site	Annex	55073
Highline	Woodside Site	Main Building	55072
Hockinson	Hockinson Heights Elementary School (East)	Building 800 H	58325
Hoquiam	Hoquiam High School	D-Business Education	58347
Hoquiam	Hoquiam High School	E-Library	58344
Hoquiam	Hoquiam High School	F-Humanities	58345
Hoquiam	Hoquiam High School	G-Little Theater	58346
Hoquiam	Lincoln Elementary School	East Wing	58355

Hoquiam	Lincoln Elementary School	Multipurpose Building	58354
Hoquiam	Lincoln Elementary School	West Wing	58353
Kelso	Coweeman Middle School	Main Building	58393
La Center	La Center Elementary & Middle Schools	Building 300 - ES Main Building	50901
Lake Washington	Rockwell Elementary School	Main Building	55771
Longview	Mint Valley Elementary School	Building A - 1	58459
Longview	Mint Valley Elementary School	Building B - 2	58458
Longview	Mint Valley Elementary School	Building D - 4	58461
Longview	Northlake Elementary School	Main Building	58447
Longview	Olympic Elementary School	Annex Building	58438
Longview	Olympic Elementary School	Main Building	58436
Longview	Olympic Elementary School	Multipurpose Building	58437

Longview	R. A. Long High School	RA Long Annex	58426
Longview	R. A. Long High School	Science Wing	58424
Lopez Island	Lopez Middle High School	Junior Senior High Building	56068
Mabton	Mabton Jr/Sr High School	Main Building	52288
Mabton	Mabton Jr/Sr High School	Shop/Ag Building	52289
Mary M Knight	Mary M. Knight School	Elementary School	50921
Marysville	Cascade Elementary School	Unit A	56103
Marysville	Cascade Elementary School	Unit B	56101
Marysville	Cascade Elementary School	Unit C	56104
Marysville	Cascade Elementary School	Unit D	56102
Marysville	Liberty Elementary School	Main Building	56194
Marysville	Marysville Middle School	Building C - Shop Classrooms	56213

Marysville	Marysville Middle School	Main Building	56214
Marysville	Marysville Pilchuck Sr High School	Arts and Crafts Building - Bldg B	56254
Marysville	Marysville Pilchuck Sr High School	Business Ed and Home Learning - Bldg C	56242
Marysville	Marysville Pilchuck Sr High School	East Building - Bldg H	56240
Marysville	Marysville Pilchuck Sr High School	Gym & New Food Commons - Bldg M	56246
Marysville	Marysville Pilchuck Sr High School	Life Science Building - Bldg F	56253
Marysville	Marysville Pilchuck Sr High School	Mech Plant and Former Cafeteria - Bldg E	56235
Marysville	Marysville Pilchuck Sr High School	Occupational Center - Bldg A	56245
Marysville	Pinewood Elementary School	Bldg E	56134
Marysville	Pinewood Elementary School	Bldg L (Library)	56141
Marysville	Pinewood Elementary School	Bldg M (Gym)	56139

Marysville	Pinewood Elementary School	Building A	56135
Marysville	Pinewood Elementary School	Building D	56142
Marysville	Shoultes Elementary School	B Building	56264
Marysville	Shoultes Elementary School	Gym Building A	56266
Marysville	Shoultes Elementary School	D Building	56265
Marysville	Shoultes Elementary School	C Building	56267
Marysville	Totem Middle School	Home Economics Building	56232
Marysville	Totem Middle School	Main Building	56231
Marysville	Totem Middle School	School House Cafe	56227
Marysville	Totem Middle School	Science Building	56226
Methow Valley	Methow Valley Elementary School	Main Building	52355
Morton	Morton Junior Senior High School	Gymnasium	58506
Morton	Morton Junior Senior High School	Main Building	58505

Morton	Morton Junior Senior High School	Shop	58507
Napavine	Napavine Elementary School	Main Building	58512
Napavine	Napavine Junior Senior High School	Annex	58513
Napavine	Napavine Junior Senior High School	Main	58514
Naselle-Grays River Valley	Naselle K-12 School	Administration/Misc. Building	51032
Naselle-Grays River Valley	Naselle K-12 School	Elementary	51032
North Beach	North Beach Junior/Senior High School	Main Building	58529
North Beach	Pacific Beach Elementary School	Main Building	58524
North Beach	Pacific Beach Elementary School	Quad Building	58525
North Mason	Belfair Elementary School	Gymnasium Building	58613
North Mason	Belfair Elementary School	Main Building	58614
North River	North River School	Elementary	58630

