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Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

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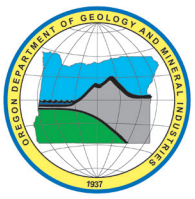
OREGON COASTAL HOSPITALS PREPARING FOR CASCADIA

by Yumei Wang[1]



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Note: A version of this technical report was submitted to the Oregon Health Authority on June 30, 2017. To make the publication more widely accessible, DOGAMI is releasing the report in open-file format.

Unless otherwise indicated, building facility photographs used in this report were taken by the author during site consultative visits in 2017.

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1.0 EXECUTIVE SUMMARY

Hospital facilities in western Oregon are not expected to perform well after a Cascadia subduction zone earthquake and tsunami. Due to their close proximity to the Cascadia fault, the 11 hospitals along the coast will likely incur the most serious damage and may take over 3 years to fully recover to an operational state (OSSPAC, 2013; Wang, 2014, 2017). The Oregon Health Authority (OHA) partnered with the Oregon Department of Geology and Minerals Industries (DOGAMI) to provide technical assistance and to determine what is needed for coastal hospitals to provide healthcare services immediately after a Cascadia earthquake. DOGAMI worked with OHA Healthcare Preparedness Program (HPP) regional liaisons and met with representatives from the coastal hospitals to learn about the expected post-earthquake performance.

Although all coastal hospitals have emergency plans and capabilities, DOGAMI findings verify that no hospital facilities are likely to be functional due to the expected severity of a magnitude 9 Cascadia earthquake and tsunami damage. Seismic vulnerabilities include building structures; non-structural components that are part of the building as well as equipment; and the limitations of on-site utilities such as power and water. Four of the eleven hospitals are located in the tsunami evacuation zone and face difficulties with tsunami planning.

To improve hospitals' state of readiness for future Cascadia earthquakes, DOGAMI's Recommendation 1 improves seismic requirements, Recommendations 2 and 3 focus on technical support and accelerating seismic preparedness activities for the eleven coastal hospitals, and Recommendation 4 provides earthquake planning information to hospitals across the state.

DOGAMI proposes that the recommended tasks be conducted in a three-year work plan. For Recommendation 1, DOGAMI proposes that OHA determine its own timeline. Recommendation 2 can be completed in the first year. Recommendations 3 and 4 can be accomplished in the second and third years. Toward the end of the third year of sustained efforts, OHA and its coastal healthcare system partners can reevaluate the need for any future efforts.

- **Recommendation 1:**
  Clarify and improve seismic requirements
  OHA evaluate, clarify, and improve existing requirements on hospitals and healthcare systems regarding seismic preparedness. This would affect all of the hospitals and healthcare systems in the state and would improve the state's level of resilience. A few specific areas to be addressed involve: Oregon Revised Statute 455.400; performance level objectives and plan review of new hospitals via the Oregon Structural Specialty Code; and seismic preparedness standards for water districts that serve hospitals.

- **Recommendation 2:**
  Conduct on-site technical assistance
  DOGAMI, with the help of HPP region 1, 2, and 3 liaisons, conduct on-site consultative visits to each coastal hospital to provide technical assistance. This would allow coastal hospitals to focus and make progress on key aspects of disaster preparedness.

- **Recommendation 3:**
  Establish a coastal hospital resilience network
  OHA establish a coastal hospital resilience network with specific focus on preparing for Cascadia earthquakes. This would involve developing and sharing ***best practice guidance*** and other preparedness information among hospitals and healthcare systems. Periodic ***training sessions***, co-organized by HPP region liaisons, DOGAMI, and hospitals, would allow for networking and acceleration of preparedness activities. Although this network is designed to improve the resilience of coastal hospitals, certain aspects of the network would also benefit noncoastal hospitals and improve the state's resilience.

- **Recommendation 4:**
  Share Cascadia earthquake and fuel planning information statewide
  DOGAMI and the Oregon Department of Energy (ODOE), in coordination with HPP regional liaisons, provide Cascadia earthquake and emergency fuel planning information to all hospitals across the state. This would provide critical information to help improve statewide preparedness.

2.0 INTRODUCTION

The State of Oregon is exposed to significant earthquake risk due to a future Cascadia subduction zone earthquake. Currently, hospital facilities in western Oregon are not expected to perform well during a magnitude 9 Cascadia earthquake and accompanying coastal tsunami. Hospital facilities along the coast will likely incur serious damage due to expected prolonged strong ground shaking (Wang, 2014, 2017). Furthermore, four of the eleven hospitals are located in the tsunami evacuation zone, as defined in 2013 by Oregon Department of Geology and Mineral Industries (DOGAMI). Depending on the size of the actual tsunami that is generated, these hospitals may experience tsunami damage as well as problems relating to tsunami evacuation.

The 2013 Oregon Resilience Plan, considered to be the State of Oregon's road map to preparing Oregon's infrastructure and communities for the next Cascadia earthquake, estimates that it may take over 3 years for coastal hospitals to recover fully to an operational state that is comparable to conditions prior to the event (OSSPAC, 2013). The State of Oregon strives to improve the resilience of Oregon's communities, including its coastal communities, by dedicating technical assistance to coastal hospitals. Many current hospital vulnerabilities can be better assessed, understood and, over time, mitigated, which combined will improve safety in Oregon communities. The State of Oregon's goal is for all coastal hospitals to be operable to provide medical services after a Cascadia earthquake.

> *"The need for functioning hospitals after a major earthquake is obvious and rarely disputed. While emergency field hospitals, medical tents, and air-lifts to available facilities are often used to supplement for damaged hospitals, they will never provide a sufficient substitute. Only modern health care facilities, located within the damaged region and capable of functioning at full capacity can adequately provide the needed medical assistance." (Tokas and Lobo, 2009, p. 137-138)*

2.1 Funding Statement

Funding for this project was made possible by the Centers for Disease Control and Prevention via a federal grant to OHA (number 6 NU90TP000544-05-01), which passed funds through OHA-DOGAMI agreement number 153095. The views expressed in written materials or publications and by speakers or moderators do not necessarily reflect the official policies of the Department of Health and Human Services, nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government. This $48,000 project was funded with 100% federal funds.

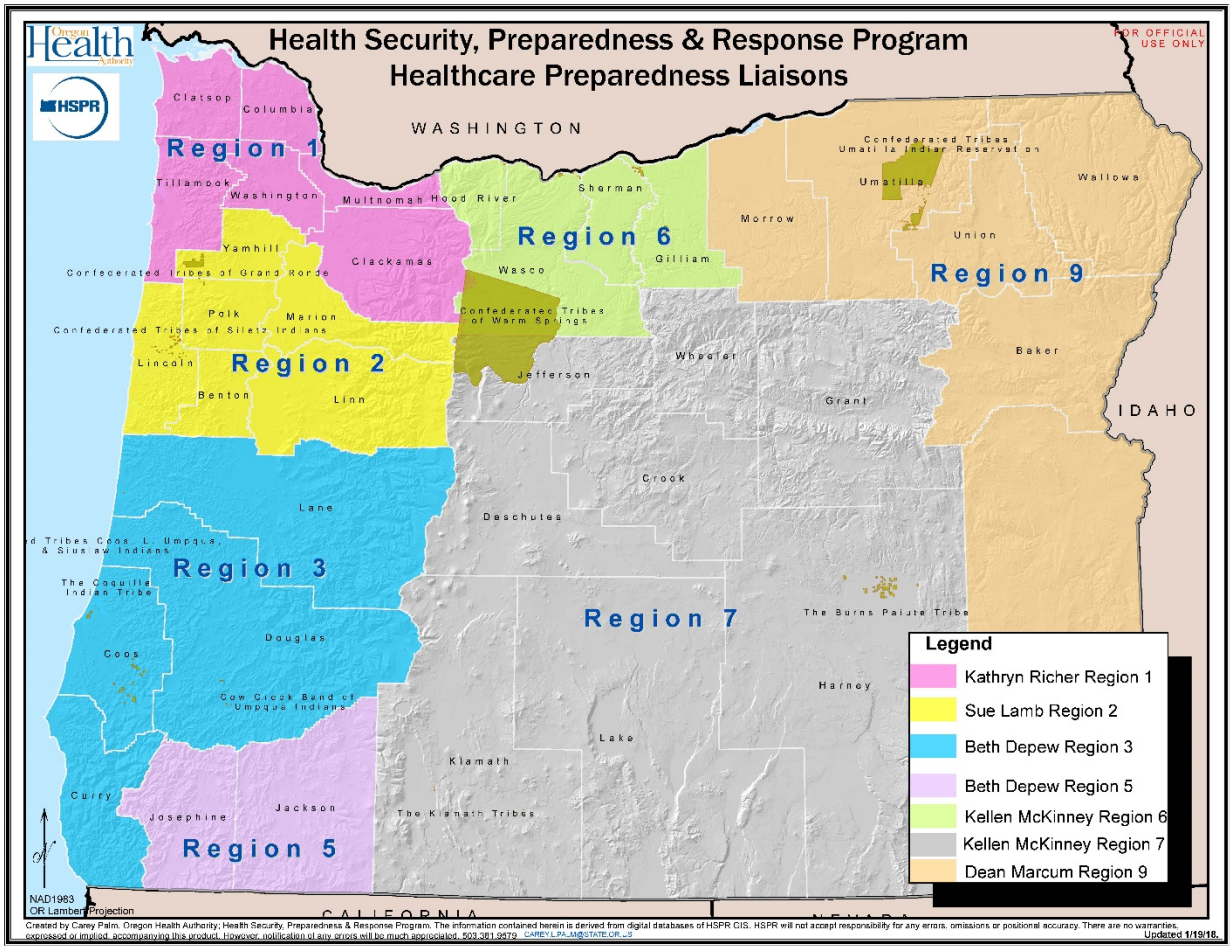
2.2 Purpose and Scope

The project purpose and scope was developed largely based on findings from a 2014 hospital and water system earthquake risk evaluation (Wang, 2014). The evaluation indicated that a Cascadia earthquake would severely impact the functionality of a coastal hospital due to hospital and water system damage, and the hospital would slowly recover to operate at about 52% bed capacity in 90 days (Wang, 2014, 2017). This project was conducted to determine the state of preparedness of coastal hospitals in response to a Cascadia earthquake and tsunami and to assess what is needed to reduce earthquake damage in order to provide sufficient healthcare services following the event. The Health Security, Preparedness and Response (HSPR) program, under the Oregon Health Authority Public Health Division (herein referred to as

OHA) partnered with DOGAMI, the state's lead scientific agency on earthquakes and tsunamis, to complete this project.

DOGAMI worked closely with the OHA Healthcare Preparedness Program (HPP) regional liaisons from Regions 1, 2, and 3 (**Figure 2-1**). Together, HPP liaisons and DOGAMI met with representatives from 10 of the 11 hospitals along the Oregon coast, local emergency managers, and others from the healthcare industry.

Figure 2-1. Map showing the locations of OHA HPP Regions 1, 2, and 3 (Source: OHA HSPR, dated 1/19/18).



The overall approach in the 2017 project accomplished the following:

1. providing currently available Cascadia Subduction Zone earthquake and tsunami information pertinent to each hospital site;

2. assessing each hospital's level of awareness and preparedness for earthquakes and tsunamis;

3. finding out what information and resources the hospitals need to effectively plan for a magnitude 9 Cascadia earthquake and accompanying tsunami; and

4. developing a proposed 3-year work plan that would provide the needed framework and tools for hospitals to become prepared to operate following a Cascadia earthquake disaster; this work plan is presented in this report.

Specific information on the project scope of work, as outlined in the contract between OHA and DOGAMI, is provided below. All work has been completed.

The project scope of work as outlined in the 2017 OHA-DOGAMI contract 1530951.

DOGAMI shall complete, publish in written form, and make available to OHA the 2014 report ("Report"), entitled "Hospital and Water System Earthquake Risk Evaluation".

2. DOGAMI, in accordance with a schedule acceptable to both Parties, shall meet with representatives of each of the eleven Oregon coastal hospitals (Hospital(s)) for a period not less than 90 minutes at three regional HSPR meetings. OHA will assist DOGAMI in arranging for and coordinating the three scheduled HSPR meetings to be held in Region 1, 2 and 3. At each of the meetings, DOGAMI shall:

2.1 Present to each Hospital currently available multi-hazard information, including a summary of the Report.

2.2 Request information from each Hospital on the Hospital's current plans for a Cascadia Subduction Zone earthquake event and subsequent tsunami (CSZ Event).

2.3 Assess each Hospital's level of awareness and preparedness for a CSZ Event based on available information.

2.4 Discuss what information and resources the Hospitals will need to more effectively plan for a CSZ event.

2.5 Provide available state data and information resources Hospitals upon request. e.g., Seismic rehabilitation grant information and DOGAMI data sources.

2.6 Coordinate with Oregon Department of Energy (ODOE) to include a fuel presentation, subject to ODOE availability, in coordination with the DOGAMI presentation

3. DOGAMI shall use the information that DOGAMI and OHA gather from the three Hospital Preparedness Program meetings to design a detailed and comprehensive written plan for a second phase study of Hospital preparedness, the goal of which will be to provide Hospitals with the needed data and resources to better prepare for a CSZ Event.

4. DOGAMI shall prepare a written summary report on what DOGAMI and OHA learned about each Hospital's current state and needs. In preparing this report, DOGAMI shall:

4.1 Include detailed plans to provide the necessary new resources to the Hospitals, to include identifying the provider of these resources if the resource is not provided by OHA or DOGAMI.

4.2 Prepare for future site hospital preparedness consultations at each of the eleven Hospitals, subject to the availability funding and DOGAMI personnel.

3.0 OREGON HOSPITALS

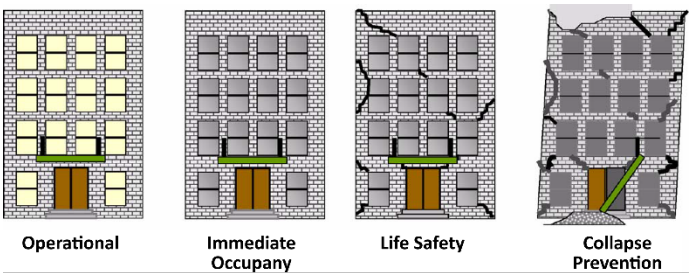
3.1 Background

Hospitals are critical for the life safety of the entire population and must be capable of surviving Cascadia earthquakes. A hospital's survival requires that the buildings remain functional immediately after the earthquake, be available to respond to a surge of emergency needs, and tolerate large earthquake aftershocks in the months following the primary earthquake.

New hospital buildings are designed according to requirements in the 2014 Oregon Structural Specialty Code (OSSC), which is issued by the Oregon Building Codes Division (BCD) (www.oregon.gov/bcd/codes-stand/Pages/commercial-structures.aspx). Four performance levels are defined by the OSSC: operational, immediate-occupancy, life-safety, and collapse prevention. **Figure 3-1** shows these four performance levels (FEMA, 2004). The Oregon's current building code does not explicitly require *new* hospitals to be designed to meet a specific performance level; however, the implied expectation is for new hospitals to meet an *Immediate Occupancy* performance level after major earthquakes but only a *Life Safety* performance level after a magnitude 9 Cascadia earthquake (Richard Rogers, Oregon Building Codes Division, oral commun., June 29, 2017). Requirements on these four performance levels are applied to *existing* buildings, not *new* buildings. Additional discussion on the Oregon building codes is in Section **3.5 Current Building Code Lacks Designing for Resilience.**

The State of Oregon has recognized since the late 1990s the importance of hospital and other essential services following a Cascadia earthquake (Wang and Clark, 1999). In 2001, Oregon Revised Statute 455.400 was enacted and directed that, subject to available funding, acute inpatient care facilities that "pose an undue risk to life safety during a seismic event" should be rehabilitated to a *life-safety* performance level by 2022 (https://www.oregonlaws.org/ors/455.400). The Oregon Business Development Department, which manages the state's seismic rehabilitation grant program (SRGP), has defined, in general (non-engineering) terms, that a "Life Safety" performance level means that a building may be damaged beyond repair during an earthquake but people will be able to safely exit the building and that an "Immediate Occupancy" performance level means that not only will the building remain standing after an earthquake but emergency services will be able to continue to operate and provide services (www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab/). Hospitals may apply for SRGP funds if they plan to upgrade their buildings to an "Immediate Occupancy" performance level.

Figure 3-1. Diagram illustrating four performance levels after earthquakes: operational, immediate occupancy, life safety, and collapse prevention (FEMA, 2004). New hospital buildings are intended to be designed to meet an Immediate Occupancy performance level for major earthquakes. Although new hospital buildings are expected to incur limited damage and be able to maintain or quickly restore function, current building codes lack comprehensive resilience requirements, such as for on-site utilities including water and waste water, that would ensure maintaining function.



In 2007, DOGAMI published a statewide seismic needs database that includes seismic hazard information on all of Oregon's hospital buildings built before 1995 (Lewis, 2007). In 2009, Oregon's Seismic Rehabilitation Grant Program was established to provide funding to qualified applicants including eligible hospitals.

Medical response planning for earthquake and tsunami impacts is currently underway. OHA HSPR has the lead responsibility on the State of Oregon's health and medical emergency response needs (i.e., emergency support function 8 according to the Oregon Emergency Response System http://www.oregon.gov/oem/emops/Pages/OERS.aspx) during a Cascadia earthquake disaster. In preparing for the 2016 Cascadia Rising exercise on a hypothetical magnitude 9 earthquake and tsunami, OHA HSPR prepared several exercise documents. According to OHA HSPR's Cascadia Subduction Zone Response Planning presentation dated August 2015 (Larry Torris, OHA, oral commun., February 8, 2017), the Oregon coast estimates include the expectation of:

- on the order of 22,200 people in the tsunami hazard zone
- 3,552 fatalities due to tsunami hazards
- 1,154 injuries due to tsunami hazards
- additional casualties due to earthquake shaking hazards in coastal communities

The source of the above planning estimates is the 2013 FEMA Region X Cascadia Subduction Zone Earthquake and Tsunami Response Planning, a working document that was used to inform Cascadia disaster exercises. Other studies have suggested significantly higher exposure values. Wood and others (2015) used 2010 U.S. census information to evaluate the number of people living in tsunami inundation zones along the Pacific Northwest coast and in Northern California. For the Oregon coast, the data of Wood and others indicate that approximately 33,000 people live in the "Large" tsunami inundation zone as defined by DOGAMI (Priest and others, 2013). This number does not include the tourist population.

3.2 Coastal Hospitals

Eleven hospitals serve critical healthcare functions on the coast of Oregon. **Figure 3-2** shows the location of each hospital as well as the seismic vulnerability of the bridges along U.S. Highway 101. Each hospital is composed of either a single building or multiple buildings that form a hospital complex. Additional buildings that do not serve acute care needs often exist within each hospital complex. For the most part, these additional buildings have not been considered as part of this project. Buildings, such as clinics, and ambulances that are part of the larger healthcare system are also outside of the scope of this project.

Figure 3-2. Map showing hospital locations and U.S. Highway 101 bridges in three vulnerability states: vulnerable (red), potentially vulnerable (yellow), and not vulnerable (green) (source: Yumei Wang, DOGAMI).

The construction dates of the coastal hospital buildings range from the 1950s to the present. Due to inadequate state seismic building codes prior to the mid-1990s, many pre-1995 hospital buildings have structural system vulnerabilities.

Following a Cascadia earthquake, a surge of medical services will be needed at a time when coastal hospitals are expected to incur earthquake shaking damage (Wang, 2014, 2017). According to 2013 Oregon Resilience Plan documents (OSSPAC, 2013), there are about 483 licensed beds at the 11 coastal hospitals, of which 359 are staffed beds (oral commun., Trent Nagele, VLMK Consulting Engineers, May 19, 2017). It is important for the hospitals to be able to operate existing beds as well as provide services during surge conditions.

3.3 Building Structure

Many hospital buildings in Oregon were constructed prior to any knowledge of the risk of a magnitude 9 Cascadia earthquake and tsunami, and before substantial building code changes were made in the mid-1990s, requiring hospitals to have more robust structural systems capable of resisting the expected earthquake forces. Thus, most hospitals in western Oregon are not prepared to function after major expected earthquakes.

In addition to the building's structural system, two common types of structural shapes can create problems in hospital 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 (OSSPAC, 2013). 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, and can result in structural failures.

The second type of structural irregularity is a vertical irregularity, which can occur when the building steps back in plane as the floor levels increase, such as created by certain towers or atriums. Structural irregularities also can occur when hospital buildings are on slopes and the buildings have fewer stories on the upslope side.

Adjoining buildings that are too close to each other can sway independently during earthquake shaking and pound into each other, causing structural damage. Seismic joints between buildings need to be designed and installed to avoid such damage (**Figure 3-3**).

Figure 3-3. A seismic joint, which has a black rubber accordion appearance, has been designed and constructed between two buildings. It accommodates earthquake shaking movement by each building and avoids damage from the buildings pounding into each other.

3.4 Building Non-Structural Components

Historically, performance of hospitals around the world has been extensively affected by damage to non-structural components, including permanent equipment as well as parts of the building, such as veneer, partition walls, ceilings, and lighting. The ability of hospitals to function is greatly dependent on the non-structural components 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 non-structural damage alone. These non-structural vulnerabilities typically include:

- lack of proper anchorage of mechanical, electrical, and medical equipment; and,
- lack of proper bracing of exterior cladding, ceilings, pipes, ductwork, electrical elements, medical gas such as oxygen, and other critical service lines.

