Oregon Seismic Safety Policy Advisory Commission
OSSPAC

Tsunami Resilience
on the Oregon Coast

OSSPAC Publication 21-01
January 12, 2021

THE STATE OF OREGON
Mike Harryman, State Resilience Officer

Oregon Seismic Safety Policy Advisory Commission

After the Loma Prieta earthquake in 1989, Oregon residents demanded that the State of Oregon better address earthquake hazards throughout the state. The state legislature established the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) in 1991 through Senate Bill 96. The Commission is a group of eighteen individuals appointed by the Governor. They represent a variety of interests regarding public policy and earthquakes and include representatives of many state agencies, a member each from the Oregon House and Senate, representatives of important stakeholder groups, and members of the public. The OSSPAC mission is to positively influence decisions and policies regarding pre-disaster mitigation of earthquake and tsunami hazards; increase public understanding of hazard, risk, exposure and vulnerability through education; and be responsive to new studies or issues raised around earthquakes and tsunamis.

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preface

In 2019, the Oregon legislature passed HB3309 and Governor Brown signed it into law. The main impact of this legislation was to remove the moratorium established 25 years ago through SB379 on constructing critical buildings on the Oregon coast within the tsunami inundation zone. This change in policy caught many in the emergency management and resilience community by surprise, including those of us serving on the Oregon Seismic Policy Advisory Safety Commission (OSSPAC).

The purpose of this report is to review the history of the original SB379 legislation, study the work done by state agencies in assisting coastal communities with tsunami planning, explore recent changes in codes and standards, and recommend a way forward to assure the tsunami safety and resilience of our coastal communities.

Throughout this report, the term "Cascadia event" is used to represent the Cascadia Subduction Zone earthquake and resulting tsunami. "Tsunami Hazard Overlay Zone" refers to local land use planning regulations that restrict certain uses and require other safety measures within tsunami inundation zones.

In gathering input for this report, the Tsunami Working Group of OSSPAC consulted with the State Resilience Officer and engaged other state and local government officials. OSSPAC heard testimony from representatives of non-governmental engineering organizations, code committees, representatives of coastal stakeholders, and members of the public. Included in Appendix A is a list of the testimony received from stakeholders.

OSSPAC received support from the Department of Consumer and Business Services (DCBS), especially the Division of Financial Regulation and the Department of Land Conservation and Development (DLCD). OSSPAC gratefully acknowledges the financial support of the Department of Consumer and Business Services, Oregon Department of Geology and Mineral Industry (DOGAMI), and the Office of Emergency Management (OEM).

Jeffrey Soulages
OSSPAC Chair

Tiffany Brown
OSSPAC Vice-Chair

executive summary

In 2020, the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) voted to form a working group to investigate ways to address the tsunami safety and resilience of Oregon's coastal communities. This was in reaction to the Oregon Legislature passing HB3309 in 2019, which removed the moratorium established 25 years ago on constructing critical buildings on the Oregon coast within the tsunami inundation zone. Through workgroup meetings and stakeholder testimony, OSSPAC investigated the work done by state agencies in aiding coastal communities with tsunami planning, as well as recent changes in building codes and standards. The commission's major recommendations are as follows:

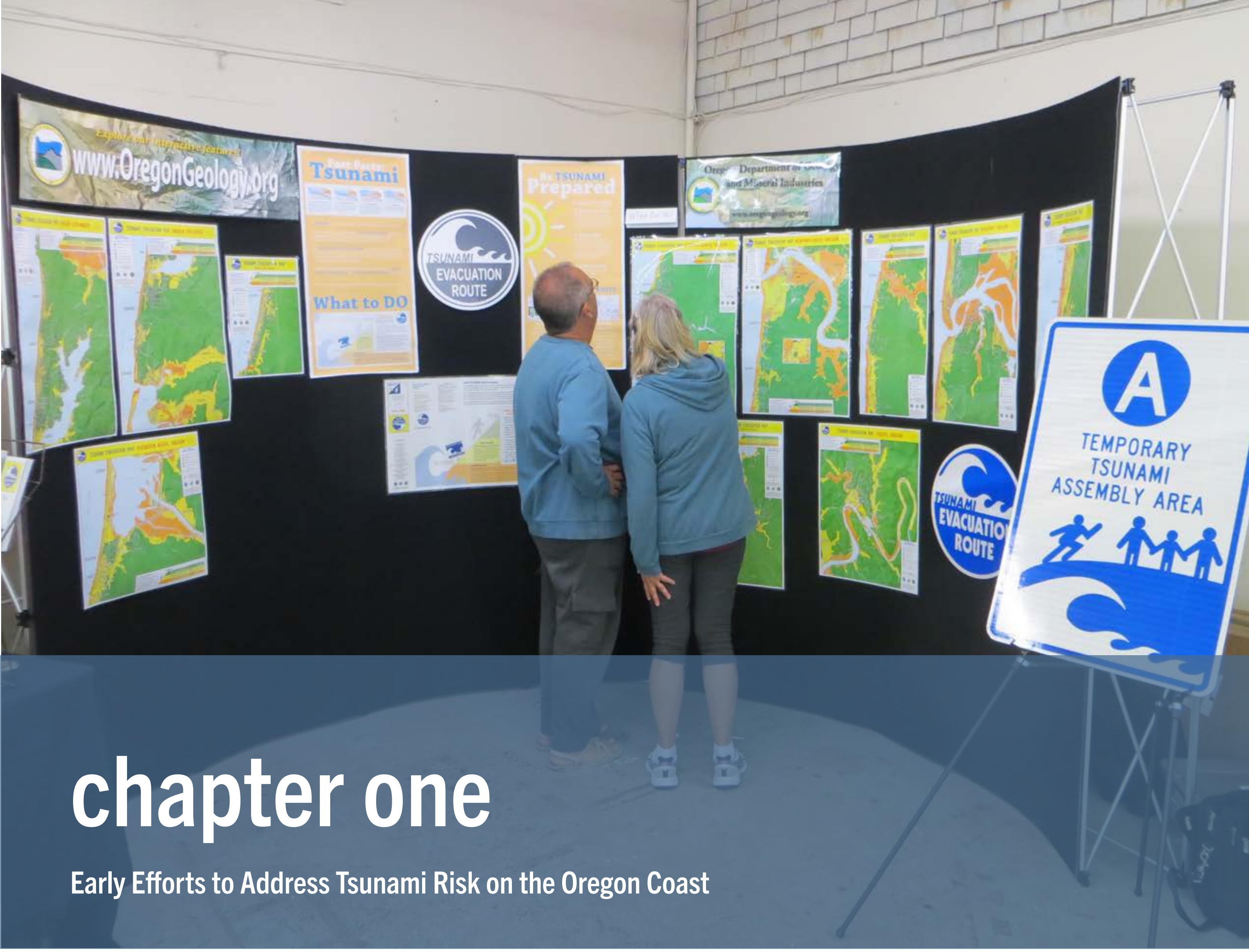
Recommendations

A. **Support and strengthen the use of tsunami overlay zones and evacuation planning by coastal communities in Oregon.** The first step to ensuring that coastal communities thrive after a major earthquake is to encourage good land use and evacuation planning. This allows each community to determine for itself what functions are most important, as well as their own level of acceptable risk. Support communities in their efforts to establish Tsunami Hazard Overlay Zones. Encourage the Oregon Department of Land Conservation and Development (DLCD) to continue to assist these communities and support critical projects like future revisions of the Tsunami Land Use Guide. Provide adequate funding to DLCD to support this mission in the form of $250K per biennium for grants directly to communities and a limited duration FTE for providing direct consulting to coastal communities. Work with DLCD, DOGAMI, and OEM to establish robust tsunami evacuation and wayfinding routes. Continue to support coastal community efforts to hold annual tsunami drills to improve evacuation wayfinding.

B. **Continue to improve tsunami maps for use on the Oregon Coast.** Maps and models are the data that inform land use planning, evacuation routes, and structural design. Different maps are required for different purposes. Support mapping efforts to give Oregon the best data on which to base decisions about the future. This includes worst-case maps used for evacuation, other maps for land use planning, and maps for structural design that are compatible with those used to design other hazards. Support DOGAMI's efforts to develop updated maps for structural design using high-resolution for the best detail of the Oregon coast. The effort should incorporate the latest research in tsunami source characterization and be based on the consensus of experts throughout the nation. These maps should follow the procedures of ASCE 7-16 including surface roughness and nonlinear factors and should be consistent with earthquake inputs to the national earthquake hazard maps of USGS.

