Beyond the Obvious: National Economic Impact of a Likely New Madrid Earthquake

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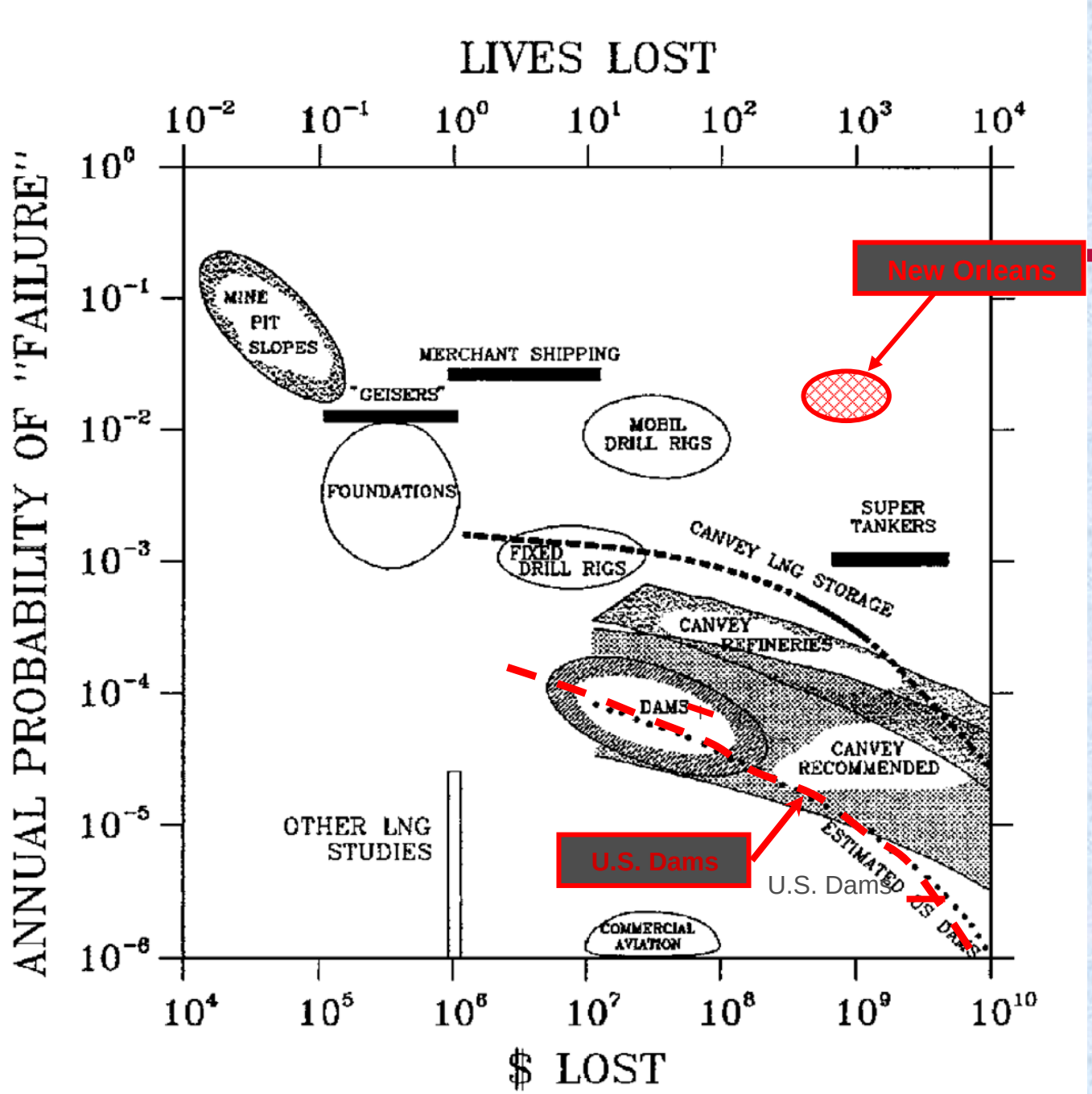
Question #1

Why should all Americans be concerned about the impacts of a New Madrid Earthquake?

