

WASHINGTON STATE SCHOOL SEISMIC SAFETY PILOT PROJECT— Providing Safe Schools for Our Students



by the Washington State Seismic Safety Committee



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written by Timothy J. Walsh and John D. Schelling
for the Washington State Seismic Safety Committee



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WASHINGTON STATE DEPARTMENT OF
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Cover photo: Green Park Elementary School in the Walla Walla School District.

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for the Washington State Seismic Safety Committee

INTRODUCTION

Washington State has the second highest earthquake risk in the U.S. after only California, according to a study performed by the Federal Emergency Management Agency (FEMA, 2008). Major earthquakes in western Washington in 1946, 1949, 1965, and 2001 killed 15 people and caused billions of dollars worth of property damage. In eastern Washington, earthquakes near Chelan in 1872 and near Walla Walla in 1936 caused significant damage.

Throughout the world, schools have been among the most dramatic examples of earthquake damage. Most notably, the 2008 Sichuan earthquake in China collapsed nearly 7,000 classrooms and killed thousands of students and teachers (*Seattle Times*, May 3, 2009). Schools in the United States have also been damaged in earthquakes, but certainly to a far lesser extent. In 1933, a major earthquake in Long Beach, California, destroyed 70 school buildings and severely damaged 120 more (Meehan, 1982), but the loss of life was minimized by its occurrence shortly before 6:00 p.m. when the buildings were unoccupied. The realization that school children could have been harmed led to the passage of the Field Act, which mandated special seismic safety provisions for California schools (Stover and Coffman, 1993). Washington State has not been exempt from earthquake damage to school buildings. In 1949, a large earthquake collapsed the gymnasium roof at Puyallup High School (Fig. 1). The earthquake occurred at 11:58 a.m., and the gym had just been vacated by students for lunch. Fortunately, many school districts, including Puyallup and Seattle, were on spring break at the time or the casualties might have

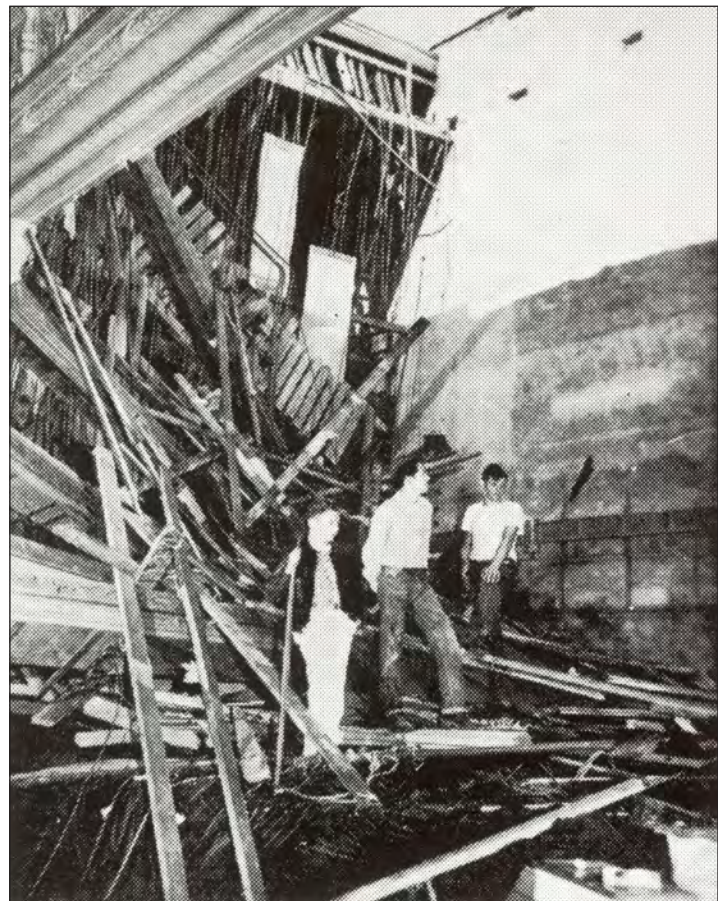


Figure 1. Open air theatre—Three members of the stage crew at Puyallup High School survey the wreckage of the stage, which was caved in by the earthquake just as they were leaving for lunch. Under the debris are a ping-pong table and a grand piano. *Seattle Times* staff photo by Larry Dion (from Ulrich, 1949).

been greater. At Castle Rock High School, however, falling masonry killed the student body president as he tried to escape from the building (Fig. 2). Another student was killed by falling bricks at Lowell Grammar School in Tacoma (*Seattle Post-Intelligencer*, April 14, 1949). In all, thirty schools were damaged in this earthquake (Washington State Seismic Safety Council, 1986). This earthquake eventually led to enactment of RCW 70.86 in 1955, which established “Earthquake Standards for Construction” and required that all schools and other high-occupancy buildings be “designed and constructed to withstand probable earthquake intensities at the location thereof”. This standard was strengthened in 1974 when the Washington State Legislature passed RCW 19.27, the State Building Code Act, which incorporated the more stringent standards of the Uniform Building Code. In 1993, the Scott’s Mills earthquake in Oregon severely damaged Molalla High School, requiring it to be torn down and rebuilt (Wang and Clark, 1999). This led to a number of actions in the state of Oregon. Of particular interest here is Oregon Senate Bill 2, which requires that all schools be evaluated for seismic risk and that all high-risk schools be retrofitted.



