Tsunami Hazard Mitigation on the Washington Coast

by

Timothy J. Walsh

Washington Geological Survey

Washington Department of Natural Resources

August 16, 2017

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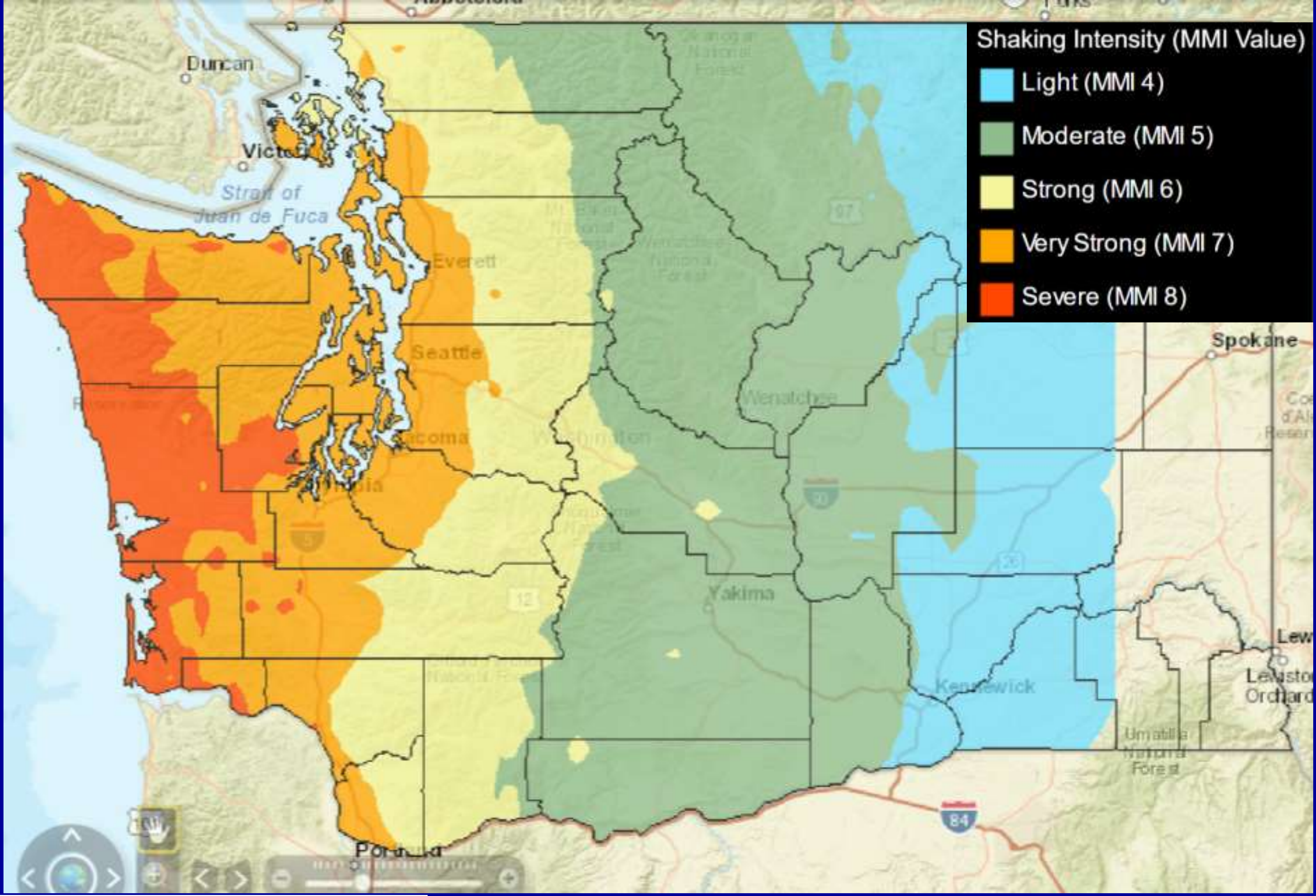

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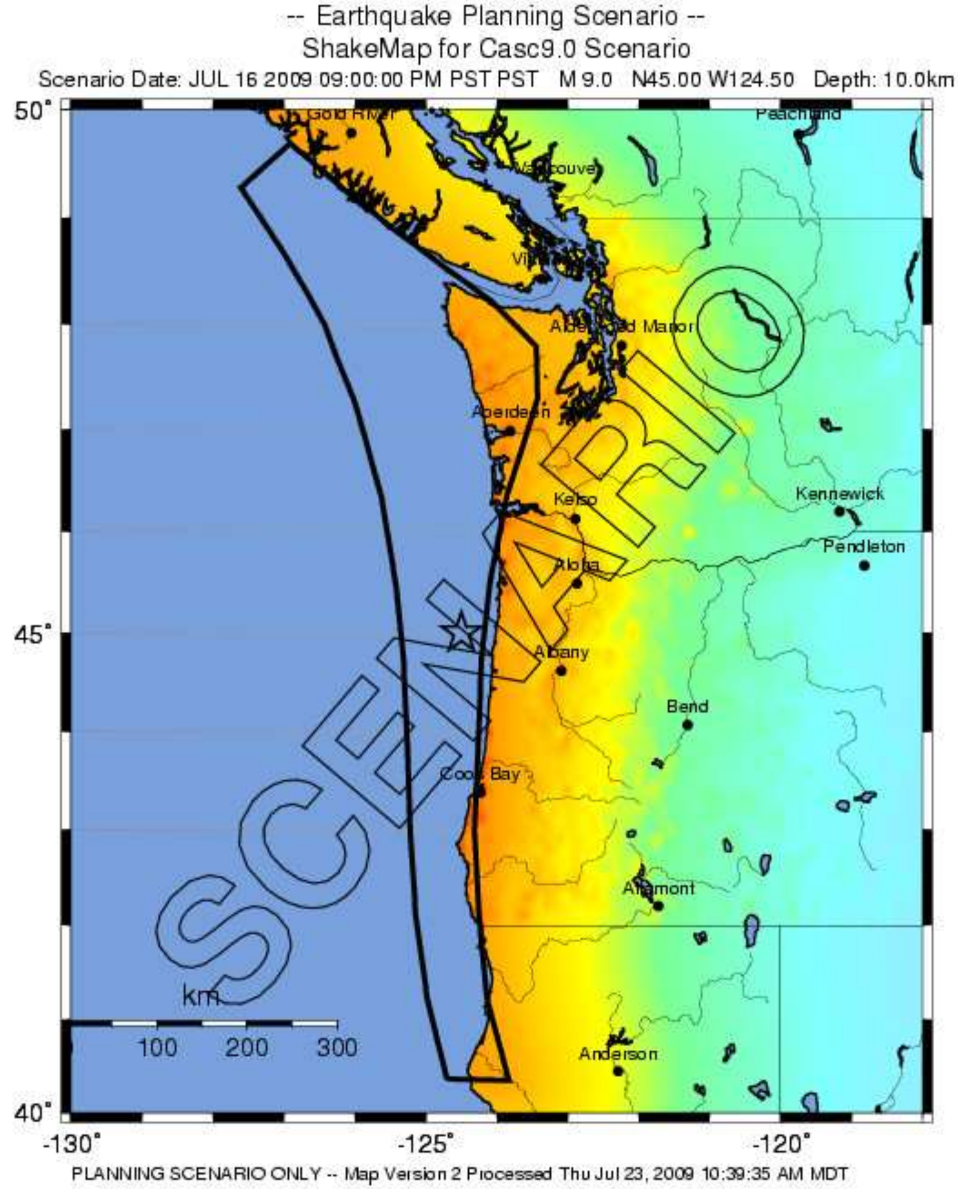
Most of that earthquake hazard along the Washington coast is due to the Cascadia subduction zone (from Art Frankel)