C. **Establish state-wide structural load standards for designing critical buildings in the tsunami zone and vertical evacuation shelters.** While land use planning will address many critical structures, it won't catch them all. Not all coastal communities have a tsunami hazard overlay yet, and even those that do will have certain structures like fire stations that need to be located within the inundation zone in order to meet critical every day response needs. For those situations, a technically based, state-of-the art national consensus procedure for safely designing structures to survive in the tsunami inundation zone is required, and it needs to be applied consistently throughout the entire state. Adopt ASCE 7-16, including the entirety of Chapter 6 and the tsunami design geodatabase for the design of all Risk Category III and IV structures within the Tsunami Design Zone in the State of Oregon. Re-align the remaining portions of ORS 455.446 and 455.447 with this direction.

D. **Assist local communities with moving existing critical facilities out of the tsunami inundation zone.** Making sure that new critical facilities are either out of the inundation zone or built to survive the tsunami's effects is vital and will, over time, provide communities with resilient facilities. However, there are many existing hospitals, schools, and fire and police stations within the inundation zone along the coast that are not addressed by land use planning or modern building codes. Some communities have tried for years to move these facilities out of harm's way; most do not have the resources to make it a reality. Develop a competitive grant program similar to but separate from the Seismic Rehabilitation Grant Program (SRGP) that can be used to replace critical existing public buildings and relocate them out of the inundation zone. Direct Business Oregon to administer and run the program, building upon their leadership of the SRGP. Pass legislation to authorize the issuance of bonds to provide the funding mechanism for the grants. Direct bond resources to fund the grants on a biannual basis with a goal of $50M per biennium. Explore the use of FEMA Building Resilience Infrastructure and Communities (BRIC) grants to leverage more dollars to flow to coastal community relocation projects using state grants as 25% match.



chapter one

Early Efforts to Address Tsunami Risk on the Oregon Coast

The Oregon coast has experienced catastrophic tsunamis for at least 10,000 years. As described in the Oregon Resilience Plan, scientists expect a powerful 20 to 100 foot tsunami to arrive on the coast 10 to 20 minutes after a major Cascadia event. It will flood low-lying coastal communities and devastate anything in its path. While Cascadia events are infrequent, we should not have a false sense of security. Tsunamis generated by distant earthquakes created significant damage on the Oregon coast in 1964 and 2011. Still, many coastal communities do not have recent experience with tsunami damage, nor do most of the people who visit the coast each year. Tsunami planning is not always a top priority for coastal communities when more immediate needs require attention. However, incremental planning efforts for this impending disaster can significantly increase coastal community resilience.

Distant Versus Local Tsunamis:

Distant tsunamis are caused by earthquakes across the Pacific Rim from Oregon (e.g., Japan, Alaska, etc.). Coastal residents will not feel this earthquake, and the first wave will arrive four or more hours after the earthquake occurs. Notification could be by siren, NOAA radio alerts, citizen alerts, or social media. Local tsunamis, on the other hand, are caused by an earthquake near Oregon's coast. Coastal residents will feel strong shaking and should "drop cover and hold on" to protect themselves during the earthquake and then immediately evacuate to high ground, preferably on foot. The first wave will arrive 15-20 minutes after the earthquake, and citizens should not wait for official warning. Everyone in the area should have a "grab and go" bag of emergency supplies handy for either type of event.

1995 – Senate Bill 379

After the 1992 Northern California earthquake and the 1994 Hokkaido Japan earthquake and tsunami, scientists and engineers in the Pacific Northwest began to warn the public about the significant threat of a major tsunami off the coast due to a subduction zone earthquake. In 1995, the Oregon Legislature passed SB379, which established a tsunami inundation zone along the Oregon coast set at approximately 40 feet elevation. This pioneering legislation was the first of its kind on the Pacific Coast. Two Oregon statutes (ORS 455.446 and 455.447) were established to prohibit new construction of Essential facilities including schools, hospitals, police stations, and fire stations within the tsunami inundation zone. The legislation also instituted a series of maps that defined the inundation zone for the entire coast of Oregon. The maps are still in use today. They are often called the "SB379" maps (see Figure 1.1).

The 1995 maps were based on early run-up models created by DOGAMI for Siletz Bay. To create maps for the entire coastline, DOGAMI partnered with the Oregon Graduate Institute of Science and Technology and the National Oceanic and Atmospheric Association. They developed a new worst-case scenario based on a possible Gulf of Alaska earthquake and observations of other subduction zones worldwide. In a proceedings paper by Dr. George Priest, the authors explain that the original maps were based on the best data available at the time but that much was unknown about potential Cascadia sources. They go on to say, "There is no agreement among scientific professionals on the likelihood of segmented ruptures, location and size of asperities, width of ruptures, amount of prompt slip relevant to tsunami generation and slip distribution." It was noted that the large number of uncertainties needed to be greatly reduced to get a better understanding of the hazard and provide more accurate data.

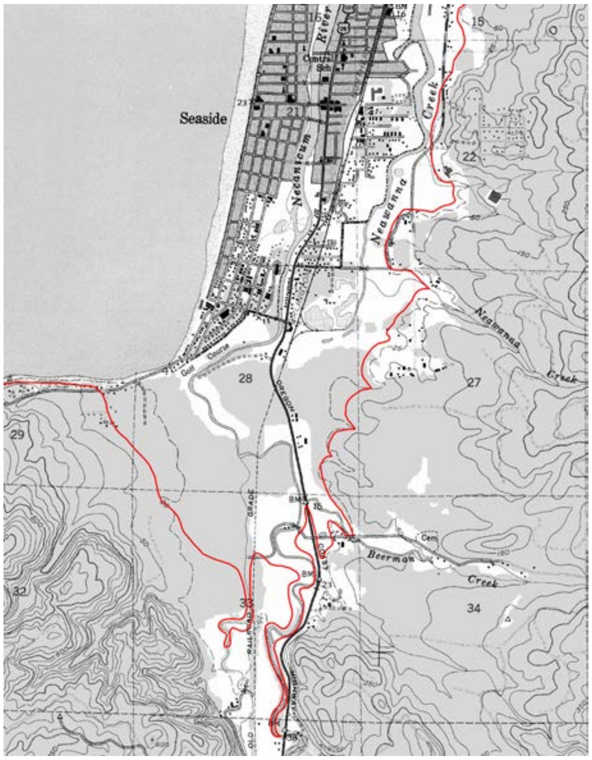


Figure 1.1: Part of an SB 379 tsunami hazard map of the Tillamook Head quadrangle. Red line indicates the extent of modeled tsunami inundation.

As part of SB379, certain structures like hospitals, fire stations and police stations were prohibited from being built in the inundation zone. However, a process was developed for communities to request an exemption. As described in OAR 632-005-0080, applicants were required to submit written documentation along with maps and other data to demonstrate how they intended to ensure the safety of building occupants. DOGAMI would then review the documentation and grant or deny an exemption. The moratorium did not apply to other types of buildings, including Major structures and Hazardous facilities. For those buildings, the law only required consultation with DOGAMI before receiving a building permit.

The tsunami inundation zone restrictions enacted by SB379 were not intended to be a decision on land use, although many perceived that to be the case. The restrictions were meant to be a “legislative” restriction applied as a “public safety screening tool” before a permit would be issued by the local jurisdiction. This was meant to give control to local entities, some of whom had their own building codes enforcement, while others shared it with neighboring communities, and still others lacked this function entirely and relied instead on the state Building Codes Division of the Department of Business and Consumer Affairs.

In addition to directing DOGAMI to create inundation maps, SB379 also gave them the responsibility to adopt new maps when better science and state-of-the-art data was made available. However, it took almost two decades before newer, better maps were produced due to lack of funding by the state legislature. Federal grants ultimately became available in 2013 to fund the production of new maps.