Figure 2. At Castle Rock, a high school student was killed as unanchored gable masonry cascaded to the walk outside the entrance. There could have been more casualties. (From Edwards, 1951.)

In the last decade, the application of LiDAR (Light Detection And Ranging), a new technology that permits highly detailed imaging of the ground surface, has greatly advanced the pace

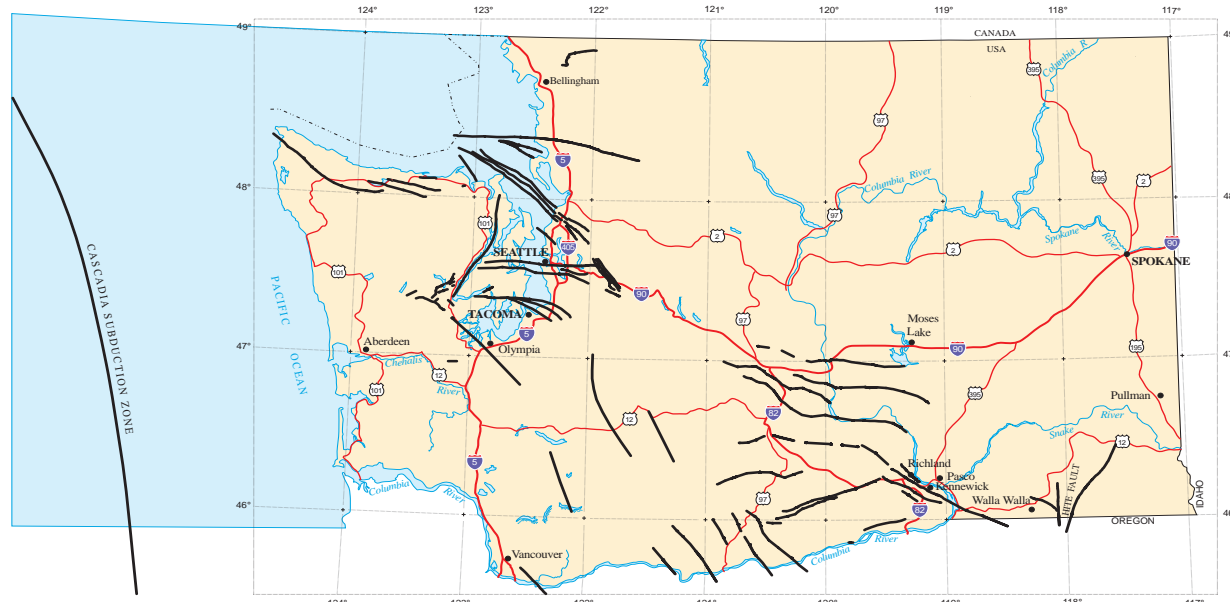


Figure 3. Simplified map of known and suspected active faults (heavy black lines) affecting earthquake hazard in Washington. It includes faults that have been demonstrated to have caused earthquakes since the last ice age but also faults that are under investigation.

of research into the state's earthquake hazard (Haugerud and others, 2003). Aided by lidar, geologic and geophysical studies have identified numerous active faults that have not generated large earthquakes in historic time but have done so in recent geologic time (Fig. 3). Moreover, since its creation in 1969, the Pacific Northwest Seismic Network has steadily increased its capabilities and now detects more than 1,000 earthquakes per year of magnitude 1.0 or greater. As our understanding of the earthquake hazard has increased, the building code standards for seismic design in Washington have steadily increased over the last half century, and while the current International Building Code has strong protections, schools and other buildings built to older building code standards may not fare as well as modern buildings in future earthquakes.

The Washington State Seismic Safety Committee, which is a subcommittee of the Emergency Management Council, has consistently called for a comprehensive assessment of school seismic safety. In 2010, the Western States Seismic Policy Council (WSSPC) issued a policy recommendation that says, in part, "**Children have the right to be safe in school buildings during earthquakes.** WSSPC recommends each state, province, territory, and community adopt a program that would identify and rank the potential seismic vulnerability of schools in their communities in a timely manner. Furthermore, programs to reduce the seismic vulnerability of those schools at greatest risk should be developed. WSSPC also recommends that FEMA provide dedicated financial support for the establishment of a program that improves the safety of seismically vulnerable schools." In 2010, National Earthquake Hazard Reduction Program funding through FEMA became available to initiate a pilot project aimed at investigating the feasibility and costs of implementing such an assessment program in Washington State. The purpose of this pilot project was to help determine an appropriate method of assessing the earthquake performance of school buildings in order to recommend future courses of action.

