Appendix A - Critical Buildings Technical Report

DRAFT 3-25-13

Introduction

This appendix is a companion report to the Critical Buildings Report prepared by the Critical Buildings Task Group as part of the Oregon Resilience Plan prepared by the Oregon Seismic Safety Policy Advisory Commission (OSSPAC). Whereas the Critical Buildings Report is generally written in laymen terms to be appropriate for as wide an audience as possible, some of the background and technical details of how data was analyzed are intentionally not addressed in depth so that the main report can focus on the results of the analysis and the corresponding recommendations. This technical appendix will fill in many of the analysis details, and is primarily intended for earthquake and engineering professionals who have some background and familiarity with the topics and reference documents being discussed. The methods utilized by the Task Group to analyze the data largely centered on manipulating existing data sets to fit the resilience model set forth in the Oregon Resilience Plan. As a result, the most significant technical background is contained in the methodologies developed by FEMA to create the evaluation procedures and data sets. These methodologies are referenced in the discussion briefly, but will not be addressed in detail.

Data Overview

The Critical Buildings Task Group was asked to review the building sectors that will be critical to resilience in the State of Oregon after a M9.0 Cascadia Subduction Zone (CSZ) earthquake. These sectors include those buildings necessary for immediate response to the seismic event and the building sectors necessary for providing basic services to communities as they begin to restore function and return to normal life afterwards. There are other buildings and sectors that could have also been considered vital for resilience, but the Task Group chose to limit the study to those believed to be the most critical. In addition to police, fire, emergency operations, education, healthcare, retail, banking, residential and critical government sectors, the task group evaluated a group of buildings classified as vulnerable buildings. These buildings are unreinforced masonry and non-ductile concrete structures that have historically performed poorly in past earthquakes and pose a very significant and direct threat to life safety, regardless of their use.

In any analysis, it is necessary to have information about the topic being studied. To evaluate buildings for seismic resilience, one needs to have information about the buildings structural systems and where it is located. . To accurately assess a specific building, detailed information is typically collected about the subject building and analyzed. To assess large populations of structures, it is often not possible to evaluate individual buildings in detail, so more generalized methods that utilize statistical estimations of building performance, based on factors such as building construction type, vintage, geometry, and supporting soil characteristics are employed

In 1996, the Seismic Rehabilitation Task Force that was created by Senate Bill 1057 presented their report to the Sixty-Ninth Oregon Legislative Assembly. One of the findings in this report estimated that conducting an inventory of Oregon's non-residential buildings, which they estimated to be approximately 97,000 structures, would cost approximately 1.7 million dollars and would take 5-years to complete. This does not include 27,000 buildings of this total that were estimated to be located within the City of Portland and part of a previous city inventory. (Page 31 of 1996 seismic rehabilitation task force study)

The scope of the Critical Buildings Task Group study was limited to critical structures, which are those that must be operational during, or soon after, a CSZ event. Working as a volunteer committee with limited time to complete an analysis and reports the task group primarily relied on existing data sets and damage estimate models to assess the resiliency of the existing building stocks in each sector.

Two data sources for the existing critical buildings were identified and used to estimate their seismic resilience:

- The *2007 Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings* (Open File Report 07-020), by Don Lewis, DOGAMI (the Oregon Department of Geology and Mineral Industries), Report to the Seventy-Fourth Oregon Legislative Assembly. This document will be referred to as the 2007 SSNA.

  The building sectors evaluated with the 2007 SSNA are:
  - Emergency Operations Centers
  - Police Stations
  - Fire Stations
  - Healthcare Facilities
  - Primary/K-8 Schools
  - Secondary/High Schools
  - Emergency Sheltering*

- The Hazus Earthquake Model developed by the Department of Homeland Security and FEMA, which will be referred to a FEMA Hazus.

  The building sets evaluated using FEMA Hazus are:
  - Critical Government Facilities
  - Residential Housing
  - Community Retail Centers
  - Banks
  - Vulnerable Buildings

It is important to draw a clear distinction between these two information sources. The 2007 SSNA study cataloged and evaluated each individual building using the FEMA-154 Rapid Visual Screening method. Each building that housed emergency operations centers, police and fire stations, and heath care facilities was reviewed. In the case of schools a smaller sample of buildings was examined due to the size of the overall building inventory. These reviews were performed, by qualified, licensed Structural Engineers.

The FEMA Hazus Model, on the other hand, was generated using an entirely different approach. This model created a statistical data set of buildings, including their occupancy classifications and construction types based on census data which it calculates for each census track and then aggregates by County. Fragility curves were then used to estimate damage states and losses for the statistical data. In contrast to the 2007 SSNA, the FEMA Hazus buildings and their estimated responses do not actually exist, they are purely statistical estimations. Qualitatively, the Task Group found that the 2007 SSNA had a much higher degree of reliability than FEMA Hazus. Fortunately, the 2007 SSNA evaluated the most essential structures included in the Critical Buildings Task Group study.

Scenario

To simplify analysis and reporting, a single seismic event was considered in evaluating the State's seismic resilience. This event was defined to be a full length rupture of the Cascadia Subduction Zone (CSZ) fault producing a magnitude 9.0 earthquake. Mappings of this scenario, including Peak Ground Acceleration, Peak Ground Velocity, Landslide Probability, Liquefaction Probability, Coastal Subsidence and Tsunami Inundation Zones were produced by the Scenario Task Group and made available to all of the task groups through the course of our study.

Figure 1 shows the Peak Ground Acceleration calculated for the for the CSZ scenario event. As expected, the most severe accelerations occur along the coast and attenuate as you move inland. It is important to keep in mind that this map represents a single event and does not necessarily represent the maximum acceleration possible all locations. For this information, which was not part of this study, other mapping that considers accelerations from all known faults should be consulted, as these faults have the potential to create larger magnitudes of shaking, particularly for many locations in the Valley and Eastern Regions.

