PNWA – AWWA 2013
Water Infrastructure Seismic Considerations

Potential Geotechnical Hazards of Seismic Events

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Presentation Outline

- Summary of Design Earthquake Events
- Ground Motion Amplification
- Fault Rupture
- Liquefaction
- Seismic Slope Stability
- Surface Settlement
- Tsunami

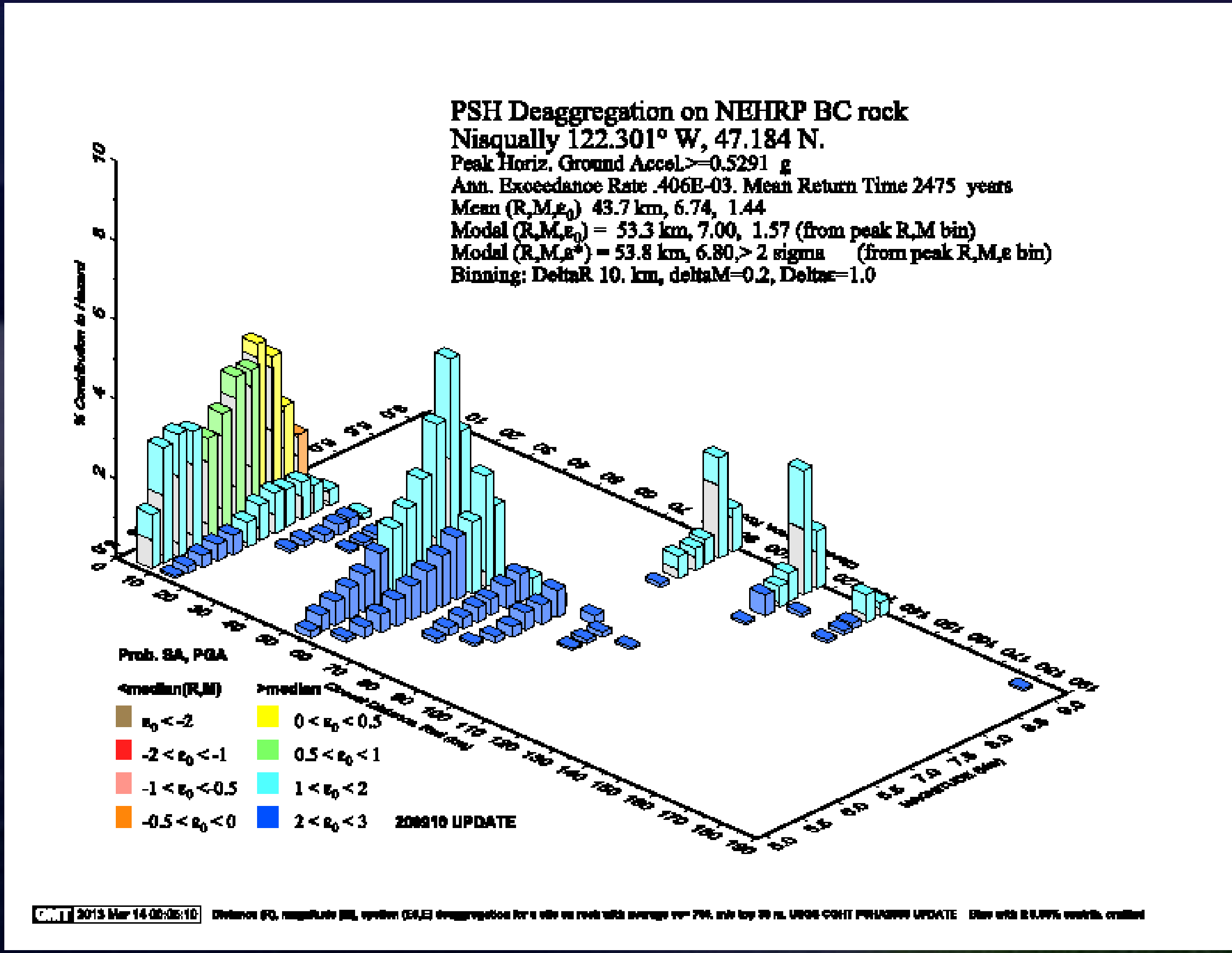
Summary of Design Earthquakes

Three major earthquake sources:

- Shallow-focus Crustal Earthquakes (Mw = 5 to 7)
- Deep-focus, Intraplate Earthquakes (Mw = 6 to 7.5)
- CSZ Interface Earthquakes (Mw = 8 to 9.2)