SELECTION PROCESS

For the pilot project, we selected two school districts in which to assess the seismic vulnerability of schools. The selection process considered four criteria: 1) demonstrated earthquake hazard, 2) matching the sizes of districts from eastern and western Washington, 3) manageable number of schools, and 4) cooperation of the district.

- 1) Our initial screening was to consider school districts that had high earthquake hazard. We mapped schools on a combination of the seismic design category map (Cakir and Walsh, 2007) and liquefaction susceptibility maps (Palmer and others, 2007). The seismic design category combines an estimate of the strength of ground shaking at any individual site with the amplification caused by the local geology. This will be discussed more fully in the next section.
- 2) We then considered school districts in both eastern and western Washington that scored high in criterion 1 and mapped them onto Figure 4.
- 3) We matched the number of schools per district, both to equalize each district and to select a number of school buildings that could be evaluated with the available resources.

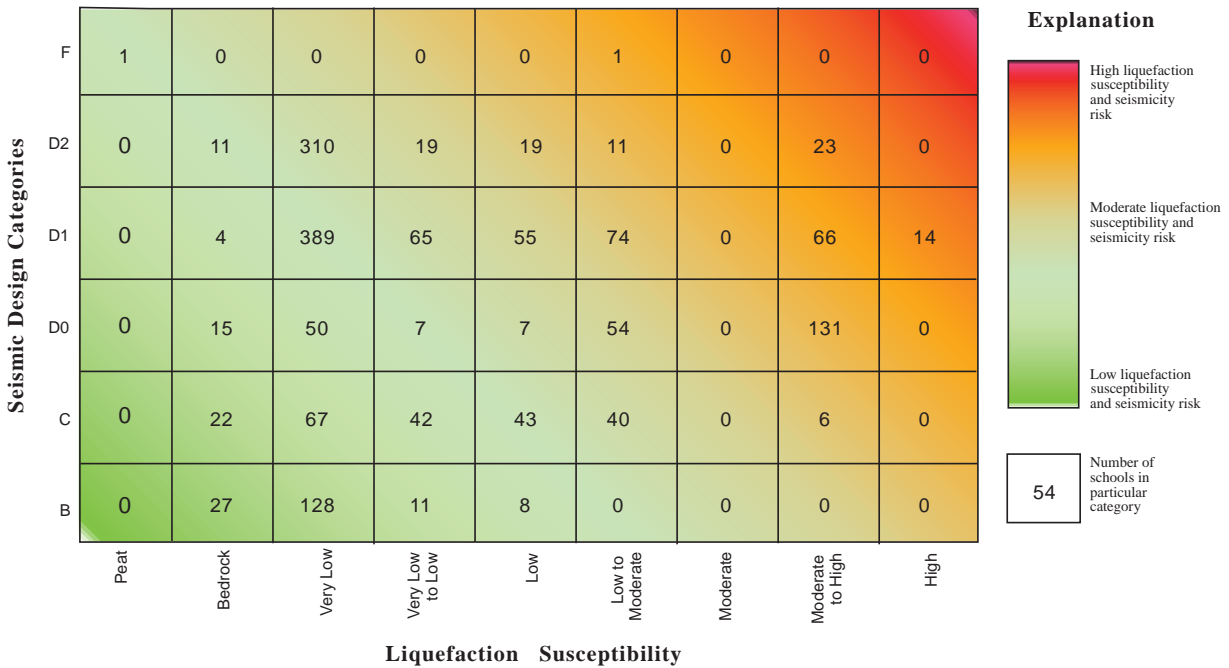


Figure 4. Number of schools in Washington in each category of the combined liquefaction susceptibility and seismic design category grid. We matrix-plotted seismic design category (a measure of the expected strength of ground shaking; Cakir and Walsh, 2007) against liquefaction susceptibility (Palmer and others, 2004). The number in each cell is the number of public schools, grades K-12.

- 4) A representative of the Office of the Superintendent of Public Instruction then contacted a select number of school districts to determine their willingness to participate.

We selected the Aberdeen and Walla Walla school districts. Each has between 5 and 10 schools, significant earthquake hazard, moderate to high liquefaction susceptibility, and a willingness to participate in this project.

PROJECT APPROACH

The project team evaluated screening approaches used elsewhere in the United States. The Rapid Visual Screening (RVS) method, *FEMA 154 Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (FEMA, 2002), was used in Oregon to implement Oregon Senate Bill 2 (Lewis, 2007) and more recently in Utah (Siegel, 2011). RVS characterizes earthquake hazard as high, moderate, or low over an entire county. The FEMA 154 process is based on a “sidewalk survey” of each building and includes a scoring process that allows classification of buildings as those expected to have acceptable seismic performance and those that may be seismically hazardous and should be studied further. The process is intended to be completed quickly for a large inventory of buildings. It has provisions for including information about the soil type if known; if not, it assumes a default value. This is significant because the near-surface soil type can have a large effect on the strength of ground shaking in an earthquake. While RVS is an inexpensive method to quickly survey a large number of buildings, it is a procedure that can produce both false positives and false negatives, that is, it can identify unsafe buildings as safe and safe buildings as unsafe. The manual for FEMA 154 (FEMA, 2002, p. 43) states, “The rapid visual screening procedure

presented in this Handbook is meant to be the preliminary screening phase of a multi-phase procedure for identifying earthquake-hazardous buildings. Buildings identified by this procedure as potentially hazardous must be analyzed in more detail by an experienced seismic design professional. Because rapid visual screening is designed to be performed from the street, with interior inspection not always possible, hazardous details will not always be visible, and seismically hazardous buildings may not be identified as such. Conversely, buildings identified as potentially hazardous may prove to be adequate.”