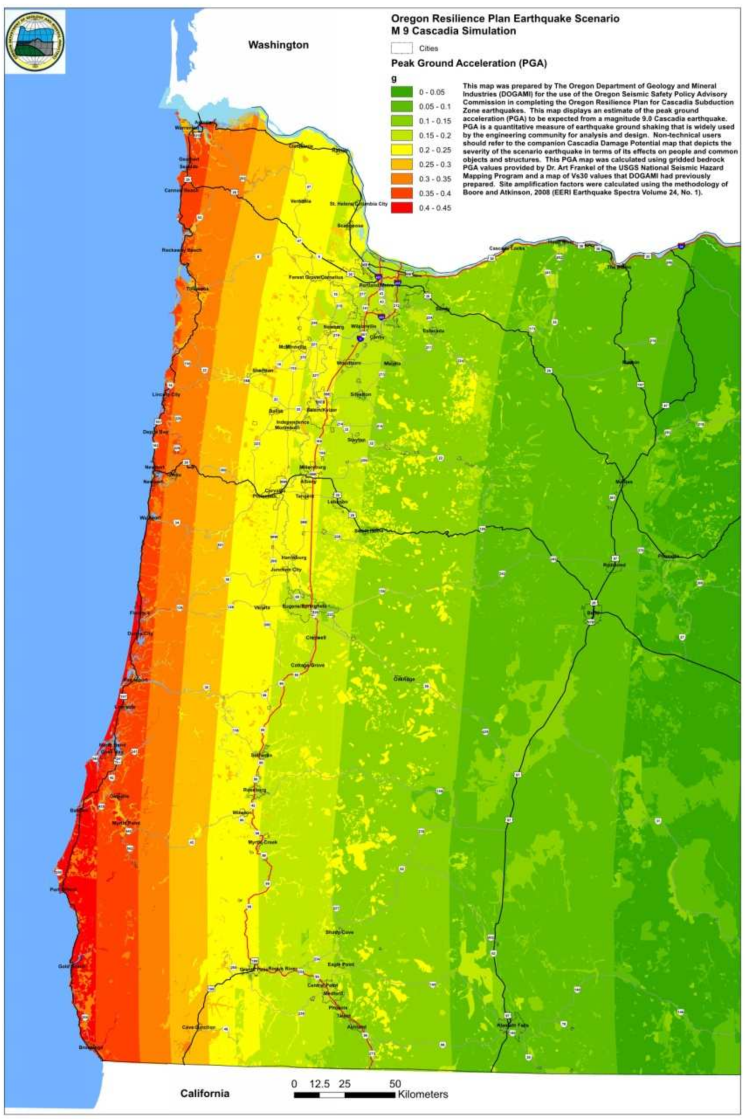

Figure 1A Peak Ground Acceleration (PGA) for M 9 Cascadia Simulation

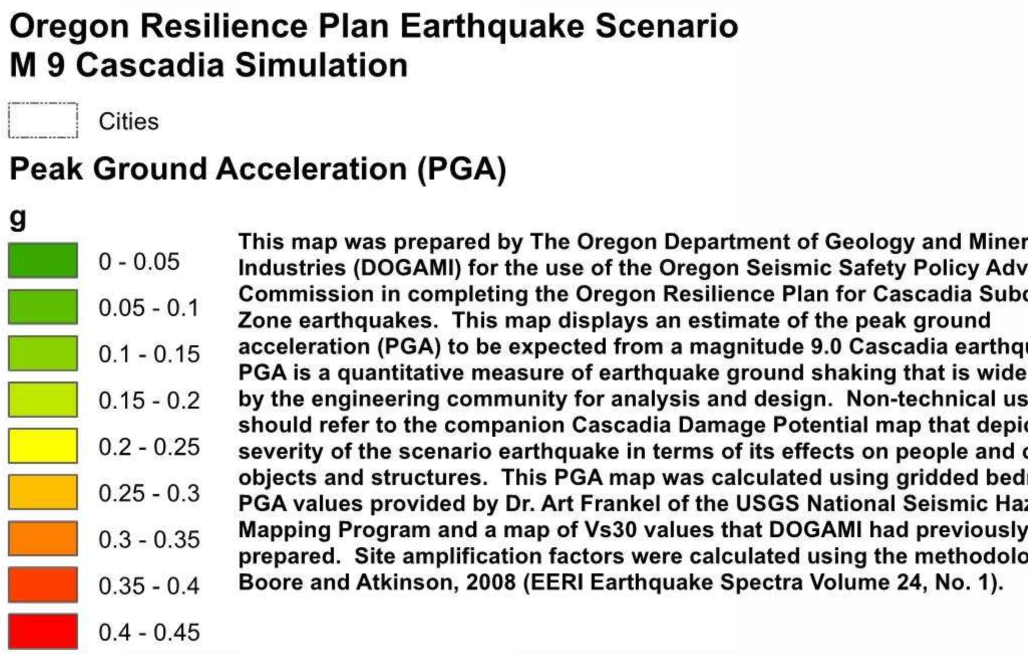

Figure 1B Legend Peak Ground Acceleration (PGA) for M 9 Cascadia Simulation

Expected duration of shaking must also be considered. The CSZ Scenario Task Group for this study estimated that the duration of strong ground motions could be between 3 and 5 minutes. By contrast, strong ground motions from intercrustal faults in the Valley and Eastern regions, while not part of this study, would be expected to have durations on the order of 20 seconds or less. This difference in duration is significant, but the full effects are not directly addressed in the evaluation procedures (FEMA-154 or FEMA Hazus) used in the data sets. Consideration was given to the expected effects of long durations of strong ground motions by employing engineering judgment to assign resilience scores. However, the full impact of strong ground motion duration remains a variable that is not well addressed in the available literature and evaluation procedures.

Zones

For ease of reference and reporting of results, this study analysis considered three geographic regions of seismic intensity (zones): Coastal, Valley and Eastern (see Figure 2). The approximate boundary delineations between zones are based on natural geographic boundaries created by the Coastal and Cascade Mountain Ranges. Trying to draw a precise line between these regions, however, would not be consistent with the level of precision in the data, analysis or results. Further, additional delineation would likely have little impact on the final accumulated results, since there are relatively small populations of significant infrastructure present in the mountainous areas between these regions.

For this study, these lines were drawn approximately as shown in Figure 2 and correspond to the isoseismal lines between the 0.25-0.3 and 0.2-0.25 PGA (Coastal/Valley demarcation), and 0.15-0.2 and 0.1-0.15 PGA (Valley/Eastern demarcation). For comparison, isoseismal lines used by FEMA-154 and the 2007 SSNA to designate between Very High, High and Moderate Seismic Zones are also shown in Figure 2. Note, though, that FEMA-154 does not contain a "Very High" level of seismicity. This was created by DOGAMI to accentuate the difference in intensity and duration of the strong ground motions that will occur along the Oregon Coast. The FEMA-154 scoring methodology is the same between the High and Very High zones.

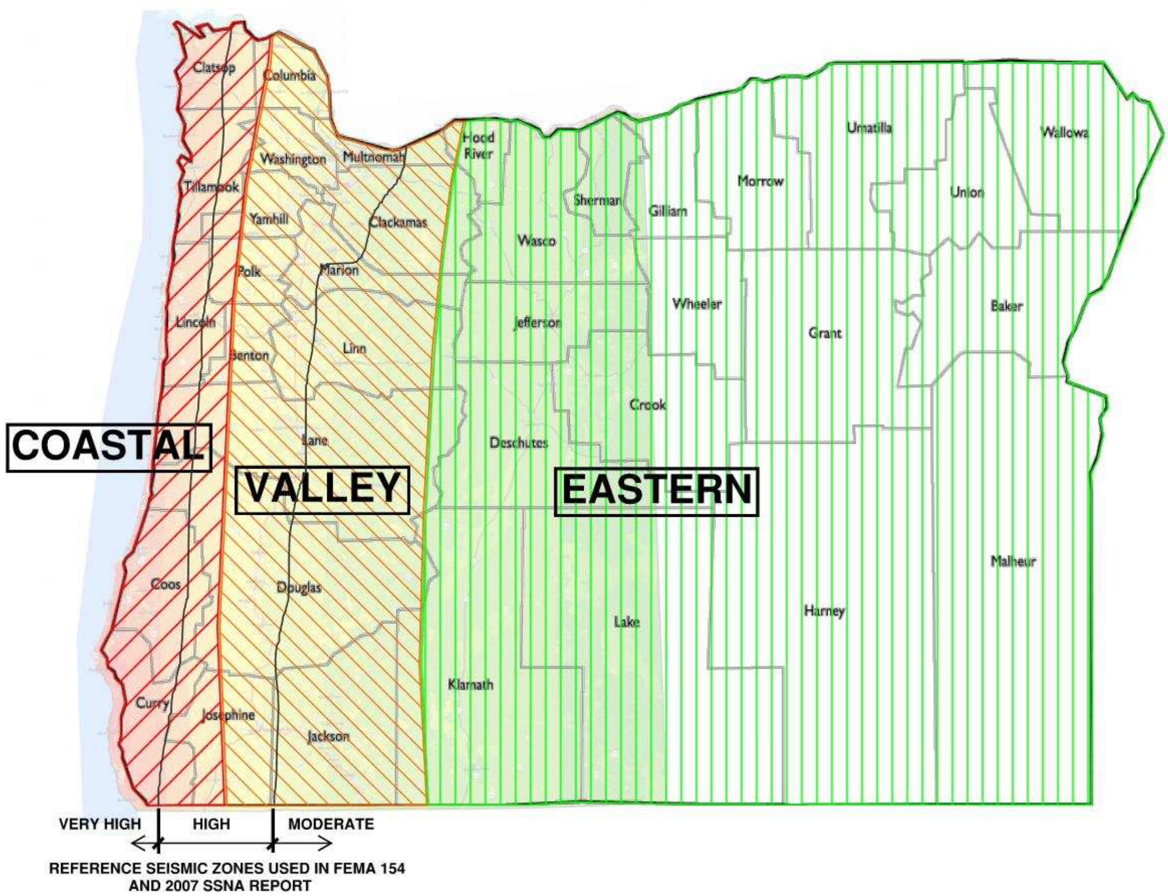

Figure 2 Resilience Study Seismic Regions

For the FEMA Hazus data analysis, it was necessary to group counties into Coastal, Valley and Eastern regions since all of the damage estimates output by the model are aggregated and reported by county. The grouping of these counties to approximate these regions was done as shown in Figure14. It should be noted, however, that results reported in Tables 1 and 8 and discussed in more depth in the main report should still be considered and thought of in terms of the regions as generally shown in Figure 2. So, for instance, resilience of the coastal regions of Lane and Douglas counties are anticipated to be the same as those of other coastal counties, even though these counties were grouped with counties in the valley region because their populations (and corresponding building count estimates) are weighted more heavily there.

2007 SSNA Data Analysis Procedures

Table 1 Shows the Estimated Current Resilience State, and Target States for the building sectors considered. These averaged scores were determined using the SSNA data as a review and conversion method described in the following pages.

Table 1. Target States of Recovery For Oregon's Buildings
Based on 2007 DOGAMI SSNA and Independent Structural Engineering Review

Infrastructure Cluster Facilities	Event Occurs	Phase 1 (hours)			Phase 2 (Days)		Phase 3 (Months)		
		4	24	72	30	60	4	18	36+
Emergency Operations Centers (Coastal)								X	
Emergency Operations Centers (Valley)							X		
Emergency Operations Centers (Eastern)					X				
Police Stations (Coastal)									X
Police Stations (Valley)							X		
Police Stations (Eastern)					X				
Fire Stations (Coastal)									X
Fire Stations (Valley)						X			
Fire Stations (Eastern)				X					
Healthcare Facilities (Coastal)								X	
Healthcare Facilities (Valley)							X		
Healthcare Facilities (Eastern)				X					
Healthcare Facilities* (Coastal)									X
Healthcare Facilities* (Valley)								X	
Healthcare Facilities* (Eastern)					X				
Primary/ K-8 (Coastal)								X	
Primary/ K-8 Centers (Valley)								X	
Primary/ K-8 (Eastern)					X				
Secondary/High School (Coastal)								X	
Secondary/High School (Valley)								X	
Secondary/High School (Eastern)					X				
Emergency Sheltering (Coastal)								X	
Emergency Sheltering (Valley)								X	
Emergency Sheltering (Eastern)					X				

* Analysis includes consideration of non-structural components

Target State X **Estimated Current State**

SSNA evaluations were based on data collected by the Department of Geology and Mineral Industries and as summarized in their report, "Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings, Report to the Seventy-Fourth Oregon Legislative Assembly", by Don Lewis, 2007 (hereafter noted as SSNA).

This document utilized the methodologies presented in FEMA-154, Rapid Visual Screening of Buildings for Potential Seismic Hazards. Figure 3 shows the typical FEMA-154 data sheet which was prepared for each building in the SSNA study.

Figure 3 – Typical RVS Report from the DOGAMI Statewide Structural Needs Assessment (SSNA) based on the FEMA 154 methodology.

The FEMA 154 methodology (and as further modified by DOGAMI) took a number of different variables into account when arriving at a Final Rapid Visual Screening (RVS) score. These also had to be accounted for in converting the RVS score to a Seismic Resilience Score, and included: 1) The varying regions of seismicity across the state, 2) The type and geometry of building construction, 3) The age of the building, and 4) The soil upon which the building rests. The most common of these various parameters that will affect building performance are taken into account as shown in Figure 4 (defined as "Score Modifiers"). Some of these values may vary depending upon what seismic zone the building is in.

Benchmark dates for when reasonable design provisions were put in place for the various structural types are also defined, as well as a "pre-code date," which DOGAMI defined for Oregon as 1941. Refer to figure 5, below.