Although the maximum intensity of shaking would be less than for a large shallow earthquake, such as on the southern Whidbey Island fault, Seattle fault or Tacoma fault, strong ground shaking from a Cascadia subduction zone earthquake would be felt from northern California to northern Vancouver Island, and it would be greatest near the coast. In addition it would be accompanied by a tsunami that would be devastating within a few miles of the coast.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

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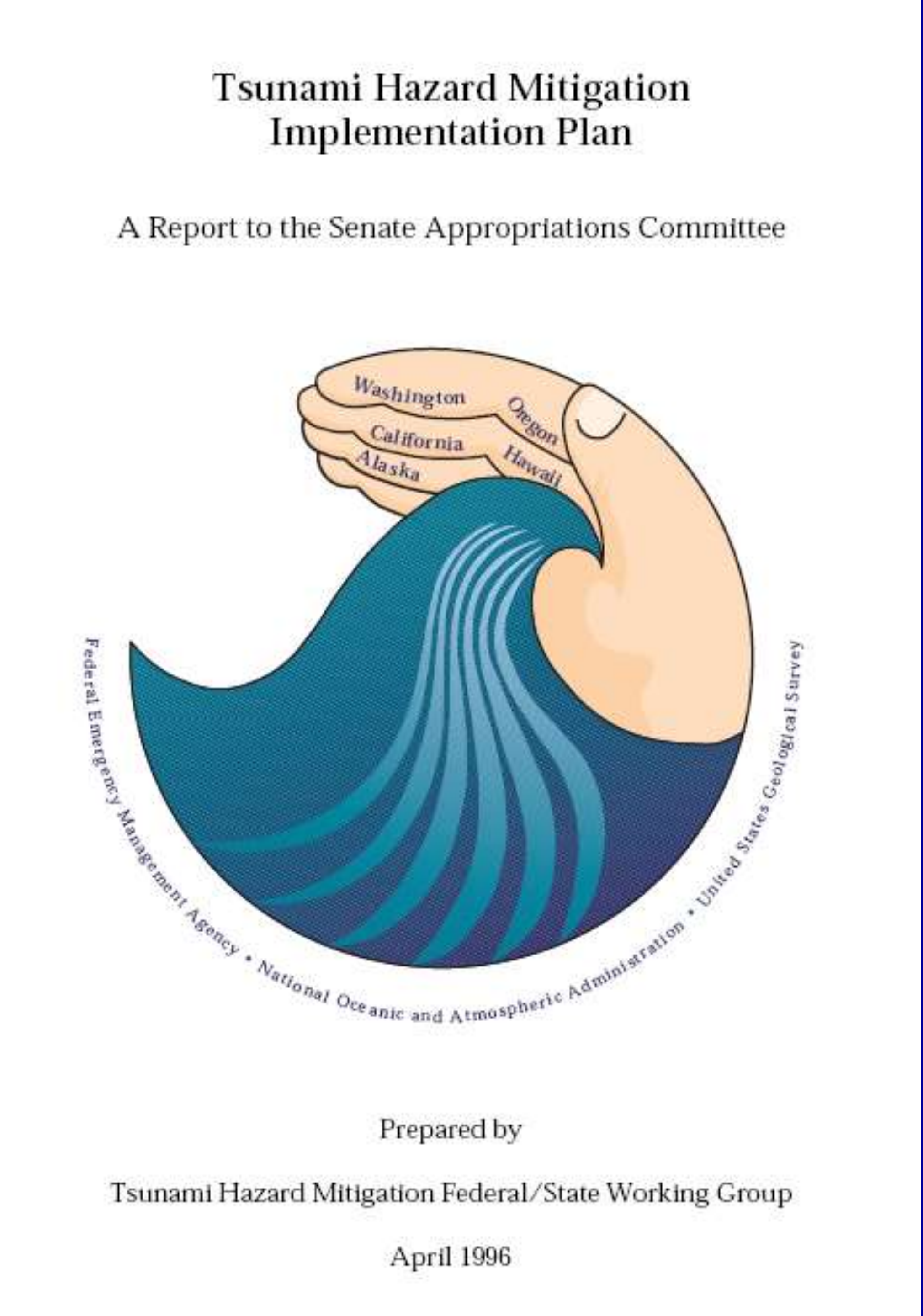
In the early 1990's, a confluence of 3 events---the realization that the Cascadia subduction zone produced both major earthquakes and major tsunamis; the 1991 Petrolia earthquake, which generated a small local tsunami; and the 1994 Kuril Islands tsunami warning; ---led the Senate Appropriations Committee, chaired by Mark Hatfield, to direct NOAA to form a partnership with the 5 Pacific states to develop a plan to safeguard the west coast from local tsunamis