Given the level of support available from the pilot school districts in the form of access to buildings and original design documents, as well as volunteer support from the Structural Engineering Association of Washington, we chose to use a more detailed methodology called *ASCE 31-03 Seismic Evaluation of Existing Buildings*. ASCE 31-03 is intended to be completed by a structural engineer with access to the building and original design documents whenever possible. It provides a three-tiered process for the evaluation of existing buildings for either Life Safety Performance or Immediate Occupancy Performance. The three tiers defined include Tier 1 – Screening Phase, Tier 2 – Evaluation Phase, and Tier 3 – Detailed Evaluation Phase. The project team and school districts agreed that we should use the ASCE 31-03 Tier 1 process and a Life Safety Performance Objective. The process of building assessment is as follows (see Fig. 6):

1. Obtain original structural and architectural drawings for each building in the pilot program.
2. Obtain seismic hazard information for each building site as provided by the Washington State Department of Natural Resources.
3. Assign a team of two structural engineers to each building and provide them with the original drawings for review.
4. Identify ‘benchmark buildings’. Benchmark buildings are those designed and constructed to defined building codes based on the building type. If a building is a benchmark building, no further structural evaluation is required.

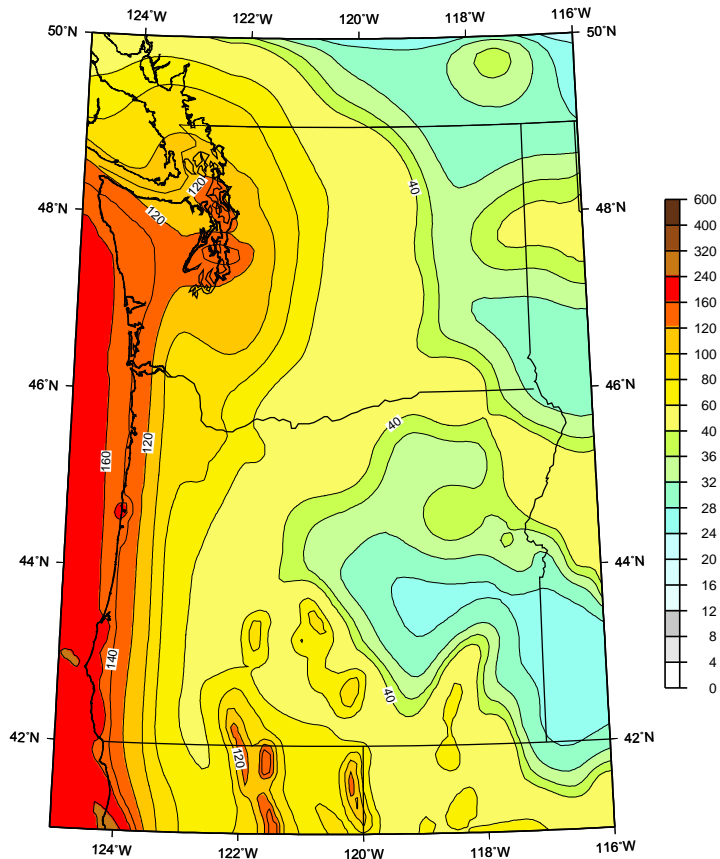


Figure 5. Probabilistic map of ground shaking that has a 2% probability of being exceeded in a 50-year period, calculated for shaking that has a frequency of 5 cycles/second. This is the map used in the 2009 International Building Code to determine the level of ground shaking for building design.

5. Conduct a site visit to each building. Each site visit required 2 to 3 hours and included full access to the building, including mechanical spaces, spaces above ceilings, attics, basements, etc.

We estimated the strength of ground shaking at school locations from the National Seismic Hazard Map by the U.S. Geological Survey (Frankel and others, 2002). This map is probabilistic, that is, it assesses the strength of ground shaking at a frequency of 5 cycles/second from all earthquake sources (Fig. 5).

