Marine Studies Initiative Building Complex
Earthquake & Tsunami Considerations

Oregon State University

Hatfield Marine Science Center

Newport, Oregon
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Final Report

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1.0 Executive Summary

Oregon State University's Marine Studies Initiative (MSI) is a bold opportunity for the University to expand its teaching and research role in improving the health of the Pacific Ocean and increasing marine-related educational opportunities for OSU students. Because of the potential for earthquakes and tsunamis and the controversy about siting the project in a tsunami inundation zone, Oregon State University contracted with our firms to develop appropriate seismic and tsunami design criteria and assist with the site selection of the new MSI Complex.

It appears logical for the MSI to expand the existing HMSC campus and take advantage of the proximity to the sea, the existing facilities and research staff, and the area's research partners. Such a building location also means making a major capital investment and expanding the population at a location that will eventually be inundated by a major tsunami.

This report strives to clarify the issues related to earthquakes and tsunamis as they relate to the proposed MSI Complex and the HMSC to facilitate an informed and balanced decision about the short and long term status of the Center. It clearly states that major earthquakes and tsunamis will occur with a low probability and that the facilities and emergency response procedures can be designed to protect the lives of the students, faculty, staff and visitors.

Figure 1 Hatfield Marine Science Center, Newport Oregon

2.0 Introduction

Oregon State University (OSU) may expand the Hatfield Marine Science Center (HMSC) as part of their newly launched Marine Studies Initiative (MSI). As shown in Figure 2, the expansion is a complex reportedly planned to include new research facilities, teaching laboratories and classrooms for approximately 350 new students, faculty and staff. The facility is a key part of the University's commitment to pioneer a new research and teaching model that will help sustain healthy oceans and ensure wellness, environmental health and economic prosperity for future generations. It is a university-wide commitment that will have local and global impacts on the economy and environment. (www.marinestudies.oregonstate.edu)

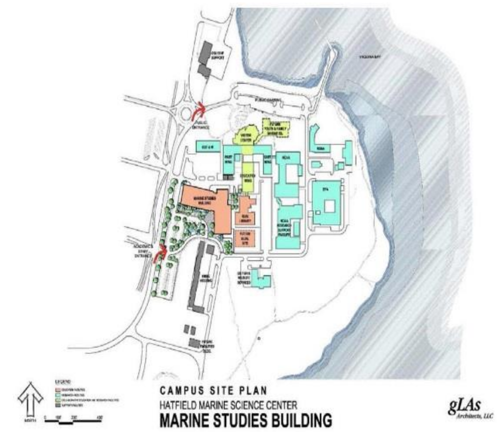

Figure 2 HMSC Site with conceptual location of new facilities (orange)

The HMSC is strategically located in the South Beach area of Newport Oregon to retain close connection to world class seawater facilities and proximity to a number of state and federal agency partners. As with all of the coast of Oregon, it is also located in an area subject to major earthquakes and within the resulting tsunami inundation zone. Figure 3 illustrates the area and the extent of the expected tsunami inundations. The yellow line shows the worst expected extent of inundation where only Safe Haven Hill and the Community College sites are on high ground.

Figure 3 South Beach Area showing the location of the community College, Safe Haven Hill, and HMSC.

Because of the potential for earthquakes and tsunamis and the controversy about siting the project in a tsunami inundation zone, OSU contracted with our firms to develop appropriate seismic and tsunami design criteria and assist with the site selection of the new MSI Complex. The focus of the work was on addressing the prevailing vulnerabilities and concerns related to expanding the existing HMSC campus.

OSU is committed to the safety of all students, faculty, staff and visitors. The HMSC facility currently has a robust emergency response program that includes tsunami evacuation plans and annual drills that are considered to be the best at OSU. The University understands and is addressing the seismic and tsunami hazards that include strong shaking, liquefaction and inundation.

The University has established the following "Building Principles" related to the planned expansion.

- All housing will be located on high ground, outside of the inundation zone.

- All new buildings will be seismically resilient structures that will survive and allow occupants to exit and follow the tsunami evacuation plan.
- Structural design criteria for the proposed building will exceed current seismic codes using state-of-the-art structural design criteria and options.
- The proposed expansion will improve current earthquake readiness and tsunami training.
- HMSC will continue to collaborate with the Tsunami Evacuation Plan Partners.