Summary of Design Earthquakes

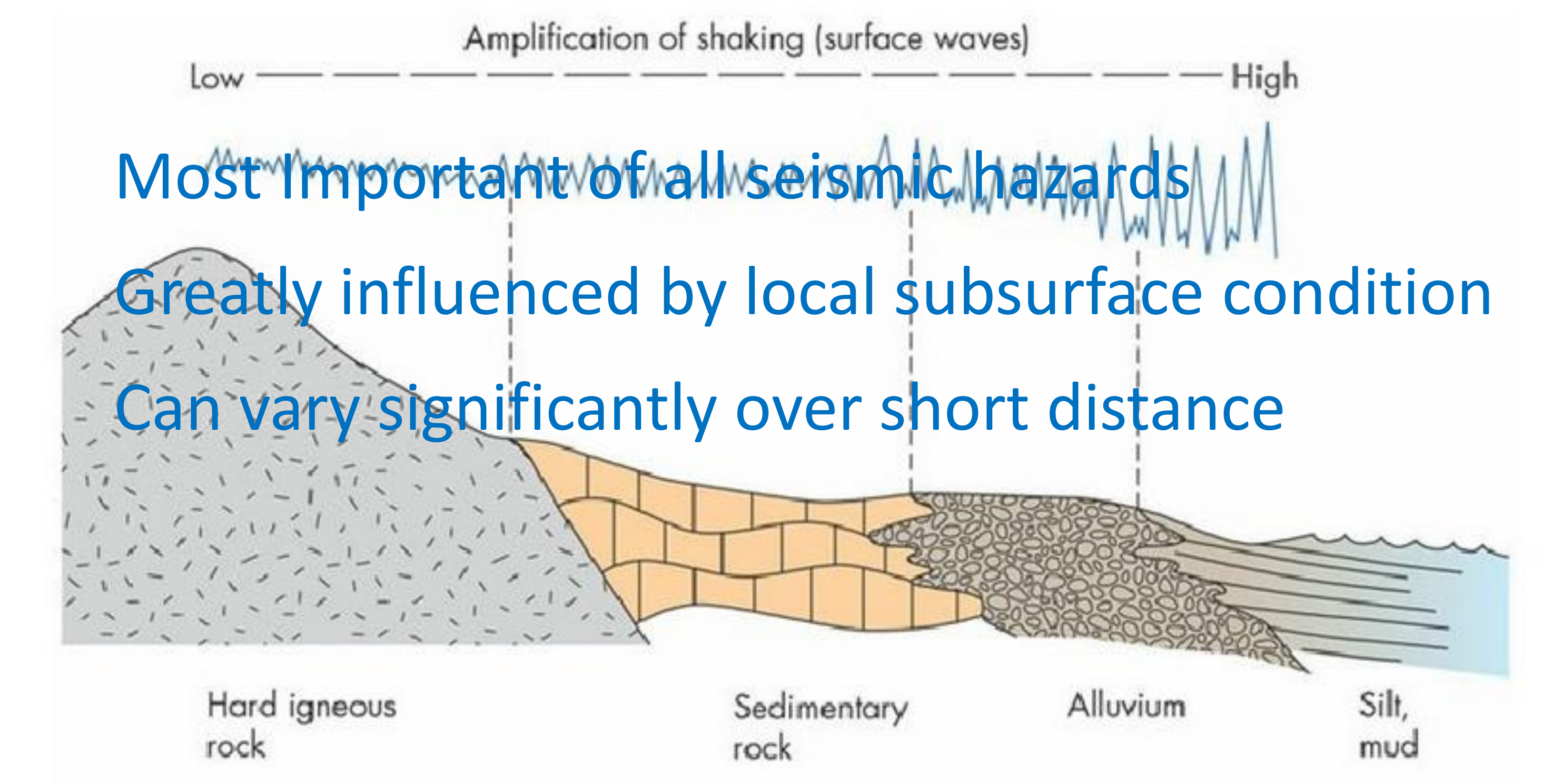
Earthquake Hazard Contributions



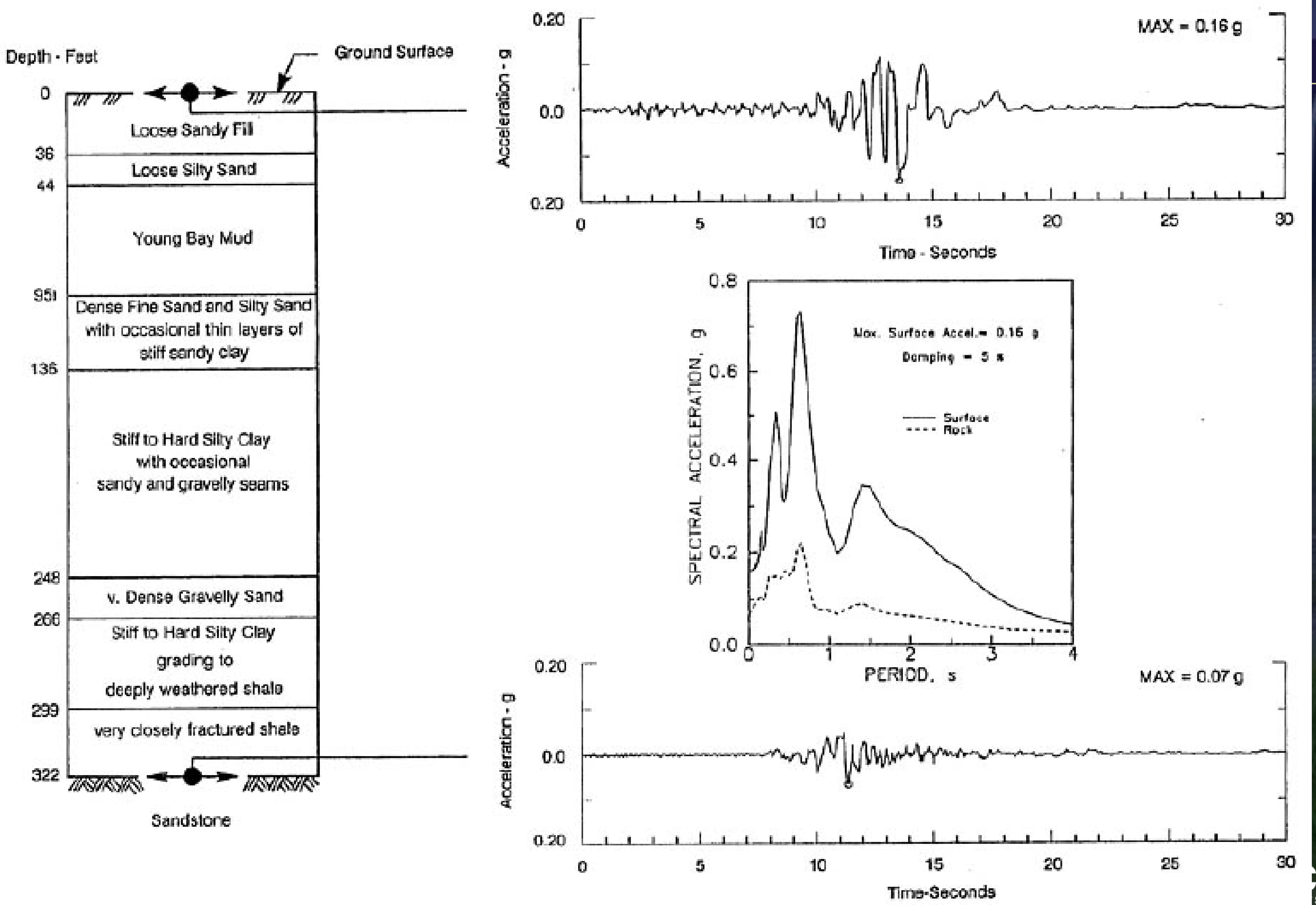
Structural Damages

Ground Motion Amplifications

- Most Important of all seismic hazards
- Greatly influenced by local subsurface condition
- Can vary significantly over short distance



Ground Motion Amplifications



Soil Response at Treasure Island during the 1989 Loma Prieta Earthquake

Ground Motion Amplifications

Depends on:

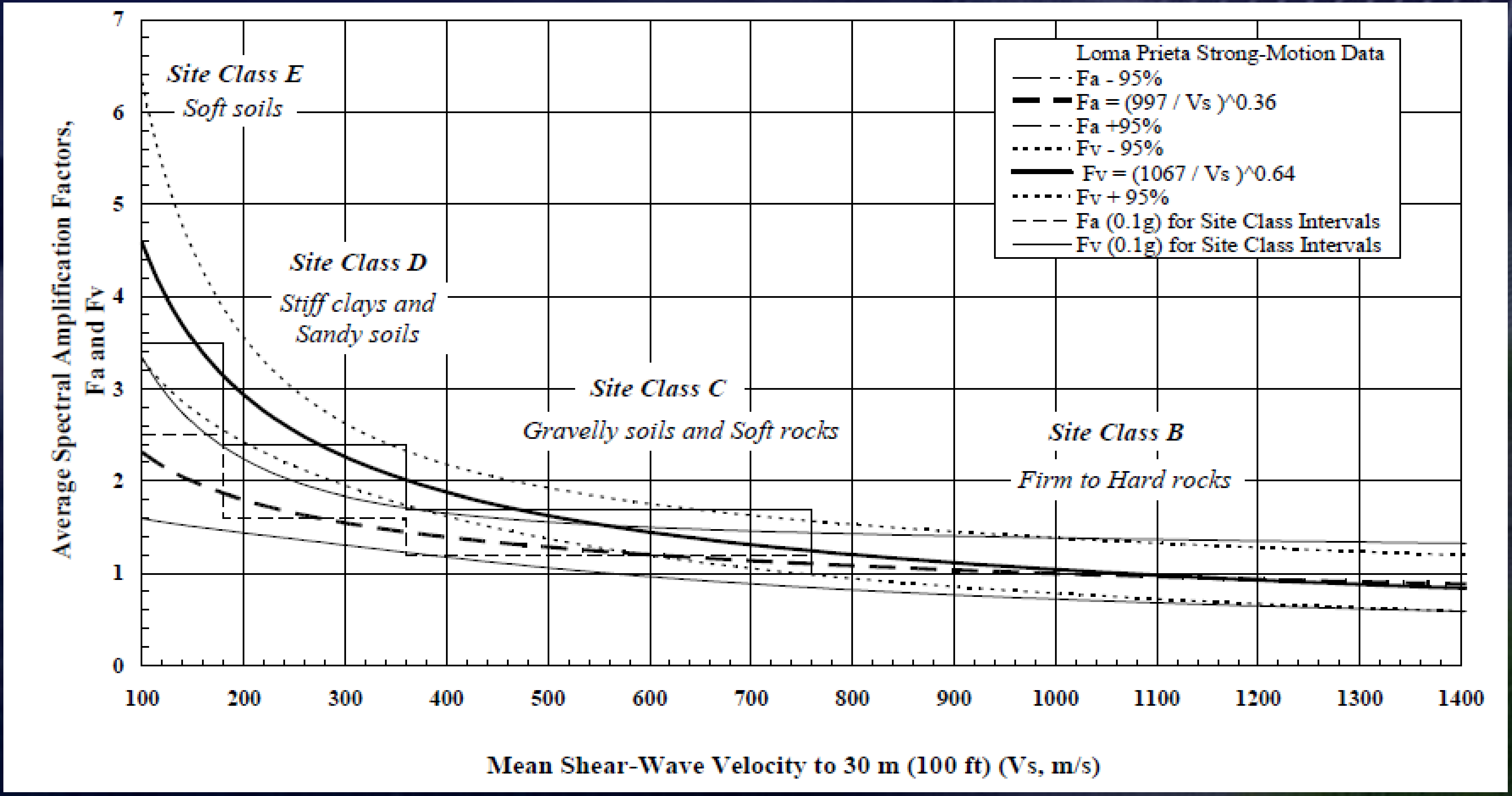
- Dynamic soil characteristics (i.e. shear modulus, shear wave velocity, damping ratio)
- Soil layers and thickness
- Ground Motion intensity

Ground Motion Amplifications

Site Effects on Ground Motions

- Soil profile acts as filter
- Changes in frequency content of motion
- Amplification or de-amplification of ground motions
- Duration of motion is increased

Ground Motion Amplifications



NEHRP 2003, **modified from Borcherdt 1994**

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Ground Motion Amplifications

Site Classification, NEHRP, ASCE 7, IBC,

TABLE 1613.5.2
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

Ground Motion Amplifications

Site Coefficients

TABLE 11.4-1 SITE COEFFICIENT, F_a

Site Class	Mapped Maximum Considered Earthquake Spectral Response Acceleration Parameter at Short Period				
	$S_S \le 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7				

NOTE: Use straight-line interpolation for intermediate values of S_S.

TABLE 11.4-2 SITE COEFFICIENT, F_v

Site Class	Mapped Maximum Considered Earthquake Spectral Response Acceleration Parameter at 1-s Period				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7				

