

Liquefaction

Thomas L. Holzer, U.S. Geological Survey

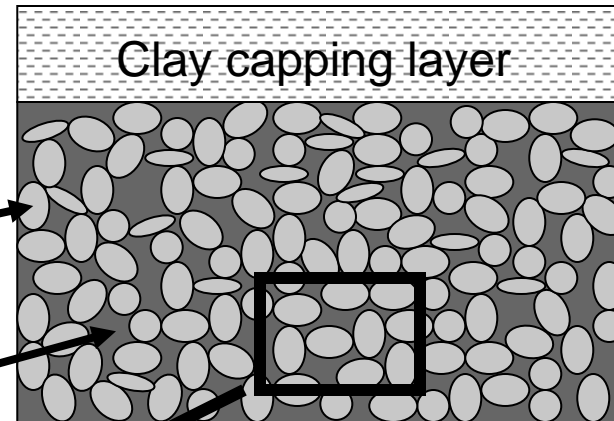
- **What is it?**
- **Effects**
- **Significance**
- **What can we do about it?**



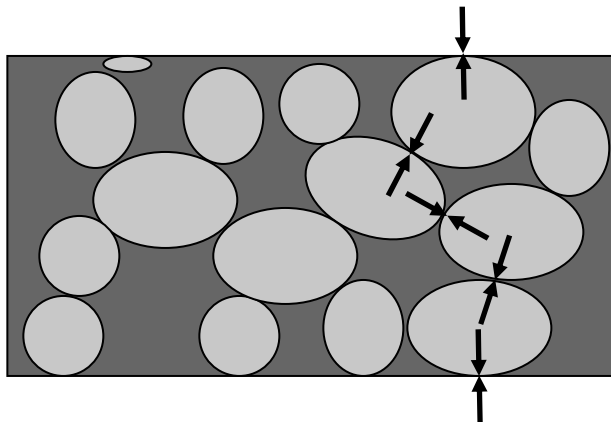
Liquefaction

Liquefaction is the transformation of sandy soil into a liquefied state. It is caused by pressure increases in the **pore water**.

Sand grain

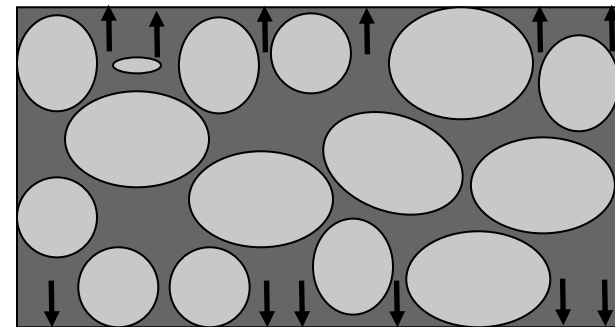


Before the earthquake



Weight of ground is supported by sand grains.

During the earthquake



Weight of ground is supported by pore water.

1989 Loma Prieta, California, Earthquake





1 Within a fill, sand grains rest loosely on each other, surrounded by water. The stage is set for the process known as liquefaction.