The 2011 Tohoku earthquake and tsunami brought the world instant images of the destructive power of a major tsunami not unlike the one that is expected along the coast of Oregon. Japan is rebuilding, but in a very cautious manner. Their new standards mandate that all 24/7 occupancies must be built on high ground and all other occupancies must be built with adequate plans for vertical and horizontal evacuation.

That event as well as the concerns expressed by many OSU professors lead to this study that is focused on what might happen and what can be done to mitigate the consequences. It began with meetings with a working group that was formed to manage the decision making process related to the siting and construction of the expansion. It involved a series of interviews with a wide variety of experts in the various disciplines related to earthquake and tsunami safety. It resulted in this statement of the issues, suggested design criteria, and opportunities for OSU to consider implementing.

3.0 Proposed Earthquake and Tsunami Design Criteria

Newport, Oregon, is located in a high seismic zone. As with the entire west coast of the United States, strong earthquakes have occurred over regular intervals and will continue to occur. In the Pacific Northwest, these earthquakes have three basic sources; shallow crustal events, deep Benioff zone events, and Cascadia subduction zone events. Over 1,000 earthquakes per year are recorded but only a few are large enough to be felt. Seismologists expect that a major earthquake ranging in magnitude 7.0 to 9.0 is possible but only expected every few hundreds of years.

Design for Earthquakes

Today, buildings and infrastructure systems at OSU, throughout the west coast and much of the United States are designed for the largest expected earthquakes as determined by the United States Geological Survey (USGS). USGS uses probabilistic theory to determine how strong the shaking will be throughout the region based on thousands of potential events. Estimates of the strong shaking with 2% probability of being exceeded in 50 years along with the levels of resulting damage that is considered acceptable are the basis of the building codes adopted and used today. The resulting designs take into account the expected strong shaking as well as the occurrence of landslides, liquefaction and lateral spreading where appropriate.

The minimum levels of acceptable damage incorporated in today's building code depend on the occupancy and function of the building or infrastructure system. At a minimum, all construction is designed to avoid damage that will cause serious injury or loss of life but without specific regard for re-use. In addition, buildings and infrastructure systems that are needed to support the immediate response and the early days of recovery are designed to remain usable. To accomplish these goals, the designs must provide appropriate foundations, robust structural systems as well as anchorage and protection of non-structural elements and contents. The new MSI complex is required by code to be designed only to the minimum code level, that is, as a Risk Category II building.

In the South Beach area of Newport, Oregon, the current building code requires design for a peak ground acceleration of .48g with consideration given to the maximum considered peak ground acceleration of .68g. At this intensity of ground shaking, liquefaction is expected to cause subsidence of up to 3 feet and lateral spreading of up to 30 feet at the HMSC sites. No liquefaction is expected in the vicinity around the Community College, though there may be some areas subject to landslides. Because of the proximity to the Cascadia subduction zone, the South Beach design values are about 50% higher than used for the design of buildings built in Corvallis at the main OSU campus.

Design for Tsunami Threats

The Cascadia subduction zone has the ability, and is expected at some time, to generate a major earthquake that will result in a significant tsunami that will inundate the Pacific Northwest Coast much like what happened in Japan in 2011. The arrival time and depth of the inundation at any particular site along the coast will depend on the size and location of the earthquake. An event of this magnitude has not occurred in over 300 years. Using turbidite paleoseismology, seismologists have been able to identify up to 41 Tsunami events of various sizes that have occurred over the past 10,000 years. They have subsequently determined that in the 100 year life of the MSI complex, there is a 39% to 58% probability that a tsunami of some size will occur at the site.

The characteristics of the expected tsunami inundation along the Oregon coast was the topic of a multi-year study by a group of experts convened by the Oregon Department of Geology and Mineral Industries (DOGAMI). The effort resulted in an Open File Report O-13-19 entitled Tsunami Inundation Scenarios for Oregon that included a digital data release of their modeling. They developed seven scenario events, five related to local Cascadia subduction zone events -- designated S, M, L, XL, and XXL and two related to events in Alaska.