North River	North River School	Gym Home Ec-Cafeteria	58634
North River	North River School	High School & Admin Building	58631
North River	North River School	Talley Building (Music/Art)	58636
Northshore	Canyon Creek Elementary School	Building A - Classroom/Library	56750
Northshore	Canyon Creek Elementary School	Building C - Cafeteria/Gym	56753
Northshore	Crystal Springs Elementary School	Building 1 - Admin	56775
Northshore	Crystal Springs Elementary School	Building 2 - Classrooms/Kitchen	56774
Northshore	Crystal Springs Elementary School	Building 3/4 - Classrooms	56772
Northshore	Crystal Springs Elementary School	Building 5 - Classrooms	56770
Northshore	Shelton View Elementary School	Building A1/10 - Classroom	56732
Northshore	Shelton View Elementary School	Building C - Gym	56727
Oak Harbor	Clover Valley School	Main Building	51299

Oak Harbor	Oak Harbor Middle School	Band Building	51291
Oak Harbor	Oak Harbor Middle School	C Wing - Cafeteria	51290
Oak Harbor	Oak Harbor Middle School	D Wing	51294
Ocean Beach	Ilwaco High School	Ilwaco High School	58649
Ocean Beach	Ilwaco High School	Stadium Complex	58650
Ocean Beach	Long Beach Elementary School	Main Building	58645
Orting	Orting Primary School	Main Building	58761
Palisades	Palisades Elementary School	Grange Hall	52635
Pateros	Pateros K-12 School	Main Building	52831
Pateros	Pateros K-12 School	Metal Shop	52830
Pateros	Pateros K-12 School	Music Building	52832
Peninsula	Discovery Elementary School	Main Building	58839
Peninsula	Gig Harbor High School	Main Building	58821

Peninsula	Gig Harbor High School	Voc-Ed Building	58820
Peninsula	Peninsula High School	500 Building	58793
Peninsula	Peninsula High School	600 Building	58795
Peninsula	Peninsula High School	800 Building - Auditorium Area	58792
Peninsula	Peninsula High School	900 Building - Pool Building	58794
Port Townsend	Port Townsend High School	Gym	58899
Port Townsend	Port Townsend High School	Main Building	58898
Port Townsend	Port Townsend High School	Math Science Annex	58900
Port Townsend	Port Townsend High School	Stuart Building	58901
Puyallup	Maplewood Elementary School	Main Building	59005
Puyallup	Meeker Elementary School	Main Building	59062
Puyallup	Mt View Elementary School	Multipurpose Building	58954

Puyallup	Puyallup High School	Gymnasium and Swimming Pool Building	58961
Puyallup	Puyallup High School	Library Science Building	58959
Puyallup	Spinning Elementary School	East	59065
Puyallup	Waller Road Elementary School	Main Building	59011
Quilcene	Quilcene High And Elementary School	Middle School	59188
Quillayute Valley	Forks Elementary School	Main Building - 1969 Portion	59199
Raymond	Raymond Elementary School	Raymond elementary	59222
Renton	Hazen Senior High School	700 Building	56887
Renton	Hazen Senior High School	Bldg 1 Gym/Pool	56888
Renton	Hazen Senior High School	Gym Addition	56885
Renton	Lindbergh Senior High School	Gym Addition	56944
Renton	Lindbergh Senior High School	Gymnasium	56944

Renton	Renton Senior High School	Cafeteria/Gym	56901
Ridgefield	South Ridge Elementary School	Main Building	59234
Ridgefield	Union Ridge Elementary School	Main Building	59224
Riverside	Chattaroy Elementary School	35 Wing Building	53052
Shaw Island	Shaw Island School	Admin/RR Building	57007
Shaw Island	Shaw Island School	Primary Classroom Building	57009
Skamania	Skamania Elementary School	Main Building	59377
Snohomish	Cathcart Elementary School	200 Building	57091
Snohomish	Cathcart Elementary School	300 Building	57089
Snohomish	Cathcart Elementary School	400 Building	57088
Snohomish	Cathcart Elementary School	500 Building	57092
Snohomish	Cathcart Elementary School	600 Building	57094