Figure 3-4 shows well designed utility lines that can tolerate shaking movement where two buildings come together. **Figure 3-5** through **Figure 3-8** show four examples of building cladding: an example of earthquake damage (**Figure 3-5**), an example of installation that is designed to tolerate earthquake shaking (**Figure 3-6**), and two examples of hospital exterior cladding that, due to the age of construction, is likely to be seismically vulnerable to falling off the building and harming people, the buildings, or other objects (**Figure 3-7** and **Figure 3-8**). **Figure 3-9** and **Figure 3-10** show a medical gas tank that is not properly anchored.

Figure 3-4. Flexible connections of utility pipes that allow for movement from earthquake shaking have been designed and constructed at the connection between two buildings (Photo credit: Deanna Henry, ODOE).

Figure 3-5. This building's brick veneer was not securely attached and was shaken loose in an earthquake (Source: FEMA, 2012).

Figure 3-6. Brick veneer cladding being installed and securely attached to withstand earthquake shaking. Cladding should be designed and constructed to withstand earthquake shaking in Oregon (Source: FEMA, 2012).

Figure 3-7. Heavy building cladding near hospital egresses should be able to tolerate earthquake shaking. Cladding installed before the mid-1990s should be evaluated for seismic hazards and, if needed, mitigated.

Figure 3-8. Safety related utilities can be damaged by seismically vulnerable building cladding. Cladding installed before the mid-1990s should be evaluated and, if needed, mitigated.

Figure 3-9. Improperly anchored medical gas tank. See Figure 3-10 for a close-up view. Medical gas systems should be seismically designed and installed.

Figure 3-10. Close-up of medical gas tank in Figure 3-9 showing inadequate anchorage.

Hospitals are often complexes consisting of multiple buildings, which include those that provide healthcare and often a central utility plant (CUP) or a central building that contains essential equipment (e.g., boilers and air handling units) that support the rest of the complex. Although this central building may not provide healthcare directly, it is critically important, as damage to its structure and contents could have a significant impact on the entire hospital complex's utilities and ability to function (OSSPAC, 2013).

3.5 Current Building Code Lacks Designing for Resilience

The current Oregon building code does not directly require for new hospital buildings any specific performance level such as an *Operational* or *Immediate Occupancy* performance level (**Figure 3-1**) to be met after a major Cascadia earthquake. Instead, there are implied performance objectives relating to expected earthquake ground motions from various "design" earthquakes associated with specified recurrence intervals, that is, specified timeframes. As discussed earlier, the building code implies that *new* hospitals are to be designed to meet an *Immediate Occupancy* performance level after a "design" earthquake event, but only a *Life Safety* performance level after a magnitude 9 Cascadia earthquake.

The building code implies performance objectives through "Risk Category" determination and site-specific seismic hazard investigations. "These implied objectives are contingent upon design event considerations versus actual event ground shaking and associated variables" (Anthony Rocco, Oregon Building Codes Division, written commun., June 29, 2017). State of Oregon Chief Building Official Richard Rogers (Oregon Building Codes Division, written commun., January 26, 2017) observed that the Oregon building code has a

> "'two-pronged approach' in the regulation of hospitals in Oregon for seismic considerations.
>
> First, Oregon Revised Statute 455.447 captures 'hospitals and other medical facilities having surgery and emergency treatment areas' in the definition of 'essential facilities.' All essential facilities must be evaluated on a site-specific basis for vulnerability to seismic-induced geologic hazards. In addition, the Oregon Structural Specialty Code (OSSC) requires that the investigation be performed by '… an especially qualified engineer or engineering geologist registered by the state to practice as such. Such an evaluation and report may require the services of persons especially qualified in fields of engineering seismology, earthquake geology or geotechnical engineering.' The investigation must address earthquake forces specific to the Cascadia Subduction Zone. This can have a significant impact on the design of the structure.
>
> Secondly, the OSSC and ASCE 7 [American Society of Civil Engineers publication 7] require essential facilities to be designed to a higher standard of care relative to seismically induced loads than other structures. This is accomplished by the inclusion of 'hospitals having surgery or emergency treatment facilities' in 'Risk Category IV' of OSSC Table 1604.5. In turn, ASCE-7 assigns a 'Seismic Importance Factor of 1.5' for Risk Category IV to increase the strength of the building and reduce the ductility demand on the structure."

The OSSC requires 90 minutes for hospital emergency power generation, as stipulated in OSSC 407.10. No emergency on-site water and waste water treatment at hospitals is required by OSSC. There are currently no Oregon building code requirements on water piping to the hospital building (Richard Rogers,

BCD, written commun., January 26, 2017). The intent of the building code for most buildings is largely aimed at meeting a *life safety* performance level—not a higher level of community resilience.

While the building code requires a higher level of design for certain aspects of new hospital buildings, the code lacks requirements on hospitals to maintain function after an extreme Cascadia earthquake. Similarly, the code does not include performance level requirements when local utilities are down. Consequently, the current building code does not include holistic requirements on new hospitals to design for resilience.

The 2013 Oregon Resilience Plan (OSSPAC, 2013) explains that in the 2011 Oregon Revised Statutes, *significant structures* must be designed under direct supervision of a licensed structural engineer (ORS 672.107). Hospitals and other major medical facilities that have surgery and emergency treatment areas are considered *significant structures* or *essential facilities* (ORS 455.447). Standby power generating equipment for essential facilities is also considered *essential* (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 hospitals to be truly resilient, all buildings that provide mechanical, electrical, plumbing, and other supporting services to the buildings must be designed to the same standard. This shift would require revisions to the building code and an expanded definition of *essential facility*.

3.6 Transportation

Coast communities will likely experience significant isolation due to expected damage from a Cascadia earthquake. Not only will highway transportation be compromised in the north-south direction along U.S. Highway 101, but the coast is expected to be physically isolated from the I-5 transportation corridor due to damage along the east-west connecting highways related to bridge failure, landslides, liquefaction, and other problems (CH2M HILL, 2012a, 2012b). **Figure 3-2** shows the locations of the hospitals and U.S. Highway 101 bridges, which have been ranked into three seismic vulnerability states: vulnerable (red), potentially vulnerable (yellow), and not vulnerable (green). Serious damage is expected to occur to the bridges ranked as "vulnerable;" these bridges comprise over 70% of the Highway 101 bridges along the coast; damage could also occur to the remaining bridges. Transportation mobility will be seriously compromised for a prolonged period.

In the 2016 magnitude 7.8 Kaikoura earthquake in New Zealand, transportation along Highway 1, which connects coastal communities in the northeast South Island, was blocked due to large landslides and damaged bridges. Following that event, it took about 6 months to reopen the Highway to single-lane traffic. Due to damaged water and waste water systems, a gastrointestinal outbreak occurred and a number of people needed to be airlifted for healthcare (Joseph Wartman, oral commun., March 9, 2017, and www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11751575).

3.7 Fuel and Water

A hospital 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 earthquake (OSSPAC, 2013). Hospitals are also dependent on electricity for power, the local water district for their water, on distribution-center buildings for medical supplies, and on roadways for the delivery of supplies and more. Hospitals often have limited control over these components.

The Oregon Department of Energy (ODOE) is the lead state agency overseeing the petroleum sector and is responsible for providing adequate fuel supplies to the state's emergency and essential services

providers to save lives and restore critical lifelines and services. According to *Earthquake Risk Study for the Critical Energy Infrastructure Hub in Oregon* (Wang and others, 2013) and *Oregon Resilience Plan* (OSSPAC, 2013), Oregon is expected to lose more than 90 percent of the state's fuel supply in the aftermath of a Cascadia earthquake. ODOE anticipates the region's petroleum infrastructure will be devastated and inoperable for at least three months. As a result, the Oregon Fuel Action Plan identifies strategies to bring bulk fuel supplies in from outside of the region to support state's emergency response and recovery activities (www.oregon.gov/energy/facilities-safety/safety/Pages/Petroleum.aspx). This will take time. ODOE anticipates it may take up to three weeks, if not longer, to move fuel from federal staging areas to the impacted communities.

It is therefore important that hospitals plan to maintain a high level of self-sufficiency. Hospitals should maintain a minimum of a three-week supply of fuel, water, medical supplies, and other items that come from external sources. If post-disaster supplies cannot be stored on site, then having pre-arranged plans to obtain the supplies from local sources are needed.

If the water distribution system to the hospital is disrupted, then on-site potable water and water purification units with non potable water are options. Potable water could also be trucked in from a local ground and surface water sources after post-earthquake water quality has been verified. Similarly, during a prolonged power outage when on-site fuel supplies are depleted, fuel for generators could be obtained from local distributors until the State can deliver emergency fuel to the county.

Figure 3-11 through **Figure 3-13** illustrate an emergency power system at a coastal hospital. **Figure 3-11** shows the emergency generator, which has been seismically certified (**Figure 3-12)** and which is part of the emergency power system. **Figure 3-13** shows the 5,000-gallon fuel tank necessary to operate the generator. **Figure 3-14** illustrates on-site emergency water supplies with a very limited capacity. Emergency supplies can be store on the grounds of a coastal hospital or at a different location, for example, at a community point of distribution if the hospital is located in the tsunami zone. **Figure 3-15** demonstrates a mobile trailer that can be towed to off-site locations. **Figure 3-16** and **Figure 3-17** show a portable water purification unit and emergency sinks stored in an emergency trailer, respectively.

Figure 3-11. Emergency generator, which is part of the emergency power system. This generator has been seismically certified, as shown in Figure 3-12.

Figure 3-12. Seismic certification label attached to emergency generator shown in Figure 3-11.

Figure 3-13. On-site emergency fuel tank.

Figure 3-14. On-site emergency water supply.

Figure 3-15. This trailer with emergency supplies can be towed to off-site locations.

Figure 3-16. Portable water purification unit stored in emergency trailer.

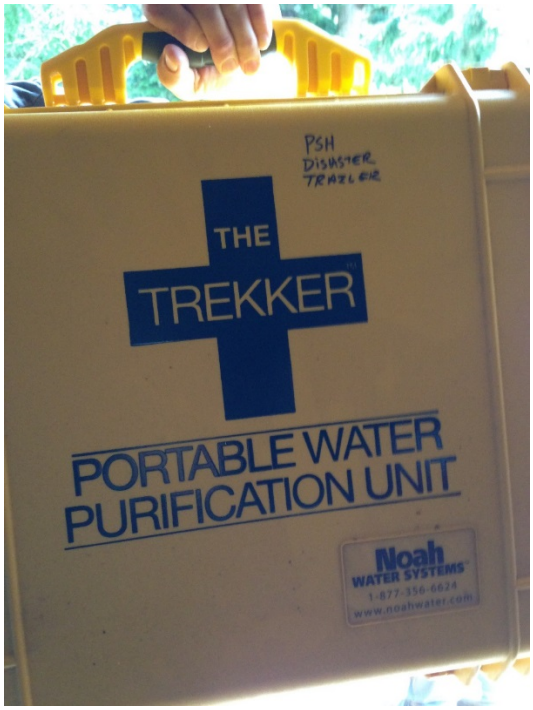


Figure 3-17. Emergency sinks stored in emergency trailer.

4.0 METHOD

For this project, DOGAMI coordinated with OHA Healthcare Preparedness Program (HPP) Region 1, 2, and liaisons and ODOE to set up meetings with these 11 coastal hospitals at HPP regional meetings:

1. Columbia Memorial Hospital, Astoria
2. Providence Seaside Hospital, Seaside
3. Tillamook Regional Hospital, Tillamook
4. Samaritan North Lincoln Hospital, Lincoln City
5. Samaritan Pacific Communities Hospital, Newport
6. PeaceHealth Peace Harbor Hospital, Florence
7. Lower Umpqua Hospital, Reedsport
8. Bay Area Hospital, Coos Bay
9. Coquille Valley, Coquille
10. Southern Coos Hospital and Health Center, Bandon
11. Curry General Hospital, Gold Beach

In preparation for the meetings, HPP liaisons first introduced this project to their partners in written correspondence or during earlier meetings, or both. DOGAMI staff then met with the hospitals and provided technical assistance on Cascadia and disaster mitigation both during and after the ensuing meetings. To facilitate this process, DOGAMI prepared *a technical resources list for hospitals* as part of the project (see **Appendix A: DOGAMI Technical Resources List for Hospitals**), with input from hospital partners on their needs and interests. This resource list includes information on preparing hospitals for earthquake shaking; regulations on hospital preparedness; case studies of hospital performance during earthquakes; grant and loan resources; resilience planning documents and tools; and selected information developed by DOGAMI. The list has been shared with all coastal hospitals as well as other hospitals in Regions 1, 2, and 3.

DOGAMI developed an *Earthquake Preparedness Survey: Request for Information from Coastal Hospitals* to serve as a tool to better understand the level of Cascadia earthquake preparedness at each of the hospitals (see **Appendix B: DOGAMI Earthquake Preparedness Survey**). This survey explored various topics including Oregon laws; Oregon's seismic rehabilitation grant program; hospital building structures; building non-structural components; emergency power; emergency water; technical training, and overall hospital strengths, weaknesses, and technical assistance needs. Ten of the eleven coastal hospitals, as well as a few other partners along the coast, and a few hospitals in the I-5 transportation corridor, completed the survey. This survey has been a helpful learning tool for both hospitals and DOGAMI to better understand the state of hospitals' Cascadia earthquake preparedness.

4.2 Technical Assistance: Presentations

At each of the HPP regional meetings, DOGAMI provided information on Cascadia earthquakes and tsunamis and seismic vulnerabilities of hospitals, while staff from ODOE provided information on emergency fuel planning. The HPP Region 1 meeting was held on April 25, 2017. For HPP region 1, DOGAMI provided information on fuel planning because ODOE was not available. Two meetings were held for HPP Region 2: ODOE presented fuel planning information on January 20, 2017, and DOGAMI presented earthquake and hospital information on March 17, 2017. The HPP Region 3 meeting was held on April 4, 2017.

A main focus of the regional meetings was on hospital buildings, both structural and non-structural building components, and on potential disruption to hospital operations due to loss of power and water supplies. DOGAMI presented an overview of an earlier 2014 pilot study (Wang, 2014) on Cascadia earthquake impacts on a coastal hospital, an inland hospital, and their interdependencies on lifelines. DOGAMI also discussed the technical resources list for hospitals (see **Appendix C: DOGAMI Presentation at OHA Healthcare Preparedness Program Region 1**).

ODOE presented their Oregon Fuel Action Plan, which identifies key actions ODOE will take in response to a severe and long-term fuel shortage caused by a catastrophic earthquake. The plan includes:

- Assessing damages and estimating repair timelines on the region's fuel supply and distribution system
- Providing situational awareness and other fuel sector information to our stakeholders
- Bringing bulk fuel supplies from outside of the region into Oregon to support response and recovery activities
- Receiving and processing emergency fuel requests from priority users
- Overseeing and facilitating bulk fuel deliveries into the impacted areas
- Implementing fuel waivers to ensure all appropriate environmental regulations are temporarily lifted to support timely deliveries of fuel

ODOE suggested that each hospital work with the local county emergency manager on their fuel needs. Based on information in the Oregon Resilience Plan, it is recommended that hospitals store or have access to a minimum of 3 weeks of fuel or alternative power source. Fuel and power are needed immediately following a disaster in order to assist with saving lives and alleviate suffering. In addition, fuel are power are critical for maintaining shelter, heating, cooking, operation of search and rescue and other heavy equipment for victims from collapsed buildings, as well as the inspection and repair of lifeline systems, roads, water, electrical lines, communication lines, and much more. Additional information on emergency fuel planning is accessible at the Oregon Department of Energy Petroleum Emergency Preparedness Program website: www.oregon.gov/energy/facilities-safety/safety/Pages/Petroleum.aspx

4.3 Technical Assistance: Consultations

In addition to the technical assistance presentations (described in section 4.2), DOGAMI met individually with 10 of the 11 hospitals to provide technical assistance consultations (see **Table 4-1**).

Table 4-1. Technical assistance consultations.

Date of Consultation	Hospital and City
March 1, 2017	Samaritan Pacific Communities Hospital, Newport
	Samaritan North Lincoln Hospital, Lincoln City
April 4, 2017	PeaceHealth Peace Harbor Hospital, Florence
	Lower Umpqua Hospital, Reedsport
	Bay Area Hospital, Coos Bay
	Coquille Valley, Coquille
	Southern Coos Hospital and Health Center, Bandon
April 25, 2017	Columbia Memorial Hospital, Astoria
	Providence Seaside Hospital, Seaside
May 16, 2017	Tillamook Regional Hospital, Tillamook

At the consultations, DOGAMI provided an overview of the potential geologic hazards at the hospital sites and shared how hospitals can obtain similar information from the DOGAMI website. DOGAMI webpage links are included in the resource list for hospitals (see **Appendix A: DOGAMI Technical Resources List for Hospitals**). A summary of the potential geologic hazards at the hospital sites is provided below.

DOGAMI also discussed local planning options with each hospital, including local fuel supplies and community points of distributions (CPOD), where non-fuel supplies would be delivered during emergencies. DOGAMI recommended that hospitals work with their county's emergency manager, as well as other local partners, to coordinate on hospital needs. County emergency managers can access information on fuel facilities and CPODs through the Oregon Emergency Management (OEM) database and web mapping application, Real-time Assessment and Planning Tool for Oregon (RAPTOR). For planning considerations, hospitals were provided information on their nearest CPOD and nearest fuel facility equipped with "card lock" access, which have higher security than at retail gas stations (available in the RAPTOR database). Where applicable, DOGAMI discussed hospital responses to the earthquake preparedness survey with the various hospital representatives (see **Appendix B: DOGAMI Earthquake Preparedness Survey**).

4.3.1 Potential geologic hazards at hospital sites

For each hospital, DOGAMI assessed the following geologic hazards: tsunami, liquefaction, landslides, and flooding. These assessments were based on examination of DOGAMI geohazard web tools, available reports, professional judgement, and discussion with hospital representatives (www.oregongeology.org/sub/hazvu/index.htm; Madin and Burns, 2013). It is important to understand that site-specific engineering studies could produce different information, for example, on liquefaction and landslide susceptibility and on tsunami inundation hazards. From these collective datasets, we have summarized the hazards in **Table 4-2**.

Table 4-2. Potential geologic hazards at hospital sites.

	Geologic Hazard			
Hospital	Tsunami (Tsunami Scenario)	Liquefaction	Landslides	FEMA 100-Year Flooding
Columbia Memorial Hospital, Astoria	X (XL)	X		
Providence Seaside Hospital, Seaside	X (M)		X	
Tillamook Regional Hospital, Tillamook	X (L)	X		
Samaritan North Lincoln Hospital, Lincoln City		X	X	
Samaritan Pacific Communities Hospital, Newport				
PeaceHealth Peace Harbor Hospital, Florence		X		
Lower Umpqua Hospital, Reedsport			X	
Bay Area Hospital, Coos Bay			X	
Coquille Valley, Coquille			X	
Southern Coos Hospital and Health Center, Bandon			X	
Curry General Hospital, Gold Beach	X (L)		X	

Four hospitals are exposed to some form of tsunami hazard. Although none are located within the tsunami regulatory line that places restrictions on the construction of certain buildings, all four are located within the tsunami evacuation zone, which is the maximum-considered tsunami inundation zone (or XXL1) as defined by Priest and others (2013). Information on the expected inundation associated with a

suite of Cascadia tsunami scenarios, ranging from small (S), medium (M), large (L), extra-large (XL), and a maximum-considered extra-extra-large (XXL) tsunami, is available through the DOGAMI online tsunami clearinghouse[1]. These scenarios cover, respectively, 26%, 79%, 95%, 98%, and 100% of potential inundation variability (Priest and others, 2013). The tsunami clearinghouse has tsunami evacuation brochures available for every community on the coast as well as a link to an online tsunami evacuation map web portal[2]. Four hospitals have liquefaction hazards. Seven hospitals have potential landslide hazards that could trigger downslope movement during Cascadia earthquake shaking. No hospitals are located in the FEMA 100-year flood zone. Tillamook Regional Hospital, however, has incurred repeated flooding and has recently constructed a flood gate that can be deployed in future flood emergencies.

4.4 Hospital Site Consultative Visits

DOGAMI staff completed two site consultative visits of hospitals. This allowed us to obtain a better understanding of the various levels of earthquake preparedness and learn about specific hospital preparedness activities and concerns. It also allowed hospital personnel to ask additional earthquake and tsunami questions, some of which were specific to their individual hospital.

4.4.1 PeaceHealth Peace Harbor Hospital

On April 5, 2017, DOGAMI and ODOE personnel toured PeaceHealth Peace Harbor Hospital in Florence. This hospital complex includes the main hospital constructed in 1989, a 1995 support building, and two clinics built in 1995 and 2007. Structural improvements have been made to the foundation of the hospital to address ground settlement caused by improperly compacted foundation soils. Non-structural seismic mitigation has been implemented in selected portions of the hospital; additional non-structural improvements may be implemented in the future.

A robust emergency power system is in place, which includes a seismically certified generator and 5,000 gallon diesel tank (**Figure 3-11**, **Figure 3-12**, and **Figure 3-13**). This system can provide emergency power for about 96 hours. Hospital personnel estimated the expected performance of the hospital's water system following a Cascadia earthquake to be low (i.e. insufficient), for both the purpose of sheltering and continuing hospital operations (**Figure 3-14**). Hospital personnel had questions about whether the hospital building was located within the tsunami inundation zone due to their close proximity to the river; the buildings are situated outside the various tsunami inundation zones.

4.4.2 Providence Seaside Hospital

On April 25, 2017, DOGAMI toured Providence Seaside Hospital in Seaside. This hospital complex is located on a slope and falls within the medium (M) tsunami inundation zone as defined by DOGAMI. The complex includes three buildings built in 1970, the 1980s, and mid 1990s as well as two out-patient clinic buildings. Seismic vulnerabilities exist in the structural system, non-structural components, and emergency power system. Hospital personnel expect performance of the on-site water storage and capability for 96 hours of sheltering after a Cascadia earthquake to be high (i.e., sufficient) but expect low performance of the hospital's water system for continuing hospital operations.

