4. Critical and Essential Buildings

Introduction

Building safety and functionality will be critical both during and after a magnitude 9.0 Cascadia subduction zone seismic event. Oregon's buildings must be able to withstand the intense ground shaking without devastating loss of life, damage to infrastructure, or significant disruption to our communities and economy. Because of this, the Critical Buildings Task Group was assigned the task of reviewing the status of buildings in critical sectors and considering how they may be affected by a Cascadia subduction zone event. Buildings in these critical sectors include those that are necessary for the immediate response to the event—such as emergency operations centers, hospitals, police and fire stations, and emergency shelters—and buildings that are necessary for the provision of basic services to communities as they begin to restore functions and return to normal life—for example, schools, housing, certain retail stores, and banks. The group reviewed one additional building category: vulnerable buildings. These are unreinforced masonry and non-ductile concrete structures that have shown time and again in past earthquakes that they pose a very significant and direct threat to life safety.

While the task group acknowledges that there are many other buildings and sectors that could also be considered vital to resilience, the group decided to limit the study to those buildings that we believe are most critical to resilience in the case of an earthquake scenario. Buildings and structures that are directly associated with and critical to the functionality of communications, utilities, ports, water supply, wastewater, and fuel storage have been evaluated separately by other task groups; the assessments and recommendations of these task groups are provided elsewhere in this report.

To assess the overall seismic resilience of critical and essential buildings in the state of Oregon, the work group considered the gap between the building-performance goal needed for seismic resilience (target state) and the expected seismic performance of the buildings as they are today (current state). Most of the building sectors that are critical to the response to a seismic event are recognized by the current building code. Oregon's current seismic design standard for new buildings, the Oregon Structural Specialty Code (OSSC), classifies buildings according to four distinct occupancy categories based on their relative importance to life safety in the event of a natural disaster (see Figure 4.1). Occupancy Categories III and IV are structures that have large assembly areas (such as schools), or that are deemed essential to emergency response (such as hospitals, police and fire stations, and emergency operations centers). Buildings that fall under these Category III or IV classifications were obvious components of the Critical Buildings data set used in our evaluation. Under current code, occupancy category type III buildings are designed for a 25-percent higher seismic load than Category I and II buildings. Category IV buildings are designed for a 50-percent higher load.

Our group also looked beyond the building code to buildings that have functions that we believe are vital to the seismic resilience of the state as a whole. Supermarkets, pharmacies, some big-box retail stores, and banks comprise a subset of buildings that will be relied upon heavily following a disaster. The importance of having an ample supply of basic provisions—such as food, water, medical supplies, and money—in affected areas after a natural disaster has been underscored by many previous events, including Hurricane Katrina and the 2011 Tohoku earthquake and tsunami in Japan. If buildings that house these resources are not seismically resilient, the ability of the community to recover after the event will be adversely affected. For these reasons, the community's large retail buildings and bank buildings have been classified as critical buildings in this study.

TABLE 1604.5
OCCUPANCY CATEGORY OF BUILDINGS AND OTHER STRUCTURES

OCCUPANCY CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Occupancy Categories I, III and IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing elementary school, secondary school or day care facilities with an occupant load greater than 250. • Buildings and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500. • Group I-2 occupancies with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5,000[a]. • Power-generating stations, water treatment facilities for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV. • Buildings and other structures not included in Occupancy Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2 occupancies having surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV structures. • Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.1(2). • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

a. For purposes of occupant load calculation, occupancies required by Table 1004.1.1 to use gross floor area calculations shall be permitted to use net floor areas to determine the total occupant load.

Figure 4.1: Oregon Structural Specialty Code, Table 1604.5

Past earthquakes have brought to light the dangerous nature of unreinforced masonry (URM) and non-ductile concrete structures. Because of their tendency to sustain excessive damage or even collapse in moderate earthquakes, these buildings pose the greatest threat to life safety of any other building type in the state of Oregon. This, along with the fact that URM and non-ductile concrete buildings can be found in all occupancy categories, was the main reason that our task group included these vulnerable buildings in our study of critical buildings.

Building Data and Analysis

After identifying the building sectors, the task group went on to identify data sources for the existing building stock that could be used for assessment of the buildings' seismic resilience. Two sources were used:

- 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) prepared by the Oregon Department of Geology and Mineral Industries (DOGAMI), hereafter referred to as the 2007 SSNA.
- The Hazus Earthquake Model developed by the Department of Homeland Security and FEMA, hereafter referred to as FEMA Hazus.

The 2007 SSNA is an assessment of existing hospitals, police and fire stations, emergency operations centers, and K-12 schools throughout Oregon. This assessment was conducted using a rapid screening method developed by FEMA to identify potential seismic hazards. The report provides evaluations of each facility, which were visited by screeners to establish a Rapid Visual Screening (RVS) score based on the FEMA 154 methodology. The data was compiled by DOGAMI, and the resulting scores were then reviewed by the structural engineers in our task group, who, in the case of emergency operation centers, police stations, fire stations, and acute care hospitals, reviewed the screening for every building and converted the RVS scores to *expected recovery* scores. These scores were then placed into the overall *Critical Building Target States of Recovery Matrix* shown in Figure 4.2. A similar procedure was also used for schools, but because of the number of school buildings, only about 10 percent of the total school building stock was reviewed directly. Additionally, the task group took into consideration tsunami inundation, liquefaction, and landslides, which were not a part of the DOGAMI study.

To assess residential buildings, community retail centers, banks, critical government facilities, and vulnerable buildings, data for expected damage estimates based on a Cascadia subduction zone event were extracted from the FEMA Hazus model, and an analysis was performed to develop *expected recovery* scores, which were then added to the overall matrix shown in Figure 4.3. Unlike the 2007 SSNA data, which looked at each individual building, the FEMA Hazus model utilizes a complex series of statistical analyses to predict damage estimates. This involves making predictions about the quantity, size, and construction of buildings in various sectors based on census data, and then calculating an expected performance for these buildings using additional statistical models. While this is a useful tool for looking at large populations of buildings, the outcomes do not correlate directly to any specific buildings. Because more detailed reports were not available, this data was used to establish *expected* *recovery* scores; these are subject to a larger variation in expected results and should not be viewed with same level of reliability as those in Figure 4.2. Recovery scores developed from the 2007 SSNA report have been separated from the scores developed through the use of FEMA Hazus due to the differences between the two sources.

Target States of Recovery

With recovery scores established, the next step was to determine the recovery state that should be targeted in planning the path to statewide seismic resilience. The recovery state is the average time that should be needed to repair a building in a given sector and restore most of its functionality. For the Phase 1 target states, which are measured in hours, there is not much differentiation in the building performance, though it should be realized that just evaluating buildings, particularly in the areas most severely affected, may take several days. Buildings with Phase 2 response times are expected to require some repairs, but generally should not sustain major damage to the primary structures. Phase 3 buildings are expected to sustain significant damage, likely requiring many months to a year or more to repair. The worst building performance—expected of structures in the 18 month and 36+ month categories—will likely be at, or near, a complete loss. Many buildings can be reconstructed in 18 months with sufficient resources; the remaining collapsed buildings will likely require 36+ months.