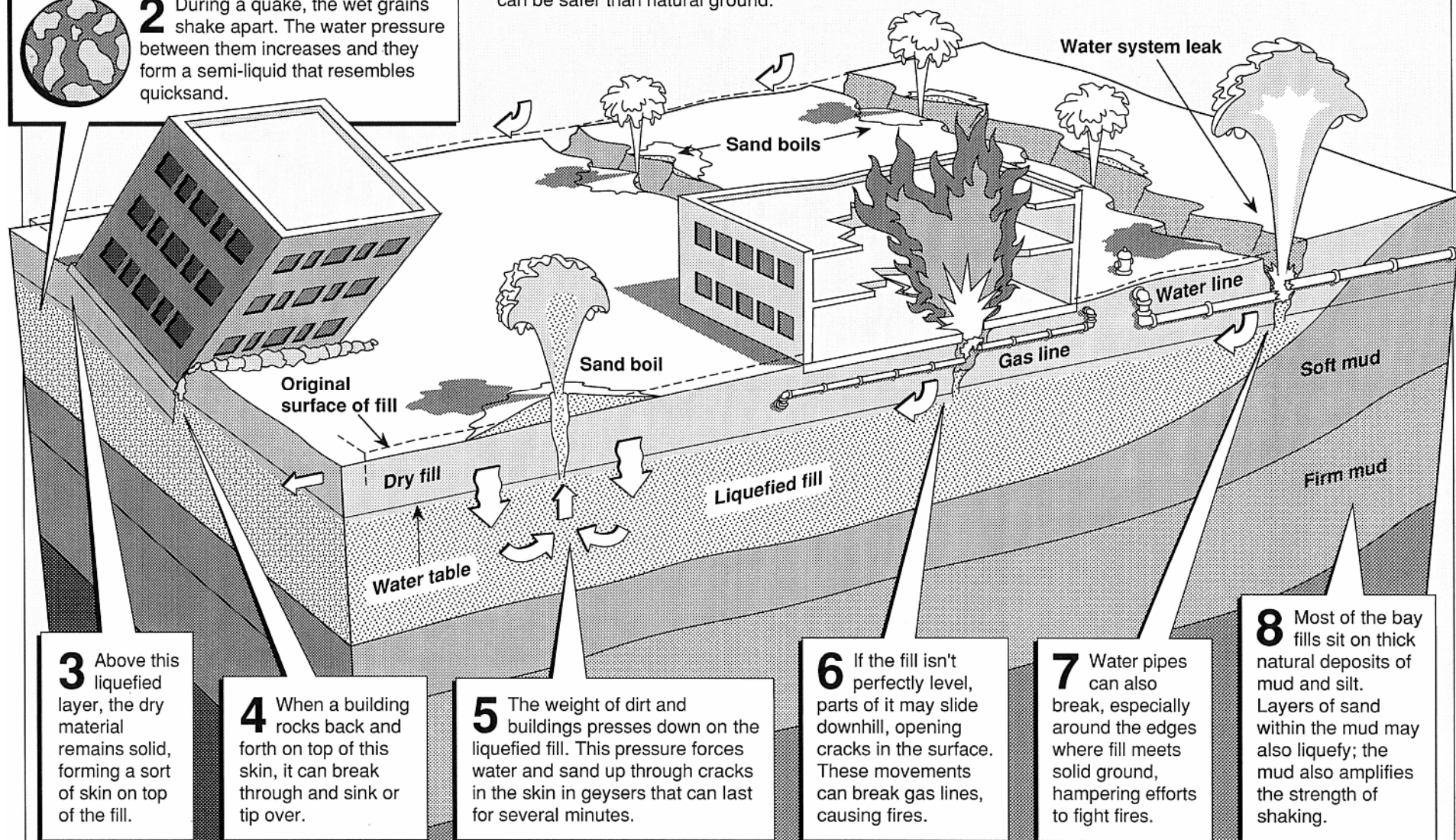


2 During a quake, the wet grains shake apart. The water pressure between them increases and they form a semi-liquid that resembles quicksand.

Anatomy of a bad fill

Not all fills are dangerous. In fact, engineers say a properly built fill can be safer than natural ground.

But many older fills contain the ingredients for disaster: loose, wet, sandy soil that can liquefy in a quake, on top of soft mud that amplifies shaking.



3 Above this liquefied layer, the dry material remains solid, forming a sort of skin on top of the fill.

4 When a building rocks back and forth on top of this skin, it can break through and sink or tip over.

5 The weight of dirt and buildings presses down on the liquefied fill. This pressure forces water and sand up through cracks in the skin in geysers that can last for several minutes.

6 If the fill isn't perfectly level, parts of it may slide downhill, opening cracks in the surface. These movements can break gas lines, causing fires.

7 Water pipes can also break, especially around the edges where fill meets solid ground, hampering efforts to fight fires.

8 Most of the bay fills sit on thick natural deposits of mud and silt. Layers of sand within the mud may also liquefy; the mud also amplifies the strength of shaking.

Sources: Tom Holzer, U.S. Geological Survey; Kent Dedrick, State Lands Commission; UC-Berkeley; Gerald Dow, "Bay Fill in San Francisco: A History of Change," and staff reports.



1906
San Francisco
Earthquake

Liquefaction
↓
Pipeline damage
↓
Fire



Lateral Spreading

Broken Water & Gas Pipelines
1994 Northridge Earthquake
Balboa Boulevard, Granada Hills