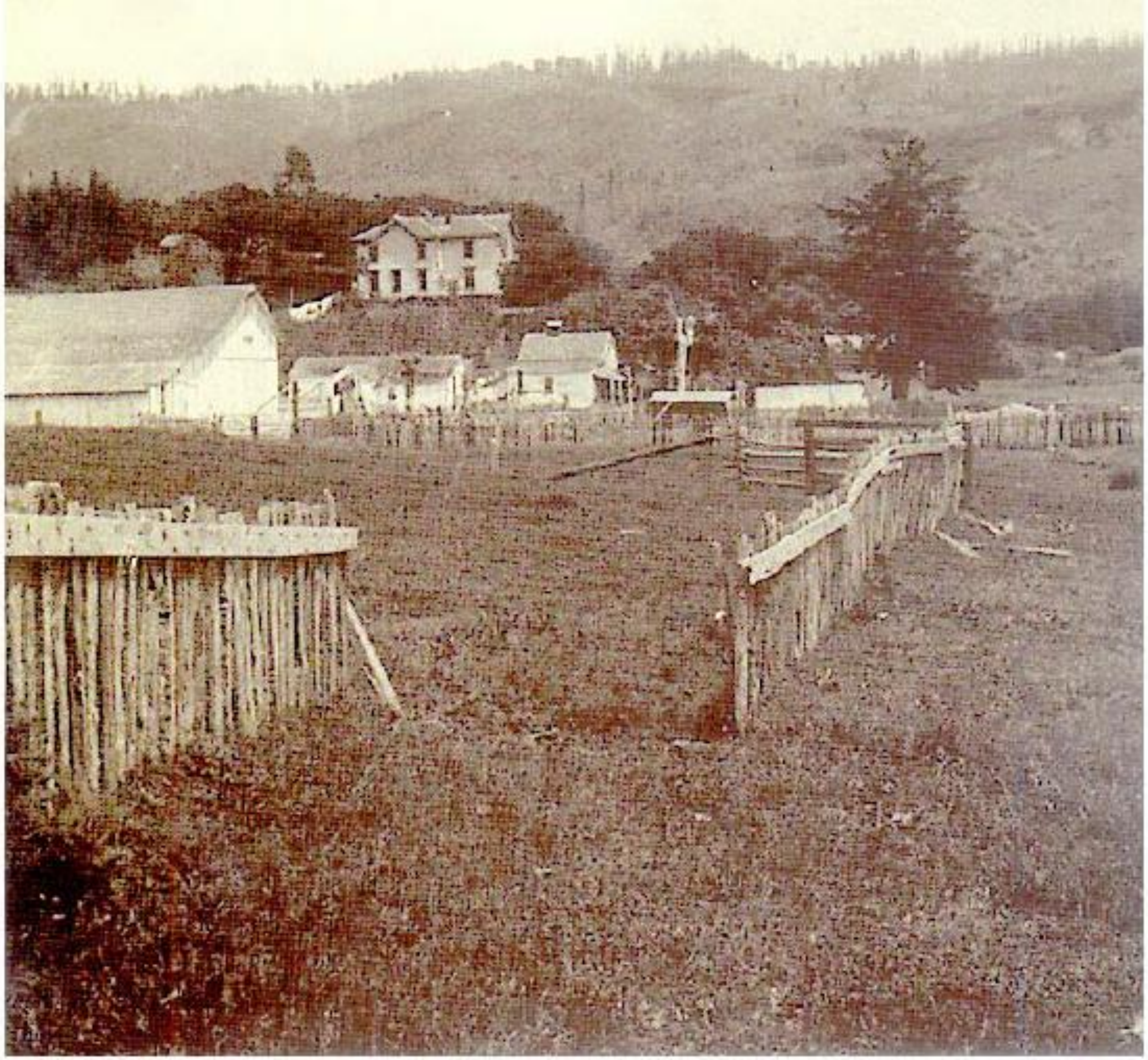
NOTE: Use straight-line interpolation for intermediate values of S_1.

ASCE 7-05

Fault Rupture

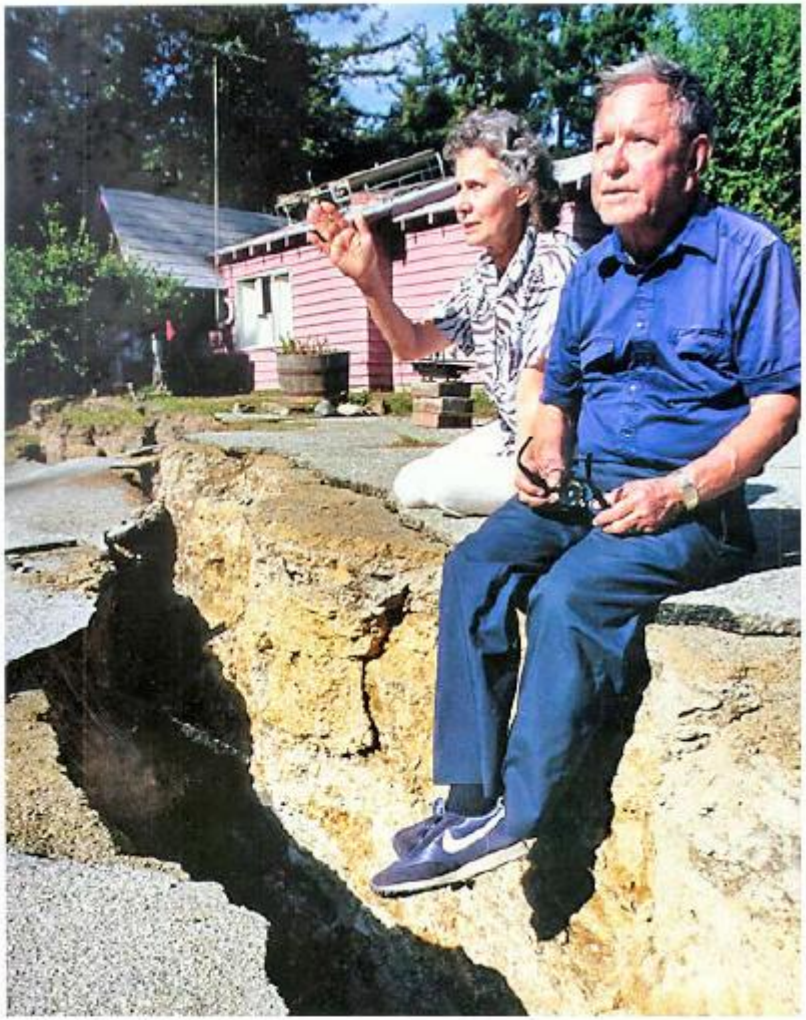
The San Andreas fault from the air. (Michael Collier, photographer)

Fault Rupture



1906 San Francisco Earthquake - Fence offset by 8 1/2 feet by the earthquake.

Fault Rupture



1989 San Francisco Bay Earthquake - Freda and John Tranbarger perch on the edge of a 15-toot-deep fissure that opened in their yard in Loma Prieta, a Santa Cruz Mountain town near the epicenter. The crack was 6 feet wide and 1,000 feet long. (Bob Carey, photogrrapher)

Fault Rupture

Liquefaction

Liquefaction Traps Christchurch Resident!

