Michael Passow's
Teacher's Seminar
Lamont-Doherty Earth Observatory
Wed August 11, 2004

Klaus Jacob
Lamont-Doherty Earth Observatory of Columbia University

Earthquakes in the Eastern US - Is New York at Risk, and What can we do About it ?

Sources:
Lamont Cooperative Seismic Network - LCSN :
http://www.ldeo.columbia.edu/LCSN/
NYC-Area Consortium for Earthquake-Loss Estimation - NYCEM :
http://nycem.org/default.asp
Media : New York Magazine - Lead article of Dec. 11, 1995 Issue.

From Seismology to Disaster Risk Management

Earth **Science** / Seismology

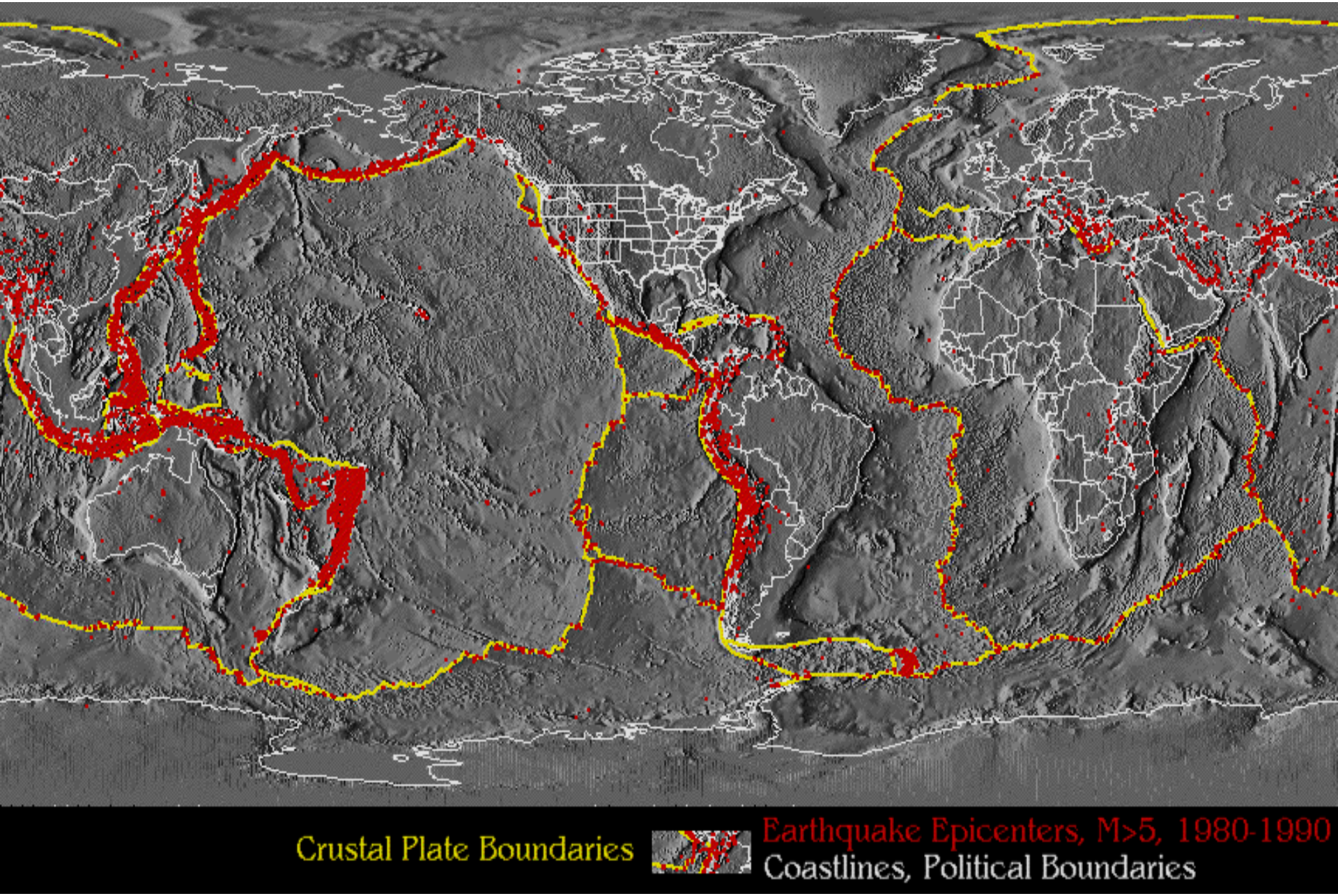
Seismic **Hazard** Assessment

Seismic **Risk** Assessment

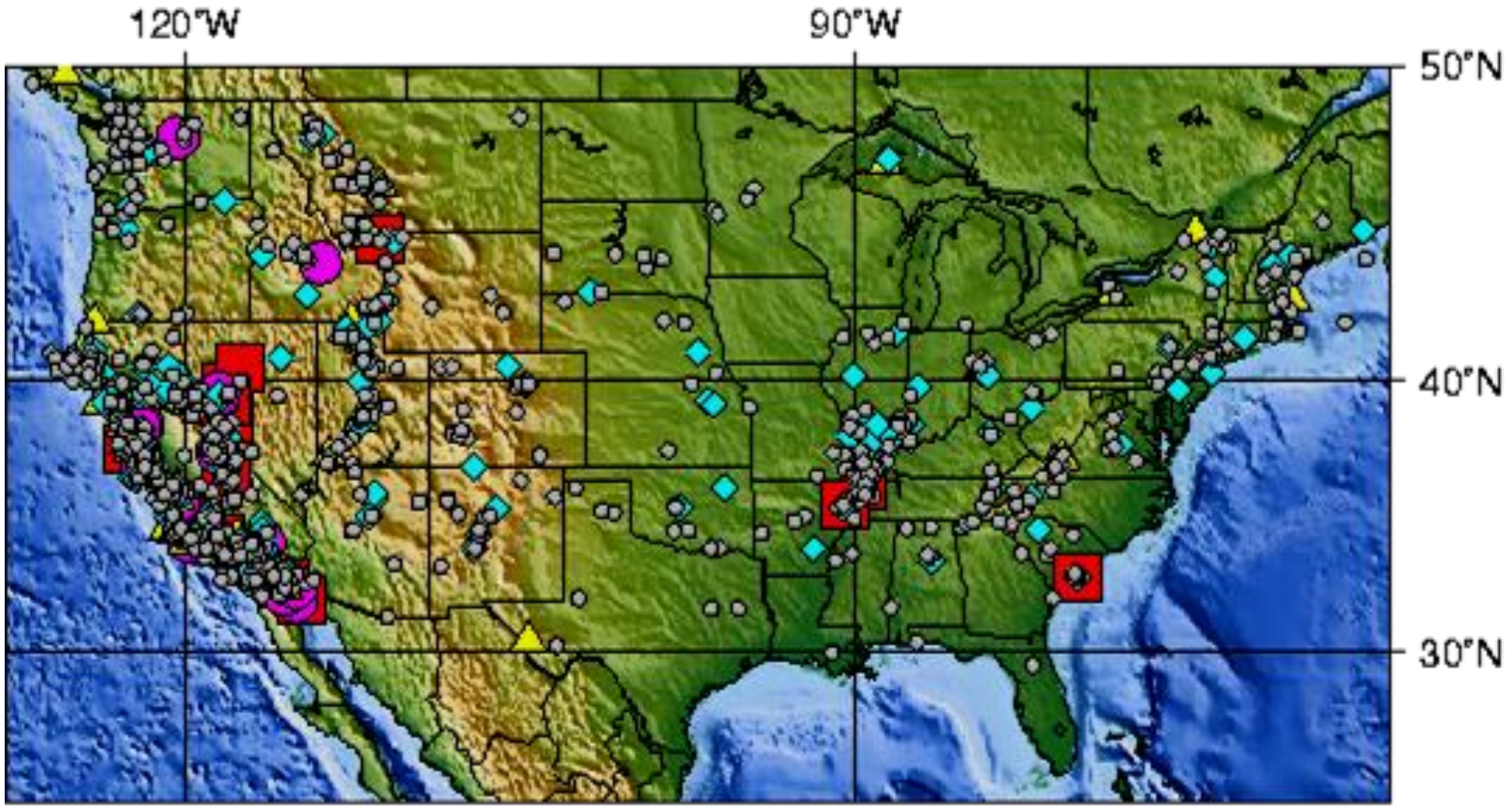
Hazard, Assets, Fragility, Risk

Disaster Risk **Management** :

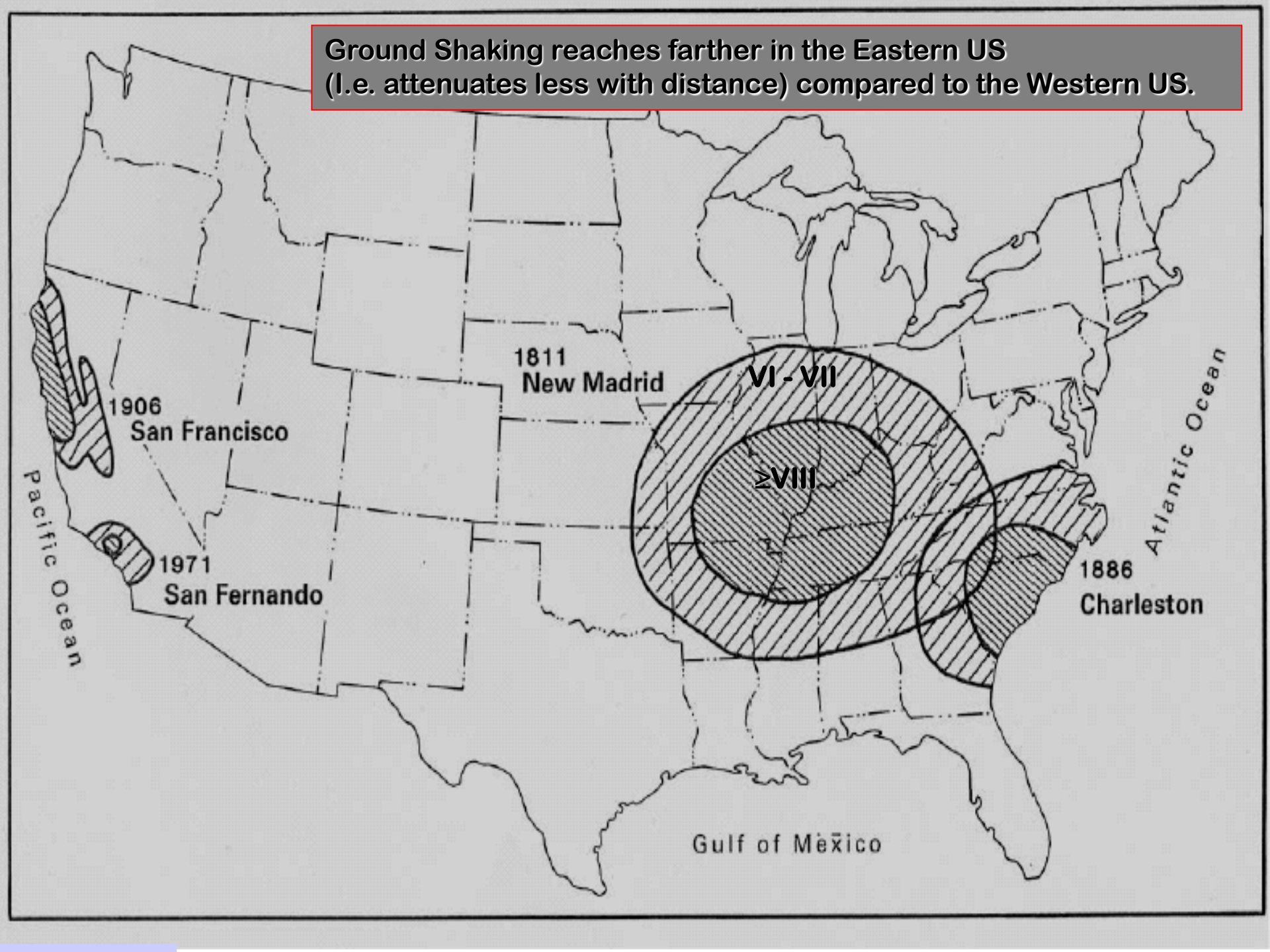
Building Codes,
Zoning,
Disaster Emergency Preparedness


Crustal Plate Boundaries
Earthquake Epicenters, M>5, 1980-1990
Coastlines, Political Boundaries