2013 – Updated Cascadia Inundation Maps by DOGAMI

Between 1995 (the time of the SB379 maps) and 2013, new research improved our understanding of potential Cascadia earthquake sources and behavior of megathrust earthquakes in general. This work included Cascadia structure modeling; paleoseismic studies based on turbidite deposits that revealed the magnitude, recurrence, and rupture length of past events coupled with land-based investigations of coastal estuaries and lakes; better theoretical understanding of megathrust earthquakes; and observations of deformations of other historical great earthquakes around the world, particularly the 2004 Indian Ocean earthquake and tsunami. In 2011, DOGAMI started work on a new set of deterministic tsunami hazard inundation maps building on a pilot project undertaken at Cannon Beach in 2008 and focusing on the southern coastal community of Bandon. The objective was to create new maps for evacuation. This work continued into 2013, at which time a full set of maps was developed for the entire Oregon coastline.

Completed in 2013, the TIMS (Tsunami Inundation Map System) incorporates 15 different deterministic earthquake rupture models for a Cascadia event, extending from southwest Washington to northern California. They encompass the maximum considered Cascadia event as well as other distant events. Based on the earlier pilot study, additional tsunami generation factors were considered, including fault slip partitioned from the main Cascadia fault to a splay fault and amount of potential slip estimated from geologic evidence of past Cascadia earthquakes and tsunamis (i.e. turbidite deposits and buried soils and sands in estuaries and coastal lakes). A new logic tree, which is a way of defining the types of earthquakes likely to produce a damaging tsunami, was developed to weight and rank the 15 rupture scenarios; a key parameter was the estimated frequency of each size of earthquake based on data for the last 10,000 years. In addition to Cascadia ruptures, it included two Alaska earthquake sources, the maximum tsunami to impact Oregon in 1964, and a hypothetical maximum distant tsunami from beneath the Gulf of Alaska. These source characterizations were used as input into a hydrodynamic computer model to generate tsunamis and estimate their propagation, inundation, and run-up at each point on the coast.

While the SB379 maps had relied on a single Cascadia inundation line for the entire coast, TIM maps illustrate five different Cascadia inundations and two distant tsunami inundations. The five Cascadia inundations were named like sizes of T-shirts, each representing a range of years of return period and confidence that each covers the full range of potential Cascadia inundations: small (S, 300 years, 26% confidence), medium (M, 425–525 years, 79% confidence), large (L, 600–800 years, 95% confidence), extra-large (XL, 1050–1200 years, 98% confidence) and extra-extra-large (XXL, maximum scenario at 1200+ years, 100% confidence), (see Figure 1.2). The two distant tsunami inundations give emergency managers guidance on the worst that can be expected when a distant tsunami is on its way.

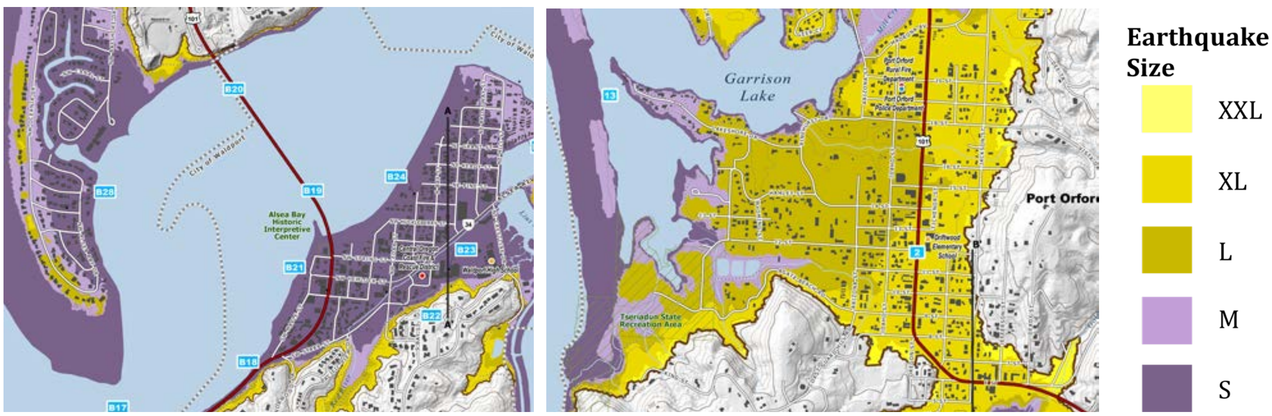


Figure 1.2: Detailed TIM series tsunami inundation maps for (left) Waldport and (right) Port Orford.

In 2014, DOGAMI and OEM convened a series of public meetings to review the TIMS and reach consensus regarding a specific scenario that could be used for evacuation planning. They invited coastal stakeholders, including emergency managers, community leaders, architects, and engineers. They recommended using the maximum, XXL scenario for evacuation planning because it was most likely to ensure that the public would find safety after any event. They also recommended that other events could be used for land use planning and future revisions to the building code for the engineering design of buildings on the coast, as these captured the most likely mechanisms and provided choices based on the risk tolerance and policy objectives of each community.

In early 2018, the DOGAMI Governing Board established a tsunami line subcommittee to explore how to incorporate the new work into the 1995 SB379 legislation. It was recognized that the TIM lines were based on far superior digital terrain modeling than available in 1995 and much more accurate tsunami simulation technology. The subcommittee initially recommended that the L (“large”) scenario replace the existing SB379 maps. However, it was clear that the L line was significantly higher than the SB379 line and its impact on coastal communities was unknown. A number of maps showing the difference between SB379 and the L inundation line were produced by DOGAMI to aid in this understanding. But later that year, the Board ultimately decided not to pursue changing the regulatory line as they had been directed in the original legislation. Instead, they asked the Governor to convene a multi-agency taskforce to recommend updates to the existing ORS 455.446 and 455.447 laws. They also recommended that DOGAMI cease to maintain the tsunami line regulatory and enforcement position.

2015 – DLCD Land Use Planning Guide, OEM Efforts, and Local Efforts

In 2014, Oregon DLCD prepared a comprehensive Tsunami Land Use Guide and initiated outreach efforts to help communities that wanted to adopt a tsunami land use overlay zone to address future development and improve evacuation planning in tsunami inundation zones (see Figure 1.3). The development guide begins with information about the 2011 Tohoku earthquake and tsunami in Japan because the impacts to life and property align closely with what Oregon could expect during a Cascadia event.

Figure 1.3: Evacuation improvements to Nedonna Beach.

The guide then walks communities through appointing an advisory committee, setting land use resilience goals, having community meetings to solicit stakeholder input, deciding on the level of risk the community is willing to accept for new buildings and existing infrastructure, and how to incorporate new tsunami rules within their existing comprehensive plan. It contains model code language in the form of a Tsunami Hazard Overlay Zone, which outlines the boundaries of the regulatory tsunami inundation zone, prohibits the development of certain new Essential and Special Occupancy facilities, requires evacuation improvements to be included in new land divisions, and provides an optional flexible permit process to modify underlying code standards in order to achieve a higher degree of risk reduction. It also addresses tsunami awareness education and outreach, debris management, and hazardous materials, as well as options for financing evacuation facility improvements.

