ATKINS

State of Washington Military Department - Emergency Management Division,
Lewis County, Washington

Loss Avoidance Study

Reanalysis of eight Earthquake Hazard Mitigation Projects using Hazus-MH

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Introduction

Several earthquake hazard mitigation projects have been implemented in Washington state over the last few years. In this report, the losses avoided or benefits achieved for eight of these projects are highlighted and reanalyzed using Hazus-MH.

Hazus-MH is FEMA's nationally applicable standardized methodology that estimates potential losses from earthquakes, hurricane winds and floods. Hazus-MH was used for this report to generally document losses that may be avoided by implementing certain types of mitigation projects.

Table 1 on the following page lists the eight projects selected, categorizing the type of hazard mitigation undertaken, and providing a brief description of each hazard mitigation action. Figure 1 provides the general locations of the projects.

Six of these projects used structural strengthening for the buildings as a hazard mitigation measure, one project used structural reinforcement of a water reservoir, and one project involved only non-structural strengthening measures.

Figure 1 – Location of projects selected for analysis

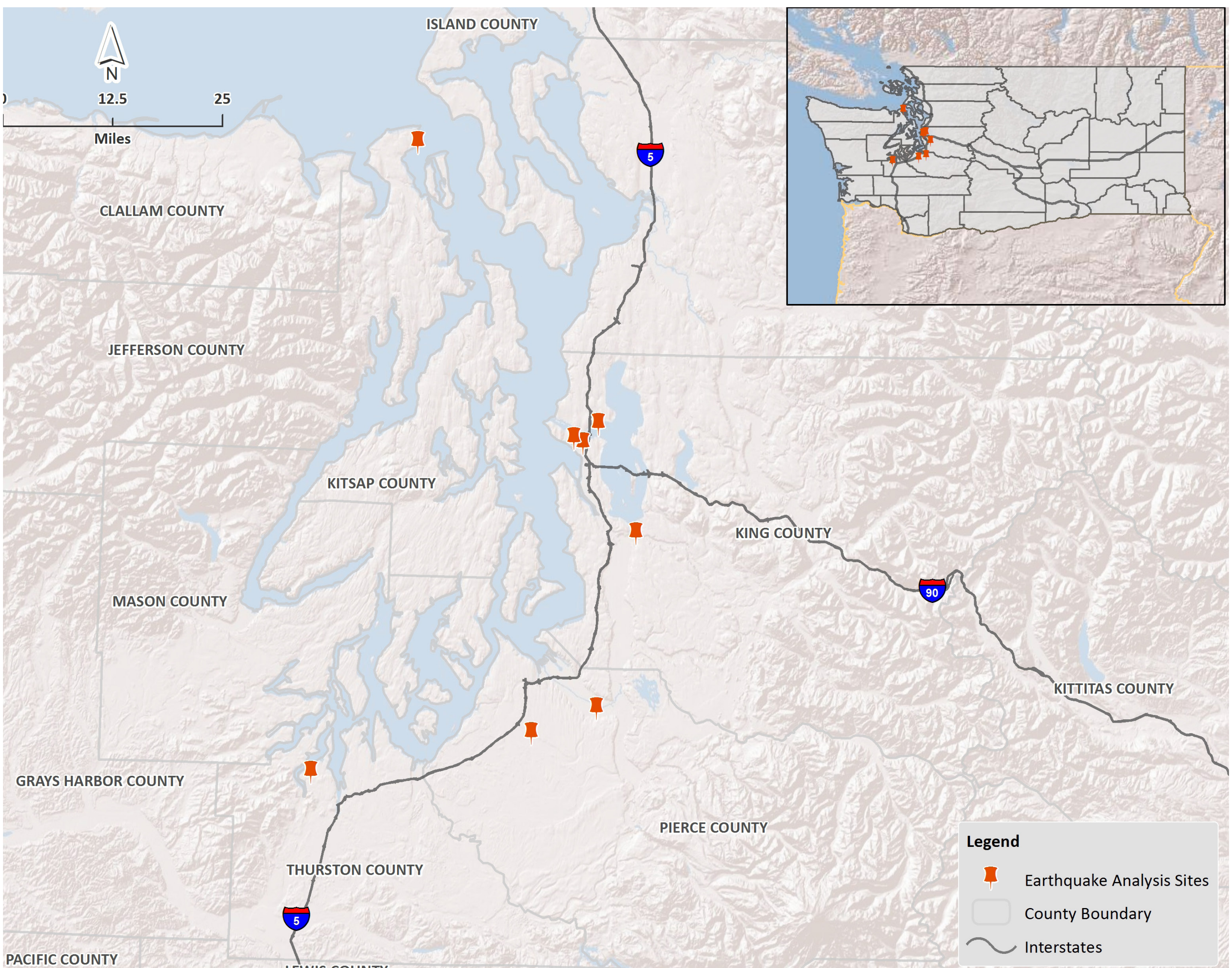


Table 1 – Projects selected for this study

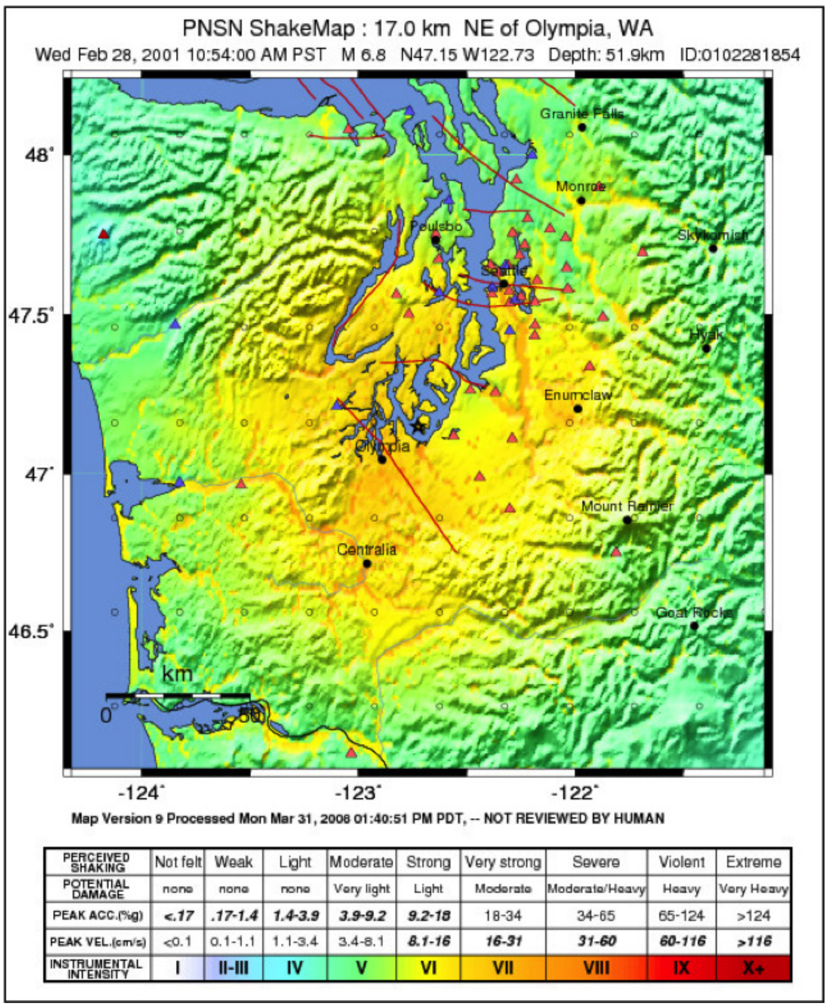