The determination of target states was based mostly on assessing the relative importance of each of the occupancy types to the response and recovery effort after the seismic event. Buildings that house first responders or provide emergency functions are the most vital to the response effort and will need to be functional immediately after the seismic event occurs. Schools in the affected areas need to provide a level of life-safety protection for the children and adults in them during the earthquake, but could be out of service for up to 60 days without significant impacts on resilience. The exceptions are those schools designated as emergency shelters for displaced citizens after the event occurs. The availability of food, water, medical supplies, and money will also be critical to the speed of recovery of the communities affected by the seismic event. Consequently, retail centers, pharmacies, and banks will have to be able to return to normal operation in a reasonable amount of time. All of these considerations informed the development of the *target recovery* scores for each building class that are reflected in Figures 4.2 and 4.3. Note that a specific target state was not determined for vulnerable buildings. This is because the use and function of these structures varies widely. Instead, the recovery state should either match the building's occupancy category, if the building is used for a critical function, or upgrade criteria should be established based on the needs of the facility—but these criteria should not be less than life safety.

With both expected and target recovery states identified and tabulated for each building class by seismic region, the gaps between expected and target building performance can easily be seen.

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[1] (Coastal)									X
Healthcare Facilities[1] (Valley)								X	
Healthcare Facilities[1] (Eastern)					X				
Primary/K-8 (Coastal)						[2]		X	
Primary/K-8 Centers (Valley)						[2]		X	
Primary/K-8 (Eastern)					X	[2]			
Secondary/High School (Coastal)						[2]		X	
Secondary/High School (Valley)						[2]		X	
Secondary/High School (Eastern)					X	[2]			
Emergency Sheltering (Coastal)								X	
Emergency Sheltering (Valley)								X	
Emergency Sheltering (Eastern)					X				

[1] Analysis includes consideration of nonstructural components

[2] Range recognizes preference for shorter time frame, but acknowledges a longer period can be tolerable.

Target State X **Estimated Current State**

Figure 4.2: Target States of Recovery for Oregon's Buildings Based on 2007 DOGAMI SSNA and Independent Structural Engineering Review

Table 2. 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**[2]				
Residential Housing (Valley)				**X**[2]					
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 the *Critical Government Facilities* section (below) for a definition of this building type.

[2] Average underestimates expected performance of older houses, which are vulnerable to several structural deficiencies.

Target State **X Estimated Current State**

Figure 4.3: Target States of Recovery For Oregon's Buildings Based on FEMA HAZUS Loss Estimations

While the gaps between the target state and the estimated current state may appear large, it was our task to look beyond them and formulate a 50-year plan for closing these gaps. The Critical Buildings Task Group has therefore developed an extensive list of recommended actions that, if followed, provide a framework for achieving this objective. These recommendations, along with a proposed implementation timeline, can be found in the *Conclusions and Recommendations* section at the end of this chapter. As the building stock continues to age and the likelihood of the next Cascadia subduction zone event continues to grow, the gaps that we have identified will only continue to get larger. We cannot underscore enough the importance of taking immediate action so that the movement to an acceptable level of seismic resilience in the most essential and vital buildings in our state can begin.

Assessment of Current Building Performance: A Sector by Sector Review

EMERGENCY OPERATIONS CENTERS, POLICE AND FIRE STATIONS

Introduction

In 2005, the Oregon Department of Geology and Mineral Industries (DOGAMI) published a report titled *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*. This report catalogued the vast majority, if not all, of the emergency operations centers, police stations, and fire stations within Oregon. Of the sources of data collected, 82 emergency operations centers, 109 police stations (which includes city police, state police, and county sheriff), and 595 fire stations (which includes city and rural fire protection districts) provided enough information for the Critical Buildings Task Group to reasonably assess the state of seismic resilience of each of these buildings.

Most of the buildings considered by the task group are one- or two-stories tall and are constructed from reinforced masonry or wood. The median building age is approaching 40 years. Despite the good performance record of wood structures during earthquakes, the age of these buildings and the low level of seismic design used prior to 1995 places the older structures at risk. Additionally, a number of buildings located in the coastal region are at risk of earthquake-caused tsunami inundation or large ground displacements due to either liquefaction or landslides. A number of buildings in the valley region are also at risk of significant movement due to liquefaction or landslides resulting from an earthquake. All of these factors increase the level of risk for many buildings exposed to the effects produced by a Cascadia subduction zone event.

Estimated State of Recovery

The expected state of recovery of these buildings ranges from a few buildings remaining fully functional during and immediately following a Cascadia subduction zone event, to many other buildings requiring three or more years for repair before they are deemed fully functional or are demolished. Of particular concern are the buildings along the Oregon coast, where 82 percent of the emergency operations centers, 86 percent of the police stations, and 67 percent of the fire stations will most likely take 18 months or more to resume normal operations. The buildings within the valley zone are also problematic, with 27 percent of the emergency operations centers, 38 percent of the police stations, and 31 percent of the fire stations likely to sustain damage to the extent that 18 months or more will most likely be required to resume normal operations. Therefore, instead of being able to withstand and operate during and after a Cascadia subduction zone seismic event, which is what we should expect of buildings performing these vital life-safety functions, it is anticipated that a significant percentage of the buildings that house these types of essential services will not be functional for some time after the event. Of significant concern is the longer recovery time anticipated for many of the critical buildings that are located along the coast and in portions of the valley.

Target State of Recovery

The importance of emergency operations centers, police stations, and fire stations to the post-earthquake response and recovery is widely recognized. Building codes have required for some time that these facilities be designed to a higher standard, with the intent that they will remain operational after a major earthquake. The public also recognizes that these facilities are the centers for first response, and there is consequently a general expectation that they will remain functional after the disaster. For these reasons, the target state of recovery for these facilities must be *Event Occurs* as indicated in the recovery matrix, Figure 4.2.

Sector Specific Recommendations and Conclusions

To our knowledge, a mandatory program with a formal mechanism to identify deficient structures and require their upgrade with a firm timeline does not currently exist. ORS 455.400 requires seismic rehabilitation of publicly-operated emergency operations centers, police stations and fire stations by 2022, but with the caveat of being, “subject to available funding.” As a result, it appears to have had only limited effect in this and other essential and critical building sectors. Typically, the impetus to evaluate these types of buildings to determine their seismic-resisting capability is motivated at the local level, often by the public agency itself. Once the evaluation has been completed, a determination can be made about whether a particular building or group of buildings requires seismic rehabilitation. The agency will then submit a request to the voters within that community to support a general obligation bond to accomplish the needed work. This was recently done within the city of Portland, where a general obligation bond was passed in 1998 to rehabilitate the city’s fire stations (See Figure 4.4). The last fire station rehabilitation was completed in 2012.

