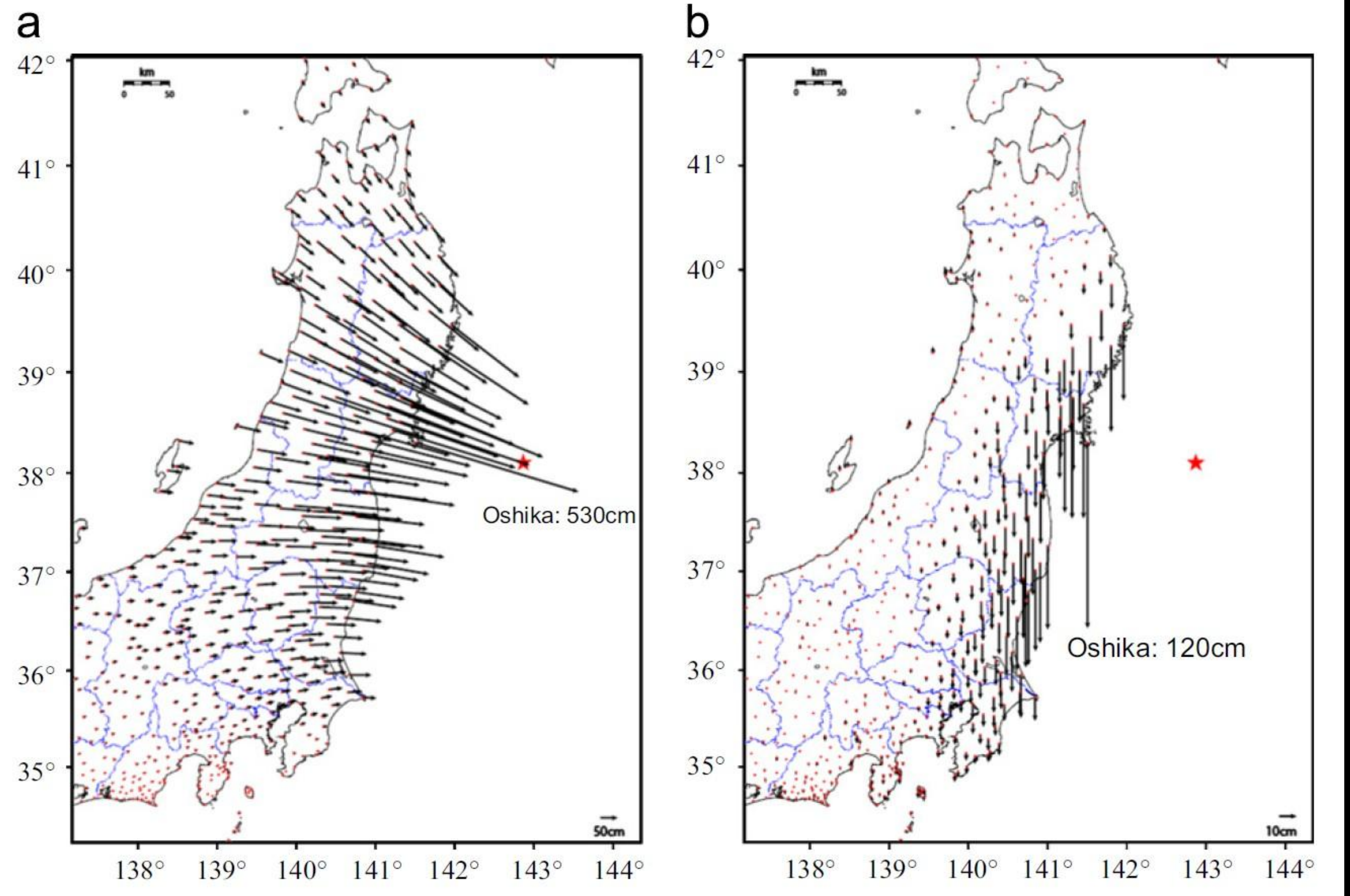
Fire Station Workshop

City of Gearhart

January 29, 2019



QUAKES STRIKES WITHOUT WARNING. LAND LURCHES SEAWARD AND DROPS.

Shaking damages older buildings


HEIGHT OF L-1 SCENARIO TSUNAMI
50'
50'
42'
42'
42'
14 ft
28'
28'
27'
26'
Unreinforced masonry
structures collapse


Landslides block roads

Landslides block roads


Liquefaction and
Lateral spreading

Poorly Designed bridges Damaged by Shaking

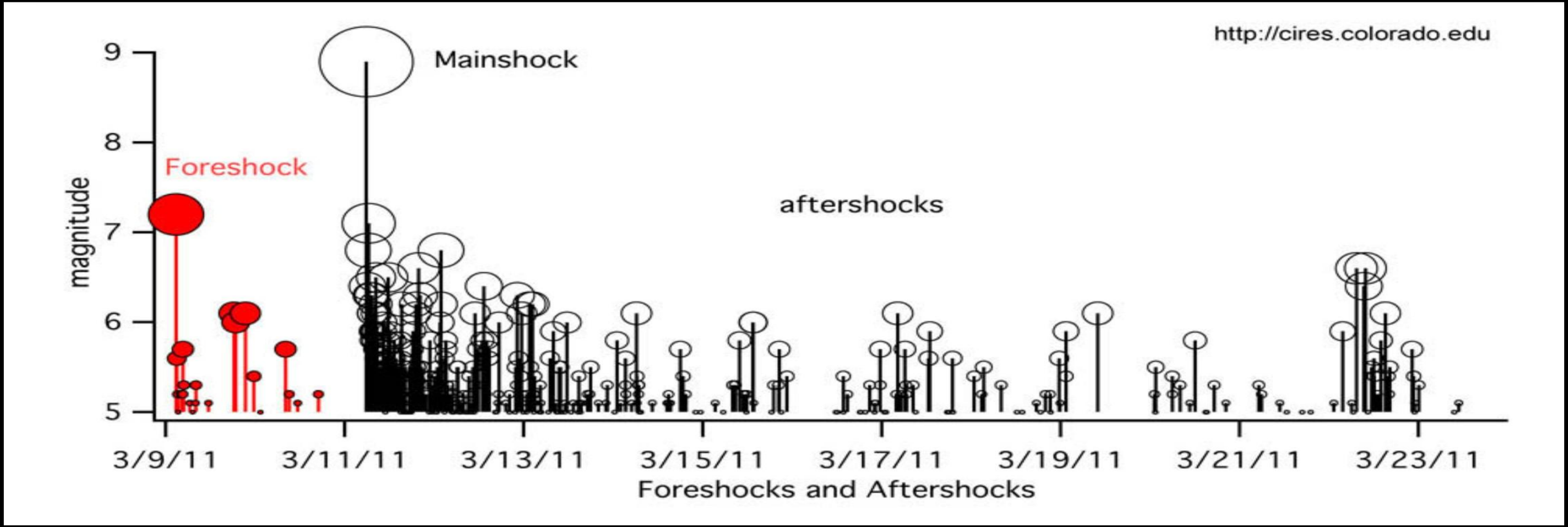
Well-design

Settlement of Bridge Approach

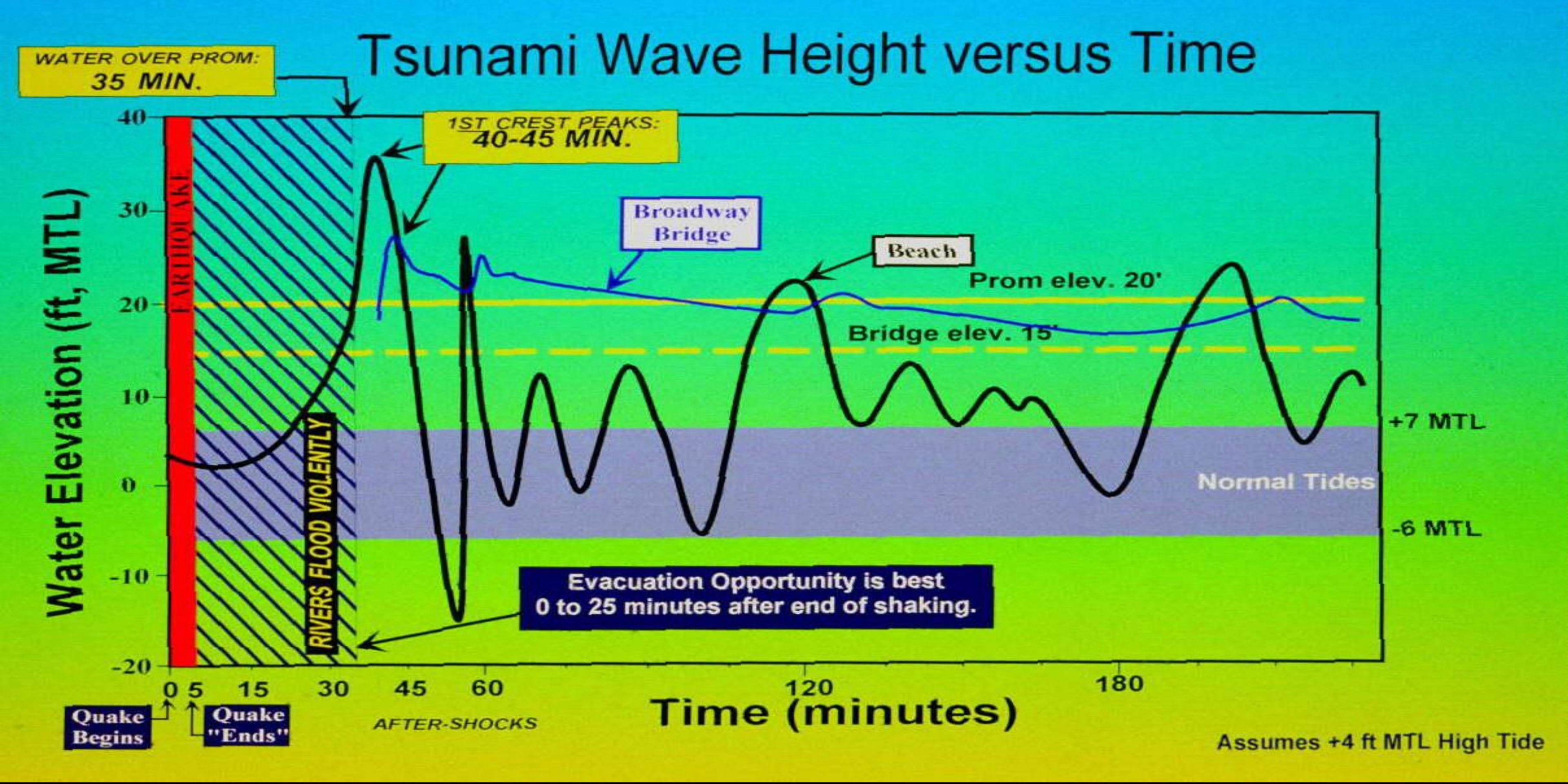
Road Damage


FIRE
San Francisco 1906

After Shocks



TSUNAMI


Tsunami Wave Height versus Time
WATER OVER PROM: 35 MIN.
1ST CREST PEAKS: 40-45 MIN.
Broadway Bridge
Beach
Prom elev. 20'
Bridge elev. 15'
EARTHQUAKE
RIVERS FLOOD VIOLENTLY
+7 MTL
Normal Tides
-6 MTL
Evacuation Opportunity is best 0 to 25 minutes after end of shaking.
Water Elevation (ft, MTL)
40
30
20
10
0
-10
-20
0 5 15 30 45 60 120 180
Time (minutes)
Quake Begins
Quake "Ends"
AFTER-SHOCKS
Assumes +4 ft MTL High Tide