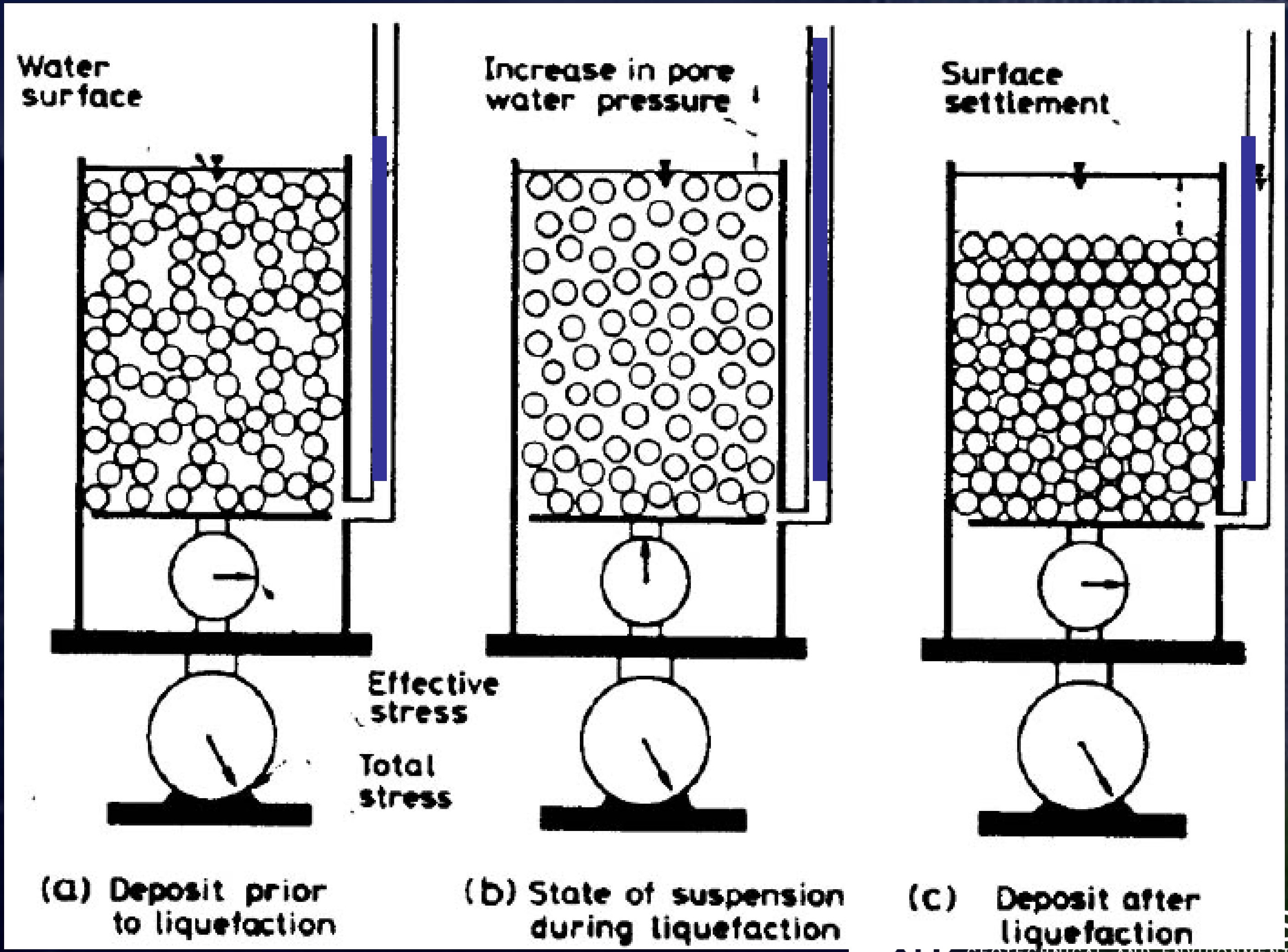
www.abc.net.au/news/2011-06-15/liquefaction-traps-christchurch-resident/2759046

Liquefaction

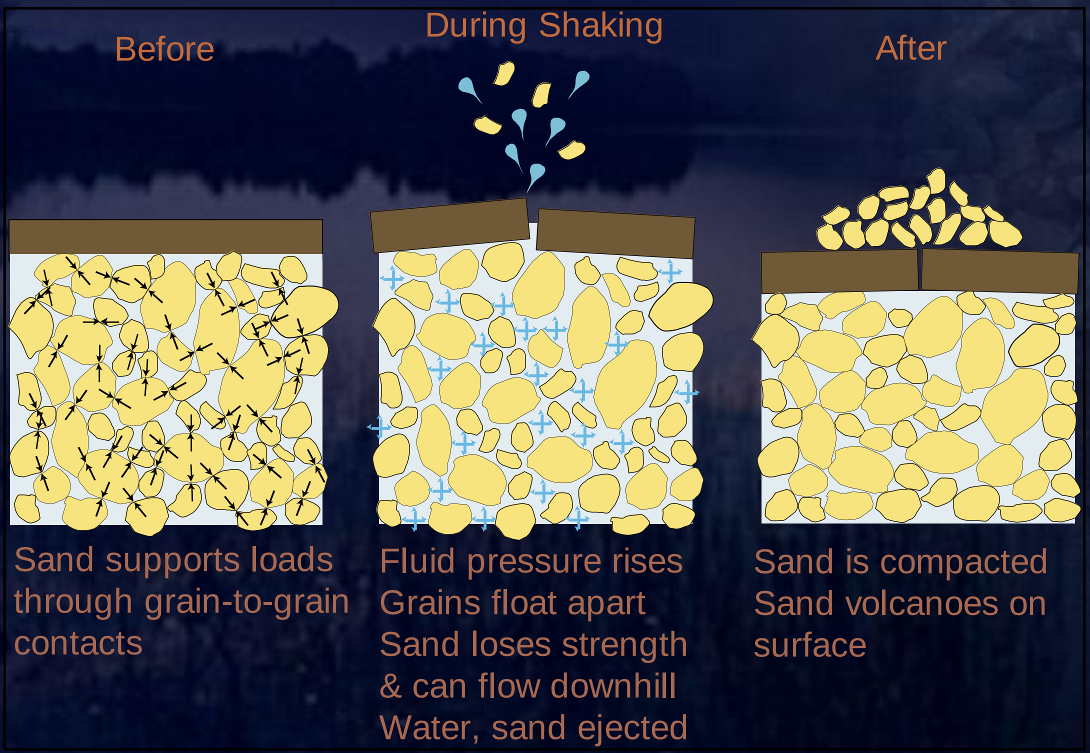
Liquefaction involves the substantial loss of shear strength in saturated soil caused by the rapid increase in pore water pressure when subjected to impact by seismic loading.