Figure 4.4: Some cities in Oregon have already started seismic rehabilitation program to strengthen the fire stations that are susceptible to serious damage in an earthquake. Fire Station #1, the largest in Portland, was retrofitted in 2009. It should now be in working order after an earthquake, serving downtown Portland. (Source: Peck Smiley Ettlin Architects)

Financing methods for the rehabilitation of public buildings are much more limited than the opportunities that exist for privately-owned buildings. As a result, general obligation bonds, or some variation thereof, are likely to be the primary method to finance the seismic upgrading of these critical facilities. Oregon Senate Bill 3 and 5 (2005) provided for the establishment and funding of a grant program for emergency services buildings to assist with upgrades of these facilities, but funding to date for this program has been limited. Public buildings ultimately must be financed, either substantially or completely, with public funds. This can only happen by implementing a broad program of education to inform the voters of the risks associated with these seismic hazards and the impact that those risks, if unmitigated, will have on their communities when the Cascadia subduction zone event occurs.

In addition to the types of public buildings discussed above, other types of critical government facilities exist, including, but not limited to, city halls, public safety answering points (PSAPs, usually termed 911 Centers), and jails. The 2007 SSNA report did not collect data on these types of facilities, and to our knowledge, no publicly-available data exists about them within Oregon, except for broad statistical data which can be inferred from the FEMA Hazus data discussed in the *Critical Government Facilities* section of this chapter (see below). Consequently, no specific, data-driven recommendations regarding the seismic resilience of these other critical government facilities have been provided as part of this report.

EDUCATION FACILITIES

Introduction

Public school facilities make up a special category of Oregon's public infrastructure. Oregon has 1,355 K-12 public schools organized in 197 school districts that are overseen by independent elected local school boards. Combined, these schools have a total of over 2,000 buildings of various structural types, sizes, and vintages, including numerous buildings that are more than a century old.

Schools are among the most heavily used public buildings in Oregon and one of a few classes of buildings whose occupants' presence is compulsory. In 2010, the Western States Seismic Policy Council (WSSPC) adopted a policy recommendation that states, "Children have the right to be safe in school buildings during earthquakes" (WSSPC, 2010). Based on the findings of the Critical Buildings Task Group, the state of Oregon is far from meeting this ideal of student safety today.

The 2007 Statewide Seismic Needs Assessment (SSNA) employed the FEMA 154 Rapid Visual Screening (RVS) methodology to characterize the structural performance of buildings by placing them into one of four broad categories of collapse potential. Of the full sample of 2,018 K-12 educational facilities assessed using the FEMA 154 methodology, 12 percent rated Very High, 35 percent rated High, 23 percent rated Moderate, and 30 percent rated Low collapse potential (Lewis, 2007). The assessment focused on school facilities constructed before 1994, although some more recent buildings were included. Of the buildings assessed, roughly 80 percent were built before Oregon first adopted a statewide building code in 1971, and 60 percent are more than 50 years old. The assessment revealed that inadequate or non-existent seismic design is pervasive in every region of Oregon, and that seismic retrofit investment at the school district level has been limited.

Schools are typically large, complex buildings with plan irregularities that will be sources of poor seismic performance. Many schools are campuses that are comprised of multiple buildings of varying sizes and construction dates, and often varied construction materials. Primary, K-8, and high schools generally consist of one- or two-story wood-frame or concrete masonry unit (CMU) and concrete buildings with flexible roof diaphragms. One- to three-story lightly-reinforced concrete buildings braced by concrete shear walls, concrete tilt-up buildings, and unreinforced masonry (URM) buildings are also common.

Figure 4.5: The previous Molalla High School building, a three-story unreinforced masonry structure, was damaged from the M5 .6 Scotts Mills, Oregon earthquake in 1993. It happened during spring break, when the school was empty, which prevented serious injuries. The district took the opportunity to forecast future needs and decided not to rebuild at the same location. Molalla High School is now housed on a larger campus with a stronger, more spacious building. Many URM schools and other buildings in Oregon could suffer a similar fate in future earthquakes. Communities can act now to plan how and when to rehabilitate or replace these aging, potentially dangerous facilities. (Source: DOGAMI)

The building stock of Oregon's K-12 schools possesses seismic vulnerabilities that are common to the specific building types of which it consists. Unreinforced masonry (URM) buildings historically perform poorly in seismic events and are the most dangerous existing building type in the school building stock (See Figure 4.5). Many 1930s-era multistory schools rely on lightly-reinforced concrete shear walls that are historically poor performers as well. Wood framed schools should perform well provided they are well constructed, even though many of them pre-date building codes. These wood buildings may possess deficiencies, including weak or missing roof-to-wall connections, and weak or missing anchorage of walls to foundations—all of which could contribute to poor seismic performance. Concrete tilt-up buildings have also proven to perform poorly in earthquakes. Newer tilt-up buildings have been improved by code changes adopted following the 1994 Northridge earthquake in California, but older tilt-up buildings, and even CMU buildings, may remain vulnerable due to poor connections between heavy rigid walls and flexible roofs. Modular classrooms may also be vulnerable, because they may have insufficient connections to their foundations. In addition, many schools contain unsecured and inadequately braced nonstructural components that may present falling hazards during a seismic event (See Figure 4.6).

Figure 4.6: Pendant light fixtures failed in this elementary school library during the 1983 M6.5 Coalinga, California earthquake. If the room had been occupied, this could have caused injuries. Bracing nonstructural elements in homes, schools, and offices can often be done easily and relatively inexpensively. (Source: NOAA/NGDC, Earthquake Engineering Research Institute)

Estimated State of Recovery

The 2,377 educational facility records in the 2007 SSNA were too numerous to be analyzed individually by members of the educational facilities subgroup. Our analysis and results are based on a random sample of approximately 300 records (224 primary school buildings and 79 secondary school buildings) that were selected as representative of the broader data set. We classified the building records into the appropriate geographic seismic zone (coast, valley, and eastern) and verified that we had assembled an adequate sample size for each zone.

Our analysis revealed that in a Cascadia subduction zone earthquake scenario, pervasive structural vulnerabilities would likely result in recovery durations of 18 months or longer for primary and secondary schools in the seismic zones of the coast and valley. Primary and secondary schools in the eastern seismic zone are expected to have recovery times of 60 days or less, mainly due to the minimal level of ground motion expected in that geographical area.

Target States of Recovery

Giving consideration to the prioritized needs of the entire community for resilience and recovery, returning children to school within 30 days is preferred. However, it was also the opinion of the task group that a disruption of the public education system for up to 60 days could be tolerated without having a major impact on communities and students. This determination was based on several considerations:

- School buildings will not initially be as critical to the recovery as most other critical buildings included in our study. The exception to this would be those schools that are needed as emergency shelters, and as such, should have a target state of recovery of 72 hours.
- Teacher/employee contracts can be adjusted to accommodate a 2 month stoppage of work more readily than employee contracts in many private businesses.
- Temporary facilities, including portable buildings and large buildings that are undamaged after the event, can be employed to serve some of the more immediate needs of education until full recovery is achieved.