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)
Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		**Year Seismic Codes Initially Adopted and Enforced***	**Benchmark Year when Codes Improved**
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	______	______
W2	Wood frame buildings, > 5000 square feet.	______	______
S1	Steel moment-resisting frame	______	______
S2	Steel braced frame	______	______
S3	Light metal frame	______	______
S4	Steel frame with cast-in-place concrete shear walls	______	______
S5	Steel frame with unreinforced masonry infill	______	______
C1	Concrete moment-resisting frame	______	______
C2	Concrete shear wall	______	______
C3	Concrete frame with unreinforced masonry infill	______	______
PC1	Tilt-up construction	______	______
PC2	Precast concrete frame	______	______
RM1	Reinforced masonry with flexible floor and roof diaphragms	______	______
RM2	Reinforced masonry with rigid diaphragms	______	______
URM	Unreinforced masonry bearing-wall buildings	______	______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: ______

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

Figure 4 – FEMA-154 Model Building Types and Score Modifier Definitions (from FEMA 154)

DOGAMI used the FEMA default value of 1941 as the pre-code year. After examination of the building code history in Oregon we selected the post-benchmark years shown in Table 8, reflecting when appropriate seismic zones and UBC criteria were adopted.

Table 8. FEMA 154 Post-Benchmark Dates for Oregon

	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM
Post-benchmark year:	1979	1979	1996	1994	NA		NA	1994		NA	1999	NA	1999		1993
Year if 3 or more stories						1979			1979					1979	
Year if 1 or 2 stories						1990			1990					1990	

Figure 5 – DOGAMI 2007 SSNA Benchmark Dates and Pre-Code Date (from DOGAMI)

Adjustment for Coastal, Valley and Eastern Zones

In the SSNA report, the area located predominantly east of the Cascade Range was defined by DOGAMI as possessing “Moderate” seismicity due to the effects of all faults, including those local to the region (refer to Figure 16 of the SSNA report). Similarly, the area that constitutes the valley section of Oregon was defined by DOGAMI as possessing “High” seismicity, which is also based upon consideration of all sources of earthquakes, including local faults. Reviewing isoseismal maps for only the Cascadia ground motions, however, reveal the effect of attenuation of the ground motions with distance from this offshore fault. This attenuation is significant.

The recent Cascadia Subduction Zone isoseismal maps provided by DOGAMI were based upon 0.3 second and 1.0 second spectral responses. (Typically, in building design, as well as FEMA 154, 0.2 second and 1.0 second spectral responses are used). Therefore, reasonable consistency exists for comparison purposes between the ground accelerations noted in the maps provided by DOGAMI and those listed in the FEMA 154 report. These maps reveal ground accelerations for the valley much closer to the Moderate seismicity zone as defined by FEMA 154 for both short and long period responses. Following the discussion above regarding reclassification of some areas, the following adjustments were made to the FEMA 154 Rapid Visual Screening scores for all buildings: 1) Reclassify the valley area as “moderate” (down from “high” seismicity). In a similar manner, to estimate a separate score for eastern Oregon to reflect the effect of a Cascadia Subduction Zone event, the RVS scores for eastern Oregon were modified by assuming this area to be in a region of “low” seismicity as defined in the FEMA 154 document. The coastal region retains its “high” seismicity classification (as defined by FEMA 154 when using their scoring guide).

Information exists within the FEMA 154 documents to complete this reclassification for both the valley and eastern Oregon regions. When dropping down from high to moderate seismicity for the valley region, the RVS scores are increased by about 10% (25% healthcare <<Verify>>), which captures the range of possible scores in the FEMA 154 scoring sheets for the types of buildings (construction and configuration) encountered in this particular survey. The conversion of eastern Oregon RVS scores from moderate to low seismicity was accomplished by increasing the FEMA 154 RVS scores by 33% to reflect the average increase in those scores (refer to the FEMA 154 data collection charts). It should be noted that depending upon the characteristics that these buildings possess (e.g. vertical or horizontal irregularities) these recommended adjustment values will not be accurate, but for the majority of buildings encountered in this survey (which do not typically possess these irregularities, or the case of healthcare facilities, do typically have irregularities), these factors should reasonably, though approximately, reflect the changes in RVS scores one would expect.

The following is a summary of the number of buildings evaluated from the SSNA data set, as segregated by region and building sector:

Table 2. Building Count for Each Region

Building type	Coastal region	Valley region	Eastern Oregon region	Total by Building Type
EOC, POLICE AND FIRE STATIONS				
Emergency Operations Centers	11	41	30	82
Police Stations	14	58	37	109
Fire Stations	108	289	198	595
Total by Region	133	388	265	
			Total	786
HEALTHCARE FACILITIES				
Healthcare Facilities	11	28	21	60
SCHOOLS (Sample Considered from 2,377 Total in SSNA)				
Primary Schools	14	121	89	224
Secondary Schools	13	38	28	79
Total by Region	27	159	117	
				303

Converting RVS to Resilience Score

Recovery Scores noted in Table 1, above, and designated with an "X", were determined by a multistep process.

First, the FEMA 154 Rapid Visual Screening Scores (RVS) for each building, as tabulated in the SSNA report, were converted into a basic Recovery Score. This was done using the following scheme:

a. RVS score ≤ 2.0, basic Recovery Score is in Phase 3
b. 2 < RVS score ≤ 3.0, basic Recovery Score is in Phase 2
c. RVS score > 3.0, basic Recovery Score is in Phase 1 or during Event Occurs.

SPUR has defined performance goals in terms of four "clusters" of infrastructure (page 9), eight performance categories and three response and recovery phases (shown in this table). We are not recommending that all facilities be upgraded without regard to cost. Rather, our intent is to require only those improvements needed to assure a quick recovery — or the level of resilience desired for each stage of recovery.

DEFINING STAGES OF DISASTER RECOVERY

PHASE	TIMEFRAME	CONDITION OF THE BUILT ENVIRONMENT
1	**1 to 7 days**	**Initial response and staging for reconstruction**
	Immediate	Mayor proclaims a local emergency and the City activates its Emergency Operations Center. Hospitals, police stations, fire stations, and City department operations centers are operational.
	Within 4 hours	People who leave or return to the city in order to get home are able to do so. Lifeline systems that support critical response facilities are operational.
	Within 24 hours	Emergency response workers are able to activate and their operations are fully mobilized. Hotels designated to house emergency response workers are safe and usable. Shelters are open. All occupied households are inspected by their occupants, and less than 5 percent of all dwelling units are found unsafe to be occupied. Residents can shelter in place[1] in superficially damaged buildings even if utility services are not functioning.
	Within 72 hours	Ninety percent of the utility systems (power, water, wastewater, natural gas and communication systems) are operational and serving the facilities supporting emergency operations and neighborhoods. Ninety percent of the major transportation system routes, including Bay crossings and airports, are open at least for emergency response. The initial recovery and reconstruction efforts will be focused on repairing residences and schools to a usable condition, and providing the utilities they need to function. Essential City services are fully restored.
2	**30 to 60 days**	**Housing restored — ongoing social needs met**
	Within 30 days	All utility systems and transportation routes serving neighborhoods are restored to 95 percent of pre-event service levels, public transportation is running at 90 percent capacity, public schools are open and in session. Ninety percent of the neighborhood businesses are open and serving the workforce. Reconstruction efforts will be focused on repairing residences, schools and medical provider offices to a usable condition, and providing the utilities they need to function. Essential City services are fully restored and medical provider offices are usable..
	Within 60 days	Airports are open for general use, public transportation is running at 95 percent capacity, minor transportation routes are repaired and reopened.
3	**Several years**	**Long-term reconstruction**
	Within 4 months	Temporary shelters are closed, with all displaced households returned home or permanently relocated. Ninety-five percent of the community retail services are reopened. Fifty percent of the non-workforce support businesses are reopened.
	Within 3 years	All business operations, including all City services not related to emergency response or reconstruction, are restored to pre-earthquake levels.

Source: SPUR analysis

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Figure 6 - Seismic Resilience Definitions (from SPUR)

Further delineation within each of these phases was then achieved by examining the DOGAMI data for each building, particularly structural irregularities, soil conditions, and age of construction, to estimate the time to recovery. This was done by assigning the RVS score for each building to a final Recovery Score of 1 to 9, based upon the number of columns that appear in Table 1. See Figure 7 below.

This evaluative work was done for each building by a team of two professional Structural Engineers, each independently reviewing each building and then comparing and discussing results. Engineering judgment based upon experience was often employed in order to arrive at this final Recovery Score from the basic Recovery Score. For a number of buildings, our evaluations differed from those of the DOGAMI evaluators, particularly with regards to classifying buildings with vertical irregularities.

RVS Score	RVS Score > 3.0				3.0 ≥ RVS Score > 2.0		RVS Score ≤ 2.0		
Resilience Score (Column Number)	1	2	3	4	5	6	7	8	9
Infrastructure Cluster Facilities	Event Occurs	**Phase 1** (hours)			**Phase 2** (Days)		**Phase 3** (Months)		
		4	24	72	30	60	4	18	36+
Emergency Operations Centers (Coastal)									
Emergency Operations Centers (Valley)									
Emergency Operations Centers (Eastern)									
Police Stations (Coastal)									

Figure 7 – Basic Framework of RVS to Resilience Score Conversion for Table 1. (Target States of Recovery For Oregon's Buildings Based on 2007 DOGAMI SSNA and Independent Structural Engineering Review)

Recovery time following a seismic event for buildings receiving a score of 4 months or less only includes an estimate of the time for repair to be completed and does not include time for securing any needed permits, funding, or any estimate of contractor and material availability. For those buildings receiving a score of 18 months or more, it has been assumed that building damage is so extensive, that additional time will be needed for design, partial or complete demolition of the building and then reconstruction, all with limited resources due to anticipated areas of infrastructure damage and qualified personnel availability. These additional factors could prolong the expected time to recovery. Using the post-earthquake evaluation methodology of ATC-20, we have assumed that those buildings receiving a Phase 2 (30 to 60 day) Recovery Score will experience damage and disruption to their utility services and nonstructural damage, and some damage to the primary structural system. Structural repairs should be relatively modest. These buildings may be re-occupied after repairs have been made and are expected to receive a green tag or yellow tag after the "expected" earthquake.