Destroyed Buildings
1989 Loma Prieta Earthquake
Moss Landing Marine Laboratory

Sinking Buildings



1964 Niigata, Japan

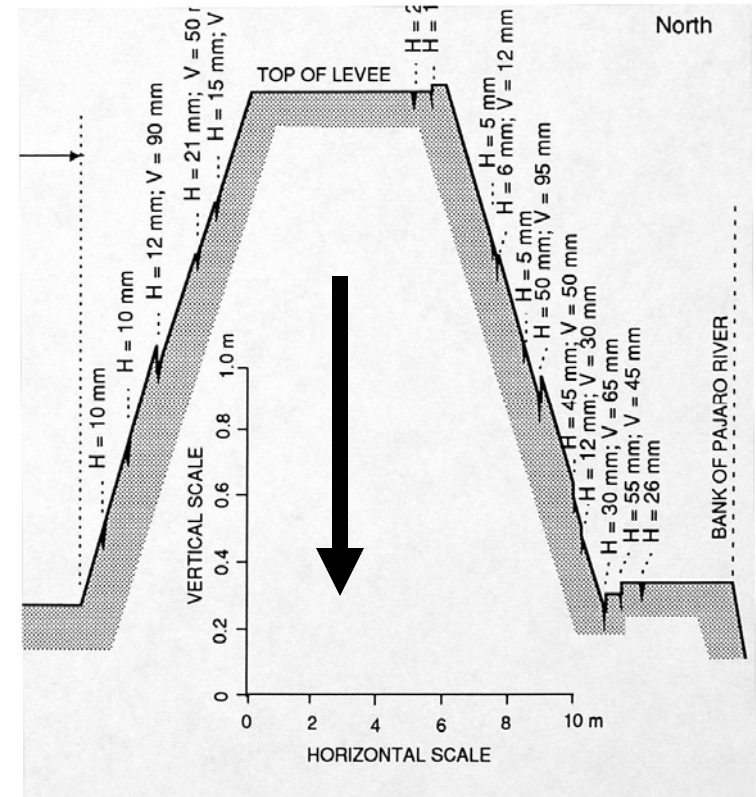


1999 Kocaeli EQ, Adapazari, Turkey

Levee Cracking and Failure



**Cracked levee
Monterey Bay region
1989 Loma Prieta Earthquake**





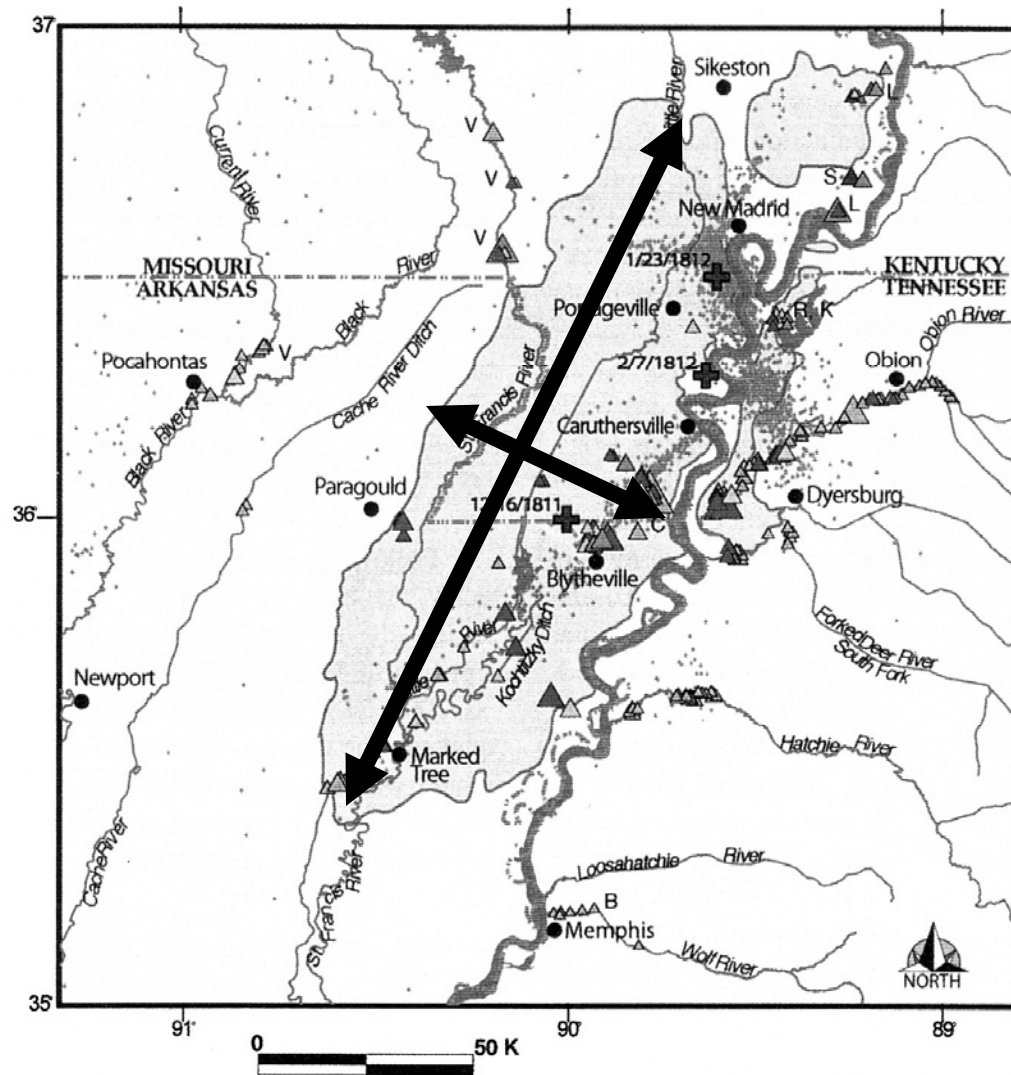
Losses (in % of total loss) by Hazard 1989 Loma Prieta Earthquake

<u>Earthquake Hazard</u>	<u>%</u>
Shaking	
Normal	28
Enhanced	70
Liquefaction	2
Fault rupture	0
Total	100