Discussion and Sector Specific Recommendations

Oregon's K-12 educational facilities have been the focus of seismic rehabilitation policy efforts for more than a decade. In 2001, legislation (ORS 455.400) directed that, subject to available funding, K-12 educational facilities with seismic deficiencies should be rehabilitated to a life-safety performance level by 2032. In 2002, Oregon voters adopted ballot measures amending Oregon's constitution with Articles XI-M and XI-N, provisions that allow the state to issue general obligation bonds for the purpose of seismic retrofits to existing schools and emergency response facilities. In 2005, a series of bills (Senate Bills 2, 3, 4, and 5) directed DOGAMI to organize and conduct the *Statewide Seismic Needs Assessment*, directed Oregon Emergency Management to establish a seismic rehabilitation grants program, and allowed the Department of Administrative Services and the Oregon State Treasurer to issue bonds to finance seismic rehabilitation.

In 2007, Senate Bill 1 provided funding to establish and staff the seismic rehabilitation grants program. The first opportunity to authorize a bond sale for an inaugural round of seismic retrofit grants came in the 2009-2011 biennium. The legislative assembly authorized $30 million for seismic grants, divided equally between the program for K-12 schools and the companion program for emergency response facilities. The first round of K-12 grants directed $5.6 million to projects at twelve schools in eight school districts in the spring of 2010. As the recession deepened, the governor chose to rescind $7.5 million of the original authorization for the program, limiting additional granting during 2009-2011. Three additional seismic grants were awarded to K-12 schools (including two URM buildings) in early 2011. These grants marked the end of the first funded cycle of the program.

On the final day of the 2011 legislative session, the legislature authorized $7.5 million in new seismic grants for K-12 schools during the 2011-2013 biennium. These grants, announced in Fall 2011 and funded by a bond sale in July 2012, directed $7.2 million to seven K-12 schools. To date, the Seismic Rehabilitation Grants Program has funded retrofit projects at 22 schools, about 2 percent of the need documented by the *Statewide Seismic Needs Assessment*.

During the short 2012 session of the legislative assembly, legislators passed Senate Bill 1566. The bill directs the state's Department of Education, which communicates with parents about student achievement and school performance via an annual report card, to inform the public in that report that a database of seismic ratings exists and to provide a web link to the ratings. Further, the bill asks school districts to advise DOGAMI when they rebuild or renovate schools, so that the state can share information about the upgrades. The first reports submitted by individual school districts are now posted on the DOGAMI website, although the agency has no funding to integrate information from the reports in an update of the statewide database itself.

Given both the limited impact that existing policies have had on restoring resilience in Oregon's schools and the uneven success that Oregon school districts have had passing local capital bond measures for school rehabilitation and construction in recent years, an evaluation of Oregon's approach to characterizing and addressing the seismic vulnerability of school facilities is in order. Past outreach using the results of the *Statewide Seismic Needs Assessment* has emphasized the threat to life safety and the possibility of mass casualties in collapsed school buildings. By contrast, the gap analysis we have performed as part of this resilience study focuses on quantifying the state's ability to resume public education after a region-wide Cascadia subduction zone earthquake, given what is known about the condition of the state's school facilities. With the anticipated level of damage to those facilities, the disruption of public education could extend considerably beyond a full school year, particularly in the coast and valley regions—a factor that could impede Oregon's economic and social recovery for years after the Cascadia subduction zone earthquake.

HEALTHCARE FACILITIES

Introduction

There are 60, mostly privately-owned, healthcare facilities within the state of Oregon, with the majority of the buildings being over 40 years old. Each healthcare facility is comprised of either a single building or multiple buildings that form a campus. Roughly 180 structures within all of the 60 healthcare facilities serve critical healthcare functions. There are additional buildings within each healthcare facility's campus that have not been included in this study because they do not serve acute care needs and are not considered essential.

In essential healthcare buildings, the most prevalent construction material is concrete, with approximately 70 percent of concrete structures relying on concrete shear walls to resist lateral loads and the remaining structures relying on concrete moment frames. The second most prevalent construction material is steel: approximately an equal distribution using steel braced frames and steel moment frames to resist lateral loads. Reinforced masonry and wood are seen more often in the smaller structures located in the coastal or eastern zones.

The most notable structural lateral-system vulnerabilities found within healthcare facilities are the non-ductile concrete and non-ductile steel frame buildings. These building structures were typically constructed before the increased seismic risk in Oregon was well understood in the early 1990's, and before substantial code changes were made to require more robust connections that are better able to resist seismic forces.

Independent of the type of lateral system, two very notable structural irregularities that typically create problems were found in many of the healthcare buildings. The first is a horizontal irregularity in the footprint of the building. Seismically, the most reliable shape for a floor plan of a building is a square or a rectangle. The least reliable shapes are T, E, L, and X configurations or variations of these. In association with these irregular shapes, many problems occur at parts of the structure called *reentrant* or *interior* corners, which do not occur in a rectangular floor plan. The second notable structural irregularity is a vertical irregularity, which occurs when the building steps back in plane as the floor levels increase.

Historically, performance of healthcare facilities around the world has been extensively affected by nonstructural damage. The ability of a healthcare facility to function is greatly dependent on the nonstructural items within that facility. The building's structure may perform very well during the expected earthquake, but the hospital might not be functional after such an event due to nonstructural damage alone. Nonstructural vulnerabilities typically includes lack of proper anchorage of mechanical, electrical, and medical equipment and lack of proper bracing of ceilings, pipes, ductwork, electrical elements, medical gas such as oxygen, and other critical service lines. Healthcare facilities are often campuses made up of multiple buildings, which include those that provide healthcare and often a central utility plant (CUP) or a central building that contains a large number of pieces of essential equipment (such as boilers and air handling units) that support the rest of the campus. Although this central building may not provide healthcare directly, it is considered a vulnerability, because damage to its structure and contents can have a great impact on the entire campus' utilities and ability to function.

Estimated State of Recovery

Currently, essential healthcare facilities in Oregon are not expected to perform well during a Cascadia subduction zone seismic event. The facilities on the coast and in the valley will likely take over three years to recover to an operational state. Some facilities in eastern Oregon will take approximately 30 days to recover to an operational state.

Target State of Recovery

Essential healthcare facilities are critical for the life safety of the entire population and must be capable of surviving the expected Cascadia subduction zone seismic event. This survival requires that the buildings remain completely functional during the event and be available to respond to emergency needs immediately following the earthquake and any aftershocks that may occur. For these reasons, the target state of recovery for these facilities must be *Event Occurs* as shown in the Recovery Matrix.