Emergency supplies, including small water purification units, are stored in cargo containers and mobile emergency trailers (**Figure 3-15**, **Figure 3-16**, and **Figure 3-17**).

[1] http://www.oregongeology.org/tsuclearinghouse/pubs-inumaps.htm
[2] http://nvs.nanoos.org/TsunamiEvac

In 2011 during the distant tsunami threat from the Tōhoku, Japan, earthquake, hospital personnel were evacuated from the lower to the upper level of the hospital, although the hospital does not need to evacuate when a distant tsunami occurs—the hospital is not in the distant tsunami zone. The evacuation plan route to avoid a local tsunami from a Cascadia earthquake is up an unpaved hill just east of the hospital. **Figure 4-1** shows a portion of a tsunami evacuation route including signage. Evacuation would prove difficult in an actual Cascadia earthquake.

Figure 4-1. Tsunami evacuation route sign. Evacuation of hospitals to protect patients and hospital personnel from local Cascadia tsunamis is difficult and requires careful planning.

5.0 MAJOR FINDINGS

5.1 Key Findings

All Oregon coastal hospitals are aware of the Cascadia earthquake and tsunami hazard. Each has developed and tested emergency plans and has multiple forms of emergency communication systems. However, due to expected damage to pre-1995 hospital buildings including structural systems and non-structural components of hospital buildings, coupled with the expected long-term disruptions of power and water supplies, ***none of Oregon's coastal hospitals are ready to operate immediately after a Cascadia disaster***.

The construction dates of Oregon coastal hospital buildings range from 1950s to the present. Due to the inadequate seismic provisions in the State building codes which until the mid-1990s did not account for Cascadia earthquakes, many pre-1995 hospital buildings have serious structural system vulnerabilities as well as vulnerabilities in the buildings' non-structural components (such as suspended ceilings,

emergency power systems, and medical gasses). Furthermore, current Oregon building codes do not explicitly require new hospital buildings to be designed to be able to operate immediately following Cascadia earthquakes. Although all hospitals have emergency power systems, most have not been designed to be able to function after a Cascadia earthquake. Some hospitals include clinics and other buildings that house healthcare services as part of their system, and these may also have seismic vulnerabilities.

All 11 hospitals are located in a very high earthquake shaking zone, and four hospitals have tsunami hazards. Four hospitals have potential liquefaction hazards; seven have potential landslide hazards, and one has had repeated flooding. The most notable concerns include:

- Lack of seismic preparedness of hospital buildings and non-structural components, including parts of building and equipment
- Lack of planning for reliable water supply for hospitals to be able to operate immediately after a Cascadia earthquake and tsunami
- Lack of planning for reliable fuel supply for hospitals to be able to operate immediately after on-site supplies are depleted
- Lack of robust tsunami plans for those hospitals located in the tsunami zone

The 11 coastal hospitals share many similar risks posed by Cascadia earthquakes and, not surprisingly, have similar needs in learning how to best prepare their facilities to operate after such as earthquake. Coastal hospitals can learn together and share with each other in an effective manner. Providing a productive network can facilitate efficient progress on Cascadia preparedness knowledge and activities. Coastal hospitals can develop the best local solutions for their own medical communities. The State can help provide resilience training opportunities and education and can help incubate and accelerate best practices.

5.2 Overview of Findings

As a result of this study, we find that all coastal hospitals have emergency planners, but most of the planners have additional hospital-related responsibilities. We find that hospital emergency planners and stakeholders show varying degrees of understanding of the risks associated with a major Cascadia earthquake, tsunami, and associated geologic hazards. Most, if not all, hospital emergency managers engage in emergency training, exercises and drills, and continuity of operations planning. Most hospital emergency managers consider Cascadia earthquakes as their most significant hazard and water as their most vulnerable critical infrastructure.

As described previously, such an event will cause significant structural and non-structural damage to buildings and facilities, will compromise basic infrastructure such as power, water, and waste water, and will cause significant disruption to transportation corridors both along the coast and between the coast and the I-5 corridor. All hospitals have made at least minimal preparations for short-duration disasters lasting 72 to 96 hours (e.g., severe winter storms), including for power, communication, and water outages. All hospitals have emergency generators and multiple forms of communication. However, because many of the existing emergency systems were not specifically designed to address earthquake hazards, it can be expected that many will fail during a Cascadia earthquake.

Hospital staff estimated the level of preparedness of their hospitals for Cascadia earthquakes in these categories: building structure; non-structural components; emergency generator(s); emergency fuel supply; water for short-term sheltering; and, water for hospital functionality as part of the DOGAMI survey (**Appendix B: DOGAMI Earthquake Preparedness Survey**). **Table 5-1** provides a summary of their self-

assessments on their levels of preparedness from a Cascadia earthquake in five qualitative rankings: very low, low, moderate, high, and very high. From survey results, planning for water during emergencies is a common concern. Some emergency managers have made plans with county emergency managers and suppliers of external resources that they depend on, such as local water districts and fuel delivery companies.

Table 5-1. Hospital self-assessment of expected performance.

	Number of Hospitals by Expected Performance Level				
Expected Performance of:	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Building structure	0	4	5	0	1
Non-structural components	0	5	4	1	0
Emergency generator(s)	1	3	2	4	0
Emergency fuel supply	1	3	3	3	0
Water for short-term sheltering	4	3	1	2	0
Water for hospital functionality	4	5	0	1	0

Note: 10 of 11 hospitals provided self-assessment results.

Many of the hospitals appear to have alternate care systems, which could involve having clinics providing extra medical services, mobile assets, caches of equipment and supplies, partnerships with local medical reserve corps (MRC), emergency supply delivery, and more. However, none of the hospitals are prepared for prolonged isolation due to widespread damage to power, water, and waste water lines, as well as to the transportation system. From our findings, we conclude that none of the hospitals are likely to be operable due to the expected severity of the Cascadia earthquake and tsunami damage.

Project findings are generally consistent with the 2013 Oregon Resilience Plan, the 2014 DOGAMI pilot study, and other studies such as ODOT's post-earthquake transportation mobility studies (OSSPAC, 2013; Wang, 2014, 2017; CH2MHILL, 2012a, 2012b). Further discussion of our findings is provided below, which have been divided into the following topics: state regulations on seismic preparedness; finances: grants and loans; geologic hazards; building structure; building non-structural components; power and fuel; water; requests from coastal hospitals; and general findings.

5.2.1 State requirements on seismic preparedness

Hospital personnel appear to be highly committed to providing healthcare services during disasters with a fast and effective response. As one example, OHA HPP has worked with coastal hospitals to complete an OHA checklist on emergency preparedness and, although it is not a requirement, hospitals have been responsive.

As discovered as part of the project activities, about half of the hospitals were aware of Oregon Revised Statute 455.400 and its requirement for hospitals to meet earthquake life safety conditions by 2022. ORS 455.400 is under the authority of the Oregon Building Codes Division. DOGAMI is not aware of any Oregon Administrative Rules relating to the statute.

Hospitals have expressed the need to better understand what is required to comply with ORS 455.400, and ramifications for being out of compliance. Some hospitals have specifically asked whether they are currently in compliance.

As determined from this study, most of the vulnerable pre-1995 hospital buildings along the coast have not been seismically upgraded. No state agency or organization is tracking hospitals that have been seismically upgraded or hospitals that meet the intent of ORS 455.400. In contrast, the California Office of Statewide Health Planning and Development (OSHPD; www.oshpd.ca.gov) requires and tracks the progress on each of these:

- seismic evaluations and performance ratings;
- structural compliance; and,
- non-structural compliance.

In 2007, DOGAMI completed a statewide seismic needs assessment (Lewis, 2007) that includes rapid visual screening information for all of the hospitals in the state. The collected information is at a high level and is therefore inadequate for determining if an individual hospital is prepared to operate after a major earthquake. Some of the information on hospitals was incomplete or has errors. Furthermore, the 2007 assessment is now over 10 years old and is outdated.

OSSC, the Oregon state building code, does not require new hospitals to be designed and constructed to be able to maintain operations after a major earthquake, including a Cascadia earthquake. The building code does not include explicit requirements on performance levels that must be met. The state building code could be upgraded to require hospital buildings to meet specific performance levels, such as an *Operational* or an *Immediate Occupancy* performance level from a Cascadia earthquake (**Figure 3-1**). Furthermore, certain buildings that support hospital functions often have lower requirements. These could include buildings that house medical records on data servers or provide utility services and medical gasses. The code could be upgraded to require hospital buildings that support critical hospital functions to be *essential facilities*, which would improve the reliability of post-earthquake operations (OSSPAC, 2013).

The current state building code allows but does not require new hospitals to have plan reviews on earthquake designs by a qualified engineer (OSSPAC, 2013). Further, it allows but does not require new hospitals to have special inspection during construction by inspectors qualified to inspect earthquake designs (OSSPAC, 2013).

OHA requires hospitals to have 96 hours of water supply for sheltering purposes but does not require hospitals to have water to continue operations following a Cascadia earthquake. The state building code does not place any requirements on water pipes, such as those connecting from the local water system to the exterior of the hospital building. In contrast, OSHPD requires California hospitals to be able to function independently for 72 hours.

Before January 2018 the OHA drinking water program did not require water districts to consider seismic hazards in their master plans. Most water districts, especially those that serve hospitals, must now conduct seismic vulnerability assessments and long-range seismic mitigation planning to improve hospitals' water security and reliability (Wang, 2014, 2017).

5.2.2 Finances: Grants and loans

Our meetings with coastal hospitals have demonstrated that many hospitals are interested in learning more about financial opportunities that support seismic rehabilitation. The Oregon Seismic Rehabilitation Grant Program (SRGP), managed by the Infrastructure Finance Authority of the Oregon Business Development Department (OBDD), provides eligible applicants funds for seismic upgrades. Starting in 2018, the maximum grant limit has been increased to $2.5 million.

Some hospitals are committed to working within their communities on emergency response planning through education, prevention, and preparedness measures. If hospitals can help encourage local water

districts to become better prepared, it will help with hospital preparedness—hospital operations consume large amounts of water. OBDD and other state agencies, such as OEM, are in a position to provide information about grants and loans that would help with the reliability of external water supplies that hospitals need to operate. As an example, eligible water district applicants may request funds from the Safe Drinking Water Revolving Loan Fund (SDWRLF) and Sustainable Infrastructure Planning Projects (SIPP)[3]. Some funds can be used for feasibility and resilience studies. For actual construction related to seismic improvements of water facilities, those are eligible costs through SDWRLF to an eligible public water system (Jeremy McVeety, written commun., May 5, 2017).

5.2.3 Geologic hazards

All 11 hospitals are located in a very high earthquake shaking zone and are subject to prolonged ground shaking on the order of 3–5 minutes. Four hospitals have tsunami hazards as described previously. Four hospitals have potential liquefaction hazards; seven are subject to potential landslide hazards, and one has had periodic flooding problems; the latter has recently been mitigated.

Hospital personnel have various levels of understanding of Cascadia earthquake hazards, while a few have detailed knowledge. To assist with this, we shared regional geologic hazard information on expected shaking, liquefaction, and earthquake-triggered landslides with 10 hospitals. For the most part, there were no major surprises to hospital personnel. Site-specific geotechnical reports contracted by the hospital could include more detailed information that might supersede the information shared by DOGAMI staff. Although the Tillamook Regional Hospital is not in the FEMA 100-year flood plain, it has incurred flooding damage and has recently developed flood mitigation measures to resolve this problem.

Hospital personnel also demonstrated varying levels of understanding of the tsunami hazards associated with a local Cascadia tsunami and distant-source tsunami; for example, personnel were familiar with the distant tsunami triggered by the 2011 magnitude 9 Tōhoku, Japan, earthquake. DOGAMI staff provided detailed tsunami hazard information during the various meetings, particularly during individual consultations with three of the four hospitals in the tsunami evacuation zone. Information on the specific tsunami zones in which the hospital is located, and expected tsunami flow depths surrounding the hospital, were provided. Each of the three hospitals has developed tsunami evacuation plans. In the advent of strong earthquake shaking, we recommended that everyone located in the tsunami evacuation zone, including those in hospitals, evacuate to an area outside of the maximum-considered tsunami evacuation zone. Maps depicting these zones are accessible through DOGAMI's tsunami clearinghouse[4].

Hospital personnel requested additional technical assistance on tsunamis, specifically: evacuation response plans for a local Cascadia earthquake versus a distant-source tsunami; options on limited evacuations; ethics surrounding staff and patient evacuations; tsunami vertical evacuation structures; and tsunami hazard maps that highlight detailed evacuation routes for each hospital. DOGAMI also discussed the option of running new site-specific tsunami models that include landscape friction parameters in order to obtain improved tsunami hazard maps for the hospitals.

5.2.4 Building structure

From information provided in the DOGAMI surveys, we find that there are about 25 hospital buildings at the 11 coastal hospital complexes. Hospital buildings were designed and constructed starting in the 1950s. Currently, several hospitals have construction projects underway or are in the planning stages.

[3] https://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/SRF/Pages/sipp.aspx
[4] http://www.oregongeology.org/tsuclearinghouse/

From self-assessment survey responses (see **Table 5-1**), the preparedness levels for the building structures range from low to very high. It is possible for structures with lower preparedness levels to incur only modest structural failures, or partial to even entire building collapses. The building construction dates for all hospitals are shown in **Table 5-2**. The data indicate that about 60–68 percent of the hospital buildings were built to pre-1995 building codes. Due to inadequate building codes at that time, these are seismically vulnerable structures. Most of the hospital buildings have vertical and plan irregularities, which could contribute to seismic vulnerability of the structure's integrity. Although the intent of the survey was to determine the construction date of hospital buildings, some of the buildings included in the survey results are outpatient clinics, not hospital buildings.

Table 5-2. Construction dates of hospital buildings.

Hospital	City	Decade of Building Construction
Columbia Memorial Hospital	Astoria	1970s, early 1990s, 2000s, and 2010s
Providence Seaside Hospital	Seaside	1960s, 1980s, and early-to-mid 1990s
Tillamook Regional Hospital	Tillamook	1950s, 1970s, 1980s, and late 1990s
Samaritan North Lincoln Hospital	Lincoln City	1960s
Samaritan Pacific Communities Hospital	Newport	1950s, 1970s, and 1980s
PeaceHealth Peace Harbor Hospital	Florence	1980s and early-to-mid 1990s
Lower Umpqua Hospital	Reedsport	1960s
Bay Area Hospital	Coos Bay	1970s, 1990s, and 2010s
Coquille Valley	Coquille	1960s and 2010s
Southern Coos Hospital and Health Center	Bandon	1990s
Curry General Hospital	Gold Beach	2017

5.2.5 Building non-structural components

Similarly, we determined that the seismic preparedness levels of non-structural components of the hospital buildings range from low to high. Vulnerability is prevalent in the pre-1995 buildings due to deficiencies in earlier building codes. DOGAMI observed non-structural vulnerabilities of mechanical, electrical, and plumbing equipment, as well as building components, such as veneer at egresses, and unanchored medical gas tanks. At least one hospital has conducted seismic mitigation of suspended ceilings in a portion of the hospital. Vulnerability of hospital non-structural components is a significant problem, which in many cases can be mitigated in a prioritized manner and at relatively low cost.

5.2.6 Power and fuel

All hospitals have on-site emergency power systems including at least one generator and on-site emergency fuel. However, the level of preparedness, quality of the systems, and the amount of fuel stored on-site to operate backup generators varied significantly. In general, most of the hospitals are unprepared to operate "off the grid" for more than a few days without power.

Overall, the hospitals' emergency power systems are not designed to withstand earthquake shaking and could fail completely. Only one of the emergency power systems observed incorporates seismic design. All emergency power systems should be specifically designed, include seismically certified equipment where available, and be properly installed to withstand catastrophic earthquake impacts.

Importantly, the amount of fuel stored at the hospitals to run the backup generators varied significantly. One hospital reported that their emergency fuel supplies would last over 4 months. However, fuel

supplies at most hospitals ranged from 3 to 8 days. It remains unclear how accurate the reported fuel supplies are, because some of the hospitals do not know their generator's fuel consumption rate.

Some hospitals have plans in place for fuel deliveries in times of disasters. In most cases, these hospitals have contracted with local suppliers to ensure fuel deliveries are made to their facility when on-site supplies are depleted. Furthermore, some hospitals have worked with their local emergency managers on the need for emergency fuel. This is consistent with the Oregon Department of Energy's (ODOE) Oregon Fuel Action Plan. ODOE will work with the county emergency management agencies to assess fuel needs to ensure adequate fuel supplies are provided to counties to support local life safety and life sustaining missions. More information on emergency fuel planning is at the ODOE Petroleum Emergency Preparedness Program website: www.oregon.gov/energy/facilities-safety/safety/Pages/Petroleum.aspx.

5.2.7 Water

All but one hospital considers water as a major vulnerability in terms of their disaster preparedness. All hospitals require considerable amounts of water to operate and depend heavily on their local water districts. The hospitals are therefore dependent on the seismic preparedness of the water districts.

Although a few hospitals were found to have the recommended 96 hours of emergency water supply for sheltering either on-site or nearby, most would not be able to sustain normal operations for even a few hours if their normal water supply was cut off. Some hospitals have on-site emergency water purification equipment that could produce a limited amount of water. Most hospitals were largely unaware of that water districts have facilities with seismic vulnerabilities and that hospitals should expect damage to the water facilities and an ensuing loss of water supply. Many hospitals requested DOGAMI's technical assistance to help with further discussions and expressed an interest in meeting with their water supplier.

As part of this project, DOGAMI explored funding opportunities for water districts to conduct seismic vulnerability analyses, develop prioritized mitigation programs, and conduct seismic mitigation and preparedness activities (**Appendix A: DOGAMI Technical Resources List for Hospitals**). Activities include:

- building new tank-style reservoirs
- installing seismic shut-off valves to water tanks to prevent loss of water
- replacing rigid piping connections to flexible connections to tolerate earthquake shaking
- burying vulnerable water pipes at river crossings, such as those co-located on vulnerable bridges
- replacing fragile and poor performing water pipe (e.g., cast iron pipe)
- adding pumping capacity at pump stations in pressure zones with expected major pressure deficiencies
- purchasing equipment, such as seismically certified generators, water purification equipment, and emergency piping and hoses

5.2.8 Requests from coastal hospitals

Overall, we found that the hospitals benefitted from the project information and consultations. Most hospitals requested additional consultations with DOGAMI. Also, most hospitals requested further training on one or more of the following subjects:

- pre-and post-earthquake building inspections
- non-structural vulnerability assessments and mitigation
- hospital performance improvements during earthquakes

Because many of the hospital emergency managers and facility managers have multiple, sometimes diverse, responsibilities outside of emergency management, their resources are necessarily limited. Some

requested help with educating their leadership and other hospital personnel as well as learning more themselves on Cascadia earthquake and tsunami hazards. Some hospital personnel discussed the benefits of working with other coastal hospitals outside of their HPP region, while others asked if DOGAMI could assist non-hospital medical facilities (e.g., clinics, ambulance stations) and organizations (e.g., medical reserve corps) along the coast.

5.2.9 General findings

We identified a number of more general findings that could further assist coastal communities and their hospitals as well as benefit noncoastal hospitals. Findings include information provided in the DOGAMI resource list (**Appendix A: DOGAMI Technical Resources List for Hospitals**), the questionnaire survey (**Appendix B: DOGAMI Earthquake** Preparedness Survey), and the earthquake and fuel presentations (**Appendix C: DOGAMI Presentation at OHA Healthcare Preparedness** Program Region 1**).**

General findings include:

- Several hospitals from the I-5 corridor expressed a strong interest in the project activities, requested technical assistance, and submitted DOGAMI survey responses.
- Several project participants requested assistance with emergency management activities, such as with training exercises and receiving earthquake and tsunami warning information. We recommend OHA and OEM as potential leaders in this role.
- Besides the state agencies mentioned throughout this report, agencies such as the Oregon Department of Land Conservation and Development (DLCD) and Oregon Department of Transportation (ODOT) are potential key partners in helping coastal hospitals prepare for Cascadia earthquakes and tsunamis. DLCD could assist with land-use planning and recovery planning, while ODOT serves a critical role with respect to post-earthquake transportation mobility planning.

6.0 RECOMMENDATIONS

For Oregon's coastal hospitals, DOGAMI provided technical assistance, learned about their current state of preparedness, and developed recommendations as part of a 3-year work plan to improve their resilience for a Cascadia earthquake.

We developed four key recommendations to address the concerns outlined in the Major Findings section of the report. Detailed information on each recommendation is provided later in this section. Of great importance, we recommend that coastal hospitals prepare not just for more frequent disasters, such as winter storms, but specifically for a major Cascadia earthquake and tsunami that will cause a prolonged (weeks to months or even years) disruption to essential services. Although DOGAMI developed a 3-year work plan to address the four recommendations, we expect that hospital preparations will take many years, and that any preparations taken before a major Cascadia earthquake or a lesser earthquake will increase public safety and improve resilience.