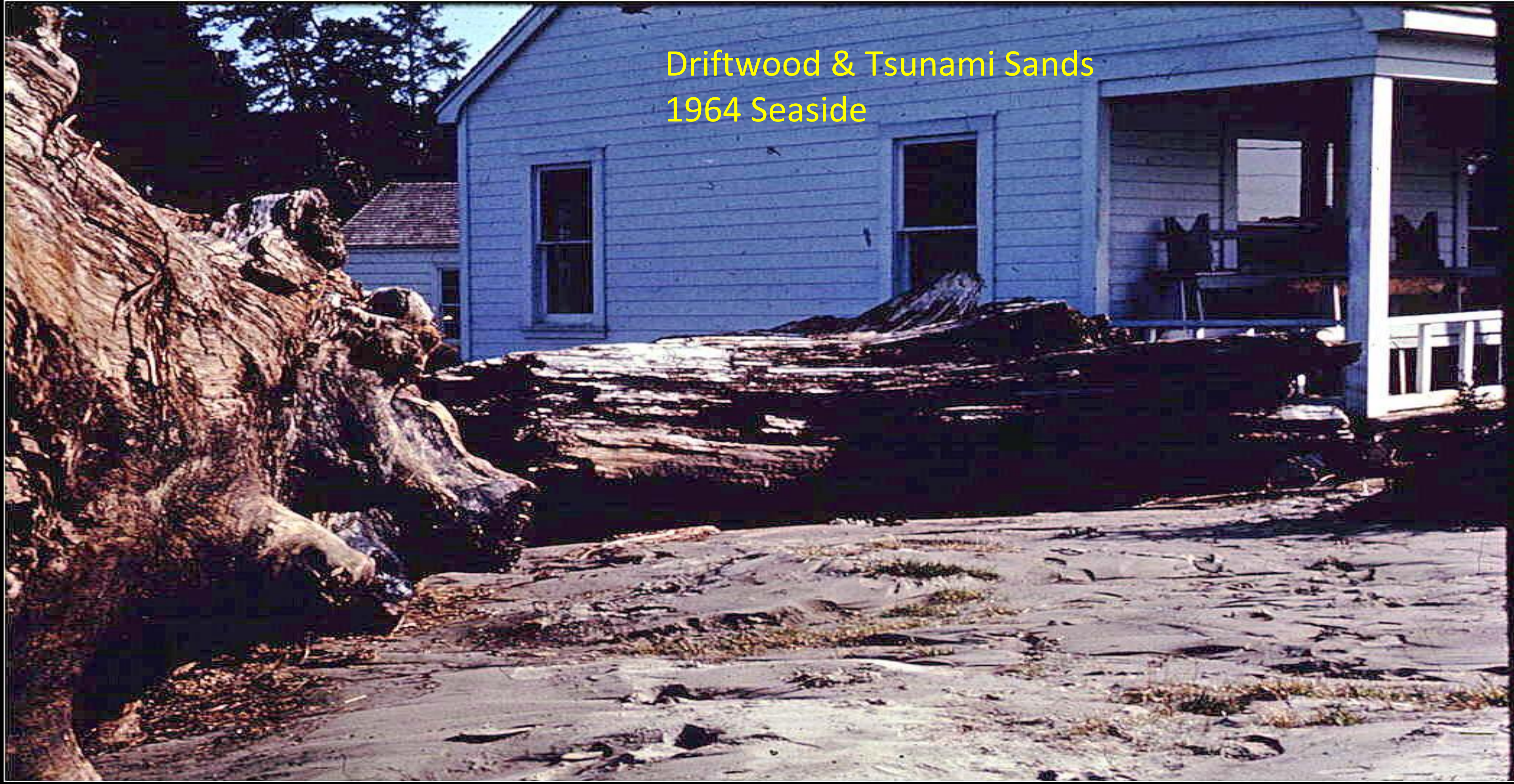

20 minutes after the onset
of shaking, tsunami hits shore
Sendai
Airport






USGS

Driftwood & Tsunami Sands
1964 Seaside




Drowned marshes
Tsunami Sands


まだ・まだやるよ
ありがとう
鎮魂
3.11

Coseismi
1 to 6 ft

Shor
500

The Oregon Resilience Plan

Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami

Report to the
77th Legislative Assembly

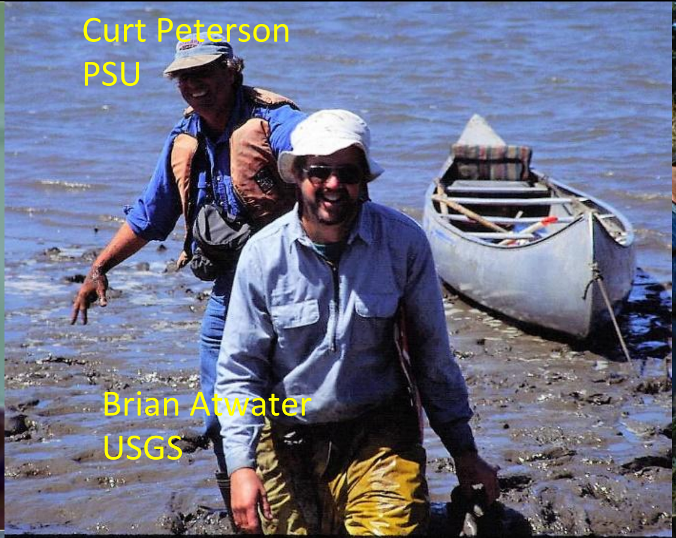
from
Oregon Seismic Safety Policy
Advisory Commission (OSSPAC)

2013

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

Oregon Resilience Plan (2013)