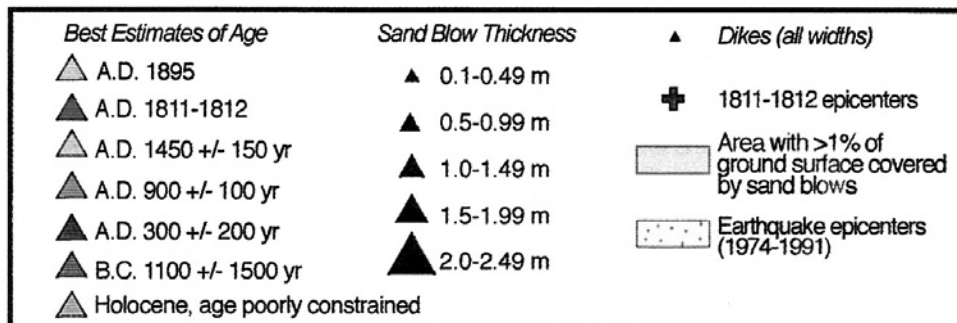


Damaged Levee

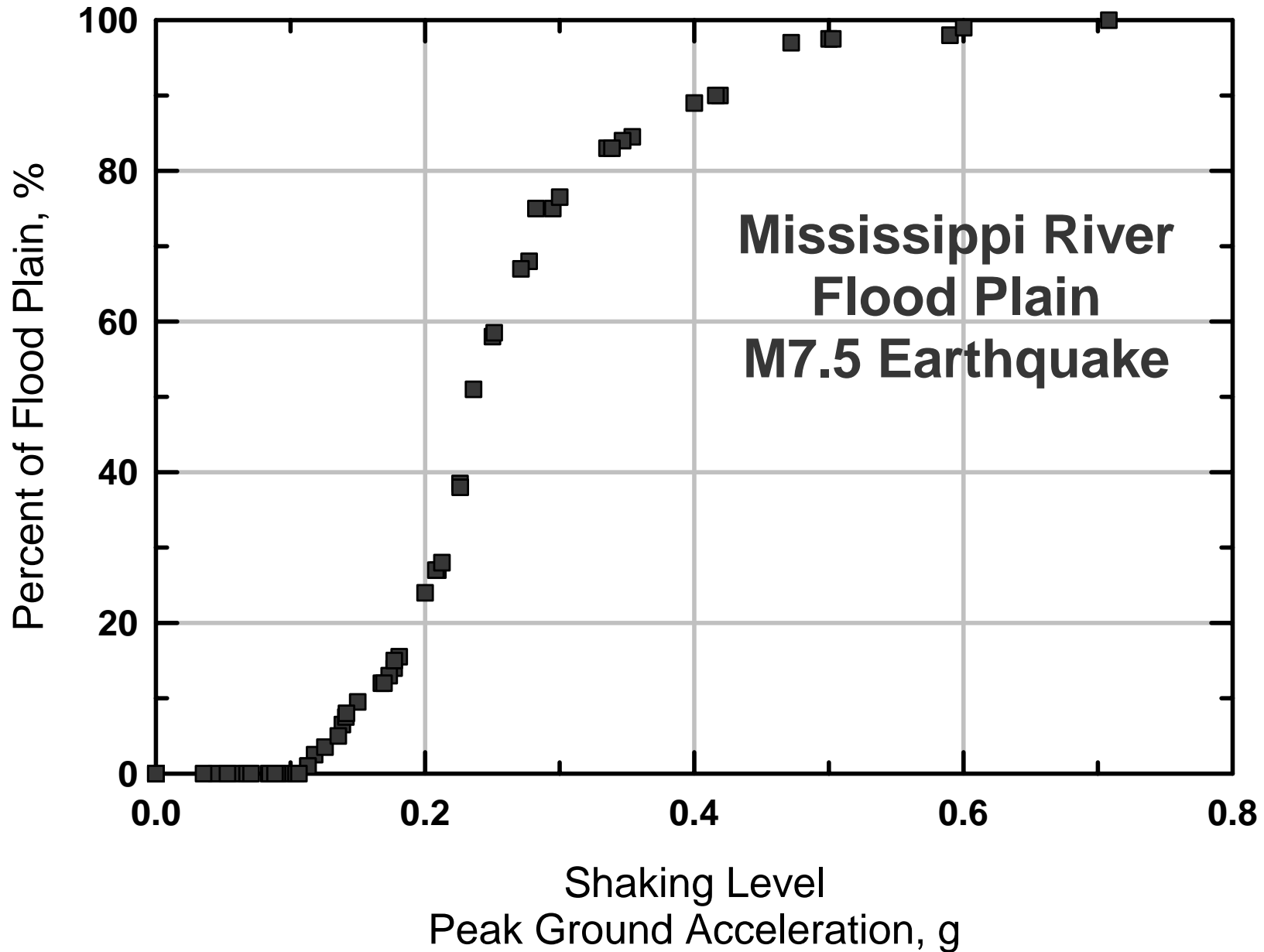
Total Dollar Loss (2005 dollars) = \$10 - \$16B



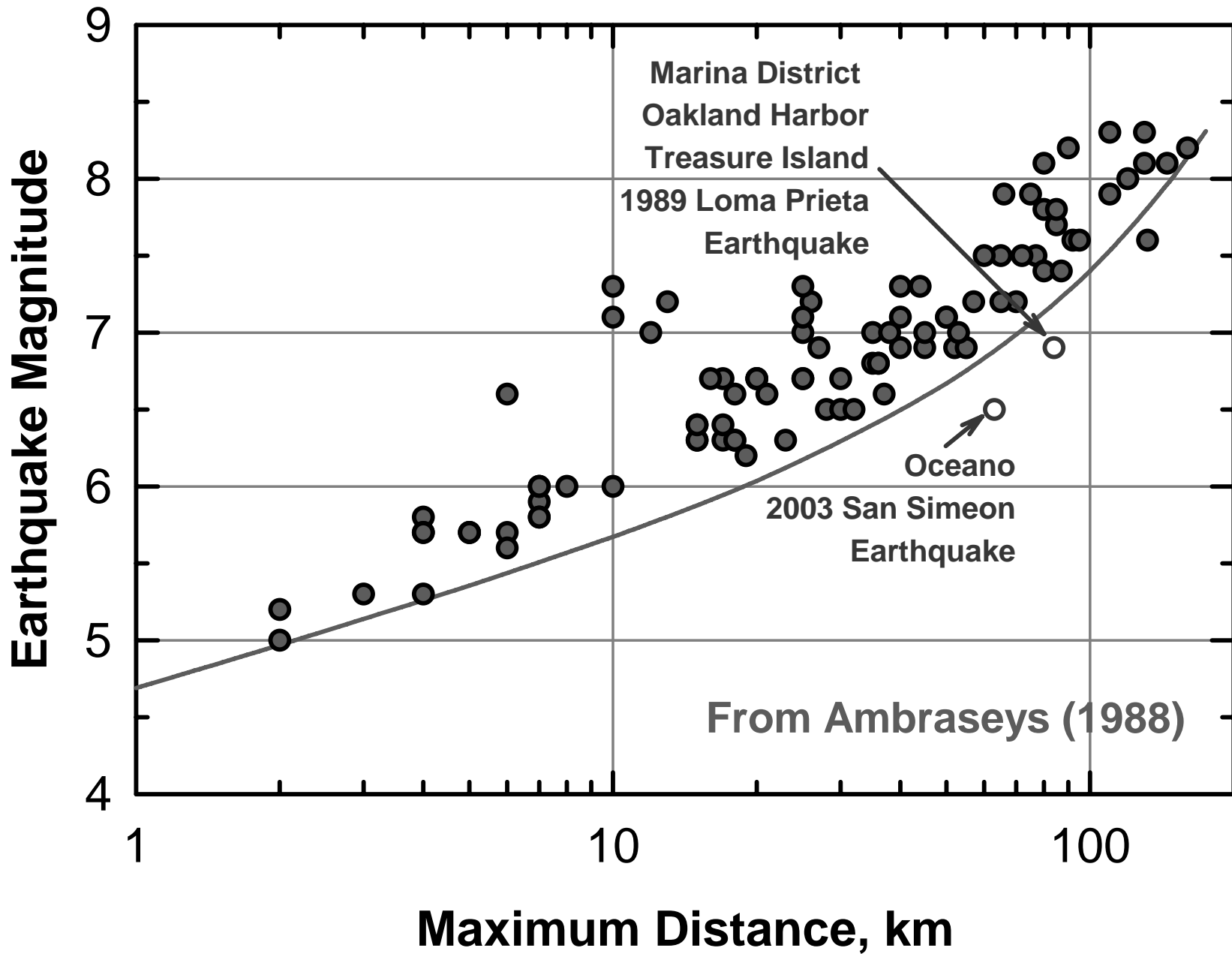
~6000 mi²
Sand Blow
Area
1811/1812
New Madrid
Earthquakes