To improve hospitals' states of readiness for Cascadia earthquakes, DOGAMI's Recommendation 1 improves seismic requirements, Recommendations 2 and 3 focus on technical support and accelerating seismic preparedness activities for the 11 coastal hospitals; and Recommendation 4 provides earthquake planning information to hospitals across the state. Key recommendations are:

- **Recommendation 1: Clarify and Improve Seismic Requirements**
  OHA evaluate, clarify, and improve existing requirements on hospitals and healthcare systems regarding seismic preparedness. This would affect all of the hospitals and healthcare systems in the state and would improve the state's level of resilience.
- **Recommendation 2: Conduct On-Site Technical Assistance**
  DOGAMI, with the help of HPP region 1, 2, and 3 liaisons, conduct on-site consultative visits to each of the coastal hospitals to provide technical assistance. This would allow coastal hospitals to focus and make progress on key aspects of disaster preparedness.
- **Recommendation 3: Establish a Coastal Hospital Resilience Network**
  OHA establish a coastal hospital resilience network with specific focus on preparing for Cascadia earthquakes. This would involve developing and sharing ***best practices*** and other preparedness information among hospitals and healthcare systems. Periodic ***training sessions***, co-organized by HPP region liaisons, DOGAMI, and hospitals, would allow for networking and acceleration of preparedness activities. Although this network is designed to improve the resilience of coastal hospitals, certain aspects would also benefit noncoastal hospitals and improve the state's resilience.
- **Recommendation 4: Share Cascadia Earthquake and Fuel Planning Information Statewide**
  DOGAMI and Oregon Department of Energy (ODOE), in coordination with HPP regional liaisons, provide Cascadia earthquake and emergency fuel planning information to all hospitals across the state. This would provide critical information to help improve statewide preparedness.

DOGAMI proposes that Recommendations 1 to 4 be conducted in a 3-year work plan. For Recommendation 1, DOGAMI proposes that OHA determine its own timeline. Recommendation 2 can be completed in the first year. Recommendations 3 and 4 can be accomplished in the second and third years. Toward the end of the third year of sustained efforts, OHA and its coastal healthcare system partners can reevaluate the need for any future efforts.

In developing these recommendations, DOGAMI synthesized the findings outlined in this report, considered earlier recommendations from a DOGAMI pilot study (Wang, 2014), all which are still considered to be valid, integrated selected recommendations from the Oregon Resilience Plan (OSSPAC, 2013), and incorporated practicalities balancing hospital needs and available state resources and roles. The four recommendations are discussed below.

6.1 Recommendation 1: Clarify and Improve Seismic Requirements

> *OHA evaluate, clarify, and improve existing requirements on hospitals and healthcare systems regarding seismic preparedness. This would affect all of the hospitals and healthcare systems in the state, and improve the state's level of resilience.*

6.1.1 Clarify and improve ORS 455.400

OHA should address 2013 Oregon Resilience Plan (ORP) recommendations that ORS 455.400 should be improved to achieve hospital preparedness for Cascadia disasters (OSSPAC, 2013). The statute language is unclear and is insufficient to meet its general intent of hospitals being prepared by 2022 to serve medical needs after a Cascadia disaster. OHA can work with the Department of Justice, BCD, and its hospital partners on clarifications and improvements.

6.1.2 Evaluate and improve current State of Oregon requirements

Both BCD and OHA have current requirements and regulations on hospital preparedness. However, they are insufficient as they do not effectively address Cascadia earthquakes. In order to determine how to best strengthen Oregon's seismic resilience, DOGAMI recommends that OHA examine its current requirements, work with BCD to examine Oregon Structural Specialty Code (OSSC) requirements, and explore the requirements in California's OSHPD on earthquake preparedness.

One limitation, for example, is that the State of Oregon via the OSSC does not explicitly require new hospitals to meet a specific performance level, such as an *Operational* or an *Immediate Occupancy* performance level after a Cascadia earthquake. OHA requires hospitals to be able to provide shelter but not necessarily to be operational. OSSC requirements are for 90 minutes of on-site back-up power, but there are no OSSC requirements relating to on-site emergency water or waste water. In contrast, OSHPD explicitly requires hospitals to be able to operate immediately after a major earthquake. OHA should work with its partners to make prudent improvements and provide incentives to hospitals and the healthcare industry to meet any new requirements.

Below are additional areas that could be addressed to help improve hospital preparedness for Cascadia disasters.

6.1.2.1 Improve plan review of new hospitals and construction oversight

There needs to be improvement in the plan reviews of new hospitals as well as construction oversight, as recommended in the 2013 ORP. 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 currently required by code for hospitals but may not necessarily be enforced by local building officials. Local building officials should verify that all designated seismic systems (including emergency generator systems) are seismically certified, which is a current code requirement stipulated in American Society of Civil Engineers (ASCE) 7-10, Chapter 13, section 13.2.2 (OSSPAC, 2013). DOGAMI

recommends that OHA, BCD, or another state organization require qualified licensed design professionals or qualified structural engineer to provide periodic plan reviews for new hospital buildings reciprocal with the licensing required to provide the design, and enforce the state building code on Special Inspections and Structural Observations on hospitals.

6.1.2.2 Reclassify supporting buildings as "essential" in building code

Non-hospital buildings that provide supporting functionality to hospitals in order to meet "immediate occupancy" performance levels should be considered as "essential" in the OSSC, as recommended in the 2013 ORP (OSSPAC, 2013). This would require changes to the building code. The ORP (p. 87) states:

> "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 hospital buildings must be designed to the same standard. This shift will require revisions to the building code and an expanded definition of *essential facility.*"

6.1.2.3 Improve water preparedness of hospitals

We restate the recommendation that OHA and hospital partners require seismic preparedness standards for drinking water systems that serve hospitals (Wang, 2014, 2017). As an initial step, OHA's Drinking Water Program can require seismic vulnerability assessments and mitigation planning in master plans that are submitted to OHA by water districts, including those serving hospitals. The Oregon Administrative Rules were updated in January 2018 to require seismic analyses and planning in most water districts.

6.1.2.4 Update hospital building inventory

Hospital building inventory information undertaken as part of the 2007 DOGAMI statewide seismic needs assessment (SSNA) should be updated, as recommended in the 2013 ORP. Information from SSNA is currently used in the state's seismic rehabilitation grant program. SSNA data could also be used to better understand each hospital's state of preparedness for Cascadia earthquakes and tsunamis, as discussed in the 2013 ORP (OSSPAC, 2013). DOGAMI recommends that OHA share any updated building inventory information and use it to encourage all existing hospitals to evaluate their building systems and, if needed, make upgrades in order to be operable after a Cascadia earthquake.

6.1.2.5 Track hospital preparedness on Cascadia earthquakes

OHA should develop a tracking system to evaluate the state of preparedness of each hospital for a Cascadia earthquake. This should start with establishing a baseline rating and include a method to track progress on the state of preparedness. Selected information from SSNA could be used to help establish the baseline rating.

6.2 Recommendation 2: Conduct On-Site Technical Assistance

DOGAMI, with the help of HPP region 1, 2, and 3 liaisons, conduct on-site consultative visits to each of the coastal hospitals to provide technical assistance. This would allow coastal hospitals to focus and make progress on key aspects of disaster preparedness.

During this project, DOGAMI provided limited off-site technical assistance to 10 of the 11 hospitals, at which time, many of the hospitals requested additional technical support. On-site consultative visits would allow for dedicated individualized attention and the opportunity to focus on particular needs. DOGAMI would require assistance from the HPP regional liaisons to set up the visits with a designated hospital representative.

Before the visits, DOGAMI would evaluate FEMA's hospital resources then obtain and distribute materials during the visits. For each facility, DOGAMI would provide technical assistance during a facility walk-through and meet with hospital personnel and local organizations, as requested. Visits would take between 0.5 and 1.5 days depending on each hospital's requests.

The site visits would include: observing the building structure, non-structural components, and emergency power and water systems; and discussing emergency fuel plans, water plans, and other lifeline services that are required to maintain operations both during and following a major Cascadia disaster. If hospitals are in or near the tsunami inundation zone, then review of the existing tsunami evacuation plans would be conducted. If hospitals request consultations on other aspects of their hospital system, such as coastal clinics and ambulances, then assistance would be provided.

At the time of the visit, DOGAMI would gather the necessary information that could be used to update the hospital building inventory originally compiled in the 2007 DOGAMI statewide seismic needs assessment (SSNA). DOGAMI would also briefly describe the ASCE 41 method, which is the state-of-practice engineering seismic vulnerability assessment for structural and non-structural components. This assessment is needed as part of all SRGP applications (ASCE, 2017).

After the facility walk-through, DOGAMI would be available to meet with leadership or other hospital personnel. Furthermore, DOGAMI could, at the initiation of hospital representatives, meet with local stakeholders immediately after the on-site hospital visit. These meetings would be pre-scheduled by the hospital and must have a direct bearing on the post-earthquake operability of the hospital. Meetings could be held with representatives of the water district in order to help represent hospital emergency water needs. Similar meetings could be held with representatives of the local fuel suppliers or transportation system owners. At these meetings, DOGAMI could discuss seismic vulnerability assessments, seismic mitigation planning, holistic community engagement, and long-range planning.

6.3 Recommendation 3: Establish a Coastal Hospital Resilience Network

*OHA establish a coastal hospital resilience network with specific focus on preparing for Cascadia earthquakes. This would involve developing and sharing **best practices** and other preparedness information among hospitals and healthcare systems. Periodic **training sessions**, co-organized by HPP region liaisons, DOGAMI and hospitals, would allow for networking and acceleration of preparedness activities. Although this is designed to help coastal hospitals, certain aspects would also help other hospitals in the state to improve resilience.*

6.3.1 Cascadia Coastal Hospital Resilience Network

The 11 coastal hospitals share many similarities and overlapping interests on how to best prepare their hospitals for Cascadia earthquakes and tsunamis. Currently, coastal hospitals do not have a convenient means to connect, share, and learn from each other on common issues. They are spread throughout three separate HPP regions that also include hospitals along the I-5 corridor. Commonly, as smaller hospitals, their needs and concerns are overshadowed by bigger inland hospitals that serve larger population centers. Coastal hospitals can learn together in an efficient and accelerated manner—they can learn from and share with each other. In feedback from hospital personnel, many expressed the need for concentrated and sustained training opportunities in order to prepare their hospitals for Cascadia earthquakes.

DOGAMI recommends that OHA establish a coastal hospital resilience network to focus on preparing for Cascadia earthquakes and tsunamis, herein called ***Cascadia Coastal Hospital Resilience Network***, or simply ***Cascadia Network*** (another name could be used). Cascadia Network would be a new action-oriented network driven by coastal hospital personnel. It would provide an established means for coastal hospitals in rural communities to connect, share, and learn from each other on difficult disaster preparation issues, such as transportation immobility and mass casualties from a tsunami. The success of Cascadia Network is dependent on the leadership of Region 1, 2, and 3 HPP regional liaisons and engaged hospital participants. OHA could host a Cascadia Network webpage with resources and list of activities.

6.3.2 Best practices

Guidance documents of ***best practices*** on how to prepare hospitals for Cascadia earthquakes should be developed and shared. Local examples, where available, should be highlighted. This could include working with coastal hospitals to determine, develop, and share "best practice" stories to highlight hospital preparedness activities that will inspire action by other hospitals. The role of DOGAMI could be directed at developing information sheets and other best practice materials (with assistance from the coastal hospitals and others) that would be transferable between hospitals. To facilitate transfer of knowledge, tours that include not only hospital staff but also local officials, including the Coastal Caucus, and media may be warranted. Tentative topics for best practice stories could include the following:

- seismic mitigation of buildings
- emergency fuel planning
- emergency water planning
- storing emergency supplies
- community resilience
- tips for securing funds from the Oregon Seismic Rehabilitation Grant Program (www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab).

The organizations, groups, and individuals who are responsible instigating best practices are commonly not recognized for their excellence. The responsible parties should be recognized and could be recognized through a Cascadia Network webpage and activities, in particular at Cascadia Network training sessions (discussed below). Best practice stories can also benefit those extending beyond Cascadia Network, such as at the Oregon Prepared conference and elsewhere. Five hypothetical best practice stories have been outlined in **Appendix D: Cascadia Network Training Schedule and Training Agenda**.

6.3.3 Cascadia Network training sessions

We recommend that periodic ***training sessions*** serve as a primary Cascadia Network function for coastal hospitals. Earthquake and tsunami preparedness tools, information, and activities to support coastal hospitals to make the needed progress to be able to provide healthcare services after a Cascadia disaster will be shared and discussed at the training sessions. The training sessions would provide an effective means to distribute best practice stories. Not only would best practices be shared and perpetuated, responsible parties would share their stories and be celebrated at the training sessions.

HPP regional liaisons should organize Cascadia Network training sessions and serve as leads on logistics. In order to fully engage hospitals in Cascadia Network, we suggest that hospitals serve as co-hosts of the training sessions. DOGAMI, with input from the coastal hospitals and HPP, could serve as the lead on technical content. Specialists and technical experts could be invited to the training sessions. The training sessions would serve as a venue for group exploration and discussion on particularly challenging topics, such as ethical issues relating to hospital evacuations during tsunamis—a topic that arose during this project.

Hospital resilience depends on a wide variety of stakeholders, communities, and others in the region. The training sessions can serve as a venue for hospitals to engage the community in regional resilience planning that specifically addresses hospital lifeline interdependencies. Existing partnerships can be strengthened and new partnerships can be forged in advance of earthquake disasters to improve outcomes. This activity and other important networking activities should be conducted at Cascadia Network training sessions.

On the basis of feedback from hospitals on their training needs, DOGAMI recommends that five training sessions be held on the coast during the course of the 3-year work plan. Toward the end of this period, as part of an evaluation effort, the need for additional training sessions should be determined. The location of the training session could be alternated among Regions 1, 2, and 3.

Five hypothetical training sessions have been outlined in **Appendix D: Cascadia Network Training Schedule and Training Agenda**. Each proposed training session includes a suggested date, HPP region, topics for discussion and education, subjects for best practice (BP) guidance, possible venues to present BP guidance stories, and a possible hospital co-host.

DOGAMI proposes one full day of training session activities to be spread across two half days. This framework was suggested by hospital personnel as part of this project to accommodate travel along the Oregon coast, which can be time consuming. If training sessions are held in spring and fall, then difficult winter road conditions and expensive summer hotel accommodations may be avoided.

A hypothetical framework for the training session agenda is provided in Appendix D. There are four sessions: Leadership, Best Practices, Technical, and Group Discussion. Each training session would commence with a 90-minute Leadership session, which is for coastal hospital leaders to learn and participate in hospital preparedness activities on a limited basis with hospital emergency managers, facility planners, and others. Keeping in mind that leaders may have limited time and interest on technical details, this session is nontechnical in nature. The session would include information from coastal hospital leadership, major updates, new funding opportunities, recognition of leadership on best practices, and more. Following the Leadership session, after which most hospital leaders will depart, the Best Practices session will feature a best practice story. The best practice speakers will present their story with assistance from DOGAMI if requested. A Technical session will be held the following morning. The topics may be a continuation of the best practice story or another topic. Last is the Group Discussion session, which can be focused on particularly difficult issues and, at times, led by an outside facilitator or subject matter expert. Additional special technical programs can be scheduled as needed.

6.4 Recommendation 4: Share Cascadia Earthquake and Fuel Planning Information Statewide

> *DOGAMI and Oregon Department of Energy (ODOE), in coordination with HPP regional liaisons, provide earthquake and emergency fuel planning information to all hospitals across the state. This would provide critical information to improve statewide resilience.*

To assist hospitals across the state prepare for Cascadia earthquakes, we recommend that DOGAMI and ODOE provide hospital earthquake preparedness and fuel planning at HPP liaison meetings for Region 1, 3, 5, 6, 7, and 9 (See **Figure 2-1**). DOGAMI and ODOE would present material similar to what was provided to the coastal hospitals as part of this project (e.g., similar presentations, the resource list, and questionnaire survey; see Appendices A–C). Region 2 has not been included because this information has already been shared with them as part of this project. This activity would require the HPP regional liaisons to provide about 3 hours of meeting time at one of their regular meetings.

DOGAMI further recommends that each year OHA organize sessions specifically aimed at preparing hospitals for Cascadia earthquakes at the annual Oregon Prepared conference, which is co-hosted by the OEM and OHA. Presentations on the 2014 pilot study, this project on coastal hospitals, and future OHA-DOGAMI-ODOE efforts could be offered.

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9.0 APPENDICES

9.1 Appendix A: DOGAMI Technical Resources List for Hospitals

9.1.1 Hospital information

- Oregon Health Authority's earthquake risk report by DOGAMI on hospitals, water systems, transportation, and interdependencies:
  - report: http://public.health.oregon.gov/Preparedness/Prepare/Documents/oha-earthquake-risk-report-2014.pdf
  - executive summary: http://public.health.oregon.gov/Preparedness/Prepare/Documents/oha-earthquake-risk-execsum-2014.pdf
  - website: http://public.health.oregon.gov/Preparedness/Prepare/Pages/PrepareForEarthquake.aspx
- FEMA P767, Earthquake Mitigation for Hospitals https://www.fema.gov/media-library/assets/documents/22391
- FEMA 577, Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings https://www.fema.gov/media-library-data/20130726-1609-20490-1678/fema577.pdf
- FEMA E-74, Reducing the Risks of Nonstructural Earthquake Damage https://www.fema.gov/fema-e-74-reducing-risks-nonstructural-earthquake-damage
- Oregon Administrative Rules on New Construction and Alternations of Existing Hospitals http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_333/333_535.html
- Oregon Law on Seismic Rehabilitation of Existing Hospitals by 2022 https://www.oregonlaws.org/ors/455.400
- California Office of Statewide Health Planning and Development (OSHPD) www.oshpd.ca.gov; Pre-approved lists http://www.oshpd.ca.gov/FDD/Pre-Approval/index.html
- Oregon Crisis Care Guidelines: www.theoma.org/node/4539
- Selected Case Studies
  - 2010 Chile earthquake: https://jhu.pure.elsevier.com/en/publications/impact-on-hospital-functions-following-the-2010-chilean-earthquak-4
  - 2011 New Zealand: http://earthquakespectra.org/doi/abs/10.1193/032013EQS074M?code=eeri-site
  - 2014 Nepal earthquake presentation: http://peer.berkeley.edu/events/wp-content/uploads/2015/07/04-PEER_MitraniReiser_2015_Aug11_copy.pdf
  - Comparison Study: http://www.seismic.ca.gov/meeting_info/July11_2013/05-Item%20V%20Hospital%20Evac%20Survey.pdf

9.1.2 Grant and loan information

- State of Oregon Seismic Rehabilitation Grant Program, including hospitals
  www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab/
- Oregon Health Authority Public Health
  https://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/SRF/Pages/sipp.aspx
  http://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/SRF/Pages/index.aspx
- Oregon Business Development Department (OBDD) Infrastructure Authority (IFA)
  Special Public Works Fund http://www.orinfrastructure.org/Infrastructure-Programs/SPWF/

9.1.3 Cascadia resilience planning information

- 2013 Oregon Resilience Plan by Oregon Seismic Safety Policy Advisory Commission (OSSPAC)
  http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf
- Oregon Department of Energy's 2016 presentation on emergency fuel planning
  https://olis.leg.state.or.us/liz/2015I1/Downloads/CommitteeMeetingDocument/89758
- Oregon Department of Transportation Lifeline Routes (2012)
  http://www.oregon.gov/ODOT/TD/TP/Reports/Lifeline%20Selection%20Summary%20Report.pdf
- State of Oregon National Hazard Mitigation Plan (NHMP) (contact counties for county NHMP)
  http://www.oregon.gov/LCD/HAZ/Pages/nhmp.aspx
- Oregon Office of Emergency Management earthquake information, including RAPTOR web tool
  www.oregon.gov/OMD/OEM/Pages/plans_train/earthquake.aspx
  https://www.oregon.gov/OMD/OEM/Pages/plans_train/RAPTOR.aspx
- FEMA technical assistance, including pre- and post earthquake assessment methods
  https://www.fema.gov/national-earthquake-technical-assistance-program
- U.S. Resilience Council's earthquake building rating system http://usrc.org
- Beaverton School District on Resilience Planning for new schools
  https://www.beaverton.k12.or.us/depts/facilities/Documents/150710_Beaverton%20School%20Report.pdf

9.1.4 DOGAMI information

DOGAMI is the state's scientific agency with technical information on earthquakes, tsunamis, landslides, liquefaction, and selected rapid visual screenings http://www.oregongeology.org

- DOGAMI's 2007 Rapid Visual Screening (FEMA 154) project information, includes hospitals
  http://www.oregongeology.com/sub/projects/rvs/
- Geologic hazards in Oregon
  - HazVu web tool http://www.oregongeology.com/sub/hazvu/index.htm
  - Landslides web tool (SLIDO) http://www.oregongeology.org/sub/slido/
  - Oregon tsunami hazards http://www.oregongeology.org/tsuclearinghouse/
- Oregon Risk Study on Critical Energy Infrastructure 2013
  http://www.oregongeology.org/pubs/ofr/p-O-13-09.htm
  - Cascadia newsletter http://www.oregongeology.org/sub/quarpub/CascadiaWinter2010.pdf

9.2 Appendix B: DOGAMI Earthquake Preparedness Survey

DOGAMI Earthquake Preparedness Survey
Request for Information from Coastal Hospitals

Hello! DOGAMI is requesting information from Oregon's coastal hospitals to better understand the state's level of earthquake preparedness and how to provide improved technical assistance. Please complete this DOGAMI Earthquake Preparedness Survey with the best available information and send to Yumei Wang by April 28, 2017. Questions? Email Yumei.Wang@oregon.gov or call 971-673-1551. See the DOGAMI Technical Resource List for more information.

Earthquake Preparedness of Oregon Hospitals

In 2001, the Oregon Legislature passed a law requiring hospitals to be prepared by 2022 to operate after major earthquakes. To better understand the state's seismic vulnerabilities of schools and emergency service buildings, including hospitals, in 2007 DOGAMI conducted rapid visual screenings (RVS) using FEMA methods. Since 2009, Oregon's seismic rehabilitation grant program (SRGP) has provided up to $1.5 million to mitigate eligible buildings, including hospitals.