George Priest
DOGAMI


Curt Peterson
PSU
Brian Atwater
USGS

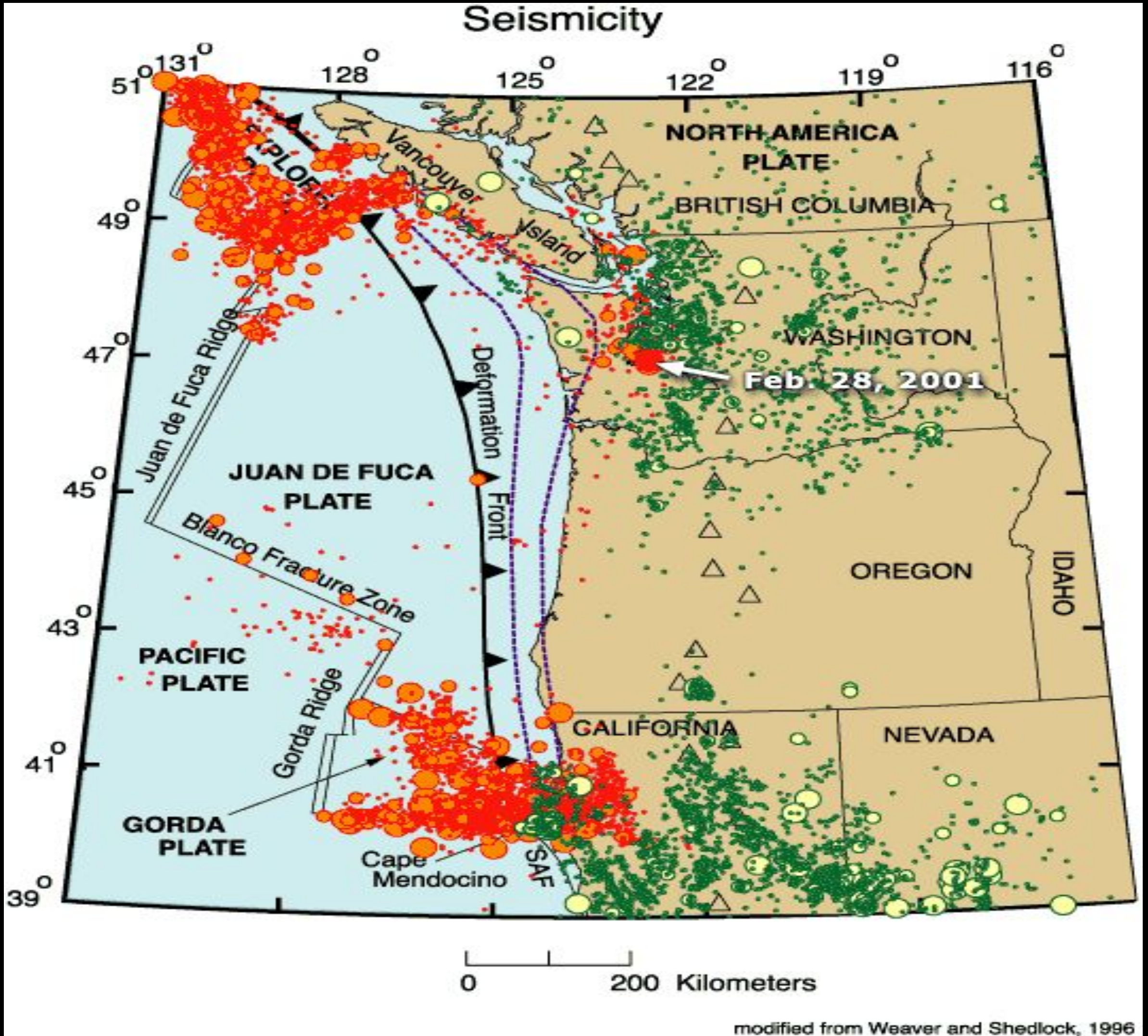

Ken Cruikshank
PSU
Harry Jol
UW Aue Claire
Goldfinger

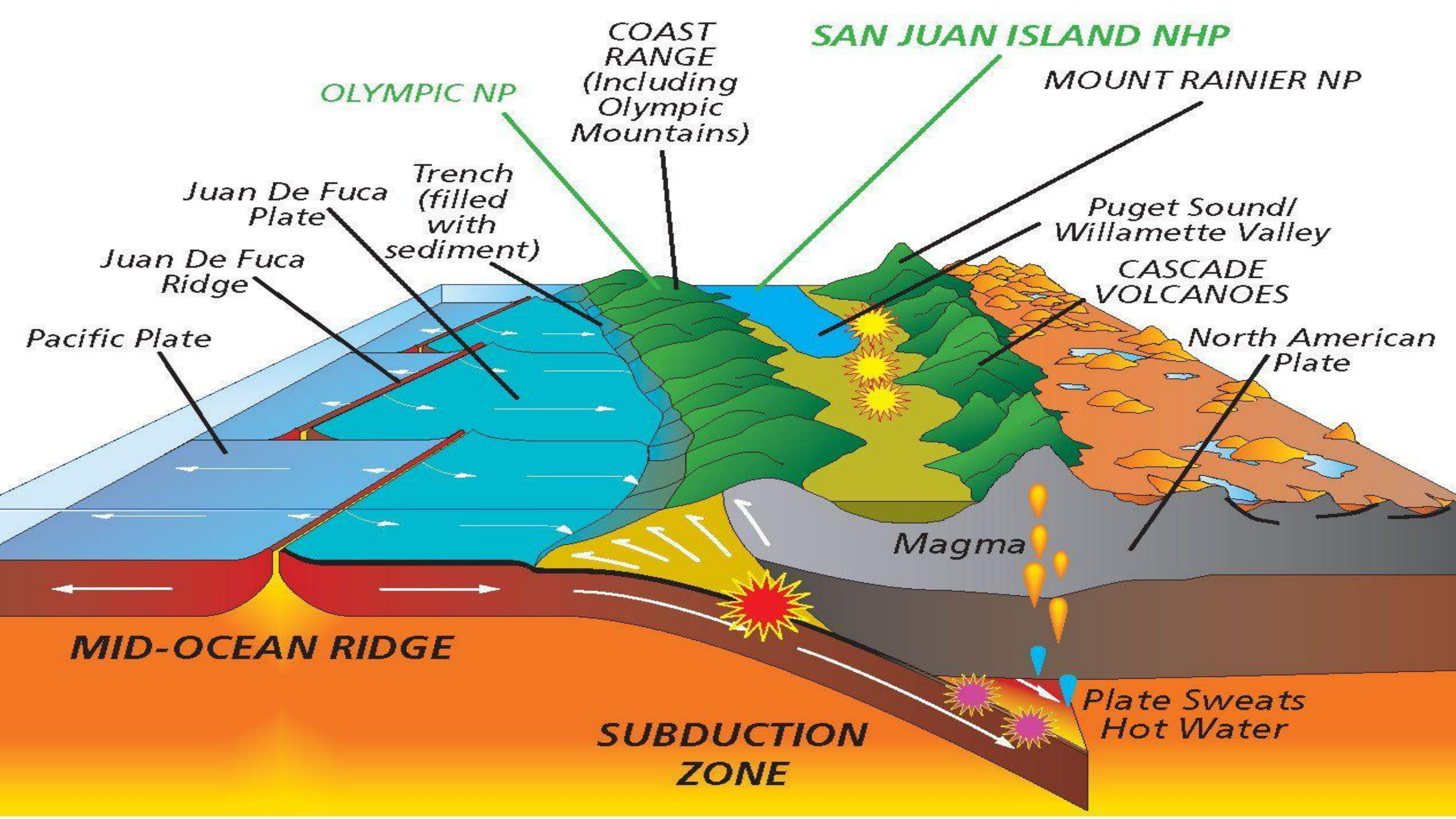

PSU Students

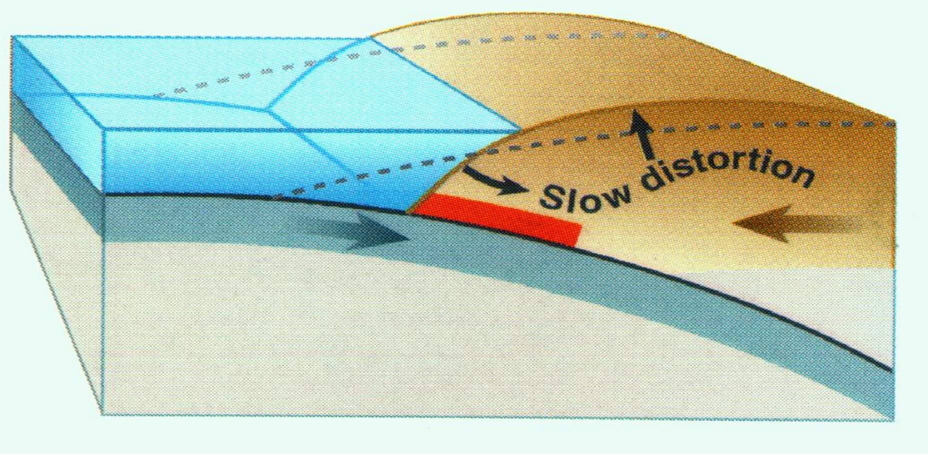

Chris Goldfinger
OSU

EARTHQUAKE & TSUNAMI BACKGROUND

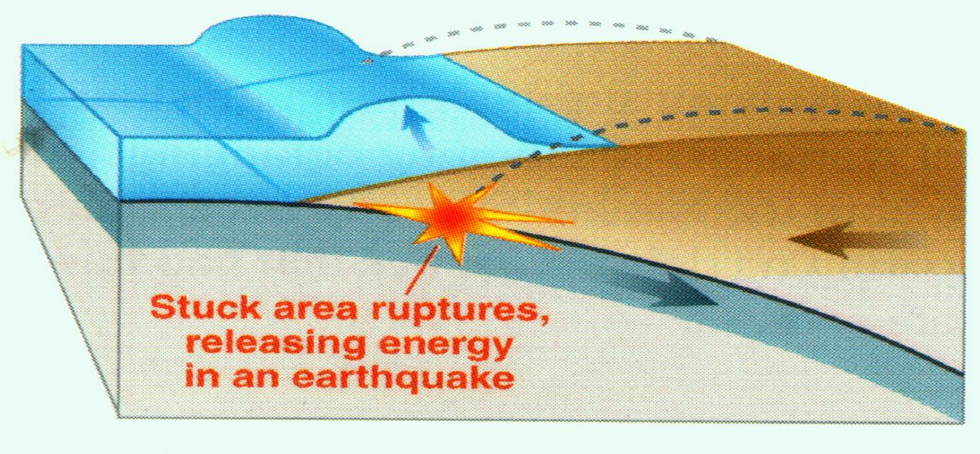
Earthquakes in the Pacific Northwest



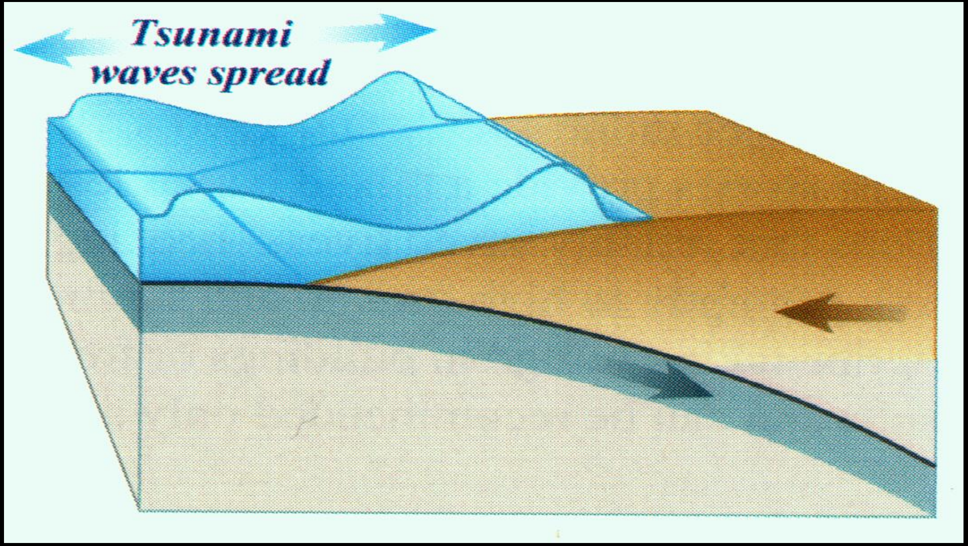

COAST RANGE (Including Olympic Mountains)
SAN JUAN ISLAND NHP
OLYMPIC NP
MOUNT RAINIER NP
Trench (filled with sediment)
Juan De Fuca Plate
Puget Sound/ Willamette Valley
Juan De Fuca Ridge
CASCADE VOLCANOES
Pacific Plate
North American Plate
Magma
MID-OCEAN RIDGE
Plate Sweats Hot Water
SUBDUCTION ZONE



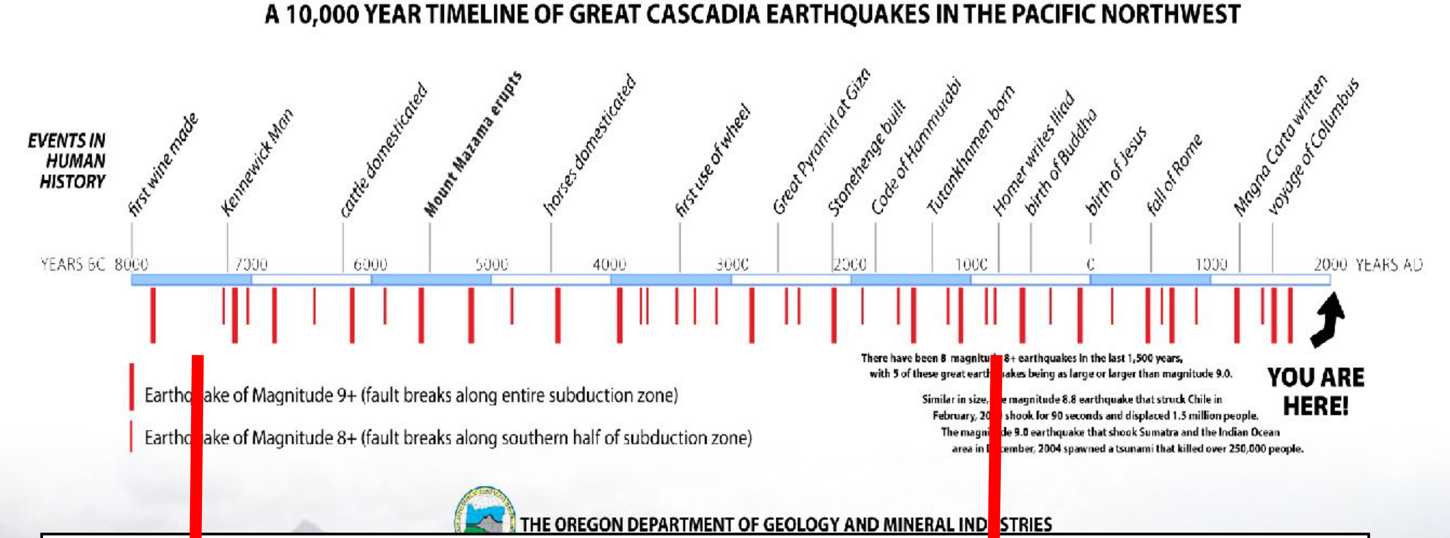
A. Between Earthquakes

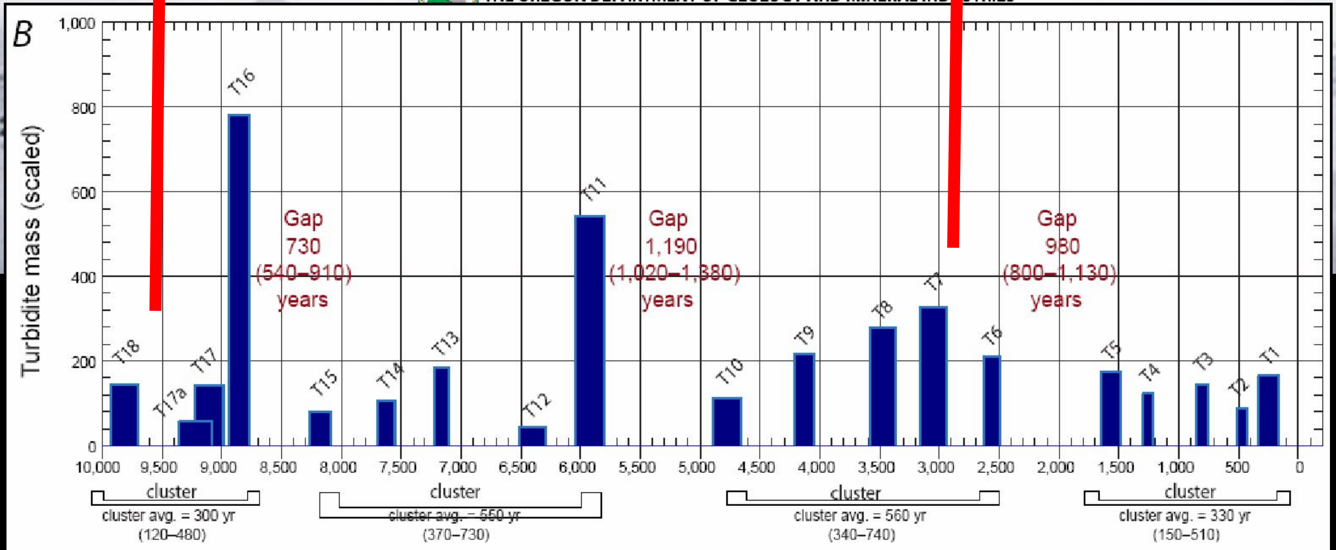


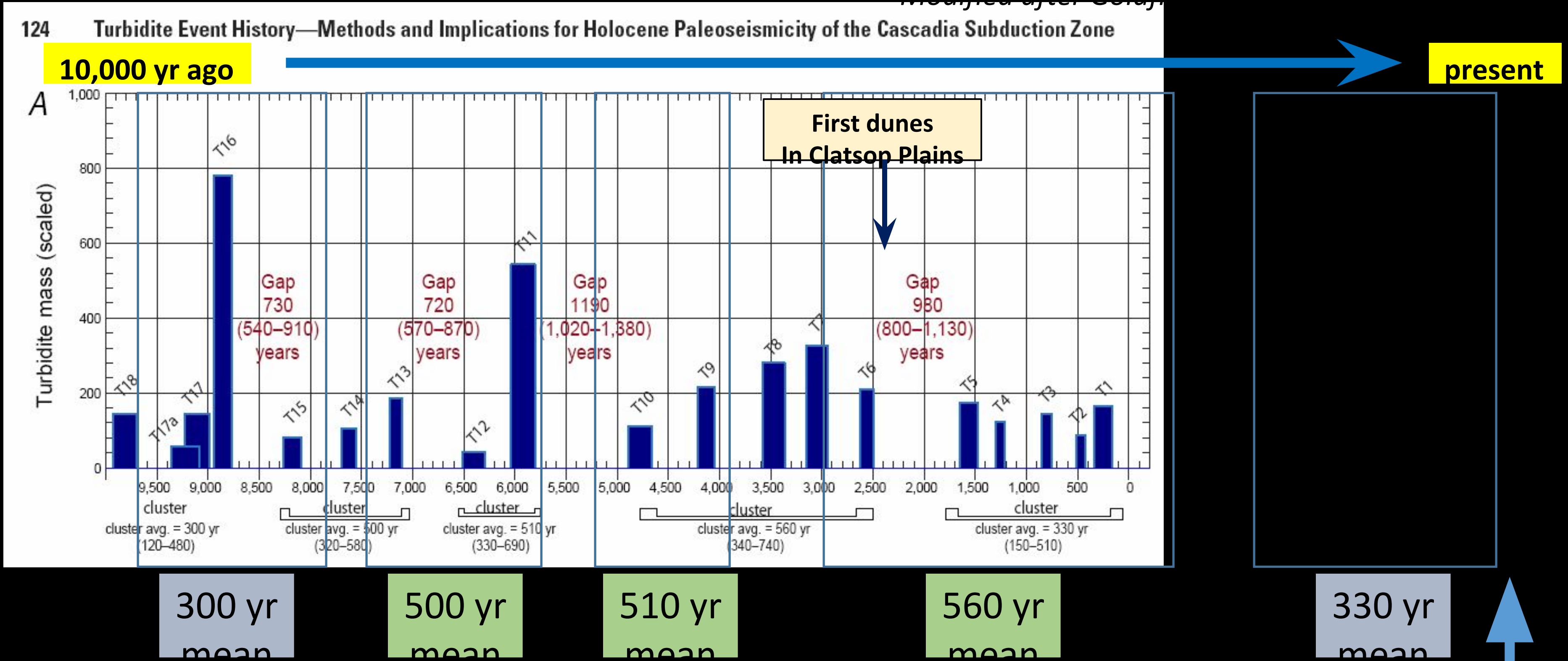
B. During an Earthquake



WHEN WILL THE NEXT QUAKE STRIKE?