The ground-shaking values in the National Seismic Hazard Map assume that the site is on bedrock or firm soil. However, the strength of ground shaking can be increased (or amplified) by the near-surface geology or soils. The International Building Code (IBC) classifies soils or the near-surface geology by the speed at which the most damaging seismic waves, called shear waves, travel through the upper 100 feet of the soil or rock column. This value defines the site class, which designates soils as classes A through E, with a special studies class F. The site class determines a multiplier of the input from the National Seismic Hazard Map. We have measured this value at each school using a portable seismograph and multiple noninvasive geophysical techniques. The soil amplification factor is multiplied by the value for high-frequency ground shaking from the National Seismic Hazard Map. This method of selecting the seismic force to be used in the design of a new building is used in the IBC, which was adopted by the state of Washington in 2004. For purposes of seismic design, two-thirds of this value is used and is called the design value. We determined the design value for each building. This method is much more detailed than that used in the Uniform Building Code (UBC), which was the model code used in Washington before the adoption of the IBC. The UBC divided the state into several broad zones and did not explicitly consider specific active faults, such as the Cascadia subduction zone or the Hite fault, but instead relied heavily on historic earthquakes. The UBC also used a method of soil classification that was inconsistent and more difficult to apply. Using the ASCE 31-03 (American Society of Civil Engineers, 2003) method and on-site geophysical testing allowed us to estimate the strength of ground shaking with a much higher resolution than was possible with the Rapid Visual Screening method.

The ASCE 31-03 method's more rigorous engineering assessment of buildings includes checklists that guide the evaluator through inspection of building type, foundation type, connection types, condition of materials, quality of workmanship, soil types as discussed above, and nonstructural hazards. Additionally, the structural plans for most of the schools were available, including subsequent upgrades and remodels, and supplied to structural engineers from the Structural Engineers Association of Washington (SEAW) and building inspectors from the Washington Association of Building Officials (WABO). They inspected each building, determining the structural type in detail and noting building condition and irregularities of design or construction. Potential nonstructural hazards were also noted. This evaluation was the first tier of ASCE 31-03. Higher tiers are successively more detailed and time-consuming.

We then combined these inputs into HAZUS-MH, FEMA's loss estimation model (Fig. 6), to estimate the potential damage to school buildings from two different levels of earthquake ground shaking—the level of ground shaking specified in the current building code and for a likely scenario earthquake deemed appropriate for the site (Schelling and others, in prep.). HAZUS-MH applies empirically derived fragility curves, which are estimates of the probability of damage to a structure from a specified strength of ground shaking, to each building type

and estimates a probability that it will be in a particular damage state—slight, moderate, extensive, or complete. The exact definition of each of those states varies with building type, but they are generally illustrated in Figure 7. It is important to be aware that the performance level required in the building code is life safety, that is, collapse prevention. A building can suffer extensive damage during an earthquake and still be considered to have met the building code standard of life protection, even if it is not usable afterward. Only some buildings in the ‘complete’ damage state are considered to be at risk of collapse. However, nonstructural hazards can also be life safety issues, and they are addressed in the ASCE 31-03 checklists as well as in assessments by the WABO building inspectors, who used a spreadsheet to record observation rather than the checklists.

In addition to participating in this pilot project, both school districts joined in the process of updating the local hazard mitigation plan, led by the local emergency management agency. Once a single or multi-jurisdiction hazard mitigation plan is approved by FEMA, participating agencies like school districts are eligible to apply for federal funding to retrofit identified deficiencies through the FEMA Pre-Disaster Mitigation (PDM) Grant Program and the post-disaster Hazard Mitigation Grant Program (HMGP).

RESULTS

The results of the assessments for each school building (including administration buildings) for current building code levels of ground shaking are presented in Tables 1 and 2. Details of the analysis, including the ASCE 31-03 evaluation forms, photos, and shear wave velocity profiles, are contained in an appendix to this report (available online only). HAZUS-MH estimates damage by the probability that a building will be in one of four damage states—by that standard, most of the buildings in this pilot project are expected to meet code. No building in Walla Walla School District is projected to have a significant probability of extensive or complete damage under the building code standard. How large a probability constitutes a concern depends on the overall

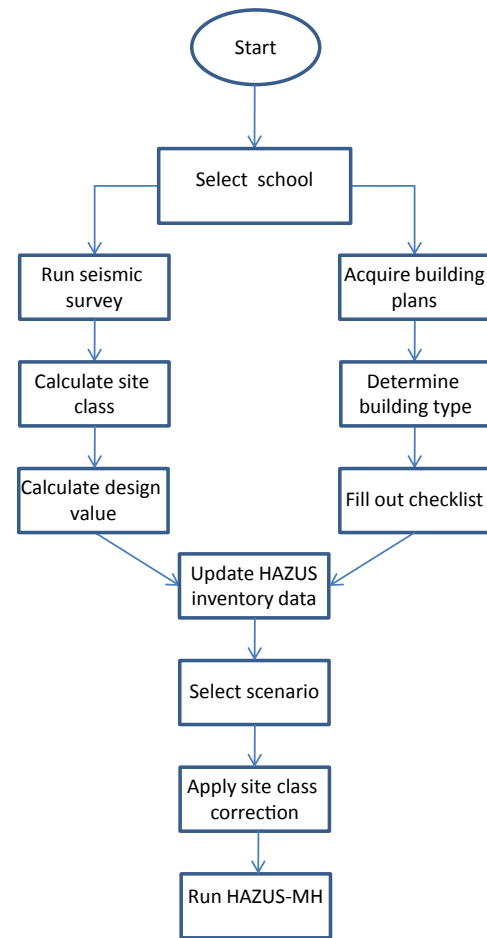


Figure 6. Flowchart of data collection and analysis for HAZUS-MH. Data collection for geologic conditions is on the left and data collection for buildings is on the right.