In 2011, the Oregon State Legislature unanimously approved a resolution supporting the development of the Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami. The subsequent report was published in 2013 and included a series of recommendations related to actions that needed to be taken to make Oregon more resilient to a tsunami generating earthquake. A Governor's task force was convened after publication to develop specific recommendations for the plans implementation. This task force report was submitted to the legislature in 2015. Included in their recommendations is to designate the DOGAMI “L” Tsunami as the design and planning inundation zone for new construction as required by ORS 455.446 and 455.447. The following new facilities are therefore not permitted inside the “L” inundation zone.

- Hospitals and other medical facilities
- Police and Fire Stations
- Government communication centers and other facilities required for emergency response.
- K-12 schools and child care centers with a capacity greater than 250.
- Colleges or adult education schools with a capacity of greater than 500 persons
- Jails and detention facilities

All MSI buildings being considered to be located within the HMSC campus are permitted to be built in the tsunami inundation zone according to the recommendations of the Governor’s Task Force. (http://www.oregon.gov/OMD/OEM/docs/resilience_tf/2014%2009%2029%20ORTF%20Report.pdf)

Regardless of the legal requirements, OSU has stated that consideration will be given to the feasibility of designing the MSI complex to be repairable given the occurrence of a DOGAMI “L” event. In addition, an evaluation of the risk to ongoing research projects and evacuation planning will be done based on the occurrence of a “XXL” event.

Figure 4 illustrates the estimated inundation depths at the HMSC site (DOGAMI Station 86) and arrival times for DOGAMI’s five local events. Note that the depths at the site vary from less than 1 foot to 27 feet for the five local events and the arrival times are all about 30 minutes after the initial rupture.

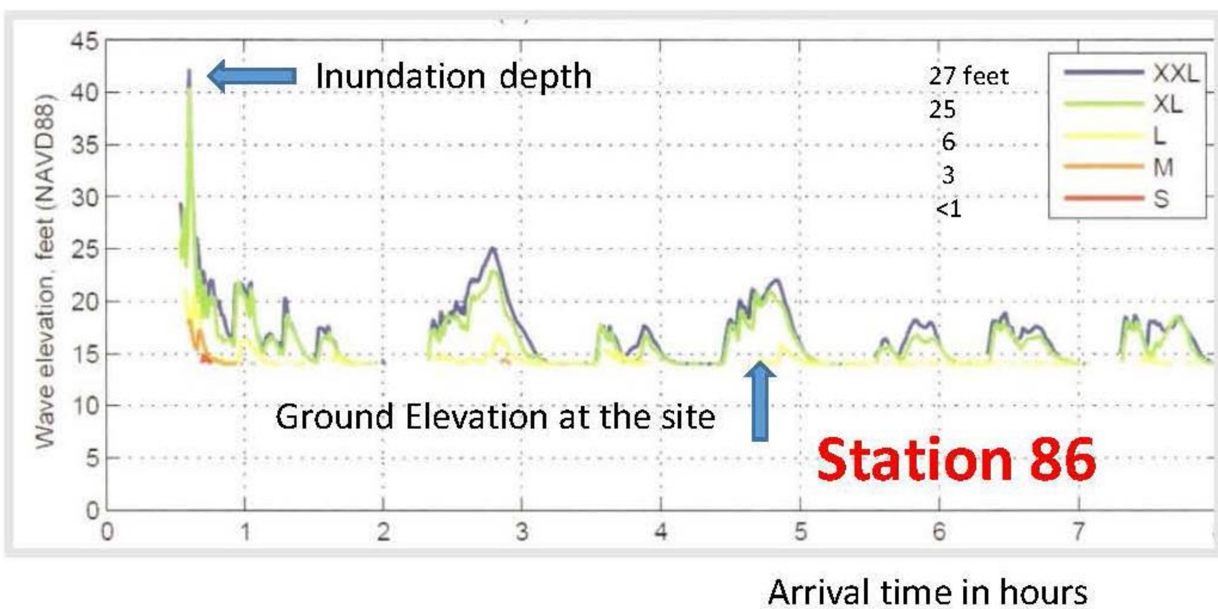

Figure 4 Tsunami Inundation Scenarios for HMSC Site (DOGAMI Station 86)

4.0 Considering the Effects of Earthquakes and Tsunamis

The consulting team worked with and interviewed OSU faculty and staff, DOGAMI staff, Newport City and Port Officials and members of Oregon Emergency Management to understand how to put these facts into perspective. The interview began with a brief written survey of issues to be considered followed by a series of questions related to the tsunami hazard, the associated risks, and the appropriate mitigation measures. The survey form and summary of results are included as Appendix A. The list of interview questions are attached as Appendix B.

