PREPARE FOR TSUNAMIS: SCIENCE AND TOOLS TO HELP US SURVIVE THE BIG ONE

Washington Coast Marine Advisory Council Meeting
June 13th, 2018

Daniel Eungard, LG
Washington Geological Survey

Talk outline

- What – is a tsunami and how do they form?
  - Sources, propagation and wave physics, local vs. distant
- When – have they occurred before in Washington/elsewhere?
  - Geologic and historical record of tsunamis
- How – do we know what to expect next?
  - Local and distant scenarios, tsunami modeling
- Where – can we get information to prepare for tsunamis?
  - Informational maps, maritime guidance, community outreach

Tsunami– "a great sea wave produced especially by submarine earth movement or volcanic eruption"

—Merriam-Webster dictionary

Sources of Tsunamis

- **Earthquakes**
- Landslides
- Volcanos
- Meteorological events
- Meteor Impacts

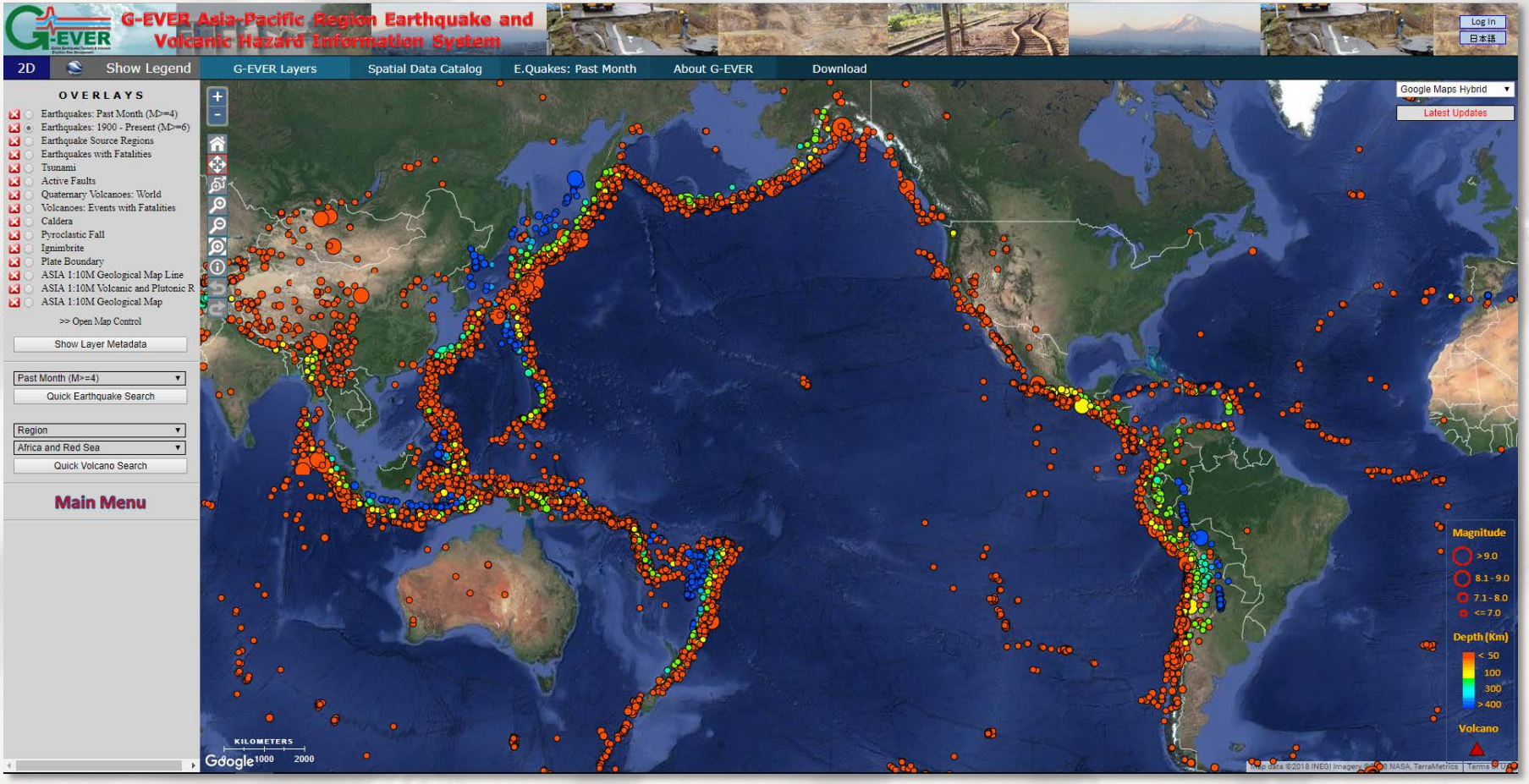
Image credit: Wikimedia commons

Why We Focus On EQ Tsunamis?

- **Earthquakes**
- Landslides – highly unpredictable/localized
- Volcanos – no known danger to WA
- Meteorological events – too common/small
- Meteor Impacts – too rare/catastrophic

Image credit: Wikimedia commons

EQ Distribution 1900-present



Map credit: http://ccop-geoinfo.org/G-EVER/

Juan de Fuca plate and the Cascadia subduction zone

- Highly dynamic geologic environment
- 1000 km (620 mi) long subduction zone
- Numerous crustal faults

Image credit: Wikimedia commons

Washington earthquake sources

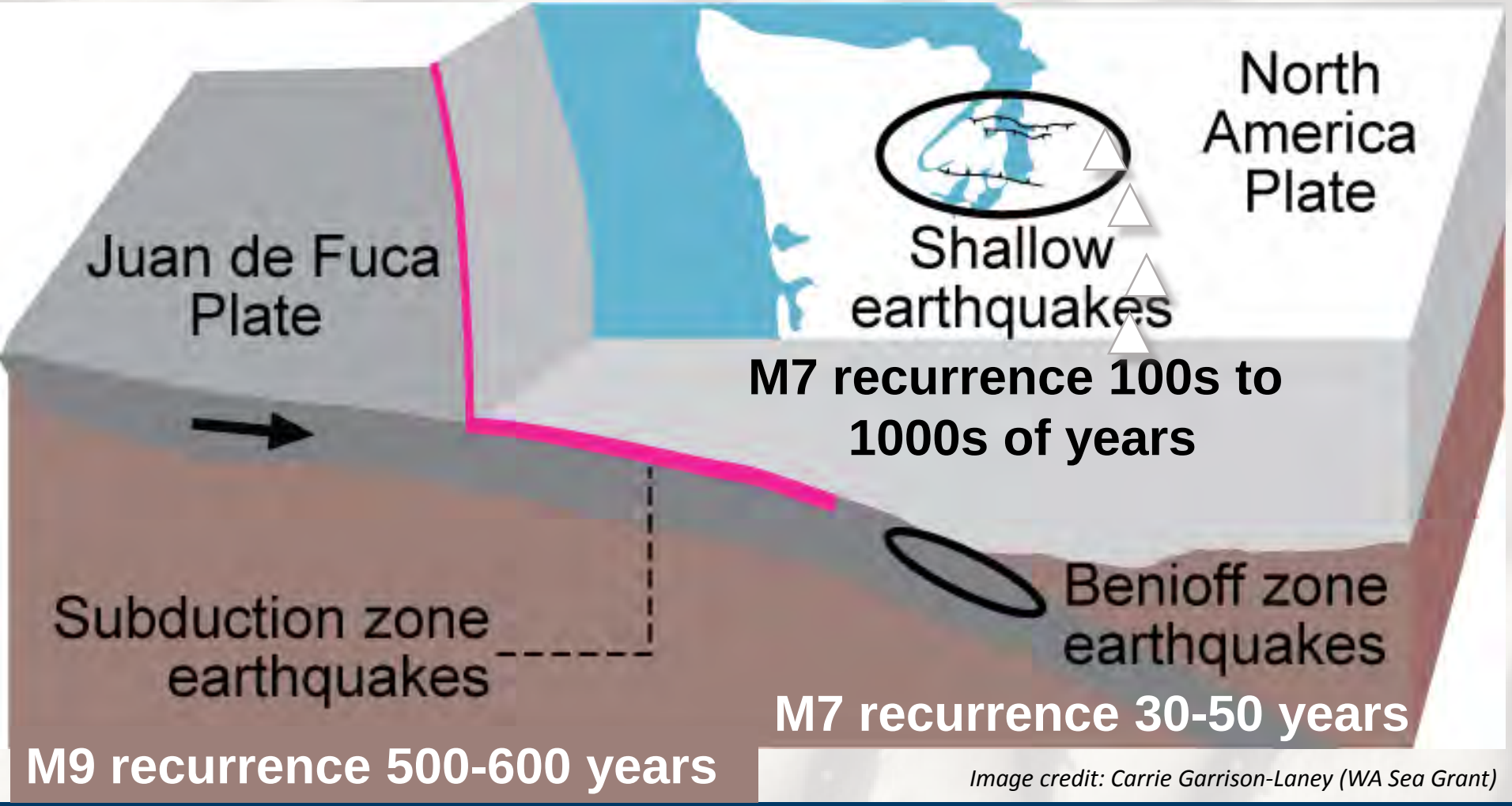


Image credit: Carrie Garrison-Laney (WA Sea Grant)