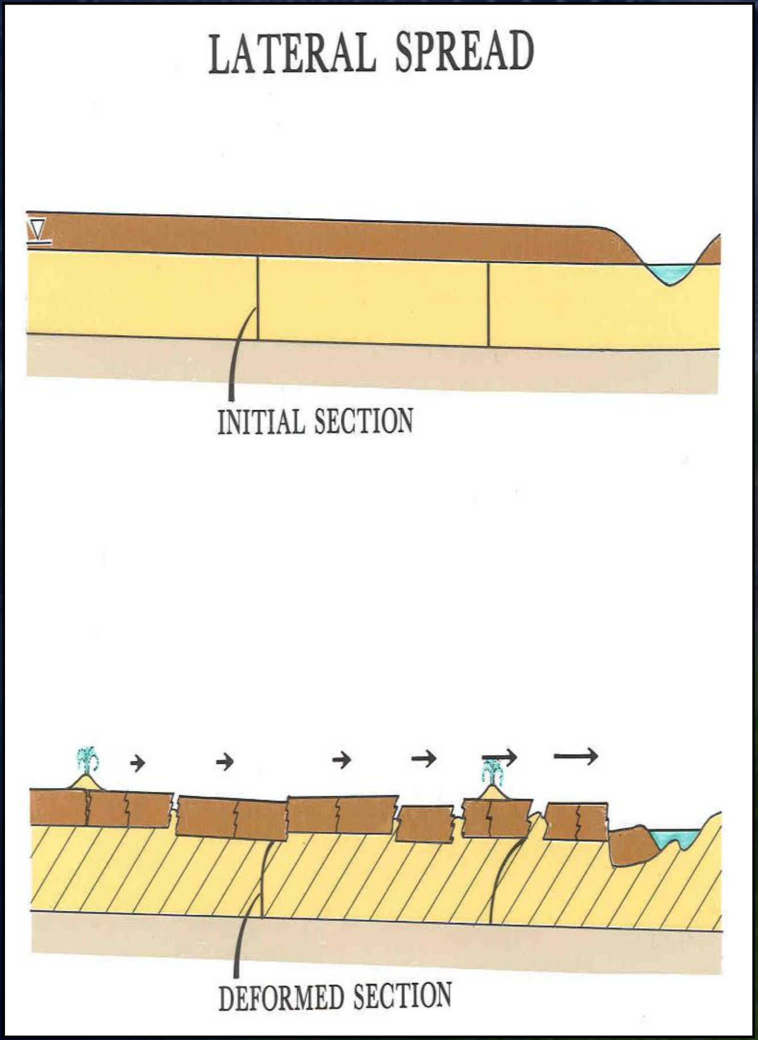
- Bearing capacity failure
- Ground loss (sand boil)
- Excessive settlement (especially differential settlement)
- Lateral spreading
- Floatation
- Increased lateral pressure

Liquefaction



Liquefaction





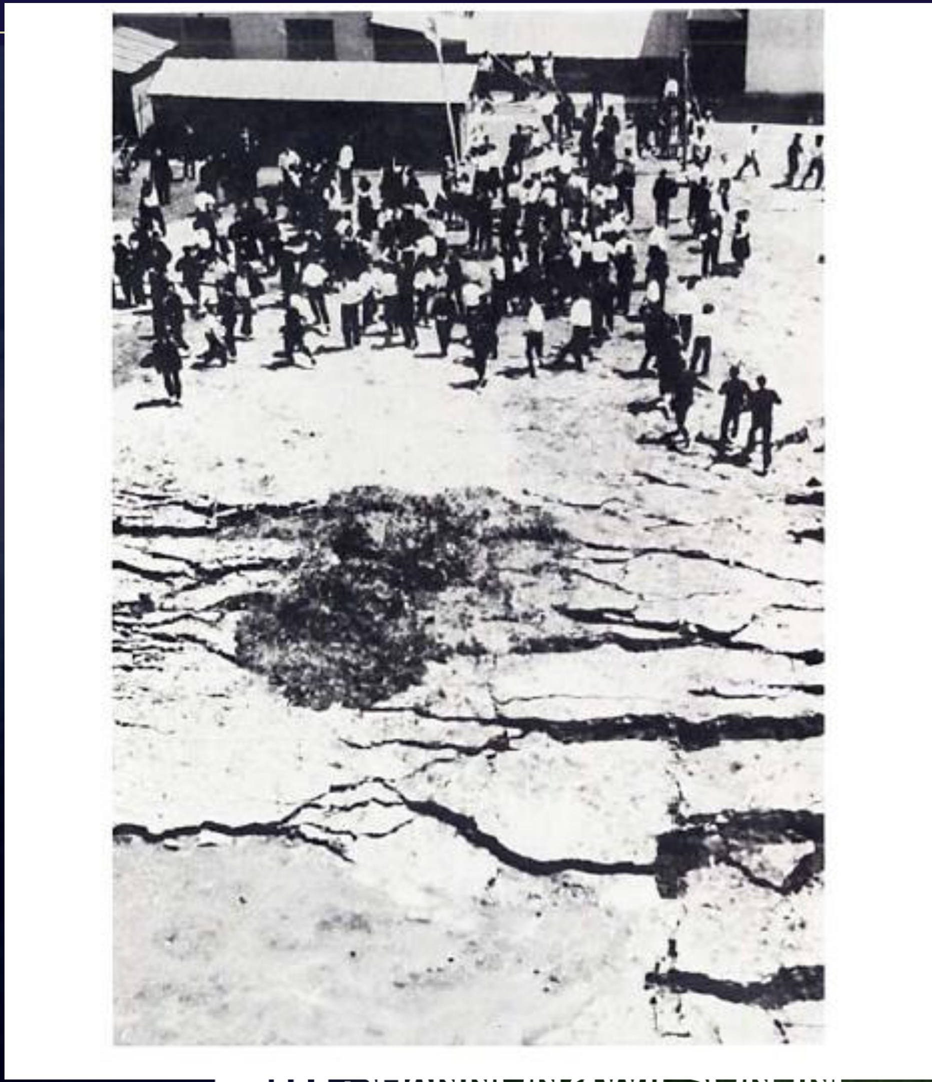
Liquefaction – Bearing Capacity Failure

Liquefaction – Sand Boil

www.telegraph.co.uk/news/picturegalleries/picturesoftheday/8351875/Pictures-of-the-day-28-February-2011.html?image=9

Liquefaction – Sand Boil

Initial Stage of Sand Boil



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Liquefaction – Differential Settlement

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Liquefaction – Differential Settlement

www.geerassociation.org/GEER_Post%20EQ%20Reports/Baja%20California_2010/Baja10_Ch05.html

Liquefaction – Lateral Spreading

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Liquefaction – Lateral Spreading