Tsunami Hazard Mitigation Implementation Plan

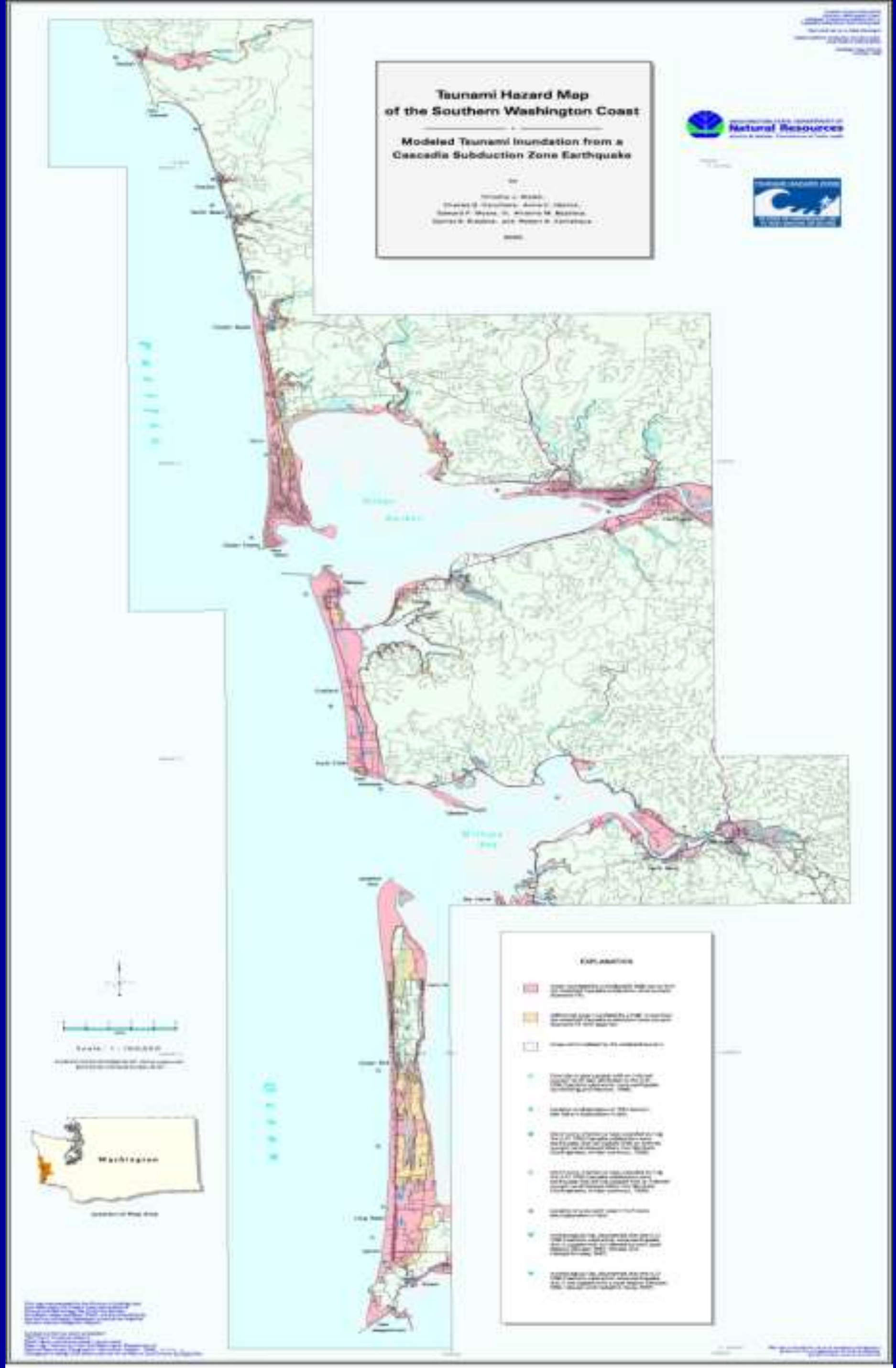
A Report to the Senate Appropriations Committee

Prepared by

Tsunami Hazard Mitigation Federal/State Working Group

April 1996

This led to the creation of the National Tsunami Hazard Mitigation Program, which, among other things, creates tsunami hazard maps for U.S. coastlines. This map of the southern Washington coast indicates many hazard areas on accretionary shoreforms of low relief, where most of the resident population of the outer Washington coast lives and where evacuation is most difficult or even impossible in the short time available.



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In 2002, we held a workshop to investigate whether it was feasible to design facilities to withstand a nearfield M9 earthquake, suffer so little damage as to be attractive for an evacuation refuge, and also be high and resilient enough to serve as a shelter for people in the near-field.

PROCEEDINGS
of a
WORKSHOP ON CONSTRUCTION GUIDANCE
FOR AREAS OF HIGH SEISMIC AND TSUNAMI LOADING
convened by

TIMOTHY J. WALSH[1], GEORGE CRAWFORD[2], RICHARD EISNER[3], AND JANE V. PREUSS[4]

for the
NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM
NOVEMBER 21, 2002

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Doug Sutherland - Commissioner of Public Lands
Division of Geology and Earth Resources
Ron Teissere - State Geologist

THE SEAL OF THE STATE OF WASHINGTON 1889

OES CALIFORNIA
Governor's Office of Emergency Services

GEOENGINEERS

1. Washington Department of Natural Resources, Division of Geology and Earth Resources, Olympia, Washington
2. Washington Emergency Management Division, Camp Murray, Washington
3. California Governor's Office of Emergency Services, Oakland, California
4. GeoEngineers, Inc., Redmond, Washington

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That led to a study of the characteristics these buildings and others like them that allowed them to survive devastating tsunamis when everything else in the area was destroyed.

Development of Design Guidelines for Structures that Serve as Tsunami Vertical Evacuation Sites

by Harry Yeh,
Ian Robertson,
and Jane Preuss

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Open File Report 2005-4
November 2005

This report has not been edited or reviewed for conformity with Division of Geology and Earth Resources standards and nomenclature

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Doug Sutherland - Commissioner of Public Lands

We formed a partnership with FEMA and the Applied Technology Council to provide building code style guidance for building facilities to withstand a near-field magnitude 9 earthquake and be suitable for vertical evacuation. Planning for the right size earthquake is critical.

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Guidelines for Design of Structures for Vertical Evacuation from Tsunamis

FEMA P646 / June 2008

FEMA

But how to build these? John Schelling at Emergency Management Division launched Washington's approach to tsunami evacuation in places that have no nearby high ground

PROJECT SAFE HAVEN:
VERTICAL EVACUATION ON THE WASHINGTON COAST

Grays Harbor County, Washington
2011

FEMA
UNIVERSITY of WASHINGTON

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Near Westport, a logical place to build a safe haven is at the site of Ocosta Elementary School.

Ocosta Elementary School is an old school that the district tried twice to replace, but the bond issue failed twice. In April, 2013, another bond issue was on the ballot to replace the school, this time including $2 million for a wing to be built to FEMA 646 standards.

WE DID IT!

Sch Dist 172 - Ocosta Proposition No. 1 Bonds to Renovate Ocosta Elementary School
*Multi-county race. Results include all counties involved.

County	Measure	Vote	Vote %
Grays Harbor	Approved	865	69.87%
	Rejected	373	30.13%
Pacific	Approved	197	70.36%
	Rejected	83	29.64%
Combined Total			
All	Approved	1,062	69.96%
	Rejected	456	30.04%
Total Votes		**1,518**	**100%**

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Landslides are often collateral damage in earthquakes. This landslide was generated by the April 13, 1949 Puget Sound earthquake, although 3 days later. It caused a tsunami that reflected off the opposite shore and drowned the houses on the beach (left).

Hazards often recur in the same location. In 2001, the Nisqually earthquake reactivated that landslide and damaged some of the same houses (right).

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Much of the Washington coast is made up either low-lying accretionary shoreforms or bluffs composed of weak sedimentary rock, sometimes disrupted by gas seeps, that are landslide-prone.

As part of the task of evaluating the suitability of potential sites for tsunami evacuation structures, we evaluated the vulnerability to earthquake-induced ground failures, both for siting of the facilities but also for inclusion in the tsunami inundation modeling.