Tsunamis are…

- Fast
- Powerful
- Multiple waves
- Unexpected

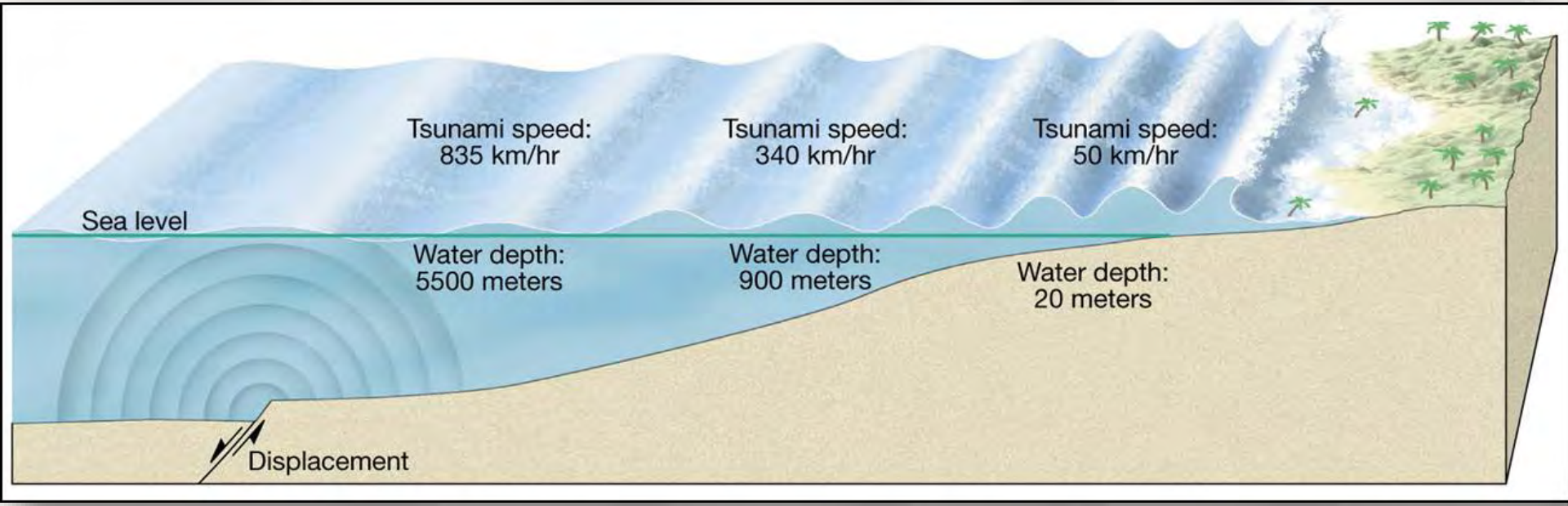
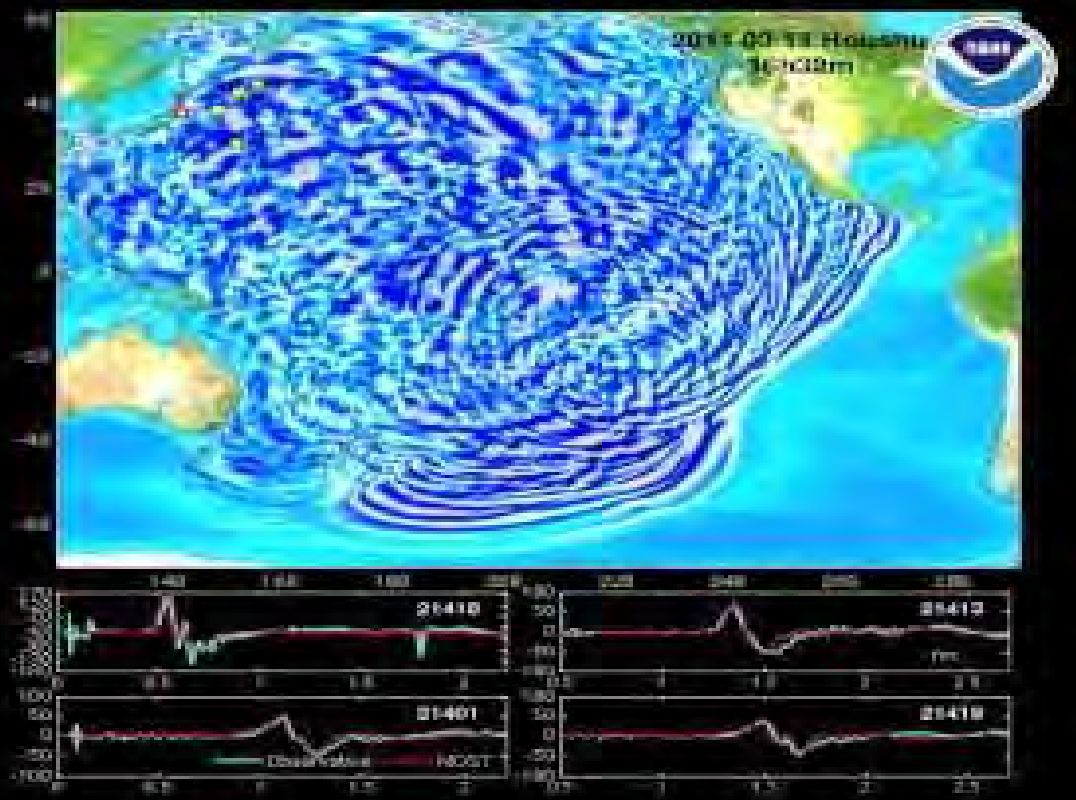
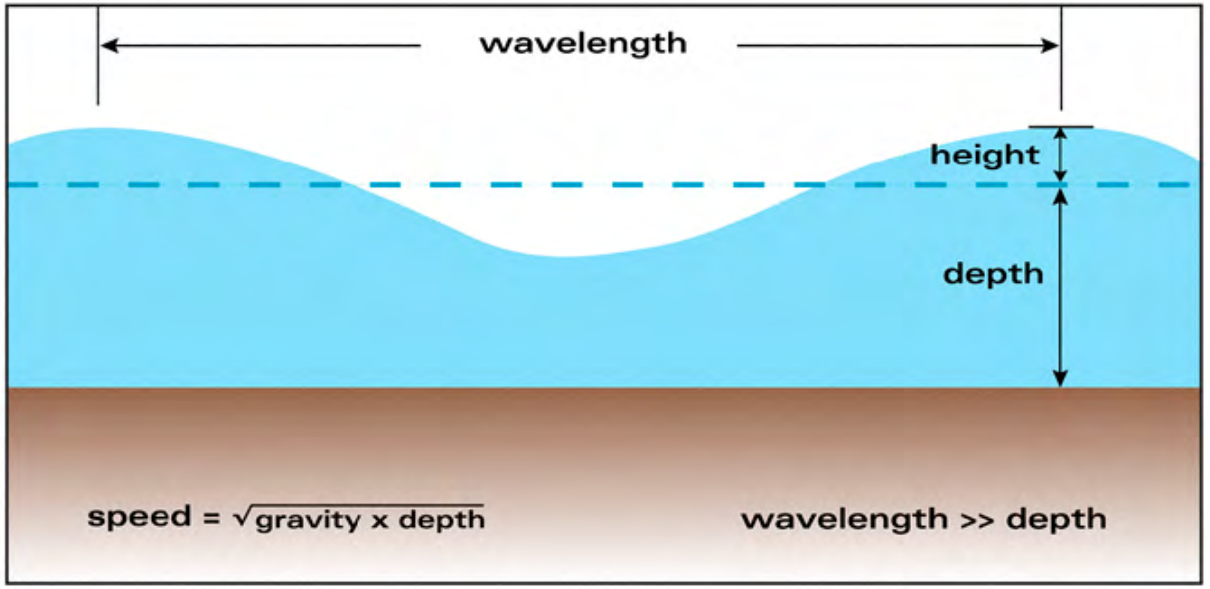


Image credit: geophile.net

Tsunami propagation



Tsunami wave physics



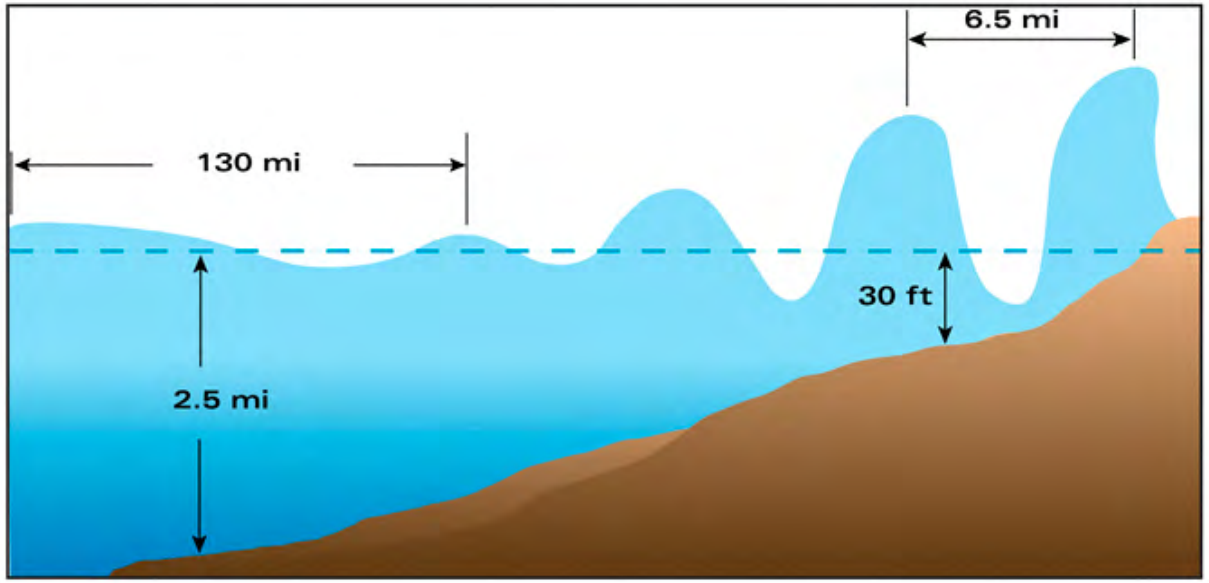


Image credit: discovertsunamis.org

Tsunami vs Storm Waves

	Tsunami	Storm
Water depth	Entire water column	10-100 ft
Wavelength	1000s of feet	10-100s ft
Speed	100s mph	10s mph

Distant vs Local Tsunamis

Distant

- >3 hours warning
- Warning must be distributed
- Less inundation/currents
- Minimal impact to coast

Local

- < 3 hours warning
- Event will typically be felt
- More inundation/currents
- Significant impact to coast