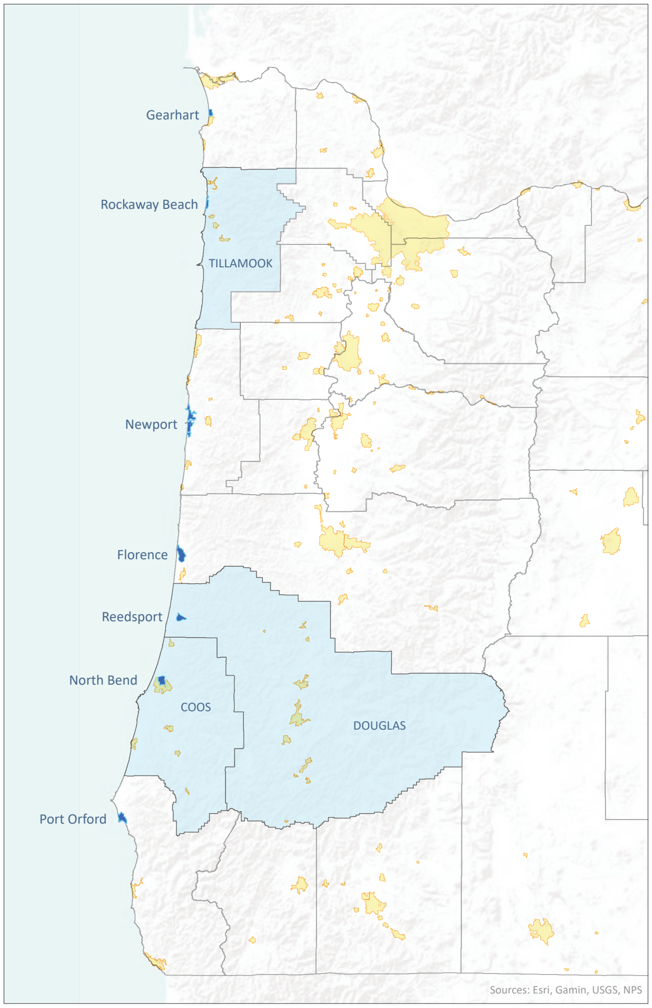


Figure 1.4: Map showing communities on coast that have adopted overlay zones.

After a great deal of hard work by citizens throughout Oregon and the staff of DLCD, seven cities and three counties have completed comprehensive tsunami land use planning and adopted tsunami hazard overlay zones customized for their communities (see Figure 1.4). These locally adopted zoning rules identify which scenario size (S through XXL) applies to their community based on the community's acceptable level of risk and prohibits the building of new Essential facilities within that designated inundation zone. This approach allows for tailored decision-making based on each community's unique tsunami hazard.

chapter two

Recent Developments and Setbacks

2019 – ASCE 7-16 Adopted by State of Oregon

ASCE 7 is the primary reference document for the International Building Code and the Oregon Structural Specialty Code. In 2011, the American Society of Civil Engineers created a subcommittee of 30 professional engineers to draft provisions for an entirely new Chapter 6 that addresses tsunami loads on structures for the first time and includes specific provisions for vertical evacuation structures. It was officially approved in March of 2016 after three years of development plus two years of ASCE and public review including eight consensus ballots.

How Building Codes Work in Oregon

Oregon's statewide building code is based on national consensus codes, amended to address Oregon-specific conditions. The code is typically administered and enforced by the local jurisdiction, but where a local jurisdiction determines that they do not have the resources to administer the code, the state administers it. Local governments cannot require stricter construction standards than those adopted by the state, but they have flexibility to incentivize particular construction standards in order to meet local development goals. Additionally, the state has adopted several optional appendices that a local jurisdiction can adopt based on local conditions and priorities.

The main provisions of the new standard are intended to apply to Risk Category III and IV buildings, as well as Risk Category II buildings when adopted by local jurisdictions. This covers Essential facilities like hospitals, police and fire stations, and ambulatory care facilities as well as schools, universities, jails, nursing homes, and hazardous and very large occupancy structures. The standard addresses structural design procedures for buildings within the inundation zone with a sliding scale depending on depth, with smaller depths requiring very few countermeasures and higher depths requiring extensive countermeasures. Loading includes hydrostatic and hydrodynamic loads, debris impact loads, and foundation design to resist undermining. Structures and non-building structures are both addressed, as are nonstructural systems. It also includes specific provisions for those choosing to construct vertical evacuation structures.

Included with the code is a tsunami design geodatabase for all five western states that contains engineering design parameters for the maximum considered tsunami and serves as input parameters for the rest of the code design procedures. This digital map parallels the maximum considered ground motion maps established by USGS already included in ASCE 7 using the same definition of hazard of a 2% probability of exceedance in 50 years or a 2500-year return period. To develop the maps, a probabilistic tsunami hazard analysis (PTHA) was conducted by a contractor to ASCE and reviewed by a broad stakeholder and technical group convened by the NOAA National Tsunami Hazard Mitigation Program (NTHMP). The inputs into the model on earthquake source characterization were taken directly from the USGS probabilistic seismic hazard model.

	TIM Maps	ASCE 7-16 Maps
Basis	Deterministic	Probabilistic
Rupture scenarios	15 for Cascadia local earthquake and 2 for Alaska distant earthquake	1000's of plausible, synthetic rupture events including 372 scenarios of Cascadia
Cascadia source characterization	Full set of paleoseismic data based on full and partial ruptures	Weighted full set of data by 50 percent in logic tree
Account of total slip	Slip limited for each earthquake event	No maximum slip parameter included
Effects of surface friction	Not incorporated	Included

Table 2.1: Comparison of TIM maps to ASCE 7-16 maps.

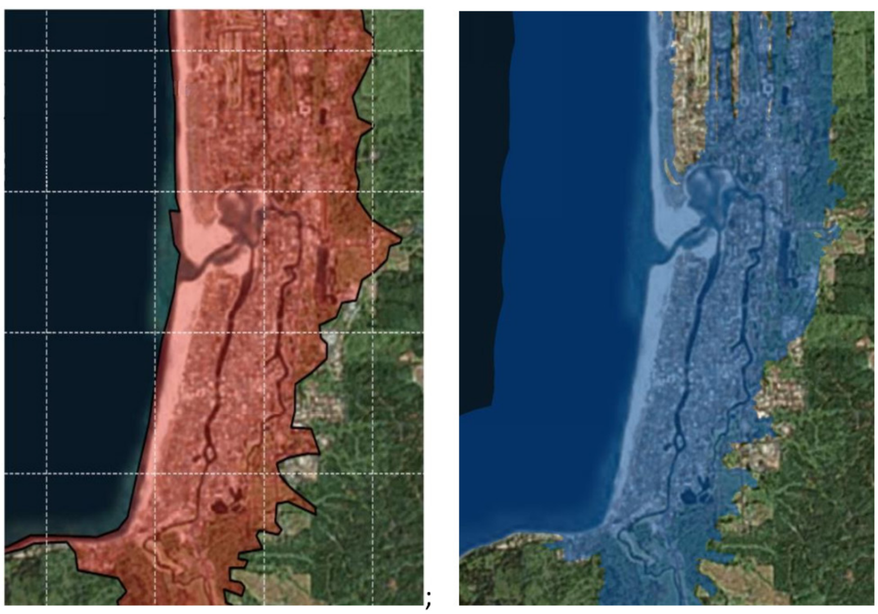


Figure 2.1: Comparison of ASCE 7-16 map (left) with TIMS map for M scenario (right) for Seaside, Oregon.

OSSPAC has received a great deal of testimony regarding the tsunami maps included in the ASCE Standard, especially as they compare with the TIM maps developed by DOGAMI. They are essentially different, as illustrated in Table 1.1 and Figure 2.1. The reader is directed to work by Priest and Allan in 2019 and testimony from HK Thio given to OSSPAC, which covers both sides of this controversy.

In 2018, the Building Code Structures Board of the state of Oregon recommended to Building Code Division of the Department of Consumer and Business Services to adopt the 2018 version of the IBC for use in the 2018 Oregon Structural Specialty Code. As part of that effort, ASCE 7-16 was adopted as a reference standard. However, when the state adopted ASCE 7, they did not adopt Chapter 6 of the standard on tsunami loads and effects into the body of the code. Instead they adopted the chapter into Appendix O of the OSSC as an option for individual adoption by local jurisdictions within Oregon.

The argument from BCD was that this provided more flexibility to Oregon coastal communities to allow them to adopt tsunami design standards or not. It was also clear in communications between ASCE (Gary Chock, ASCE Tsunami Loads and Effects Subcommittee Chair) and BCD (Mark Long, BCD Administrator) that BCD felt they could not adopt Chapter 6 in the body of the code as there was confusion as to how to use the maps embedded in ASCE 7 with the existing SB379 maps. The result is that the ASCE consensus tsunami standards are voluntary within Oregon until adopted by a local jurisdiction.

2019 – HB3309 Passed by Legislature

In 2019, the Oregon Legislature passed HB3309, which ended the moratorium on construction of Essential facilities within the tsunami inundation line of SB379. All structures that were formally prohibited within the SB379 line now can be constructed and only require consultation with DOGAMI prior to issuing a building permit. This was a deep disappointment to many in the Oregon earthquake and tsunami resilience community. The original legislation was a point of pride, as Oregon was the only western state with regulations directly addressing the tsunami threat on the Pacific coast.