Survey Questions

Hospital Name _____

Hospital Location (City) _____

Hospital Point of Contact for this Survey (name, position, phone, and email):

_____

Yes	No	
☐	☐	Are you aware of the 2022 deadline for hospitals to be prepared for major earthquakes?
☐	☐	Does your hospital have funding for seismic evaluations and, if needed, mitigation?
☐	☐	Has your hospital applied for an Oregon Seismic Rehabilitation Program grant?
☐	☐	Does your hospital plan to apply for a grant in the next 2 years?

Buildings

Buildings designed and constructed before 1994 that have not been seismically mitigated are likely to be seismically deficient structures and may also include seismically deficient non-structural building components (e.g., suspended ceilings, partitions, generators).

(list all buildings from oldest to newest)	Name (if applicable)	Year Built	Size (sq ft)	Is there a basement?	Is this an expansion of another building?
Building 1:				☐Yes ☐No	N/A
Building 2:				☐Yes ☐No	☐Yes ☐No
Building 3:				☐Yes ☐No	☐Yes ☐No
Building 4:				☐Yes ☐No	☐Yes ☐No
Building 5:				☐Yes ☐No	☐Yes ☐No

☐ Are there more buildings? If yes, please add the same information for these buildings on a separate sheet.

Estimate **expected performance of structural and non-structural components** in magnitude-9 Cascadia earthquake and tsunami:

Very low	Low	Moderate	High	Very high	⇦ *Check only one number per row.*
☐1	☐2	☐3	☐4	☐5	Hospital complex
☐1	☐2	☐3	☐4	☐5	Non-structural building components (e.g., suspended ceilings, partitions, generators)

Power

Estimate the **expected performance of the hospital's emergency power system(s)** in magnitude 9 Cascadia earthquake and tsunami:

Very low	Low	Moderate	High	Very high	⇦ *Check only one number per row.*
☐1	☐2	☐3	☐4	☐5	On-site generator(s) and related control equipment and piping (i.e., is generator seismically certified?)
☐1	☐2	☐3	☐4	☐5	On-site fuel storage tanks, and related control equipment and piping

What is the name of your emergency fuel (diesel or propane) supplier?

_____

Yes	No	
☐	☐	Have you provided fuel supply requirements to the County Emergency Manager for fuel delivery in case your regular supplier cannot supply fuel during a major earthquake disaster?

Estimate the expected daily fuel consumption rate for the hospital complex in gallons (assume generators functioning at maximum capacity): _____

Yes	No	
☐	☐	Does your hospital operate with natural gas?
☐	☐	If yes, do you have a gas seismic shut off valve to your hospital complex?

Water

Estimate the **expected performance of the hospital's water system** in magnitude 9 Cascadia earthquake and tsunami:

Very low	Low	Moderate	High	Very high	⇦ *Check only one number per row.*
☐1	☐2	☐3	☐4	☐5	On-site water storage and capability for 96 hrs of sheltering
☐1	☐2	☐3	☐4	☐5	On-site water storage, control equipment, piping and capability for Hospital Operations

What is the name of your district water supplier?

_____

Yes	No	
☐	☐	Have you discussed water needs for hospital operations during a major earthquake disaster with your water district or other water suppliers?
☐	☐	Do you have a stub out to receive potable water from off-site, e.g., from a potable water truck?

Estimate the expected daily water consumption rate for the hospital complex in gallons (assume disaster mode usage): _____

Technical Training

Check box if you (or your hospital partners) are interested in obtaining State-provided training courses on:

☐	FEMA Pre- and Post-Earthquake Assessment Methods (FEMA 154/ATC 20) More at: https://www.fema.gov/national-earthquake-technical-assistance-program
☐	FEMA Earthquake Mitigation for Hospitals (FEMA P767) More at: https://www.fema.gov/media-library/assets/documents/22391
☐	Evaluation and Mitigation of Non-Structural Building Components (FEMA E-74) More at: https://www.fema.gov/fema-e-74-reducing-risks-nonstructural-earthquake-damage

Optional

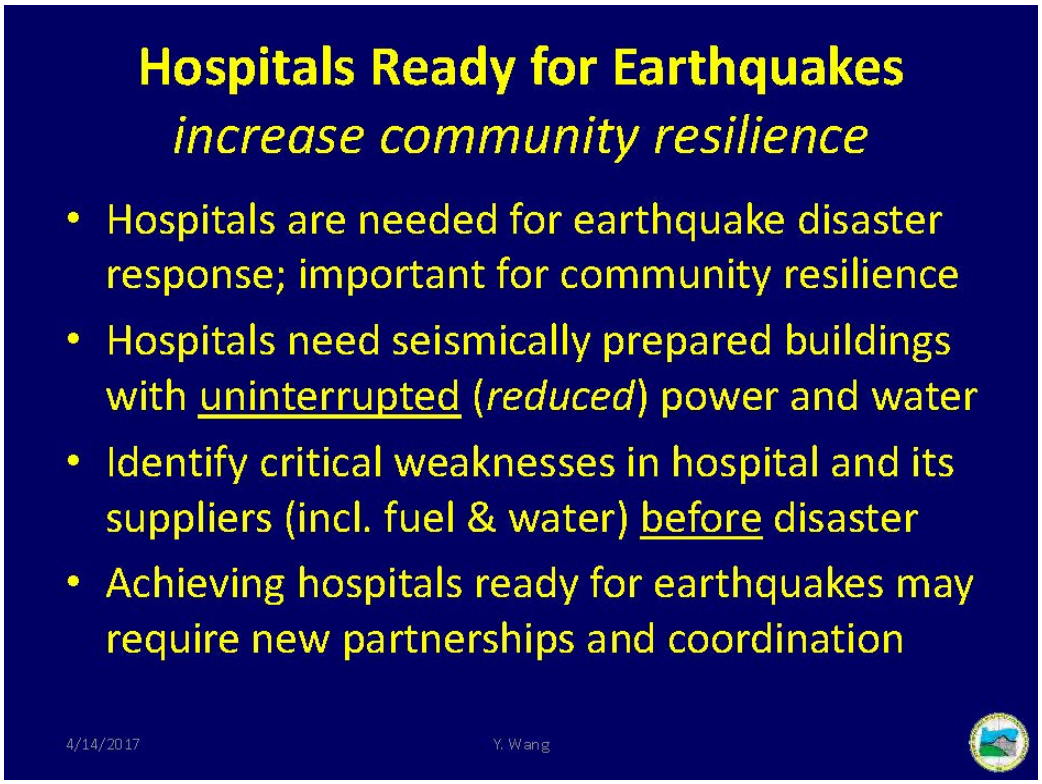
What are key strengths in your earthquake and tsunami preparedness? Please explain.

What are key weaknesses in your earthquake and tsunami preparedness? Please explain.

What type of additional technical assistance on earthquake preparedness would interest you (and your hospital partners)? Please explain.

Additional comments or questions?

9.3 Appendix C: DOGAMI Presentation at OHA Healthcare Preparedness Program Region 1



Purpose of Coastal Hospital Project

- DOGAMI to better understand "How will coastal hospitals operate after Cascadia earthquake and tsunami?"
  - Strengths, Weaknesses, Needs
- Offer technical assistance to help examine preparedness: group meeting followed by individual hospital consultative meetings
  - Discuss site information; learn about specific concerns
- Explore ways to improve expected performance of coastal hospitals after Cascadia disaster
  - Would on-site consultative meetings be helpful?
  - Meet together with water districts?

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State of Oregon's Priority is Life Safety

Coastal communities will have casualties and be isolated. Preparations to increase sustained independence is needed.

A Cascadia Subduction Zone (CSZ) event will have farther reaching impacts than that of Katrina and Sandy combined"

Quote from Ken Murphy, FEMA Region X administrator

	Cascadia	Japan Tsunami	Sandy	Katrina	Cascadia multiplier (of Sandy + Katrina)
Fatalities	12,000+	16,000	162	1,833	6x
People Needing Short-term Shelter	933,000	470,000	174,000	273,000	2x
Housing Units Damaged	961,000	>1,000,000	305,000	215,000	2x

Table from Ken Murphy, FEMA Region X administrator

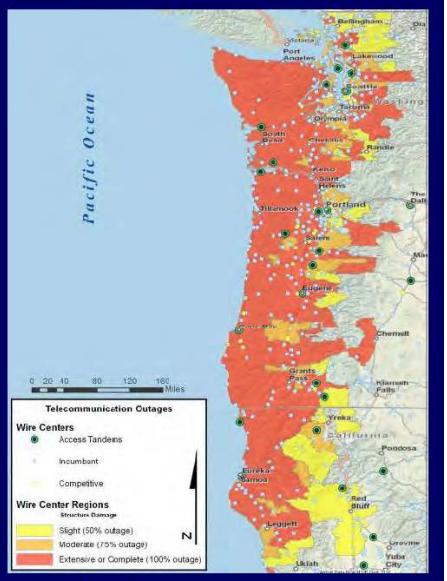
Y. Wang, DOGAMI, 2017

Cascadia: Poor Expected Performance for PNW

Increase Life Safety and Community Resilience for Estimated Cascadia EQ Impacts

Expected Damage Maps for Highways and Communications

Source: DHS FEMA 2011



Source: DHS FEMA 2011

Wang, DOGAMI, 2017

Outline

1. Oregon Resilience Plan
   - Findings: Oregon is not ready for Cascadia earthquake and tsunami
2. 11 coastal hospital project: DOGAMI technical assistance
   - Oregon hospitals: Get ready for earthquakes by 2022 (Oregon law)
   - Earthquake effects on hospitals: buildings, people, goods
     - Buildings: ***structural, non-structural, contents***
   - To operate after Cascadia earthquake, hospitals need ***fuel & water***
3. Deanna Henry, Fuel Planning, Oregon Dept of Energy
4. 2014 DOGAMI report "Hospital and Water System Earthquake Risk Evaluation"
   - Coastal hospitals need most help due to geographic "isolation"
   - Valley hospitals expected to have prolonged impacts on service
   - Hospitals impact community – requires community planning
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6. DOGAMI Technical Resources List
7. Q and A
8. Lunch / Individual hospital consultative meetings

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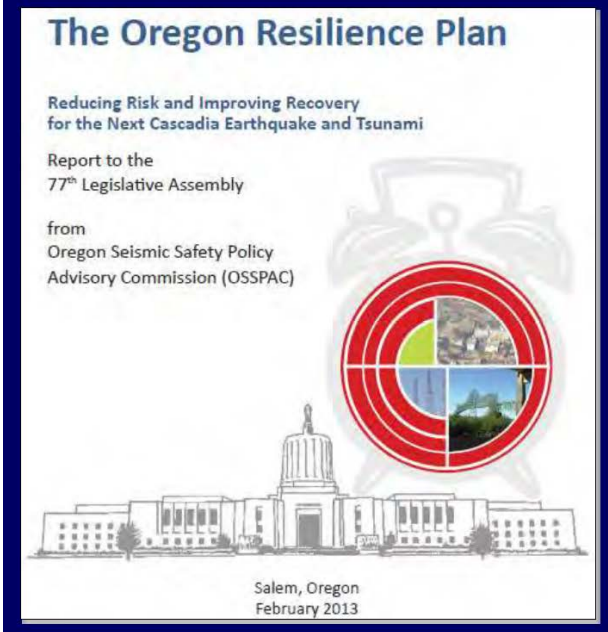
Oregon Resilience Plan

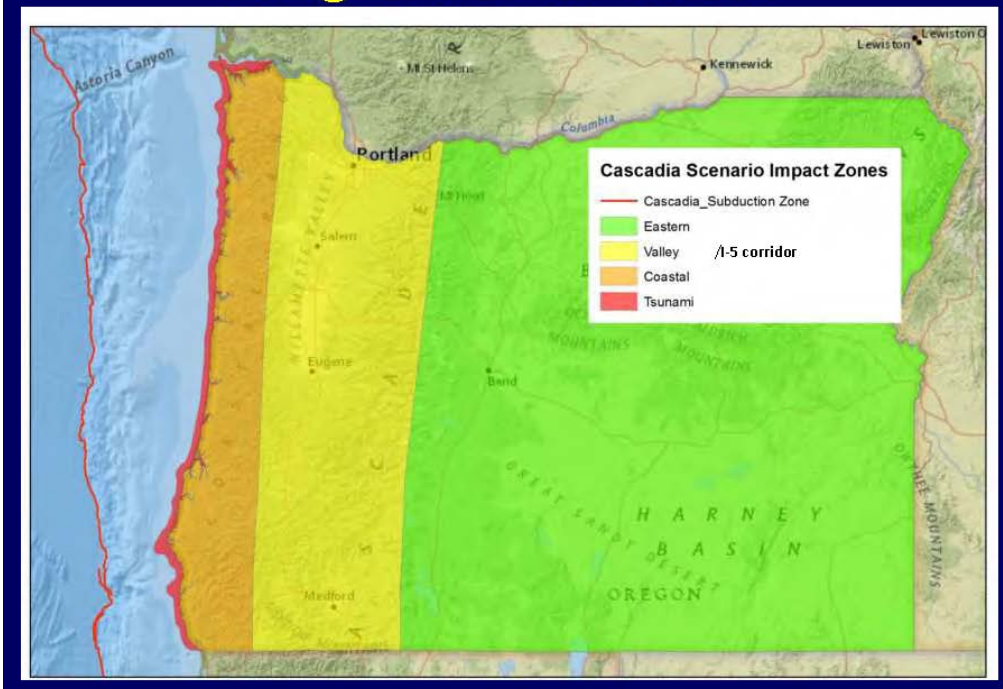


50-year Comprehensive Plan

- **Save Lives**
- **Protect our Economy**
- **Preserve our Communities**

Yumei Wang, DOGAMI, 2017

Oregon's Four Zones



Yumei Wang, DOGAMI, 2017

Current Resilience Gap

Business can only tolerate two to four weeks of disruption of essential services

Critical Service	Zone	Estimated Time to Restore Service
Electricity	Valley	1 to 3 months
Electricity	Coast	3 to 6 months
Police and fire stations	Valley	2 to 4 months
Drinking water and sewer	Valley	1 month to 1 year
Drinking water and sewer	Coast	1 to 3 years
Top-priority highways (partial restoration)	Valley	6 to 12 months
Healthcare facilities	Valley	18 months
Healthcare facilities	Coast	3 years

Yumei Wang, DOGAMI, 2017

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Source: DOGAMI

11 Coastal Hospitals Technical Assistance

1. Columbia Memorial, Astoria (Tsunami XL)*
2. Providence Seaside, Seaside (Tsunami M)*
3. Tillamook Regional, Tillamook (Tsunami L)*
4. Samaritan North Lincoln, Lincoln City
5. Samaritan Pacific Communities, Newport
6. PeaceHealth Peace Harbor, Florence
7. Lower Umpqua Hospital, Reedsport
8. Bay Area Hospital, Coos Bay
9. Coquille Valley, Coquille
10. Southern Coos Hospital and Health Center, Bandon
11. Curry General, Gold Beach (Tsunami L)*

*TSUNAMI ZONE:
Seismically hardened
egress for safe evacuation

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Cascadia Earthquake and Tsunami

- Earthquake- and tsunami-related casualties
- Impacts to hospital, people & goods (supply chain)
- Disruption to utilities & roads to hospitals

- To provide service, prepare to operate "off the grid" for many weeks to many months
  - No electricity so need reliable power. **Fuel** for generator
  - No water so need reliable potable **water** sources

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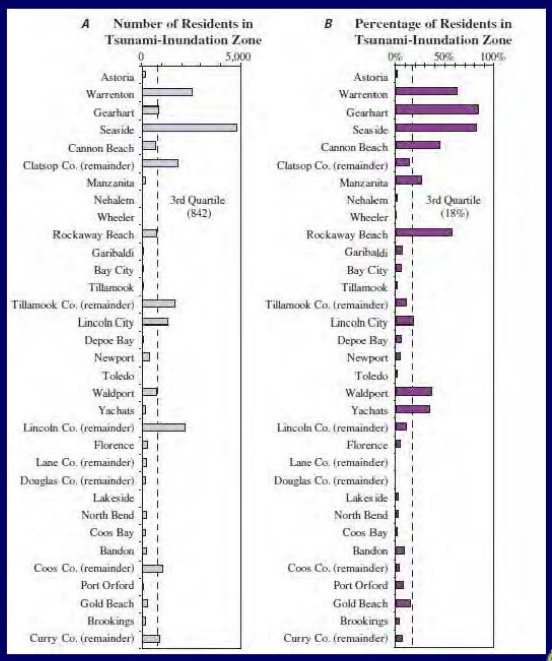
Oregon Tsunami Exposure >20,000 people



(Source: Nate Wood/2007, USGS)

Yumei Wang, DOGAMI, 2017

ODOT Seismic Lifeline Routes

HPP Region 1
Coastal Bridges

Source: DOGAMI

Source: ODOT Seismic Lifeline Routes (2012)

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Hospital Building: Structural Integrity

Must design to tolerate earthquake (sideways) shaking.
ASCE 41 standard-of-practice engineering evaluation method

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Source: Wikipedia. Photo by Gary B. Edstrom. See 2014 DOGAMI report

2007 DOGAMI Statewide Assessment

Rapid Visual Screening (RVS) Method

- RVS Purpose is to identify:
  - Older buildings (when building codes deficient)
  - Buildings on poor soils
  - Buildings having performance characteristics that negatively influence their seismic response

Five Key Factors Drive Building *Collapse*[1] Potential

1. **Seismicity Zone** (USGS Ground Motion, %g)
2. **Building Structural Type** (15 FEMA possibilities)
3. **Building Irregularities** (Plan and Vertical)
4. **Original Construction Date** (vs. Building Codes)
5. **Soil Type** (A to F; amplify motion up to 10x)

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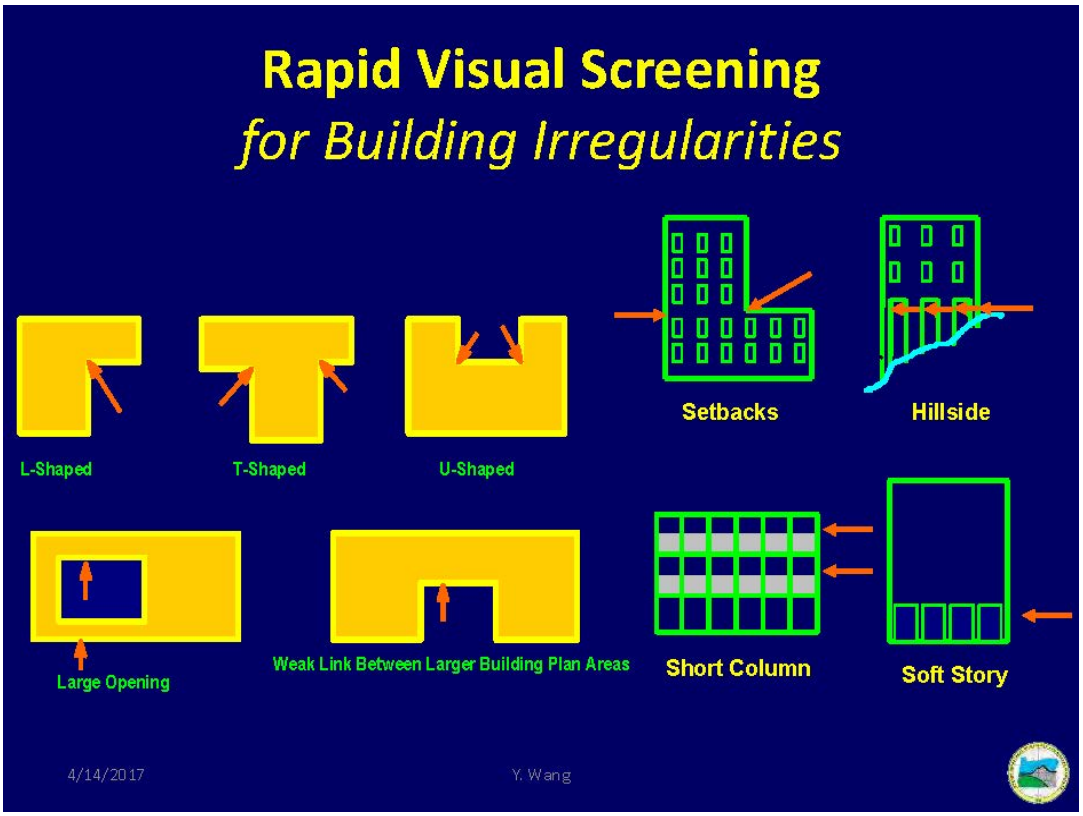
Rapid Visual Screening
for Building Irregularities
L-Shaped
T-Shaped
U-Shaped
Setbacks
Hillside
Large Opening
Weak Link Between Larger Building Plan Areas
Short Column
Soft Story
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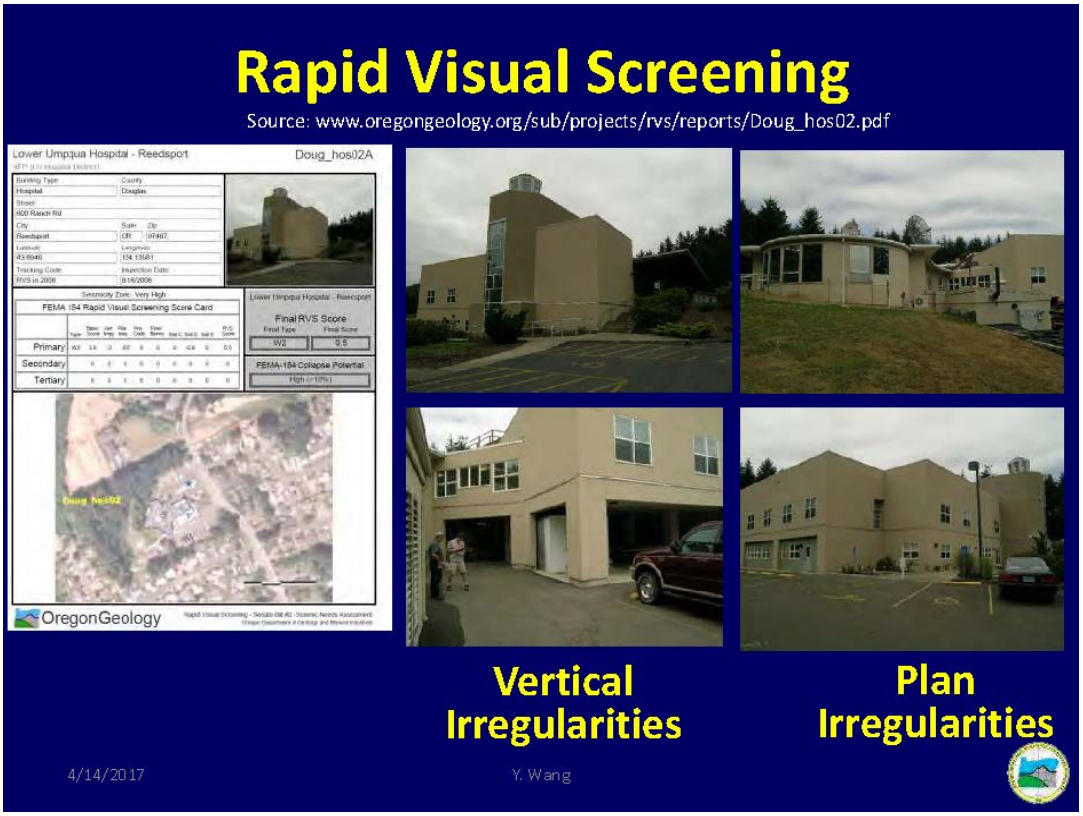
Rapid Visual Screening
Source: www.oregongeology.org/sub/projects/rvs/reports/Doug_hos02.pdf
Lower Umpqua Hospital - Reedsport
Doug_hos02A
FEMA 154 Rapid Visual Screening Score Card
Final RVS Score
W2
0.5
FEMA-154 Collapse Potential
OregonGeology
Vertical Irregularities
Plan Irregularities
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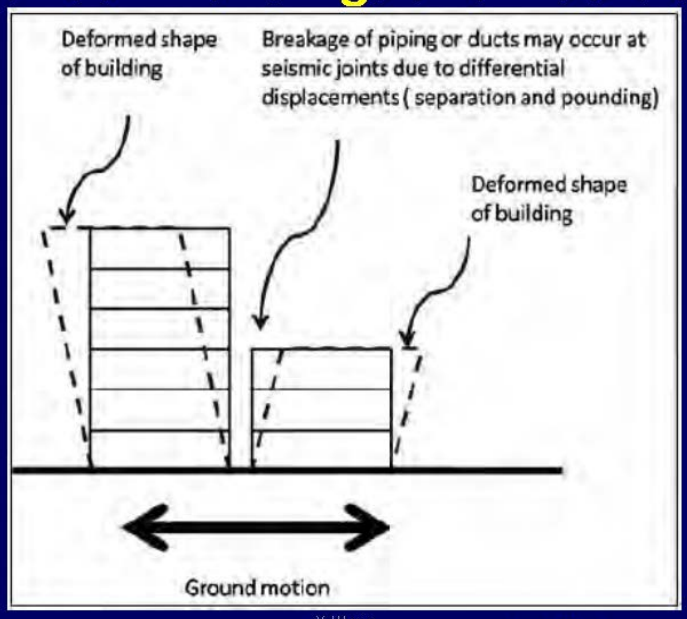
Seismically Designed Separations *between* Buildings and Additions