Damaging US Earthquakes 1750 - 1996 with Modified Mercalli Intensities VI - XII



Intensity
VI
VII
VIII
IX
X-XII

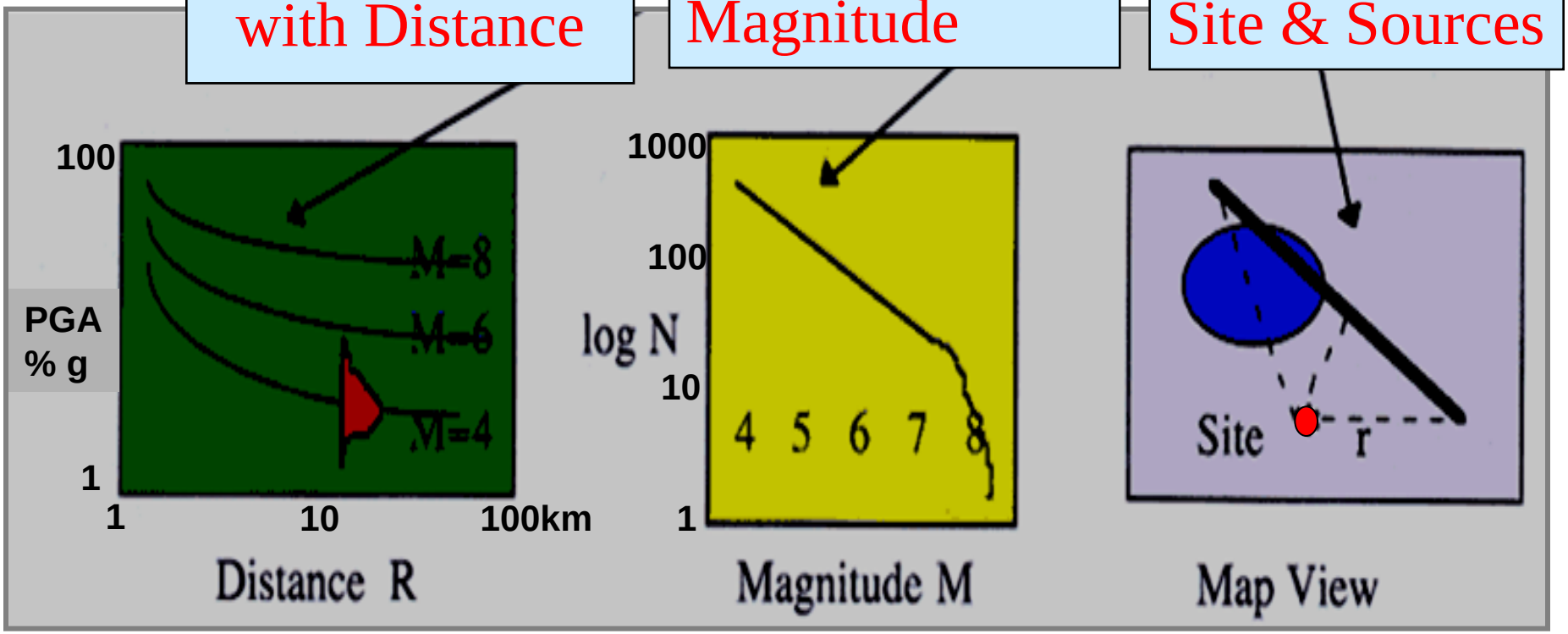

Ground Shaking reaches farther in the Eastern US
(I.e. attenuates less with distance) compared to the Western US.
1811
New Madrid
VI - VII
≥VIII
1906
San Francisco
1971
San Fernando
1886
Charleston
Pacific Ocean
Atlantic Ocean
Gulf of Mexico

The 3 Basic Elements of Probabilistic Seismic Hazard Assessment:

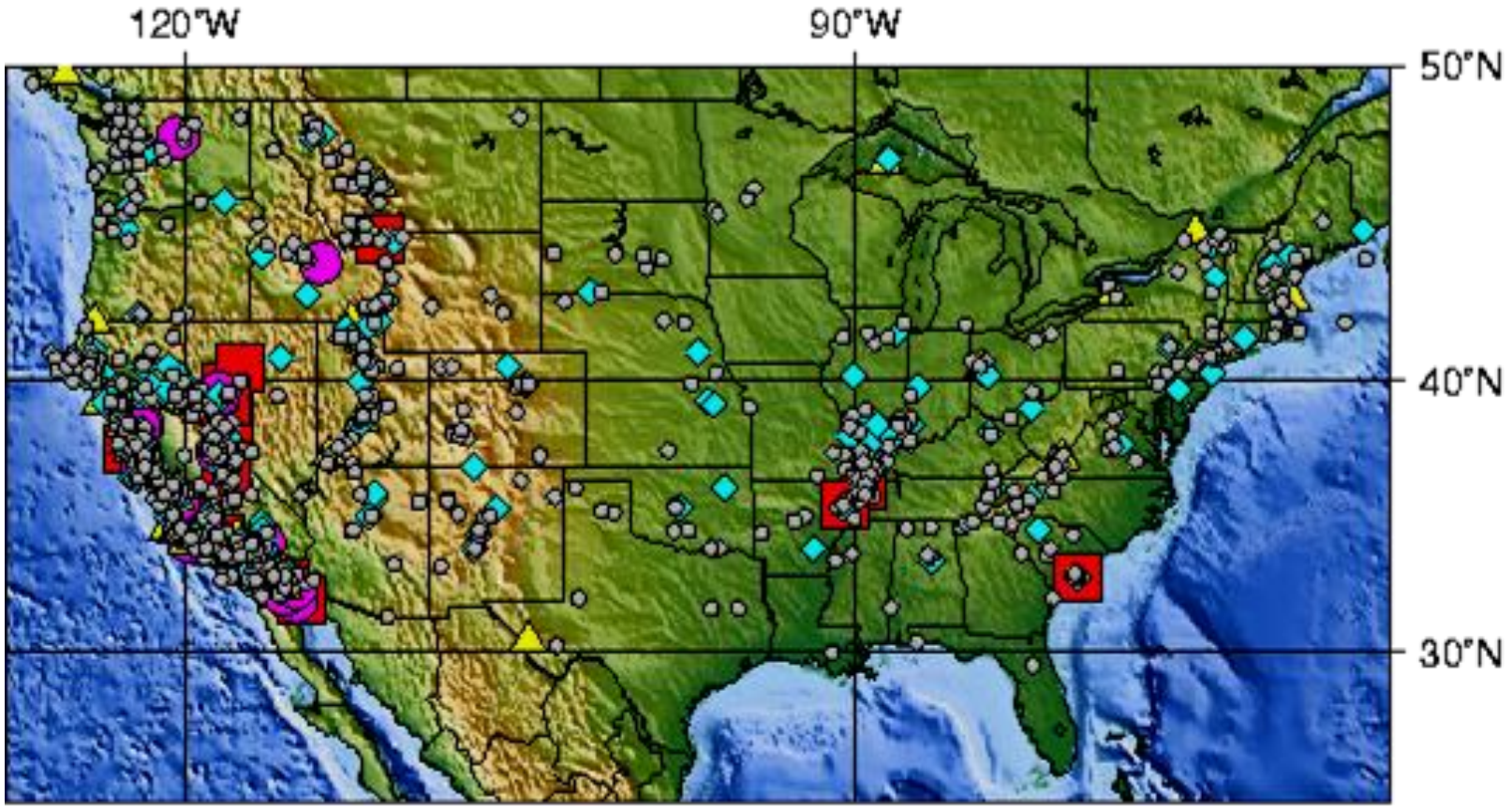
Attenuation of Groundmotion with Distance

Number of Earthquakes vs. Magnitude

Distances between Site & Sources



Damaging US Earthquakes 1750 - 1996 with Modified Mercalli Intensities VI - XII



Intensity
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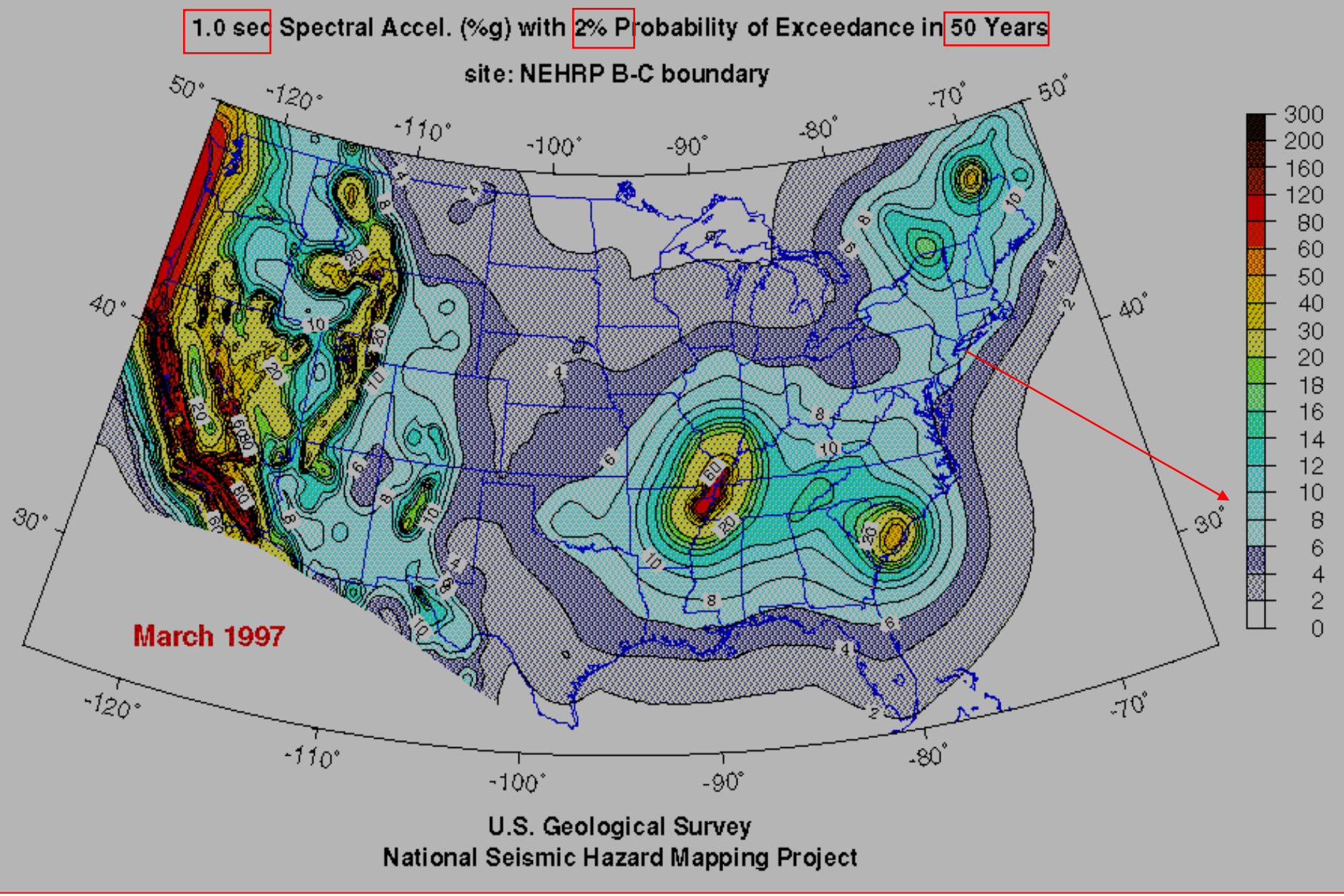

1.0 sec Spectral Accel. (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
March 1997
U.S. Geological Survey
National Seismic Hazard Mapping Project
300
200
160
120
80
60
50
40
30
20
18
16
14
12
10
8
6
4
2
0

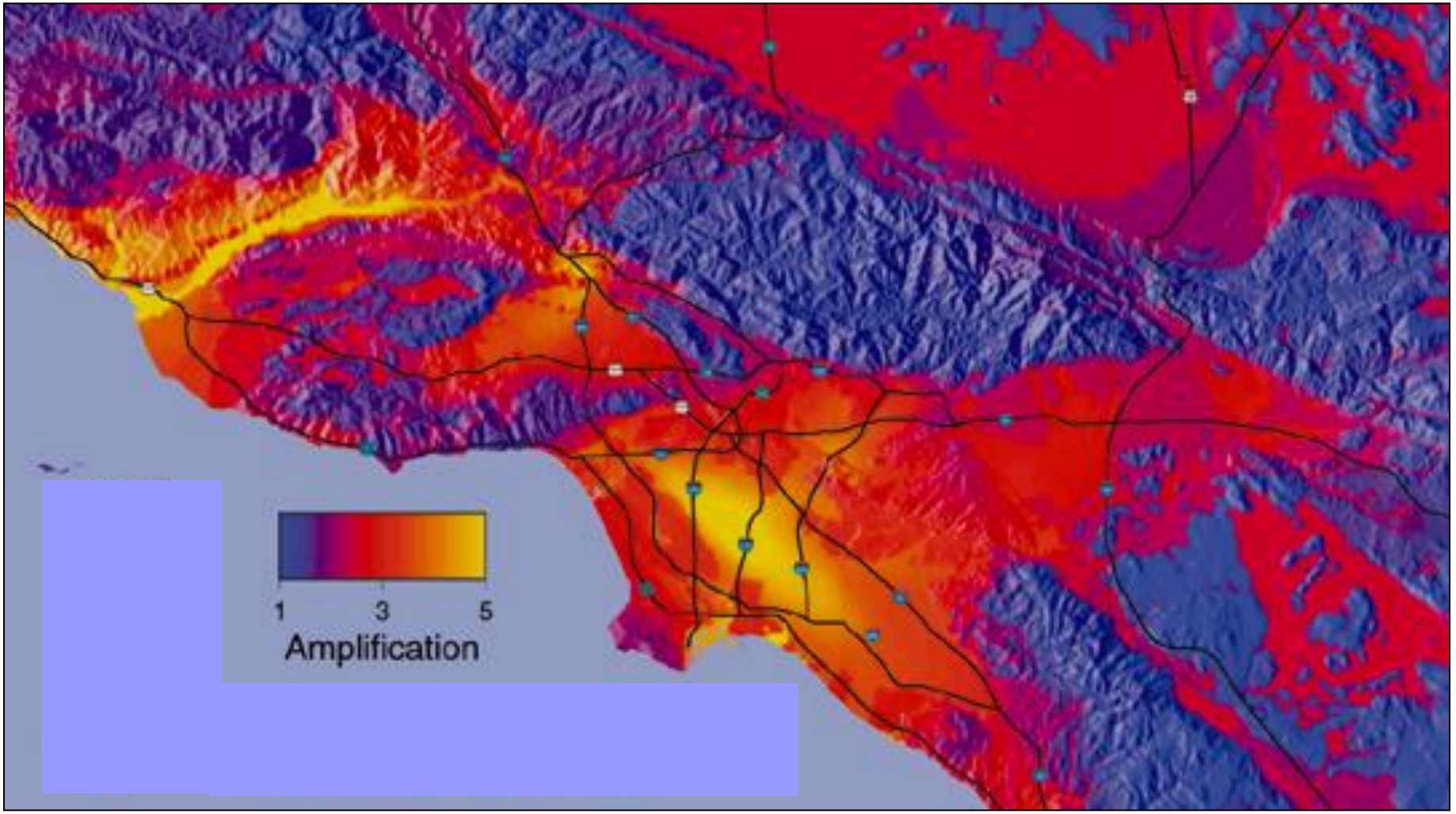
Site Response:

…. is the local modification of ground shaking due to near-surface soil and subsurface rock- basement configurations.