For those buildings receiving a Phase 3 (4 months or more) Recovery Score, it has been assumed that these buildings, at the very least, may experience significant structural damage that will require repairs prior to resuming unrestricted occupancy. These buildings are expected to receive at least a yellow tag after the "expected" earthquake. Time required for repair will likely vary from four months to three years or more. If temporary vertical and lateral stability repairs (shoring and bracing) are undertaken soon after an expected earthquake, essential work could possibly resume within some of these buildings, but public access may need to be restricted until final repairs are completed. However, it is possible that some of these buildings may experience extensive structural damage and may be near collapse. Even if repairs are technically feasible, they might not be financially justifiable. Many buildings performing at this level are expected to receive a red tag after the "expected" earthquake. Lastly, some buildings we reviewed may even partially or completely collapse. Damage will most likely lead to significant casualties in the event of an "expected" earthquake.

Healthcare Facilities

Recovery Scores for Healthcare Facilities noted in Table 1, above, and designated with an "X", were determined by a multistep process. First, the FEMA 154 Rapid Visual Screening Scores (RVS) for each building, as tabulated in the SSNA report, were reviewed and verified based on available data from the SSNA report data. Healthcare facilities were then contacted to determine the availability of existing ASCE 31 (formerly FEMA 178), FEMA 310, or other seismic studies, and, inquire if any seismic strengthening of essential buildings had occurred. If available, this information was used to confirm or modify the RVS Scores where appropriate. Such reports were available for approximately 50% of the buildings included in this study. Once a final RVS Score had been determined for individual buildings within a healthcare facility campus, they were converted and grouped into a single basic Recovery Score for the campus.

Schools

The SSNA data tabulated 2377 entries for educational facilities. These entries were spread across 189 school districts and include data for primary schools (kindergarten through 8th grade), secondary schools (middle and high schools), and community colleges. Of these entries, 10% were selected to form an initial data sample. The selection for the initial data sample was random but selected entries were weighted by district in an attempt to preserve the distribution of the original 2377 entries. The number of entries per district was rounded up to the nearest whole number and at least 1 entry was selected from each district. Evaluation of community colleges was considered to be outside the scope of this report, therefore entries from community colleges were removed from the sample.

The above process resulted in a representative sample containing 303 entries, or 12.7% of the tabulated educational facility entries. This representative sample was used to determine the final Recovery Score using the process described in parts 4 through 8 of this report.

Tsunami

According to the SSNA report, a number of the buildings in the coastal region are located in a tsunami inundation zone (refer to SSNA Table 14). Those buildings were evaluated using an additional criterion: Will these buildings survive a tsunami? Light framed wood buildings, light framed metal buildings, and unreinforced and under-reinforced masonry buildings were assumed to either experience significant damage as a result of tsunami wave loads as characterized by DOGAMI or they will be completely destroyed. This places these structures in the 36+ month category of the Recovery Score table above. This is a very serious concern for coastal communities since 36% of the police stations and 24% of the fire stations will most likely fall within this 36+ month category.

<<count of schools and hospitals in this zone?>>

Only a small number of the Healthcare Facilities were located in the tsunami inundation zone. <<how many?>>

Landslide and Liquefaction Induced Ground Displacement

According to DOGAMI, recent studies indicate that areas exist within all zones, but particularly at the coast, where landslides and liquefaction will occur during CSZ ground motions. The significance of these hazards at each of the critical buildings was cataloged. The magnitude of ground displacement and probability of occurrence for each of these hazards for each building varies greatly. For simplicity, it was decided that for those buildings that possess at least a 10% chance of a risk to these hazards, in combination with at least a 6" ground displacement from either landslides or liquefaction, a 36+ month category of the Recovery Score table above was appropriate. Given the average age and size (relatively small, one and two story) and their type of construction (predominantly wood), these buildings most likely are founded on shallow foundations not designed to resist these types of ground motions and resulting displacements. As with tsunami inundation, these hazards are very prevalent along the coast, but also do occur in areas within the valley, and to a much more limited extent in isolated areas in the east zone (as delineated in figure 16 of the SSNA report).

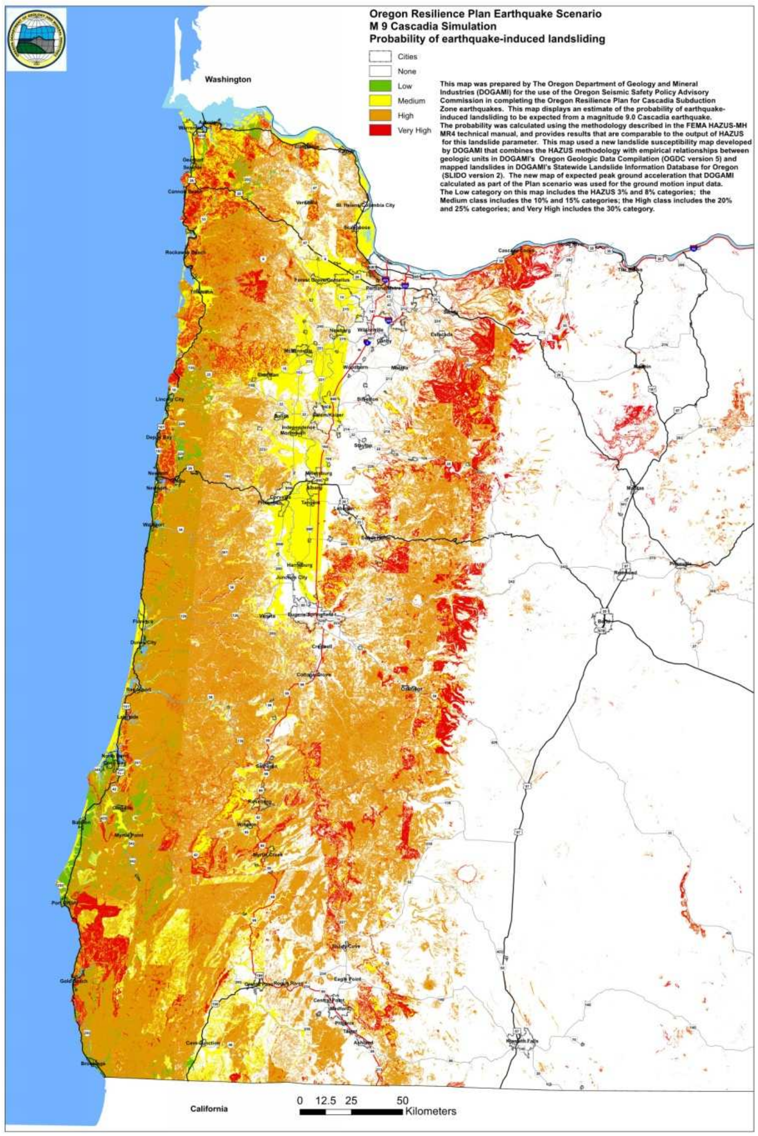

Figure 8A Probability of Earthquake Induced Landsliding for M9 Cascadia Simulation

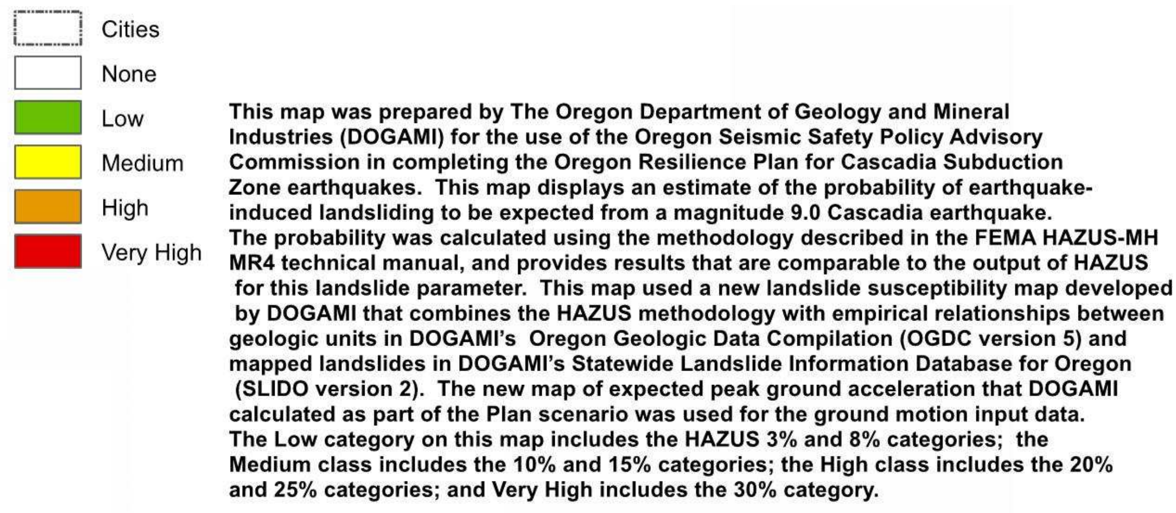

Figure 8B Legend Probability of Earthquake Induced Landsliding for M9 Cascadia Simulation