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www.geerassociation.org/GEER_Post%20EQ%20Reports/Baja%20California_2010/Baja10_Ch05.html

Liquefaction – Flotation

Liquefaction – Flotation

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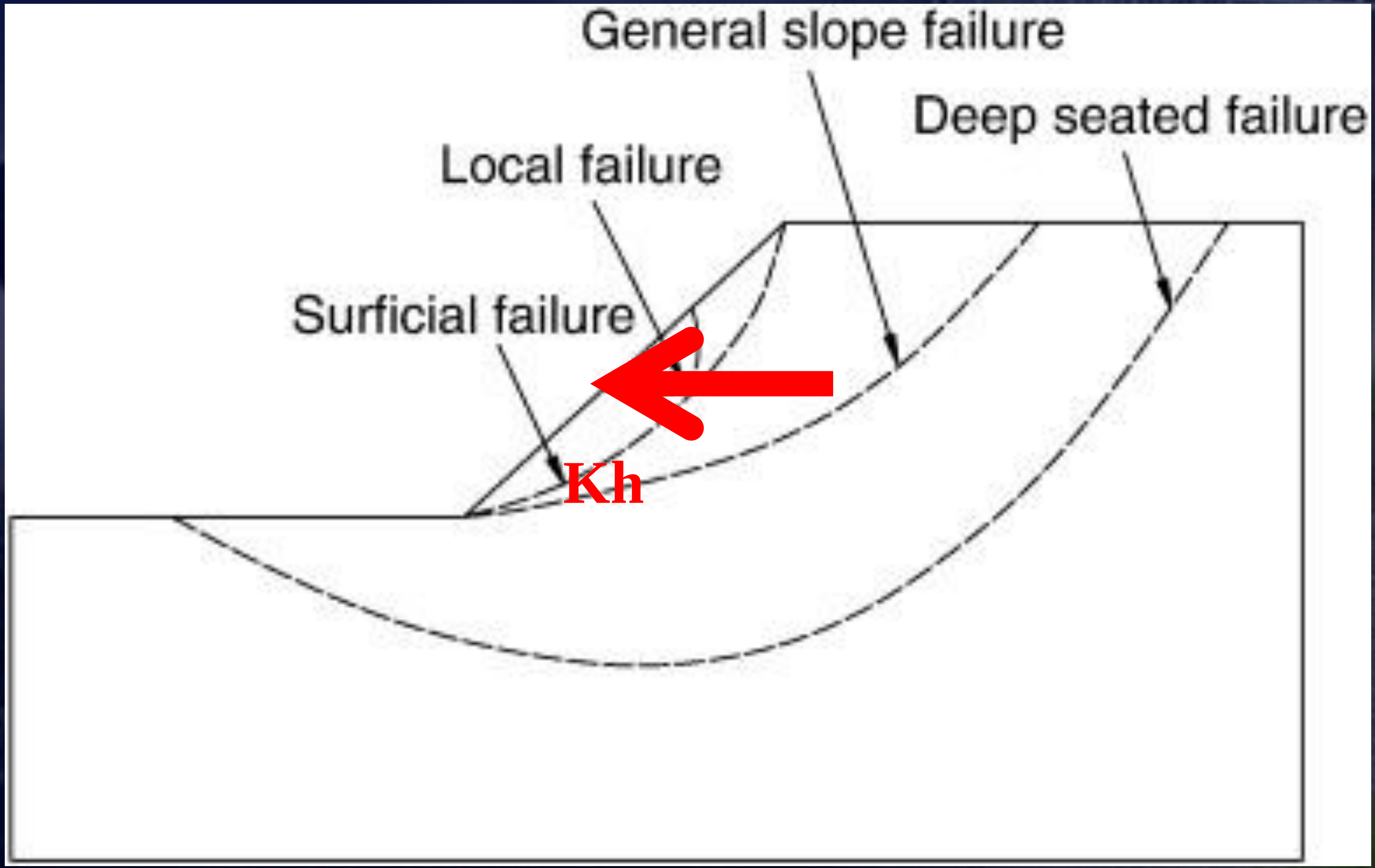
Liquefaction – Increased Lateral Pressure

- Also, liquefied soils will generate higher lateral pressures on the embedded walls.
- The liquefied soils can be treated as a heavy viscous fluid exerting a hydrostatic pressure on the wall. The viscous fluid has the total unit weight of the liquefied soil.
- If unsaturated soil is present above the liquefied soil, it is treated as a surcharge that increases the fluid pressure within the underlying liquid soil.
- May even consider Hydrodynamic effect.