Snohomish	Cathcart Elementary School	700 Building	57093
Snohomish	Emerson Elementary School	Main Building	57132
South Bend	South Bend Jr/Sr High School	Main Building High School	51397
South Whidbey	South Whidbey Grades 5 & 6	A- Classrooms	57247
South Whidbey	South Whidbey Grades 5 & 6	C - Classrooms/Admin	57245
South Whidbey	South Whidbey Grades 5 & 6	D - WIA Office/Classrooms	57249
South Whidbey	South Whidbey Grades 5 & 6	E - Classrooms	57250
South Whidbey	South Whidbey Grades 5 & 6	F - Multipurpose	57248
Spokane	Adams Elementary School	Gym and Cafeteria Building	53538
Spokane	Adams Elementary School	Main Building	53538
Spokane	Bancroft (The Community School)	Main Building	53586
Spokane	Bryant Center	Main Building	53558

Spokane	Havermale (Montessori)	Main Building 1928 Gym	53500
Spokane	Havermale (Montessori)	Main Building 1928 and 1940 Areas	53500
Spokane	Havermale (Montessori)	Main Building 1965 Areas	53500
Spokane	Libby Center	Main Building	53496
Spokane	Madison Elementary School	Main Building	53579
Stanwood-Camano	Stanwood Elementary School	Main Building Unit C 1981	51456
Stanwood-Camano	Stanwood Middle School	Building 3 - Music	51449
Stanwood-Camano	Twin City Elementary School	Main Building	51411
Stevenson-Carson	Carson Elementary School	Main Building	59495
Stevenson-Carson	Stevenson High School	Main Building	59488
Stevenson-Carson	Stevenson High School	Vocational Building	59491
Stevenson-Carson	Wind River Education Center	Main Building	59499

Sunnyside	Outlook Elementary School	Outlook Elementary Main Building	53661
Tacoma	DeLong Elementary School	Original Bldg-Bldg A	59597
Tacoma	Foss High School	Main Building - North	59802
Tacoma	Mann Elementary School	Main Building	59664
Tacoma	Point Defiance Elementary School	Main Building	59730
Tacoma	Reed Elementary School	Main Building	59628
Tacoma	Stanley Elementary School	Gym Bldg	59635
Taholah	Taholah School	Main Building	59810
Toledo	Toledo Elementary School	Main Building	59838
Toledo	Toledo Middle School	Classroom Bldg. (Bldg #2)	59842
Toledo	Toledo Middle School	Main Building (Bldg. #1)	59844
Touchet	Touchet Elementary and High School	Elementary - Main Building	53697

Touchet	Touchet Elementary and High School	Secondary Facility	53695
University Place	Curtis Senior High School	500 Building	59969
University Place	Sunset Primary School	Main Building	59982
Vashon Island	Vashon Island High School	Building K - Annex	57366
Wahkiakum	Julius A. Wendt ES/John C. Thomas MS	J A Wendt Elementary School	53717
Washougal	Hathaway Elementary School	Main Building	60133
Washtucna	Washtucna Elementary High School	Ag Shop/ Music Room	53815
Washtucna	Washtucna Elementary High School	Main Building	53817
White Salmon Valley	Columbia High School	C Court - Gym	51632
White Salmon Valley	Columbia High School	Libray	51631
White Salmon Valley	Columbia High School	Metal /Wood Shop	51628
White Salmon Valley	Wayne M. Henkle Middle School	Middle School	51638

Willapa Valley	Willapa Elementary School	Main Building	60150
Wilson Creek	Wilson Creek K-12	Main - Gym & Classrooms	53893
Woodland	Columbia Elementary School	Main Building	60181
Yakima	Adams Elementary School	8 Plex Bldg D	53950
Yakima	Adams Elementary School	BLDG C-1	53950
Yakima	Adams Elementary School	Old Gym C	53953
Yakima	Hoover Elementary School	Main Building - Area A	54023
Yakima	Hoover Elementary School	Main Building - Area B	54023
Yakima	Nob Hill Elementary School	Main Building	53961
Yakima	Wilson Middle School	Main Building	53968
Yakima	Wilson Middle School	Science Building	53969

Table C3. List of schools labeled as moderate priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