A 10,000 YEAR TIMELINE OF GREAT CASCADIA EARTHQUAKES IN THE PACIFIC NORTHWEST
EVENTS IN HUMAN HISTORY
first wine made
Kennewick Man
cattle domesticated
Mount Mazama erupts
horses domesticated
first use of wheel
Great Pyramid at Giza
Stonehenge built
Code of Hammurabi
Tutankhamen born
Homer writes Iliad
birth of Buddha
birth of Jesus
fall of Rome
Magna Carta written
voyage of Columbus
YEARS BC 8000
7000
6000
5000
4000
3000
2000
1000
0
1000
2000 YEARS AD
Earthquake of Magnitude 9+ (fault breaks along entire subduction zone)
Earthquake of Magnitude 8+ (fault breaks along southern half of subduction zone)
YOU ARE HERE!
THE OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

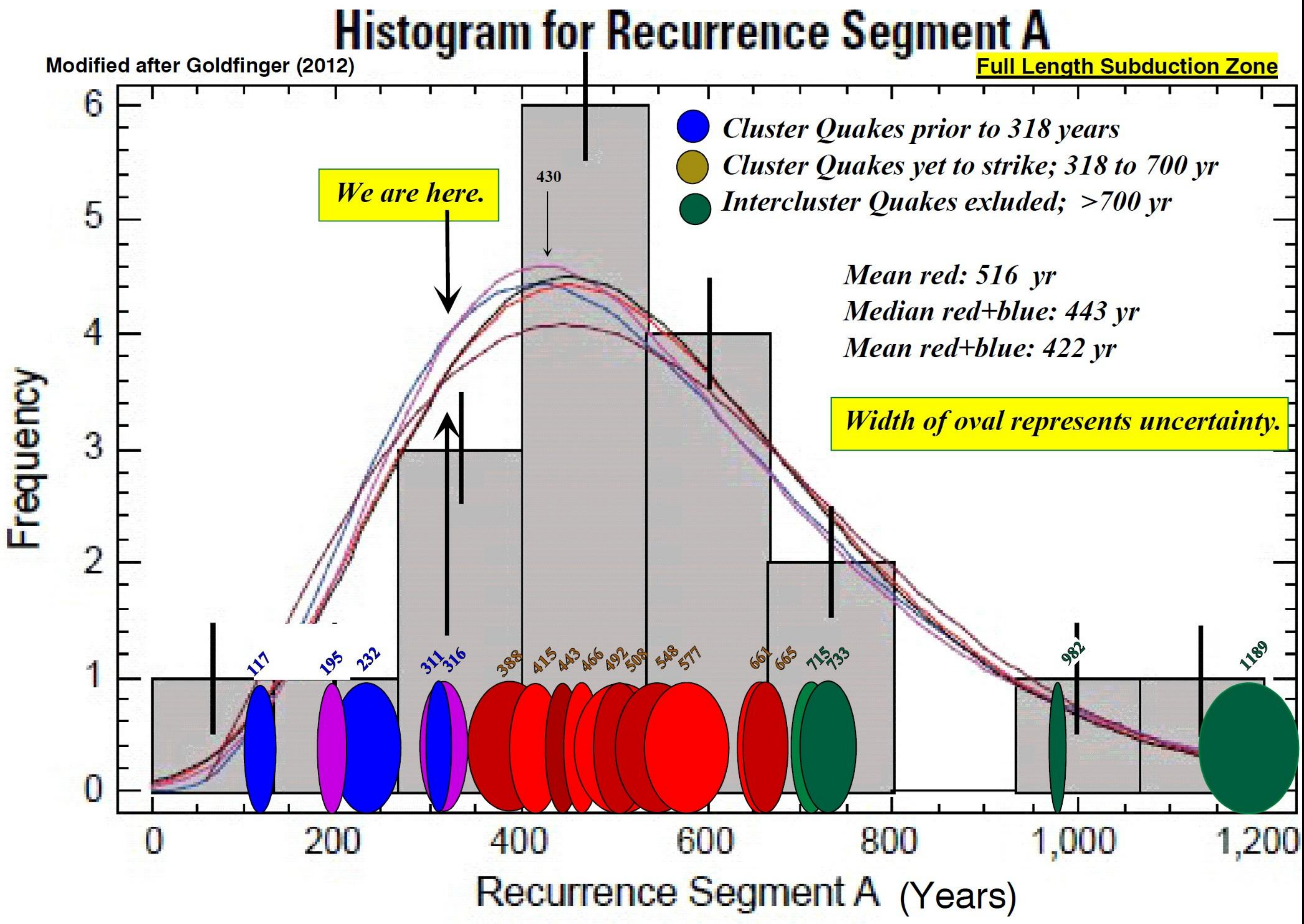

B
Turbidite mass (scaled)
1,000
800
600
400
200
0
T18
T17a
T17
T16
Gap 730 (540–910) years
T15
T14
T13
T12
T11
Gap 1,190 (1,020–1,380) years
T10
T9
T8
T7
T6
Gap 980 (800–1,130) years
T5
T4
T3
T2
T1
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
cluster
cluster avg. = 300 yr (120–480)
cluster
cluster avg. = 550 yr (370–730)
cluster
cluster avg. = 560 yr (340–740)
cluster
cluster avg. = 330 yr (150–510)



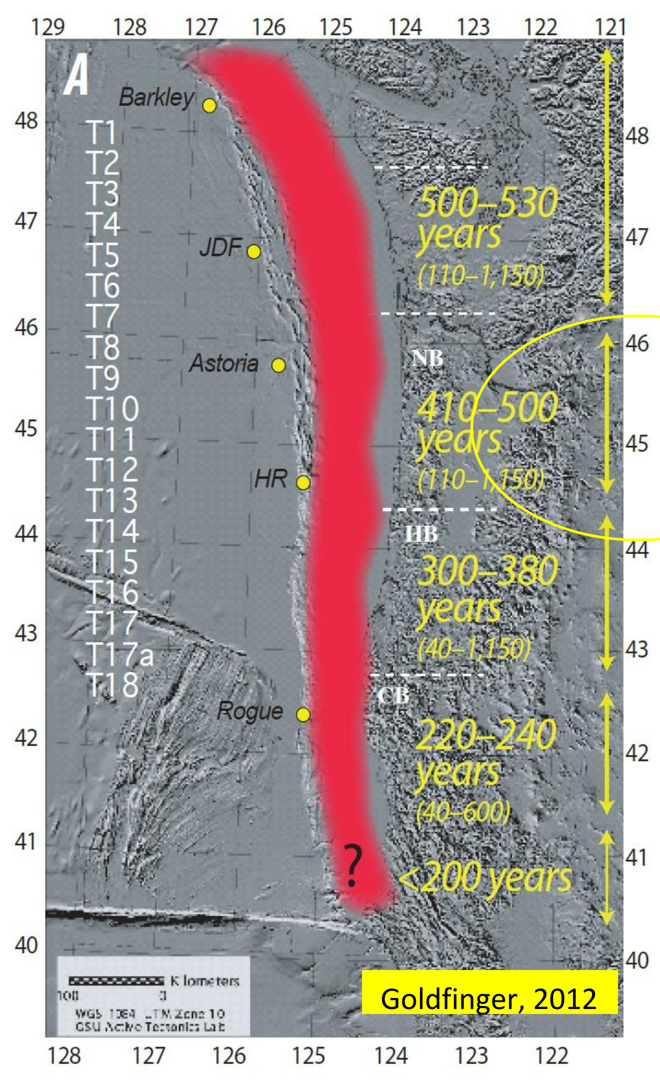
We are here

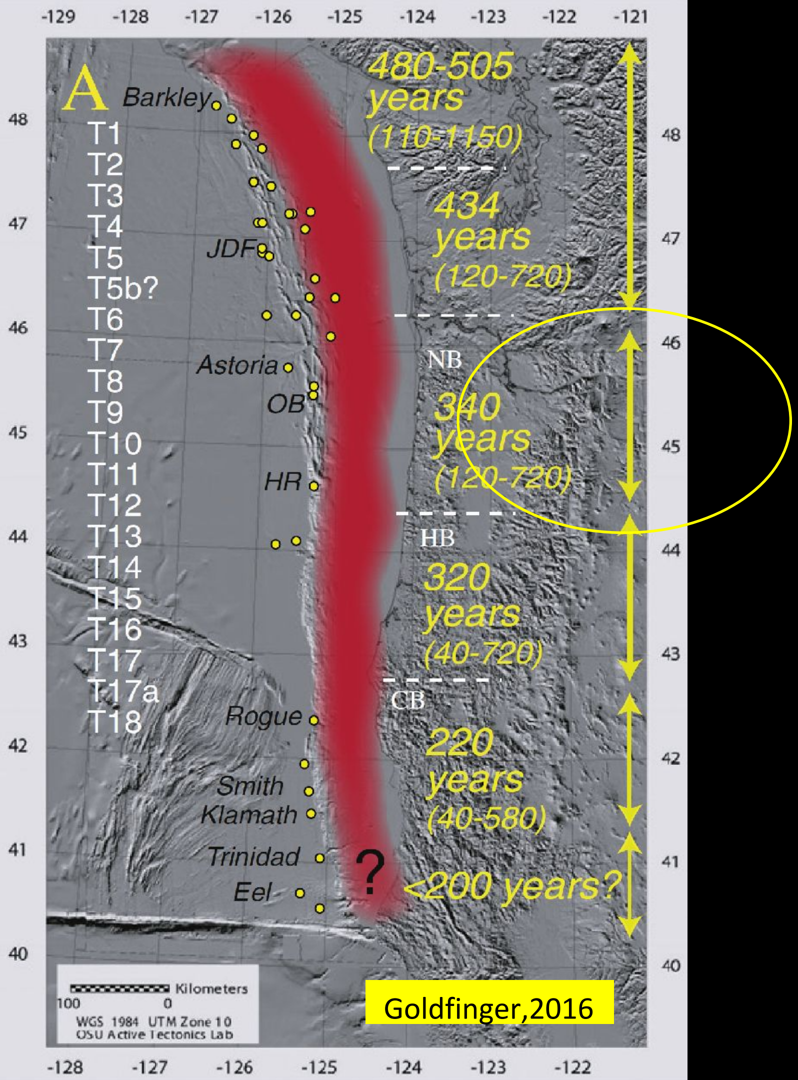
Odds 80 percent we are in a cluster.

Odds 40:60 to 80:20 the mean cluster recurrence is 300-330 yr.



Histogram for Recurrence Segment A
Modified after Goldfinger (2012)
Full Length Subduction Zone
Cluster Quakes prior to 318 years
Cluster Quakes yet to strike; 318 to 700 yr
Intercluster Quakes exluded; >700 yr
We are here.
430
Mean red: 516 yr
Median red+blue: 443 yr
Mean red+blue: 422 yr
Width of oval represents uncertainty.
117
195
232
311
316
388
415
443
466
492
508
548
577
661
665
715
733
982
1189
Frequency
0
1
2
3
4
5
6
0
200
400
600
800
1,000
1,200
Recurrence Segment A (Years)


A
Barkley
JDF
Astoria
HR
Rogue
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
T17a
T18
500–530 years (110–1,150)
NB
410–500 years (110–1,150)
HB
300–380 years (40–1,150)
CB
220–240 years (40–600)
?
<200 years
Kilometers
WGS 1984 UTM Zone 10
OSU Active Tectonics Lab
Goldfinger, 2012


A
Barkley
JDF
Astoria
OB
HR
Rogue
Smith
Klamath
Trinidad
Eel
T1
T2
T3
T4
T5
T5b?
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
T17a
T18
480-505 years (110-1150)
434 years (120-720)
NB
340 years (120-720)
HB
320 years (40-720)
CB
220 years (40-580)
?
<200 years?
Kilometers
WGS 1984 UTM Zone 10
OSU Active Tectonics Lab
Goldfinger,2016

QUAKES APPEAR TO OCCUR IN CLUSTERS

THE PRESENT CLUSTER HAS QUAKES 330 YEARS, ON AVERAGE

IT HAS BEEN 319 YEARS SINCE THE LAST QUAKE & TSUNAMI

ARE THE NEXT QUAKE AND TSUNAMI IMMINENT?

Can you afford to be wrong?

HOW HIGH WILL THE TSUNAMI FLOOD?