Seismic Slope Stability



Seismic Slope Stability

Seismic Slope Stability

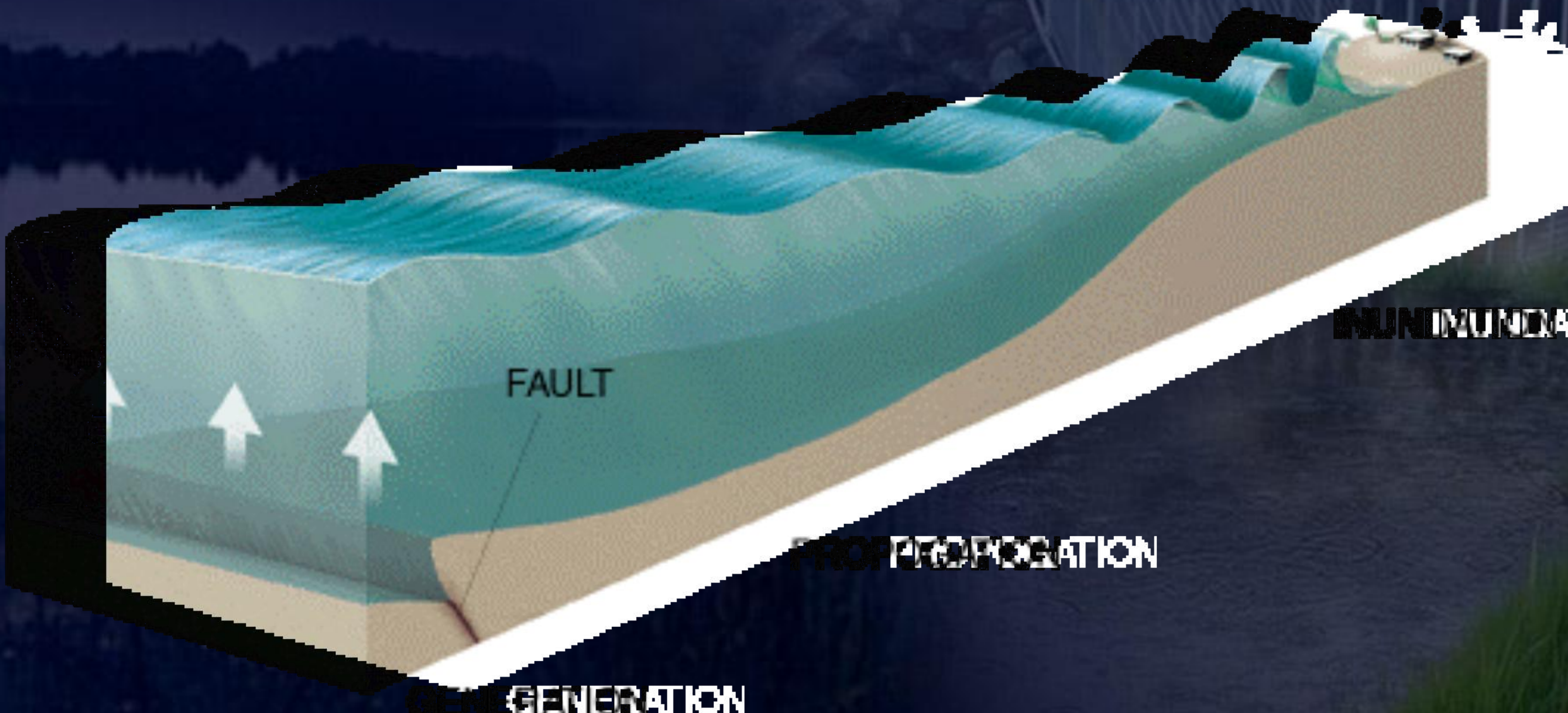
This landslide into Tacoma Narrows occurred 3 days after the 1949 earthquake and generated an 8 ft tsunami at Gig Harbor that reflected back and drowned all of these houses 3 ft deep

This landslide at Salmon Beach triggered by the Nisqually earthquake (2001) destroyed the houses that survived in 1949

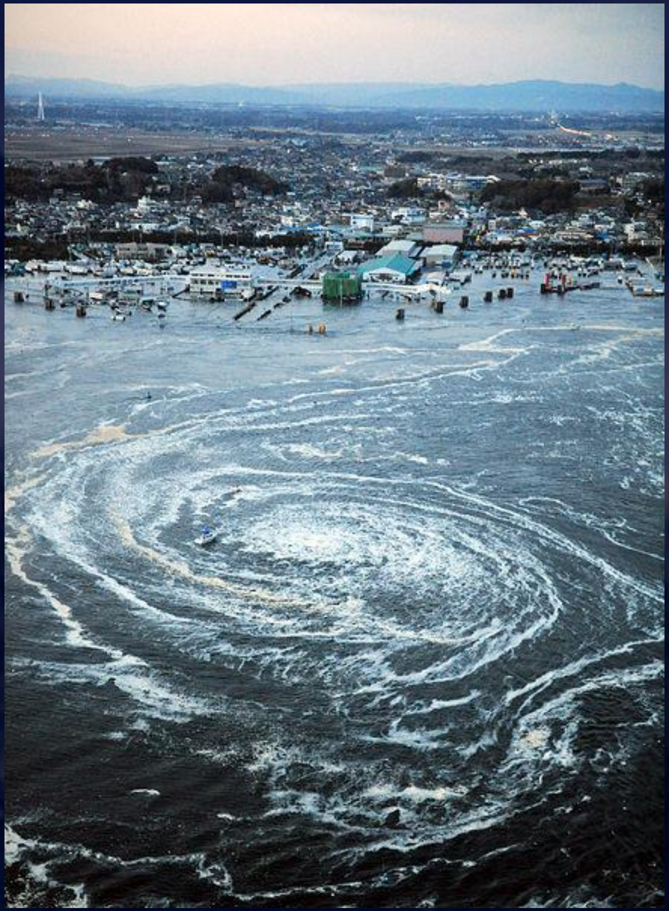
Washington Department of Natural Resources
Division of Geology and Earth Resources

Seismic Slope Stability

Tsunami



Tsunami Damage



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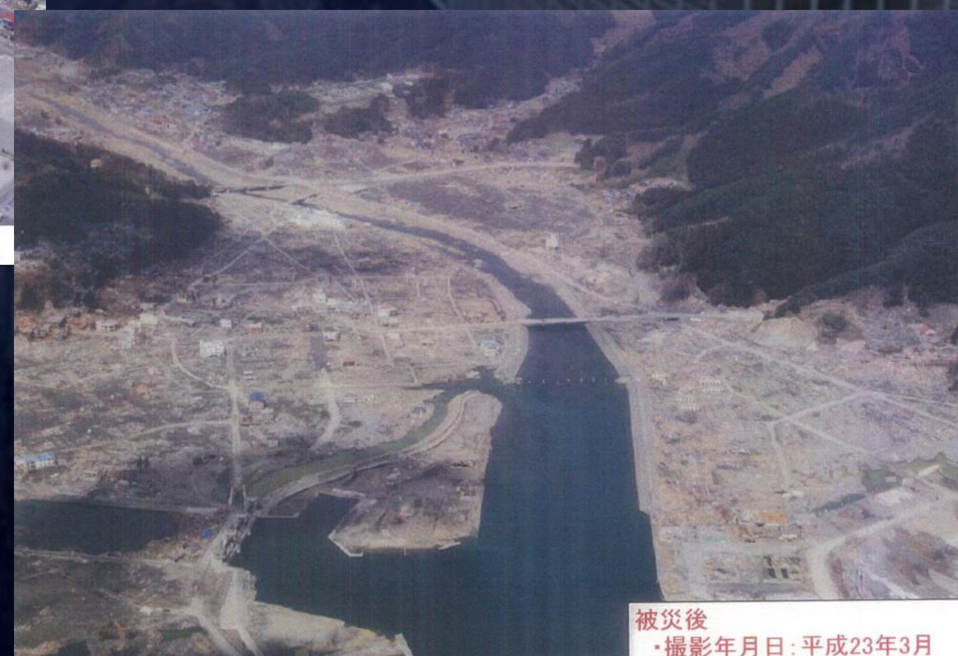
Tsunami Damage



Tsunami Damage

Floating Debris

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Questions?