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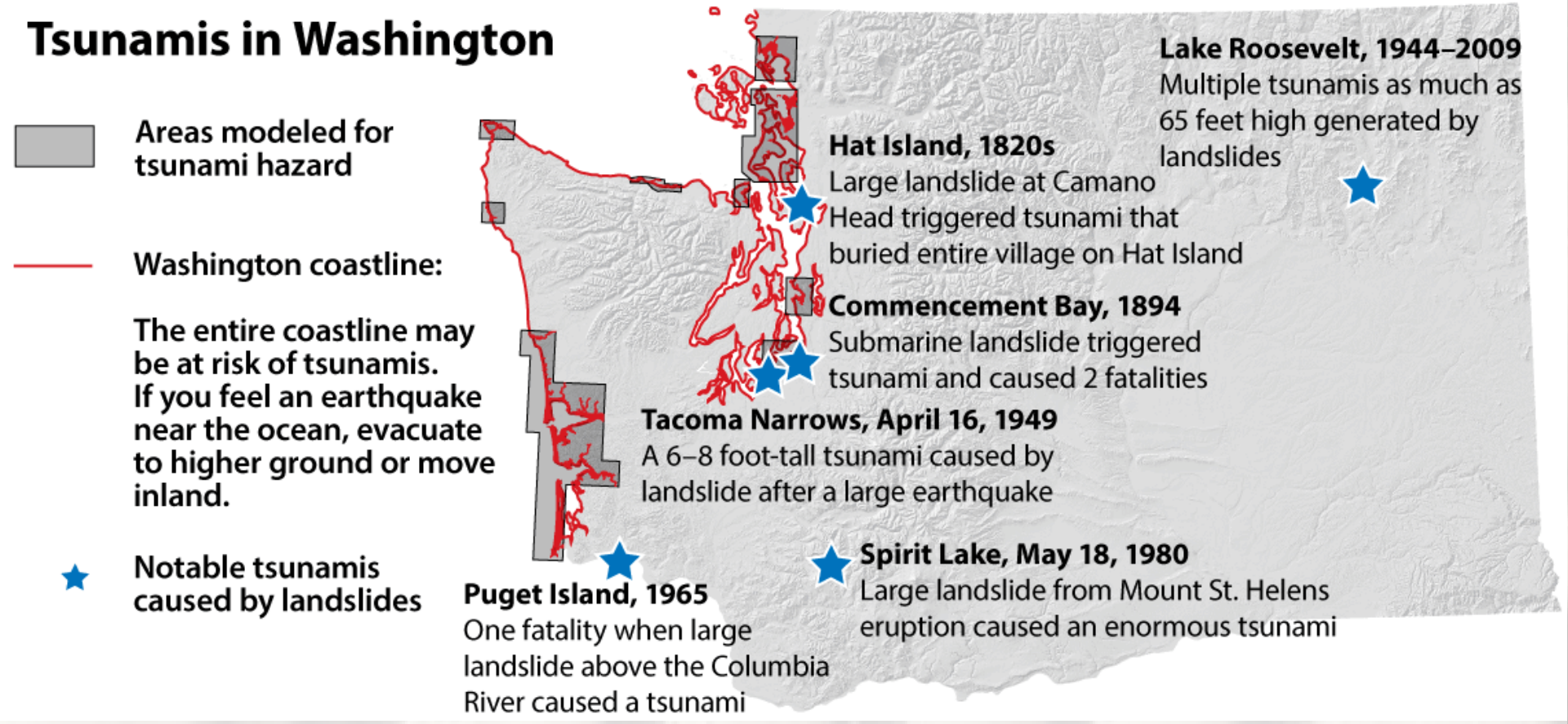
Historic Events

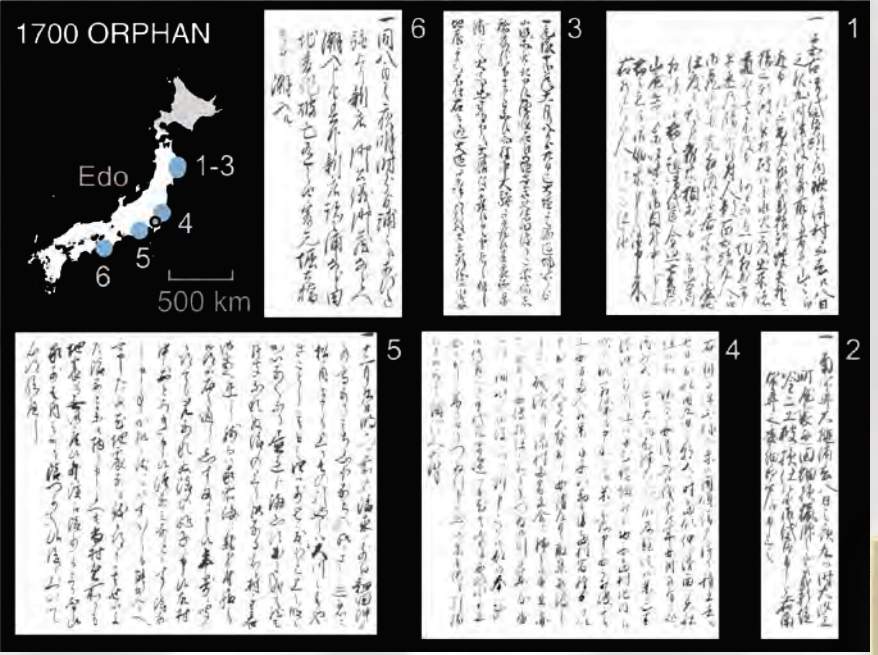


A late-19th century interior ceremonial screen from Port Alberni, B.C. It shows Thunderbird carrying Whale in its talons, a common native depiction of seismic activity. The original screen is housed in the American Museum of Natural History. (Photo: University of Washington)

Excerpt from:
THUNDERBIRD FIGHTS MIMLOS-WHALE
as told by Luke Hobucket of Quileute Tribe

"*The noise that Thunderbird made when he flapped his wings shook the mountains. They stripped the timber there. They tore the trees out by their roots. Then Mimlos-whale got away.*"

From: *Reagan, Albert, and L.V.W. Walters, 1933, "Tales from the Hoh and Quileute", Journal of American Folklore, V. XLVI, pp. 297-346*



Time of last Cascadia event: 9 pm on January 26th, 1700

Image credit: Wikimedia commons

Alaska 1964 9.2 M_w EQ

- $105,000 in damages (1964 currency)
- Largest wave arrived 12 hours after the initial tsunami according to eyewitness accounts

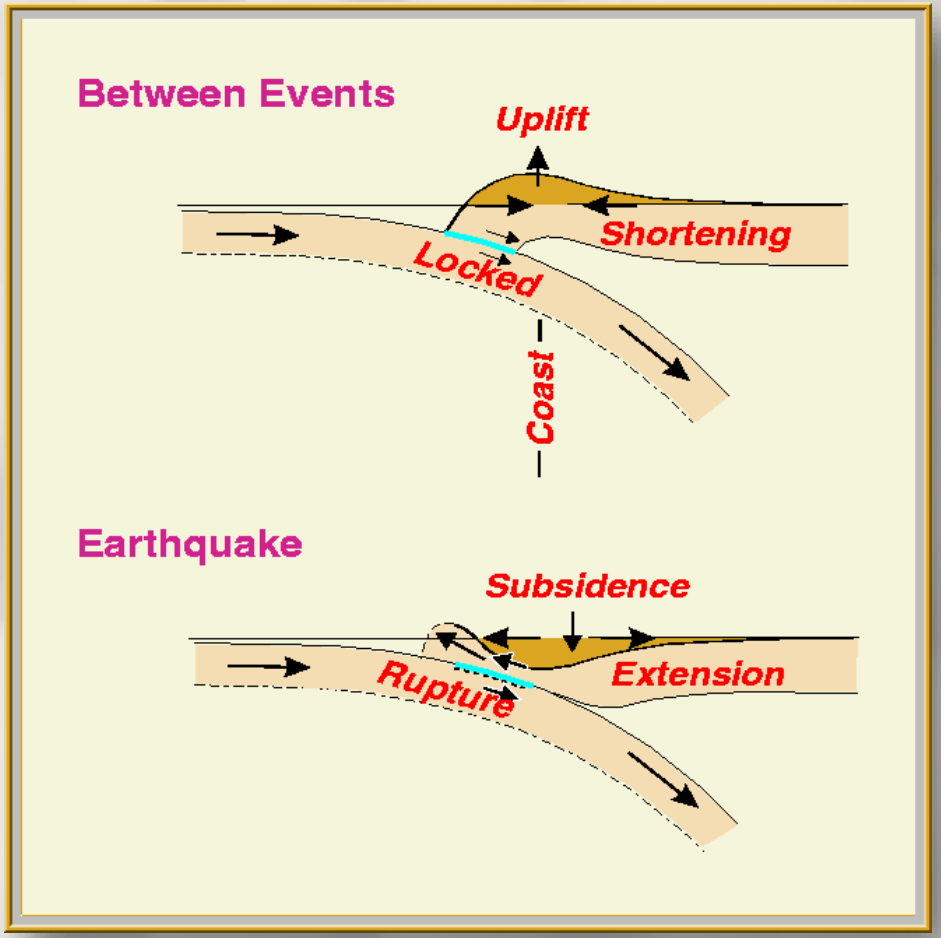
Figure 3. Photo 9-1-A. Two spans lost and timber bent. Two other 20-foot spans are shown considerably deflected. Map location 5.

Figure 4. Photo 8-3-A. Two spans of bridge and middle pile bent lost. Pile bents on each side damaged, right side has been deflected from original position. Map location 8.

Figure 5. Photo 8-2-A. Portion of house completely torn from main part. Entire house was moved northwest 40 ft (12.2 m) from foundation. Map location 9.

Earthquake Generated Land-Level Change

- Strain accumulates between events
- Land levels shift to accommodate
- Release of strain (earthquake) causes rebound of earth's surface
- Land level may be changed significantly for great periods of time

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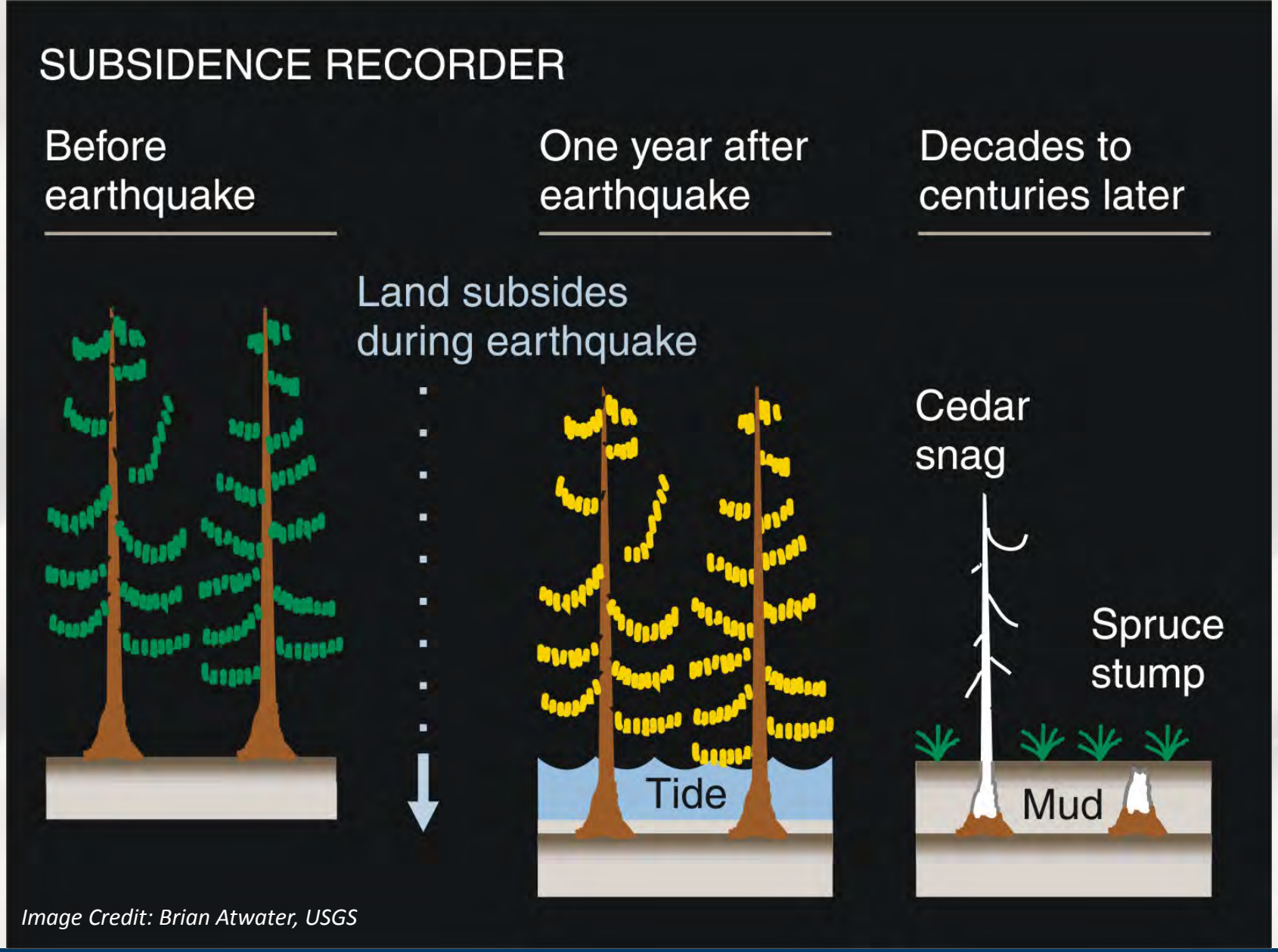