#	Name of project	Type of mitigation	Description	Original project costs	Without casualties		With casualties	
					Original Project Benefits	Original BCR	Original project benefits	Original BCR
1	South Lake Union Naval Armory (community center - MOHAI Museum of History & Industry) in Seattle [SLU]	Structural	Cross bracing of the roof system, stiffening of the walls through the addition of concrete blocks to the high window walls, and strengthening of the columns by adding composite wrap to interior columns.	$713,229	$6,982,372	9.79	$13,441,471	18.85
2	UW Burke Museum non-structural retrofit in Seattle [UWBM]	Non-structural	Anchoring storage racks and library shelves. Unable to determine from data provided by WA EMD	Unable to determine from data provided by WA EMD				
3	Retrofit of the historic Carnegie Library in Port Townsend [CLT]	Structural and Non-structural	Seismically retrofit the 1913 portion of the Port Townsend Carnegie Library both structurally and non-structurally by adding in-plane and out-of-plane diaphragms; diaphragm cross-ties; anchorage of framing components; anchorage of masonry chimney to diaphragms; redoing canopy attachment; and adding book shelf bracing. The goal is to bring this portion of the library complex up to Life Safety Performance Level based on a 2% probability of exceedance in 50 years, corresponding to a 2,500-year return period for the event.	Unable to determine from data provided by WA EMD				