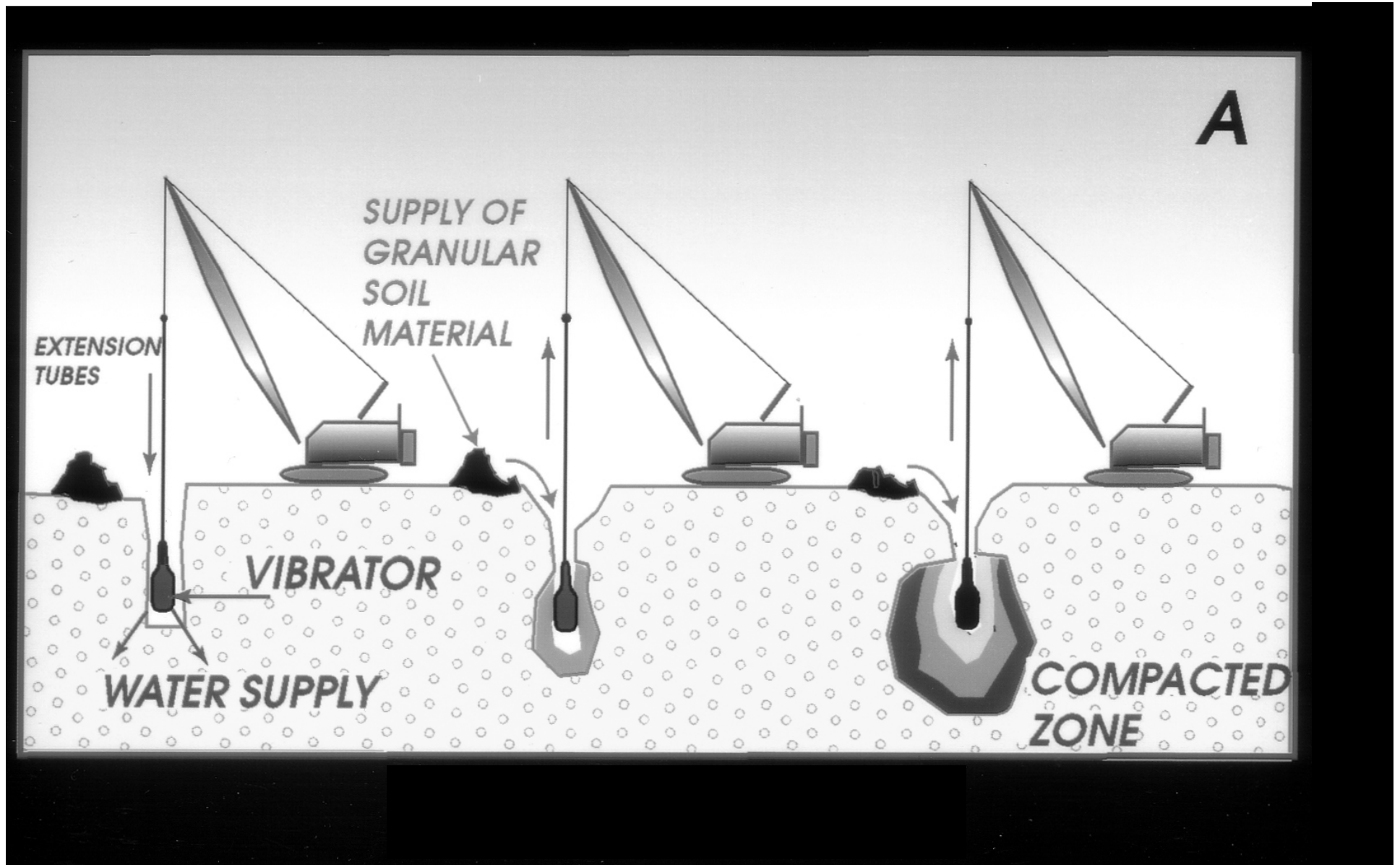
Predicted Size of Liquefaction Area



Maximum Distance from EQ to Liquefaction

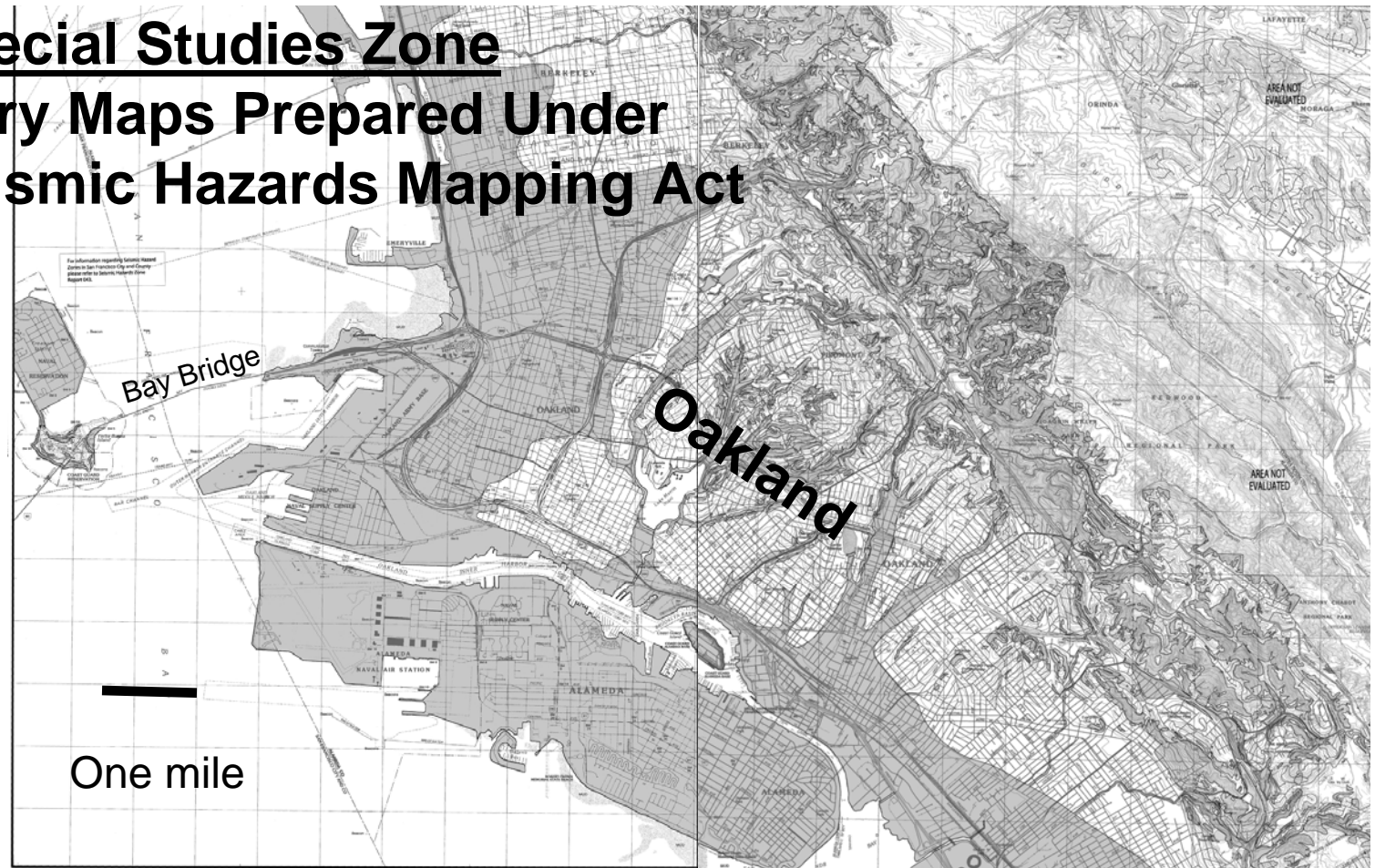


Soil Improvement