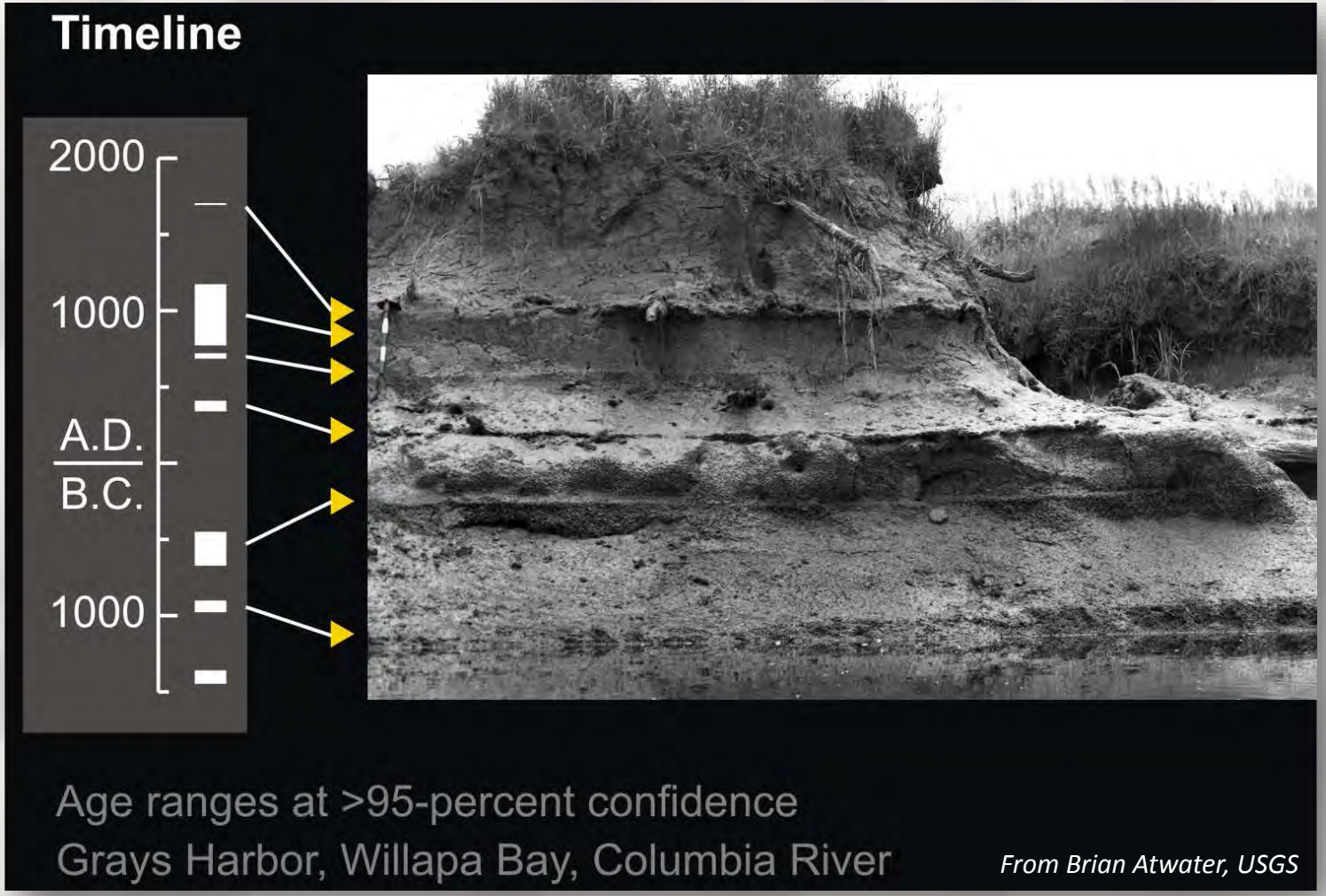
Image Credit: Brian Atwater, USGS

Land Level Changes — Examples

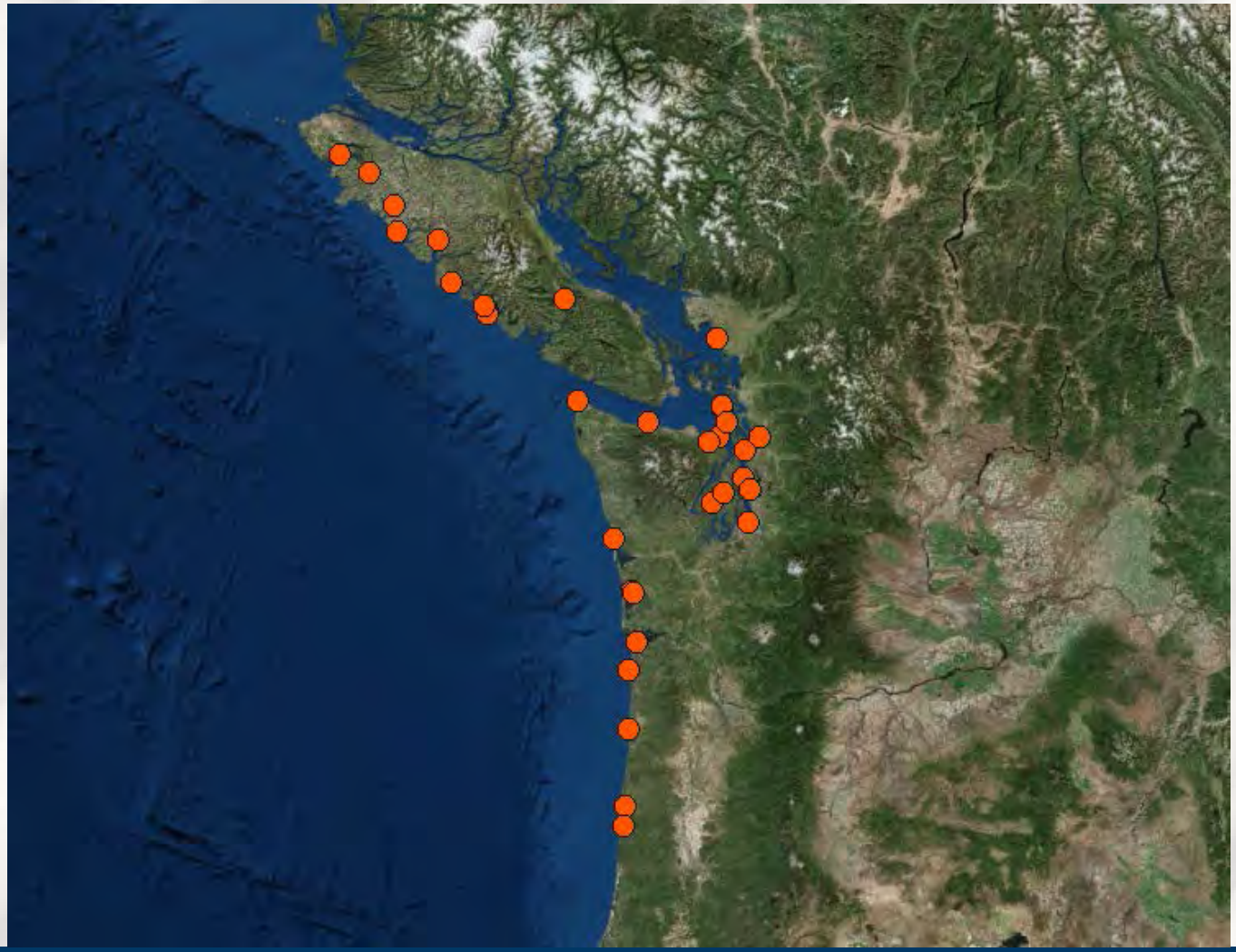
Drowned forest in Girdwood, Alaska, killed in 1964

Drowned forest along the Copalis River, Washington, killed in A.D. 1700

Geologic Record in Tidal Marshes



Physical Sampling Locations in PNW



Map credit: Carrie Garrison-Laney (WA Sea Grant)