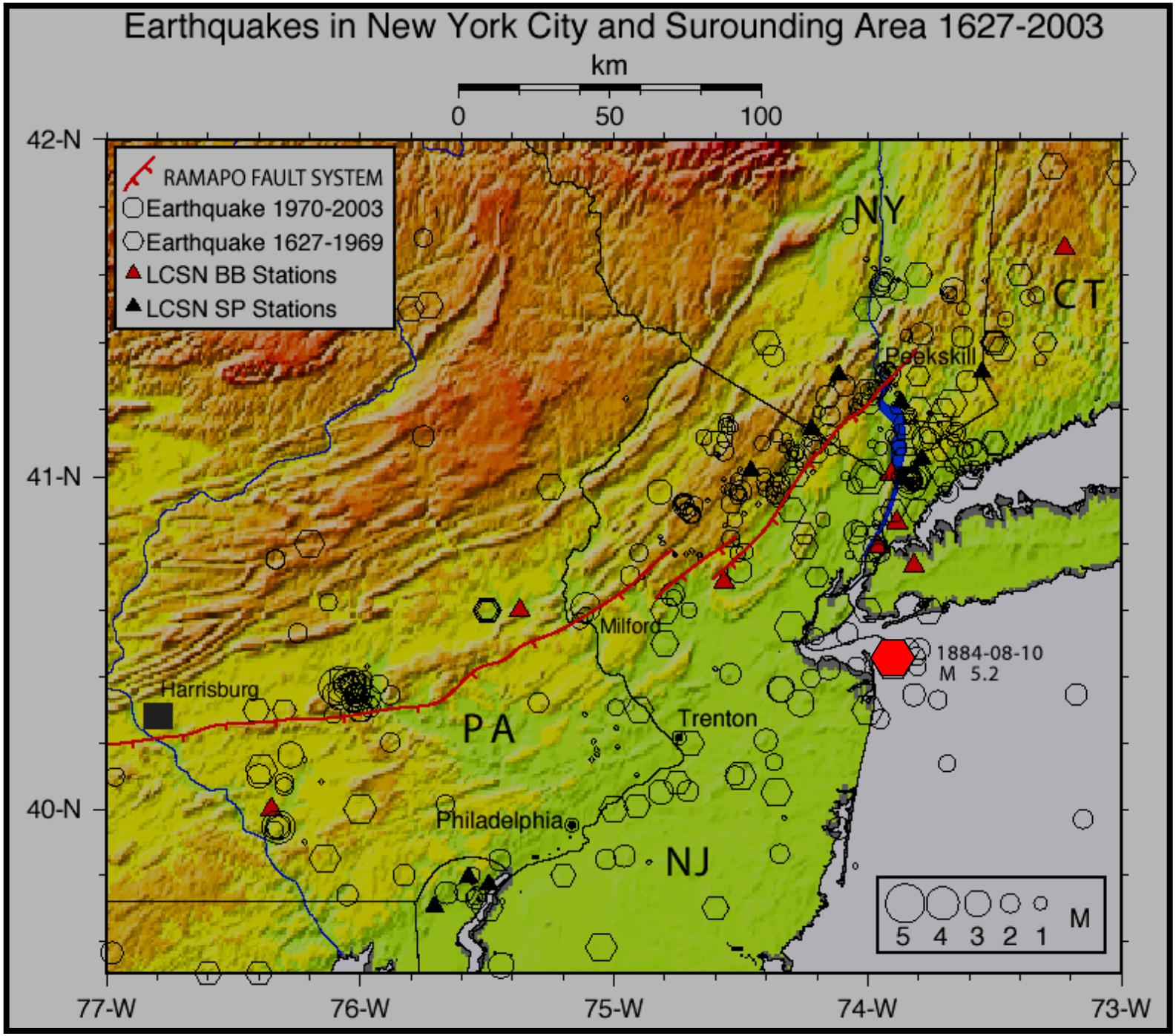
Deep soft soils typically amplify long-period motions (periods of 1 second and more) and diminish (attenuate) high-frequency motions (several Hz range).

This phenomenon is very important for the effects of shaking of tall buildings on deep soft soils.

Examples: Mexico City, Leninakan, Caracas, SF Marina => in NYC : Battery Park City)



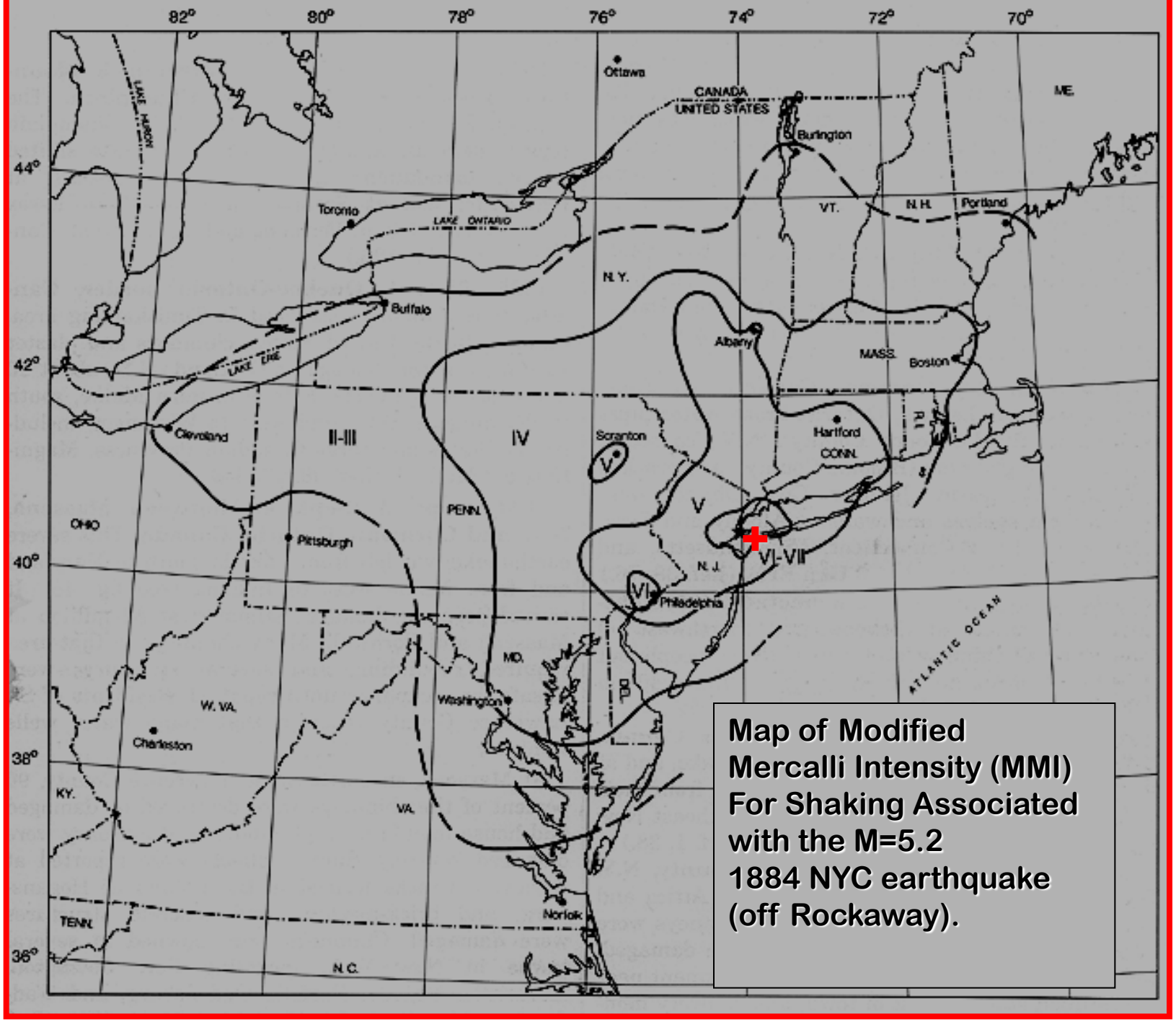
Source: E. Field, USGS & SCEC


Earthquakes in New York City and Surounding Area 1627-2003
km
0
50
100
RAMAPO FAULT SYSTEM
Earthquake 1970-2003
Earthquake 1627-1969
LCSN BB Stations
LCSN SP Stations
NY
CT
Peekskill
Milford
1884-08-10
M 5.2
Harrisburg
PA
Trenton
Philadelphia
NJ
M
5 4 3 2 1
42-N
41-N
40-N
77-W
76-W
75-W
74-W
73-W

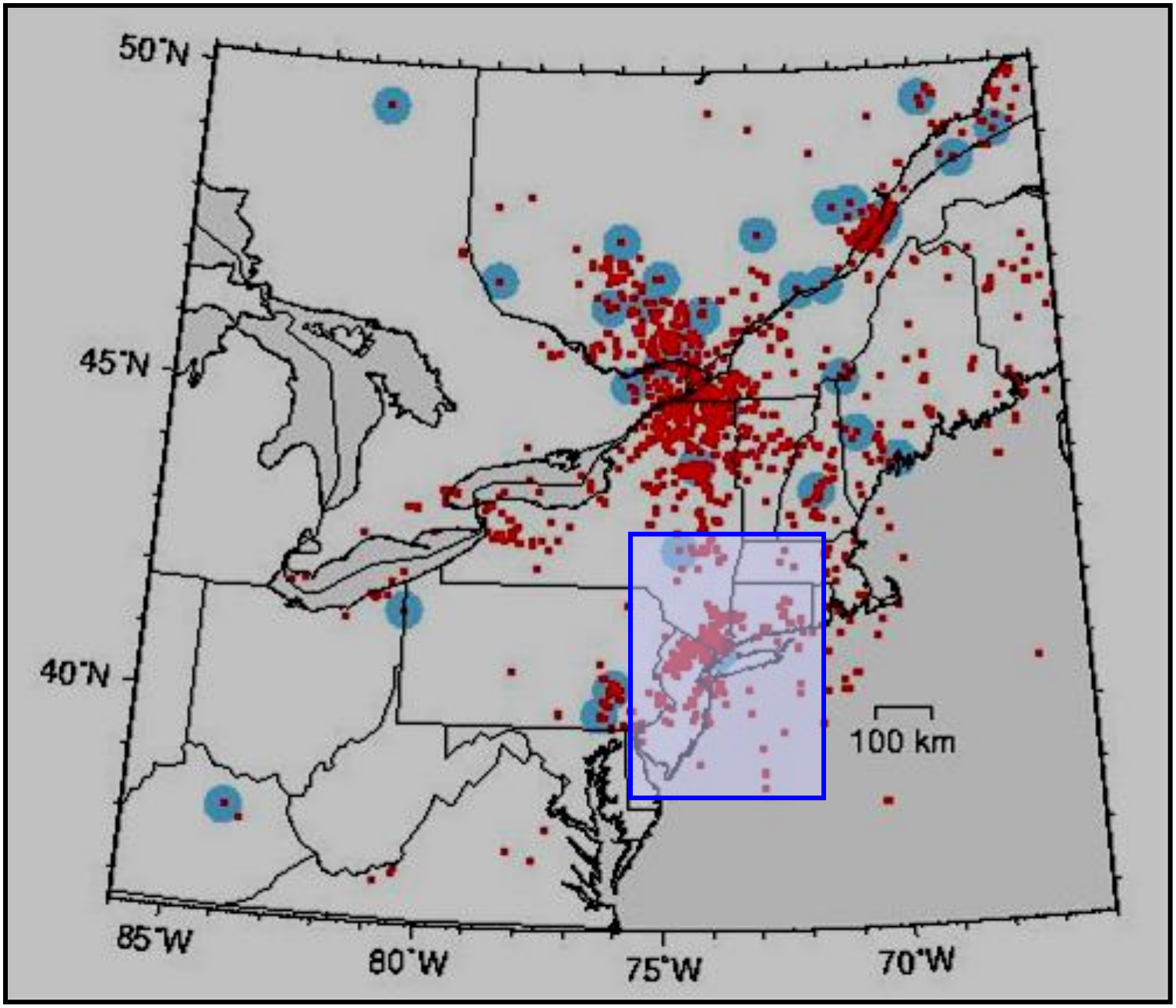
EXAMPLES OF STRONGLY FELT EARTHQUAKES NEAR NEW YORK CITY

(In order of decreasing magnitude)