Damage state		Description
	Slight	Small plaster cracks at corners of door and window openings and wall–ceiling intersections; small cracks in masonry chimneys and masonry veneers. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as “large” cracks).
	Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear-wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
	Extensive	Large diagonal cracks across shear-wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
	Complete	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple-wall failure or failure of the lateral-load-resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

Figure 7. Examples of damage states estimated by HAZUS-MH. The actual damage states vary slightly with building type, but this is representative.

Table 1. Results of analysis of buildings in the Aberdeen School District for the level of ground shaking required to be designed for in the 2009 International Building Code.

Hazus Damage Probabilities for Aberdeen Schools						
Name	None	Slight	Moderate	Extensive	Complete	Extensive + Complete
A J West Elementary	14.8%	56.1%	28.4%	0.7%	0.0%	0.7%
Aberdeen S Dist Admin Bldg	0.0%	0.0%	0.1%	2.1%	97.9%	99.9%
Alexander Young Elementary	0.0%	0.0%	0.2%	7.6%	92.2%	99.8%
Central Park Elementary	0.0%	0.5%	27.6%	54.4%	17.4%	71.8%
Harbor High School	0.0%	0.0%	0.2%	7.6%	92.2%	99.8%
Hopkins Elementary	0.0%	0.0%	0.2%	7.6%	92.2%	99.8%
J M Weatherwax – Aberdeen HS	41.4%	45.4%	13.0%	0.2%	0.0%	0.2%
McDermoth Elementary	44.7%	42.3%	12.7%	0.4%	0.0%	0.4%
Miller Junior High	0.0%	0.0%	4.6%	42.4%	53.0%	95.3%
Robert Gray Elementary	54.1%	41.0%	4.8%	0.0%	0.0%	0.0%
Sam Benn Gym (Aberdeen HS)	34.1%	53.7%	12.1%	0.1%	0.0%	0.1%
Stevens Elementary	0.0%	0.0%	4.6%	42.4%	53.0%	95.3%
Stewart Bldg – Robert Gray Elm	0.0%	0.0%	2.6%	31.6%	65.8%	97.3%

Table 2. Results of analysis of buildings in the Walla Walla School District for the level of ground shaking required to be designed for in the 2009 International Building Code.

Hazus Damage Probabilities for Walla Walla Schools						
Name	None	Slight	Moderate	Extensive	Complete	Extensive + Complete
Berney Elementary	52.8%	22.1%	20.2%	4.4%	0.6%	5.0%
Berney Elementary Gym	52.8%	22.1%	20.2%	4.4%	0.6%	5.0%
Blue Ridge Elementary	61.7%	23.7%	12.2%	2.4%	0.0%	2.4%
Edison Elementary	60.9%	20.1%	16.4%	2.5%	0.2%	2.7%
Garrison Middle School	64.4%	26.3%	8.8%	0.6%	0.0%	0.6%
Green Park Elementary (additional)	64.4%	26.3%	8.8%	0.6%	0.0%	0.6%
Green Park Elementary (original)	39.3%	25.9%	23.7%	8.9%	2.2%	11.1%
Lincoln Alternative HS	39.3%	25.9%	23.7%	8.9%	2.2%	11.1%
Lincoln Alternative HS Annex	61.8%	27.3%	9.7%	1.1%	0.1%	1.2%
Pioneer Middle School	64.4%	26.3%	8.8%	0.6%	0.0%	0.6%
Prospect Point Elementary	28.5%	15.4%	31.4%	21.9%	2.8%	24.7%
Sharpstein Elementary (gym and lunchroom)	68.9%	15.8%	12.5%	2.7%	0.1%	2.8%
Sharpstein Elementary	51.2%	28.4%	19.2%	0.9%	0.3%	1.2%
Walla Walla HS (academic)	60.8%	18.4%	16.5%	4.1%	0.1%	4.2%
Walla Walla HS (auditorium)	41.6%	26.1%	28.0%	4.0%	0.3%	4.3%
Walla Walla HS (commons)	28.5%	15.4%	31.4%	21.9%	2.8%	24.7%
Walla Walla HS (large gym)	60.8%	18.4%	16.5%	4.1%	0.1%	4.2%
Walla Walla HS (library)	47.7%	22.8%	24.0%	5.1%	0.5%	5.6%
Walla Walla HS (music)	31.8%	21.0%	36.4%	8.9%	2.0%	10.9%
Walla Walla HS (science)	28.5%	15.4%	31.4%	21.9%	2.8%	24.7%
Walla Walla HS (small gym)	28.5%	15.4%	31.4%	21.9%	2.8%	24.7%
Walla Walla HS (vocational)	47.7%	22.8%	24.0%	5.1%	0.5%	5.6%

context, but probabilities greater than 50% are definitely significant and probabilities below about 5% are not. In the Aberdeen School District, several school buildings have significant probabilities of extensive or even complete damage according to the HAZUS-MH projection. Older buildings that have not been retrofitted and were constructed prior to the incorporation of a Cascadia subduction zone earthquake into the building code have a greater chance of damage.