Table 1 – Projects selected for this study

#	Name of project	Type of mitigation	Description	Original project costs	Without casualties		With casualties	
					Original Project Benefits	Original BCR	Original project benefits	Original BCR
4	Retrofit of the Sumner Springs water reservoir in Sumner [WRS]	Structural	Sumner reservoir tank anchoring. Seismic retrofit water reservoir, install seismically activated shutoff valve and emergency generator.	$1,127,615	Not calculated	Not calculated	$1,263,966	1.12
5	Retrofit of the Queen Anne Community Center, Seattle [QACC]	Structural	Upgrading roof deck diaphragm and building component connections at Queen Anne Community Center to bring the building into compliance with current seismic codes, and allowing the building to continue to be used as an emergency shelter.	$848,118	$1,577,957	1.86	$2,035,793	2.40
6	Retrofit of Residence Hall A at The Evergreen State College [RH-ESC]	Structural	Retrofit building to meet requirements for Life Safety	$1,456,463	$1,645,186	1.13	$5,265,044	3.61
7	Retrofits of two dormitories at Pacific Lutheran University [PLU]	Structural	Seismic upgrade and renovation of the Hinderlie Hall to meet current seismic code requirements.	$1,343,206	$528,297	0.39	$2.082,219	1.55
8	Retrofit Fire Station 11 in Renton [FSR]	Structural	Immediate Occupancy (IO) performance objective for an earthquake with a probability of occurrence of 2% in 50-years.	$479,279	Not calculated	Not calculated	$1,054,837	2.20

According to Washington State Department of Natural Resources, over 1,000 earthquakes occur annually in the state of Washington. This is an average of approximately 3 per day, though most go unfelt and do not cause damage. Larger magnitude earthquakes, which result in damage, occur less frequently in the state. The February 28, 2001, 18:54 UTC Mw 6.8 Nisqually, Washington Earthquake, which is shown in Figure 2, was the last major earthquake that hit the Puget Sound Region. Of the projects selected, only the Renton Fire Station 11 suffered some damage during this event. The primary cause of the damage was some structural irregularity in the building caused by three intersecting walls, along with changing roof elevation, and openings in the wall.

Figure 2 – The February 28, 2001, 18:54 UTC Mw 6.8 Nisqually, Washington Earthquake



The original benefit cost studies for these eight projects were done at different times during the last ten years and supported by the FEMA BCA tool. This study only focuses on the benefit or losses avoided side, relies on Hazus-MH, and uses 2013 dollar values for calculating losses avoided.

Key modeling parameters

Table 2 below highlights the values used for the key modeling parameters in estimating the losses avoided. These values are derived after a thorough review of the original BCA reports and adjusted for 2013 valuation based on an assumed 3% inflation rate since the original study was performed.

Table 2 – Key modeling parameters

Prop. #	Building value (2013 $ million)	Content value (2013 $ million)	Square footage	Year built	Number of stories	Building type before mitigation	Building type after mitigation	Average number of occupants
1 (SLU)	16	0.6	51,000	1940	3	Concrete moment frame (C1L) – Pre Code	Concrete moment frame (C1L) – Moderate Code	120
2 (UWBM)	N/A	124.3	Unknown	1885	3	Wood	Wood	40
3 (CLT)	4.2	1.9	8,000	1913/ 1989 (renovation & expansion)	5	Concrete shear walls (C2M) – Pre Code	Concrete shear walls (C2M) – Moderate Code	155
4 (WRS)	N/A	N/A	N/A	N/A	N/A	Steel	Steel	N/A
5 (QACC)	6.7	0.6	27,000	1949	2	Concrete shear walls (C2M) – Pre Code	Concrete shear walls (C2M) – High Code	60
6 (RH-ESC)	16	1	47,000	1967	10	Concrete shear walls (C2H) – Low Code	Concrete shear walls (C2H) – High Code	500
7 (PLU)	6.6	2.0	34,000	1954/5	3	Steel frame with unreinforced masonry infill walls (S5L) – Pre code	Steel frame with reinforced masonry infill walls (S4L) – Moderate Code	130
8 (FSR)	4.0	3.1	14,600	1975	1	Reinforced Masonry (RM1L) – Moderate Code	Reinforced Masonry (RM1L) – High Code	9