MODERATE PRIORITY SCHOOL BUILDINGS

District Name	Facility Name	Building Name	ICOS#
Aberdeen	A.J. West Elementary School	1952 Building	57384
Aberdeen	A.J. West Elementary School	Annex Building	57385
Aberdeen	Central Park Elementary School	Annex Building	57391
Aberdeen	Central Park Elementary School	Main Building	57392
Bainbridge Island	Commodore Options School	Art and Classrooms	57422
Bethel	Rocky Ridge Elementary School	Main Building	57514
Bickleton	Bickleton Elementary and High School	Bldg B - Vocational/Transportation	51647
Camas	Dorothy Fox Elementary School	Main Building	57808
Camas	Skyridge Middle School	Main Building	57782

Central Kitsap	Emerald Heights Elementary	Main	57877
Chimacum	Chimacum High School	High School 100 Bldg A - North Wing	58034
Chimacum	Chimacum High School	High School 100 Bldg A - South Wing	58034
Concrete	Concrete K-6 School	Gym	54520
Concrete	Concrete K-6 School	Main Building	54521
Cosmopolis	Cosmopolis Elementary School	Gymnasium Building	58040
Coupeville	Coupeville Elementary School	Main	54540
Coupeville	Coupeville Elementary School	Multipurpose	54539
Coupeville	Coupeville High School	Annex	54534
Dayton	Dayton High School	Gymnasium	51841
Dayton	Dayton K-8 School	Elementary and Middle School Building	51842
East Valley (Yakima)	East Valley Elementary School	Main Building	50345
Ephrata	Parkway School	Main Building	51938

Federal Way	Brigadoon Elementary School	Main Office Building - E	50844
Federal Way	Brigadoon Elementary School	Multipurpose Building - C	50838
Federal Way	Kilo Middle School	Building A Main Office	50808
Federal Way	Kilo Middle School	Building B	50803
Federal Way	Kilo Middle School	Building C	50806
Federal Way	Kilo Middle School	Building F1-F4 and Library	50811
Federal Way	Kilo Middle School	Building F5-F8	50807
Federal Way	Kilo Middle School	Building H Gymnasium	50810
Federal Way	Kilo Middle School	Building I Cafeteria	50802
Federal Way	Kilo Middle School	Building J	50812
Fife	Fife High School	Building IX 900 Science	58141
Fife	Fife High School	Building VI 600 Gyms	58143
Glenwood	Glenwood School	Main Building	51977
Grand Coulee Dam	Lake Roosevelt K-12	CTE Building	51986
Grand Coulee Dam	Lake Roosevelt K-12	Wood Shop	51988

Granite Falls	Granite Falls Middle School (form. HS)	Multi-Purpose Building	55030
Granite Falls	Mountain Way Elementary School	Main Building	55012
Highline	Southern Heights Elementary School	Building A	55185
Highline	Southern Heights Elementary School	Building B	55186
Hockinson	Hockinson Heights Elementary School (East)	Building 100 A	58331
Hockinson	Hockinson Heights Elementary School (East)	Building 200 C	58332
Hockinson	Hockinson Heights Elementary School (East)	Building 300 D	58328
Hockinson	Hockinson Heights Elementary School (East)	Building 400 B	58326
Hockinson	Hockinson Heights Elementary School (East)	Building 500 E	58327
Hockinson	Hockinson Heights Elementary School (East)	Building 600 F	58329

Hoquiam	Lincoln Elementary School	Administrative and Library Building	58352
La Conner	La Conner High School	High School Main Building	55668
Lake Washington	Einstein Elementary School	Main Building	55836
Longview	Robert Gray Elementary School	Main Building	58432
Lopez Island	Lopez Elementary School	Elementary	56065
Lopez Island	Lopez Middle High School	Gym/Tech Building	56067
Marysville	Marysville Middle School	Building B	56212
Mount Baker	Mount Baker Senior High School	800 Building (Former Deming Elem.)	56430
Naches Valley	Naches Valley High School	Gym Building	52476
Naches Valley	Naches Valley High School	Main Building	52476
Naches Valley	Naches Valley High School	Vocational Building	52475
Oak Harbor	Oak Harbor Middle School	C Wing	51290