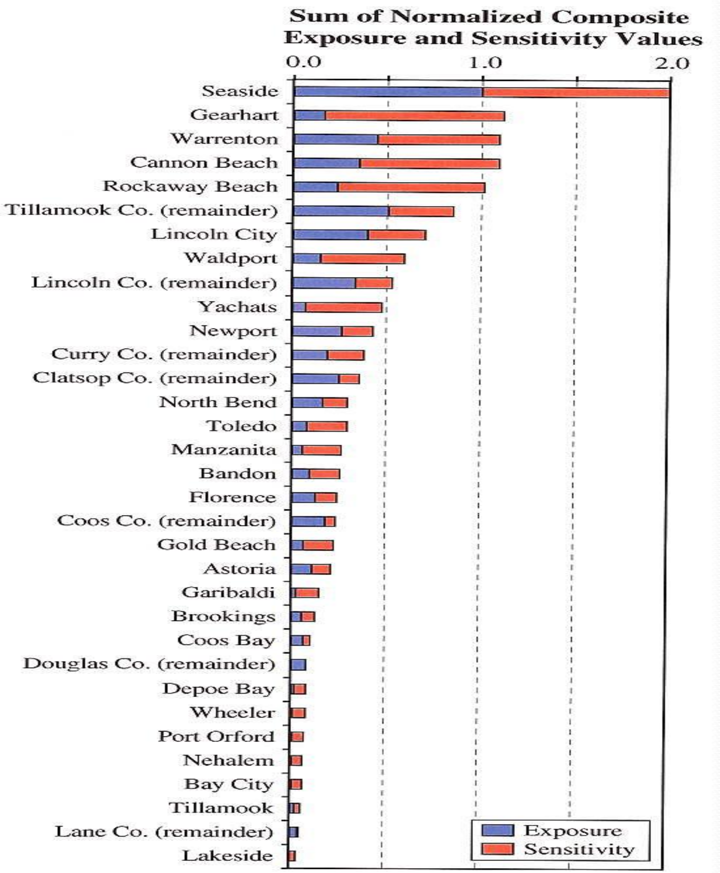
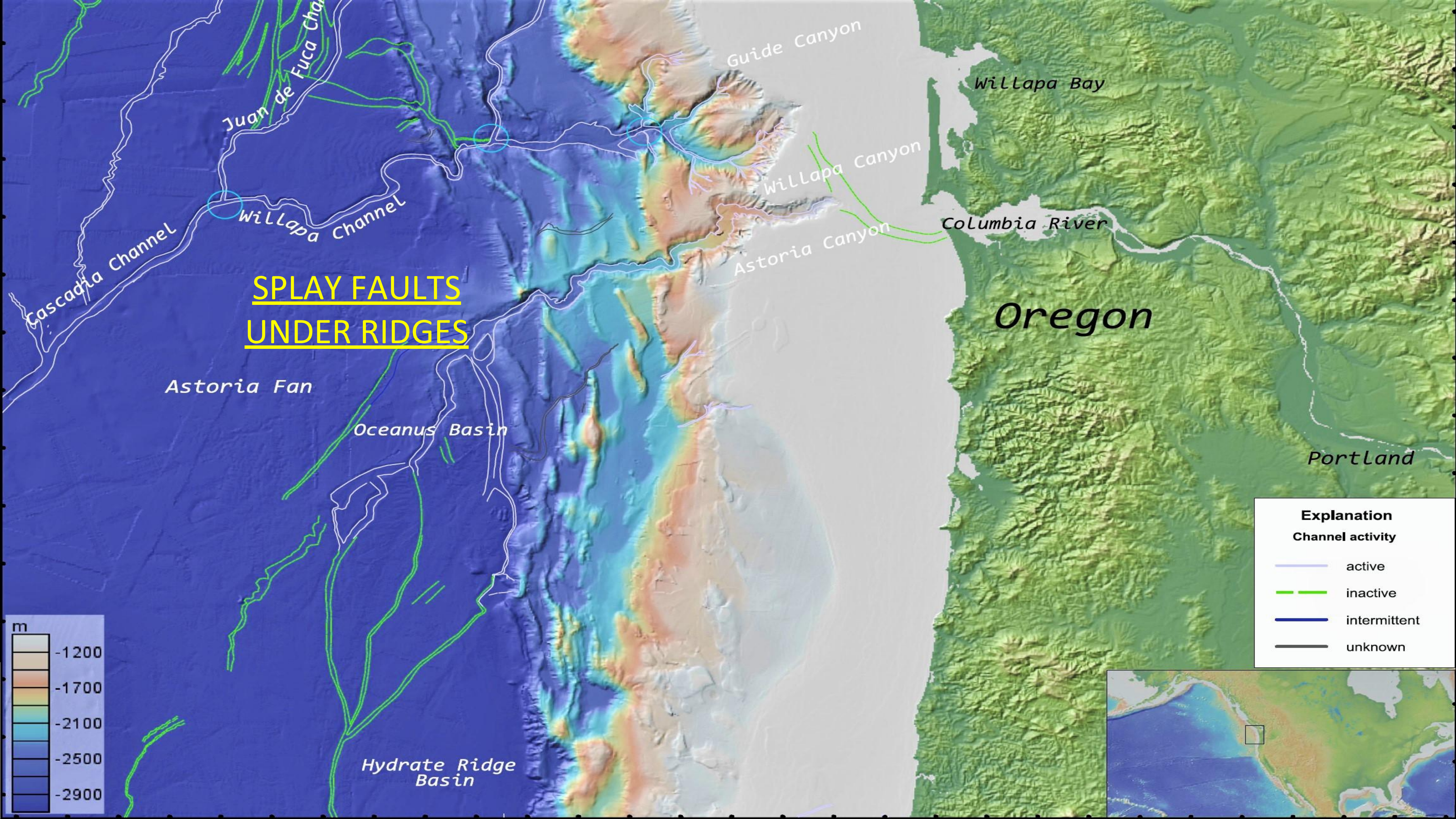


Figure 22. Sum of normalized exposure and sensitivity indices for incorporated cities in the Oregon tsunami-inundation zone.

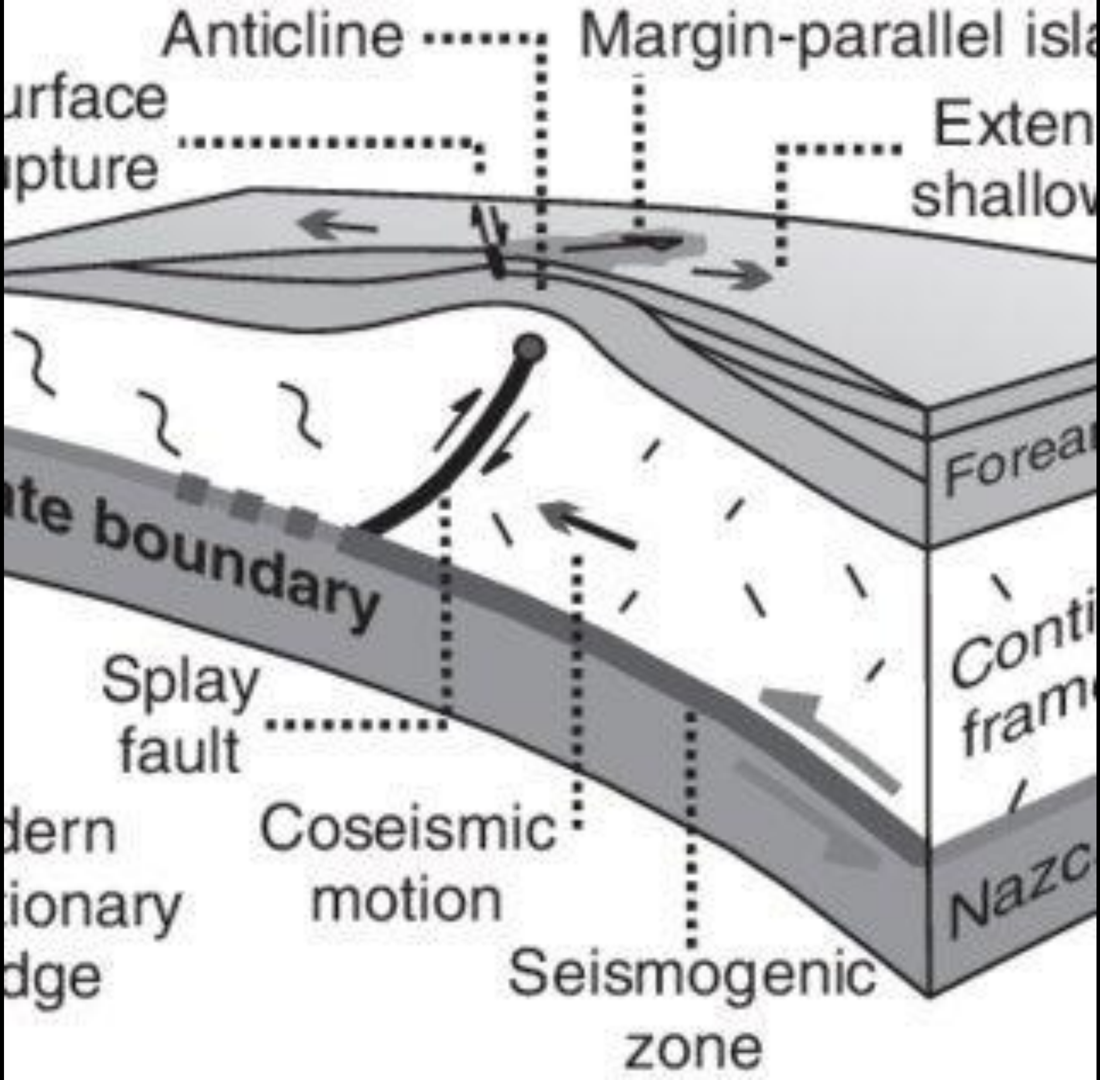
Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon

USGS Scientific Investigations Report 2007-52-83

Nathan Wood (2007)

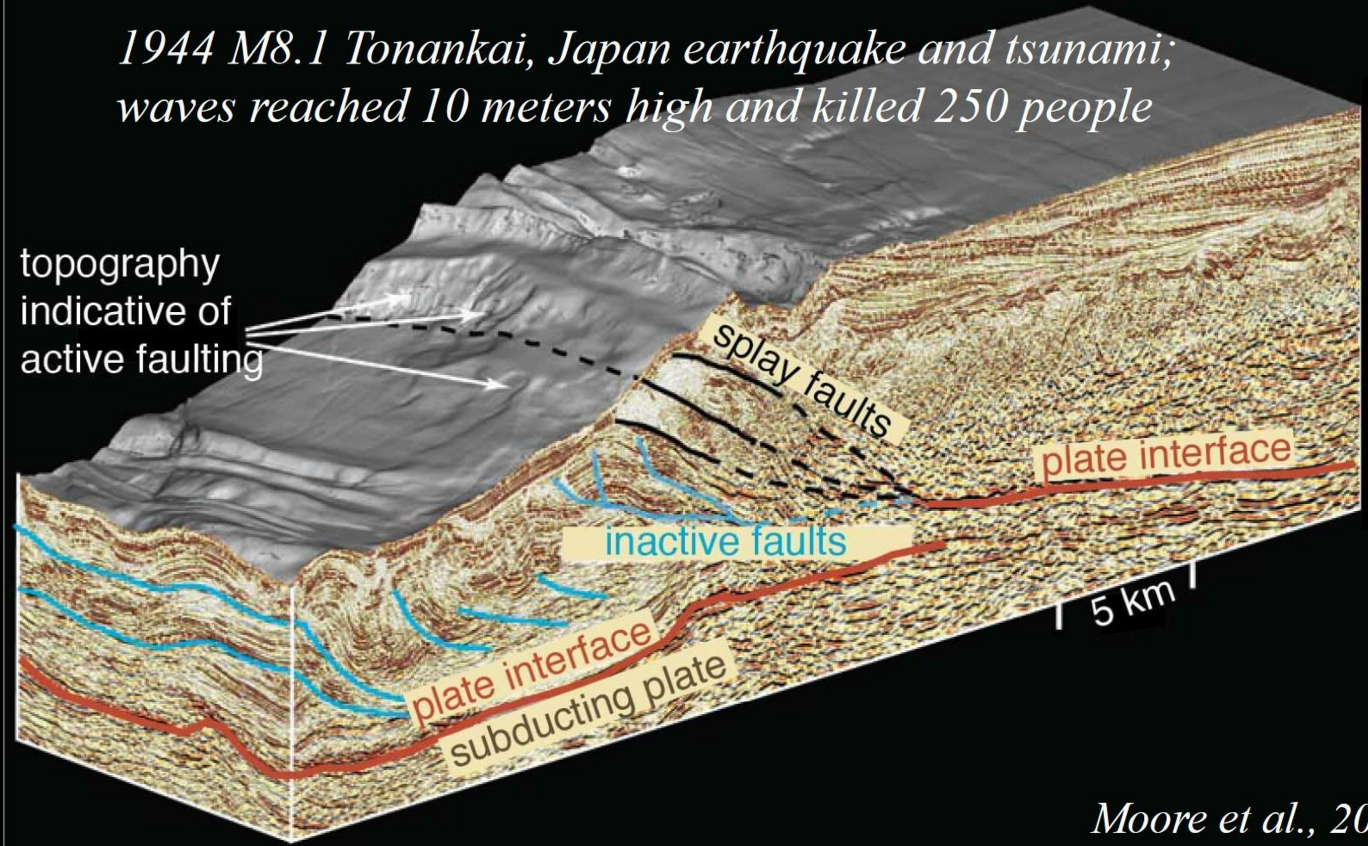


SPLAY FAULTS
UNDER RIDGES
Guide Canyon
Willapa Bay
Juan de Fuca Cha
Willapa Canyon
Willapa Channel
Columbia River
Cascadia Channel
Astoria Canyon
Oregon
Astoria Fan
Oceanus Basin
Portland
Explanation
Channel activity
active
inactive
intermittent
unknown
m
-1200
-1700
-2100
-2500
-2900
Hydrate Ridge
Basin