Assumptions and limitations

This section summarizes the key assumptions, approach, and limitations used in estimating the benefits.

- First, Hazus-MH 2.1 was used in all of the analyses except for UW Burke Museum and the Sumner Springs water reservoir. For these two projects, benefits were extrapolated from the original BCA by simply converting the original numbers to 2013 dollars. This was unavoidable given the limitation of Hazus-MH analytical capabilities in modeling the specific mitigation measures undertaken for these two projects. That is, Hazus-MH does not provide reliable results when simulating non-structural retrofit or when analyzing non-buildings.
- Second, the categories of losses avoided that were measured include building-related benefits (structural and non-structural), content-related benefits, and casualties avoided. This latter was converted to dollars by assuming a value of $4M for an avoided death, $20K for an avoided serious injury and $2K for an avoided light injury.
- Displacement costs were not included in this analysis since Hazus-MH does not provide reliable information in this regard.
- The Advanced Engineering Building Module (AEBM) was used to conduct the analyses. AEBM is an extension of Hazus that is used to model how specific buildings may react to an earthquake.
- Several different scenarios were run in Hazus to document losses avoided for the eight selected projects. Scenarios include:
  - 100-year event (approximately 5.5 Moment Magnitude)
  - 250-year event (approximately 5.5 Moment Magnitude)
  - 500-year event (approximately 5.5 Moment Magnitude)
  - 750-year event (approximately 6.0 Moment Magnitude)
  - 1000-year event (approximately 6.5 Moment Magnitude)
  - 1500-year event (approximately 6.5 Moment Magnitude)
  - 2000-year event (approximately 6.5 Moment Magnitude)
  - 2500-year event (approximately 7.0 Moment Magnitude)

In addition, two ShakeMap planning scenario events were also modeled in Hazus to document losses avoided. They are the Cascadia event and the Seattle event. The Cascadia event is for a Mm 9.0 earthquake with an epicenter located off the coast close to the border between Oregon and Washington. The Seattle event is for a Mm 7.2 earthquake with the epicenter located south of downtown Seattle.

ShakeMap is a product of the U.S. Geological Survey Earthquake Hazards Program in conjunction with seismic network operators. ShakeMaps are used by federal, state, and local organizations, both public and private, for post-earthquake response and recovery, public and scientific information, as well as for preparedness exercises and disaster planning. Maps are produced for both real-time events and scenarios that are often used for planning purposes. ShakeMaps can be imported into Hazus for modeling purposes. A more detailed discussion of this methodology is provided below.

ShakeMaps methodology

While a comprehensive instruction guide for processing ShakeMaps can be found at the FEMA library, the six major steps are:

- Obtain ShakeMap Data
  - http://earthquake.usgs.gov/earthquakes/shakemap/
  - The four files found here are Esri shapefiles
  - Each file must be downloaded for a complete ShakeMap file
- Define the ShakeMaps Projection
  - Spatial projection must be in the same coordinate system as other Hazus data, GCS NAD83.
- Convert ShakeMaps shapefiles to Hazus-MH compliant personal geodatabase
- Import ShakeMaps data to a Hazus-MH Study Region
  - Four shaking parameter feature classes must be added to the Hazus-MH Study Region
    1. Peak Ground Velocity (PGV)
    2. Peak Ground Acceleration (PGA)
    3. Spectral Acceleration at 1.0 seconds (SA10)
    4. Spectral Acceleration at 0.3 seconds (SA03)
- Create a new user-supplied hazard scenario in Hazus-MH
- Run the analysis in Hazus-MH

Findings

Tables 3 and 4 summarize the losses avoided for the categories considered. Losses avoided in Table 3 do not include benefits associated with avoided casualties, while Table 4 does include these.