Oak Harbor	Oak Harbor Middle School	Gym	51293
Oak Harbor	Oak Harbor Middle School	Main Building A	51289
Ocean Beach	Kaino Gym	Kaino Gym	58644
Ocosta	Ocosta Junior Senior High School	Junior Senior High	58651
Oroville	Oroville Elementary School	Main Building	52577
Paterson	Paterson Elementary School	Main Building	52838
Pe Ell	Pe Ell School	Fitness Center	51320
Peninsula	Peninsula High School	700 Building - Voc Ag	58791
Port Angeles	Roosevelt Elementary School	Main Building	58869
Puyallup	Mt View Elementary School	Main Building	58954
Puyallup	Wildwood Elementary	Main Building	58921
Snohomish	Emerson Elementary School	Annex	57133

Stanwood-Camano	Stanwood Elementary School	Main Building Unit C 1966	51456
Stanwood-Camano	Stanwood Elementary School	Main Building Units A	51456
Stanwood-Camano	Stanwood Middle School	Main Building (Building 1) Unit D	51448
Stanwood-Camano	Stanwood Middle School	Main Building (Building 1) Unit G	51448
Tacoma	DeLong Elementary School	First Bldg-Bldg B	59598
Tacoma	Franklin Elementary School	Main Building	59589
Tacoma	Larchmont Elementary School	Original Building	59804
Tacoma	Lister Elementary School	Main Building	59790
Tacoma	Roosevelt Elementary School	Main Bldg	59688
Taholah	Taholah School	Covered Court	59808
Touchet	Touchet Elementary and High School	CTE Building	53696
West Valley (Yakima)	West Valley Junior High School	WVJH (Gym Building)	51547

West Valley (Yakima)	West Valley Junior High School	WVJH (Main Building)	51546
White Pass	White Pass Elementary School	Main Building	51565
Woodland	Columbia Elementary School	1991 Addition	60181
Yakima	Hoover Elementary School	Area D - Annex Building	54025
Yakima	Hoover Elementary School	Classrooms - Area F	54021
Yakima	Robertson Elementary School	100 Building - Bldg "B"	53918
Yakima	Robertson Elementary School	200 Building - Bldg "C"	53917
Yakima	Robertson Elementary School	300 Building - Bldg "D"	53919
Yakima	Robertson Elementary School	400 Building - Bldg "E"	53930
Yakima	Robertson Elementary School	500 Building - Bldg "G"	53920

Table C4. List of schools labeled as lower priority for seismic retrofits, organized in alphabetic order. Light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

LOWER PRIORITY SCHOOL BUILDINGS

District Name	Facility Name	Building Name	ICOS#
Aberdeen	J. M. Weatherwax High School	Main Building	57378
Bainbridge Island	Bainbridge High School	300 Building	57407
Bainbridge Island	Commodore Options School	Eagle Harbor HS	57422
Bainbridge Island	Woodward Middle School	2-Story Classroom Wing	57424
Bainbridge Island	Woodward Middle School	Gym	57424
Bainbridge Island	Woodward Middle School	Main Building	57424
Battle Ground	Maple Grove K-8	Gym	50043
Battle Ground	Maple Grove K-8	Main Building	50044
Battle Ground	Praire High School	400 Building	50013
Battle Ground	River Homelink	Main Building	50050

Bellingham	Fairhaven Middle School	Main Building - Classrooms	54454
Bellingham	Fairhaven Middle School	West Wing	54455
Bellingham	Whatcom Middle School	Music Building	54468
Bethel	Camas Prairie Elementary School	Main Building	57577
Bickleton	Bickleton Elementary and High School	Main Building	51649
Burlington-Edison	Edison Elementary School	Original Building	50089
Cape Flattery	Neah Bay Junior/ Senior High School	Neah Bay Middle School & Gym	57834
Carbonado	Carbonado Historical School 19	Computer Lab and Library	57840
Cascade	Beaver Valley School	Main Building	51675
Central Kitsap	Emerald Heights Elementary	Gym	57877
Central Kitsap	Green Mountain Elementary	Gymnasium	57875
Central Kitsap	Green Mountain Elementary	Main	57875
Central Kitsap	Pinecrest Elementary	Gymnasium	57854