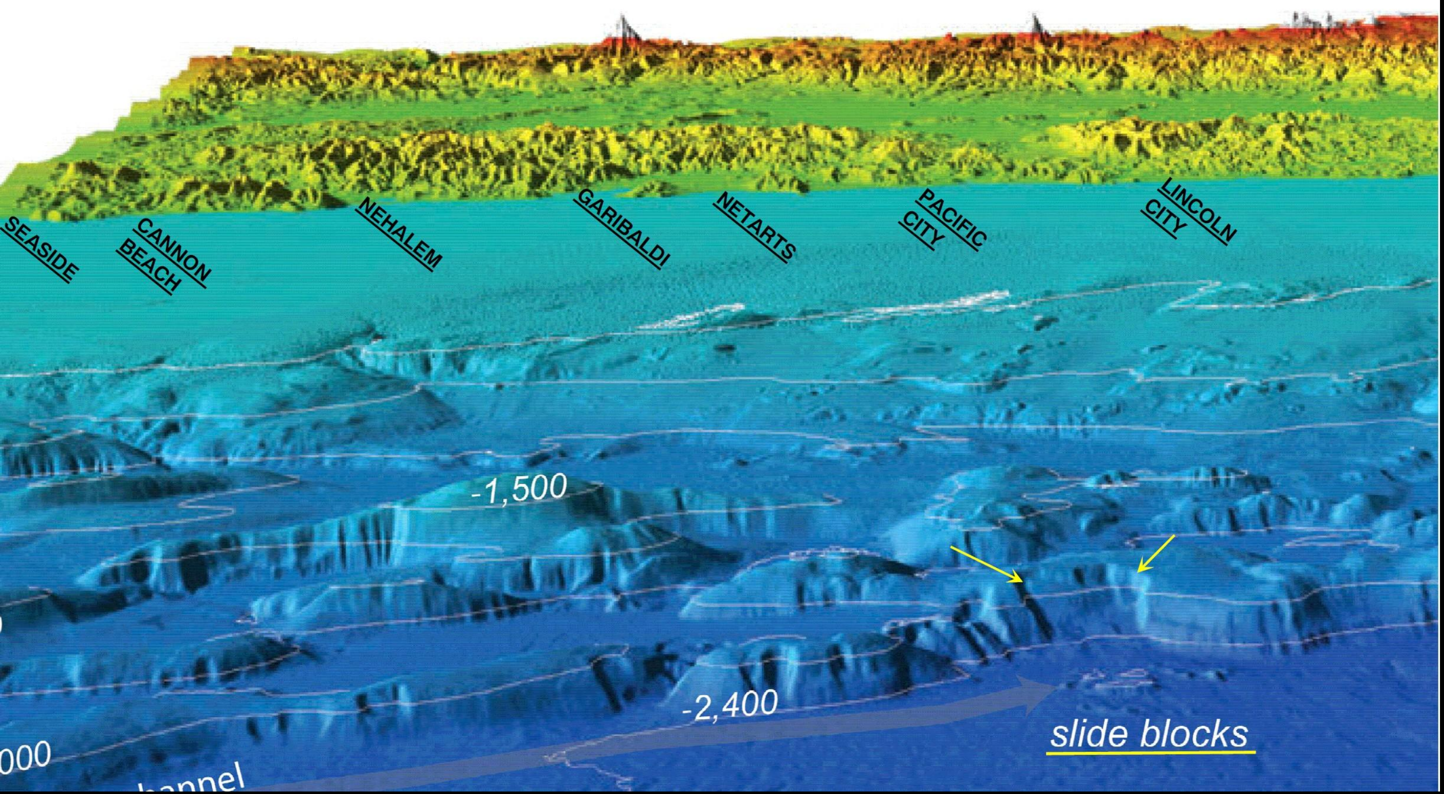


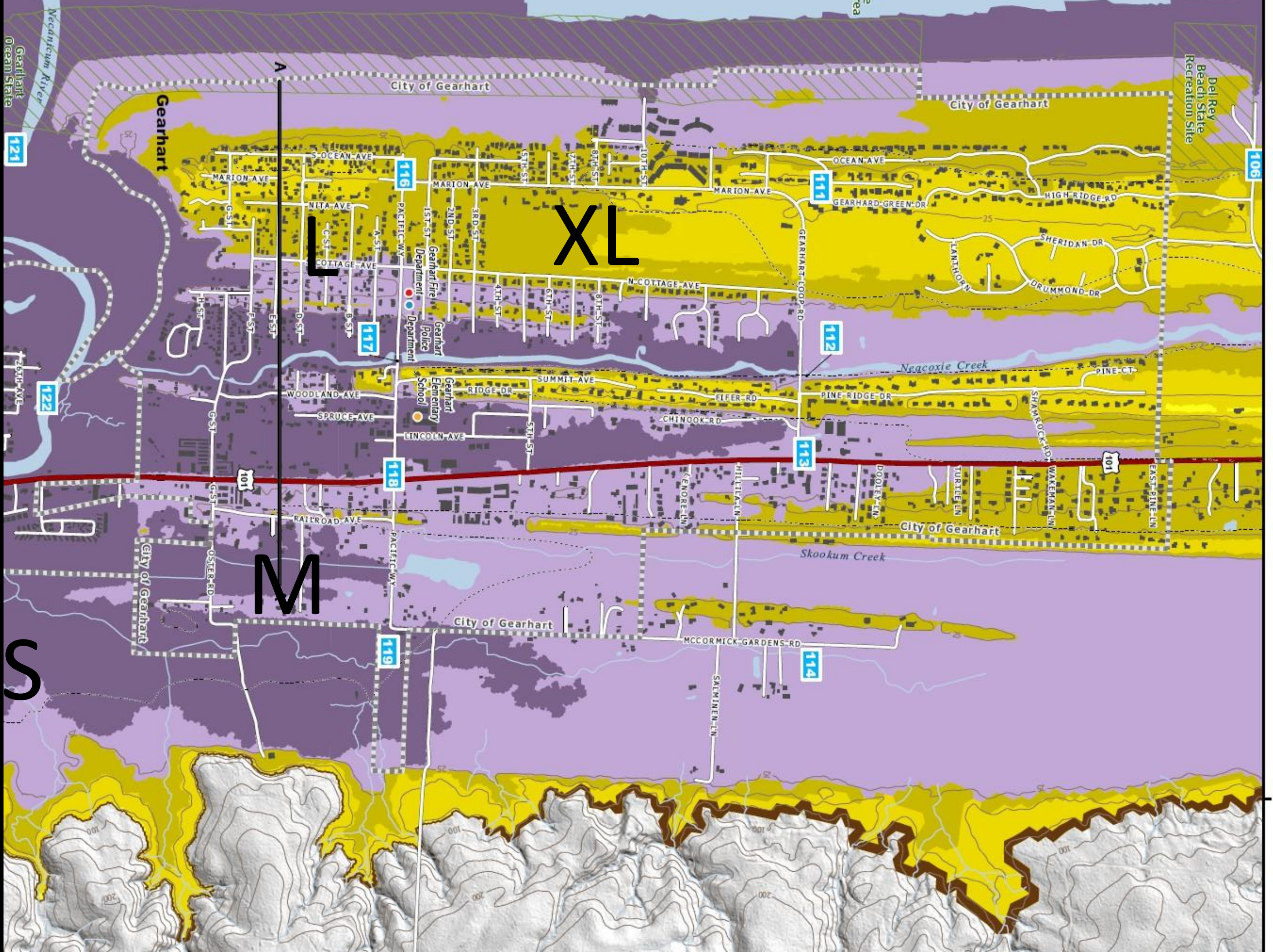
Anticline
Margin-parallel isla
urface
pture
Exten
shallov
Forea
ate boundary
Conti
fram
Splay
fault
dern
tionary
dge
Coseismic
motion
Seismogenic
zone
Nazc

1944 M8.1 Tonankai, Japan earthquake and tsunami; waves reached 10 meters high and killed 250 people



Moore et al., 2007


SEASIDE
CANNON BEACH
NEHALEM
GARIBALDI
NETARTS
PACIFIC CITY
LINCOLN CITY
-1,500
-2,400
slide blocks



XL
L
M
S
A
Gearhart
City of Gearhart
Necanicum River
Gearhart Ocean State
Del Rey Beach State Recreation Site
Neacoxie Creek
Skookum Creek
S-OCEAN-AVE
MARION-AVE
NITA-AVE
COTTAGE-AVE
N-COTTAGE-AVE
OCEAN-AVE
GEARHARD-GREEN-DR
HIGH-RIDGE-RD
SHERIDAN-DR
DRUMMOND-DR
GEARHART-LOOP-RD
SUMMIT-AVE
RIDGE-DR
FIFER-RD
PINE-RIDGE-DR
PINE-CT
CHINOOK-RD
WOODLAND-AVE
SPRUCE-AVE
LINCOLN-AVE
RAILROAD-AVE
PACIFIC-WY
MCCORMICK-GARDENS-RD
SALMINEN-LN
OSTER-RD
Gearhart Fire Department
Gearhart Police Department
Gearhart Elementary School
101
106
111
112
113
114
116
117
118
119
121
122

Table 3. Cascadia earthquake source parameters used to define 15 rupture scenarios. Logic tree branch weights shown in parentheses. Total scenario weight listed in right column.

Earthquake Size	Interevent Time (yrs)	Fault Geometry	Slip Range (m) Maximum	Slip Range (m) Average	M_w	Scenario Name	Total Weight
Extra Extra Large (0.025)	1,200	Splay fault (0.8)	36–44	18–22	~9.1	**XXL 1**	0.02
		Shallow buried rupture (0.1)	36–44	18–22	~9.2	**XXL 2**	0.0025
		Deep buried rupture (0.1)	36–44	18–22	~9.1	**XXL 3**	0.0025
Extra Large (0.025)	1,050–1,200	Splay fault (0.8)	35–44	17–22	~9.1	**XL 1**	0.02
		Shallow buried rupture (0.1)	35–44	17–22	~9.2	**XL 2**	0.0025
		Deep buried rupture (0.1)	35–44	17–22	~9.1	**XL 3**	0.0025
Large (0.16)	650–800	Splay fault (0.8)	22–30	11–15	~9.0	**L 1**	0.128
		Shallow buried rupture (0.1)	22–30	11–15	~9.1	**L 2**	0.016
		Deep buried rupture (0.1)	22–30	11–15	~9.0	**L 3**	0.016
Medium (0.53)	425–525	Splay fault (0.6)	14–19	7–9	~8.9	**M 1**	0.318*
		Shallow buried rupture (0.2)	14–19	7–9	~9.0	**M 2**	0.106
		Deep buried rupture (0.2)	14–19	7–9	~8.9	**M 3**	0.106
Small (0.26)	275–300	Splay fault (0.4)	9–11	4–5	~8.7	**SM 1**	0.104
		Shallow buried rupture (0.3)	9–11	4–5	~8.8	**SM 2**	0.078
		Deep buried rupture (0.3)	9–11	4–5	~8.7	**SM 3**	0.078

*Scenario M1 carries the highest weight and represents the "most likely" event in our analysis.