DISCUSSION

As would be expected, school buildings designed under older building code standards are more likely to sustain significant damage in what are now considered appropriate levels of earthquake hazard. This is more the case in the Aberdeen School District, where the greatest threat is from the Cascadia subduction zone. Ground motions from a Cascadia event were not considered at all in building codes before the 1991 Uniform Building Code, and not explicitly so until the 2003 International Building Code. In contrast, ground shaking levels in building codes for Walla Walla have not changed as significantly.

The advantage of ASCE 31-03 plus a detailed site analysis is that it will provide information that can immediately be put to use for mitigation, particularly nonstructural mitigation and repairs. Within and between school districts, this approach allows a relative ranking that can be used to target the more extensive analyses that will be necessary to apply for retrofit or replacement funding.

A key component of this pilot project was to assess the feasibility of evaluating all school buildings throughout the state. The determination of seismic soil class requires about a half day at each site, so that two to three schools can be assessed in a day if travel time between schools is short, as it is for the Aberdeen and Walla Walla School Districts (Figs. 8, 9). Likewise, the time necessary to evaluate buildings using ASCE 31-03 is approximately one half day. With travel time to nearby schools, a trained engineer can evaluate two to three schools in a day. Because this method requires an inspection inside the building, irregularities, maintenance issues, and nonstructural hazards are identified that are not seen with Rapid Visual Screening. This has the distinct advantage of identifying relatively inexpensive mitigation measures, as well as providing more detailed information for effectively prioritizing mitigation measures.

CONCLUSIONS

This study has demonstrated the feasibility of performing more detailed analyses of the seismic safety of school buildings than the previously used method of Rapid Visual Screening. Both methods require significant technical skills to perform, but the added time necessary to perform the ASCE 31-03 method used in this study provides significantly more and more usable information, especially for future engineering design work. Additionally, the likelihood of both underestimating and overestimating the status of any individual school building is significantly decreased. The more detailed information from this analysis will also point toward mitigation measures, including nonstructural measures, that may reduce seismic hazards at each site.

NEXT STEPS

Funding from Washington State Emergency Management through the FEMA State Earthquake Assistance Program enabled the evaluation and ranking component of this pilot project to be



Figure 8. Orthophoto map of the Aberdeen School District showing the location of buildings analyzed in this study.

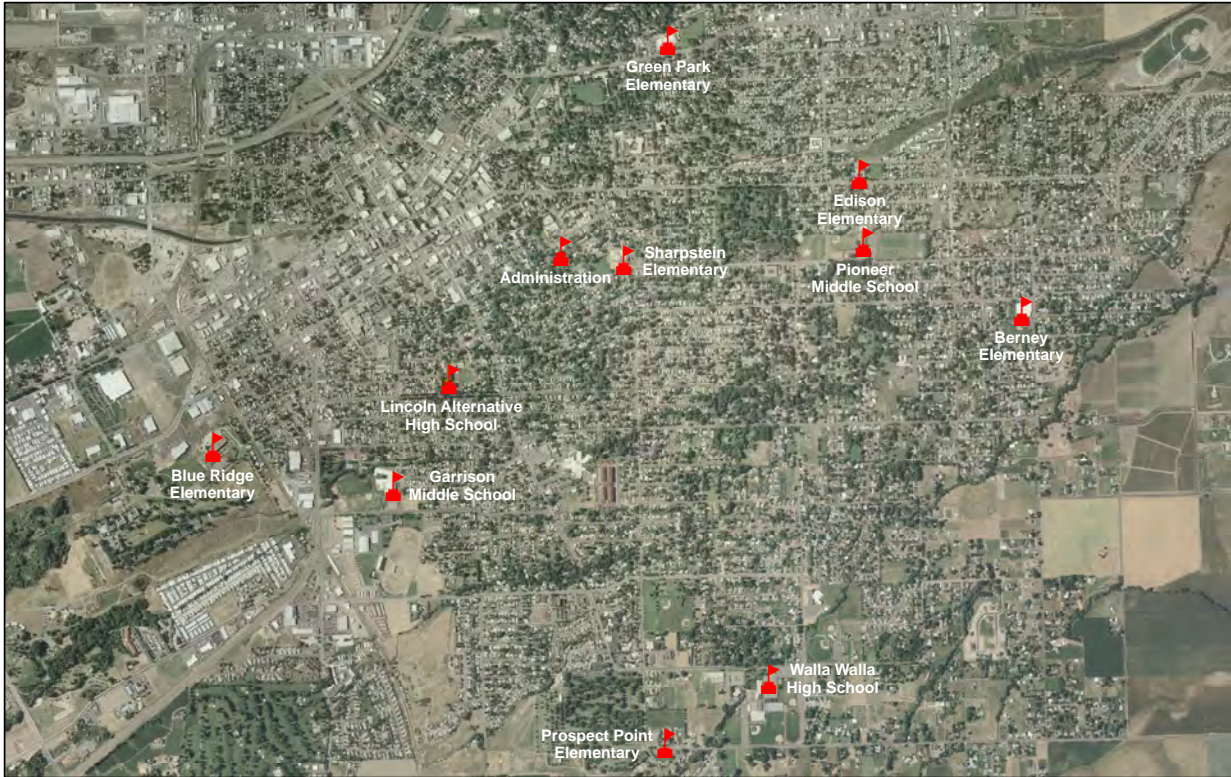


Figure 9. Orthophoto map of the Walla Walla School District, showing the location of buildings analyzed in this study.