Year	Location	Richter Magnitude	Maximum Felt Intensity (MMI)
1884	Offshore, south of N.Y. City	5.2	VI-VII
1737	Greater N.Y. C. / Northern N.J.	5.2	VII
1783	Greater N.Y. City area. 4.7	VI	
1848	Greater N.Y. City area	4.5	V
1895	Central New Jersey	4.2	VI
1985	Westchester County	4.0	V
1938	Central N.J.	4.0	V
1937	Western Long Island, N.Y.	4.0	IV
1845	North of N.Y. City	3.9	VI
1951	Rockland County, N.Y.	3.9	V
1927	Near Asbury Park, N.J.	3.8	VI-VII
1979	Near Cheesequake, Central N.J.	3.5	V
1874	Near Nyack and Tarrytown, N.Y.	3.5	V
1957	Central N.J.	3.4	VI
1878	Hudson Valley	3.4	V

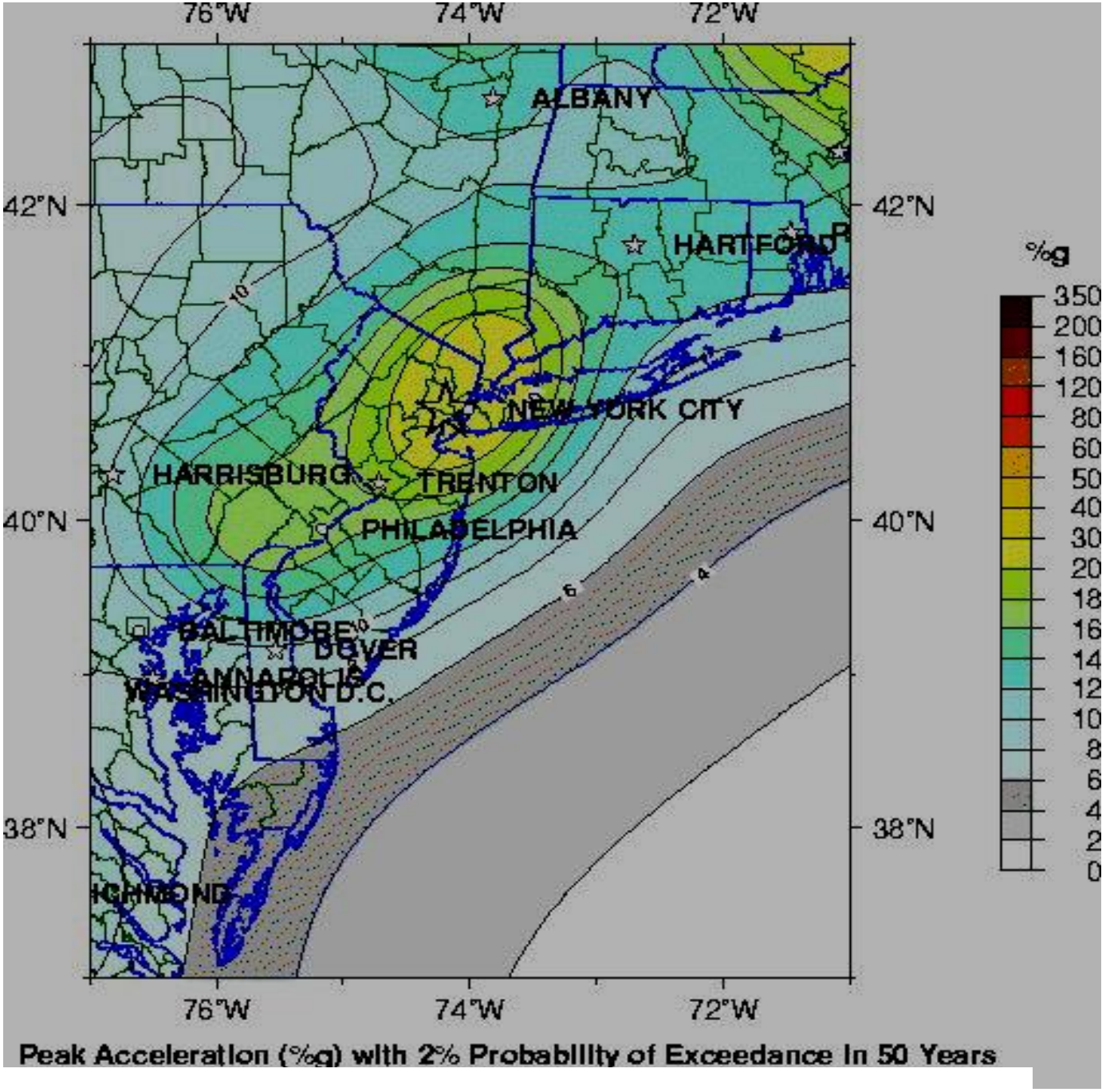


Map of Modified Mercalli Intensity (MMI) For Shaking Associated with the M=5.2 1884 NYC earthquake (off Rockaway).



NE Seismicity 1977-1999 (22 Years)

Blue Circles: M≥4



Peak Acceleration (%g) with 2% Probability of Exceedance In 50 Years

RISK : Potential for Future Losses

Risk = Sum (Hazard x Assets x Fragility)

$$ / year	year^{-1}	$$	0 to 1

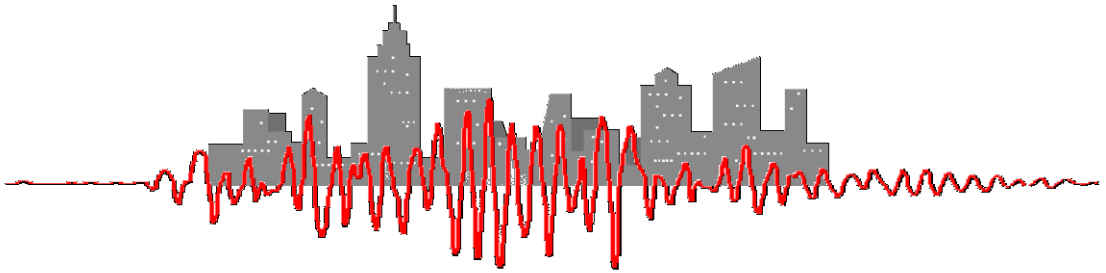
Hazard: Probability of Strong Ground Shaking

Assets:
- People
- Buildings & Infrastructure
- Economic Output

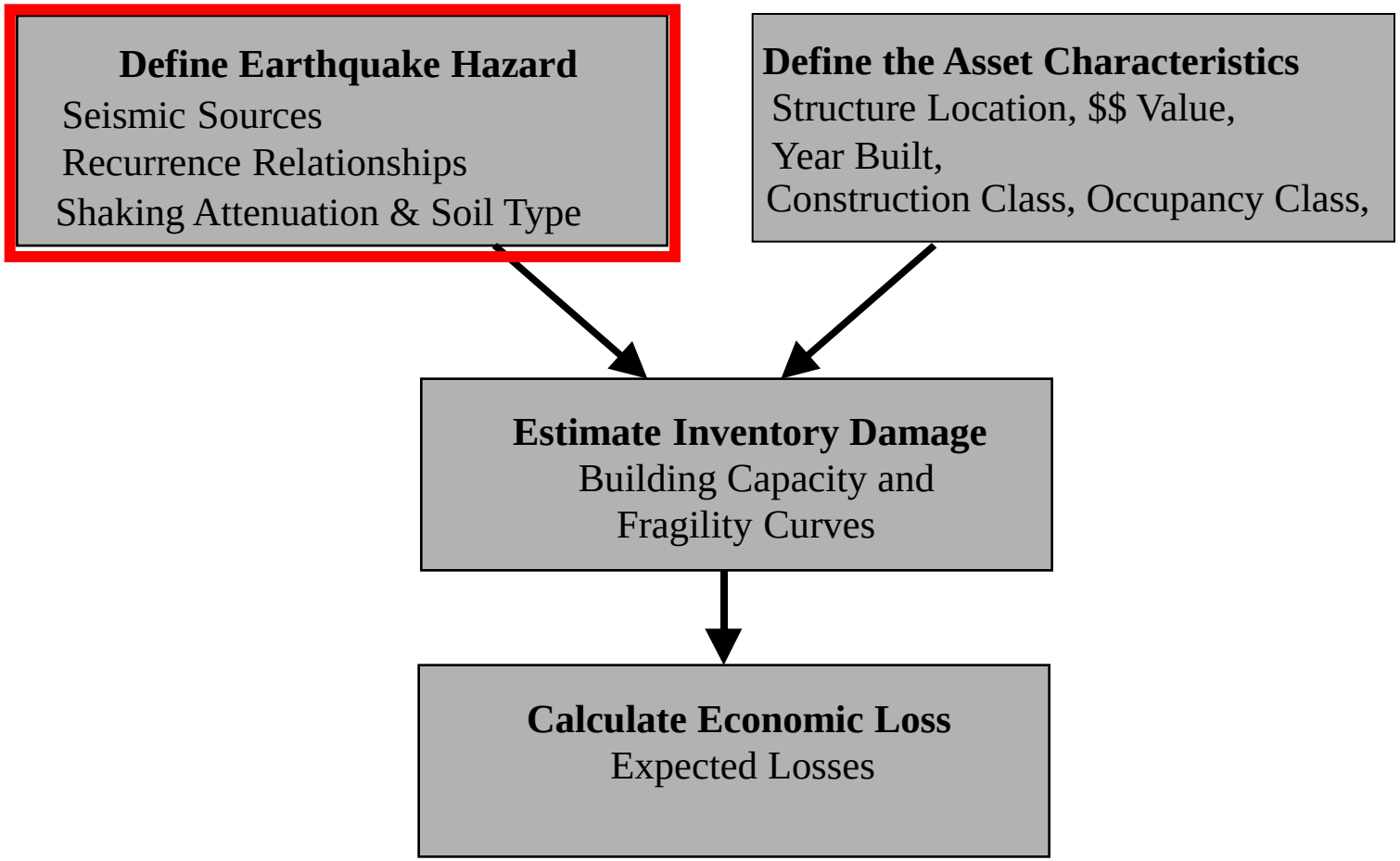
Fragility: Variable from 0 (no loss) to 1 (total loss), depends on type of building and level of shaking

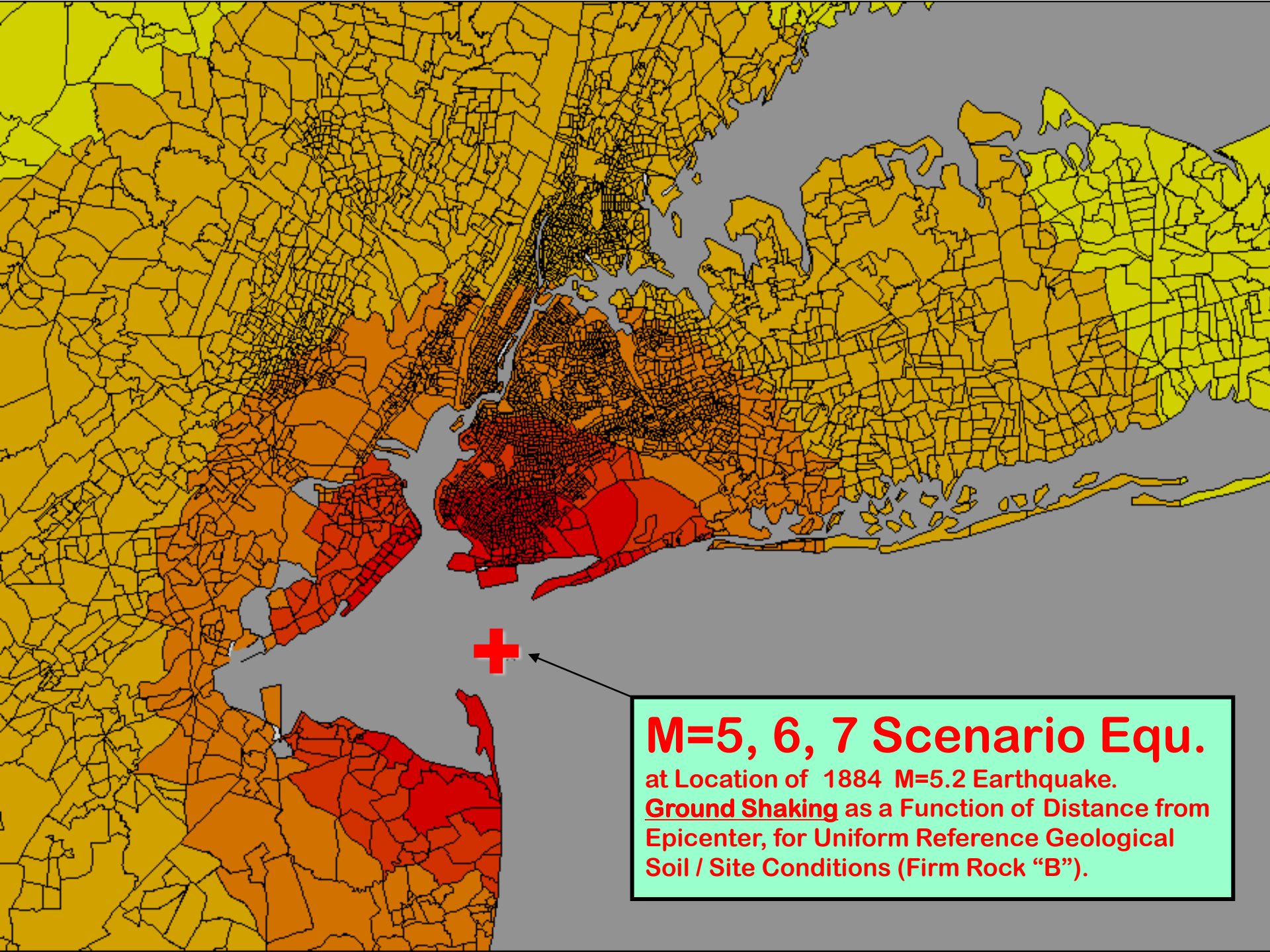
- **Computer Modeling of Earthquake Losses:**

  Attempt to provide a Forecast of the types of losses that the New York area could suffer after an earthquake. First we model the Hazard for three scenario events, then we need to determine the Asset Value, and Fragility of the building stock. Finally we compute the Losses and other Effects.