The interview participants were selected by the working group and provided to the consultants. In person group interviews were conducted in 2015 on March 12-13 and November 16-17 and two additional interviews were conducted by phone later in November. As is apparent in the survey results, all participants were keenly interested in the MSI complex and committed to the program, as well as the health and safety of the University students, faculty and staff. The interviewers kept notes of the sessions and used them as the basis of the observations and considerations that follow.

The following people participated in the study as members of the working group, people interviewed, or both.

OSU College of Earth, Ocean, and Atmospheric Sciences

Jack Barth	Professor and Associate Dean for Research
Bob Cowen	Director, Hatfield Marine Science Center
Patrick Corcoran	Associate Professor, Geography, Environmental Sciences and Marine Resource Management
Bob Dziak	Affiliate Professor, Geology and Geophysics
Chris Goldfinger	Professor, Geology and Geophysics
John Nabelek	Professor, Geology and Geophysics
Anne Trehu	Professor, Geology and Geophysics
Bob Yeats	Professor Emeritus, Geology and Geophysics

OSU Administration

Mike Bamberger	Emergency Preparedness Manager
Glenn Ford	Vice President for Finance and Administration
Steve Clark	Vice President, University Relations and Marketing
Jock Mills	Government Relations
Kirk Pawlowski	University Architect, Capital Planning and Development

OSU College of Engineering

Scott Ashford	Kearney Professor of Engineering and Dean

OSU College of Engineering, Civil and Construction Engineering

Andre Barbosa	Assistant Professor, Structural
Dan Cox	Professor, Coastal and Ocean
Ben Mason	Assistant Professor, Geotechnical
Armin Stuedlein	Associate Professor, Geotechnical
Harry Yeh	Professor, Coastal and Ocean

DOGAMI

George Priest	Geologist
Ian Madin	Interim Director, State Geologist
Jonathan Allan	Coastal Geomorphologist

City of Newport and Port Officials

Spencer Nebel	City Manager
Kevin Greenwood	General Manager, Port of Newport
Derrick Tokos	Community Development Director

Oregon Office of Emergency Management

Dennis Sigrist	State Hazard Mitigation Officer
Althea Rizzo	Geologic Hazards Program Coordinator

There was considerable variation in the opinions expressed about the characteristics of the expected earthquakes and tsunamis and the opportunities for understanding and mitigating the consequence. Over 90 percent of those interviewed expressed support for locating the MSI complex as planned at HMSC. They collectively expressed the following major benefits and suggested mitigation measures to reduce the inherent life-safety risks. Some of the mitigation measures are already included in the building principals and design criteria established by the university. A number of other suggestions were made by those that did not support the current plans.

Major Benefits

1. Promotes increased collaboration among researchers at HMSC.
2. Enhances students' educational experience.
3. Strengthens the collaboration between the South Beach research partners.
4. Brings economic benefit to the community.
5. Provides access to the highest quality seawater for use in the labs.
6. Establishes new benchmarks for when and how to build in a tsunami inundation zone.
7. Creates an opportunity to improve the existing HMSC evacuation plans.
8. Provides an opportunity to enhance safety for all occupants in the South Beach area.

Additional Mitigation Measures

1. No 24/7 occupancies ever at HMSC (i.e. student housing). Relocate all that currently exist.
2. Evacuation measures should be based on worst-case inundation (XXL) -- regardless of probabilities.
3. Work closely with DOGAMI to define the "worst-case" scenario.
4. Consider relocating non-essential teaching and research activities to higher ground.
5. Design for sea level rise.
6. Design facility to be usable after repairs for the "L" tsunami with consideration given to the expected debris impacts.
7. Plan for total building loss and subsequent reconstruction of HMSC after a significant tsunami.