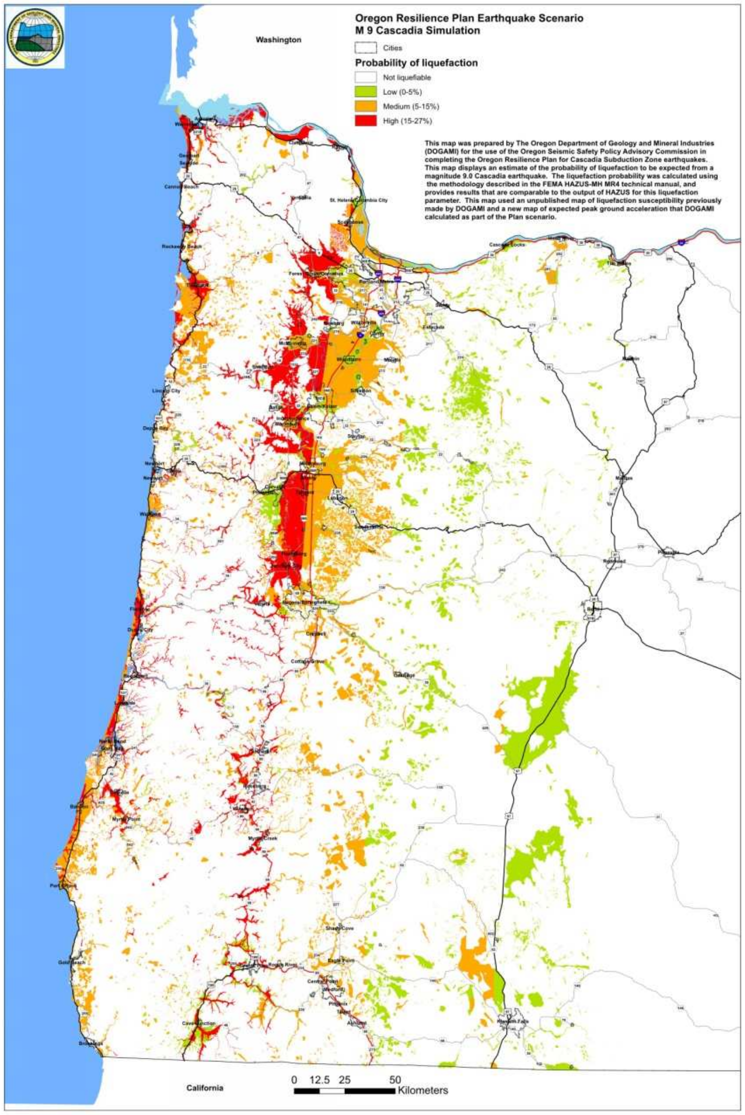

Figure 9A Probability of Earthquake Induced Liquefaction for M9 Cascadia Simulation

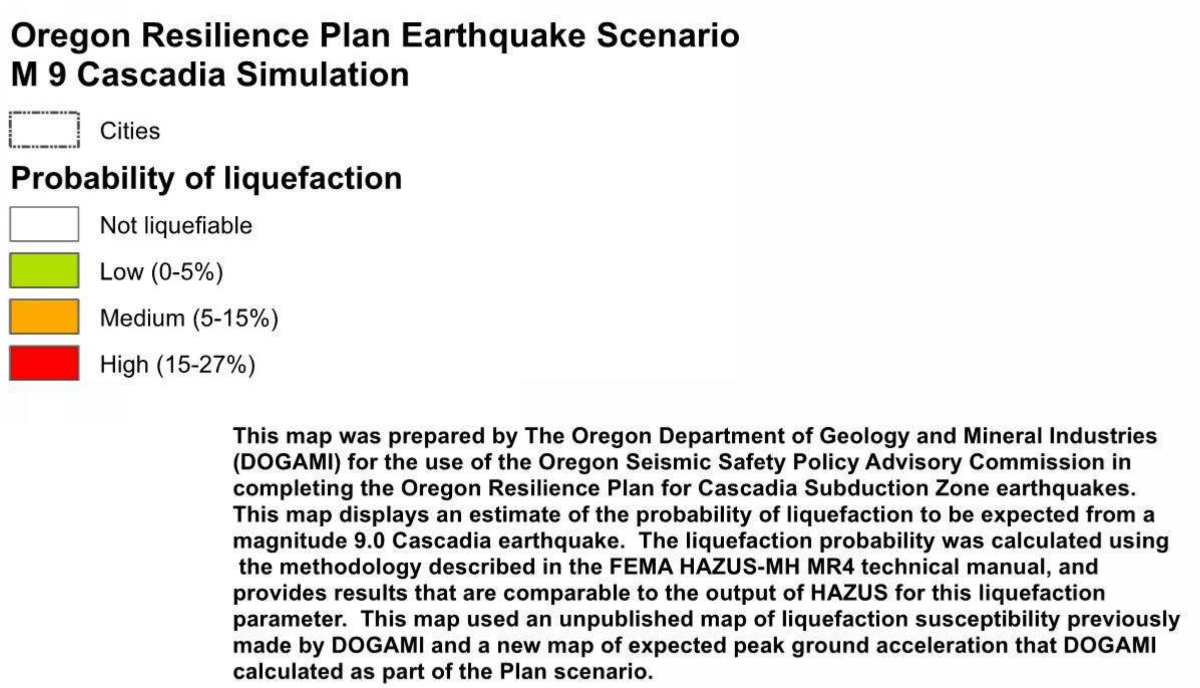

Figure 9B Legend Probability of Earthquake Induced Liquefaction for M9 Cascadia Simulation

Nonstructural Items

Nonstructural items within buildings (e.g. equipment, racks, utilities, finishes and furnishings) were not evaluated in most cases because that data was not included in the scope of the FEMA 154 evaluations performed as part of the SSNA study. However, based on the observed performance of older buildings in earthquakes around the world, it is known that nonstructural items often adversely impact building resilience even after moderate earthquakes. In Oregon, the design of nonstructural items to resist seismic ground motions was typically not seriously addressed until the 1990's. It is anticipated that damage to nonstructural items will be extensive during the model CSZ seismic event, particularly in those buildings located along the coast that will experience the most severe ground shaking.

Healthcare Facilities

Historically seismic performance of healthcare facilities around the world has been extensively affected by nonstructural damage. Nonstructural components such as heavy medical equipment, overhead lights and gas booms, and suspended ceilings are critical to the proper function of healthcare facilities. . The building structure itself could perform very well during the "expected" earthquake, but the hospital might not be functional after the event due to nonstructural damage alone. Table 1 above includes distinct estimated recovery times for structure-only and structural-plus-nonstructural for each region. These are based on historical recovery times of healthcare facilities and the evaluating engineers' experiences with the condition of nonstructural component bracing/anchorage and not on concrete data from all healthcare facilities in Oregon.

In addition to the seismic bracing and anchorage of nonstructural, the ability of healthcare facilities to be fully resilient following the CSZ event will also be greatly affected by the performance of the medical equipment itself. For example, take an MRI machine that is properly anchored to the building structure. During the seismic event, the building structure and MRI anchorage may perform well but the MRI machine itself may sustain damage not be operational after the event. This scenario can have a great impact on the seismic resilience of any healthcare facility.

Healthcare facilities are often campuses made up of multiple buildings providing healthcare services and often have a Central Utility Plant (CUP) or a central building that contains a large number of pieces of essential mechanical equipment (boiler, air handling units, etc) that support the rest of the entire campus. Although this building may not be associated with providing healthcare services directly, it should be carefully considered because damage to it and its contents can have a great impact on the resilience of the campus as a whole.

Summary of Results

After making the modifications for seismicity as described above for both the valley and eastern Oregon regions, and then adjusting the scores of the coastal region buildings that lie within the tsunami inundation, liquefaction and landslide zones, as well as adjustments to some of the valley and eastern Oregon buildings for liquefaction and landslides, the final Recovery Scores were statistically analyzed by determining the mean, median, and mode values of the final Recovery Scores for each building type and for each region (coastal, valley, and eastern Oregon). These mean, median and mode values were then examined (refer to summary tables 3, 4, 5, and 6 below) to determine the final Recovery Scores as shown in Table 1, above.

Table 3. Emergency Operations Centers Frequency Distribution

Recovery Score	Coastal region	Valley region	Eastern Oregon region
1 (Event Occurs)	0 buildings	0 buildings	1 buildings
2 (4 hours)	0	2	1
3 (24 hours)	0	4	4
4 (72 hours)	1	6	2
5 (30 days)	1	5	10
6 (60 days)	0	2	4
7 (4 months)	0	11	0
8 (18 months)	4	4	5
9 (36+ months)	5	7	3
Total building count	11 buildings	41 buildings	30 buildings
Mean Recovery Score	7.8	6.1	5.4
Median Recovery Score	8	7	5
Mode Recovery Score	9	7	5
Recovery Score	**8** (18 months)	**7** (4 months)	**5** (30 days)

Table 4. Police Stations Frequency Distribution			
Recovery Score	Coastal region	Valley region	Eastern Oregon region
1 (Event Occurs)	0 buildings	0 buildings	1 buildings
2 (4 hours)	0	0	8
3 (24 hours)	0	5	8
4 (72 hours)	1	3	1
5 (30 days)	0	5	12
6 (60 days)	1	15	1
7 (4 months)	0	8	1
8 (18 months)	2	3	3
9 (36+ months)	10	19	2
Total building count	14 buildings	58 buildings	37 buildings
Mean Recovery Score	8.3	6.8	4.3
Median Recovery Score	9	7	5
Mode Recovery Score	9	9	5
Recovery Score	**9** (36+ months)	**7** (4 months)	**5** (30 days)

Table 5. Fire Stations Frequency Distribution			
Recovery Score	Coastal region	Valley region	Eastern Oregon region
1 (Event Occurs)	0 buildings	2 buildings	1 buildings
2 (4 hours)	1	24	19
3 (24 hours)	0	39	70
4 (72 hours)	14	56	34
5 (30 days)	8	21	37
6 (60 days)	5	37	11
7 (4 months)	8	21	3
8 (18 months)	8	11	7
9 (36+ months)	64	78	16
Total building count	108 buildings	289 buildings	198 buildings
Mean Recovery Score	7.6	5.6	4.3
Median Recovery Score	9	6	4
Mode Recovery Score	9	9	3
Recovery Score	**9** (36+ months)	**6** (60 days)	**4** (72 hours)