Originally, HB3309 was entered as a bill to amend the definition of "surface mining" to exclude certain excavation and grading activities, but it was changed by an amendment that removed the language from ORS 455.446 prohibiting construction of Essential facilities in the inundation zone. The bill was sponsored by Rep. McKeown (HD 9), Rep. Gomberg (HD 10) and Rep. Smith (HD 1), and it was supported by the entire Coastal Caucus, which includes all senators and house members that represent districts bordering the coast. The bill passed by a 56/4 vote in the House and 28/1 in the Senate. The Governor signed it into law right before the session effectively ended due to a lack of quorum in the senate.

The bill's passage caught many by surprise and created a lot of anger and confusion within the seismic-safety and emergency-management community in Oregon. The timing was particularly odd, as earlier in the year the Governor had convened a tsunami workgroup at the request of the DOGAMI Board to address options on what to do to update the SB379 regulatory maps that were very out of date with the current Cascadia science. One objective of the workgroup was to study the impact of the current regulatory framework on local communities. The group had met several times and included state agencies, OSSPAC, representatives from the Governor's office, coastal stakeholders, and members of the Coastal Caucus. But after three meetings, the group was disbanded.

In hindsight, we can reflect on the effectiveness of the original SB379 legislation and whether the loss of the moratorium was truly the blow some perceive it was or whether it was simply time to try a different approach. A key fact often missed is that the original legislation was never intended to be a land use law and was simply intended as a "safety check" on construction of critical infrastructure within the inundation line. The final decision-making power remained with the local community building official. The perception was that the original legislation was stifling development on the coast. However, that didn't appear to be true, as no building was ever prevented from being built in the tsunami zone if a community chose to do so. It appears the perception of a barrier to local control was enough to garner support from the Legislature to eliminate the moratorium.

Case Study: OSU Hatfield Marine Studies Building

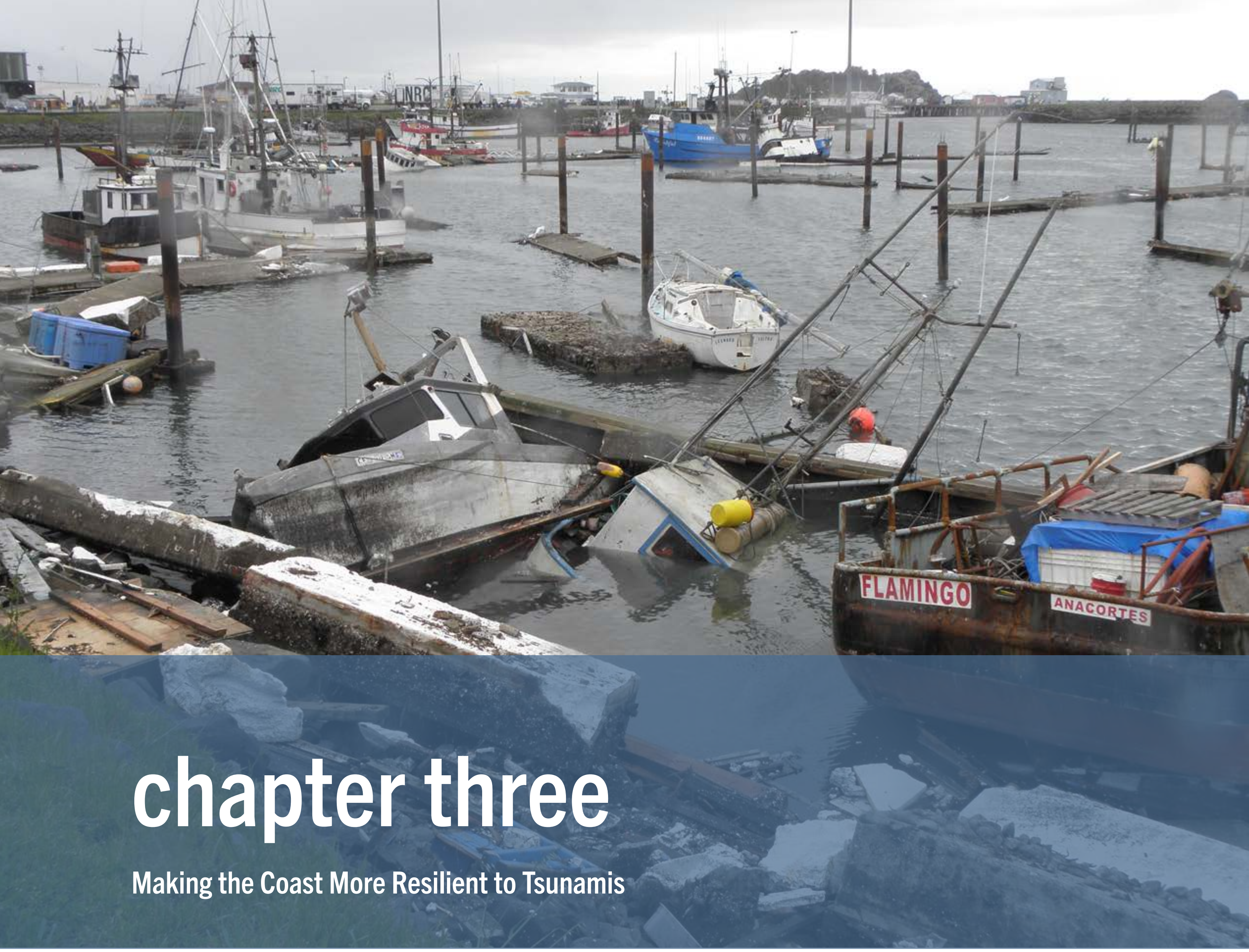
Located in Newport, Oregon near Yaquina Bay, the Gladys Valley Marine Studies Building houses 72,000 square feet of research, meeting, and classroom space. It is constructed in the tsunami inundation zone. This provoked controversy for many that believe new development should be avoided in such a high-risk area (see additional discussion, p. 20). However, it is the first building designed as a tsunami vertical evacuation structure in Oregon. The building's 47 feet high roof can support 900 people and is meant to serve not only OSU students and faculty but the nearby community in South Beach. A large exterior ramp is designed to accommodate the high numbers of people during an evacuation. A special elevator on emergency power is designed to assist the evacuation of those with limited mobility. The building is designed to be repairable after a major tsunami.

In addition, SB379 put DOGAMI into the role of granting exceptions to the building moratorium in the tsunami inundation zone, but they were uncomfortable in that role as they were not the Building Codes Division, which administers state construction standards. Even in an advisory role, DOGAMI's excellent advice could too easily be ignored. According to DOGAMI testimony, no buildings were ever exempted from building within the inundation zone.

2020 – HB4119 – Not Successful

During the May 2019 OSSPAC Meeting, a proposal was made to support state-wide adoption of the ASCE 7-16 tsunami provisions. The motion passed with three abstentions by state agency representatives. With this support, the OSSPAC Chair and Vice-Chair wrote a letter in June of 2019 recommending the state adopt the new tsunami design provisions in the ASCE 7-16 national consensus standard.

This letter led directly to HB4119, a bipartisan bill authored by Rep. Gomberg (HD 10) and Rep. Smith (HD 1) during the 2020 short Legislative session. It essentially rewrote ORS 455.446 and 455.447 to direct the state to use ASCE 7-16 tsunami provisions for the design of all Risk Category III and IV buildings built on the Oregon coast. The bill passed the House with a vote of 51 to 6. However, once it moved to the Senate, the lack of quorum prevented any legislation from moving forward. It did not receive a vote by the end of the session and thus was not successful.



chapter three

Making the Coast More Resilient to Tsunamis

The question now is: how best to move forward? The answer is not clear-cut, as there are many diverse stakeholders including state agencies, tsunami experts, engineers, coastal community representatives, and business interests. In addition, the turbulent activities of the past year have hardened positions and divisions instead of helping to bring consensus.