RISK ASSESSMENT METHODOLOGY

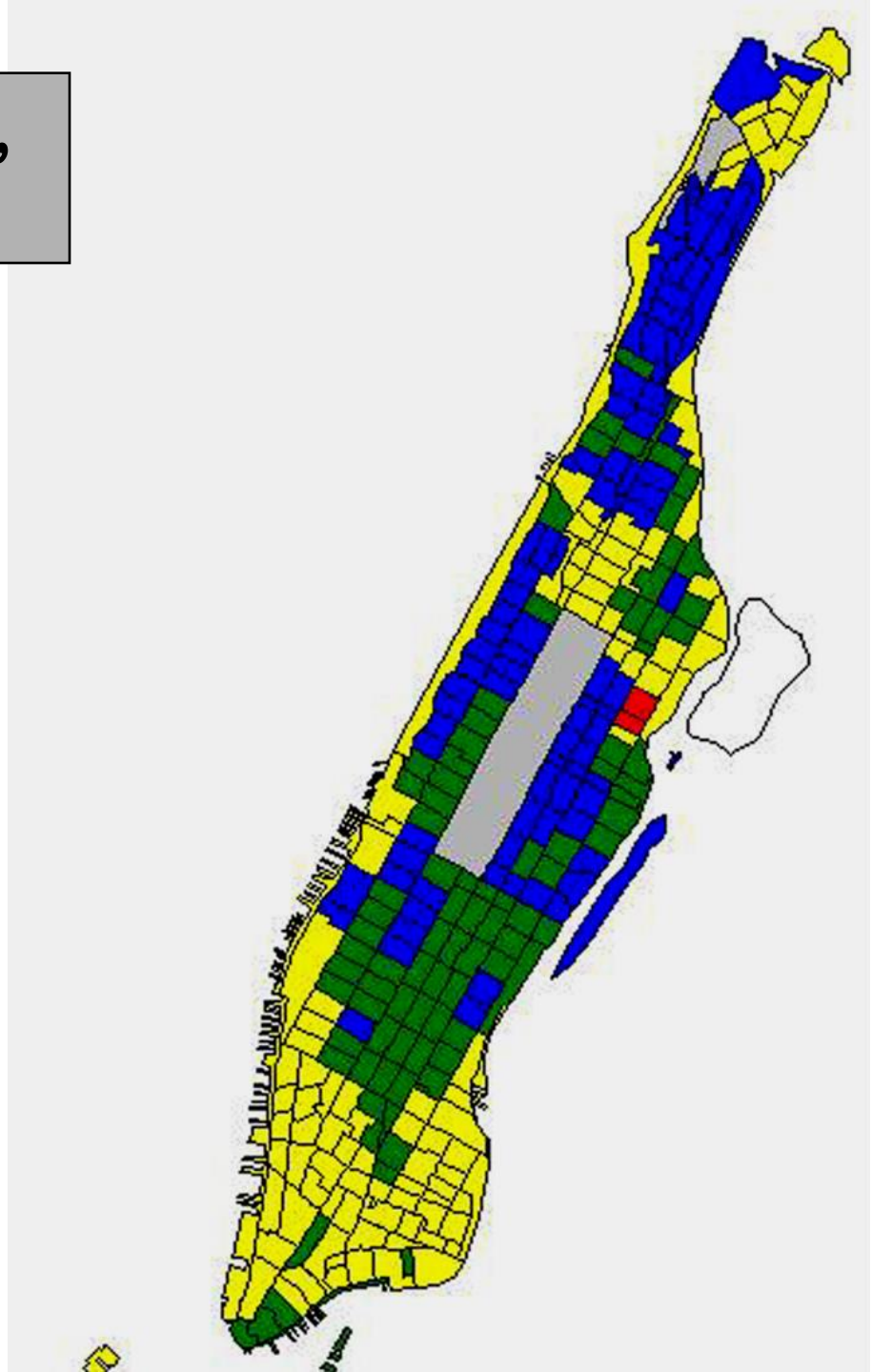



M=5, 6, 7 Scenario Equ.
at Location of 1884 M=5.2 Earthquake.
Ground Shaking as a Function of Distance from Epicenter, for Uniform Reference Geological Soil / Site Conditions (Firm Rock "B").

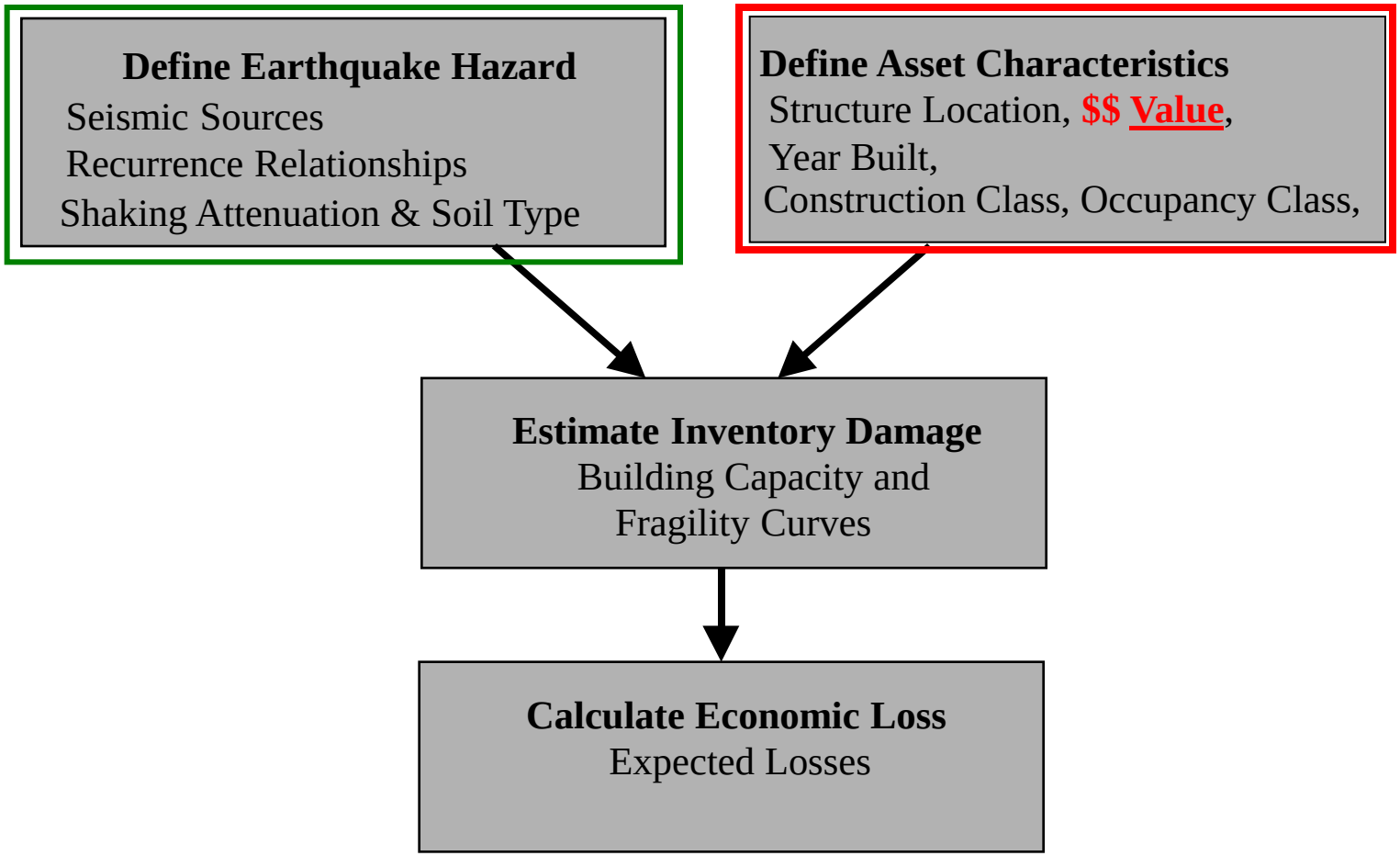
Manhattan Site Classes, Census Track - Based