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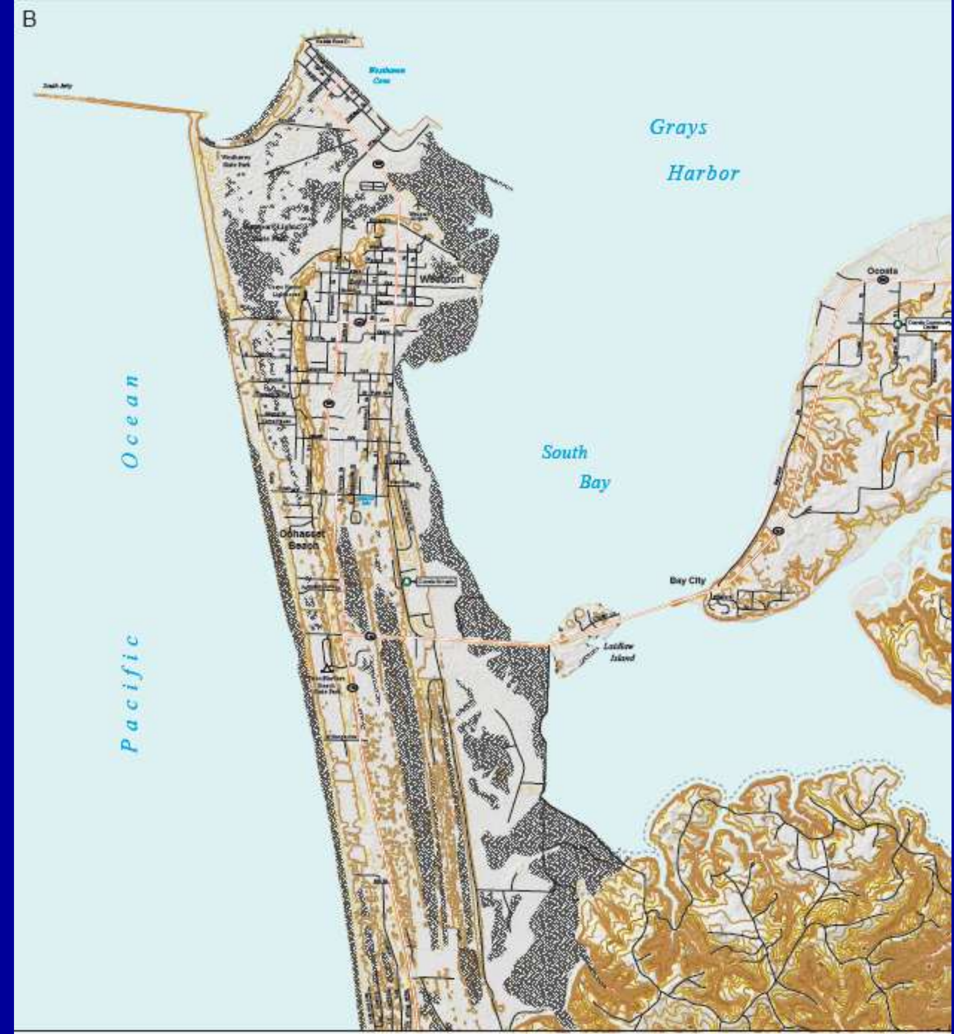
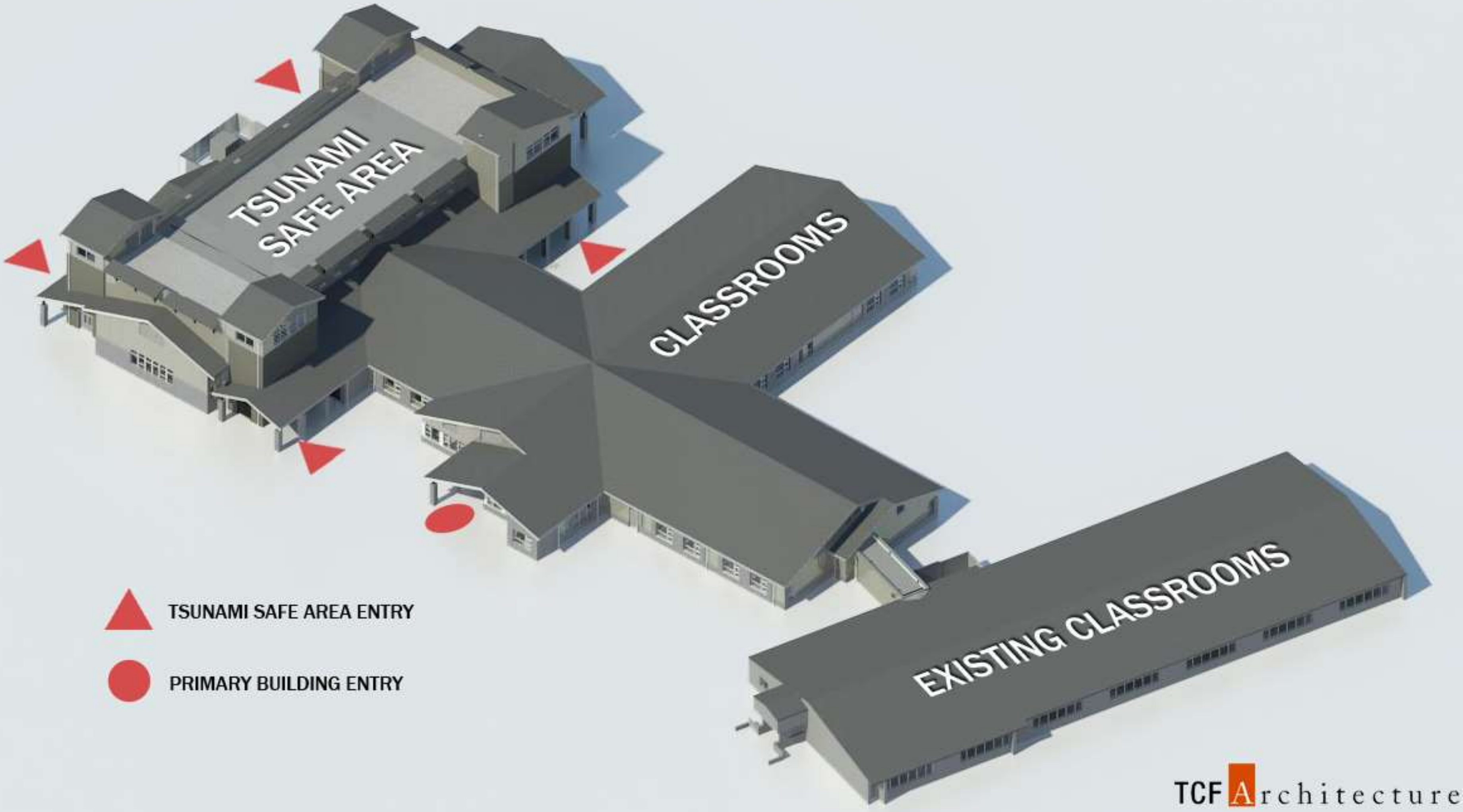


Sheet 2. Shallow landslide vulnerability during a wet period for a Cascadia subduction zone magnitude 9+ earthquake for the Ocean Shores and Westport Peninsulas, Grays Harbor County, Washington

by

Stephen L. Slaughter, Timothy J. Walsh, Anton Ypma, and Recep Cakir

July 2014



Cale Ash at Degenkolb Engineers was retained to make the seismic and tsunami designs complying with FEMA 646. He determined that the refuge would have to be 55 feet above sea level or 28 feet above grade. The design calls for using the roof of the new gymnasium as the safe haven, capable of holding more than 1,000 people. Access is by stair towers at the corners of the gym which are reached from the outside only, so that people do not have to enter the building.

Groundbreaking for the Ocosta Elementary School tsunami vertical evacuation refuge—first in the U.S.