Special Studies Zone

Regulatory Maps Prepared Under 1990 CA Seismic Hazards Mapping Act

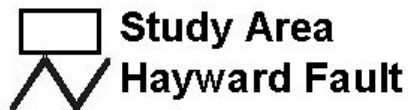


 Liquefaction zone

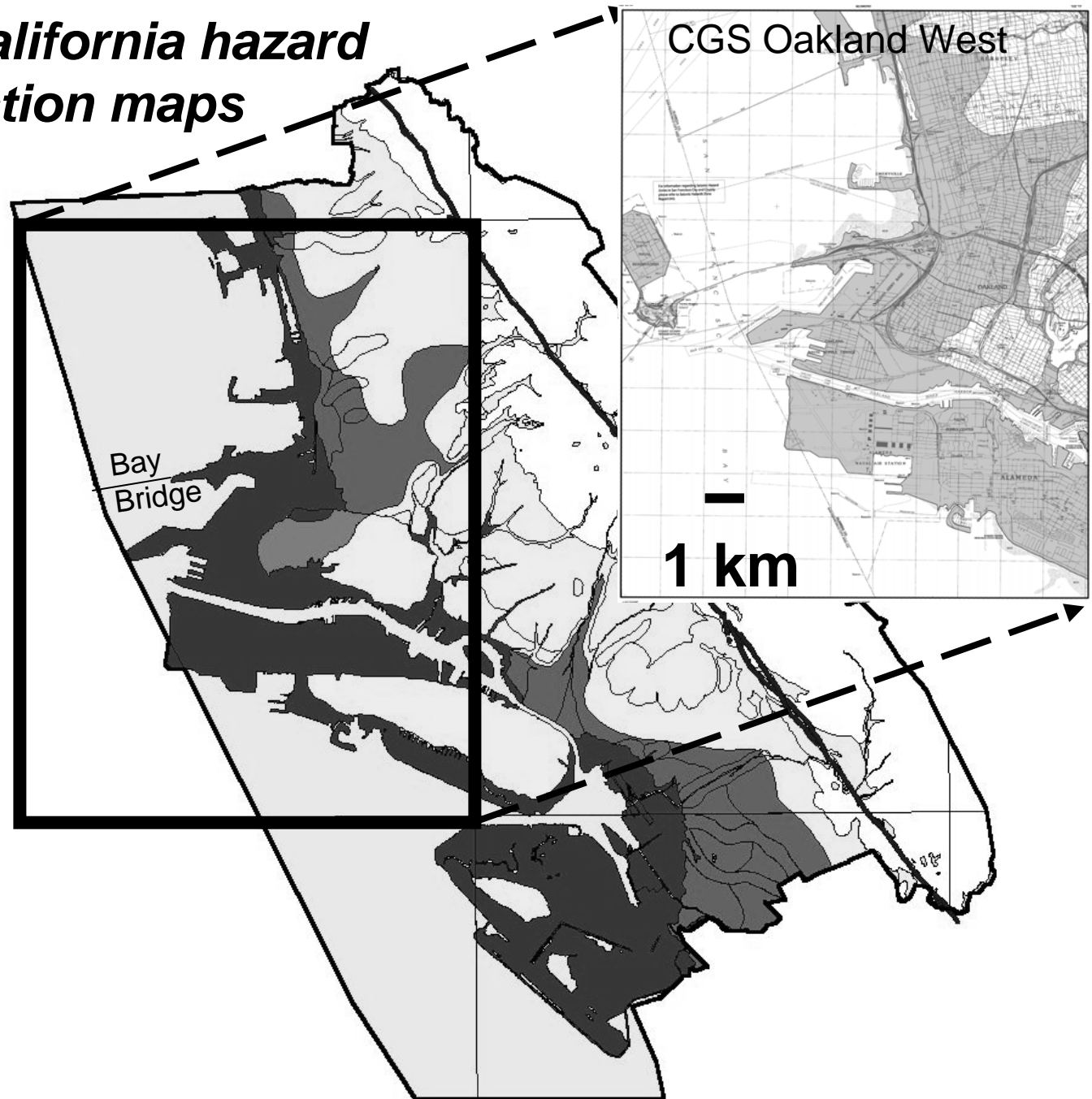