A	Hard Rock	0.8
B	Firm Rock	1.0
C	Firm Soil	1.7
D	Soil	2.4
E	Soft Soil	3.5

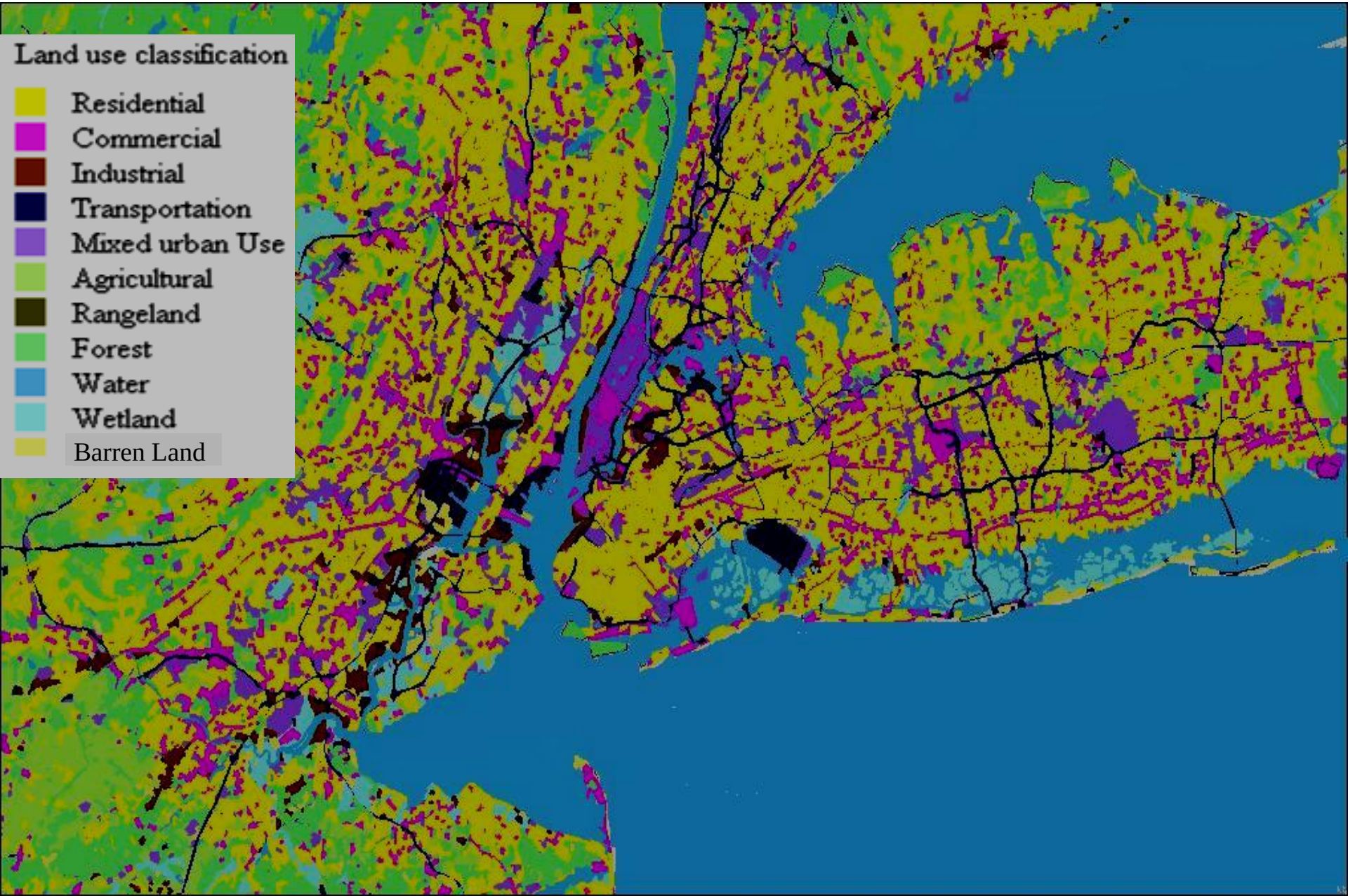
Amplification at 1.0 Hz



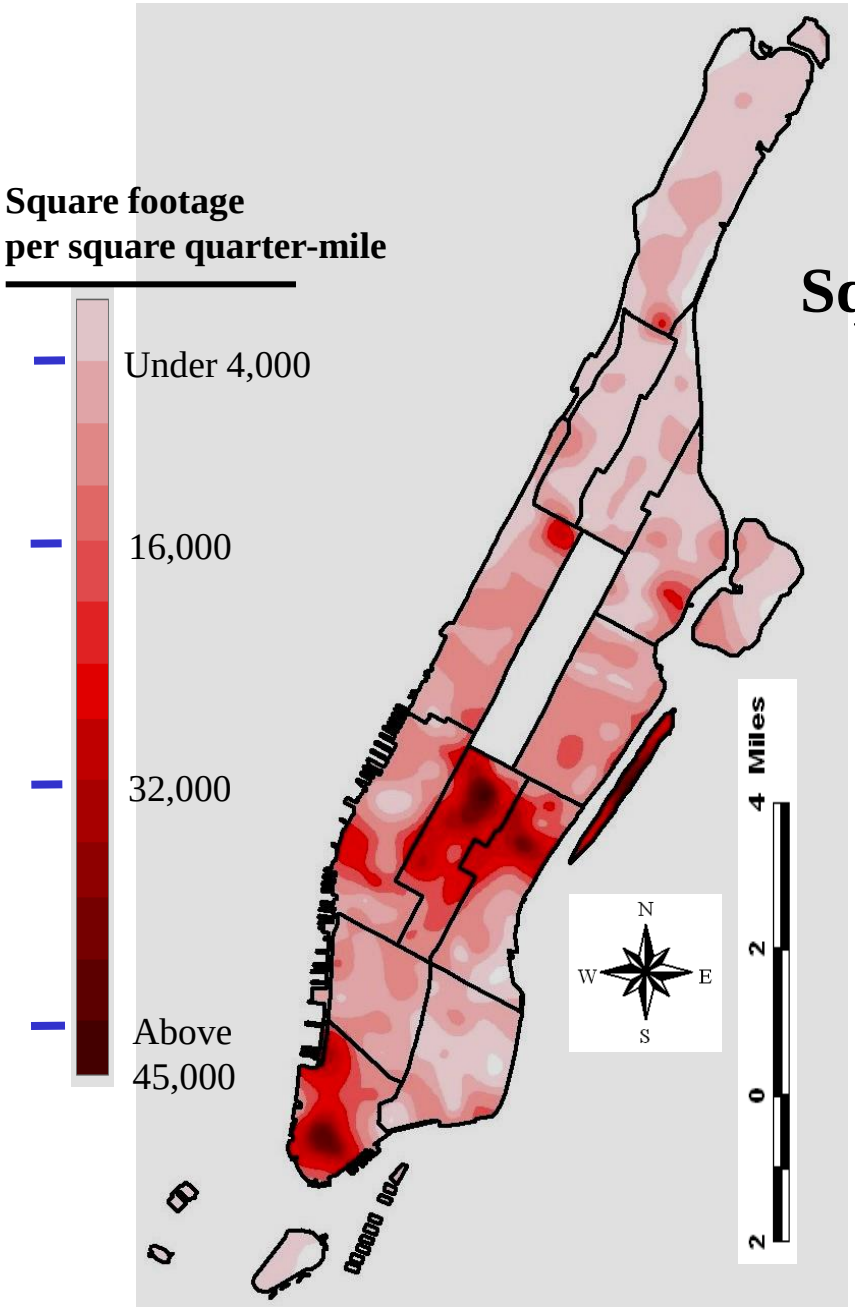
RISK ASSESSMENT METHODOLOGY

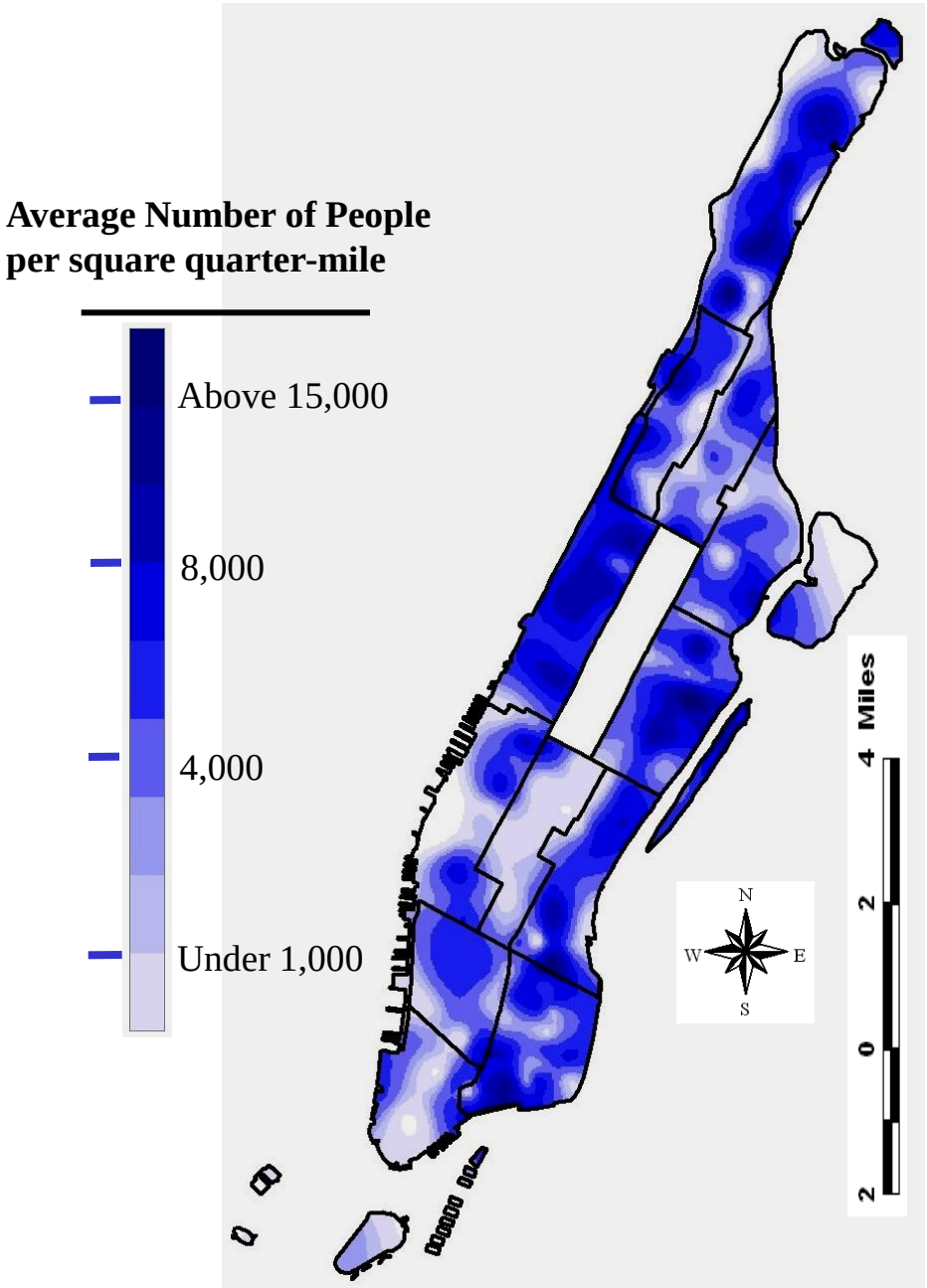


Assets: Landuse Map for Greater NYC; 20 Million People; $2 Trillion Total Built Assets, $1 Trillion Infrastructure; $ 1 Trillion Annual Economy (GRP)



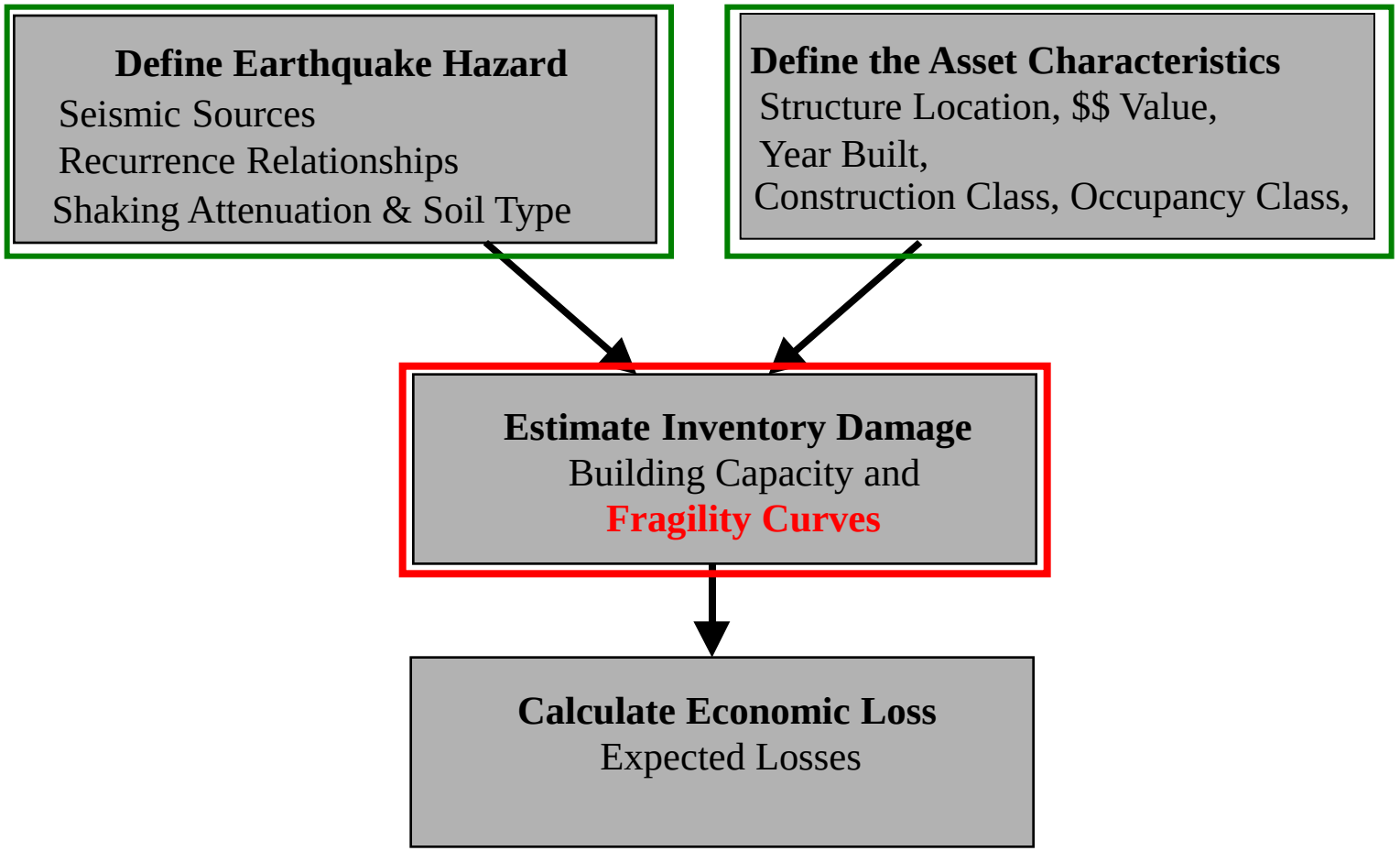
Square Footage Distribution





Average population

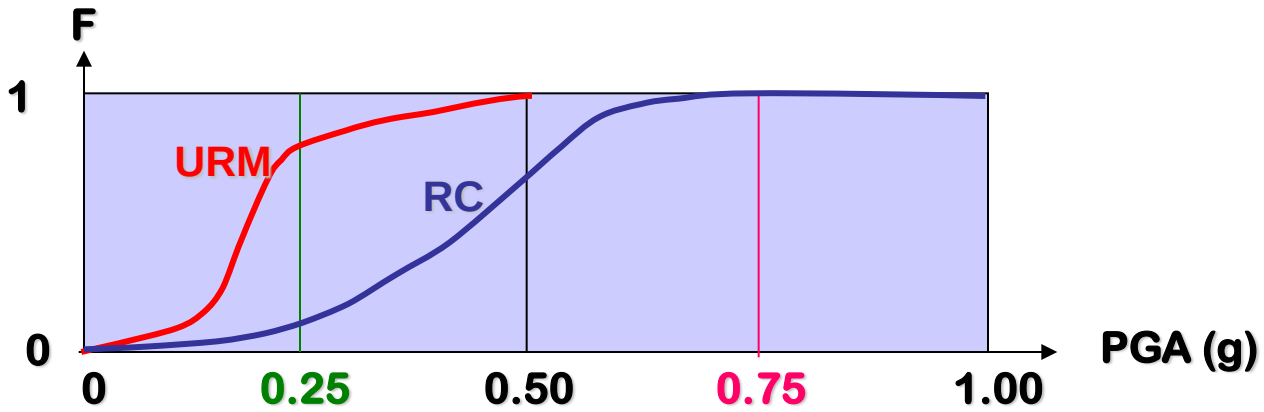
RISK ASSESSMENT METHODOLOGY



What is Fragility ?