Other Suggestions

1. Relocate HMSC and the new MSI Complex to high ground. Maintain only the existing dock, tool shed, and warehouse facility at the current location.
2. Build the new MSI Complex on high ground with the intention of a complete relocation of HMSC in the long term.

5.0 Recommended Considerations

The Marine Studies Initiative is underway and well rooted in the future of Oregon State University. A decision to site the MSI complex within the Newport, Oregon community, has been made, with the needed student housing to be located at a new site on high ground near the Community College. Funding for the project is well developed and includes a monetary commitment from the State of Oregon Legislature. The process is obviously in motion, but there is time to make a balanced decision about how to proceed.

We recommend that the University consider proceeding on two parallel tracks. The first is related to expanding the evacuation planning in a move to enhance its effectiveness and support for the surrounding community. Regardless of the final decision about the location(s) of the MSI Complex, there is ample opportunity to improve the excellent plans now in place based on the refined information and modeling techniques available. The second is related to commissioning the selected A/E design team to complete the conceptual studies needed to explore the suggestions offered during the interviews, develop cost models of the options explored, and complete the designs based on the selected solutions. Detail of each track follow.

Initiate Expanded Horizontal Evacuation Planning

1. Base evacuation planning going forward on the DOGAMI “XXL” event.
2. Expand the current planning committee to include representatives from the City of Newport and South Beach businesses and residents.
3. Build upon, augment and utilize available new technology to refine the evacuation process to improve efficiency and completeness. Seek counsel from ADA groups.
4. Determine optimized evacuation routes to Safe Haven Hill and the Community College area based on site specific, state-of-the-art agent based modeling now under development at OSU. Consider the opportunity to provide vertical evacuation structures, perhaps for use as a last resort. Strive to define a path to safety for every occupant of South Beach.
5. Seek state and local funding for evacuation route improvements including additional signage, automated alerts, evacuation route modifications, and temporary shelter support for evacuees.
6. Develop and implement a South Beach-wide evacuation plan that brings awareness and includes briefings, training and regular exercises.

Initiate the Design Process

1. Develop a cost and schedule model for relocating HSMC and the new MSI Complex on high ground.
2. Commission site specific studies related to strong shaking, liquefaction, subsidence and lateral spreading potential, tsunami inundation potential, identification of debris sources and the potential for large ship impacts at the HSMC site. Site specific design criteria is key to developing appropriate cost models.
3. Confirm the program and the adjacencies needed for the target research and teaching environment. Determine if any of the MSI Complex activities can be accomplished on high ground at the housing complex.
4. Develop alternate solutions for the design of the facilities that need to be at the HMSC. Determine cost models for code minimum construction and for construction that will be repairable after an “L” level inundation.
5. In collaboration with the evacuation planning efforts, determine the feasibility and a cost model for providing vertical evacuation at the site, perhaps as a last-resort option.
6. Using triple bottom line style of comparison (social, financial, environmental) , determine the best options for the short term and long term status of the HMSC and the new MSI Complex.
7. Design and construct the selected solution.

Appendix A

Survey Form and Summary of Results

Survey Form

OREGON STATE UNIVERSITY - HATFIELD MARINE SCIENCE CENTER
MARINE STUDIES INITIATIVE

Respondent Name: ____

How would you rate the following site selection factors?

Site Selection Factors	1 Not Important	2 Somewhat Important	3 Important	4 Very Important	5 Extremely Important
a. Site Accessibilty (Pedestrian, Vehicular, Marine)					
b. Access to critical research infrastructure such as sea water system					
c. Proximity to other scientists conducting related marine science research					
d. Proximity to research subject matter					
e. Additional costs and time associated with conducting research from a remote location					
f. Building construction project costs					
g. Economic impact on the local community					
h. Local politics and political influence					
i. Safety and security of students, faculty & staff					
j. Risks associated with potential natural disasters					
k. Shovel ready site (with utilities and other improvements)					
l. Other: (Please specify) ____________________					