Table 6. Healthcare Facilities Frequency Distribution			
Recovery Score	Coastal region	Valley region	Eastern Oregon region
1 (Event Occurs)	0 buildings	2 buildings	10 buildings
2 (4 hours)	0	2	1
3 (24 hours)	1	1	1
4 (72 hours)	1	2	4
5 (30 days)	0	4	2
6 (60 days)	2	1	0
7 (4 months)	1	3	2
8 (18 months)	5	9	1
9 (36+ months)	1	4	0
Total facility count	11 facilities	28 facilities	21 facilities
Percentage of total available beds	6%	75%	19%
Mean Recovery Score	7	7	3
Median Recovery Score	8	7	2
Mode Recovery Score	8	8	1
Recovery Score	**8**(18 months)	**8**(18 months)	4(72 hours)*

Legend:

* *Indicates score was affected by weighted average of available beds per healthcare facility.*

<<Distribution for Schools?>>

It must be emphasized that this cursory evaluation of these building stocks should not be used to provide the status of seismic fitness for any building in particular. If that knowledge is sought, a proper seismic evaluation should be performed of the subject building by an experienced registered Structural Engineer following a standardized procedure, such as that prescribed in ASCE 31 “Seismic Evaluation of Existing Buildings”, published by the American Society of Civil Engineers

Table 7. Structural Vulnerabilities by Occupancy Type for Oregon's Critical Buildings

Service/Occupancy	URM	Soft story	Non-ductile concrete frame	Unbraced cripple wall	Rigid wall-flexible diaphragm	Non-ductile steel frame	Steel or concrete frame with URM infill	Major falling hazards	Vulnerable nonstructural components
Emergency Operations Centers	E	NT	NT	U	NT	NT	U	NT	U
Police Stations	E	NT	NT	U	NT	NT	U	NT	U
Fire Stations	NT	NT	NT	U	NT	NT	U	E	U
Healthcare Facilities	NT	NT	C	NT	U	C	C	U	C
Primary Schools	E	NT	NT	U	C	NT	E	E	U
Secondary Schools	E	NT	NT	U	C	NT	E	E	U
Residential Housing	NT	E	NT	C	NT	NT	NT	NT	NT
Community Retail Centers	E	NT	NT	NT	C	NT	NT	NT	C
Financial/Banking	E	NT	NT	NT	NT	C	NT	NT	E
Vulnerable Buildings	C	C	C	NT	C	NT	E	C	E

Legend:

U	Vulnerability is Unknown
C	Vulnerability is Common
NT	Vulnerability is Not Typical
E	Vulnerability Exists

FEMA Hazus

Hazus Background

<<Ian….>>

Hazus Estimated Damage States for Magnitude 9.0 CSZ Earthquake

<<Ian….>>

Table 8. Target States of Recovery For Oregon's Buildings Based on FEMA HAZUS Loss Estimations

Infrastructure Cluster Facilities	Event Occurs	**Phase 1** (hours)			**Phase 2** (Days)		**Phase 3** (Months)		
		4	24	72	30	60	4	18	36+
Critical Government Facilities (Coastal)[1]							X		
Critical Government Facilities (Valley)[1]					X				
Critical Government Facilities (Eastern)[1]	X								
Residential Housing (Coastal)					X				
Residential Housing (Valley)		X							
Residential Housing (Eastern)	X								
Community Retail Centers (Coastal)							X		
Community Retail Centers (Valley)					X				
Community Retail Centers (Eastern)	X								
Financial/Banking (Coastal)						X			
Financial/Banking (Valley)					X				
Financial/Banking (Eastern)	X								
Vulnerable Buildings (Coastal)									X
Vulnerable Buildings (Valley)								X	
Vulnerable Buildings (Eastern)					X				

[1] **See section 4.3.5 for a definition of this building type.**

Target State **X Estimated Current State**

Retail and Banking

Hazus damage state assessments for retail and banking buildings considered 36 different Model Building Types to make up 28 different Specific Occupancy Classes. Of these Occupancy Classes, the COM1, Retail Trade; COM2, Wholesale Trade; and COM5, Banking, were of specific interest for the Retail and Banking considered critical for resilience. However, the Hazus report data does not aggregate the data based on Specific

Occupancy Classes. Therefore, it was necessary to calculate the scores utilizing summary data for the Model Building Types, aggregated by county.

Table 3A.2: Distribution Percentage of Floor Area for Model Building Types within Each Building Occupancy Class, Low Rise, Pre-1950, West Coast*
(after ATC-13, 1985)

No.	Specific Occup. Class	Model Building Type															
		1	2	3	6	9	10	13	16	19	22	25	26	29	31	34	36
		W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
1	RES1	For State-Specific "Res1" Distribution, Refer to Table 3A.17															
2	RES2																100
3	RES3	73		1	1	1		6		3	3			1		9	2
4	RES4	34		2	1	2	1	19		16	3			4		18	
5	RES5	20		5	1		1			28	18			6		21	
6	RES6	45				10		5		10				20		10	
7	COM1		22	2		6	3	20		17	1			6		23	
8	COM2		8	3		4	2	41		18	1	3		5	2	13	
9	COM3		28	1	1	3		18		7		1		8		33	
10	COM4		27	2	1	3		19		15				7		26	
11	COM5		27	2	1	3		19		15				7		26	
12	COM6		8	5	2	11		11		27	2	1		27		6	
13	COM7		25	5	2	10		10		15	2	1		20		10	
14	COM8		8	12	1	2	3	16		27	4			5	1	21	
15	COM9		5	20	7			15		20	3			10		20	
16	COM10				8		8	18		43	7		1	6	3	6	
17	IND1		3	29	13	2	2	15		14	7	1		4	2	8	
18	IND2		4	14	8	22	1	18		16	1	1		2		13	
19	IND3		1	18	8	3	3	20		22		2		3		20	
20	IND4		2	24	12	7	2	13		16		2		2	6	14	
21	IND5			21	5	5		3		35	2	10	2	15		2	
22	IND6		32	3	2	10		18		8	7					13	7
23	AGR1	56		3	2	14		2		9					1	13	
24	REL1	22		8		2		21		15	5			8		19	
25	GOV1		9	8	1	3	4	12		42	4			6		11	
26	GOV2	45					2			37				3		13	
27	EDU1	11		6		3	3	21		21	4			9		22	
28	EDU2	2		5	10		5	15		20				20	5	18	

* Refer to Table 3C.1 for states' classifications.

Figure 10 FEMA Hazus Percentage Distributions of Model Building Types in Each Occupancy Class

Table 3.2: Building Occupancy Classes

Label	Occupancy Class	Example Descriptions
	Residential	
RES1	Single Family Dwelling	House
RES2	Mobile Home	Mobile Home
RES3	Multi Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
RES4	Temporary Lodging	Hotel/Motel
RES5	Institutional Dormitory	Group Housing (military, college), Jails
RES6	Nursing Home	
	Commercial	
COM1	Retail Trade	Store
COM2	Wholesale Trade	Warehouse
COM3	Personal and Repair Services	Service Station/Shop
COM4	Professional/Technical Services	Offices
COM5	Banks	
COM6	Hospital	
COM7	Medical Office/Clinic	
COM8	Entertainment & Recreation	Restaurants/Bars
COM9	Theaters	Theaters
COM10	Parking	Garages
	Industrial	
IND1	Heavy	Factory
IND2	Light	Factory
IND3	Food/Drugs/Chemicals	Factory
IND4	Metals/Minerals Processing	Factory
IND5	High Technology	Factory
IND6	Construction	Office
	Agriculture	
AGR1	Agriculture	
	Religion/Non/Profit	
REL1	Church/Non-Profit	
	Government	
GOV1	General Services	Office
GOV2	Emergency Response	Police/Fire Station/EOC
	Education	
EDU1	Grade Schools	
EDU2	Colleges/Universities	Does not include group housing

Figure 11 FEMA Hazus Building Occupancy Classes

Table 3A.1: Distribution Percentage of Floor Area for Specific Occupancy Classes within each General Occupancy Class♦

Specific Occupancy Class			General Occupancy Class						
			RES	COM	IND	AGR	REL	GOV	EDU
No.	**Label**	**Occupancy Class**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	RES1	Single Family Dwelling	♦						
2	RES2	Mobile Home	♦						
3	RES3	Multi Family Dwelling	♦						
4	RES4	Temporary Lodging	♦						
5	RES5	Institutional Dormitory	♦						
6	RES6	Nursing Home	♦						
7	COM1	Retail Trade		♦					
8	COM2	Wholesale Trade		♦					
9	COM3	Personal and Repair Services		♦					
10	COM4	Professional/Technical		♦					
11	COM5	Banks		♦					
12	COM6	Hospital		♦					
13	COM7	Medical Office/Clinic		♦					
14	COM8	Entertainment & Recreation		♦					
15	COM9	Theaters		♦					
16	COM10	Parking		♦					
17	IND1	Heavy			♦				
18	IND2	Light			♦				
19	IND3	Food/Drugs/Chemicals			♦				
20	IND4	Metals/Minerals Processing			♦				
21	IND5	High Technology			♦				
22	IND6	Construction			♦				
23	AGR1	Agriculture				100			
24	REL1	Church					100		
25	GOV1	General Services						♦	
26	GOV2	Emergency Response						♦	
27	EDU1	Schools							♦
28	EDU2	Colleges/Universities							♦

♦ The relative distribution varies by census tract and is computed directly from the specific occupancy class square footage inventory. For Agriculture (AGR) and Religion (REL) there is only one specific occupancy class, therefore the distribution is always 100%.