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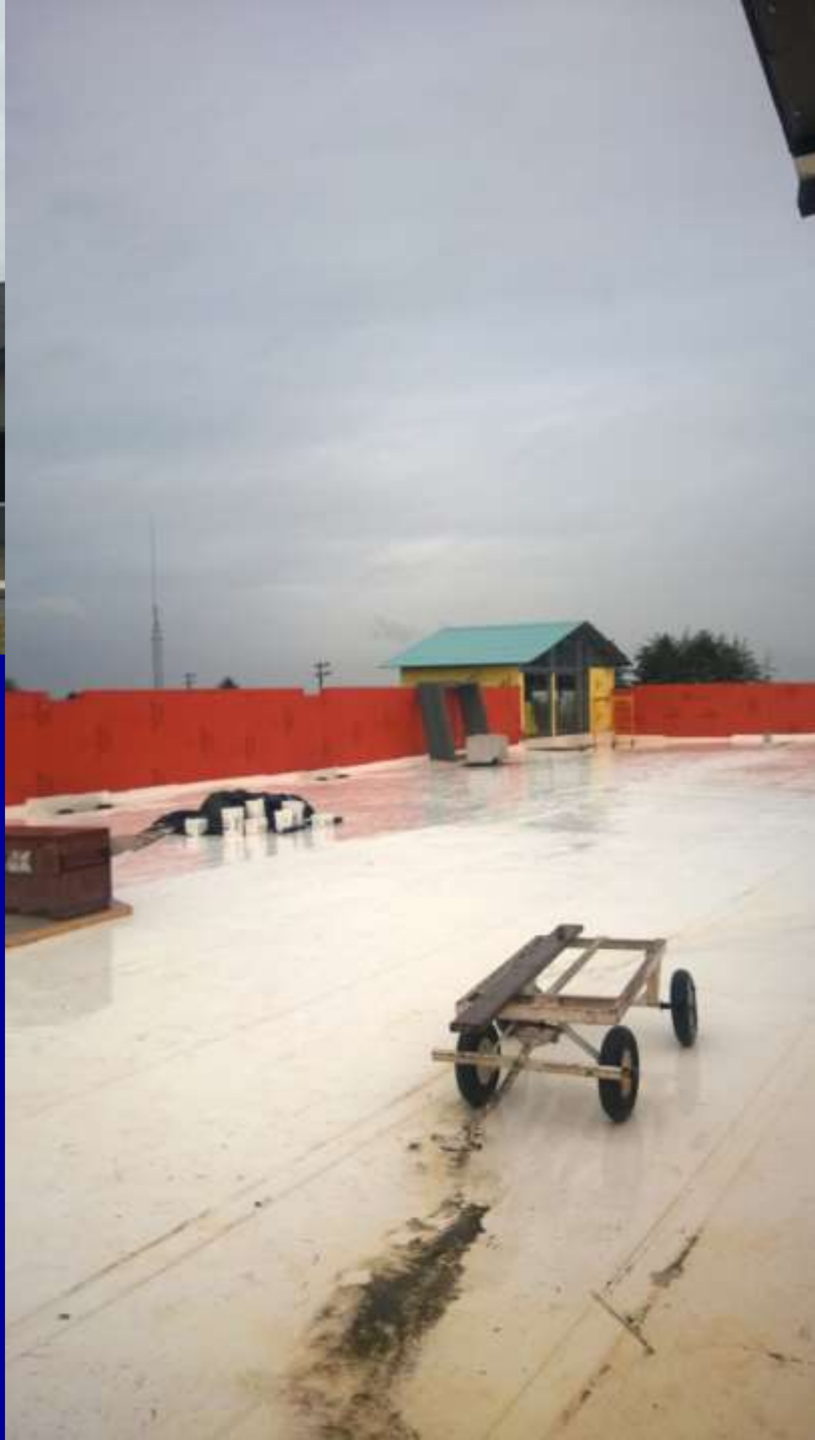
Here is the team that collaborated to build the first tsunami vertical evacuation refuge in the U.S.



The dedication of the nation's first tsunami evacuation shelter was on June 11, 2016. The roof of this gym is accessed by stair towers that have no access to the gym, for security reasons. Note that the school district decided to maintain a wall around the roof to prevent the students from seeing what might be happening to their town. Dozens more are needed but funding is scarce.

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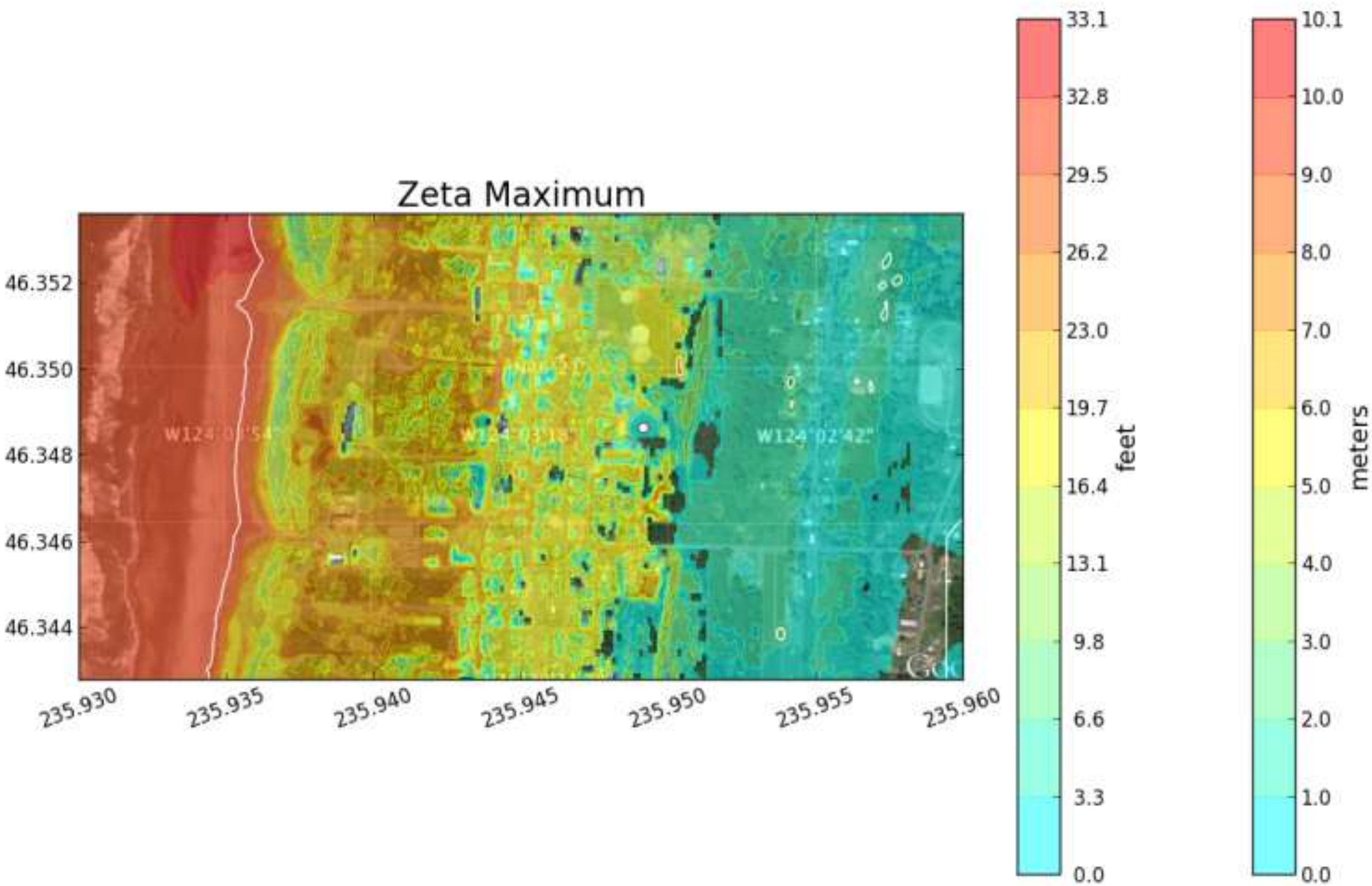
Planning for a second tsunami evacuation structure adjacent to Long Beach Elementary School was funded in 2011.