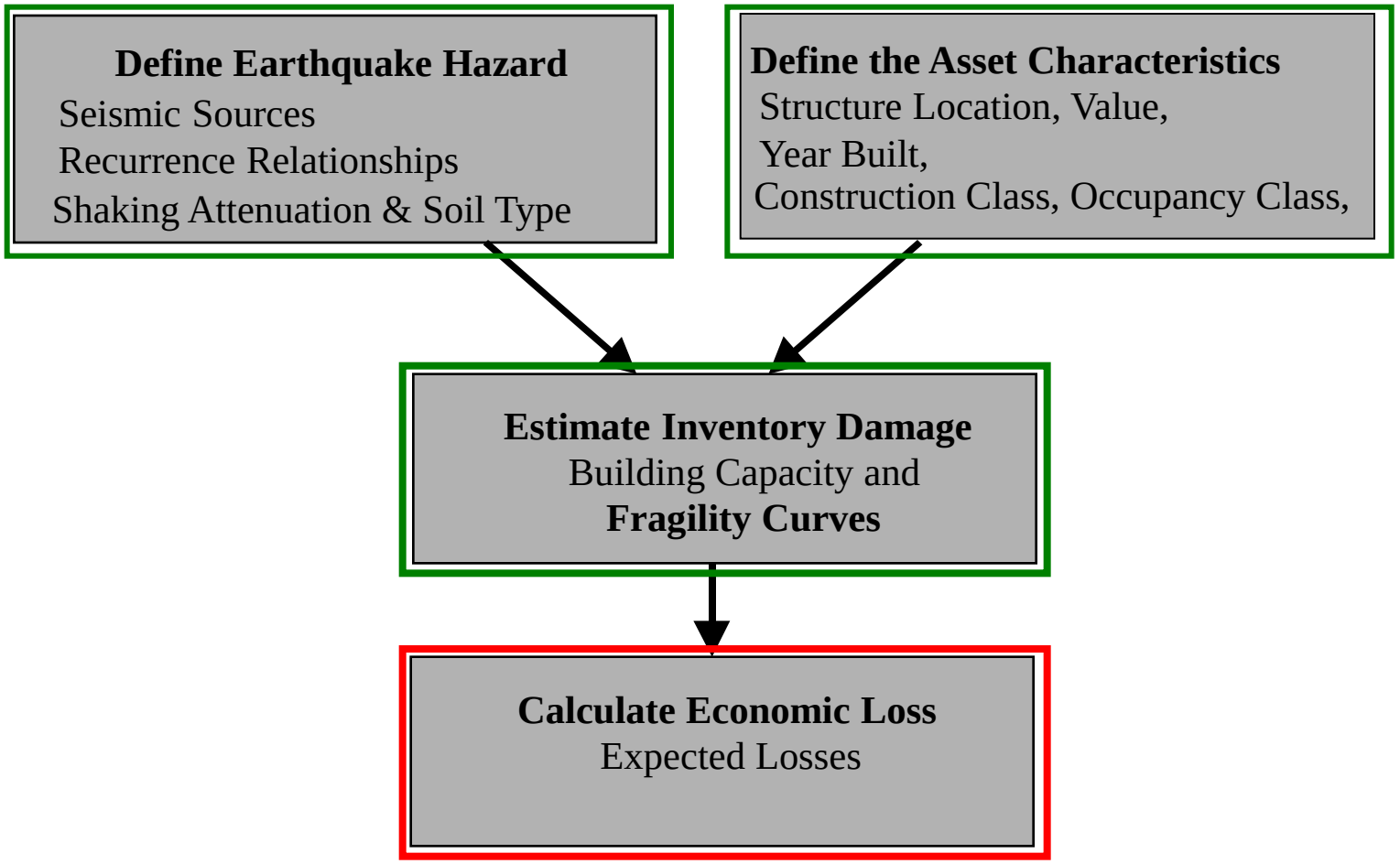
Fragility, F, is a value between 0 and 1, and represents the fraction of the asset value that is lost due to the hazard to which the asset is exposed. The fragility depends on the magnitude of the hazard, and how resilient the asset happens to be by its engineered design.

For instance, a reinforced concrete (RC) building may suffer only a 10% damage (F=0.1) of its replacement value from a peak ground shaking PGA = 0.25g, while a unreinforced masonry (URM) building may at the same shaking level have partly collapsed (F=0.8). But for a shaking PGA= 0.75g both building types, whether masonry or concrete, are likely to have completely collapsed (F=1.0).



GIS Tools are Used: e.g. the new NYC digital Base Map

RISK ASSESSMENT METHODOLOGY

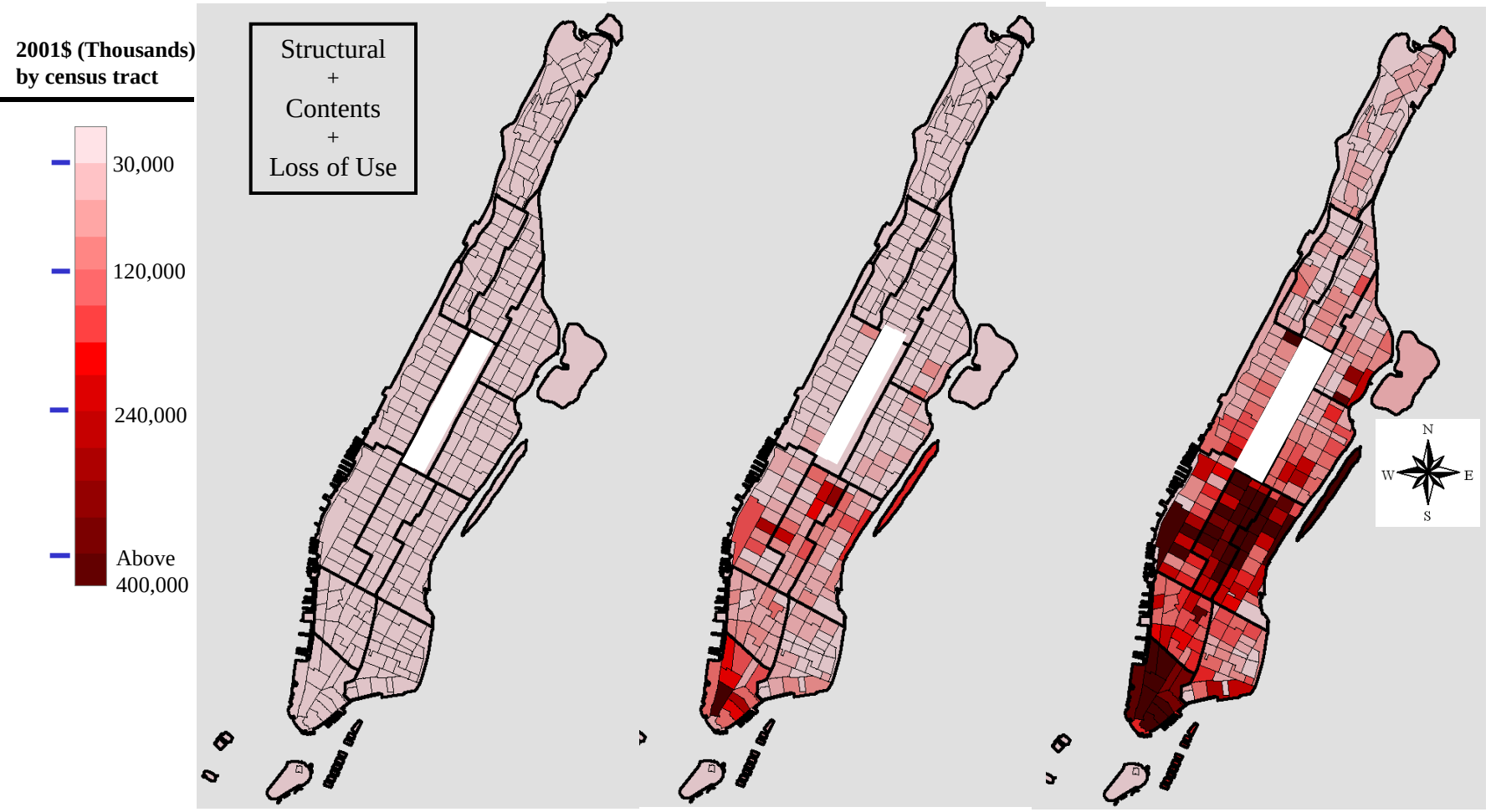


Scenario Earthquakes

Manhattan

Total Build. Loss:

5.0M	6.0M	7.0M
$ 0.7 B	**$ 10 B**	**$ 43 B**

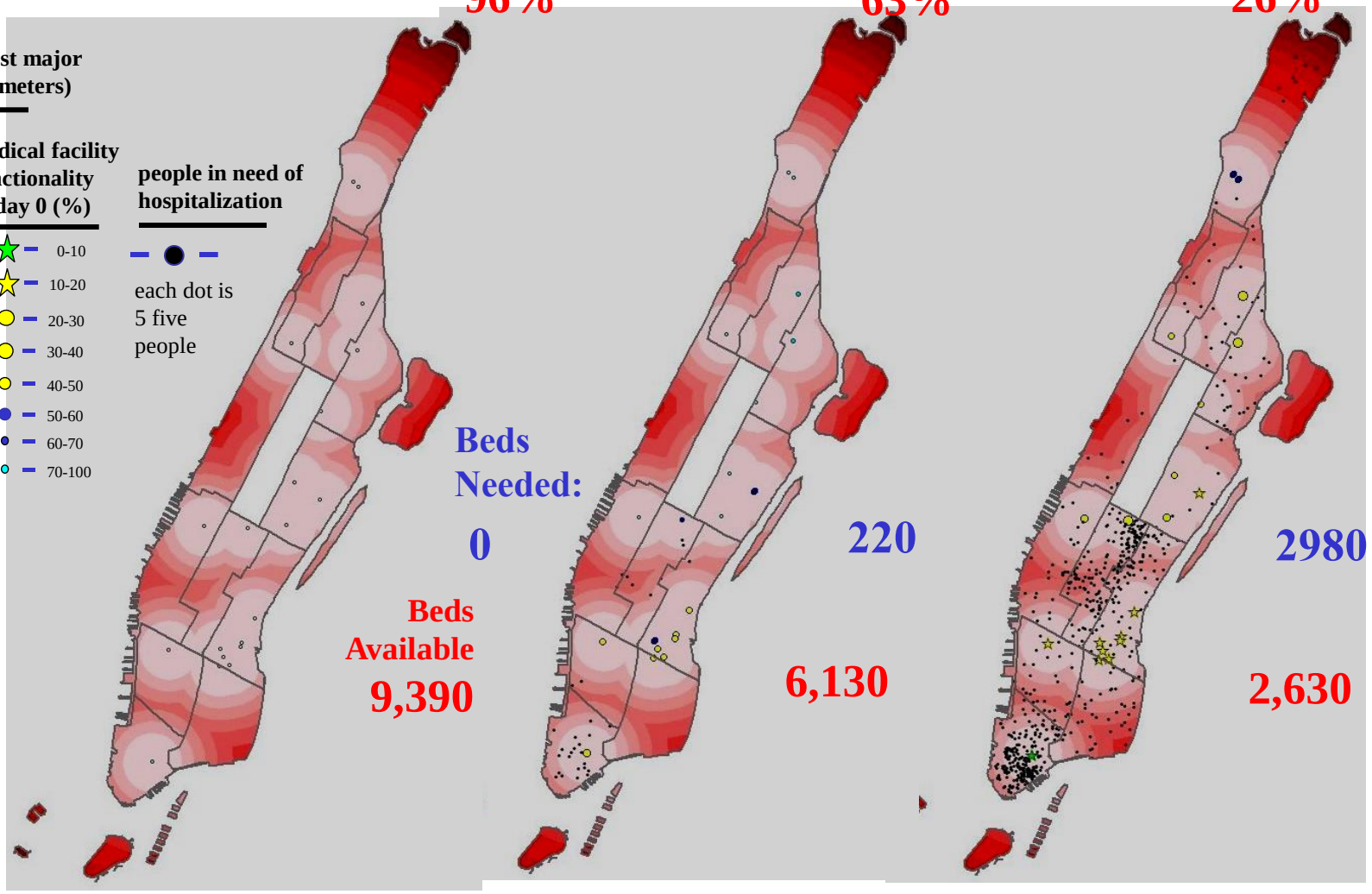


Scenario Earthquakes

Medical (Hospitals)