Sector Specific Recommendations

As outlined in the 2011 Oregon Revised Statutes (ORS 672.107), *significant structures* must be designed under direct supervision of a licensed structural engineer. Hospitals and other major medical facilities that have surgery and emergency treatment areas are considered *significant structures* or *essential facilities* according to ORS 455.447. Standby power generating equipment for essential facilities is also considered *essential* and is covered under ORS 672.107. However, buildings that contain the balance of equipment required to keep these vital facilities functional are not considered *essential*, and therefore are typically designed to a lesser seismic standard. In order for critical healthcare facilities to be truly resilient, all buildings that provide mechanical, electrical, and plumbing service to the buildings must be designed to the same standard. This shift will require revisions to the building code and an expanded definition of *essential facility*.

In 2001, legislation (ORS 455.400) directed that, subject to available funding, acute inpatient care facilities that are determined to pose an "undue risk to life" should be rehabilitated to a life-safety performance level by 2022. Currently, to our knowledge, most of the deficient acute care facilities in the state have not been upgraded in accordance with this legislation. By having the "subject to available funding clause" in the statute language, the legislation does not provide a mandate and therefore is not proving to be effective in addressing the problem. A more effective mandate should include specific measures that would give private healthcare systems incentives, whether tax credits or some other vehicle, to make seismic improvements.

A facility's buildings and internal infrastructure are not the only factors to take into consideration when assessing the facility's ability to operate without interruption after the expected Cascadia subduction zone seismic event. Healthcare facilities are also dependent on the city for their water, on distribution-center buildings for supplies, and on roadways for the delivery of supplies, to name only a few things.

Healthcare facilities do not have control over any of these components. It is therefore recommended that healthcare facilities maintain a minimum thirty-day supply of all items that come from external sources; this should include water, fuel, and medical supplies.

EMERGENCY SHELTERING

Shelter as an essential part of disaster recovery and resilience, and the need for it is great. Many facilities throughout the state are listed as designated emergency shelters by local jurisdictions and the state Office of Emergency Management. The most common buildings on these lists are schools and churches, followed by other miscellaneous buildings (including community centers) that have the capacity to hold large numbers of occupants. The expected and target states of recovery for school buildings can be found in the *Education Facilities* section of this chapter (above). As with all building sectors, the performance of churches and other facilities in a Cascadia subduction zone event will be a function of the building's vintage, construction type, and geographical location. In general, the expected and target states for churches should, at a minimum, match those of school facilities with similar construction.

Discussion of recommendations for buildings designated as emergency shelters can be found in the *Conclusions and Recommendations* section at the end of this chapter.

CRITICAL GOVERNMENT FACILITIES

Introduction

Critical government facilities are those buildings that are necessary to the continuing operation of essential services following a significant event. The most obvious of these—police stations, fire stations, and emergency operations centers (EOC)—are addressed separately in this report. Other services, however, which may include some limited administrative functions and essential health services, and certain structures, such as correctional facilities and even the maintenance buildings that are needed for repairing roads and utilities following the earthquake, are also necessary. Compiling a specific list of these services and their associated facilities was beyond the scope of this report—but in many ways, such a list was not necessary to get a general overview of how these facilities may perform.

Estimated State of Recovery

Data for general government facilities was available from the FEMA Hazus damage estimates and was reviewed to determine the resilience scores included in the resilience matrix. The statistical analysis from Hazus was based on an estimated 2,357 government buildings located throughout the state—this estimate represents the total number of government buildings, not all of which are critical to statewide resilience. We assumed that both the non-critical buildings and the remaining critical buildings (those not included in the assessment of police, fire, and EOC facilities) will generally behave in a similar manner. We were therefore able to determine with reasonable certainty the level of performance that can be expected.

The construction types anticipated by Hazus statistics are primarily steel and concrete prior to 1950, with about 20 percent 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, as well as some wood, but much more prevalent is reinforced concrete masonry (CMU), which is now estimated to comprise about 25 percent of the building stock.

Figure 4.7: Several states have rehabilitated their state capitol buildings. The Utah State Capitol was seismically retrofitted with base isolation to protect visitors and occupants and preserve historic fabric in the building. (Source: State of Utah)

Target State of Recovery

The target states of recovery for these facilities will vary depending on the facility. An average target state was estimated to be 30 days, although the task group recognized that some buildings may need to be immediately serviceable (correctional institutions, for instance), while other critical functions may not be immediately needed and could wait several weeks before coming back into service. It will be necessary for the state and local governments to determine which functions are critical for resilience and then inventory and evaluate the associated facilities, before eventually prioritizing and upgrading the deficient structures.

RESIDENTIAL HOUSING

Introduction

Following an earthquake, people must have shelter—it is one of the basic elements required for resilience. In some cases, such as when a person's residence has been damaged and is not safe to occupy or when people are temporarily unable to reach their homes, this need may be met by emergency shelters. Emergency shelters, however, cannot provide for everyone. For a large segment of the population, primary residences must serve as shelters, although in many cases, they will be without power and running water. In the absence of such residential shelters, the humanitarian needs of the population following a large earthquake grow tremendously. Post-earthquake response can also be impeded if emergency responders must first devote time to finding shelter and safety for their own families before they are available to help others.

In the state of Oregon, single-family residential homes make up the largest portion of residences, and therefore, potential shelters. The U.S. Census data for 2010 place the number of residential dwelling units in Oregon at approximately 1.6 million. FEMA's Hazus program, which was used for this review, estimates that there are approximately 960,000 single-family homes; this is generally consistent with similar census estimates.

Construction of single-family homes is almost entirely of light wood framing. Historically, these buildings have generally performed well in seismic events. One- and two-story wood frame buildings are relatively light-weight compared to other structures, and will usually see larger forces from a design-level wind storm than from a significant earthquake, since seismic forces are (in part) a function of the structure's weight.

However, the details of a wood frame structure's construction have a lot to do with its ability to withstand earthquakes, and certain common vulnerabilities make these buildings susceptible to earthquake damage, particularly if they were 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. Another common deficiency can result in the failure of cripple walls, which are short wood framed wall segments that typically extend from a foundation to the floor above. Frequently, these lack proper connections and can easily rotate in a manner similar to a hinge, allowing the building to shift laterally off of its foundation (see Figure 4.8). In older structures, unreinforced masonry chimneys can fall and cause additional structural damage.

Multifamily housing is also at risk. Depending on construction type and size, these buildings will typically have more seismic risk compared to single-family homes. Construction of multifamily buildings ranges from light wood frame construction, unreinforced masonry, to steel and concrete. The apartment buildings built of unreinforced masonry apartment buildings are particularly vulnerable.