Any lasting solution will take compromise and will need to thread together several competing priorities:

- Ensure the safety of Oregonians and coastal visitors following a Cascadia event on the coast.
- Empower coastal communities to become more resilient, which will allow them to function and build stronger after the event.

Case Study: Gearhart Fire Station

The current station, built in 1958, is woefully inadequate to support the 35-member Gearhart volunteer fire department. It is also located within the tsunami inundation zone about two blocks from the Pacific Ocean. In 2019, the department discussed replacing the station and looked at three locations: the current location on Pacific Way, a city park at North Marion Ave., or the High Point site farther north on Marion Ave. All are in the tsunami zone, as there is no buildable land within the city limits that is high enough to not be impacted by an XXL tsunami event. The city compromised by preparing for a smaller tsunami event, setting a 50-foot elevation requirement for critical infrastructure.

- Continue to allow robust economic development of coastal communities.
- Allow the state, counties, and cities certainty about tsunami regulation and building code requirements throughout the entire coast.

We believe it is important to focus on what all sides can agree on, which is the necessity of ensuring the resilience of coastal communities. And we believe that the best solutions are those that allow local communities to determine for themselves how best to protect themselves and their visitors.

The Critical Role of Land Use Planning

OSSPAC believes that good land use planning is the critical first step to ensuring that coastal communities not only survive the earthquake and tsunami but thrive afterward. This same advice has been echoed over the past two decades by the federal effort to reduce tsunami losses, the National Tsunami Hazard Mitigation Program. Long term planning that incorporates tsunami risk into the decision-making process allows each community to determine for itself what functions are most important as well as their own acceptable level of risk.

For several years, individual communities have been choosing to limit the construction of critical facilities in the tsunami inundation zone themselves. As described in Chapter 2, this work has been ongoing since 2014, guided by the Oregon Department of Land Conservation and Development. Using limited resources and staff time from DLCD, seven cities and three counties have already adopted Tsunami Hazard Overlay Zones, which is the primary means of directing land use planning around tsunami safety.

OSSPAC supports the goal of all coastal counties (7) and cities (33) establishing Tsunami Hazard Overlay Zones so that the entire Oregon coast is addressed. We know this will take a great deal of time and effort, but it is an important first step to allowing each community to individually decide how best to protect their communities. While community overlays may be different, full participation is essential in order to enable a level playing field for future development.

We are concerned that DLCD may not have the necessary resources to continue their great work addressing tsunami risk, and we believe it is important enough to designate specific resources to support them. This should include funding for DLCD so they can provide grants directly to communities to support their planning efforts, as well as a small amount of additional staff support to provide direct consulting to communities.

In addition to land use planning work for future critical facilities, state agencies (DLCD, DOGAMI, and OEM) have been doing important work to establish robust tsunami evacuation and wayfinding routes. OSSPAC heard testimony that some communities need funding to support infrastructure improvements to enable safe evacuation. Other communities without buildable land above the tsunami inundation zone may need more aggressive tactics, such as vertical evacuation structures. Keeping our communities safe by allowing them to build the necessary infrastructure they need to allow timely refuge from an incoming tsunami is critical to prevent large loss of life.

Like earthquakes, tsunamis do not happen very often. It is important to hold regular drills to ensure everyone along the coast knows how to evacuate safely to high ground, how long it takes them to do so, how to ensure loved ones are all accounted for, and the importance of having emergency supplies ready to take with them.

Different Maps for Each Need

As described in Chapter 1, Oregon has been producing tsunami maps of various kinds since 1994. As time progresses, the science of tsunami source mechanisms continues to improve. Maps and tsunami model data are critically important, as they are the mechanism of how tsunami risk is communicated to engineers, policy makers, and the public at large.

There are many types of relevant maps. Some are meant for the public to use, like evacuation maps. Others are for scientists, engineers, and planning professionals. Some are based on deterministic

Case Study: Rockaway Beach City Hall

The City of Rockaway Beach, Oregon is currently in the process of planning for the relocation of several of its critical facilities to an area outside of the tsunami inundation zone. This includes the Rockaway Beach Police and Fire stations, City Hall, and the Public Works department and equipment storage, as well as the creation of an emergency assembly area with shelter and supplies. The City has identified a parcel of forest land outside of its urban growth boundary for the relocation and is working to purchase the land, bring it inside the City's urban growth boundary, annex it into city limits, and designate the land as zoned for public facilities. Once these processes are complete, the City will create a Master Plan for the parcel and begin the relocation process.

scenarios; others are probabilistic, meaning they are based on the chance that a certain size event will occur. Some are conservative, and others are less so. There are no "one-size-fits-all" maps; each should be developed in a way that best serves its purpose.

OSSPAC believes that Oregon needs this variety of maps to ensure the safety of coastal communities. We also believe that maps should utilize the best science available at the time, and that they should not be static but rather updated on a regular basis. They should be based on a consensus of experts and align with other parallel efforts undertaken by state or federal entities like the United States Geological Survey for related earthquake hazards like the national earthquake hazard maps.

In order to highlight and learn from the best leading-edge science, OSSPAC encourages ASCE, USGS, DOGAMI, Washington DNR, and others to hold symposia to hear from current researchers in the tsunami field, build consensus on the source characterization of Cascadia, and build this data into new models. OSSPAC has heard testimony that three workshops have been scheduled over the next 12 months with the goal of building consensus amongst the scientific community. It is anticipated that an updated logic tree for source characterization of Cascadia will be available in 2021, and that this will drive the next generation of Cascadia modeling. It is important that the entire Cascadia region, from California to British Columbia, should be using the same set of expectations about tsunami and earthquake hazard risk so that different state efforts are aligned and not disjointed at arbitrary regional boundaries.

We encourage DOGAMI to regularly update their TIM maps as the need arises for evacuation and land use planning, and to create its own series of probabilistic maps based on their existing work, new data, and new consensus agreements on tsunami source characterizations. The probabilistic maps must utilize the site-specific mapping procedures contained in ASCE 7-16 so they can be used with the current code as substitutes for the current ASCE 7 maps. Consistent with what other states are doing, these should be 10-meter high-resolution maps and include surface roughness and nonlinear factors appropriate to local terrain.

Engineering Standards

In the upcoming years, land use planning will divert the construction of many new critical buildings to areas out of the tsunami inundation zone. However, it won't be enough for all coastal communities. Some do not yet have a tsunami hazard overlay. Even those that do will likely have certain structures like fire stations that need to be located within the inundation zone in order to meet critical every day response needs. For those situations, Oregon needs a technically based, state-of-the art national consensus procedure for safely designing structures to survive in the tsunami inundation zone.

OSSPAC heard testimony regarding the new Chapter 6 of ASCE 7-16, which contains the first-of-its-kind provisions to address tsunami hazards and allow structures to be safely built to withstand them. All the western coastal states, including Hawaii and Alaska, are adopting the ASCE 7-16 tsunami provisions.

The new Chapter 6 provisions are variable based on the location of the structure within the inundation zone. Buildings close to the code-mandated line will likely need no significant changes from standard structures. As the location of the building gets closer to the water, the requirements get more stringent. This provides a market incentive for locating buildings out of the zone.

Case Study: Gold Beach Hospital

Curry Hospital serves Gold Beach and all of Curry County. Built in 1948, it was antiquated, too small, and located in the tsunami inundation zone. The hospital started looking at replacement options in 2012. After looking at many different locations, including the hills above Gold Beach, they decided to stay at the current site. The hillside plot had landslide issues and would have required new road, sewer, and electrical services, which was cost prohibitive. Ultimately, they wanted to be close to the town's population to provide the emergency services they need. The old site was not within the old SB379 line, but it was within the DOGAMI L line. No measures to mitigate the impact of tsunamis were taken.

It's important to note that the new tsunami provisions of ASCE 7-16 apply only to Risk Category III and IV buildings and not to other buildings such as single-family homes, commercial buildings, or existing structures. The costs to implement the building code provisions within the tsunami inundation line appear reasonable - a few percent of the total construction budget. However, this is based on limited data from the handful of structures that have used the new standard. Costs for building a vertical evacuation structure would be significantly more. The provisions do not require any buildings to be vertical evacuation structures unless the community or owner chooses to implement them.