Geologic Record on the Sea Floor

Turbidite — a sediment or rock deposited by a turbidity current

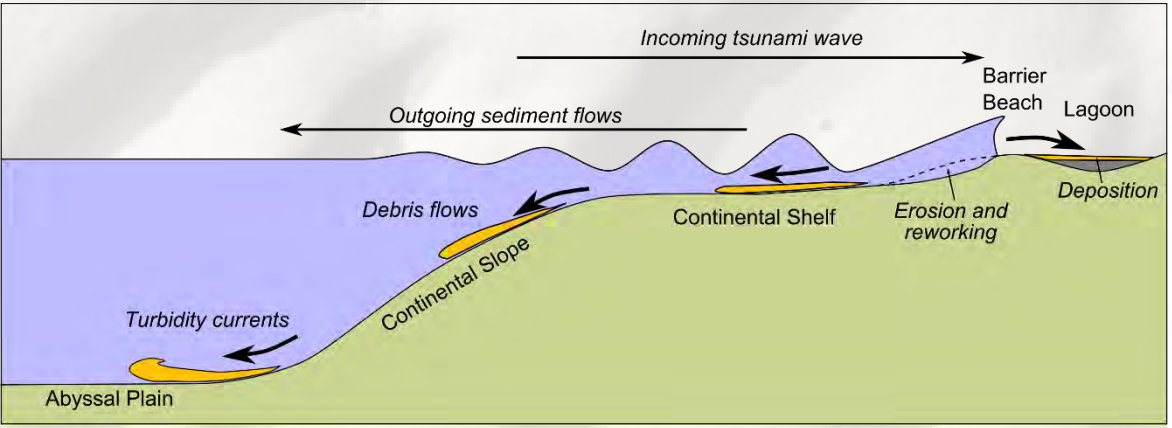


Image credit: Wikimedia commons

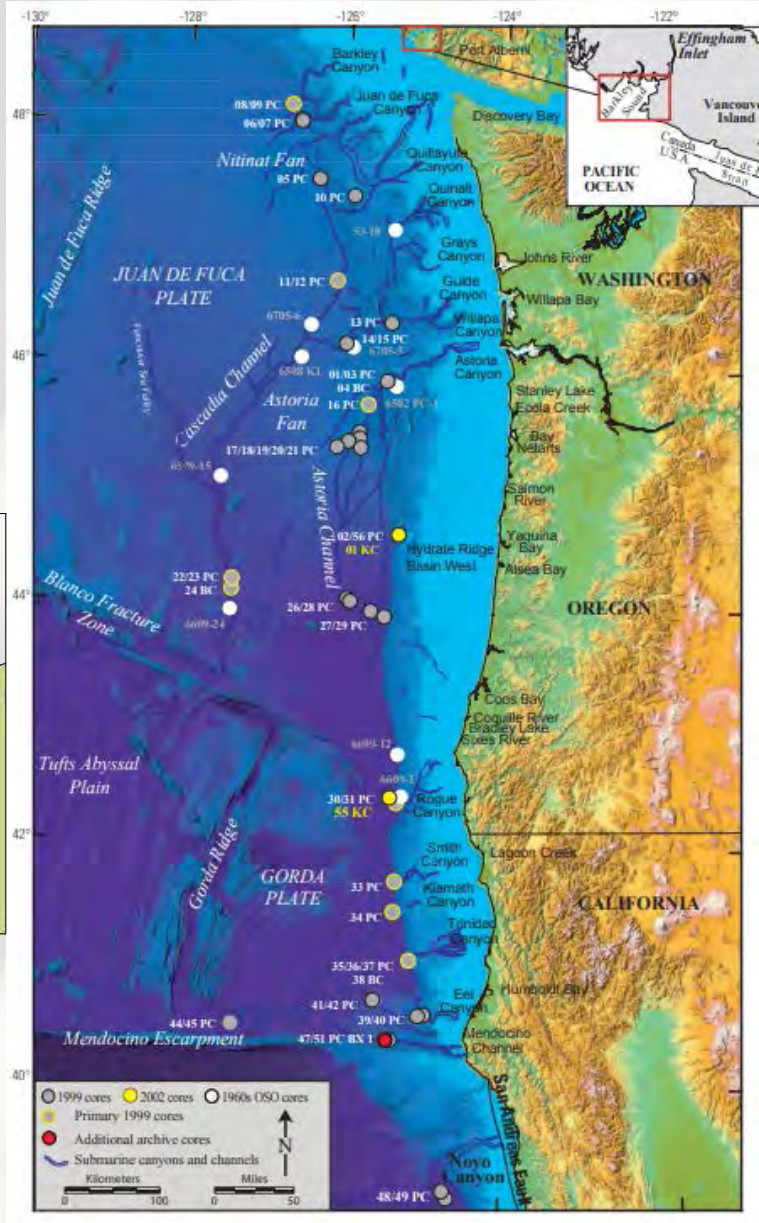


Image credit: Goldfinger and others, 2009

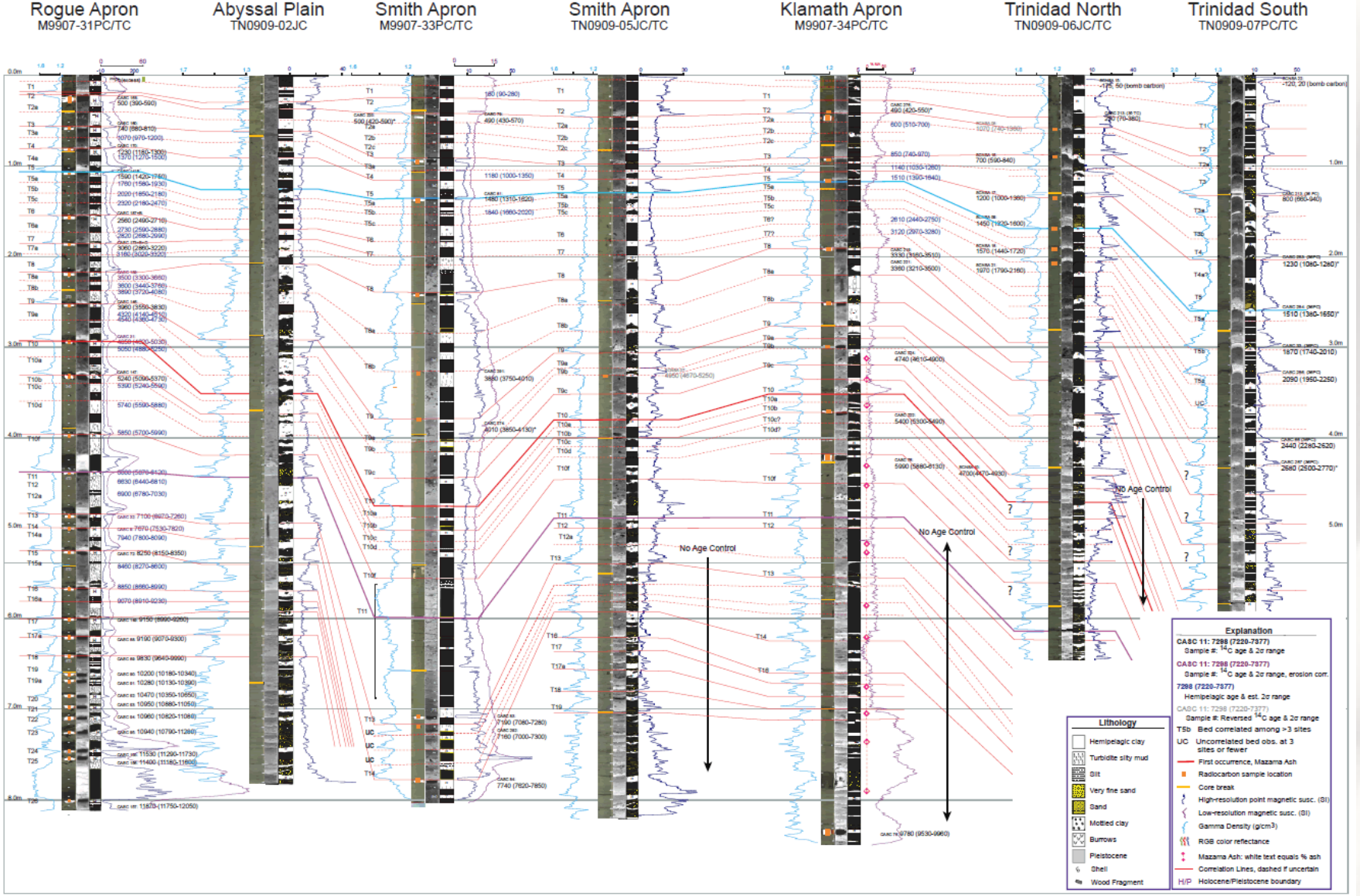


Image from: Active Tectonics, Oregon State University

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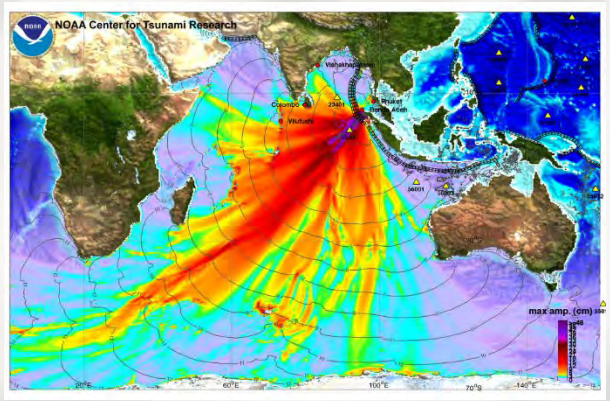
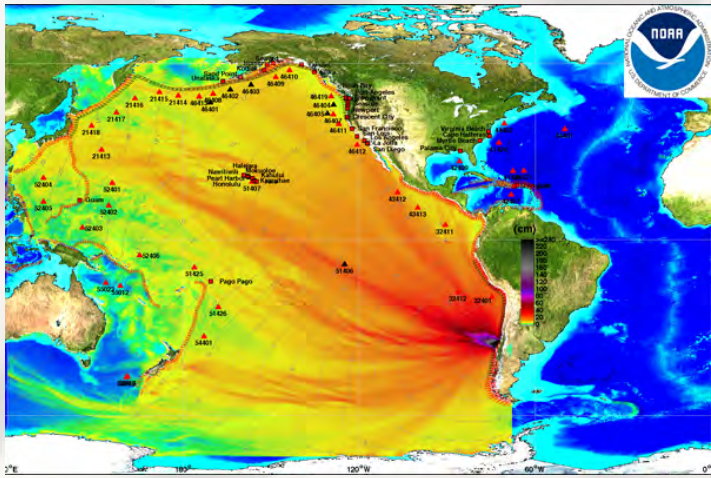
Modeling the next Cascadia

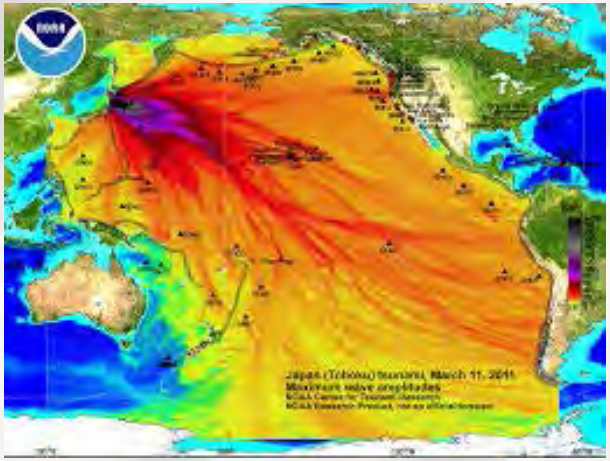
- Modeling programs predict wave behavior based on earthquake source and local topography
- Creates estimates of inundation extent, depth, timing, and current velocities

Recent events at other subduction zones

- 2004 Sumatra, Mw 9.1, 225,000 fatalities
- 2010 Chile, Mw 8.8, 525 fatalities
- 2011 Tohoku, Mw 9.0, 15,890 fatalities