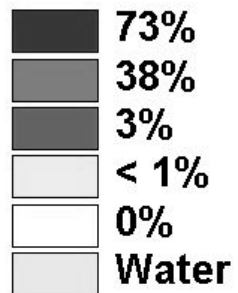
 Landslide zone



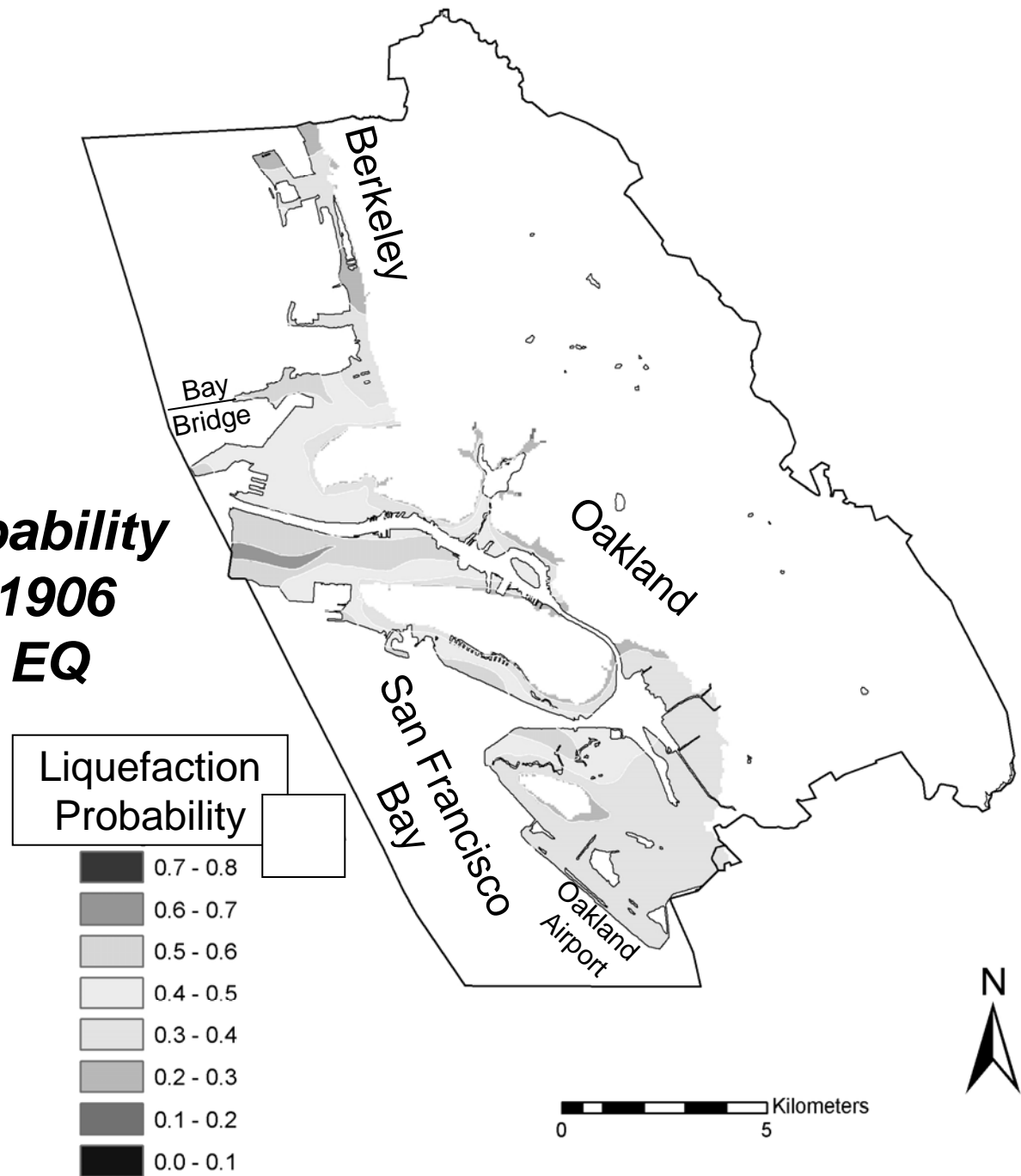
Comparison of California hazard zone and liquefaction maps for M7.1 EQ