Central Kitsap	Pinecrest Elementary	Main	57854
Central Kitsap	Ridgetop Junior High	Main	57855
Central Kitsap	Silver Ridge Elementary	Main	57857
Central Kitsap	Woodlands Elementary	Main	57903
Chimacum	Chimacum Middle School	Middle School Bldg 200	58031
Clover Park	Custer Elementary School	Library	50243
Coupeville	Coupeville High School	Gymnasium	54537
Coupeville	Coupeville Middle School	Middle and High School Building	54544
Creston	Creston Junior Senior High School	Creston K-12 School Building	51821
Darrington	Darrington Elementary School	Main Elementary School	54550
Dieringer	North Tapps Middle School	Main Building	58058
East Valley (Yakima)	East Valley Central Middle School	6th Grade Building	50349
East Valley (Yakima)	East Valley Central Middle School	Computer Lab Building	50351
Federal Way	Kilo Middle School	Building D	50804

Federal Way	Nautilus K-8 School	Multipurpose Rm Bldg	50826
Federal Way	Nautilus K-8 School	Rooms 15-20 Bldg	50827
Federal Way	Nautilus K-8 School	Rooms 1-6 Bldg	50828
Federal Way	Nautilus K-8 School	Rooms 22-25 Bldg	50829
Federal Way	Nautilus K-8 School	Rooms 7-14 Bldg	50830
Fife	Columbia Junior High School	Main Building	58132
Fife	Fife High School	Building VII 700 Cafeteria	58142
Highline	Hilltop Elementary School	400 Building - Bldg D	55175
Highline	Seahurst Elementary School	Main Building	55100
Index	Index Elementary School	Enclosed Covered Play	55233
Lake Washington	Dickinson Elementary School	Main Building	55935
Lake Washington	Emerson Campus	Emerson	55920
Lake Washington	Wilder Elementary School	Main Building	55846

Longview	Mt. Solo Middle School	Main Building	58466
Mansfield	Mansfield Elem and High School	Main Building	52291
Mary M Knight	Mary M. Knight School	High School Building	50924
Marysville	Marysville Pilchuck Senior High School	Physical Science Building - Bldg S	56251
Marysville	Marysville Pilchuck Senior High School	South Building - Bldg N	56247
Marysville	Quil Ceda Tulalip Elementary School	Main Building	56204
Methow Valley	Liberty Bell Junior Senior High School	Main Building	52358
Morton	Morton Elementary School	Gymnasium	58504
Mount Baker	Mount Baker Jr High School	200 Building - JHS	56405
Mount Baker	Mount Baker Jr High School	Pro-Rate Portion of Commons - Bldgg 100	56404
Mount Baker	Mount Baker Sr High School	300 North	56443
Mount Baker	Mount Baker Sr High School	300 South	56436

Mount Baker	Mount Baker Sr High School	700 Building	56425
Mount Baker	Mount Baker Sr High School	Pro-rate Portion of Commons - Bldg 100	56440
Naches Valley	Naches Valley Middle School	Main Building	52487
Newport	Newport High School	Main Building	52500
Oak Harbor	Oak Harbor Middle School	Building B	51288
Ocean Beach	Ocean Park Elementary School	Main Building	58647
Ocosta	Ocosta Elementary School	Primary Addition	58652
Olympia	Boston Harbor Elementary School	Main Building	58698
Olympia	Thurgood Marshall Middle School	Gym Building	58671
Olympia	Thurgood Marshall Middle School	Main Building	58672
Pasco	Edwin Markham Elementary School	Main Building	52770
Pateros	Pateros K-12 School	Wood Shop	52829

Peninsula	Gig Harbor High School	Two-Story Building	58819
Peninsula	Minter Creek Elementary School	Main Building	58834
Peninsula	Voyager Elementary School	Main Building	58817
Port Townsend	Blue Heron Middle School	Main Building	58917
Riverside	Chattaroy Elementary School	Main Building	53054
Royal	Red Rock Elementary School	Main Building	53072
Royal	Royal High School	B Main Building	53076
Royal	Royal Middle School	Main Building	53080
Shaw Island	Shaw Island School	Intermediate Classroom Building	57008
South Whidbey	South Whidbey Elementary School	Main Building	57240
Spokane	Audubon Elementary School	Main Building	53564
Tacoma	Edison Elementary School	Main Building	59747