Figure 12 FEMA Hazus Specific Occupancy Classes within each General Occupancy Class

Building Damage by Count by General Occupancy

April 09, 2012

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
Oregon						
Benton						
Agriculture	51	41	46	45	14	197
Commercial	71	254	633	516	171	1,645
Education	10	11	21	20	5	67
Government	2	5	12	14	6	40
Industrial	24	70	175	150	47	467
Religion	24	25	42	43	13	147
Other Residential	1,902	1,583	1,430	1,325	388	6,628
Single Family	12,115	7,012	875	187	44	20,234
Clackamas						
Agriculture	436	153	171	63	4	826
Commercial	2,196	2,212	2,144	597	35	7,183
Education	105	55	61	17	1	238
Government	40	30	34	9	0	113
	[illegible]	778	934	318	21	2,805
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	508

Figure 13 FEMA Hazus Building Damage by County by General Occupancy, Partial Table Showing Typical Output

Normalized Resilience Scores

Summary model building types are Wood, Steel, Concrete, Precast, Reinforced Masonry, Unreinforced Masonry, and Manufactured Home. Estimated losses for each damage state are provided by Hazus and were assigned a resilience score based on a scale of 1 to 9 as follows. Unlike the SSNA data, however, the resilience scores were normalized for the number of days before averages were calculated:

Table 9 Equivalent Resilience Scores for Hazus Damage Estimates

Hazus Damage Estimate	Equivalent Resilience Score	Equivalent Resilience Score (Normalized for Number of days)
None	1	0
Slight	2	.167
Moderate	4	3
Extensive	6	30
Complete	8	540

An average normalized resilience score was then calculated for each of the Occupancy Building Types of interest, COM1, COM2, and COM5 using the following calculations steps:

1. A normalized spur score was determined for each construction material type (Wood, Steel, Concrete, etc.) in each county based on the expected damage state reported by Hazus (Figure 13) as a weighted average:

   Normalized Resilience Score for Each Material in Each County =
   $$\sum_{Material} \{Normalized\ Resilience\ Score\ for\ Damage\ State\}\ x\ \{Hazus\ \%\ Expected\ Damage\ State\}$$

2. The normalized spur score for each Occupancy Class and Building Type were then determined for each county based on the % Material Makeup of the Class provided by the Hazus documentation as a weighted average:

   Normalized Resilience Score for Each Occupancy Class in Each County =
   $$\sum_{Bldg\ Type} \{Normalized\ Resilience\ Score\ for\ Material\}\ x\ \{Hazus\ \%\ Material\ in\ Occupancy\ Class\}$$

3. Finally, the normalized spur Score from each Occupancy Class and Building Type in each county were combined for each Seismic Region (Coastal Counties, Valley Counties, and Eastern Counties) using a weighted average based on the total estimated building count for each county considered by Hazus. Total building count for the "Commercial" General Occupancy Classification is 79,052:

   Normalized Resilience Score for Each Occupancy Class in Each Seismic Region =
   $$\sum_{Region} \{Normalized\ Resilience\ Score\ for\ Building\ Type\}\ x\ \{Hazus\ \%\ Building\ Count\ in\ Each\ County\}$$

   The county groupings into Coastal, Valley and Eastern Regions are shown in Figure 14.

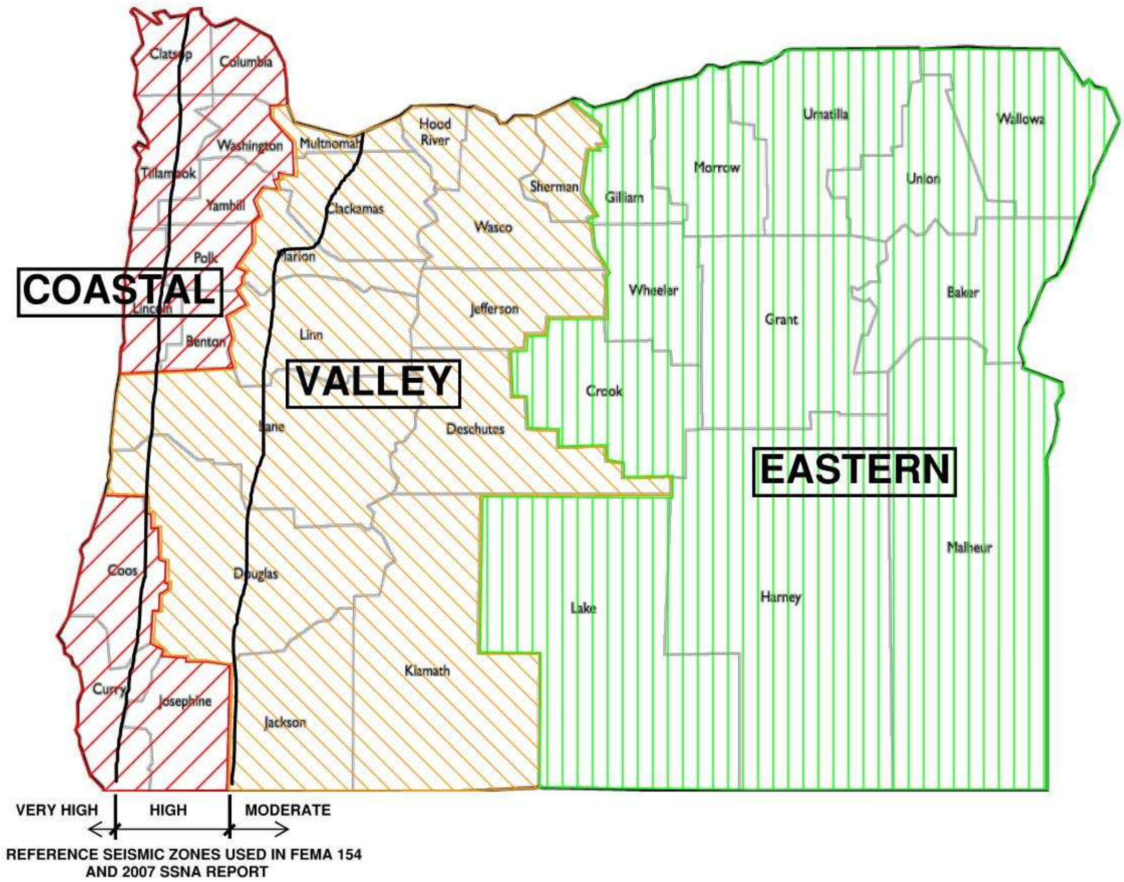

Figure 14 County Groupings for Conversion of Hazus Damage States to Resilience Score. Zone designations used by FEMA and the 2007 SSNA are shown in the lower left for reference.

The results of this analysis are shown in Table 10 for Retail Trade, Wholesale Trade and Banking. To combine these values further and obtain a single Resilience Score for each Region would require further data regarding the quantity of buildings considered for each code category and building rise. This data was not available from the Hazus analysis. Therefore, final combination of the resilience scores was based on review of the data, general familiarity with these regions and their associated building construction, and engineering judgment.

RVS Score	**RVS Score > 3.0**				**3.0 ≥ RVS Score > 2.0**		**RVS Score ≤ 2.0**		
Resilience Score (Column Number)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Normalized Resilience Score (by days)	**0**	**.167**	**1**	**3**	**30**	**60**	**120**	**540**	**1080**
Infrastructure Cluster Facilities	**Event Occurs**	**Phase 1** (hours)			**Phase 2** (Days)		**Phase 3** (Months)		
		4	**24**	**72**	**30**	**60**	**4**	**18**	**36+**
Emergency Operations Centers (Coastal)									
Emergency Operations Centers (Valley)									
Emergency Operations Centers (Eastern)									
Police Stations (Coastal)									

Figure 15 Normalized Resilience Scores by Number of Days

4. Finally, resilience scores for each Specific Occupancy Type were combined using a weighted average based on the number of commercial buildings in each County. These values were combined by for counties in three regions, Coastal Counties, Valley Counties, and Eastern Counties.

   Table 10 summarizes the data obtained from this analysis. Additional averaging of the values is needed, but sufficient data does not appear to be available to justify a specific weighting of these average. Consequently, it may be necessary for the committee to provide a combined score based on their review of the data and judgment.

Retail and Banking

Average Normalized Resilience Scores (Number of Days)

		Retail Trade (COM1)			Wholesale Trade (COM2)			Banking (COM5)		
		Pre-1950	1950-1970	Post-1970	Pre-1950	1950-1970	Post-1970	Pre-1950	1950-1970	Post-197
Low Rise	**Pre-Code**									
	Coastal	95.6	81.7	89.2	117.0	103.6	110.0	88.5	76.7	77.4
	Valley	22.2	19.3	22.3	30.3	26.4	29.2	19.6	17.6	18.2
	Eastern	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Code									
	Coastal	38.5	33.2	37.0	46.8	43.3	47.2	35.8	30.9	31.6
	Valley	6.2	5.8	6.6	8.1	7.7	8.8	5.6	5.2	5.5
	Eastern	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mid Rise	**Pre-Code**									
	Coastal	104.6	127.8	120.4	102.8	104.6	114.9	118.1	117.0	127.3
	Valley	23.8	34.9	32.0	23.3	25.6	30.0	30.0	30.7	34.7
	Eastern	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low-Code									
	Coastal	42.9	52.3	48.4	41.6	43.1	47.0	47.3	47.2	50.6
	Valley	6.9	9.7	8.7	6.8	7.4	8.4	8.1	8.4	9.2
	Eastern	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
High Rise	**Pre-Code**									
	Coastal							130.5	141.2	139.2
	Valley							35.6	40.4	39.4
	Eastern							0.0	0.0	0.0
	Low-Code									
	Coastal							51.1	55.0	54.3
	Valley							9.4	10.3	10.1
	Eastern							0.0	0.0	0.0

Table 10 COM1, COM2 and COM5 Normalized Resilience Scores (Number of Days)

Critical Government Facilities

In addition to the essential services (police stations, fire stations and emergency operations centers) addressed by the SSNA data previously in this report, other government functions are also critical for resilience. Limited administrative functions, essential health services, correctional facilities, and maintenance buildings necessary for repairing roads and utilities following the earthquake are also necessary. Defining a specific listing of these services and their associated facilities was beyond the scope of this report. However, in many ways obtaining a specific listing was not necessary to get a general overview of how these facilities may perform. The FEMA Hazus "GOV1" General Services Occupancy Classification is understood to include a wide range of government functions. Without more specific data, it was assumed that this classification is generally representative of the resilience which could be expected by a smaller "critical" subset.