Figure 4.8: This residential building shifted on its foundation after the 1989 M 7.1 Loma Prieta, California earthquake. (Source: NOAA/NGDC, C. Stover, U.S. Geological Survey)

Estimated State of Recovery

Using statistical data from FEMA's HAZUS program, the task group reviewed estimated damage data for single-family residences. The average estimated recovery duration for residences on the coast was less than 30 days, which may be low considering the intensity and duration of ground shaking that will likely result from a Cascadia subduction zone event in this area. In the valley, the estimated recovery duration is 72 hours, which again may underestimate the damage. The eastern zone is expected to have negligible damage (again based on the Hazus estimates). These results are compared with a target state of recovery of 30 days, which is based on the need for shelter as an essential part of disaster recovery and resilience.

The recovery time of multifamily housing was not reviewed by the task group. Recovery time for smaller light wood framed buildings will be similar to single family homes. Larger buildings of other construction types will have longer recovery times. The loss of low income multifamily housing will affect economic recovery.

Sector Specific Recommendations

Improving existing structures will require significant education of homeowners, who need to understand the risks, the potential costs, and the steps necessary to evaluate and correct deficiencies. Additionally, common structural deficiencies should be noted during home inspections at the time of purchase. It is likely that homeowners will bear the majority of the expenses for upgrading deficient structures; however, financial incentives, such as tax credits and low interest loans, might be considered to encourage improvements if future evaluations, based on more complete data, show unacceptable damage estimates.

Outreach should seek to provide education and resources for homeowners. A number of such tools are already available, though not widely known. FEMA provides a number of publications on their website for homeowners, such as FEMA-530 Earthquake Safety Guide for Homeowners. The City of Portland has also created a guide, Brochure #12-*Residential Seismic Strengthening – Methods to Reduce Potential Earthquake Damage* and provided additional information on the Bureau of Development Services website at www.portlandoregon.gov/bds.

COMMUNITY RETAIL CENTERS AND BANKS

Introduction

There are thousands of community retail centers and banks within the state of Oregon. These types of facilities have been deemed critical buildings because of their importance to the post-disaster recovery of communities throughout the state. The most important of the many community retail buildings in the state are large supermarket and pharmacy chain stores, which have large inventories of supplies that will be in high demand following a disaster. Many of these large chains have remote storage and distribution centers that will be of equal importance for supplying goods to damaged communities. Banks also have an important role in Oregon's seismic resilience, as they will be critical to processing vital financial transactions for businesses and consumers as they recover from the disaster. Although many banks have emergency response plans in place, if the buildings they are housed in perform poorly during an earthquake, overall resilience will be compromised.

FEMA's Hazus analysis includes a wide variety of commercial buildings, including some overlap with other structures evaluated separately in this report using different analysis methods. However, part of this large group of commercial buildings includes wholesale and retail buildings and banks, which were reviewed to estimate the resilience of these structures. A specific estimate of building quantities for this subset was not available, but the statistical analysis considered their construction types, general age, and historical performance. The number of retail and bank buildings in each county was assumed to be proportional to the overall distribution of commercial buildings.

Structural Vulnerabilities

The construction types anticipated statistically by Hazus for retail buildings vary with the building's age. Prior to 1950, wood, steel, concrete, concrete masonry (CMU), and even unreinforced masonry (URM) were common. As construction practices changed, buildings shifted toward larger stores, and the post-1970 Hazus statistics reflect this, with greater use of CMU and concrete, including precast (or tilt-up) construction which began to see much wider use after 1970. Statistics for bank buildings also reflect some similar shifts in construction, moving away from steel and unreinforced masonry after 1950 and toward more wood frame, CMU, and concrete construction.

Today, most big-box stores, supermarkets, distribution warehouses, and pharmacies are housed in concrete masonry (CMU) or tilt-up concrete structures with light-framed wood or steel roofs. Buildings of this type that were constructed prior to 1995 have historically not performed well in earthquakes. The seismic vulnerabilities of these buildings were highlighted in the aftermath of the 1994 Northridge earthquake. The most prominent structural failure in this building type has been the connection between the light framed roof and the relatively heavy exterior walls, which led to partial or full roof collapse (see Figure 4.9). Building code provisions for the design and construction of the roof/wall connections were enhanced following the Northridge earthquake, with requirements for a higher degree of resistance being incorporated in the 1997 UBC and subsequent building codes. As a result, buildings of this type that were built after approximately 1995 should have a higher degree of resilience than those built prior to that year.

Figure 4.9: Several tilt-up concrete panels of this construction material supply store in Concepcion fell away from the building, causing the roof framing to collapse after the M 8.8 February 27, 2010 Maule Chile earthquake. (Source: Kent Yu, Degenkolb Engineers)

Banks are different from big-box stores in that they are housed in a multitude of structures, including stand-alone one-story wood framed buildings, unreinforced masonry or non-ductile concrete buildings, and steel and concrete high-rise buildings. The seismic performance of these buildings will vary based on their location, vintage, and construction type; however, structural vulnerabilities are present to some degree in a large percentage of the existing building stock.

During an earthquake, many existing community retail and bank structures could also suffer extensive damage to nonstructural elements and components within the buildings. Nonstructural elements include, but are not limited to, mechanical, electrical, and plumbing systems and associated equipment, lighting fixtures, suspended ceiling and soffit systems, and unsecured storage racks and display shelving. These elements can be a falling hazard during a seismic event, impeding occupants from safely exiting the building, disrupting the operation of the facility, and extending the time it will take to restore the building to normal operation.

One unique aspect of retail and bank buildings is that they are almost exclusively privately owned. This makes establishing and enforcing building seismic upgrade requirements and mandates for these occupancies particularly difficult.

Estimated State of Recovery

The expected average time of recovery to normal operation for community retail big-box, supermarket, and pharmacy buildings after a Cascadian subduction zone seismic event is four months for Oregon's coastal region and 30 days for the valley region. The recovery duration for these types of buildings in eastern Oregon is expected to be nominal, mainly due to their distance from the earthquake source.

The recovery time for bank buildings after the Cascadia subduction zone seismic event is estimated at 60 days for Oregon's coastal region and 30 days for the valley region. As in the case of the community retail centers, the recovery duration for banks in eastern Oregon is expected to be nominal.

A critical aspect of the resilience of this building class is the degree to which the business' ancillary facilities, provided they are not located within the high seismic hazard zone, can provide support to and replacement of the functions of the damaged facilities. While this aspect was not considered in our analysis, it is possible that the actual impact of the Cascadia subduction zone event on the functionality of these buildings could be lessened if protocols are in place to replace their functions remotely. Additionally, it should be noted that the efficiency of the distribution of goods, services, and medical prescriptions to the general public has increased with the advent of one-stop-shop, big-box retailers that typically occupy newer tilt-up concrete or masonry (CMU) structures that have been designed and built to more stringent seismic code requirements. It is likely, however, that after the Cascadia subduction zone seismic event, the inventory in these facilities will be quickly depleted, so overall seismic resilience will depend upon the condition of ancillary facilities, including distribution warehouses, data centers, roads, bridges, and highways.