The Estimé Group, Inc. and Chris D Poland Consulting Engineer **May 12, 2015**

Survey Results

Respondent No.:	Site Accessibility	Access to Research Infrastructure	Proximity to Other Scientists	Proximity to Subject Matter	Additional Costs for Remote Location	Building Construction Costs	Economic Impact on Community	Local Politics	Safety & Security of Occupants	Risks Assoc. Natural Disasters	Shovel Ready Site	Other:	*Description of Other*
01	3.0	3.0	3.0	3.0	3.0	2.0		4.0	5.0	5.0	2.0	3.0	*Public Education*
02	3.0	4.0	4.0	3.0	3.0	3.0	3.0	4.0	5.0	5.0	2.0		
03	4.0	5.0	4.0	4.0	4.0	3.0	3.0	2.0	4.0	3.0	3.0		
04	4.0	5.0	5.0	5.0	4.0	4.0	4.0	3.0	5.0	4.0	4.0		
05	4.0	4.0	4.0	4.0	5.0	3.0	2.0	3.0	5.0	4.0	3.0		
06	3.0	4.0	2.0	1.0	3.0	3.0	2.0	1.0	5.0	5.0	2.0	5.0	*Hazard Resilience*
07	5.0	5.0	2.0	2.0	3.0	3.0	5.0	3.0	5.0	5.0	3.0		
08	3.0	3.0	3.0	3.0	2.0	3.0	3.0	4.0	4.0	4.0	3.0		
09	3.0	4.0	4.0	3.0	3.0	2.0	2.0	2.0	5.0	5.0	2.0		
10	2.0	2.0	3.0	3.0	3.0	2.0	4.0	4.0	5.0	5.0	1.0		
11	1.0				4.0	5.0	4.0		5.0	5.0			
12	3.0	3.0	4.0	3.0	2.0	3.0	4.0	3.0	5.0	5.0	3.0	4.0	*Vertical Evacuation*
13	3.0	5.0	4.0	3.0	2.0	3.0	2.0	4.0	5.0	5.0	3.0	5.0	*Decrease risk for community*
14	3.0	4.0	4.0	3.0	2.0	3.0	5.0	4.0	5.0	5.0	3.0	4.0	*Improve safety for community*
15			3.0			3.0	4.0	3.0	5.0	5.0			
16			3.0			3.0	4.0	3.0	5.0	5.0			
17	4.0	3.0	3.0	3.0	5.0	4.0	4.0	3.0	5.0	5.0	4.0		
18	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	5.0	5.0	2.0		
19	2.0	5.0	5.0	5.0	5.0	4.0	4.0	3.0	5.0	4.0	4.0		
Averages	*3.1*	*3.9*	*3.5*	*3.2*	*3.3*	*3.1*	*3.5*	*3.1*	*4.9*	*4.7*	*2.8*	*4.2*	

Appendix B

Interview Questions

HMSC MRI Marine Sciences Building
10 Questions for the March 12-13 2015 interviews
Roz Estime, Chris Poland

1. Does the MSB need to be located at the HMSC?
2. Can the MSB be designed to protect the faculty, students and visitors during an earthquake and Tsunami?
    a. Are there any longer term experiments that need to be protected?
    b. Should the damage to the MSB be repairable so that it can be reopened afterwards?
    c. How soon?
3. In terms of the following characteristics, what size earthquake and Tsunami do you expect in the next 50 years? What is the largest that could occur?
    a. Magnitude
    b. Water height
    c. Velocity of the flow
    d. Subsidence
    e. Lateral spreading
    f. Debris sources
4. How detailed and accurate is the computer modeling of the South Beach area?
    a. Is there agreement among scientists about how to model these events?
    b. Have the estimates been peer reviewed?
    c. Factors of safety
5. Is it possible to control/redirect the expected debris flow?
    a. Levy at the Marina
    b. River as the least path of resistance
6. What are the early warning systems now in place and what is planned?
7. What are the current evacuation plans for South Beach?
    a. Partner Agency Plans.
    b. How many people will need to evacuate?
    c. Are there plans to use the multistory buildings in the area?
    d. What high ground is available?
    e. Will the bridge approach be usable?
    f. What are the existing barriers?
8. What can be done to improve the evacuation plans?
    a. Vertical evacuation
    b. Elevated Road way
    c. Debris mound near NOAA
9. What benefits will the MSB bring to the community?
10. Other comments and suggestions