Since then, ASCE 7-16, chapter 6, has extended FEMA 646 using probabilistic hazard analysis, and is being implemented in the design of a berm adjacent to Long Beach Elementary School.



At the beginning of this project, about 5 years ago, we started with a scenario earthquake and tsunami.

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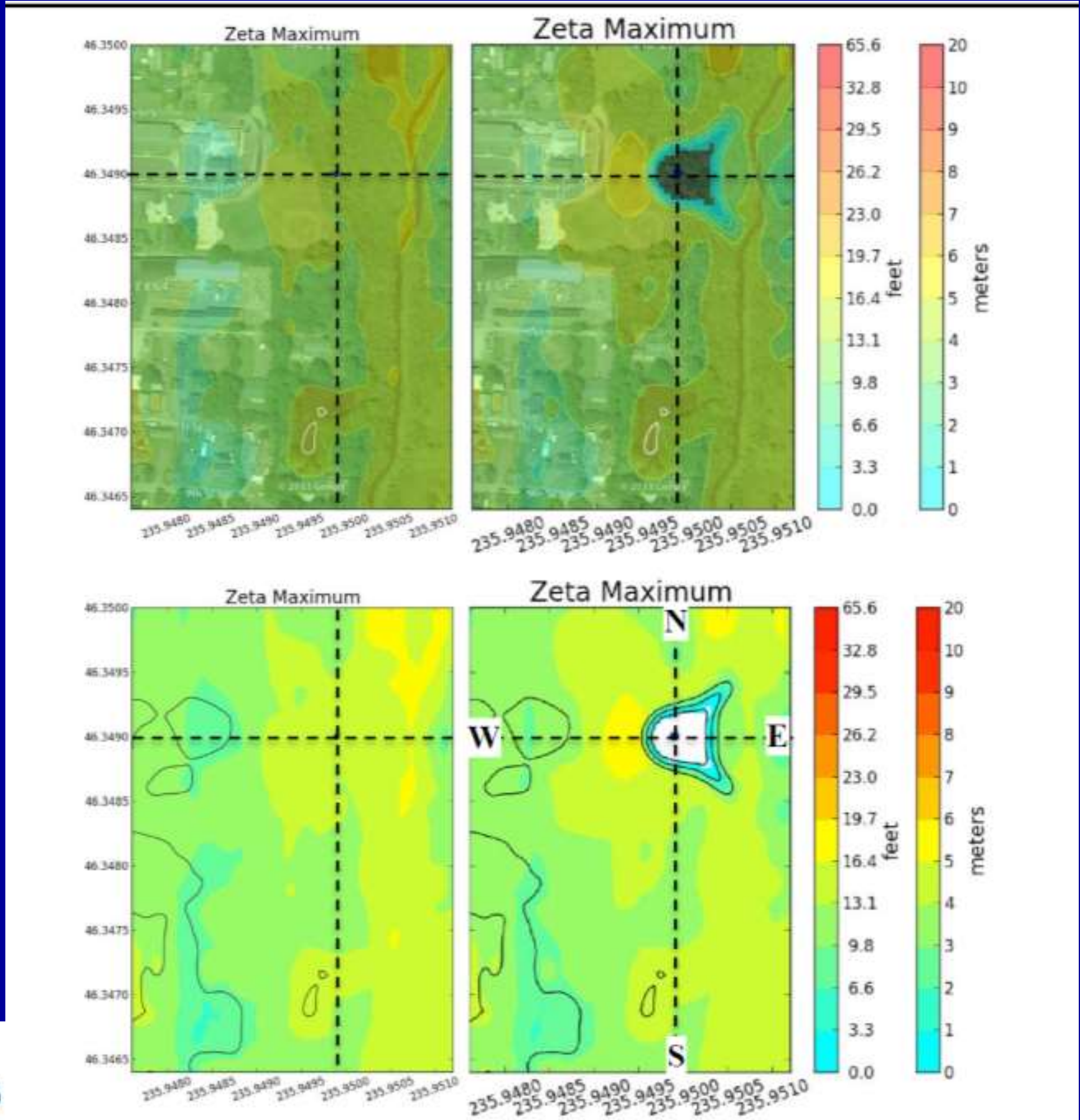
Tsunami inundation at this site was done by Frank Gonzalez and Randy LeVeque (University of Washington) using Geoclaw, based on an event with an estimated 2% probability of exceedance in 50 years, or, colloquially, the 2,500 year event.



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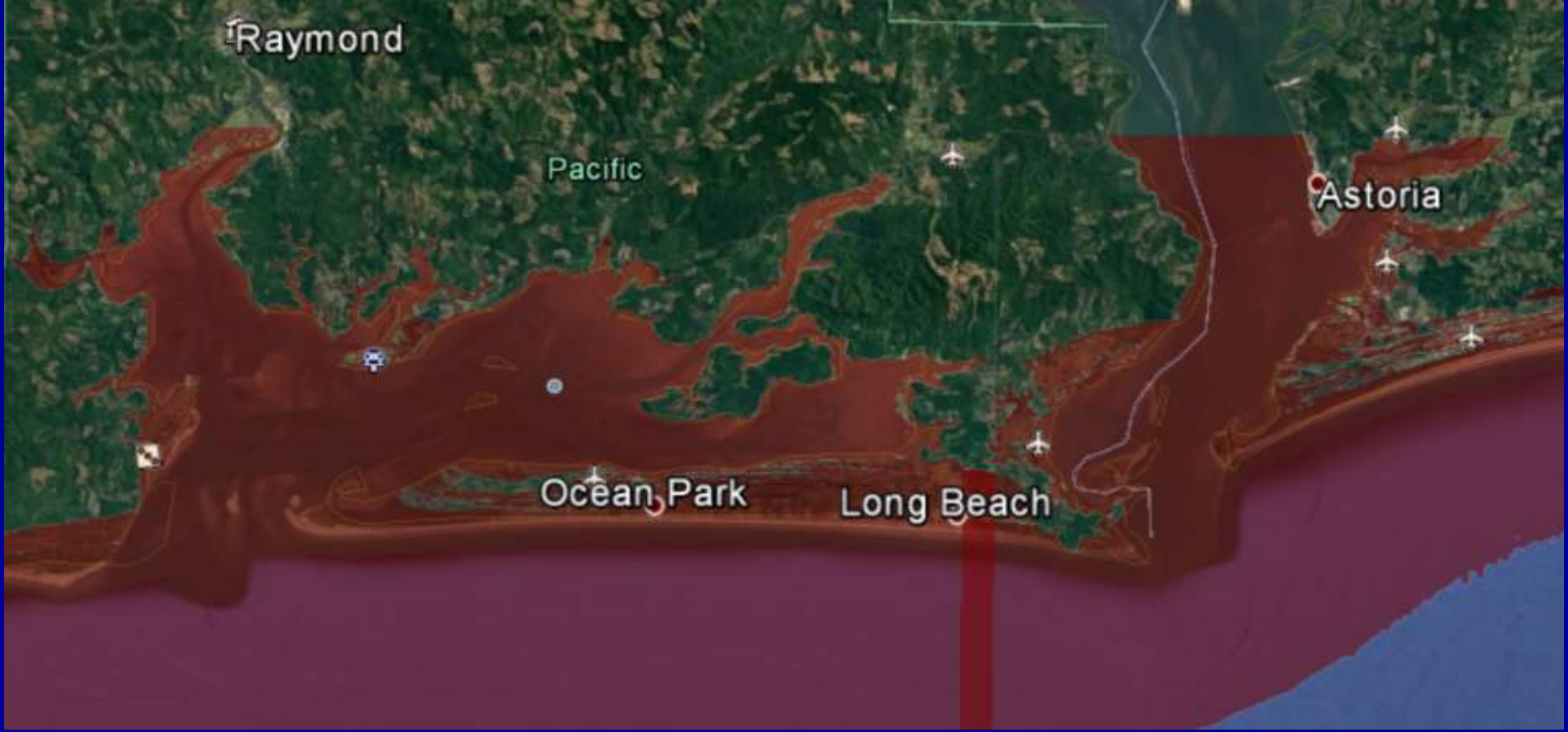