While Chapter 6 of ASCE 7-16 has been adopted by the state of Oregon, it was made voluntary and will only be in force by those jurisdictions that choose to adopt it or by developers that choose to use it. OSSPAC encourages the state to adopt all chapters of the standard in full to provide a level playing field and uniform protection for all coastal communities.

> ***The hope is that ASCE 7 standards for building in an inundation zone would be used only when no better option exists to relocate structures out of the inundation zone.***

It would take a tremendous effort to get all seven counties and 33 cities to agree to adopt standards one at a time. This is illustrated in the time it has taken to get individual communities to adopt tsunami overlays, as described in Chapter 2. But it is critically important for the state building code to provide a uniform level of safety to protect all Oregonians and visitors. Tsunami load provisions should be no different than snow, wind, seismic, and other loading provisions in the building code. Statewide consistency will remove uncertainty for communities, visitors, and developers who are currently navigating a patchwork of different requirements from one location to the next.

The hope is that ASCE 7 standards for building in an inundation zone would be used only when no better option exists to relocate structures out of the inundation zone. Critical structures built to these standards might survive a large tsunami and be repairable. But most of the surrounding structures will likely be devastated and unusable after the event, making recovery intensely challenging. That being said, some coastal communities have no buildable land available to them outside the inundation zone. For those communities, structures built to Chapter 6 standards – especially those with vertical evacuation options – will be critical in providing emergency services and shelter immediately after an event. Help will not be coming quickly if the entire region is impacted by a subduction zone earthquake.

Existing Critical Facilities in the Inundation Zone

Ensuring new and replaced buildings are either out of the inundation zone or built to survive a tsunami's effects is vital to the resilience of coastal communities. However, up and down the coast there are many existing hospitals, schools, fire stations, and police stations within the boundaries of the current inundation zone that cannot be addressed by land use planning or innovative modern building codes (see Figure 3.1).

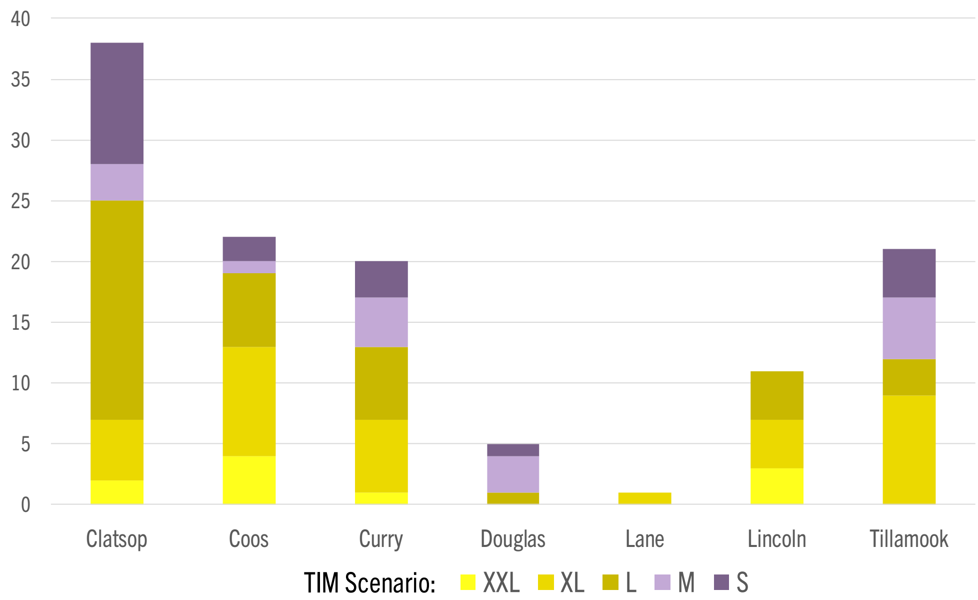


Figure 3.1: Chart of existing critical buildings within each of the TIM map zones by county.

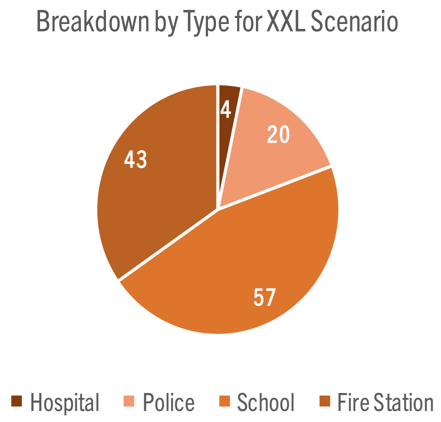


Figure 3.2: Chart of existing critical buildings in XXL zone by function. Note that a building in a larger tsunami zone is also in the smaller zones because the zones overlie each other.

Some communities have tried for years to move these facilities out of harm's way, but most do not have the resources to make this a reality. A good example of success is the effort made by the Seaside School District to address their schools near the coast. In 1999, Seaside School District confirmed that most of its schools were within the tsunami inundation zone. Working with DOGAMI, they produced several studies, and it became clear that the only option was to relocate the schools away from the coast in the east hills above the city. A bond measure was proposed in 2013 to purchase land for a new school site, but the measure failed. In 2016, the district proposed another bond measure that successfully raised $99.7M to replace the schools.

In 2005, Oregon Legislature established the Seismic Rehabilitation Grant Program (SRGP) with Senate Bill 3. It has funded the retrofit of schools and emergency services facilities, making them more resilient to earthquakes. Over the past decade, the program has distributed over $300M in grants for over 200 projects throughout the state. Business Oregon has run the program since 2014, and they have done a good job in assisting communities in determining eligibility and completing applications.

Unfortunately for coastal communities, SRGP funds have done little to protect against tsunami risk. Originally, facilities in an inundation zone were not eligible for the grants. This did change in 2019, and now those buildings are eligible. But SRGP funds can only be used to retrofit existing facilities and not for the relocation of existing facilities out of an inundation zone. In 2016, Seaside tried to use SRGP funds for its school relocation effort and was unsuccessful. Fortunately, they were able to get $4M in matching funding from the Oregon Office of Education.

It is true that relocating facilities out of the inundation zone is far costlier than a seismic retrofit project. It requires new land and utilities, not to mention the cost of a new building. But coastal communities should be eligible for assistance from the state to improve their tsunami resilience, just as other communities are eligible for assistance to improve their earthquake resilience.

It would take an act of the Legislature to allow SRGP funds to be used for building relocation. While it could be done, it seems prudent to leave the SRGP as-is and allow the program to continue to address the large number of existing buildings in the state that still need to be retrofit against earthquakes. Instead, OSSPAC recommends a separate program directed toward critical facilities in the inundation zone that need to be relocated.

The new program could be administered by Business Oregon, as they have a great deal of experience already with the SRGP. If needed, new legislation could authorize the issuance of bonds to provide a funding mechanism for the grants. These grants could be magnified with the new FEMA Building Resilience Infrastructure and Communities (BRIC) grant program. BRIC grants can pay up to 75% of project costs for hardening infrastructure susceptible to natural hazards. The state or communities would have to match 25% of the funding from FEMA. Such a program could greatly increase the mitigation dollars spent on moving critical facilities out of a tsunami's path.

Chapter 3 Recommendations

Support and strengthen the use of tsunami overlay zones and evacuation planning by coastal communities in Oregon. The first step to ensuring that coastal communities thrive after a major earthquake is to encourage good land use and evacuation planning. This allows each community to determine for itself what functions are most important as well as their own level of acceptable risk. Support communities in their efforts to establish Tsunami Hazard Overlay Zones. Encourage the Oregon Department of Land Conservation and Development (DLCD) to continue to assist these communities and support critical projects like future revisions of the Tsunami Land Use Guide. Provide adequate funding to DLCD to support this mission in the form of $250K per biennium for grants directly to communities and a limited duration FTE for providing direct consulting to coastal communities. Work with DLCD, DOGAMI and OEM to establish robust tsunami evacuation and wayfinding routes. Continue to support coastal community efforts to hold annual tsunami drills to improve evacuation wayfinding.