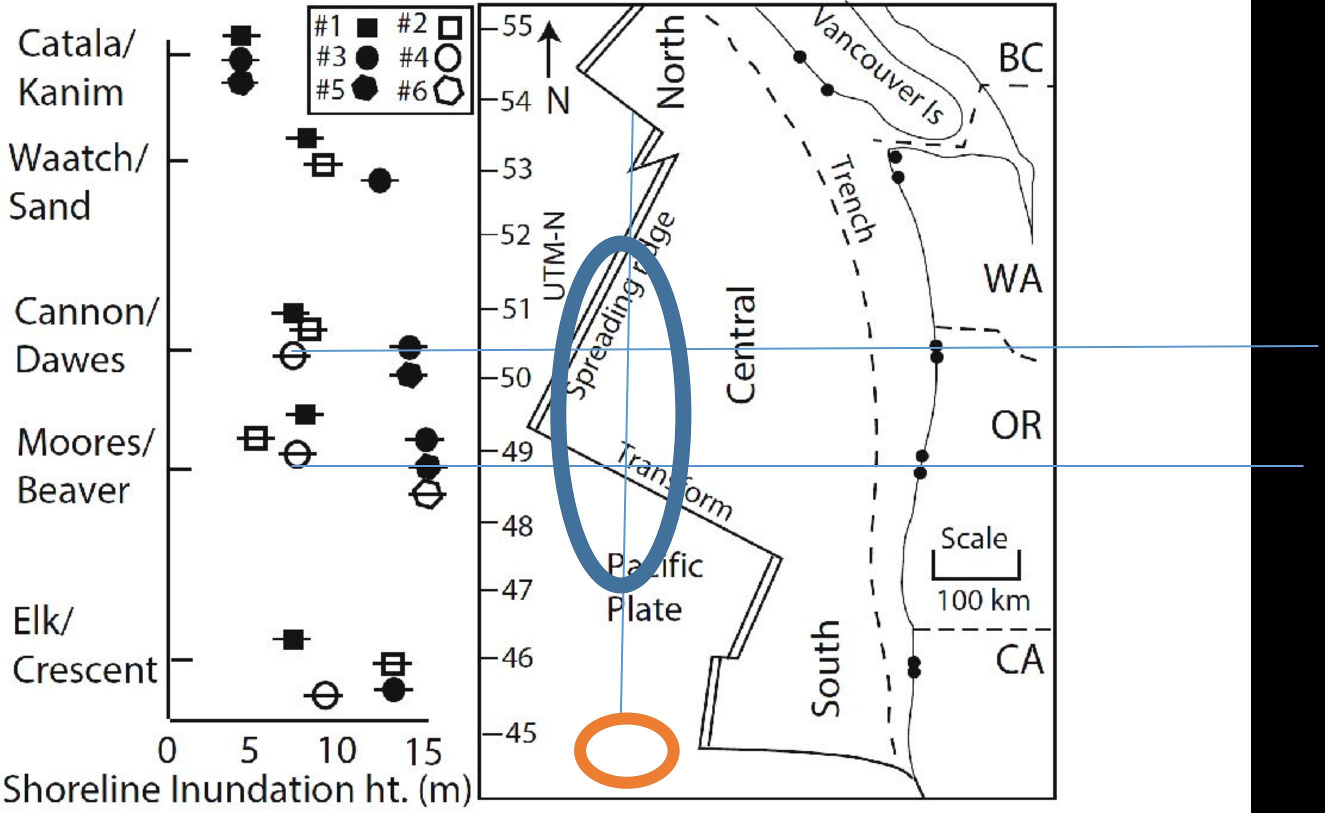
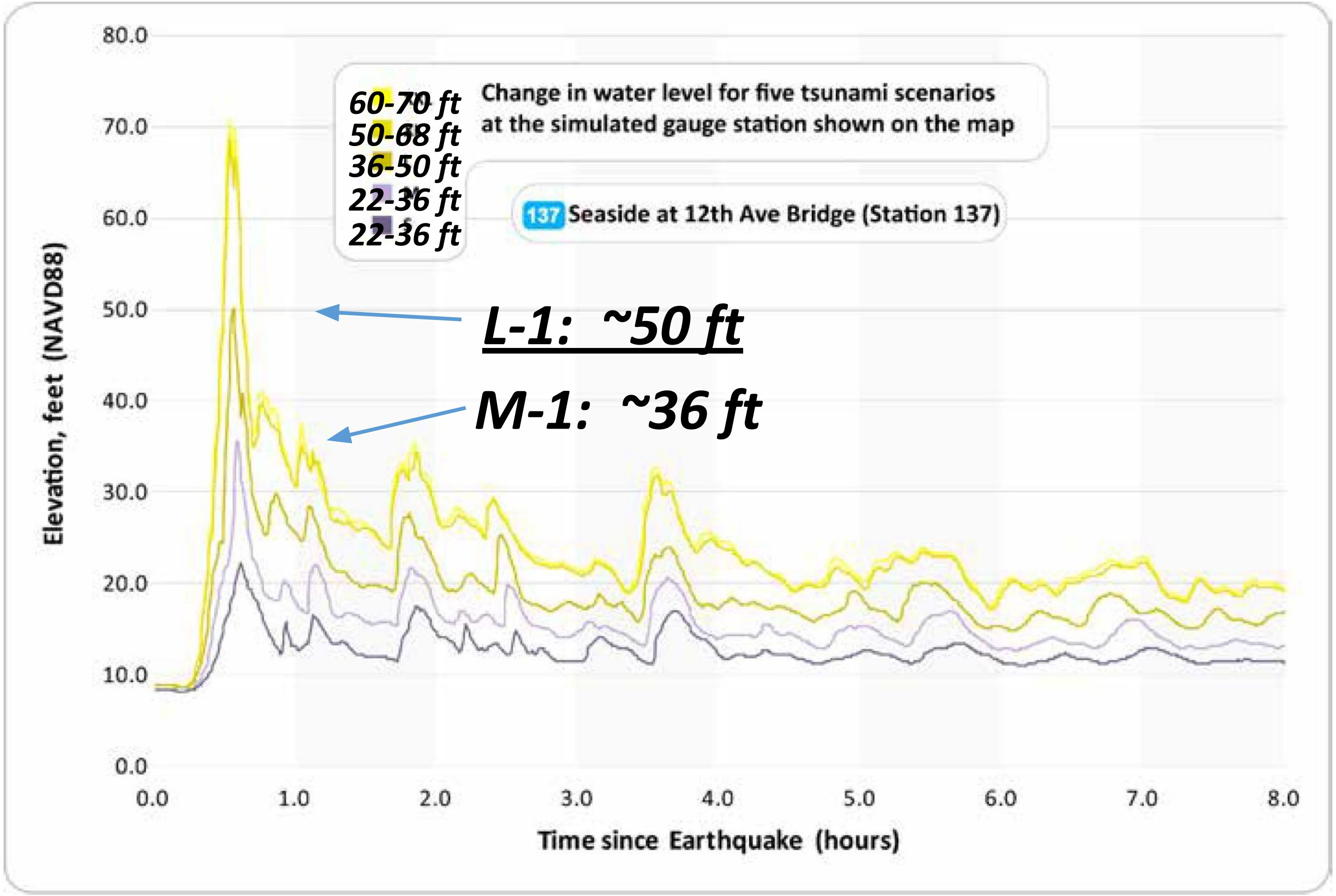


Fig. 6 Estimated shoreline inundation heights (±2 m NAVD88) for major nearfield paleotsunamis along the Cascadia margin over the past 3000 years. Ages of Cascadia rupture events and associated nearfield paleotsunamis are as follows: #1–0.3 ka; #2–1.1 ka; #3–1.3 ka; #4–1.7 ka; #5–2.6 ka; #6–2.8 ka (Tables 1, 2)

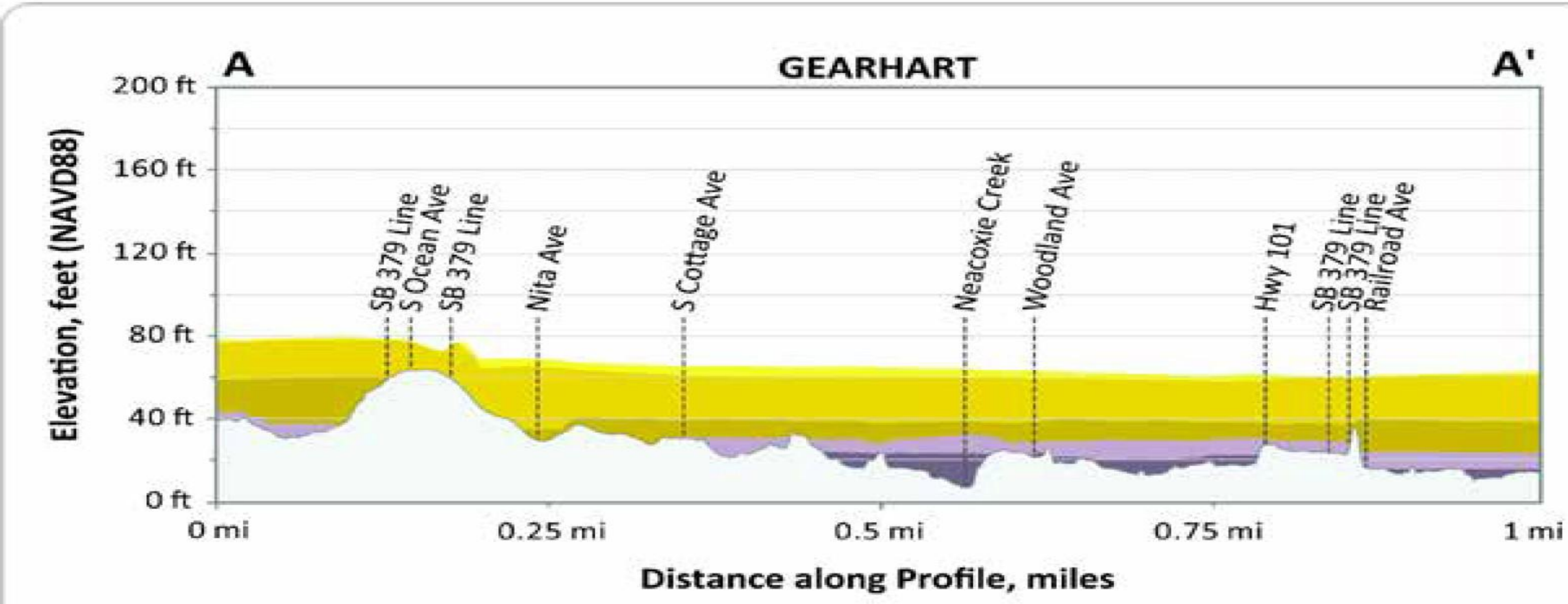
THE MOST LIKELY TSUNAMI HEIGHT IS 50 TO 55 FT