Target State of Recovery

The suggested statewide target state of recovery for community retail centers and banks is 30 days. This timeframe is primarily due to the importance of having goods, services, and medical prescriptions available to the general public after a significant seismic event. The assumption behind this target is that facilities in areas unaffected by the earthquake will be able to fill the needs of the public remotely until the damaged buildings can be repaired. This target state is also consistent with both the performance expectations behind code provisions for new buildings of this occupancy category and the recommendations of the Business Continuity Task Group that took part in the development of Oregon's resilience plan.

Sector Specific Recommendations

As community retail centers and banks are normally privately owned, the ability to mandate building upgrades with public funding is minimal. Therefore, seismic upgrades of deficient existing buildings will most likely need to be incentivized through tax credits or other similar means. Mandates, tax credits, and other incentives (whether singly or in combination) should also be developed to require or strongly encourage the building owners and tenants to properly brace and anchor deficient nonstructural elements within their buildings, as it is anticipated that nonstructural damage resulting from the Cascadia subduction zone earthquake will have a significant impact on the seismic resilience of these building types.

For the existing building stock in this sector, the redundancy of critical business continuity elements, such as distribution of goods and data, remote accessibility and support, and availability of personnel, should be assessed by each company. This redundancy is vital to achieving the 30-day target state of recovery over the entire state of Oregon.

Finally, improving awareness—both within businesses and among the general public—of the seismic vulnerabilities of the existing community retail centers and banks is critical to moving toward a more resilient Oregon. Developing a seismic resilience rating for existing retail and bank building stock could serve as an effective tool for these businesses as they select buildings to lease or prioritize buildings for upgrades. As part of this rating program, common seismic vulnerabilities could be explained in layman's terms, in an effort to improve public awareness and understanding of Oregon's current seismic resilience status.

VULNERABLE BUILDINGS

Introduction

For the purposes of this evaluation, vulnerable buildings are defined as unreinforced masonry (URM) and non-ductile concrete structures. These building types are classified as critical buildings in this study because they represent the most significant threat to life-safety and historically exhibit extremely poor performance in seismic events (see Figures 4.10 to 4.12). URM buildings are constructed with clay brick, hollow clay tiles, or concrete block, with little or no reinforcement. Most of these buildings in Oregon were originally built prior to 1940, and the majority has undergone no seismic improvements since they were constructed. Non-ductile concrete buildings have been historically 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 and are generally one to five stories in height. These vulnerable buildings represent a building *type* rather than an occupancy *use* and, as such, they can be found in many occupancy uses, including essential facilities (such as fire and police stations), retail centers, restaurants, residential buildings, and commercial office buildings.

Figure 4.10: Christchurch Cathedral of the Blessed Sacrament, New Zealand after the M 7.0 September 3, 2010 Darfield earthquake [Source: NOAA/NGDC, Steve Taylor (Ray White)]

Figure 4.11: The fourth-story wall of this unreinforced masonry building on Bluxome Street in San Francisco collapsed onto the street, killing five people in their cars, during the M7.1 October 18, 1989 Loma Prieta, California earthquake. (Source: NOAA/NGDC, E.V. Leyendecker, U.S. Geological Survey)

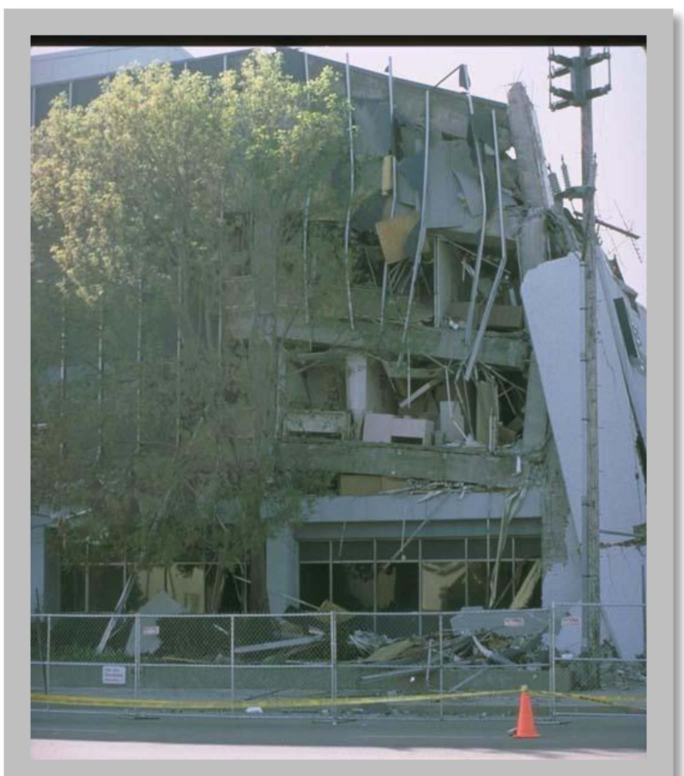

Figure 4.12: This non-ductile concrete frame medical building collapsed during the 1994 M6.8 Northridge, California earthquake. (Source: NOAA/NGDC, J. Dewey, U.S. Geological Survey)

Estimated State of Recovery

Based on the limited information available for these types of buildings throughout the state (other than those that were already addressed in the other occupancy use categories discussed above), recovery timelines were estimated based on FEMA 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 as well as the age and construction type of the buildings. In addition, the Hazus data assumes that all structures were designed prior to the incorporation of seismic provisions in the building code.

As expected, the data in Figure 4.3 indicates that most of these buildings will experience either significant structural damage or partial to total collapse. Accordingly, most of the vulnerable building stock in the coastal and valley regions will require major repairs or wholesale replacement. Buildings in eastern Oregon will experience ground shaking levels similar to or greater than those that URM buildings experienced during two previous Oregon earthquakes: Scotts Mills and Klamath Falls. Because the Cascadia subduction zone earthquake will likely be of much longer duration than these two previous events, it has the potential to cause even more damage. For this reason, the expected recovery duration for vulnerable buildings in eastern Oregon was determined to be 30 days.

It should be noted that these recovery times are based on a Cascadia subduction zone earthquake, which may not result in the highest possible ground shaking intensities in some parts of the valley and eastern Oregon, but would likely have a longer duration. Other hazards, such as soil liquefaction, landslides, and tsunamis, were considered in the projected states of recovery. DOGAMI's recent studies indicate that soil hazards exist in all three regions of the state, and many coastal regions are located in a tsunami inundation zone, which increases the vulnerability of these buildings.

Because hard data related to nonstructural components in vulnerable buildings was not readily available, the performance of these components was not a consideration in determining the recovery scores. It is likely, however, that the damage to the primary structure of these buildings will override that of nonstructural components in terms of effect on resilience.

Target State of Recovery

As mentioned above, vulnerable buildings can be found in many different building occupancy uses. Consequently, the reader should refer to the *Target State of Recovery* discussions in the occupancy-based sections of this chapter to develop an understanding of the gap between the projected and recommended performance of these buildings.