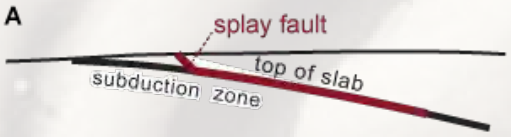


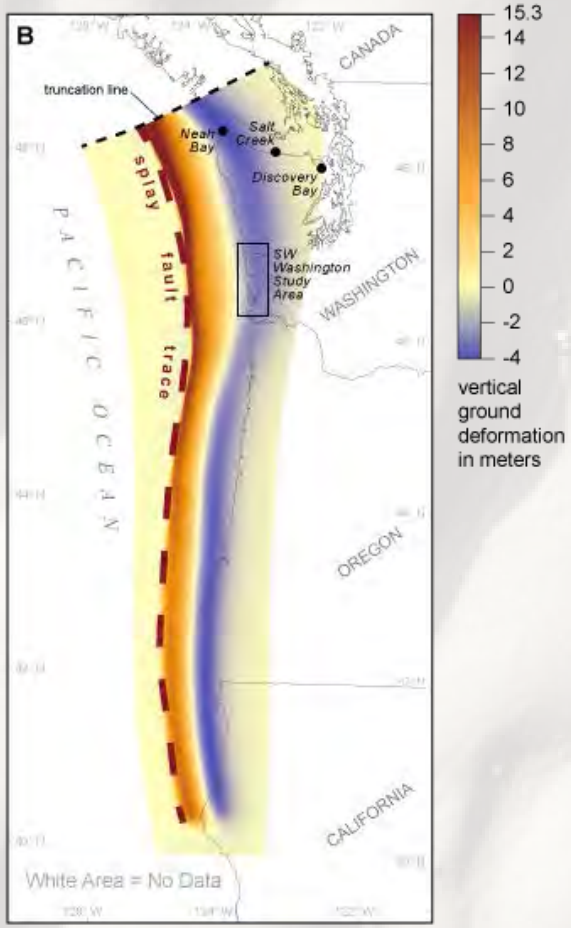




*All images from NOAA-PMEL

Cascadia earthquake scenarios





Cascadia subduction zone earthquake size and frequency based on turbidite records. Modified from Witter and others, 2011.

Earthquake size	Number of known events in 10,000 years	Approximate Magnitude (M_w)	Exceedance probability in a 50 year interval (percent)
Extra Large (XL1)	1	~9.1	1.0
Large (L1)	3	~9.0	2.0
Medium (M1)	10	~8.9	6.5
Small (SM1)	5	~8.7	9.0

Witter, Robert C., et al. "Simulated tsunami inundation for a range of Cascadia megathrust earthquake scenarios at Bandon, Oregon, USA." *Geosphere* 9.6 (2013): 1783-1803.

L1 Scenario Details/Caveats

- Incorporates 95% confidence that inundation will not be exceeded (in Oregon)
- 6.5 ft (2 m) of effectively permanent subsidence along coast

- Consistent slip distribution, in reality may have localized areas of increased slip (asperities)
- Simultaneous fault rupture, in reality fault rupture often propagates outward from a initial triggering point

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WGS Map and Data Products

Inundation and Current Velocity Maps –

Target audience are planners, EMs, other officials

- Plan evacuation routes
- Siting vertical evacuation structures
- Maritime guidance

Evacuation brochures and Pedestrian Walk Maps –

Target audience are planners, EMs, the public, tourists

- Routes and locations of safe high ground

Classified Inundation Maps

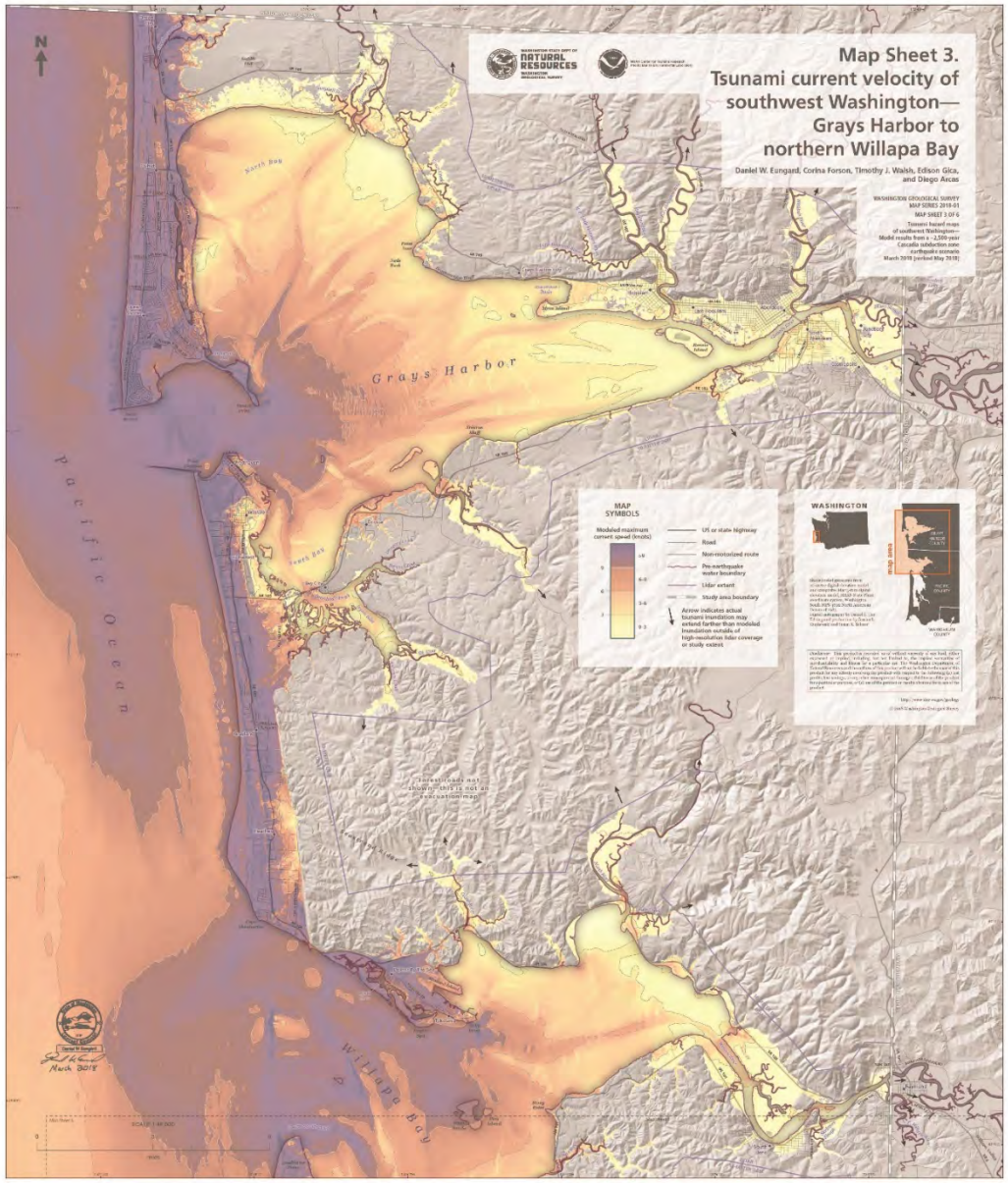
Binned for life-safety implications

- <2.5 ft, survivable in the open most structures remain
- 2.5-6 ft, must evacuate to high point, structures may be compromised
- >6 survivability unlikely, unreinforced structures likely compromised

Current Velocity Maps

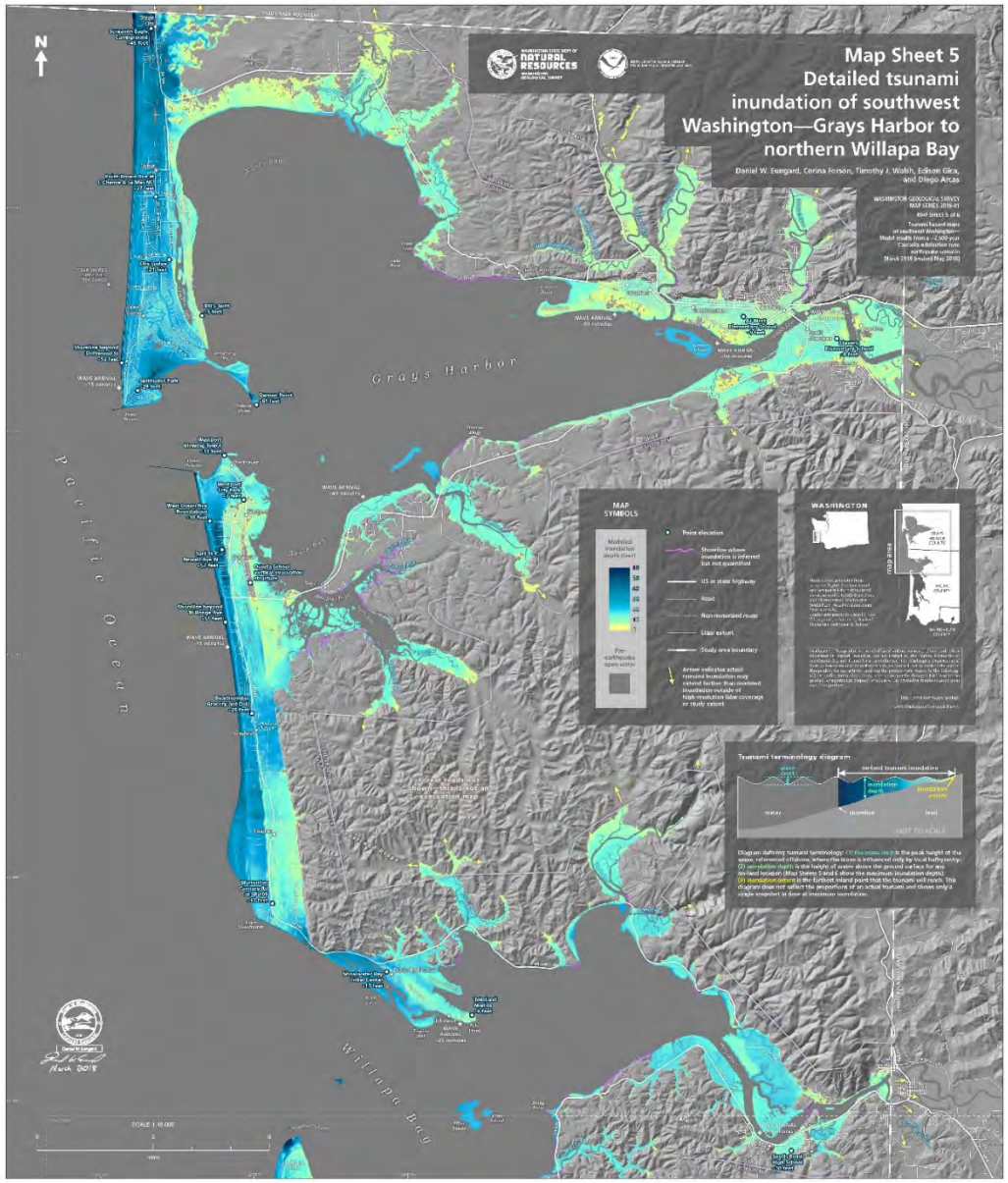
Important for maritime guidance, estimate of erosive capability