Table 3. School retrofit projects in Washington since the Nisqually earthquake, February 28, 2001. The total is the total cost of the project, including FEMA, state and local matching funds.

Project	Cost	Status
Retrofit of Residence Hall A at The Evergreen State College	\$1,456,463	Ongoing
Retrofit of Library Clock Tower at The Evergreen State College	\$1,055,600	Ongoing
Non-structural retrofit at Burke Museum at the University of Washington	\$949,039	Nearing completion
Retrofits of two dormitories at Pacific Lutheran University	\$2,100,334	Complete
Retrofits of two dormitories at Pacific Lutheran University	\$2,100,334	Complete
Retrofit shop at Lake Washington Technical College	\$72,163	Complete
Retrofit of nine elementary schools in Edmonds	\$6,966,715	Complete
Retrofit of facilities at Clark College in Vancouver	\$1,359,915	Complete
Retrofit of facilities at Clark College in Vancouver	\$1,359,915	Complete
Retrofit of school auditorium/cafeteria in LaConner	\$702,658	Complete
Retrofit of elementary school in Littlerock	\$875,535	Complete
Retrofit of Roy Elementary School near Tacoma	\$555,172	Complete
Total	\$18,998,671	

completed. Subsequent funding through this program was also sufficient to provide further engineering analysis of two buildings in each school district, using the second tier of ASCE 31-03 analysis. This additional funding will enable the districts participating in this pilot project to begin to address issues identified in the screening phase and will permit the benefit-cost analysis necessary to apply for funding through FEMA’s Pre-Disaster Mitigation Grant Program or Hazard Mitigation Grant Program (HMGP) for retrofitting of identified deficiencies. The HMGP provides mitigation funding after Presidential Disaster Declarations, with the amount of money available being a percentage of the direct losses suffered in the disaster. The available funds through these programs cannot be anticipated in advance; however, Washington has had many presidentially declared disasters in recent years, and HMGP funds have frequently been available. It is important to note that in recent years, schools in Washington have successfully applied for a number of HMGP and PDM grants for seismic retrofits, including \$875,535 for the Littlerock Elementary School Multipurpose Building and \$1,092,347 for The Evergreen State College’s Dormitory Residence Hall A. Table 3 shows a list and total cost of all school projects since the Nisqually earthquake that received mitigation grants. The totals include state and local matching funds as well as the FEMA contribution. In order to access PDM or HMGP funding, it is important that both public and private school districts engage with their local emergency management offices to become familiar with these grant programs and participate in the hazard mitigation planning process.

In subsequent years, we hope to be able to secure dedicated funding to extend this analysis statewide or at least to school districts prioritized on the basis of the analysis in Figure 3. Alternatively, school districts could be prioritized in order of the amount by which ground shaking hazard has increased in the current building code since enactment of the State Building Code Act of 1974. Based upon the results of this pilot project, it is estimated that completing a statewide assessment program using the previously described approach would cost roughly 10 to 13 million dollars that could be phased over an 8- to 10-year period. This equates to approximately \$3,500 to \$4,500 per public school throughout the state, and such an approach could be supported by a combination of federal, state, and local resources.

USEFUL WEBSITES FOR MORE INFORMATION

Cascadia Region Earthquake Workgroup

<http://www.crew.org/>

Federal Emergency Management Agency

<http://www.fema.gov/>

Pacific Northwest Seismic Network

<http://www.pnsn.org/>

Structural Engineers Association of Washington

<http://www.seaw.org/>

U.S. Geological Survey Earthquake Hazards Program

<http://earthquake.usgs.gov/hazards/>

Washington Association of Building Officials

<http://www.wabo.org/>

Washington Division of Emergency Management

<http://www.emd.wa.gov/>

Washington Emergency Management Council

<http://www.emd.wa.gov/about/WashingtonMilitaryDepartmentEmergencyManagementDivision-AboutUs-EmergencyManagementCo.shtml>

Washington State Department of Natural Resources

<http://www.dnr.wa.gov/>

Washington Office of the Superintendent of Public Instruction

<http://www.k12.wa.us/>

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Recep Cakir and Christopher Maffucci (with hammer) collect seismic data at Central Park Elementary School in the Aberdeen School District as Deirdre Clarke of the Department of Natural Resources, Chuck Wallace of Grays Harbor Emergency Management, and Glen Farley of KING-TV watch.