Codes, Past Legislation, and Funding Sources

A few jurisdictions have adopted code language mandating seismic upgrades for these types of buildings (primarily URMs) to varying degrees. For legislation, or funding sources, refer to each sector-specific section of this chapter and to the following recommendations.

Recommendations

Recommendations are provided below for Oregon's critical and vulnerable structures with the goal of achieving a resilient state. In making these recommendations, the task group recognized that not all buildings are critical and necessary to achieve resilience. Many buildings are expected to perform reasonably close to their target states in the eastern part of the state, where the seismic design category is low. Residential buildings are expected to perform reasonably well, although older homes need to be tied to their foundations and older multi-family buildings are at risk.

Leadership and resources are needed for adopting standards and policies, evaluating and inventorying buildings, and rehabilitating structures. Creating a State Resilience Office that could outline the steps required for creating seismic resilience, should be a priority. This Office can take into consideration the gaps between existing and target states of recovery and critical building functions. It can also coordinate with resiliency efforts in the other sectors (such as transportation, energy, etc.)

It is imperative, however, that implementation and funding for seismic resilience not be delayed while we wait for a full inventory, definition, and budgeting of the problem. More than enough is already known to begin making strides toward resilience. Whether the journey before us is a thousand miles or ten thousand miles, we should start moving forward now; additional inventories and studies should be made as we progress along the way.

IMMEDIATE ACTIONS

► Establish a State Resilience Office

- *Finding*: The State does not currently have person or office to provide the resources and leadership necessary for coordinating and implementing a statewide seismic resilience plan.

- *Recommended*: Establish and fund a State Resilience Office(r) to provide leadership, resources, advocacy, and expertise in implementing a statewide resilience plan.

► Prioritize Education

- *Finding*: There is a great need for education and awareness of the impact of a Cascadia subduction zone event, and how to prepare Oregon to be resilient to that impact.

- *Recommended*: Programs should be encouraged and implemented to provide a broad range of education, public awareness, and public relations regarding Cascadia subduction zone risks and State resilience.

► Complete an Inventory of Critical Buildings

- *Finding*: A complete statewide inventory of critical buildings does not exist, but is needed for future planning, assessment and upgrading of critical building structures.

- *Recommended*: An inventory, compiled within five years, should include an initial seismic screening of each building and updates to the existing inventory. More detailed evaluations should be completed for those buildings identified by the initial screening to be the most susceptible to damage from an earthquake.

► Include Inspection in Emergency Response

- *Finding*: There will be immediate demand for safety inspections of critical buildings (both public and private) following a Cascadia earthquake.

- *Recommended*: Strengthen the existing database of ATC-20 certified post-earthquake inspectors, establish procedures for their engagement and response following an event, and strengthen Good Samaritan laws to protect them. Expand database and training for ATC-45 of certified post flood and wind inspectors.

SUSTAINED ACTIONS

► **Prioritize Essential Facilities**

- *Finding*: The estimated current state of hospitals, Emergency Operation Centers, fire and police stations falls significantly short of the target state need for these facilities to be immediately available following the CSZ event.

- *Recommended*: Hospitals should be upgraded within 15 years of completing an inventory and seismic evaluations. Emergency Operation Centers, fire and police stations should be upgraded within 20 years if the building is a URM or non-ductile concrete structure, or 30 years if it is of other construction. Non-structural elements in these buildings should also be upgraded within the same timeframes, and ORS 455.400 should be strengthened and updated for consistency with these recommendations. Create publicly accessible database that shows annual seismic performance data for essential facilities.

► **Fully Fund the Seismic Retrofit of K-12 Schools**

- *Finding*: The current average estimated state of recovery for K-12 school facilities in the Coast and Valley regions of Oregon falls significantly short of the recommended target state, despite an existing statute directing seismic retrofit by January 1, 2032.

- *Recommended*: Fully fund state investment in seismic retrofit of schools; prioritize the replacement of structure types that present the greatest hazard to their occupants in a seismic event; promote ASCE- 31 (or equivalent) engineering assessment of existing school facilities; and update the state's database of public school facilities on a regular basis.

► **Expand the Passive Trigger Seismic Strengthening Program**

- *Finding:* The existing building code includes triggers that require building upgrade for a change of occupancy or increase in structural loads, but does not go far enough, allowing major building upgrades to deficient structures without requiring seismic strengthening.

- *Recommended:* Encourage local jurisdictions to adopt the triggers for seismic upgrade to include changes in the level of occupancy risk, major building renovations, and re-roof of URM and non-ductile concrete buildings. Give seismic upgrades the highest priority for non-conforming upgrades, and allow them to be phased over 10 years if needed.

► **Accelerate the Retirement or Full Upgrade of Vulnerable Buildings**

- *Finding:* Unreinforced Masonry (URM) and non-ductile concrete buildings are generally the most dangerous types of buildings in an earthquake, and should not be allowed to remain in service indefinitely unless they are fully upgraded.

- *Recommended:* Initially, the danger of URM and non-ductile concrete buildings should be disclosed at the time of building sale or lease. Through market pressures and upgrades triggered by other building repairs and changes, upgrades can be made to many of these structures.

► **Improve Plan Review and Construction Oversight**

- *Finding*: Structural plan reviews are often performed by individuals who would not otherwise be qualified to provide the design being reviewed. Special inspections and structural observations are not currently required by code for certain structure types and structural elements important for resilience.

- *Recommended*: Require a licensed design professional or structural engineer provide plan reviews for critical buildings (Cat. 3 & 4) reciprocal with the licensing required to provide the design. Strengthen state building code to expand Special Inspections and Structural Observations to include special inspections and structural observations for most commercial structures, critical non-structural components, and wall connections in tilt-up and CMU buildings with light framed roofs and floors.

► **Introduce an Earthquake Performance Rating System**

- *Finding*: Public knowledge of the seismic safety of the buildings they own, live in, and work in is often limited, or misinformed, especially in comparison with public awareness of other hazards.

- *Recommended*: Encourage and promote a voluntary, standardized rating system for the expected earthquake performance of buildings, similar to the LEED rating used for green buildings. The system should be easily understood and readily available to anyone with an interest or stake in the building.

► **Incorporate Resilience into Performance-Based Design**

- *Finding*: Many new buildings will be constructed over the next 50 years, but current code is only intended to protect the life safety of occupants, not ensure resilient performance.

- *Recommended*: Adopt incentives to encourage owners to build to performance standards that exceed the “code minimum." Support research aimed at better tools and criteria for performance based design.

► **Encourage seismic retrofit of existing homes and multi-family buildings.**

- *Finding:* Many residential homes built before 1976 have vulnerabilities to earthquakes and the damage may result in them being unusable or in need of costly repairs. Many older multi-family buildings are at risk as well.

- *Recommended:* Adopt seismic retrofit programs and incentives to encourage homeowners to tie their older homes to their foundations, and encourage the seismic retrofit of multi-family buildings.

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