Continue to improve tsunami maps for use on the Oregon Coast. Maps and models are the data that inform land use planning, evacuation routes and structural design. Different maps are required for different purposes. Support mapping efforts to give Oregon the best data on which to base decisions about the future. This includes worst-case maps used for evacuation, other maps for land use planning and maps for structural design that are compatible with those used to design other hazards. Support DOGAMI's efforts to develop updated maps for structural design using high-resolution for the best detail of the Oregon coast. The effort should incorporate the latest research in tsunami source characterization and be based on the consensus of experts throughout the nation. These maps should follow the procedures of ASCE 7-16 including surface roughness and nonlinear factors and should be consistent with earthquake inputs to the national earthquake hazard maps of USGS.

Establish state-wide structural load standards for designing critical buildings in the tsunami zone and vertical evacuation shelters. While land use planning will address many critical structures, it won't catch them all. Not all coastal communities have a tsunami hazard overlay yet, and even those that do will have certain structures like fire stations that need to be located within the inundation zone in order to meet critical every day response needs. For those situations, a technically based, state-of-the art national consensus procedure for safely designing structures to survive in the tsunami inundation zone is required, and it needs to be applied consistently throughout the entire state. Adopt ASCE 7-16, including the entirety of Chapter 6 and the tsunami design geodatabase for the design of all Risk Category III and IV structures within the Tsunami Design Zone in the State of Oregon. Re-align the remaining portions of ORS 455.446 and 455.447 with this direction.

Assist local communities with moving existing critical facilities out of the tsunami inundation zone. Making sure that new critical facilities are either out of the inundation zone or built to survive the tsunami's effects is vital and will, over time, provide communities with resilient facilities. However, there are many existing hospitals, schools, and fire and police stations within the inundation zone along the coast that are not addressed by land use planning or modern building codes. Some communities have tried for years to move these facilities out of harm's way; most do not have the resources to make it a reality. Develop a competitive grant program similar to but separate from the Seismic Rehabilitation Grant Program (SRGP) that can be used to replace critical existing public buildings and relocate them out of the inundation zone. Direct Business Oregon to administer and run the program, building upon their leadership of the SRGP. Pass legislation to authorize the issuance of bonds to provide the funding mechanism for the grants. Direct bond resources to fund the grants on a biannual basis with a goal of $50M per biennium. Explore the use of FEMA Building Resilience Infrastructure and Communities (BRIC) grants to leverage more dollars to flow to coastal community relocation projects using state grants as 25% match.

chapter four

The Future of a Resilient Coast

In the past 25 years, we have made great progress towards better understanding earthquake and tsunami risk along the Oregon coast. Our research community has collected a tremendous amount of data and developed scientific tools to help us understand and deal with the risks. Our engineering community has vastly improved tools that enable us to build structures that can withstand large tsunami loads and survive with repairable damage. Communities throughout Oregon have a much better understanding of earthquake and tsunami risk and are far more prepared due to the efforts of state agencies, local governments, non-profits, and citizen activists. We have come very far, but we still have a very long way to go.

As illustrated in this report, there is no one single approach to building critical facilities within or near the tsunami inundation zone. Some communities have chosen not to build essential facilities in these areas at all, and some have chosen to build them but strengthen them against the forces of the tsunami using new standards. Some have chosen the most conservative approach to their overlay zone, while others have chosen less-conservative approaches. Each community needs to assess their risk tolerance and weigh that against their community needs. If we can continue to provide the best science, consistent minimum standards, strong disclosures, and public education, we will continue to make progress.

Even if all of this report's recommendations are executed, the work will only just be starting. It will take decades for many of these ideas to be implemented in coastal communities. And every time a fire station, police station, city hall, school, or hospital is replaced or proposed to move, a difficult set of competing priorities will be discussed and debated in that community. Each situation will be different, and each discussion will be difficult and lead to compromises.

Many in the earthquake community including OSSPAC will not always agree with the decisions made by some communities with regard to the location or design of critical infrastructure, but that is to be expected. We need to support them in this important mission and give them the best-practice guidance needed to safeguard all Oregonians.

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appendix a

List of Stakeholders

Testimony to OSSPAC – September 10, 2019

Gary Chock	Martin & Chock
Dan Cox	Oregon State University
Seth Thomas	Structural Engineers Association of Oregon
Chris Goldfinger	Oregon State University

Testimony to OSSPAC – July 14, 2020

Art Frankel	USGS
Honk Kie Thio	AECOM
Jonathan Allan	DOGAMI
Gordon McCraw	Tillamook County
Tom Horning	Seaside City Council
Ken Murphy	Lincoln City

Testimony to OSSPAC – September 8, 2020

Larry Magura	ASCE

Testimony to OSSPAC – November 10, 2020

Sarah Absher	Director of Community Development, Tillamook County
Carole Connell	Gearhart City Planner

appendix b

Glossary of Terms

Arrival time	The time of arrival of the first wave of a tsunami.
Deterministic	A model based on individual specific scenarios where each one is given equal weight and no randomness is included. The largest controlling scenario is used for design. For earthquake models, the ground motion has a probability of being exceeded given that the scenario earthquake has occurred.
Distant source tsunami	A tsunami that is generated from a distance source, traveling a great distance across the ocean before hitting another shore.
Earthquake	An earthquake is a sudden shaking of the Earth's crust, which is its outermost, rocky layer.
Epicenter	T point on the Earth's surface directly above the place that an earthquake occurred. It is one of the indicators, along with magnitude and type of fault motion, of whether a tsunami will be propagated as a result of an earthquake.
Essential	Hospitals, fire and police stations, tanks supporting fire suppression, emergency vehicle shelters, emergency preparedness centers, standby emergency power, emergency communication centers.

Evacuation zone	The area that should be evacuated prior to the arrival of a tsunami.
Hazardous	Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be of danger to the safety of the public if released.
Inundation area	Normally dry land area that has been, or is predicted to be, flooded by a tsunami, measured horizontally landward from the shore.
Inundation line	The demarcation line between the inundation area and the safe zone.
Local tsunami	A tsunami that quickly reaches a shoreline close to the source of the earthquake or landslide. It does not have to travel far, so there is little or no warning of its arrival. Local tsunamis often cause the greatest loss of life.
Magnitude	The energy release of an earthquake as measured by the moment magnitude scale. People normally don't feel earthquakes that have a magnitude of less than 3.0. It usually takes an undersea earthquake of 7.5 or greater magnitude to generate a tsunami.
Major	Building over six stories in height with floor area of 60,000 square feet or more and all buildings over 10 stories in height.
Paleoseismic	Paleoseismicity refers to earthquakes recorded geologically, most of them unknown from human descriptions or seismograms. Geologic records of past earthquakes can include faulted layers of sediment and rock, injections of liquified sand, landslides, abruptly raised or lowered shorelines, and tsunami deposits.
Probabalistic	A model that incorporates the impact of random variation. The controlling scenario is computed from a ranked list of all possible scenarios and the probability of each one. For earthquake models, the ground motion has a probability of being exceeded in a given time period.
Safe zone	An area that should not be reached by the water from a tsunami, either by virtue of its elevation or by its distance from the shore.
Sea level	The normal level of the sea's surface, halfway between mean high and low tide levels.
Special Occupancy	Structures with public assembly occupancy with capacity greater than 300 people, primary and secondary schools or child care centers with occupancy greater than 250 people, colleges or adult education schools with occupancy greater than 500 people, medical facilities with 50 or more resident or incapacitated patients, jails and detention facilities, all structures with occupancy greater than 5,000 people.
Subduction earthquake	Subduction refers to the action of one plate sliding underneath another. Although this is normal, sometimes a portion of the underlying plate gets stuck. When it finally slips free, it results in an earthquake. Most tsunamis are caused by subduction zone earthquakes.
Subduction zone	An area where one plate is being pushed beneath another plate. When these zones are located in or near the ocean, the tsunami hazard will be higher. The Pacific Northwest and Alaska are located along subduction zones.
Travel time	The time required for the first tsunami wave to travel from its source to a given point on a coastline.
Tsunami	A series of traveling waves of extremely long wavelength and period, generated by the sudden displacement of water associated with earthquakes occurring below or near the ocean floor, volcanic eruptions, or large underwater landslides.
Tsunami hazard	The probability that a tsunami of a particular size will strike a particular section of coast.