Tacoma	Foss High School	Main Building - 2003 Addition	59802
Tacoma	Manitou Park Elementary School	Main Building	59601
Tacoma	Northeast Tacoma Elementary School	Gym Bldg-Bldg 2	59627
Tacoma	Northeast Tacoma Elementary School	Main Bldg-Bldg 1	59626
Tacoma	Sheridan Elementary School	Main Building	59723
Tacoma	Stanley Elementary School	First Bldg	59636
Thorp	Thorp Elementary and Jr-Sr High School	Thorp Elem/Jr/Sr High School	53671
Tonasket	Tonasket Elementary School	Tonasket Elementary	53674
Tonasket	Tonasket Middle-High School	High School/Middle School	53673
Tumwater	Black Lake Elementary School	Building A	59890
Tumwater	Black Lake Elementary School	Building B	59893
Tumwater	Black Lake Elementary School	Building C	59892

Warden	Warden K-12	Cafeteria	53814
Warden	Warden K-12	Middle School/High School	53812
White Pass	White Pass Junior Senior High School	Main Building	51568
White River	Mountain Meadow Elementary School	Main Building	51616
Wilson Creek	Wilson Creek K-12	Business Building/Home Ec.	53895
Wilson Creek	Wilson Creek K-12	Gym/Commons	53894
Wilson Creek	Wilson Creek K-12	Vo-Ag / Science Bldg	53892

The following scoring rationale and methodology was used to initially rank buildings before engineers used their engineering judgment to adjust the ranking category. Higher scores indicate a building that is more at-risk. The scores used for each category are shown in Tables C5–12.

Table C5. Date of construction score.

Year Category	Assigned Score
<1935	12
1935-1955	10
1955-1964	9
1965-1975	8
1976-1985	6
1986-1998	4
>1998	1

Table C6. Construction type score.

Construction Type Category	Year Cutoff	Assigned Score
Older Wood Construction	1955	9
Intermediate Age Wood	1981	6
Late 20th Century Wood	1999	2
Post-1998 Wood	2020	1
URM	-	12
Intermediate Age Masonry	1981	10
Late 20th Century Masonry	1999	3
Post-1998 Masonry	2020	1
Nonductile Concrete	1955	12
Intermediate Age Concrete	1984	9
Late 20th Century Concrete	1999	3
Post-1998 Concrete	2020	1
Older Steel	1984	7
Intermediate Age Steel	1999	3
Post-1998 Steel	2020	1
Other	-	3

Table C7. Spectral acceleration adjustment.

S_{DS} (Less than Value) (g)	Assigned Score
1.50	6
1.25	5
1.00	4
0.75	3
0.50	2
0.25	1

Table C8. Square footage adjustment.

Square Footage (Less Than Value)	Adjustment Factor Applied to Spectral Acceleration Adjustment
9000	1
18000	1.1
42000	1.2
52000	1.3
75000	1.4
105000	1.5
2320000	1.6

Table C9. Liquefaction adjustment, for schools in a mapped liquefaction zone they were given a higher score.

Value	Assigned Score
Yes	3
No	0

Table C10. SEAONC Earthquake Performance Rating System Adjustment when unknowns equal noncompliant.

Value	Assigned Score
1	2
2	1
3	0

Table C11. SEAONC Earthquake Performance Rating System Adjustment when unknowns equal compliant.

Value	Assigned Score
1	4
2	2
3	0

Table C12. EERI EPAT adjustment.

Cutoff Value (Less than Value)	Assigned Score
100%	3
67%	2
33%	1

Table C13. FEMA 154 Rapid Visual Screening adjustment.

Cutoff Value (Less than Value)	Assigned Score
1.01	3
2.01	2
4.01	1
7.01	0

Table C14. ASCE 41 Tier 1 percent noncompliant adjustment.

Cutoff Value (Less than Value)	Assigned Score
46%	9
30%	7
20%	6
10%	4
6%	2
3%	0

Table C15. ASCE 41 Tier 1 percent noncompliant plus unknown adjustment.

Cutoff Value (Less than Value)	Assigned Score
91%	3
70%	2
50%	2
30%	1
17%	1
5%	0

Appendix D: Fire Station Reports

All of the data generated from the engineering assessments for the Phase 2 fire stations are downloadable below as an engineering volume. For fire stations that participated in Phase 1, the Phase 1 report and appendices are available to download the engineering and geology data for those stations.

https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol5_Concept_Level_Design_Reports_2_Fire_Stations.pdf