Hurricane Katrina



New Orleans

U.S. Dams

U.S. Dams

- Ask 11,000 former Ford Motor Co. employees about the impacts of Hurricane Katrina on SUV sales

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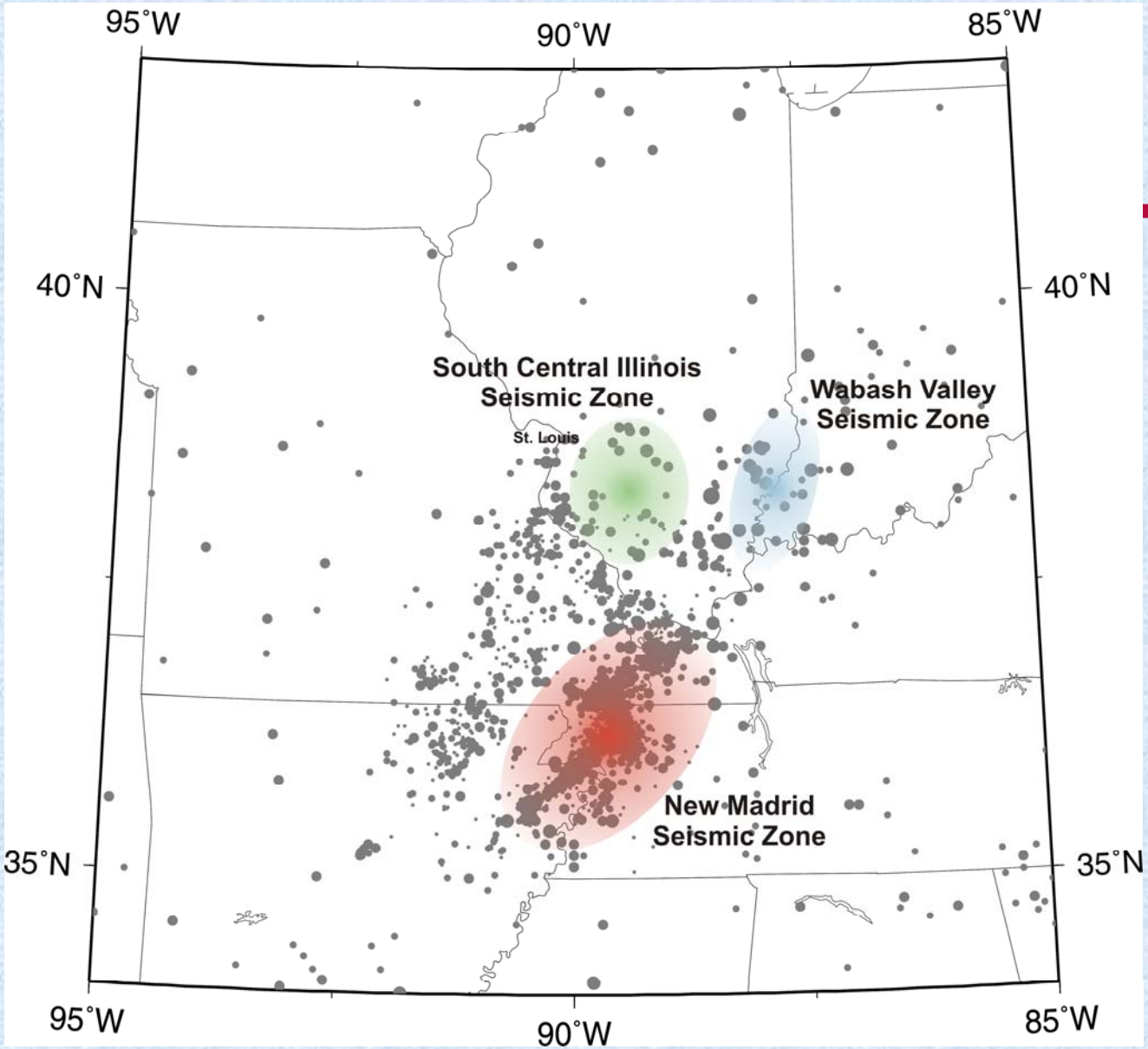
Question #2

How Could the St. Louis Area Be Damaged by an Earthquake 200 kilometers Away?