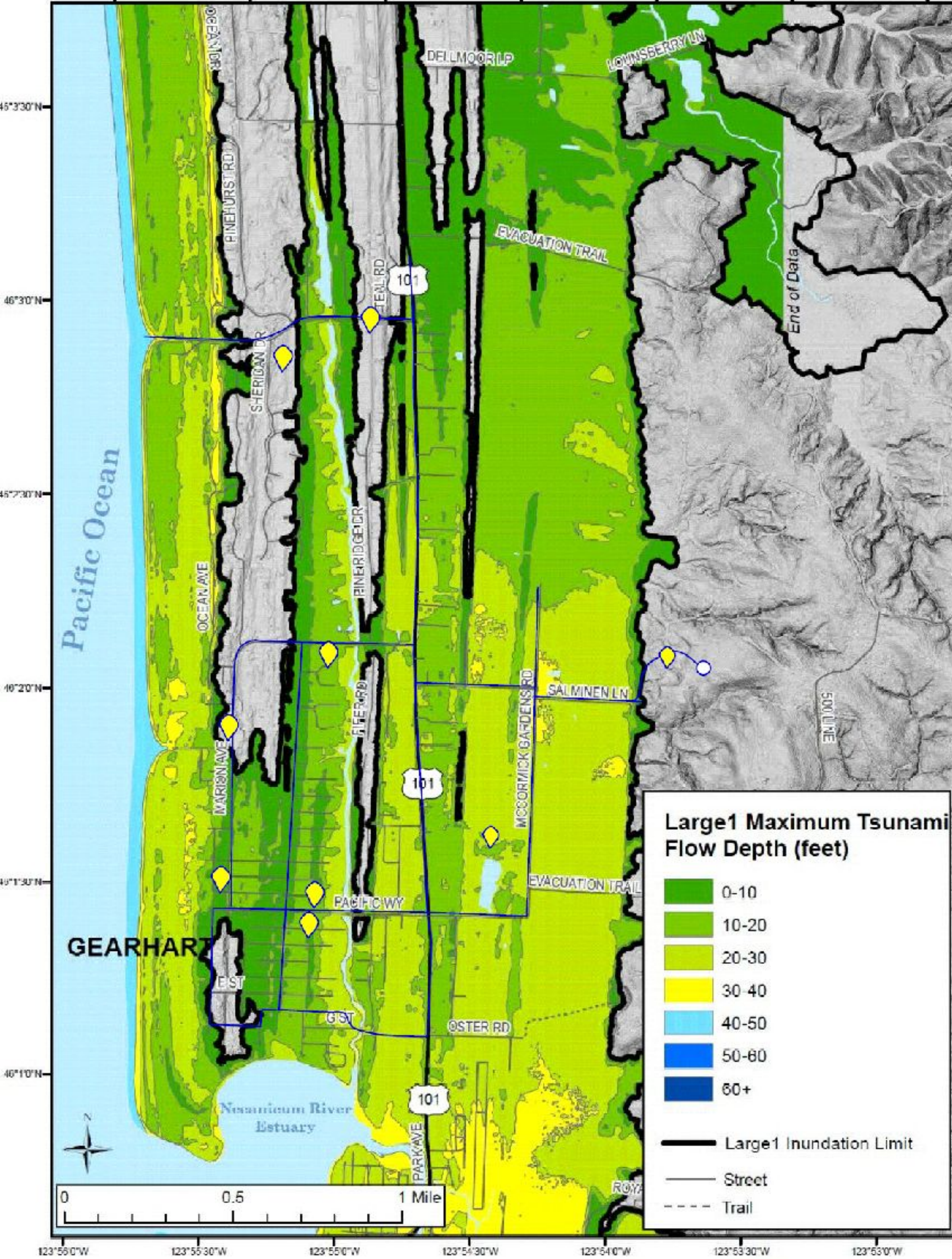
THE L-1 SCENARIO

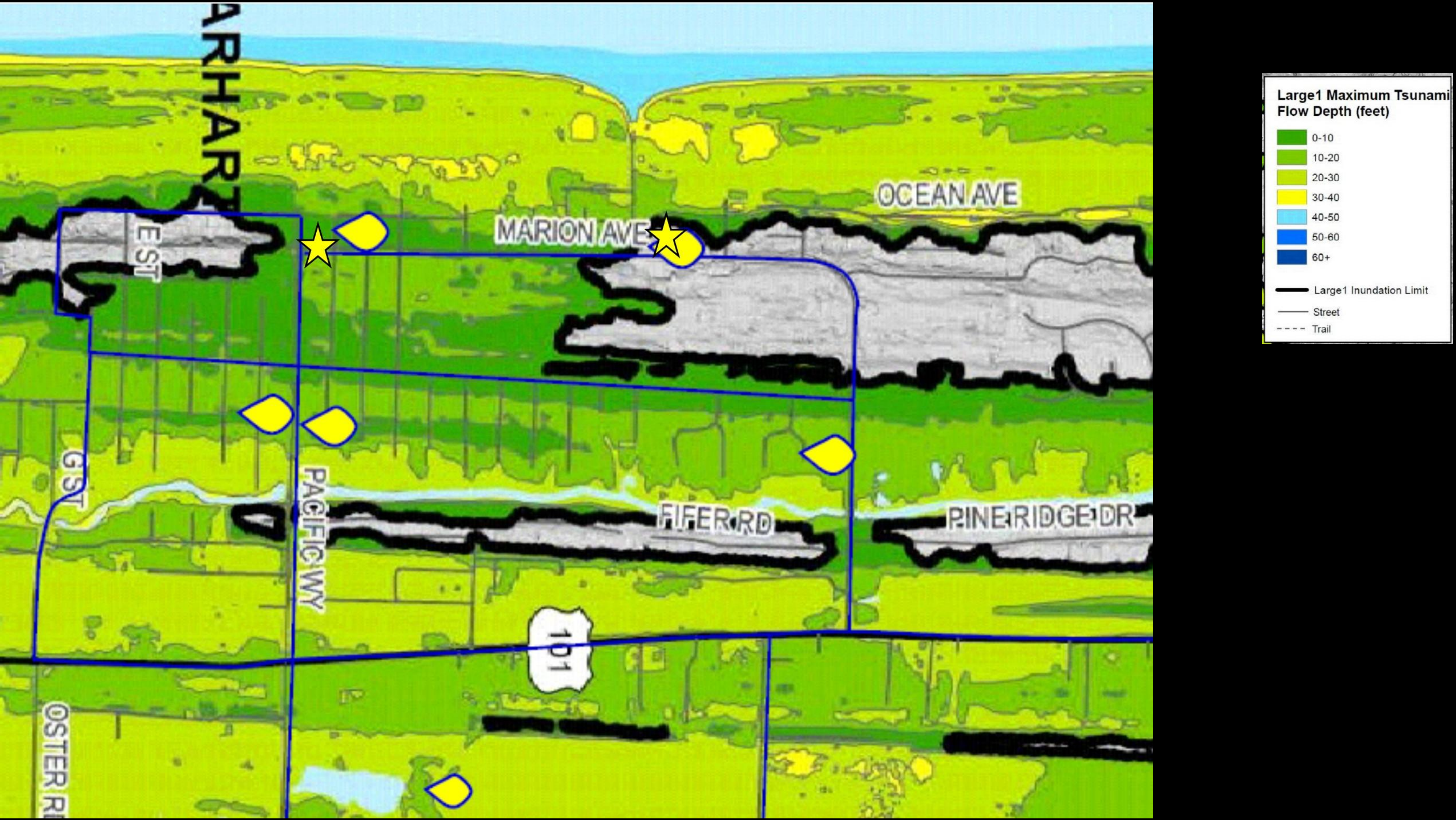
Estimated Tsunami Wave Height through Time for Simulated Gauge Station



Maximum Wave Elevation Profiles




Pacific Ocean
GEARHART
Neawanna River Estuary
OCEAN DR
PINEHURST RD
SHERIDAN DR
TEAL RD
DELLMOOR LP
LOUNSBERRY LN
EVACUATION TRAIL
End of Data
PINERIDGE DR
OCEAN AVE
FIFER RD
MARION AVE
PACIFIC WY
E ST
G ST
OSTER RD
PARK AVE
MCCORMICK GARDENS RD
SALMINEN LN
500 LINE
101
Large1 Maximum Tsunami Flow Depth (feet)
0-10
10-20
20-30
30-40
40-50
50-60
60+
Large1 Inundation Limit
Street
Trail
0
0.5
1 Mile
N
46°3'30"N
46°3'0"N
46°2'30"N
46°2'0"N
46°1'30"N
46°1'0"N
123°56'0"W
123°55'30"W
123°55'0"W
123°54'30"W
123°54'0"W
123°53'30"W
123°53'0"W


OCEAN AVE
MARION AVE
E ST
G ST
PACIFIC WY
FIFER RD
PINE RIDGE DR
101
Large1 Maximum Tsunami Flow Depth (feet)
0-10
10-20
20-30
30-40
40-50
50-60
60+
Large1 Inundation Limit
Street
Trail

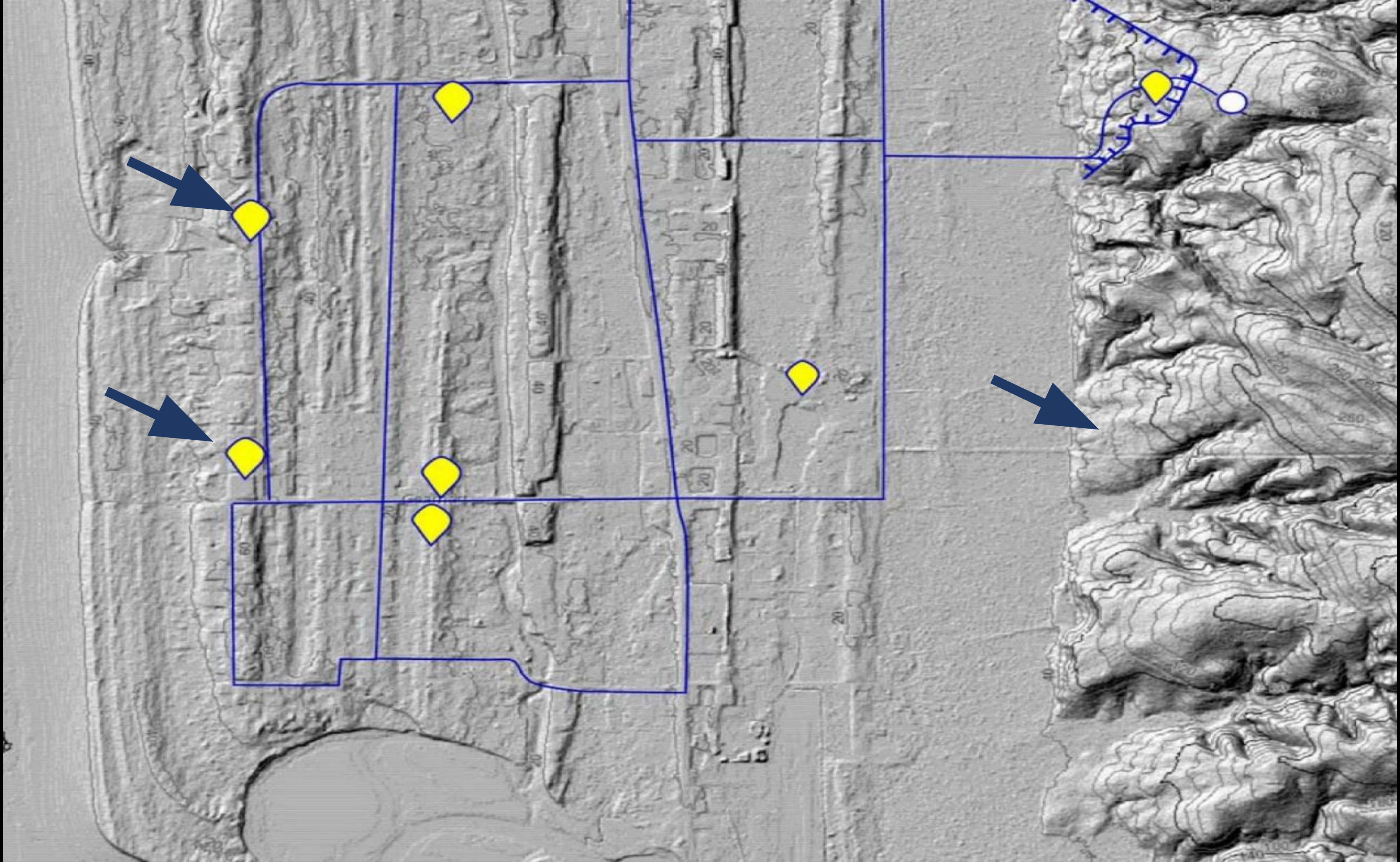
Buildings within Tsunami Inundation Zones

	Entire Map Area	City of Gearhart	City of Seaside	Unincorporated Areas
Total Buildings	6,620	1,729	4,611	280
Buildings within Tsunami Zones*				
Small	3,885	310	3,573	2
Medium	5,006	832	4,127	47
Large	5,759	1,406	4,225	128
Extra Large	6,227	1,729	4,343	155
Extra Extra Large	6,287	1,729	4,350	208
Percent of Buildings within Tsunami Zones				
Small	58.7%	17.9%	77.5%	0.7%
Medium	75.6%	48.1%	89.5%	16.8%
Large	87.0%	81.3%	91.6%	45.7%
Extra Large	94.1%	100.0%	94.2%	55.4%
Extra Extra Large	95.0%	100.0%	94.3%	74.3%

*Building counts shown are based on polygon centroids and are cumulative within the map area.

LOCATION	Gearhart Park	Current Site	Trails End	Palmberg	Meadow Ct	Gearhart By The Sea	Highlands Lane		Fraser Property	Somewhere in the Hills*
Settlement/Fill	1	2	1	2	2	2	1		1	1
Liquefaction	0	1	1	3	2	0	0		0	0
Shaking Ampl.	2	2	2	2	2	2	2		2	1
Tsunami	2	3	3	4	3	0	0		0	0
Coseismic Flood	0	0	0	2	1	0	0		0	0
Landslide	0	0	0	0	0	0	0		0	1
TOTAL	5	8	7	13	10	4	3		3	3

Low totals are better than higher. **Water tank site, inside the fencing; other, better, sites may be available on stable ground.*



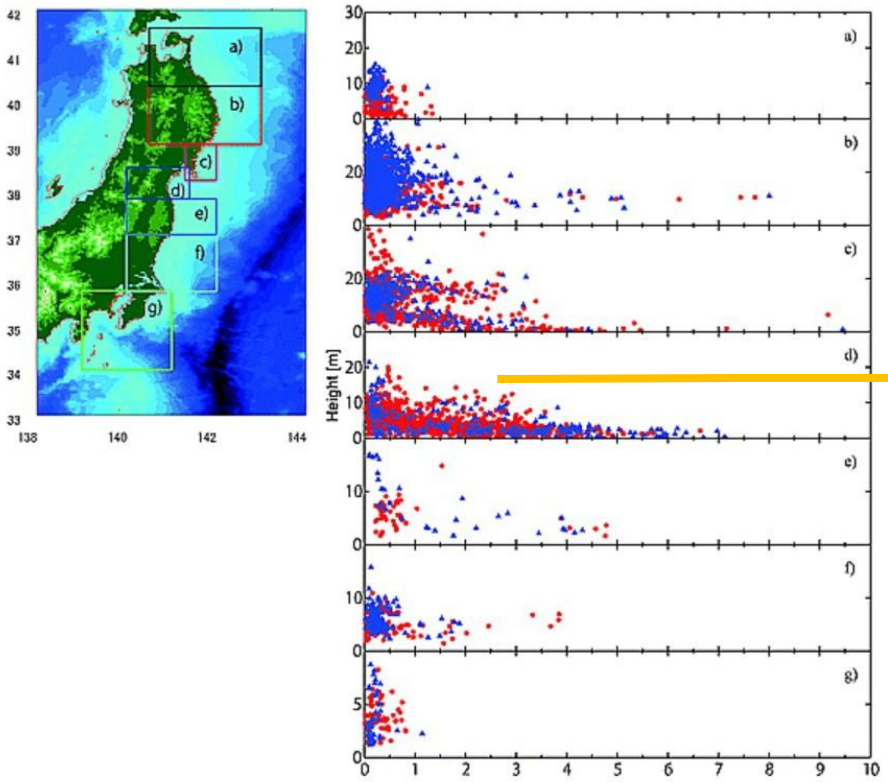


Figure 3

Open in figure viewer | PowerPoint

Regional analysis of local tsunami height and distance (circle: inundation height, triangle: run-up height). Area of analysis and inundation distance from coast line: (a) Hokkaido, (b) Iwate Prefecture, (c) North Miyagi Prefecture, (d) South Miyagi Prefecture, the Sendai Plain, (e) Fukushima Prefecture, (f) Ibaraki Prefecture, and (g) Chiba Prefecture.

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