The inundation extent of the probabilistic modeling is similar to the deterministic scenario, but the inundation depth appears to be greater. This has resulted in a need for a re-assessment of the inundation model to assure compliance with ASCE 7-16, which is in progress now.

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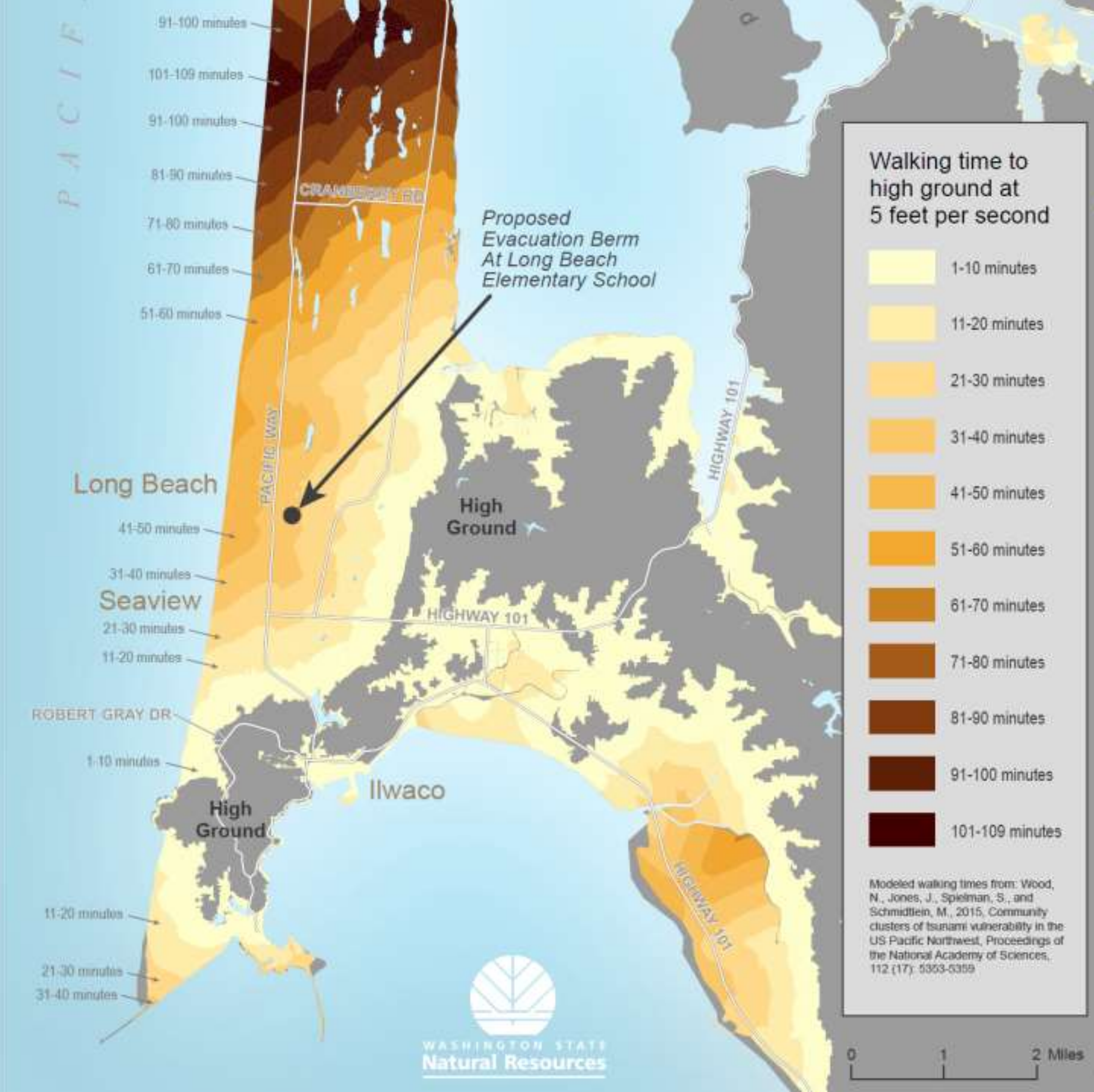
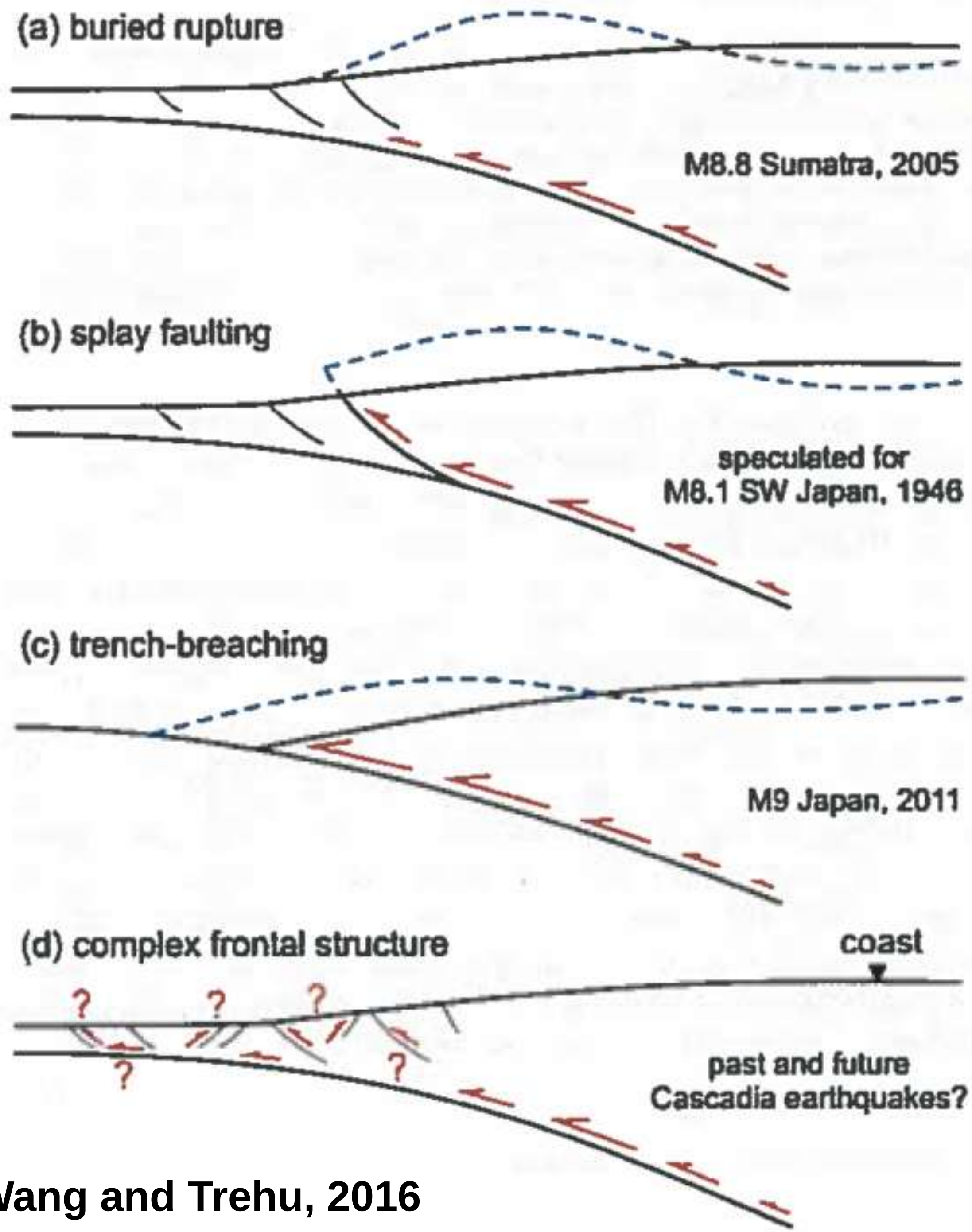
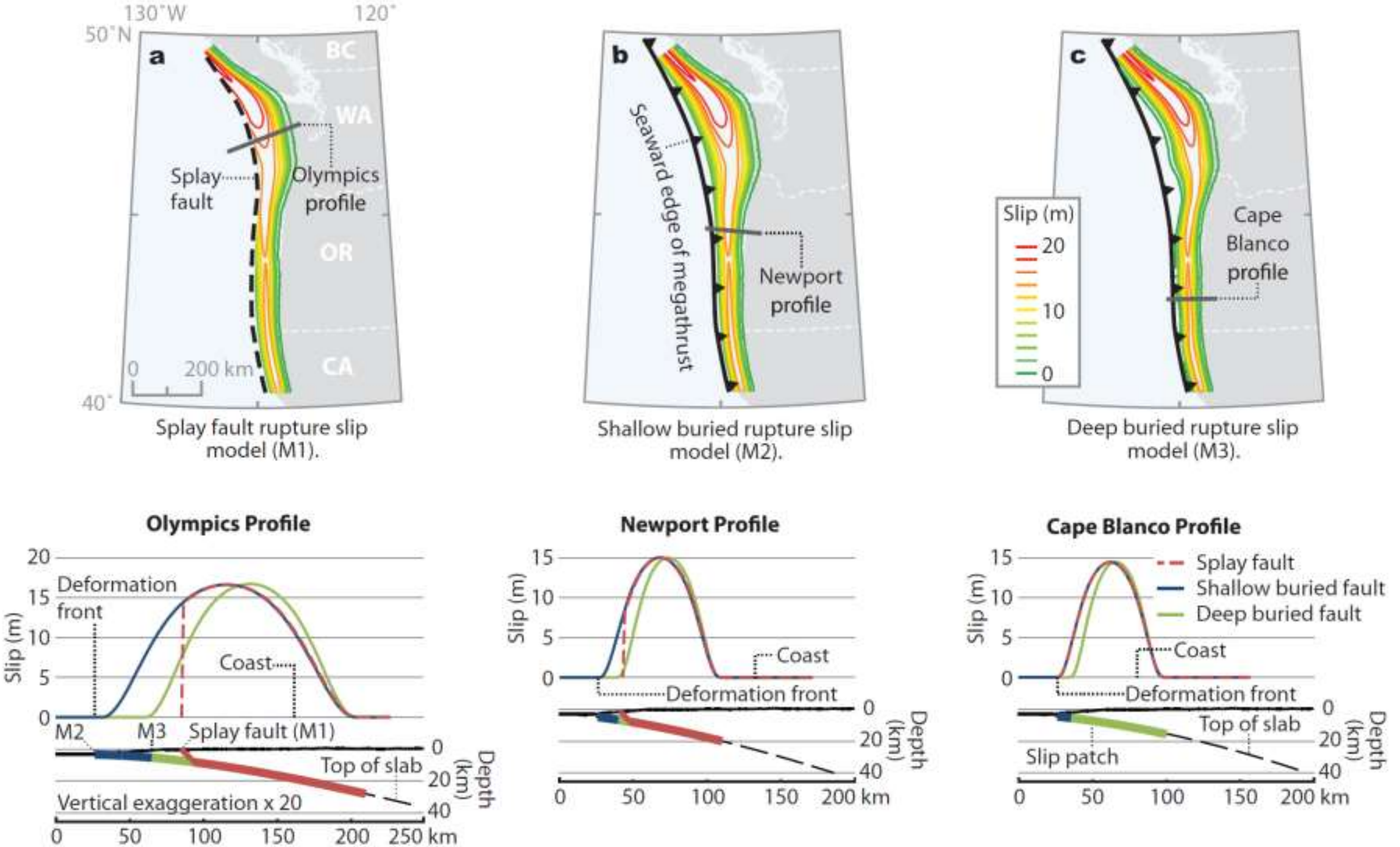


Earthquake early warning could also help facilitate successful tsunami evacuation by adding a few minutes to the short (a few tens of minutes) time available to reach high ground or a vertical evacuation structure.

There are significant uncertainties in calculating tsunami inundation depths and loads that are accounted for by adding safety factors. The most significant uncertainty, however, is in the generation of the tsunami. Slip distribution and surface deformation are the drivers of the tsunami model and they are poorly known. Seafloor geodetic and seismic monitoring would improve understanding of the seismic source and more closely constrain the initial condition for the tsunami model, which in turn could reduce the magnitude of safety factors.



Wang and Trehu, 2016



The rupture process not only determines the characteristics of the tsunami, but also the location of tsunami generation. This, in turn, determines the arrival time of the initial wave. While this is likely only a matter of minutes, in the near field the difference between 25 and 30 minutes can have significant consequences for survivability.

While these are long-term measures that would take years to implement at the local level, with luck we may have that time.

Nature, to be commanded,
must be obeyed
Francis Bacon, Novum Organum

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