Total building count for the "Government" General Occupancy Classification is 2,357, though not all would be considered critical. Construction types anticipated by Hazus statics are primarily steel and concrete prior to 1950, with about 20% of the inventory being shared between wood and unreinforced masonry (URM). These construction types change for construction periods between 1950 and 1970. The post-1970 distribution still anticipates concrete and steel, and some wood, but much more prevalent reinforced concrete masonry (CMU), which is estimated to comprise about 25% of the building stock.

Analysis to convert FEMA Hazus estimated damage states to a normalized Resilience Score was done using the same methods described for Retail and Banking facilities. Results of this analysis yielded the results shown in Table 11.

Government Facilities

Average Resilience Scores (Number of Days)

		General Services (GOV1)		
		Pre-1950	1950-1970	Post-1970
Low Rise	**Pre-Code**			
	Coastal	158.7	133.2	157.9
	Valley	27.9	22.9	29.1
	Eastern	0.0	0.0	0.0
	Low-Code			
	Coastal	67.4	56.4	67.3
	Valley	7.9	7.0	8.4
	Eastern	0.0	0.0	0.0
Mid Rise	**Pre-Code**			
	Coastal	183.1	171.0	184.7
	Valley	35.0	32.2	36.6
	Eastern	0.0	0.0	0.0
	Low-Code			
	Coastal	78.2	73.0	78.6
	Valley	9.5	9.1	10.1
	Eastern	0.0	0.0	0.0
High Rise	**Pre-Code**			
	Coastal	194.3	204.8	204.5
	Valley	39.6	43.4	43.2
	Eastern	0.0	0.0	0.0
	Low-Code			
	Coastal	81.9	86.4	86.2
	Valley	10.6	11.3	11.3
	Eastern	0.0	0.0	0.0

Table 11 GOV1 and GOV2 Normalized Resilience Scores (Number of Days)

Residential Housing

2010 US Census data place the number of residential dwelling units in Oregon at approximately 1.6 million units, including single and multi-family housing. FEMA's Hazus program, which was used for this review, estimates that there are approximately 960,000 single-family homes, and is generally consistent with similar Census estimates.

Construction of single-family homes is almost entirely light wood framing. Based on the Hazus Technical Manual, the Model Building Type for the "RES1" Building Occupancy Class is 99% wood (W1) construction. Figure 16 below shows Table 3A.17 from the Hazus Technical Manual. This table is for Pre-1950 structures. Similar tables for 1950-1970 and Post-1970 all show residential construction as 99% wood framed.

Table 3A.17: Distribution Percentage of Floor Area for Model Building Types within "RES1" Building Occupancy Class, Pre-1950, West Coast

State FIPS*	State Abbreviation	State	Model Building Type 1 W1	9 S3	13 S5L	19 C2L	29 RM1L	34 URML
02	AK	Alaska	99			1		
04	AZ	Arizona	60				25	16
06	CA	California	99				1	0
08	CO	Colorado	76				15	9
15	HI	Hawaii	92			1	4	3
16	ID	Idaho	95				3	2
30	MT	Montana	98				1	1
35	NM	New Mexico	74				16	10
32	NV	Nevada	97				2	1
41	OR	Oregon	99				1	
49	UT	Utah	82				11	7
53	WA	Washington	98				1	1
56	WY	Wyoming	92				5	3

* State FIPS are two digit unique number representative of each state and US territory. Refer to Table 3C.1 of Appendix C for a complete list of State FIPS.

Figure 16 Distribution Percentage of Floor Area for Building Types in "RES1" Building Occupancy Class.

Because residential construction is 99% wood framed, the equivalent normalized Resilience Score was determined directly for each county based on a the Expected Damage State reported by Hazus.

Normalized Resilience Score for Each County =

$$\sum_{County} \{Normalized\ Resilience\ Score\ for\ Damage\ State\}\ x\ \{Hazus\ \%\ Expected\ Damage\ State\}$$

These results were then combined for each Seismic Region (Coastal Counties, Valley Counties, and Eastern Counties) using a weighted average based on the total estimated building count for each county considered by Hazus. Total building count for the "Residential" General Occupancy Classification is 937,667.

Normalized Resilience Score for Each Seismic Region =

$$\sum_{Region} \{Normalized\ Resilience\ Score\ for\ County\}\ x\ \{Hazus\ \%\ Building\ Count\ in\ Each\ County\}$$

This analysis yielded the results indicated in Table 12.

Residential

Average Resilience Scores (Number of Days)	Residential (RES1)
Coastal	13.0
Valley	1.5
Eastern	0.0

Table 12 RES1 Normalized Resilience Scores (Number of Days)

However, the details of how wood frame structures are constructed have a lot to do with their ability to withstand earthquakes, and there are some common vulnerabilities in these structures that make them susceptible, particularly those built before 1976. One of the most common deficiencies is a lack of adequate anchorage between the upper wood frame structure and the concrete foundation or basement walls. Other common deficiencies include failure of cripple walls, which are short wood framed wall segments that typically extend from a foundation to the floor above, but frequently lack proper connections and can easily rotate similar to a hinge, allowing the building to shift laterally off of its foundation. In older structures, unreinforced masonry chimneys can fall and cause additional structural damage.

Vulnerable Buildings

For the purpose of this evaluation, vulnerable buildings are defined as unreinforced masonry (URM) and non-ductile concrete structures. These building types represent the most significant threat to life-safety and exhibit extremely poor performance in seismic events. URM buildings are constructed with clay brick, hollow clay tiles, or concrete block, with little or no reinforcement. Ages of these buildings are generally 80 years or more. Non-ductile concrete buildings are also susceptible to extreme damage in moderate to severe seismic events and have very little steel reinforcement. These buildings range in age from 40 to 100 years. Most of these buildings are one to five stories in height. Since this category represents a building "type" rather than "use", these buildings encompass a large variety of structures, ranging from essential facilities such as fire stations, to retail centers and office space.

Expected State of Recovery:

Based on the limited information available for these types of buildings throughout the state, recovery timelines were estimated based on HAZUS data provided by the Oregon Department of Geology and Mineral Industries (DOGAMI). Categories included URM buildings only; specific data was not available for non-ductile concrete structures. HAZUS software operates through a geographic information system (GIS) to display earthquake hazard information, inventory data, and estimated losses which approximate building damage from a particular seismic event. The HAZUS data used for this study was based on a Cascadia Subduction Zone earthquake and assumes that all structures were designed with no seismic considerations (pre-code), based on age and construction type.

Table 8 outlines the estimated recovery states for vulnerable buildings:

As expected, the data in the table indicates that most of these buildings will experience significant structural damage, and partial or total collapse which will require major repairs. Buildings in eastern Oregon will exhibit much less ground shaking and thus have less damage. Repairs for significantly damaged structures will likely not be feasible based on the type and age of these buildings. It is anticipated that these buildings will be partially or completely demolished after an earthquake.

It should be noted that these recovery times are based on a Cascadia Subduction Zone earthquake event, which may not result in the highest ground shaking intensities in some valley and eastern regions, but would likely have a longer duration. Other hazards also exist, such as soil liquefaction, landslides, and tsunamis, which were considered in the projected states of recovery. DOGAMI 's recent studies indicate that these soil hazards exist in all three state regions and many coastal regions are located in a tsunami inundation zone, however, details of how these relate to the vulnerable building stock are unknown.

Data for non-structural items associated with these buildings is not currently available, and therefore not included in the evaluation.

State of Recovery Determination:
As indicated above, vulnerable building recovery states were established using HAZUS data as a baseline and then adjusted using engineering judgment based on additional hazards such as soil liquefaction, landslides, tsunami, data variations, and historical performance of these types of buildings.

A normalized recovery time was assigned to each level of damage listed in the HAZUS reports as shown in Table 13 below:

Table 13: Recovery Times - URM

Level of Damage	Recovery Time
None	1 Hour
Slight	36 Hours
Moderate	45 Days
Extensive	20 Months
Complete	40 Months

A weighted average of the anticipated damage levels for URM buildings was calculated for each county to determine a recovery time. These durations were than averaged for all of the counties in each region (coastal, valley, eastern) again using a weighted formula considering the total number of URM buildings listed in the HAZUS data for each county. Table 14 below provides an example using a sample of three coastal counties:

Table 14: Recovery Determination Example (Sample = 3 Counties)

County	Damage Level[1] – Unreinforced Masonry Buildings					No. of URM Structures	Anticipated Recovery
	None (1 Hr)	Slight (36 Hrs)	Moderate (45 Days)	Extensive (20 Mo.)	Complete (40 Mo.)		
Clatsop	0%	1%	14%	43%	42%	610	26 Months
Columbia	10%	27%	43%	17%	3%	493	5 Months
Tillamook	0%	5%	26%	41%	28%	489	20 Months
						Weighted Average:	**18 Months**

[1] From DOGAMI HAZUS Data for Cascadia Subduction Zone Event – Pre-Code Seismic

Codes, Past Legislation, and Funding Sources:

Many jurisdictions have adopted code language mandating seismic upgrades for these types of buildings (primarily URM) to varying degrees. For legislation, or funding sources, refer to each specific building use section.