Percent of area predicted to liquefy for M=7.1

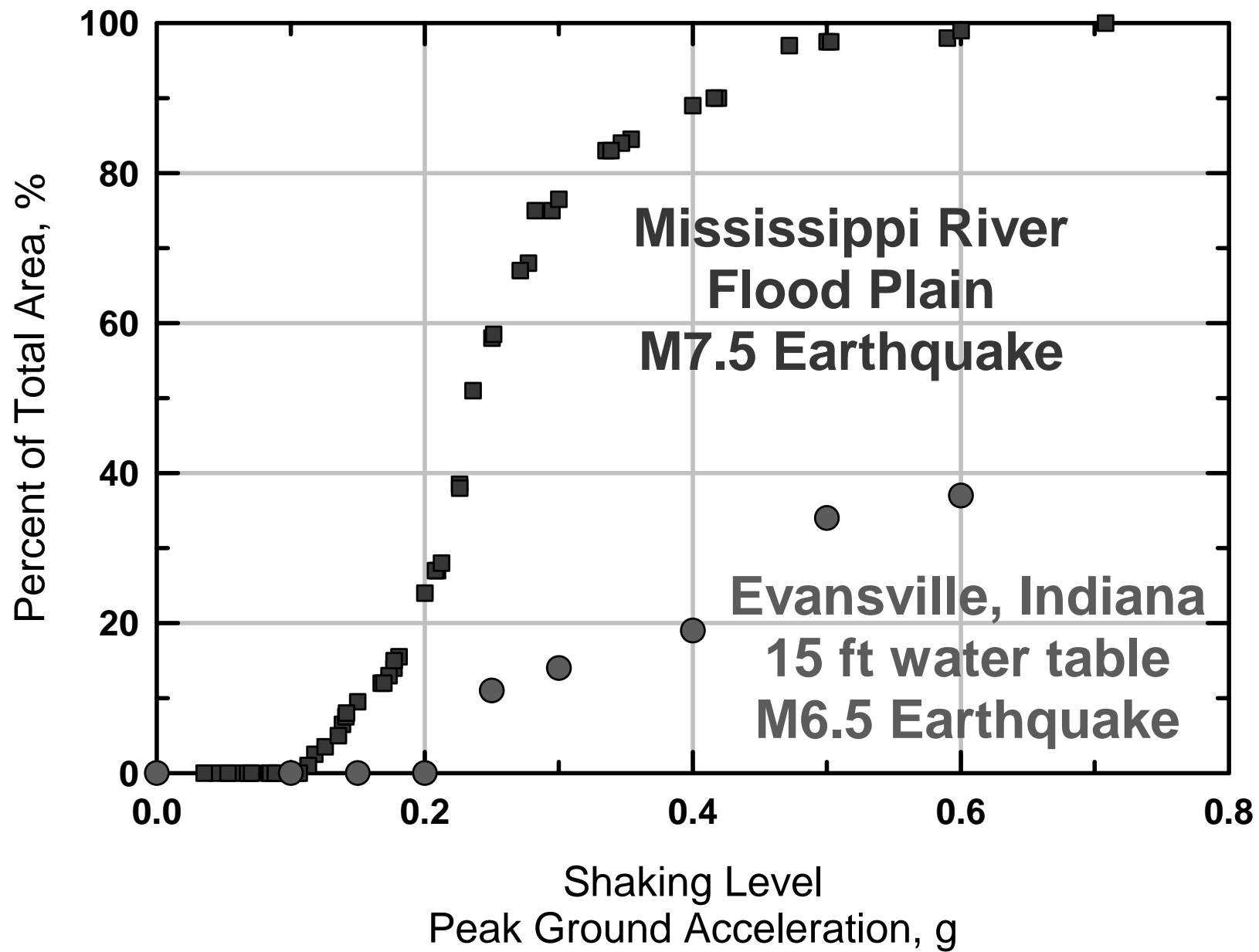


***Liquefaction Probability
for a Repeat of 1906
San Francisco EQ***



Liquefaction Summary

- **Typical damage**
 - **Buried pipelines**
 - **Bridges**
 - **River levees**
 - **Port facilities**
- **Losses are <10% of total loss**
- **Areas can be mapped**



Liquefaction Susceptibility Geologic Units

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by Age of Deposit)			
		<500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-pleistocene (6)

(a) Continental Deposits

River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	—	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low

(b) Coastal Zone

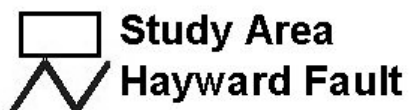
Delta	Widespread	Very high	High	Low	Very low
Estuarine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low

(c) Artificial

Uncompacted fill	Variable	Very high	—	—	—
Compacted fill	Variable	Low	—	—	—

Youd, T.L., and Perkins, D.M., 1978, Jour. Geo. Eng'g., 104(4), p. 433-446.

Liquefaction Map for M7.1



Percent of area predicted
to liquefy for M=7.1