and those requiring hospitalization

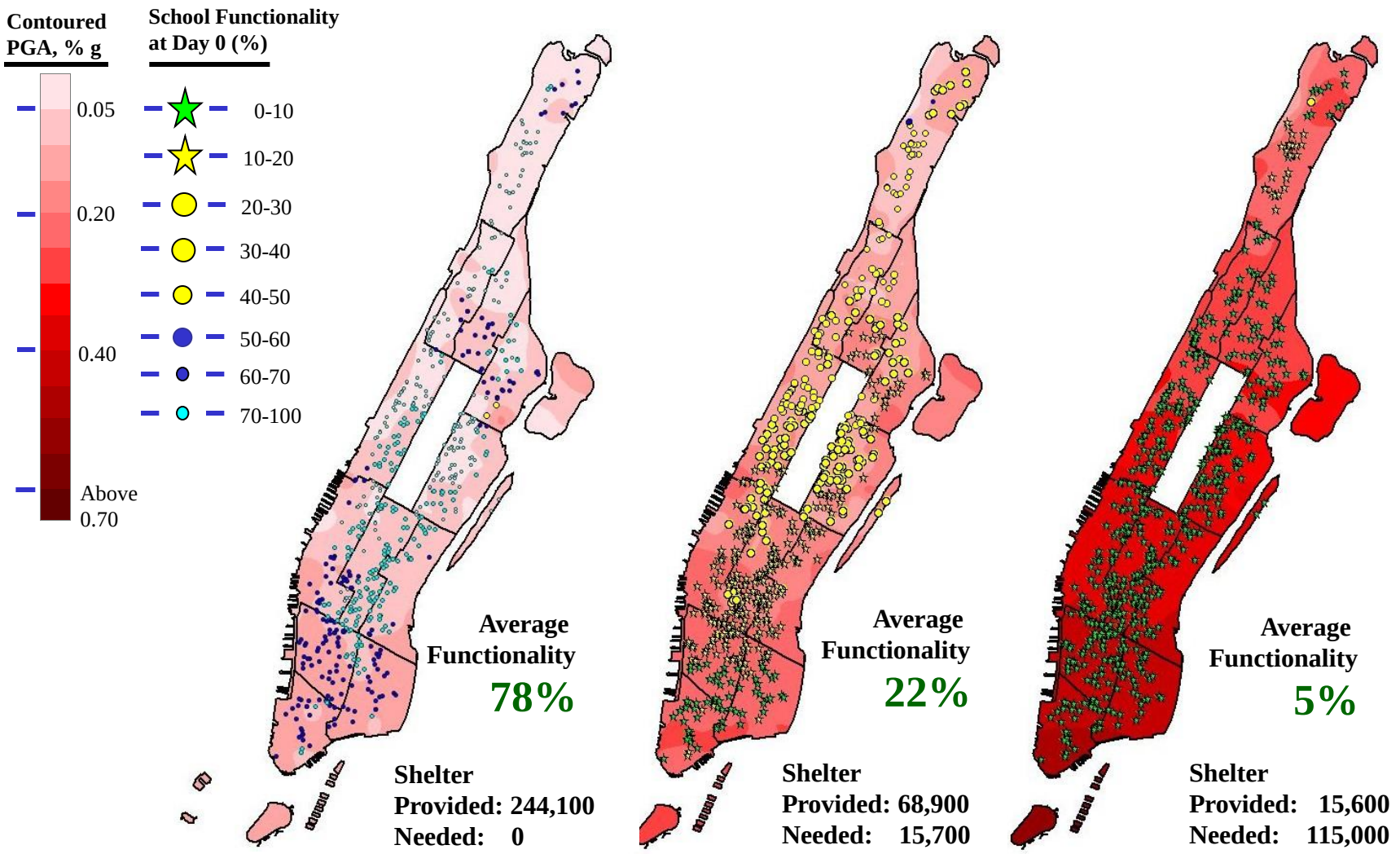
5.0M	6.0M	7.0M
Average Functionality	Average Functionality	Average Functionality
96%	63%	26%
Beds Needed: 0	220	2980
Beds Available 9,390	6,130	2,630



Scenario Earthquakes

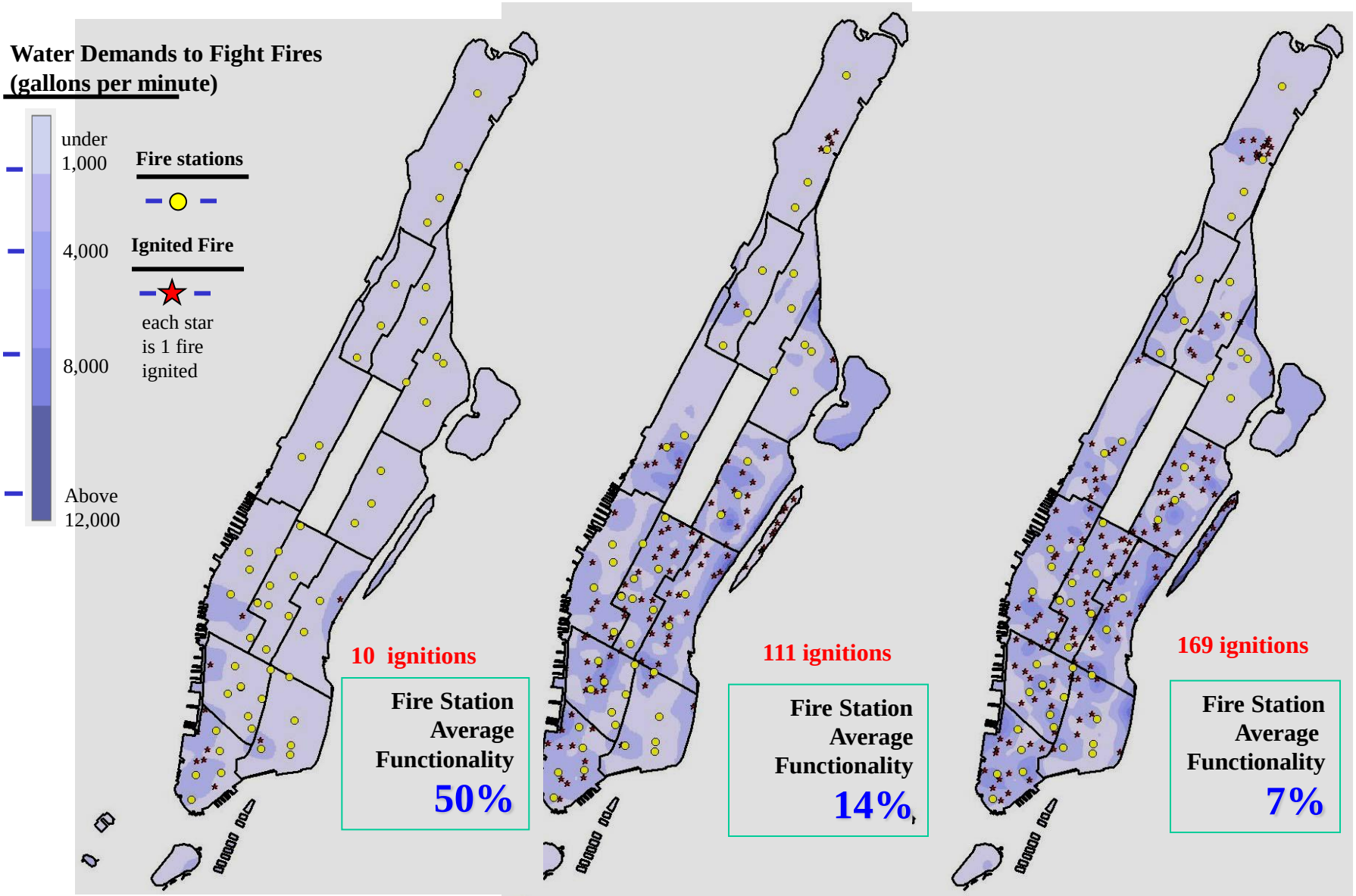
5.0M | 6.0M | 7.0M

School Functionalities and PGA



Scenario Earthquakes 5.0M 6.0M 7.0M

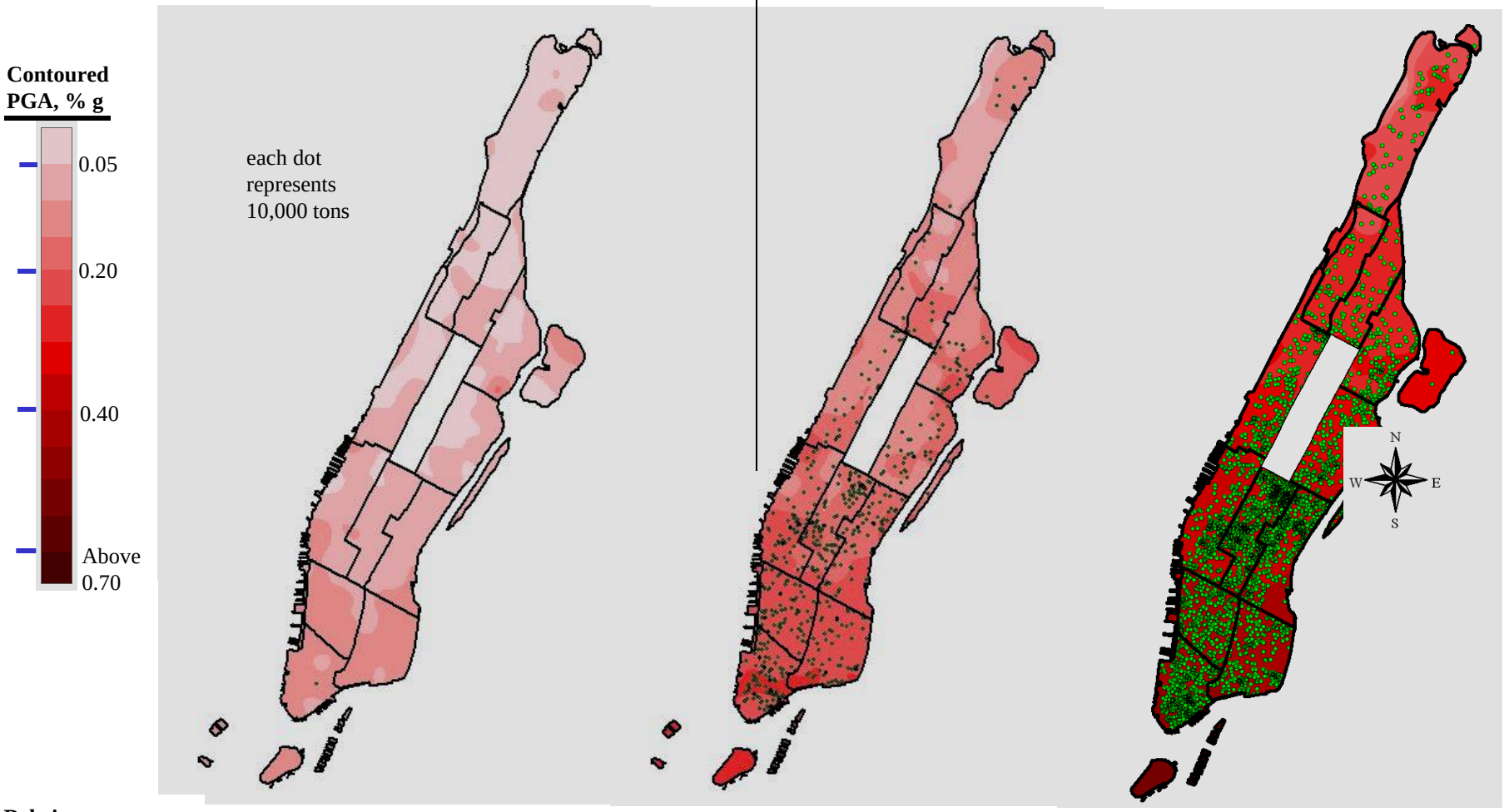
Fire Station Functionality, Ignitions and Water Demand



Scenario Earthquakes | 5.0M | 6.0M | 7.0M

Debris Generated: 88 k tons | 5,700 k tons | 27,178 k tons

WTC
1.6 Mt



Debris:
Brick, Wood, Steel and Concrete

9,000 Trucks (10t) | 600,000 Trucks | 3 Million Trucks

Conclusions from EQ Risk Assessment for NYC:

- NYC has Moderate to low earthquake hazard
- High Population & Asset Concentrations
- High Fragilities of Existing Built Assets

Therefore: --->

- Low Probability Hazard - High Consequence Risk
- Substantial Risk Exposure (>> Tens of Billions of Dollars / Event)
- In the US, NYC ranks 4th in earthquake risk after LA, SF & Seattle
- Greatest Seismic Risk is to Extensive Unreinforced Masonry with High Risk of Collapse and Threat to Lives.
- A Seismic Building Code has been adopted in 1995, but applies only to new structures built since 1996.
- Infrastructure Systems are Vulnerable. Only a few Bridges & some key structures have been seismically retrofitted
- Time May Run out Before Major Earthquake Strikes.
- Emergency Preparedness Must Remain High while Vulnerability is being Gradually Reduced.


Q. ?