4/14/2017 Y. Wang Source: FEMA 74

Good Design Between Buildings

Seismic gap between buildings and flexible piping

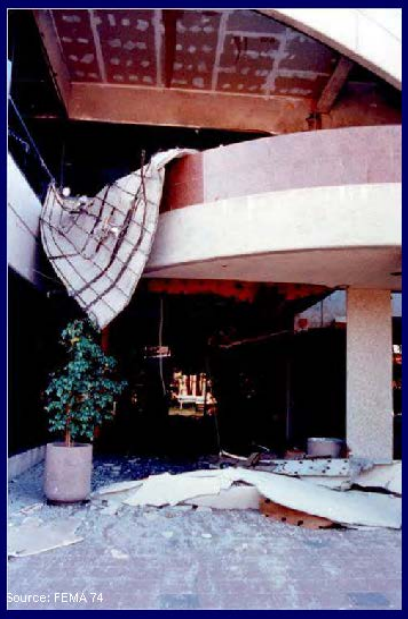
4/14/2017 Source: DOGAMI Y. Wang

Source: DOGAMI. Photo by Deanna Henry

Non-Structural Elements: DAMAGE

(see FEMA 74 reference document)

Source: FEMA 74



Source: FEMA 74

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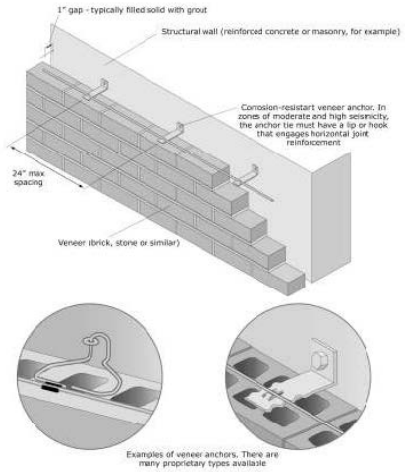
Non-Structural Elements

FEMA 74 reference document

Source: FEMA 74



4/14/2017 Y. Wang Source: FEMA 74

Non-Structural Elements

4/14/2017 Y. Wang

Non-Structural Elements

4/14/2017 Y. Wang

Non-Structural Elements: Damage

Source: FEMA 74

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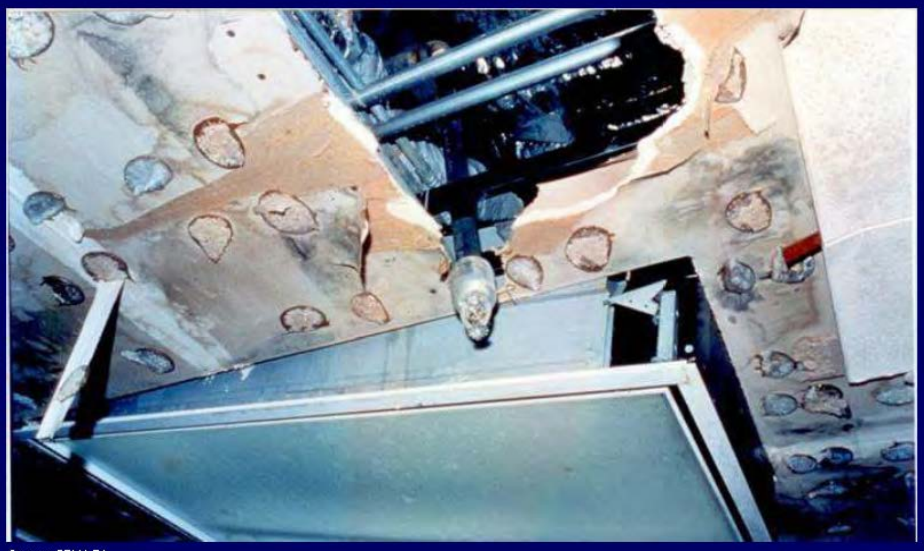
Non-Structural: Broken Sprinkler Pipe

at Olive View Hospital in 1994 Northridge Earthquake.
Pipe ruptured at elbow joint due to differential motion of pipe and ceiling



Source: FEMA 74

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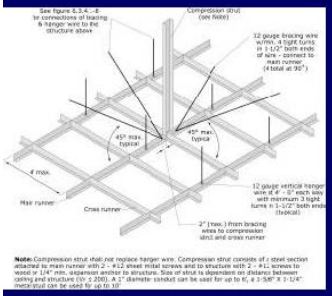
Non-Structural Elements

FEMA 74 reference document

Compression struts and diagonal splayed wires limit movement of suspended ceilings (ASTM E580)



Source: FEMA 74

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Non-Structural Damage

Anchorage & Bracing

Tanks at hospitals in 1994 Northridge EQ

Source: FEMA 74

4/14/2017 Source: FEMA 74 Y. Wang

Anchorage and Bracing
Medical Gas

Bad Example

Source: DOGAMI

Source: DOGAMI

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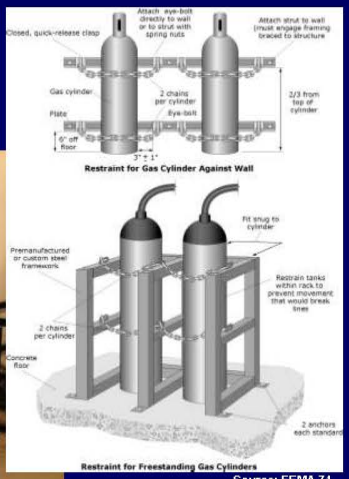
Anchorage and Bracing
Medical Gas

Bad Example

Source: DOGAMI

Good Example

Source: FEMA 74



Source: FEMA 74

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Non-Structural Damage

Anchorage and Bracing

Failure of compressor mounted on vibration isolators in 1994 Northridge earthquake

Source: FEMA 74

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Supplies Can Fall: Coastal Hospital

Source: DOGAMI

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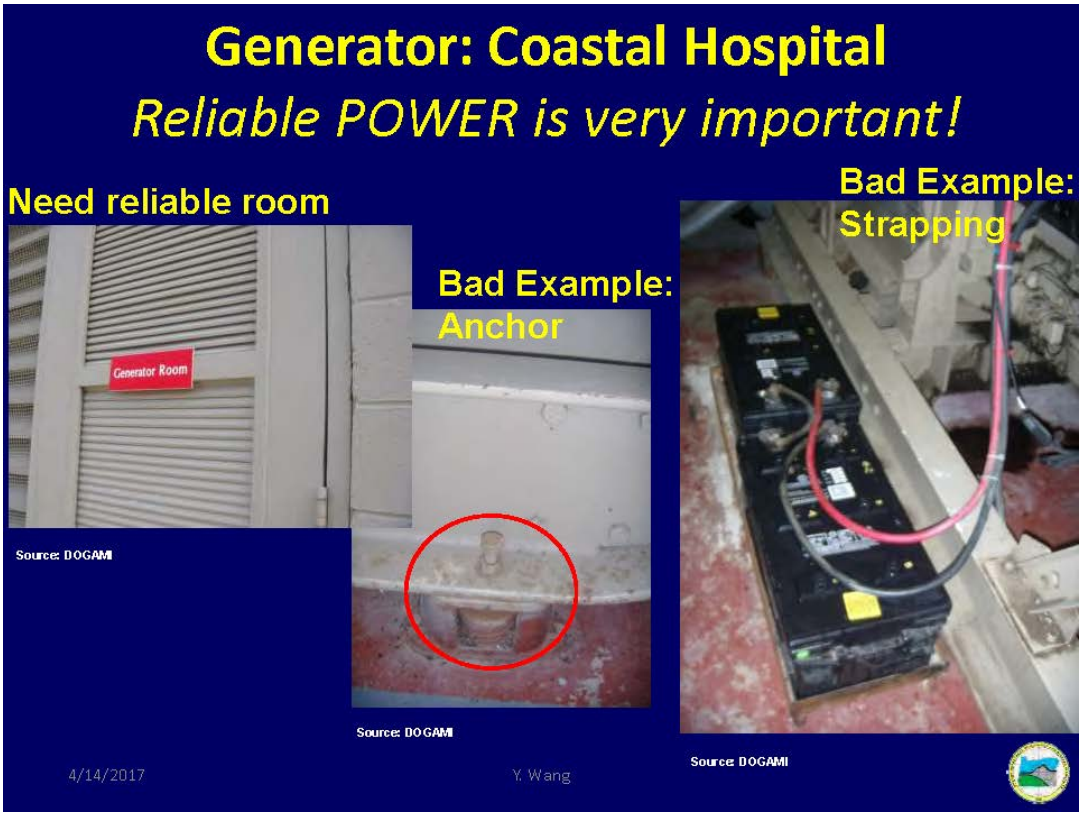
Generator: Coastal Hospital
Reliable POWER is very important!
Need reliable room
Generator Room
Source: DOGAMI
Bad Example: Anchor
Source: DOGAMI
Bad Example: Strapping
Source: DOGAMI
4/14/2017
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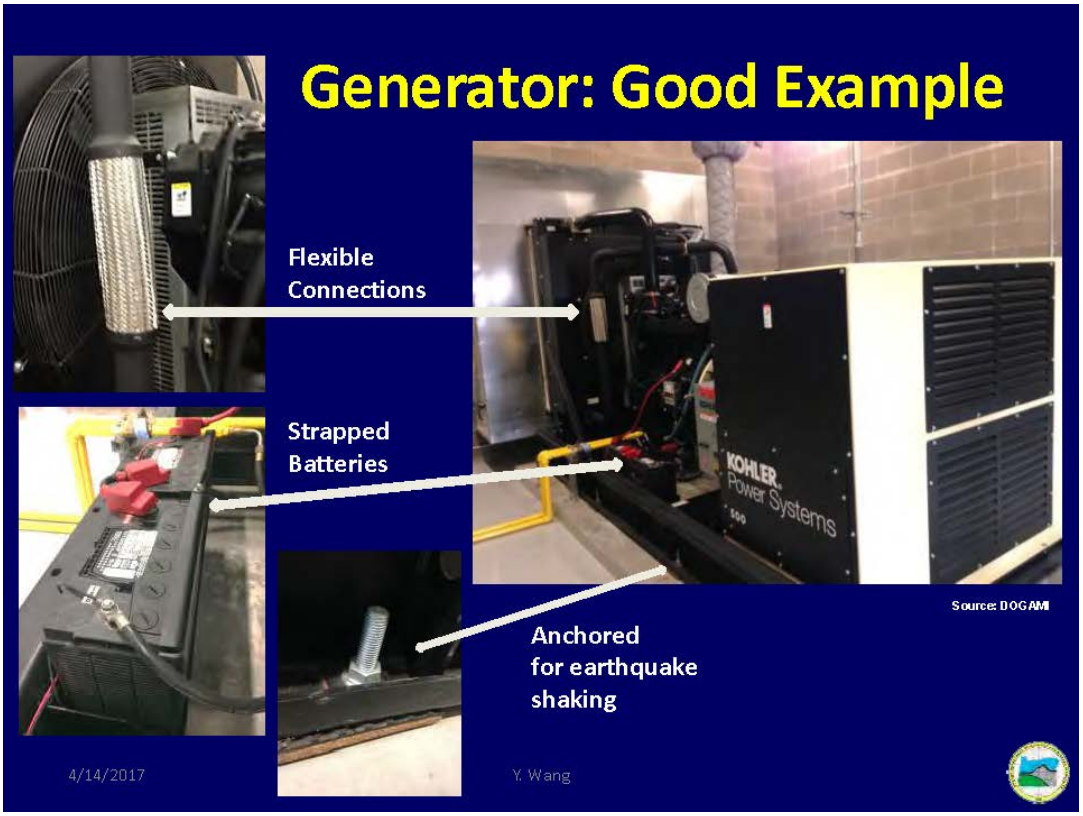
Generator: Good Example
Flexible Connections
Strapped Batteries
Anchored for earthquake shaking
KOHLER. Power Systems
Source: DOGAMI
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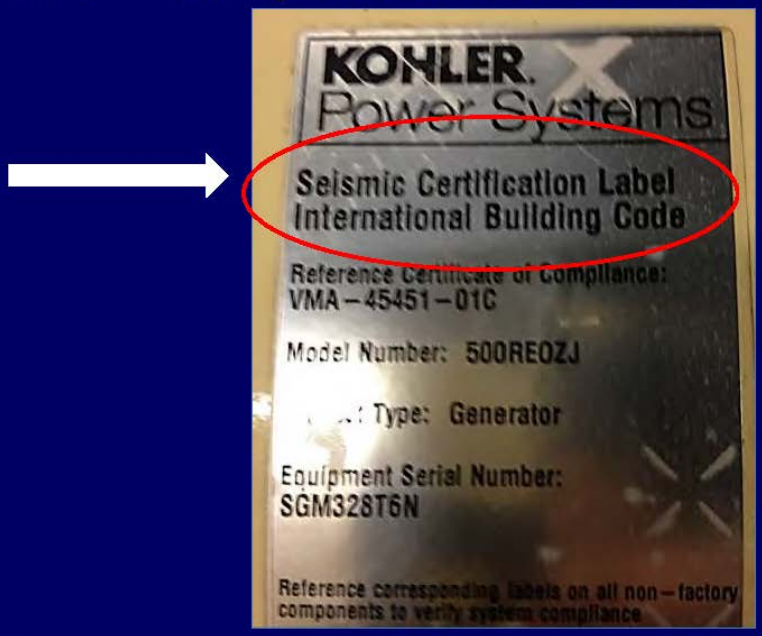
Seismically Certified Generator!



4/14/2017 Y. Wang Source: DOGAMI

Fuel Tank (5,000 gal)

Flexible Connections

Source: DOGAMI

Source: DOGAMI

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Fuel Oil Day Tank

Source: DOGAMI

Source: DOGAMI

Source: DOGAMI

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Plan for Emergency Fuel
with no interruption in supply

Coordinate among hospital, local suppliers, co. emergency manager and ODOE

On-site tanks; local "card lock" fuel facilities (lower visibility); fuel trucks, generators and pumps; county fuel points of distribution; what are alternative power options?

Source: DOGAMI

Source: DOGAMI

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Planning for Emergency Water

Hospital storage tanks, local water district (surface or ground water?), alternative suppliers, and local emergency managers

What is normal water usage? How much is needed during prolonged disaster?
Does water district part of ORWARN (Oregon Water/Waste Water Agency Response Network)?

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Generator: Coastal Water Treatment Plant

Bad Example:
Only spring
mounted

Source: DOGAMI

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Y. Wang

Water Supply Chain

Source: DOGAMI

Source: DOGAMI

Source: DOGAMI

Source: DOGAMI

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In Town Reservoir (Tank)

Source: DOGAMI

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Ground-to-Building Connections

Bad Example

Bad Example

Source: Portland Water Bureau

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DAMAGED

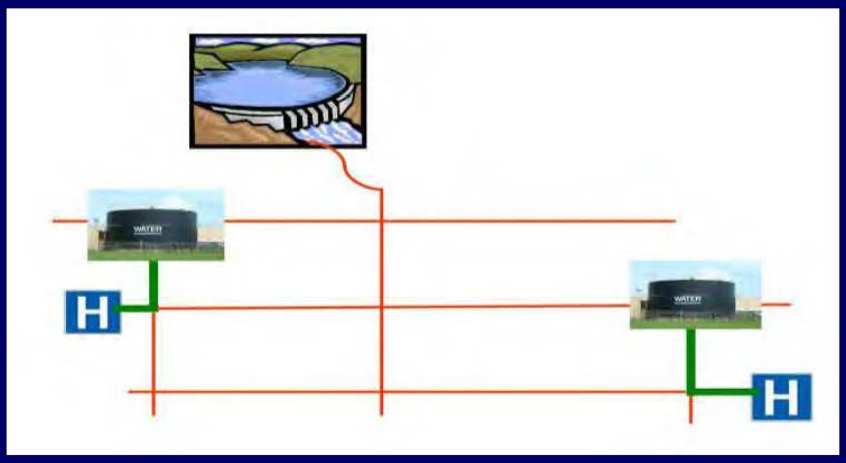
Source: TCLEE member

Good Example: Flexible connection

Source: FEMA 74

Incremental Mitigation Strategy for Critical Lifeline Systems

Strengthen Portion of the System, e.g, Closest Water Tank and Piping to Hospitals



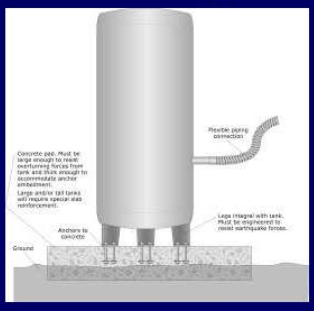
Source: Y.Wang, DOGAMI

Y. Wang , DOGAMI, 2017

Seismic Design for Entire Pathway

- Seismically Designed Tank *(AWWA D100)*
- Seismic Shut Off Valve
- Flexible Connection to Tank
- Ductile Water Pipe for Entire Path (esp river crossings)
- Flexible Connection at Hospital

Entire water system can drain during earthquakes!