Average Annualized Loss (AAL) was calculated for each project to allow for comparison. The Average Annualized Loss addresses two key components of seismic risk: the probability of ground motion in terms of physical damage and economic loss. Average Annualized Loss also takes into account the regional variations in seismic risk. Average Annualized Loss annualizes expected losses by averaging losses per return period (100; 250; 500; 750; 1,000; 1,500; 2,000; and 2,500 years), which factors in historic patterns of smaller but more frequent earthquakes with those that are larger in magnitude but are infrequent in nature. This methodology enables the comparison of risk to occur between different geographic areas.

Table 3 – Losses avoided [all values are in $1,000's] (without casualties avoided)

Scenario	1 (SLU)	2 (UWBM)	3 (CLT)	4 (WRS)	5 (QACC)	6 (RH-ESC)	7 (PLU)	8 (FSR)
2,500	$6,818.5		$1,809.8	-	$3,012.2	$4,756.7	$3,313.6	$499.9
2,000	$6,801.9		$1,764.9	-	$2,882.3	$4,573.1	$3,274.6	$359.3
1,500	$6,596.5	-	$1,623.3	-	$2,530.5	$4,090.9	$3,122.8	$240.3
1,000	$6,187.4	-	$1,366.3	-	$2,190.9	$3,138.8	$3,090.7	$144.0
750	$5,837.5	-	$1,176.6	-	$1,873.4	$2,638.1	$2,900.0	$86.2
500	$4,641.6	-	$791.3	-	$1,262.6	$1,588.6	$2,288.7	$56.7
250	$2,612.3	-	$328.3	-	$531.8	$673.9	$1,221.4	$48.8
100	$747.6	-	$71.9	-	$121.3	$184	$308.3	$39.7
AAL	16.7	96.0	3.4	91.6	5.5	8.1	8.0	0.6
Seattle Event	$4,390.1	-	$11.1	-	$923.6	$25.7	$25.7	$453.7
Cascadia Event	$2,663.4	-	$173.4	-	$265.9	$747.0	$558.9	$50.4

Table 4 – Losses avoided [all values are in $1,000's] (with casualties avoided)

Scenario	1 (SLU)	2 (UWBM)	3 (CLT)	4 (WRS)	5 (QACC)	6 (RH-ESC)	7 (PLU)	8 (FSR)
2,500	$10,264.4		$4,340.6	-	$4,116.1	$7,594.2	$5,619.4	$530.8
2,000	$10,175.1		$4,208.5	-	$3,920.6	$7,276.7	$5,520.6	$378.6
1,500	$9,766.3	-	$3,818.5	-	$3,415.9	$6,457.8	$5,198.1	$251.2
1,000	$9,068.8	-	$3,132.8	-	$2,923.4	$4,865.9	$5,049.0	$149.2
750	$5,837.5	-	$1,176.6	-	$1,873.4	$2,638.1	$2,900.0	$86.2
500	$6,553.2	-	$1,703.6	-	$1,640.4	$2,372.5	$3,564.3	$58.0
250	$3,473.0	-	$642.6	-	$666.4	$959.6	$1,774.0	$49.0
100	$887.5	-	$115.4	-	$142.3	$231.7	$386.7	$39.7
AAL	23.0	96.0	7.2	91.6	7.1	12.0	12.2	0.6
Seattle Event	$4,390.1	-	$11.1	-	$923.6	$25.7	$72.6	$453.7
Cascadia Event	$3,513.4	-	$297.5	-	$316.4	$1,023.6	$789.2	$50.4
Original project cost	$713.2	N/A	N/A	$1,127.6	$848.1	$1,456.5	$1,343.2	$479.3

Conclusions and lessons learned

Hazus-MH is a useful tool in supporting the type of losses avoided documented in this report, and in particular those that involve structural mitigation measures. Hazus-MH, out of the box, provides the flexibility to assess benefits for multiple projects simultaneously and this can help support grant applications in an economical and efficient manner.

The findings from Hazus-MH are in line with the earlier estimates based on the BCA tool and reiterate the benefits that the different mitigation measures would achieve.

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