- <3 kn, minimal risk to ships/infrastructure
- 3-9 kn, minimal to high risk
- >9 kn extreme risk to ships, port infrastructure unlikely to survive



Detailed Inundation Maps

- Evacuation times for select locations
- Structural or infrastructure loss estimates
- Siting of vertical evacuation structures



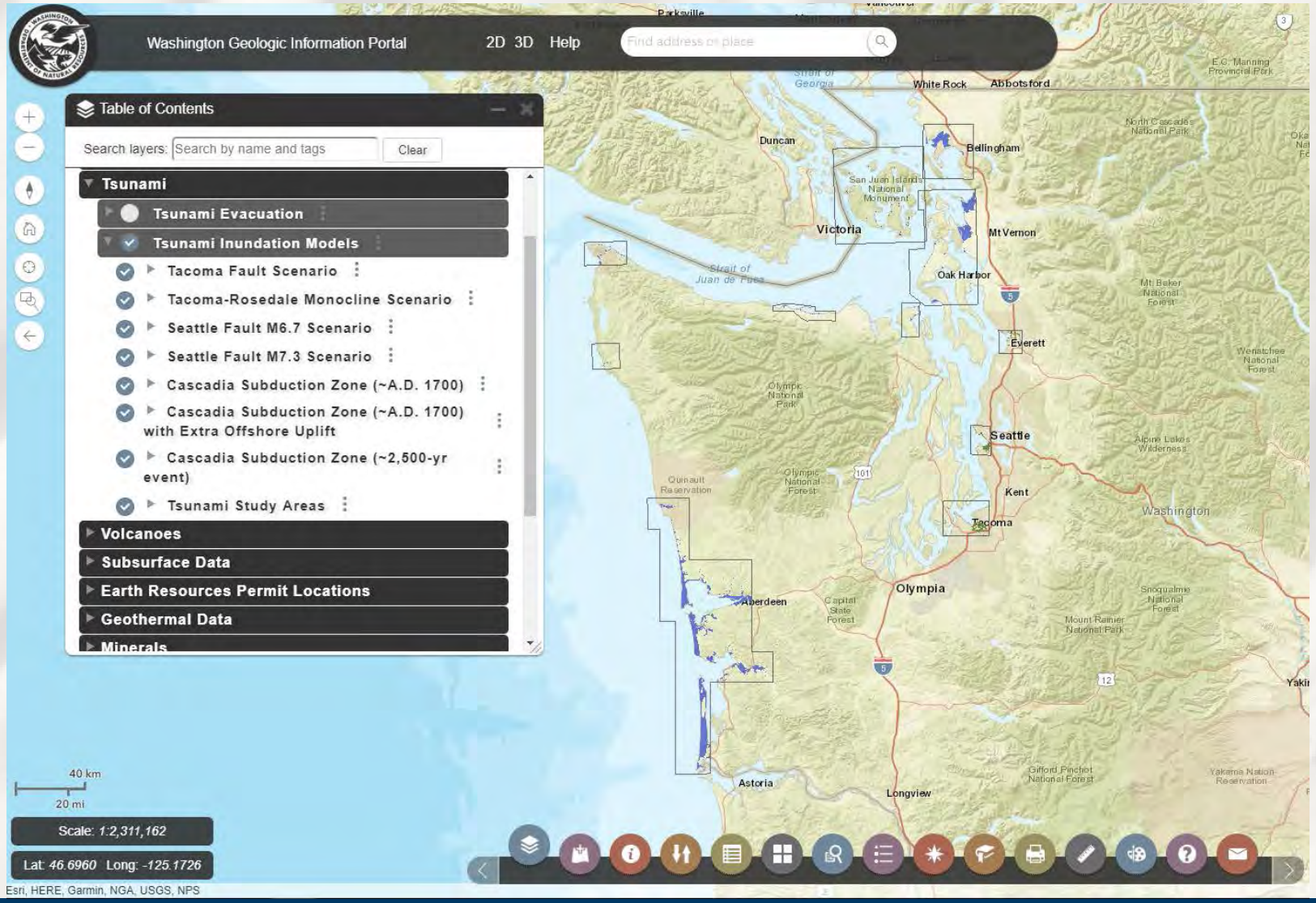
Pedestrian Walk Maps

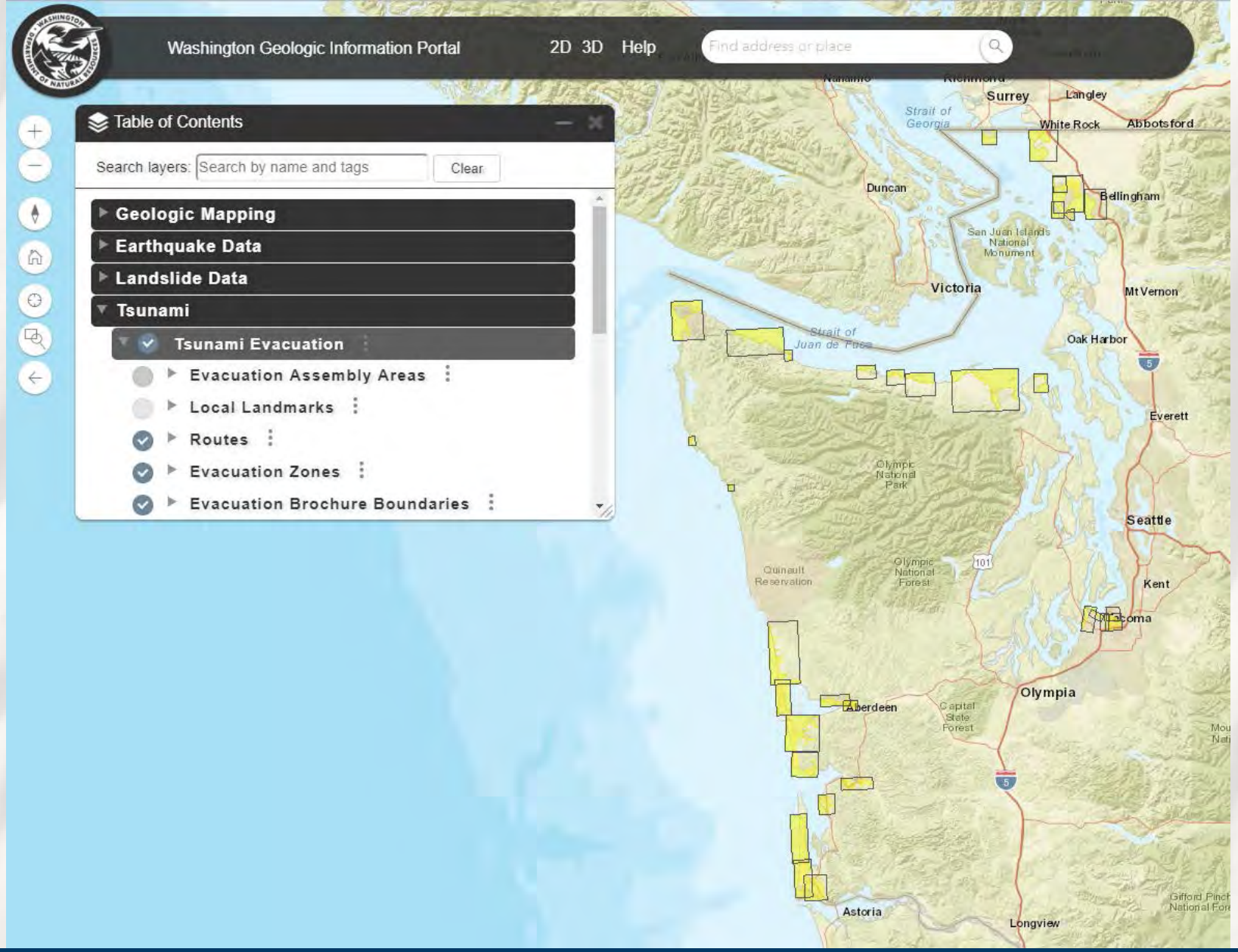
Pedestrian Evacuation Analyst Tool (PEAT) developed by USGS.

- Add-on to ArcGIS Desktop
- https://www.usgs.gov/software/pedestrian-evacuation-analyst-tool
- Incorporates slope, land cover, and USDOT travel pace
- Useful for tsunamis and lahars
- Not used for vehicular evacuation