Flexible Connections to Tank

4/14/2017 Source: FEMA 74 Y. Wang

Increase On-Site Water Storage at Hospital

Source: DOGAMI

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EVERYONE Needs Water

Emergency Distribution to Communities

Source: TCLEE team

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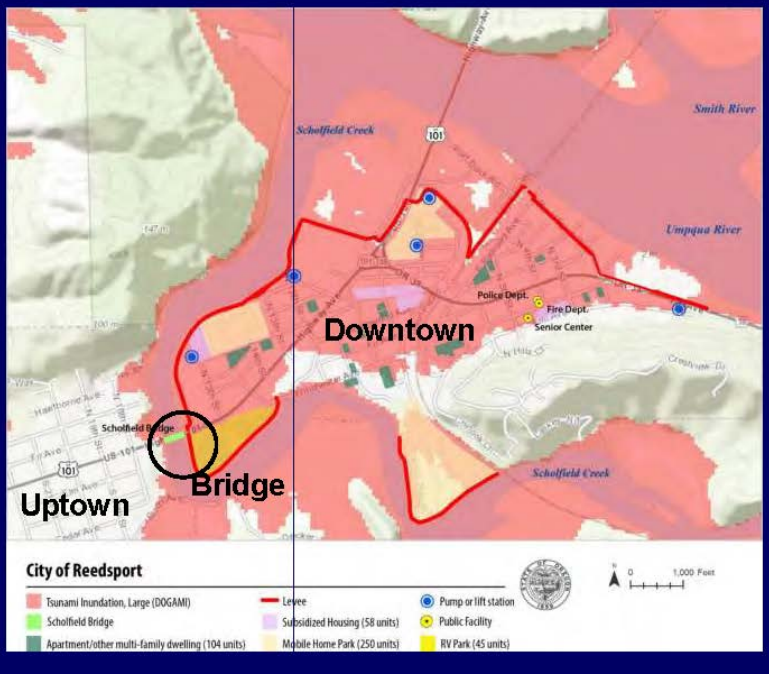
Reedsport: A Closer Look



Source: DAS CFO

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Reedsport: Critically Important Bridge

links Downtown to Uptown
and carries water transmission main

Source: City of Reedsport

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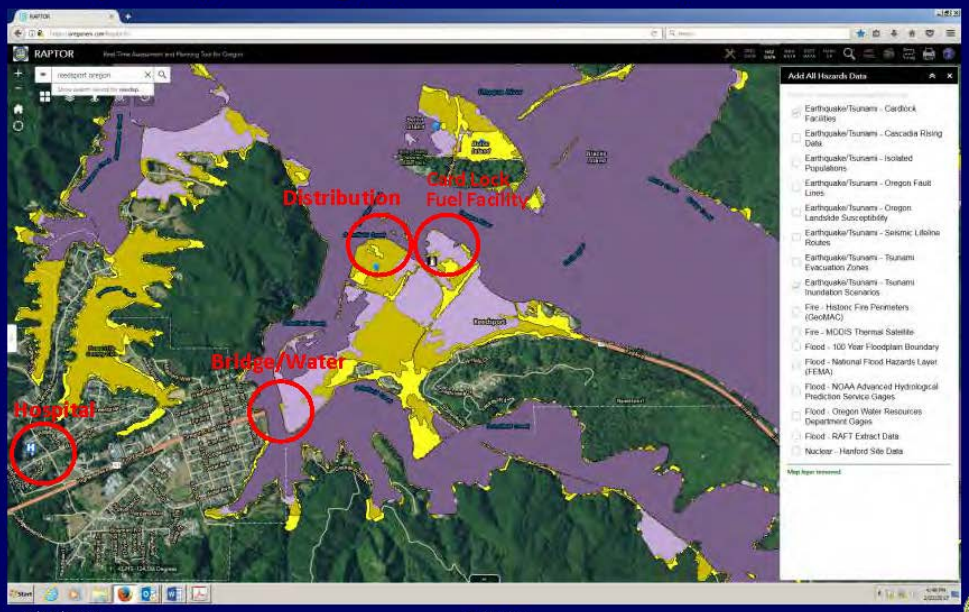
OEM's RAPTOR Planning Tool

Hospital, Bridge/Water, Fuel, Distribution



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Source: DOGAMI

New Buried Water Main, Lincoln City

Abandoned water pipe

Can't see new buried water pipe

Source: DOGAMI

4/14/2017 Y. Wang

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Hospital and Water System Earthquake Risk Evaluation Pilot Project by DOGAMI

2014 Report on OHA webpage:
public.health.oregon.gov/Preparedness/Prepare/Pages/PrepareForEarthquake.aspx

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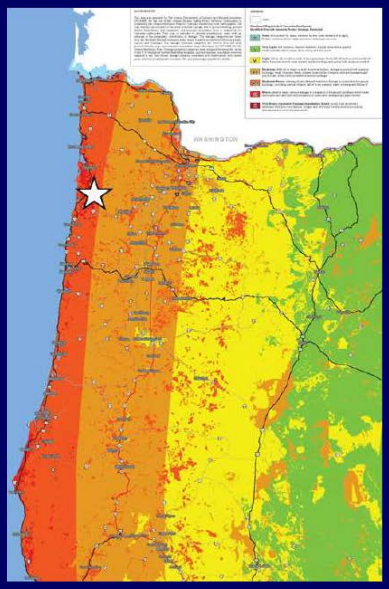
Oregon's Earthquake Hazards



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Damage to Hospitals and Water Systems

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OHA Pilot Study Area

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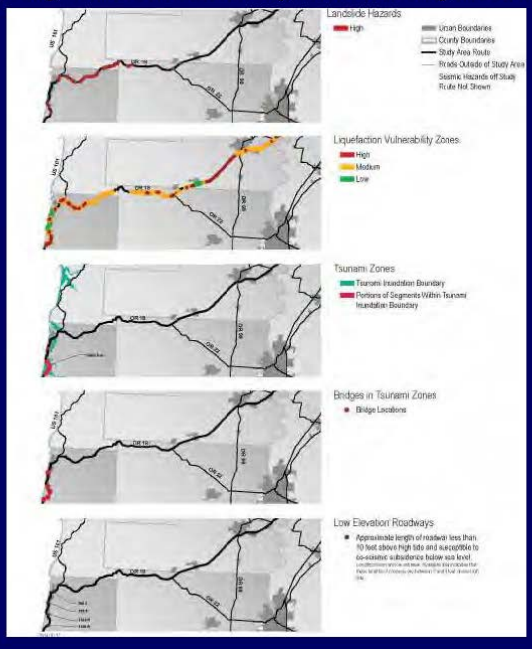
Hazards: Landslides, Liquefaction, Tsunami, Bridges/Tsunamis, Roads/Tsunamis



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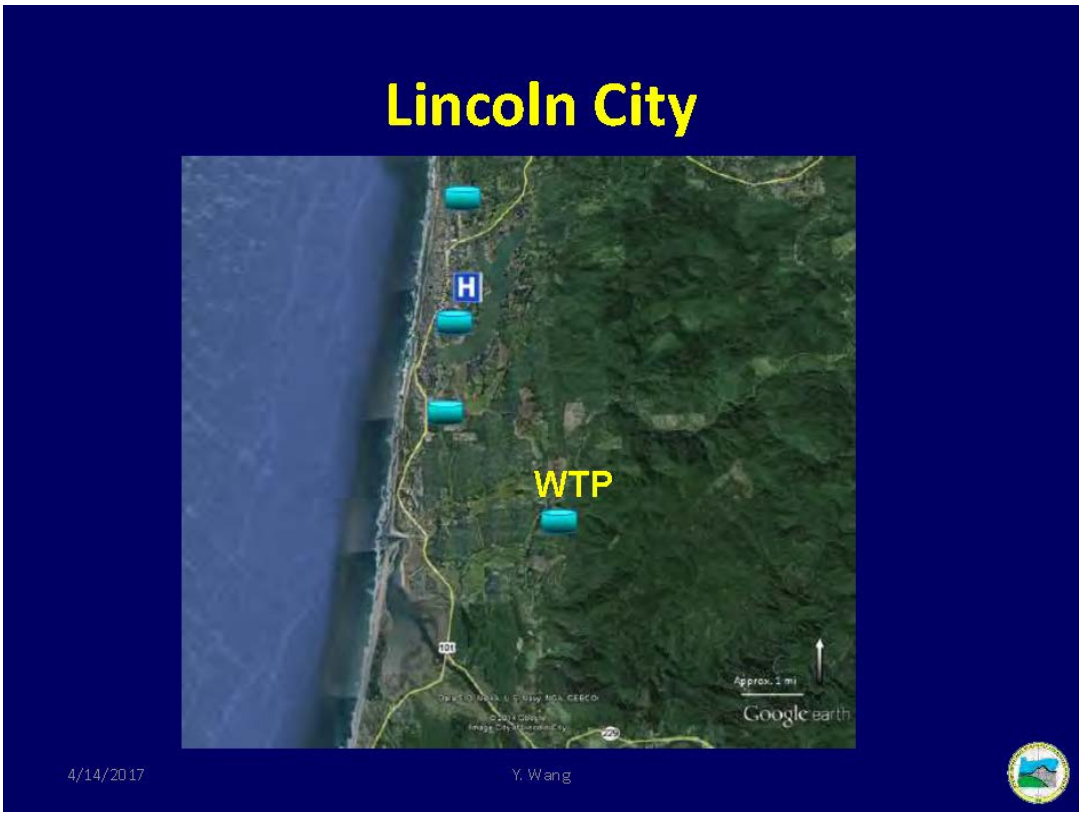
Lincoln City
H
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Approx. 1 mi
Google earth
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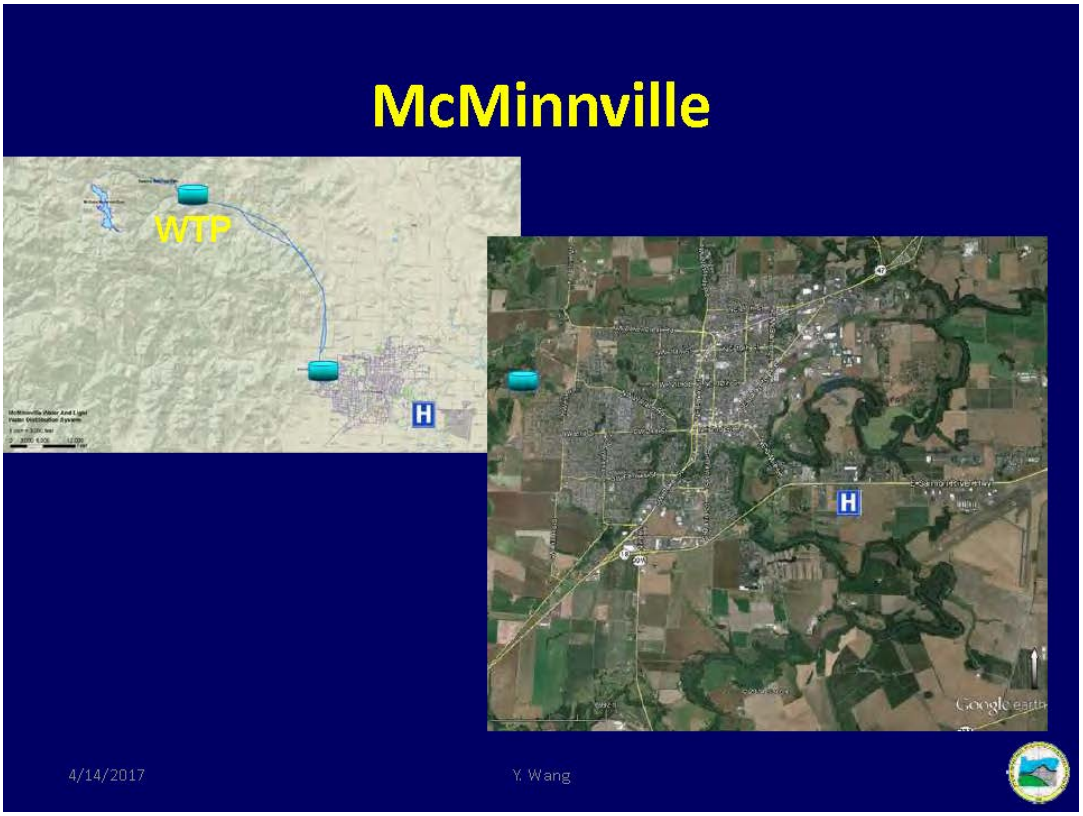
McMinnville
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Lincoln City Hospital

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McMinnville Hospital

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Lincoln City Water System

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McMinnville Water System

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Transportation
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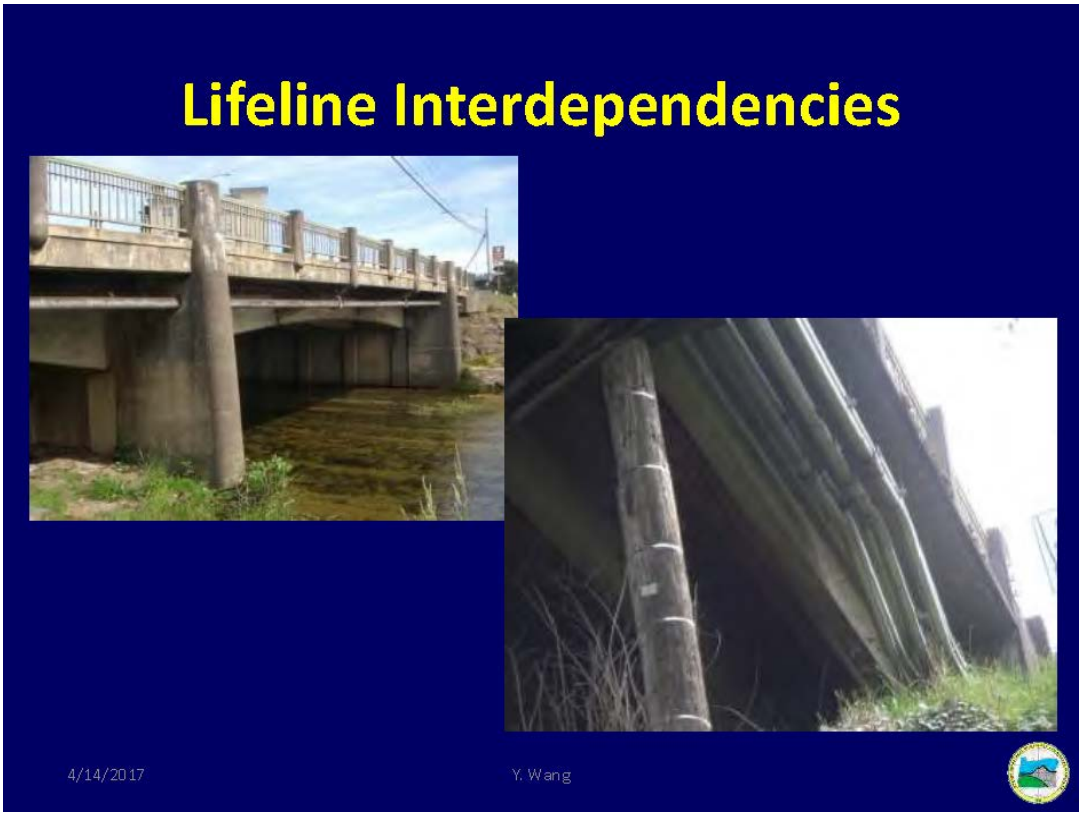
Lifeline Interdependencies
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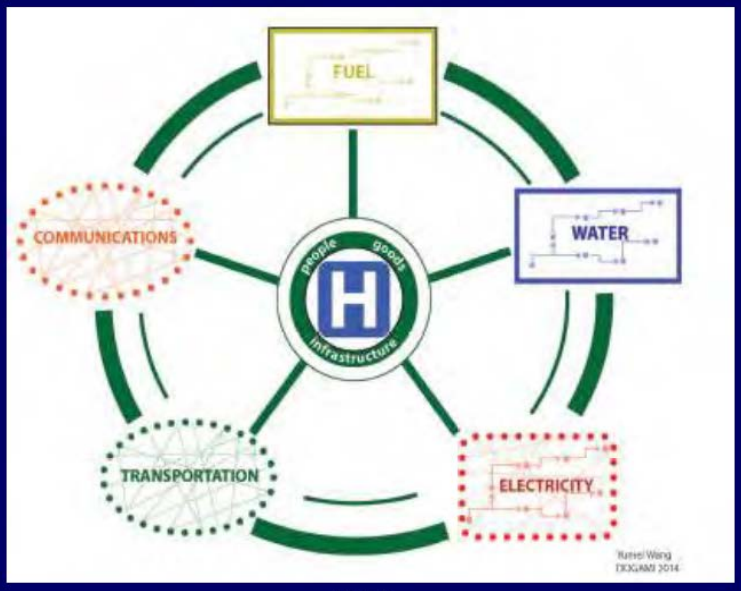
Hospital Lifeline Interdependencies

Normal Conditions



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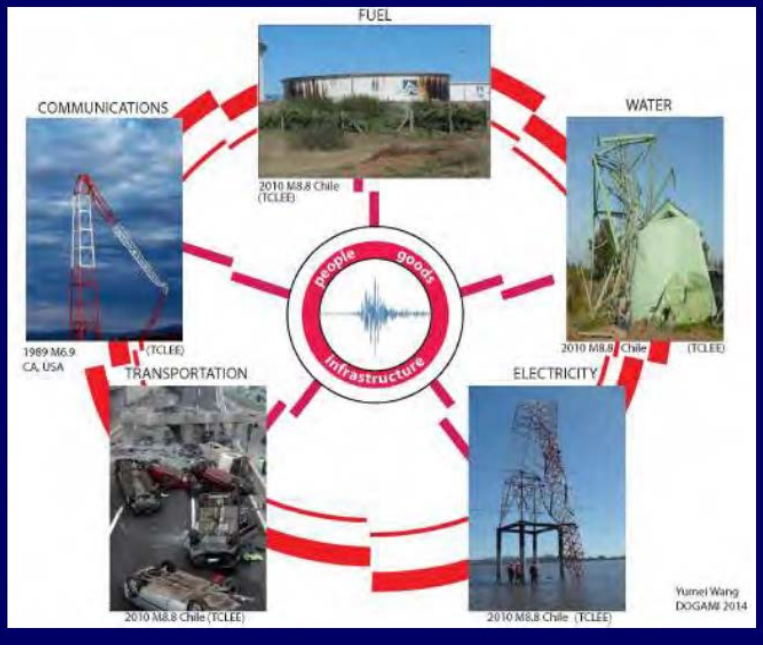
Hospital Lifeline Interdependencies

Disaster Conditions



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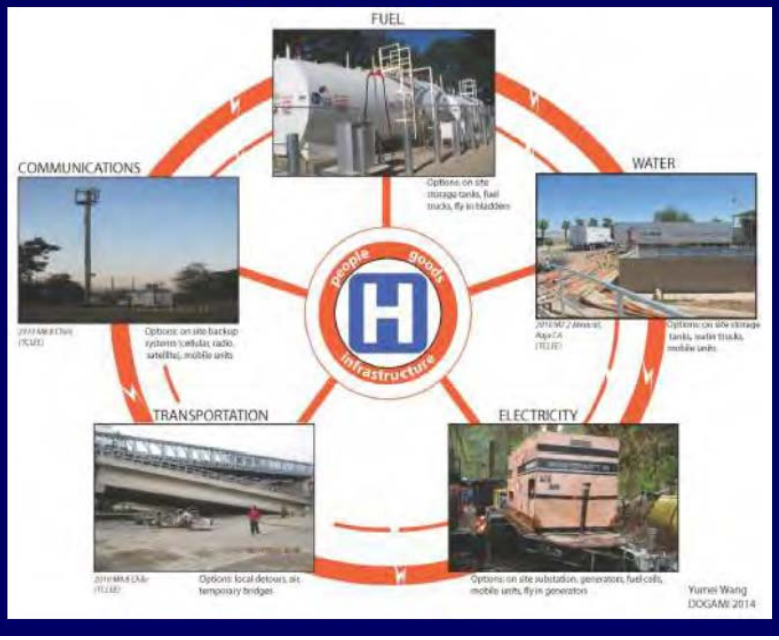
Hospital Lifeline Interdependencies

Emergency Operations



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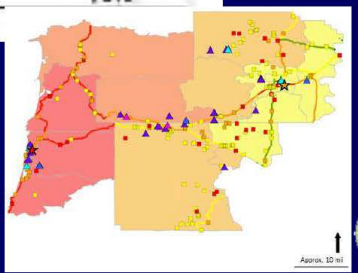
Computer Model HAZUS Results

Estimates of probability of at least moderate damage and level of functionality in hospitals after a major Cascadia earthquake

	Lincoln City Hospital	McMinnville Hospital: Two Taller Buildings	McMinnville Hospital: Shorter Building
Probability of at least moderate damage from a major Cascadia earthquake	90%	63%	38%
Estimated level of functionality* by bed count			
Day 1 and Day 3	2%	14%	43%
Day 7 and Day 14	10%	36%	61%
Day 30	42%	73%	77%
Day 90	52%	76%	79%

*Does not take into account water system functionality.



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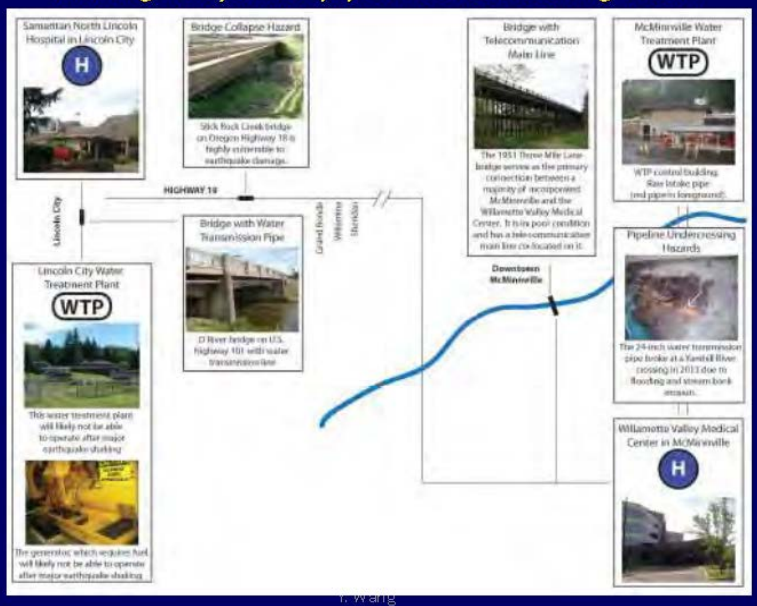
Lincoln Hospital Interdependencies:

relies on people, hospital infrastructure and supplies, and fuel, water, electricity, transportation and communications

Critical Facilities and Pathways

2 hospitals, 2 water treatment plants, and highways and pipelines connecting them



Resilience Triangle

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Resilience Planning Concepts

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Conclusions (page 1 of 4)

Hospitals are important community safety nets in disasters.
Hospitals therefore require a high level of *resilience* — they should be built and operated to sustain ***limited damage***, have ***reliable emergency methods*** to operate immediately after major earthquakes, and ***recover efficiently*** to provide services

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Conclusions (page 2 of 4)

Hospitals significant damage. Bed shortages > 90 days after Cascadia earthquake.

Hospitals severe reductions in functionality due to lifeline damage. Damage to local water systems and transportation network will slow response and recovery of hospitals, and hospital services for community members will be impaired.

Bridges significant damage. Bridge damage will limit movement of staff and injured community members as well as supplies such as potable water, gasses, and medications to and from hospitals.

Water systems have seismic vulnerabilities and complex lifelines dependencies and are expected to incur severe reductions in functionality after Cascadia earthquake. Water service to hospitals using normal water pipeline distribution system is expected to be down for weeks to months.

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Conclusions (page 3 of 4)

Lincoln City hospital: due to its proximity to Cascadia will slowly recover to operate at about 52% bed capacity in 90 days. A number of bridges that connect community and hospital, including bridges crossing Siletz River, are expected to incur major damage and impede citizen access to hospital complex.

McMinnville hospital: modern seismic structural engineering, design, and construction. Severe reduction in function and recover to about 76% bed capacity in 90 days. A number of bridges that connect community and hospital, including Three Mile Lane bridge and nearby Highway 18 bridges west of hospital complex, are expected to incur major damage and impede citizen access.

Transportation route between Lincoln City and McMinnville will be impassable immediately after Cascadia. Impede coastal community members from accessing inland hospitals.

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Conclusions (page 4 of 4)

DOGAMI and OHA communications to project partners and site visits to hospitals and water facilities helped to increase seismic awareness and encourage mitigation actions.

Hospitals should coordinate with lifeline owners, including local water and transportation districts, to improve hospital resilience.

Community resilience, including reliable hospital services in earthquake disasters, requires hospitals, lifeline owners, and other partners to conduct resilience planning in order to better protect citizens on a local and regional scale.

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Outline

1. Oregon Resilience Plan
   - Findings: Oregon is not ready for Cascadia earthquake and tsunami
2. 11 coastal hospital project: DOGAMI technical assistance
   - Oregon hospitals: Get ready for earthquakes by 2022 (Oregon law)
   - Earthquake effects on hospitals: buildings, people, goods
     - Buildings: ***structural, non-structural, contents***
   - To operate after Cascadia earthquake, hospitals need ***fuel and water***
3. Deanna Henry, Fuel Planning, Oregon Dept of Energy
4. 2014 DOGAMI report "Hospital and Water System Earthquake Risk Evaluation"
   - Coastal hospitals need most help due to geographic "isolation"
   - Valley hospitals expected to have prolonged impacts on service
   - Hospitals impact community -- requires community planning
5. **DOGAMI Earthquake Preparedness Survey ←**
6. **DOGAMI Technical Resources List ←**
7. Q and A
8. Lunch / Individual hospital consultative meetings

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DOGAMI Earthquake Preparedness Survey

Buildings ● Power ● Water ● Training

DOGAMI Earthquake Preparedness Survey
Request for Information from Coastal Hospitals

Hello! DOGAMI is requesting information from Oregon's coastal hospitals to better understand the state's level of earthquake preparedness and how to provide improved technical assistance. Please complete this DOGAMI Earthquake Preparedness Survey with the best available information and send to Yumei Wang by April 28, 2017. Questions? Email Yumei.Wang@oregon.gov or call 971-673-1551. See the DOGAMI Technical Resource List for more information.

Earthquake Preparedness of Oregon Hospitals
In 2001, the Oregon Legislature passed a law requiring hospitals to be prepared by 2022 to operate after major earthquakes. To better understand the state's seismic vulnerabilities of schools and emergency service buildings, including hospitals, in 2007 DOGAMI conducted rapid visual screenings (RVS) using FEMA methods. Since 2009, Oregon's seismic rehabilitation grant program (SRGP) has provided up to $1.5 million to mitigate eligible buildings, including hospitals.

Survey Questions

Hospital Name

Hospital Location (City) _____

Hospital Point of Contact for this Survey (name, position, phone, and email):

_____

Yes	No	
☐	☐	Are you aware of the 2022 deadline for hospitals to be prepared for major earthquakes?
☐	☐	Does your hospital have funding for seismic evaluations and, if needed, mitigation?
☐	☐	Has your hospital applied for an Oregon Seismic Rehabilitation Program grant?
☐	☐	Does your hospital plan to apply for a grant in the next 2 years?

Buildings
Buildings designed and constructed before 1994 that have not been seismically mitigated are likely to be seismically deficient structures and may also include seismically deficient non-structural building components (e.g., suspended ceilings, partitions, generators).

List all buildings from oldest to newest)	Name (if applicable)	Year Built	Size (sq ft)	Is there a basement?	Is this an expansion of another building?
Building 1:				☐Yes ☐No	N/A
Building 2:				☐Yes ☐No	☐Yes ☐No
Building 3:				☐Yes ☐No	☐Yes ☐No
Building 4:				☐Yes ☐No	☐Yes ☐No
Building 5:				☐Yes ☐No	☐Yes ☐No

☐ Are there more buildings? If yes, please add the same information for these buildings on a separate sheet.

Estimate expected performance of structural and non-structural components in magnitude-9 Cascadia earthquake and tsunami:

Very low	Low	Moderate	High	Very high	← *Check only one number per row.*
☐1	☐2	☐3	☐4	☐5	Hospital complex
☐1	☐2	☐3	☐4	☐5	Non-structural building components (e.g., suspended ceilings, partitions, generators)

Power
Estimate the expected performance of the hospital's emergency power system(s) in magnitude-9 Cascadia earthquake and tsunami:

Very low	Low	Moderate	High	Very high	← *Check only one number per row.*
☐1	☐2	☐3	☐4	☐5	On-site generator(s) and related control equipment and piping (i.e., is generator seismically certified?)
☐1	☐2	☐3	☐4	☐5	On-site fuel storage tanks, and related control equipment and piping

What is the name of your emergency fuel (diesel or propane) supplier?

_____

yes	no	
☐	☐	Have you provided fuel supply requirements to the County Emergency Manager for fuel delivery in case your regular supplier can not supply fuel during a major earthquake disaster?

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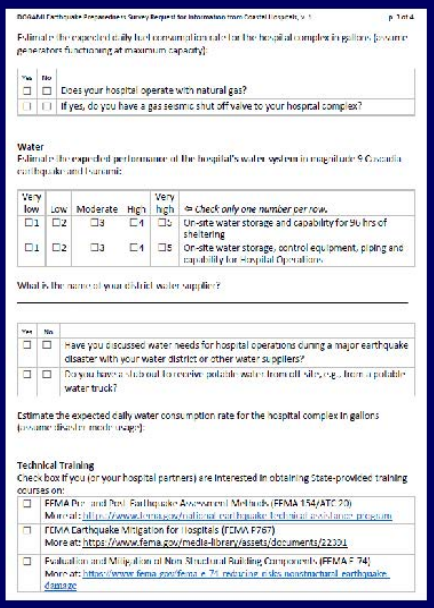
DOGAMI Earthquake Preparedness Survey

Buildings ● Power ● Water ● Training

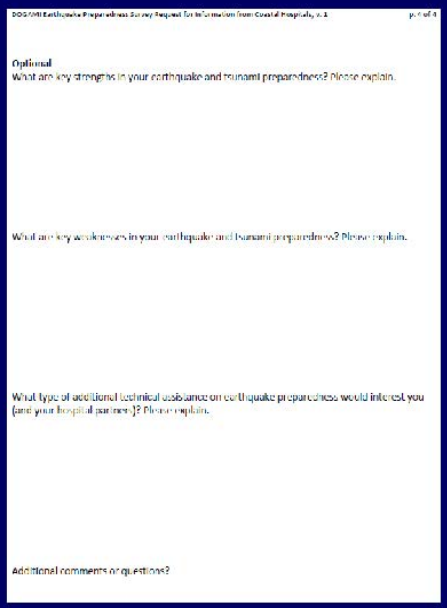


Estimate the expected daily water consumption rate for the hospital complex in gallons (assume disaster mode usage):

Technical Training

Check box if you (or your hospital partners) are interested in obtaining State-provided training courses on:

☐	FEMA Pre- and Post- Earthquake Assessment Methods (FEMA 154/ATC 20) More at: http://www.fema.gov/national-earthquake-technical-assistance-program
☐	FEMA Earthquake Mitigation for Hospitals (FEMA P767) More at: https://www.fema.gov/media-library/assets/documents/22331
☐	Evaluation and Mitigation of Non-Structural Building Components (FEMA E-74) More at: https://www.fema.gov/fema-e-74-reducing-risks-nonstructural-earthquake-damage



Optional

What are key strengths in your earthquake and tsunami preparedness? Please explain.

What are key weaknesses in your earthquake and tsunami preparedness? Please explain.

What type of additional technical assistance on earthquake preparedness would interest you (and your hospital partners)? Please explain.

Additional comments or questions?

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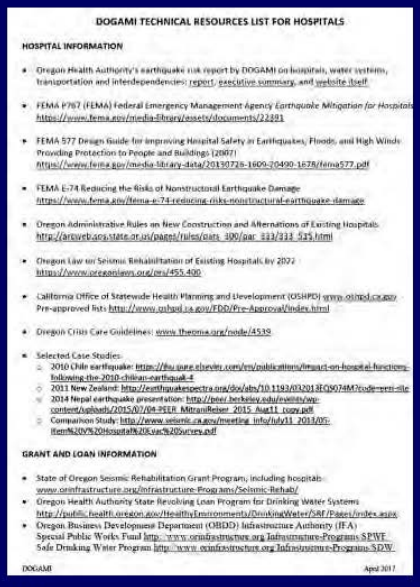
Technical Resources List for Coastal Hospitals

Hospital ● Financing ● Planning ● DOGAMI



DOGAMI TECHNICAL RESOURCES LIST FOR HOSPITALS

HOSPITAL INFORMATION

- Oregon Health Authority's earthquake risk report by DOGAMI on hospitals, water systems, transportation and interdependencies: report, executive summary, and website itself
- FEMA P767 (FEMA) Federal Emergency Management Agency *Earthquake Mitigation for Hospitals* https://www.fema.gov/media-library/assets/documents/22331
- FEMA 577 Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings (2007) https://www.fema.gov/media-library-data/20130726-1609-20490-1678/fema577.pdf
- FEMA E-74 Reducing the Risks of Nonstructural Earthquake Damage https://www.fema.gov/fema-e-74-reducing-risks-nonstructural-earthquake-damage
- Oregon Administrative Rules on New Construction and Alternations of Existing Hospitals http://arcweb.sos.state.or.us/pages/rules/oars_300/oar_333/333_525.html
- Oregon Law on Seismic Rehabilitation of Existing Hospitals by 2022 https://www.oregonlaws.org/ors/455.400
- California Office of Statewide Health Planning and Development (OSHPD) www.oshpd.ca.gov Pre-approved list: http://www.oshpd.ca.gov/FDD/Pre-Approval/index.html
- Oregon Crisis Care Guidelines: www.thecma.org/node/4539
- Selected Case Studies:
  - 2010 Chile earthquake: https://ftp.iza.ac.at/publications/impact-on-hospital-functions-following-the-2010-chilean-earthquake-E
  - 2011 New Zealand: http://earthquakespectra.org/doi/abs/10.1193/032013EQS074M?code=eeri-site
  - 2014 Nepal earthquake presentation: http://peer.berkeley.edu/events/wp-content/uploads/2015/07/04-PEER_MitraniReiser_2015_Aug11_copy.pdf
  - Comparison Study: http://www.seismic.ca.gov/meeting_info/july11_2013/05-Item%20V%20Hospital%20Vuln%20Survey.pdf

GRANT AND LOAN INFORMATION

- State of Oregon Seismic Rehabilitation Grant Program, including hospitals: www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab/
- Oregon Health Authority State Revolving Loan Program for Drinking Water Systems http://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/SRF/Pages/index.aspx
- Oregon Business Development Department (OBDD) Infrastructure Authority (IFA)
  Special Public Works Fund http://www.orinfrastructure.org/Infrastructure-Programs/SPWF
  Safe Drinking Water Program http://www.orinfrastructure.org/Infrastructure-Programs/SDW

DOGAMI April 2017

CASCADIA RESILIENCE PLANNING INFORMATION

- 2013 Oregon Resilience Plan by Oregon Seismic Safety Policy Advisory Commission (OSSPAC) http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf
- Oregon Department of Energy's 2016 presentation on emergency fuel planning https://olis.leg.state.or.us/liz/2015I1/Downloads/CommitteeMeetingDocument/89758
- Oregon Department of Transportation Lifeline Routes (2012) http://www.oregon.gov/ODOT/TD/TP/Reports/Lifeline%20Selection%20Summary%20Report.pdf
- State of Oregon National Hazard Mitigation Plan (NHMP), Contact county for county NHMP http://www.oregon.gov/LCD/HAZ/Pages/nhmp.aspx
- Oregon Office of Emergency Management earthquake information, including Raptor web tool www.oregon.gov/OMD/OEM/Pages/plans_train/earthquake.aspx https://www.oregon.gov/OMD/OEM/Pages/plans_train/RAPTOR.aspx
- FEMA technical assistance, including pre- and post earthquake assessment methods https://www.fema.gov/national-earthquake-technical-assistance-program
- U.S. Resilience Council's *earthquake building rating system* http://usrc.org
- Beaverton School District on Resilience Planning for new schools https://www.beaverton.k12.or.us/depts/facilities/Documents/150710_Beaverton%20School%20Report.pdf

DOGAMI INFORMATION

DOGAMI is the state's scientific agency with technical information on earthquakes, tsunamis, landslides, liquefaction and selected rapid visual screenings www.oregongeology.org

- DOGAMI's 2007 Rapid Visual Screening (FEMA 154) project information, includes hospitals http://www.oregongeology.com/sub/projects/rvs/
- Geologic hazards in Oregon
  - HazVu web tool http://www.oregongeology.com/sub/hazvu/index.htm
  - Landslides web tool (SLIDO) http://www.oregongeology.org/sub/slido/
  - Oregon tsunami hazards http://www.oregongeology.org/tsuclearinghouse/
- Oregon Risk Study on Critical Energy Infrastructure 2013 http://www.oregongeology.org/pubs/ofr/p-O-13-09.htm
- Cascadia newsletter http://www.oregongeology.org/sub/quarpub/CascadiaWinter2010.pdf

Source: DOGAMI

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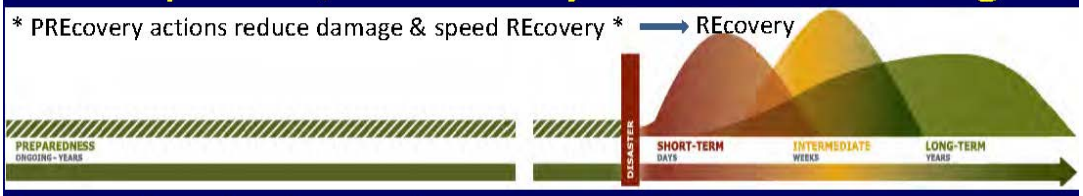
Disaster Resilience Continuum

PREpare now (PREcovery) for Response, REcovery and Rebuilding



Preparedness (requires years)

Response
Recovery
Rebuilding

Source: Modified from National Institute of Standards and Technology. 2016. Community Resilience Planning Guide.

Wang, DOGAMI, 2017

Hospitals: Are these Seismically Prepared?

Strap Batteries

Source: DOGAMI OFR O-13-09

Anchor Generators

Source: DOGAMI OFR O-13-09

1. Communications systems
2. Medical gas systems
3. Fire alarm systems
4. Emergency lighting equipment & egress signs
5. Emergency power supply *(uninterrupted access to fuel or alternate power)*
6. Water *(uninterrupted access)*

Plus buildings, non-structural, contents and more

Coordination among many partners is needed to improve resilience

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Questions?

www.oregongeology.org

Y Wang, DOGAMI, 2017

Oshiokuri Hato Tsusen no Zu (Fast Cargo Boat Battling The Waves) 1805
http://thesoundsinsidemyhead.blogspot.com/2008/05/hokusais-great-wave.html

Off Site Consultative Meetings

- Hospital's DOGAMI Earthquake Preparedness Survey
- Updates/corrections to DOGAMI Rapid Visual Screening (RVS)
- Geologic Hazards
  - Tsunami (4 hospitals): Structural. Site. Evacuation. "Hardened" Egress
  - Liquefaction and Landslides (HAZVU web tool)
- Highway Bridges and RAPTOR (OEM planning tool)
- Power-Fuel planning w/local supplier, county EM & state/ODOE
- Water on-site, local supplier, county EM
- Other? Comments? Questions?
  - Group session helpful? Y or N
  - Off-site consultation helpful? Y or N
  - Interested in on-site consultation? Y or N If Y, any specific focus?

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9.4 Appendix D: Cascadia Network Training Schedule and Training Agenda

9.4.1 Sample Cascadia Network training session schedule

Note: This schedule includes hypothetical Best Practice (BP) Guidance Topics, HPP regions, and hospital co-hosts.

Cascadia Network training session #1

Date: Spring 2018 in HPP Region 3 South coast
Topics: Hospital emergency power system and emergency fuel planning
BP subjects: PeaceHealth Hospital (Florence) and Bay Area Hospital (Coos Bay)
On-site emergency power system; on-site >30 days of fuel supply; local fuel planning
BP talks: Present at Cascadia Network training session #1
Present at Oregon Prepared in Summer 2018
Co-host: PeaceHealth Hospital in Florence.

Cascadia Network training session #2

Date: Fall 2018 in HPP Region 1 North coast
Topics: Hospital seismic mitigation and community fuel resilience
BP subjects: Tillamook Regional Hospital seismic dampers (Tillamook)
Community fuel resilience: generators at Tillamook County gas stations
BP talks: Present at Cascadia Network training session #2
Present at Oregon Prepared in Summer 2019
Co-hosts: Tillamook Regional Hospital in Tillamook

Cascadia Network training session #3

Date: Spring 2019 in HPP Region 2 Central coast
Topics Seismic Assessment (ASCE 41) and Mitigation, Building "Above Code", and County Fuel Planning
BP subjects: Samaritan Pacific Communities (Newport) and Samaritan North Lincoln Hospital (Lincoln City)
ASCE 41, State Seismic Grant Recipient ($1.5M), Building "Above Code" for resilience
BP talks: Present at Cascadia Network training session #3
Present at Oregon Prepared in Summer 2019
Co-host: Samaritan Pacific Communities in Newport

Cascadia Network training session #4

Date: Fall 2019 in HPP Region 3 South coast
Topic: Emergency Water Provisions for Hospitals
BP subjects: Southern Coos Hospital and Health Center (Bandon)
On-site, Water district and ORWARN. Seismic water valves in Brookings (state grant)
BP talks: Present at Cascadia Network #4
Present at Oregon Prepared in Summer 2020
Co-host: Southern Coos Hospital and Health Center in Bandon

Cascadia Network training session #5

Date: Spring 2020 in HPP Region 1 North coast
Topics: Emergency Equipment and Supplies (trailers and caches) at Hospitals and Community resilience:
BP subjects: Providence Seaside Hospital (Seaside) Emergency Equipment and Supplies
Nehalem Medical Reserve Corps
BP talks: Present at Cascadia Network #5
Present at Oregon Prepared in Summer 2020
Co-host: Providence Seaside Hospital in Seaside

9.4.2 Sample training session agenda

Sample Training Session Agenda

Day 1: 1:00-4:30 pm

1:00-2:30 Leadership Session:

- Local Host welcomes
- OHA HPP regional liaison describes purpose Cascadia Network and training session agenda
- Coastal Hospital Leadership Panel (roundtable introductions)
- Major Updates by Hospital Leadership and others (roundtable)
  - Hospital preparedness activities
  - New developments
  - Requests for or support by Coastal Caucus
  - Announcement of funding opportunities
- Quick overview of Best Practice (DOGAMI and/or BP subject)
- Recognition for Best Practice Certificate. Presented by HPP Liaison

2:30-2:45 Break

2:45-4:30 Best Practices Session: Presentation of Best Practice Story

Day 2: 8:00- noon

8:00-10:00 Technical Session: Various technical programs by invited trainers and guests

DOGAMI (moderator)

Example topics:

- Pre-and post-earthquake building inspections (ATC 20/21)
- Hospital Seismic Evaluation FEMA 767
- Non-structural Components (FEMA 74)
- DOGAMI hazard info—risk map, beat the wave, landslide, HAZVU, links to SSNA hospital reports
- Long range seismic mitigation planning
- U.S. Resilience Council earthquake performance ratings
- ASCE 41-13 Tier 1: structural and non-structural deficiencies
- SRPG program seismic grants

10:00-10:15 Break

10:15-noon Group Discussion Session

OHA HPP liaison (moderator) or outside facilitator

Example topics:

- Ethics on hospital evacuation in tsunami zone. Proposed Facilitator: Dr. Richard Leman referencing Oregon Crisis Care Guidance document (Oregon Medical Association, 2017)
- Long term (over 30 day) supplies of externally-dependent items, including water, fuel and medical supplies. What can be stored on-site versus locally sourced? Proposed Facilitator: OHA HSPR personnel