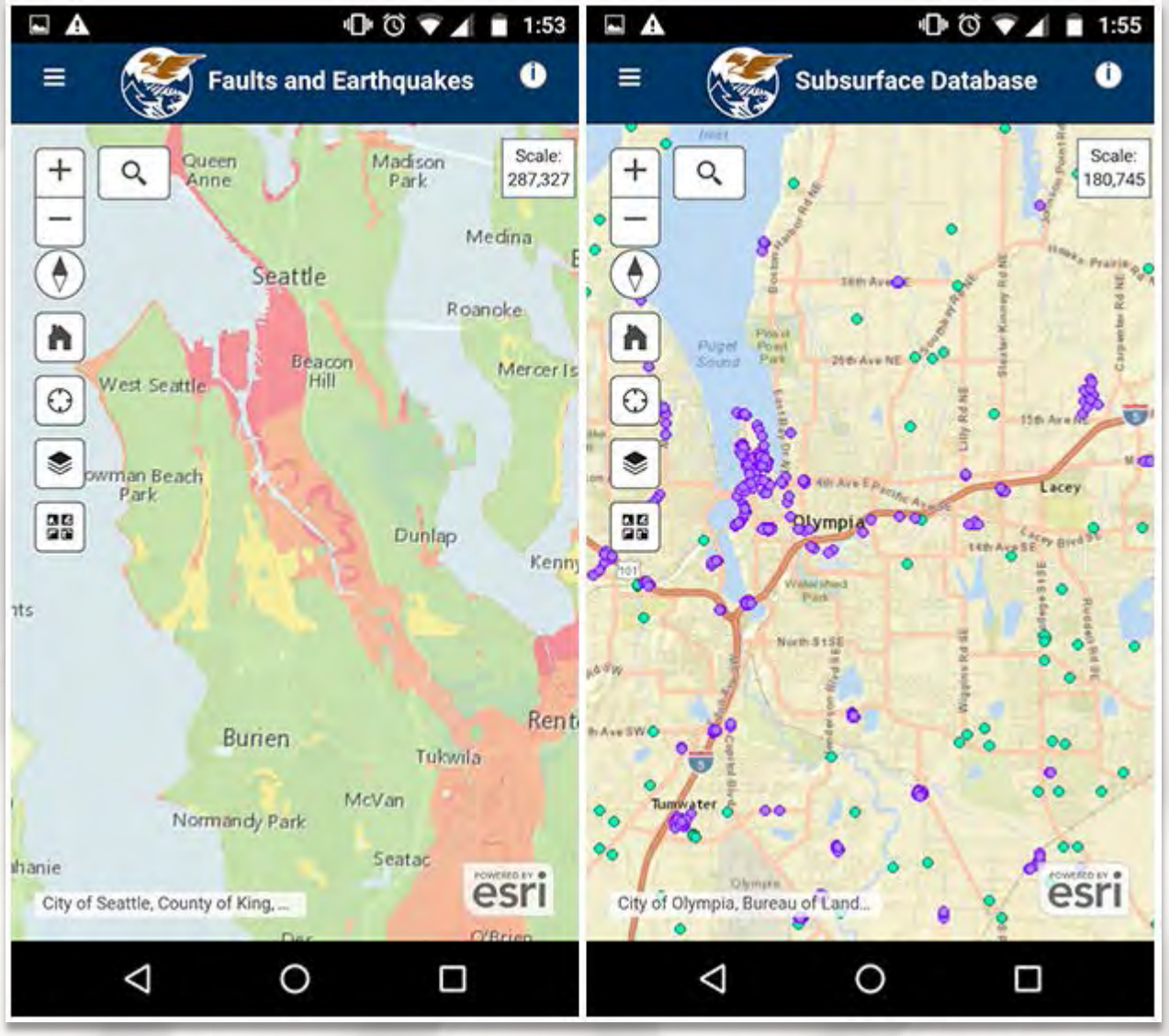
Port Angeles walk map

Washington Geologic Information Portal




Washington Geologic Information Portal
2D 3D Help
Find address or place
Table of Contents
Search layers:
Search by name and tags
Clear
Geologic Mapping
Earthquake Data
Landslide Data
Tsunami
Tsunami Evacuation
Evacuation Assembly Areas
Local Landmarks
Routes
Evacuation Zones
Evacuation Brochure Boundaries
Surrey
Langley
White Rock
Abbotsford
Strait of Georgia
Duncan
Bellingham
San Juan Islands National Monument
Victoria
Mt Vernon
Strait of Juan de Fuca
Oak Harbor
Everett
Olympic National Park
Seattle
Quinault Reservation
Olympic National Forest
Kent
Tacoma
Olympia
Aberdeen
Capital State Forest
Astoria
Longview

WA Geology Mobile App



What is new (or coming soon)

2018–

Published inundation maps for Southwest Washington (Long Beach and Ocean Shores)

- Pedestrian walk map for Aberdeen/Hoquiam
- Inundation and pedestrian walk map for Anacortes-Bellingham vicinity
- Inundation and pedestrian walk map for Port Angeles and Port Townsend
- Hiring a new tsunami modeler!!!

2019–

- Inundation modeling for remaining outer coast, Whatcom County, Bainbridge Isl. vicinity
- Update portal revising evacuation and inundation layers
- Create new and improved animations posted on our website

What is coming soon in tsunami science

- High resolution 3D models (site specific)
- State maritime guidance
  - Kickoff meeting June 20th, 2018 Seattle
    - Keily Yemm, EMD Tsunami Program Coordinator, Keily.Yemm@mil.wa.gov
- Sediment transport and debris tracking models (maritime focused)

Other Significant Activities

M9 Project

- Better understanding of EQ mechanics

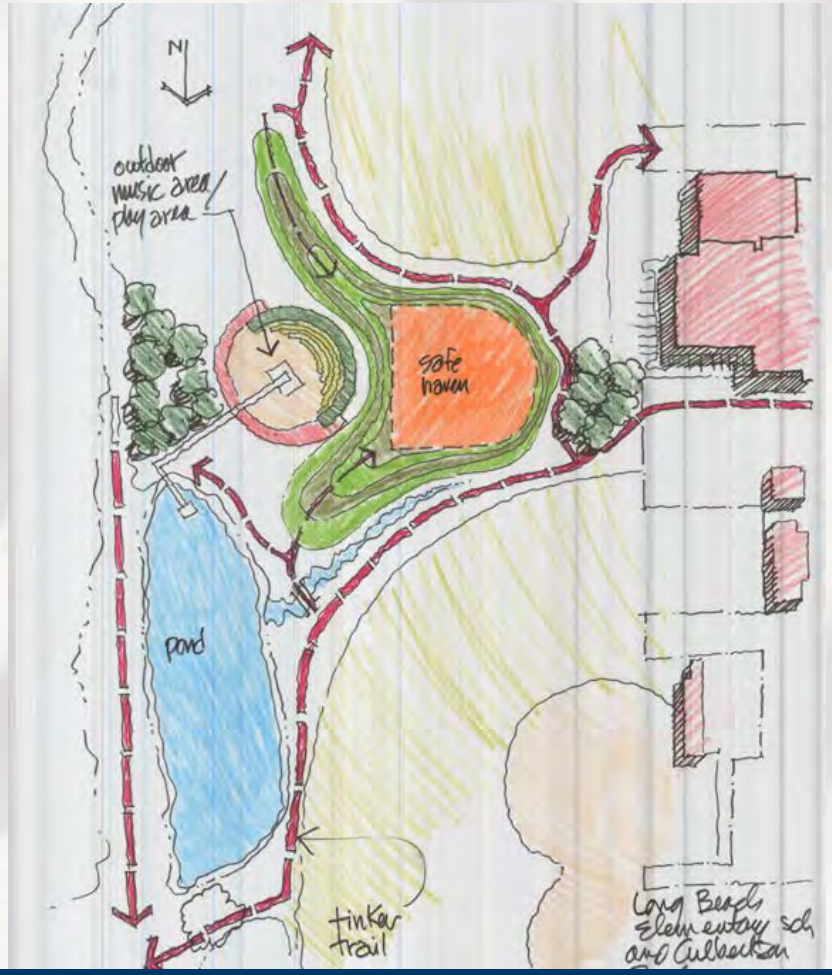
Project Safe Haven

- Design of and assistance with vertical evacuation structures

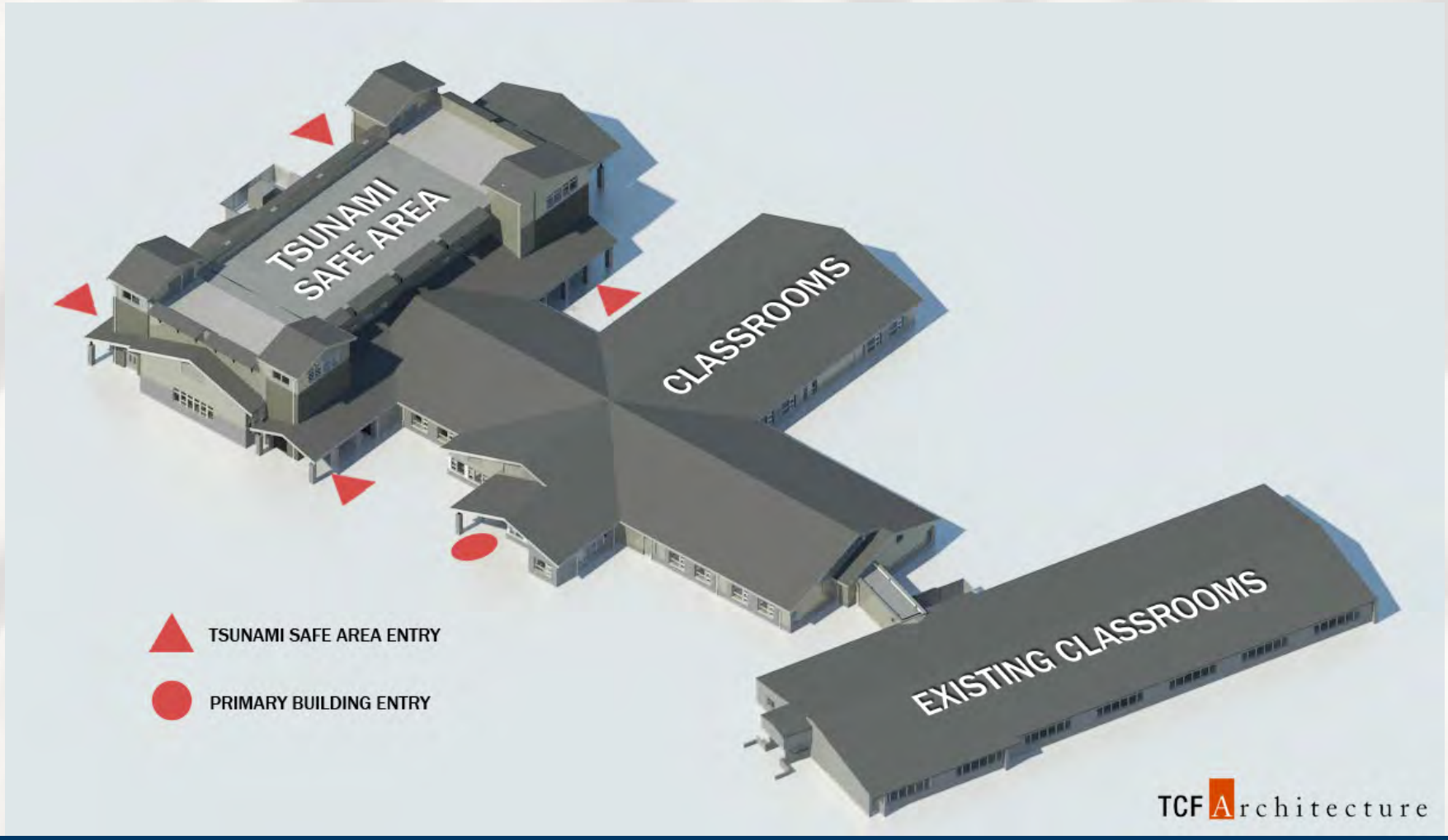
Movement of persons outside the hazard zone

- Quinault Nation's Taholah village

Project Safe Haven (EMD) Designing Structures for Vertical Evacuation



Ocosta School Design



Ocosta School Built!

Images from Degenkolb Engineers

Links to Resources

https://geologyportal.dnr.wa.gov/

https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis

https://www.dnr.wa.gov/mobilegeology

https://www.mil.wa.gov/tsunami

https://tsunami.gov/

"Civilization exists by geological consent, subject to change without notice."

— Will Durant