Active Midwest Seismic Zones

- New Madrid Seismic Zone rediscovered in 1973 NRC study of West Memphis power plant
- Wabash Valley Seismic Zone generated M 5+ quakes in 1968 and 1987; initially suspected in 1993 and accepted in 2004
- South Central Illinois spawned a M 5+ quakes in 1838, 1857, and 1891. Initially recognized in 1999

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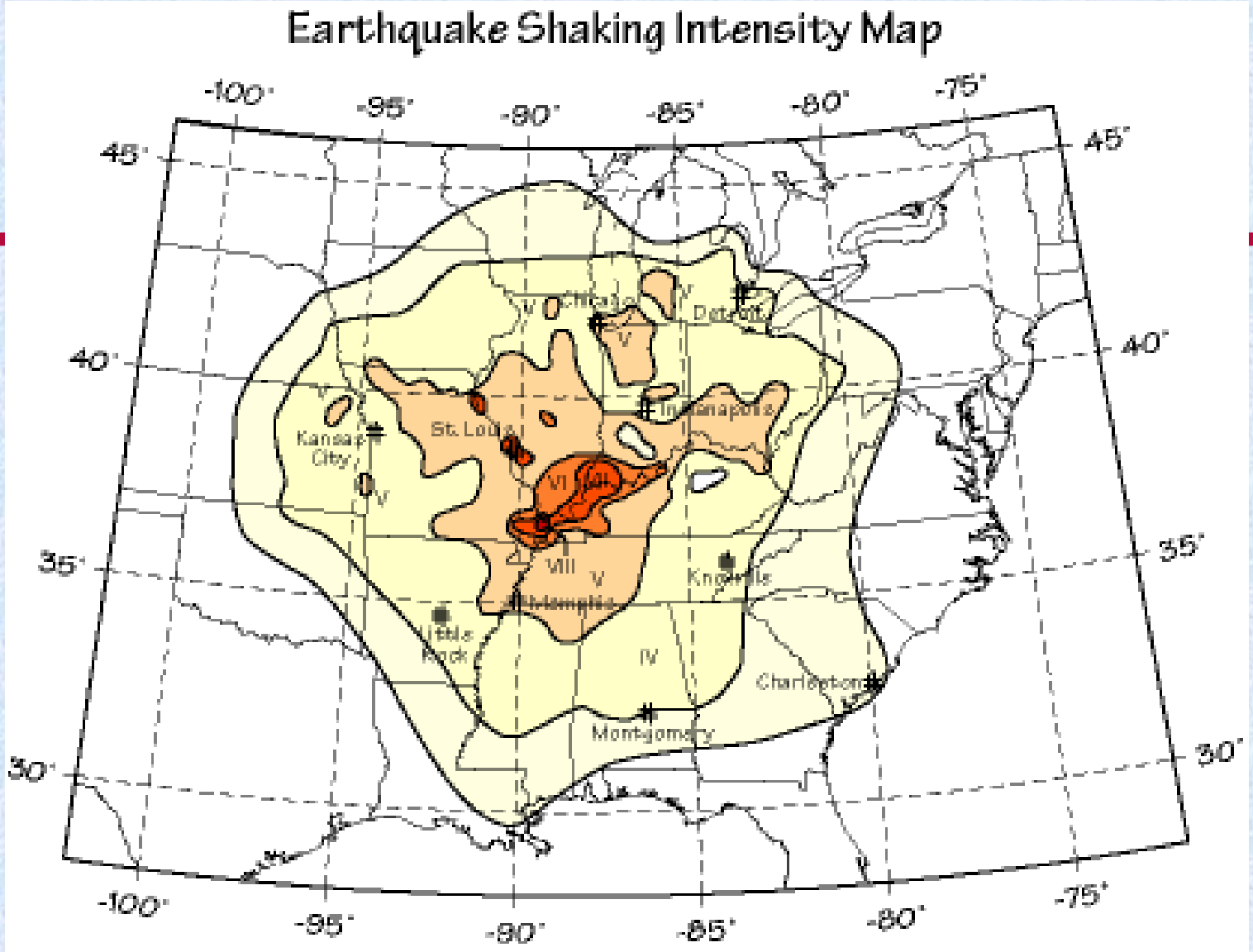

The 1895 M6.0 Charleston, MO earthquake affected an area 20X greater than an equivalent magnitude quake in California

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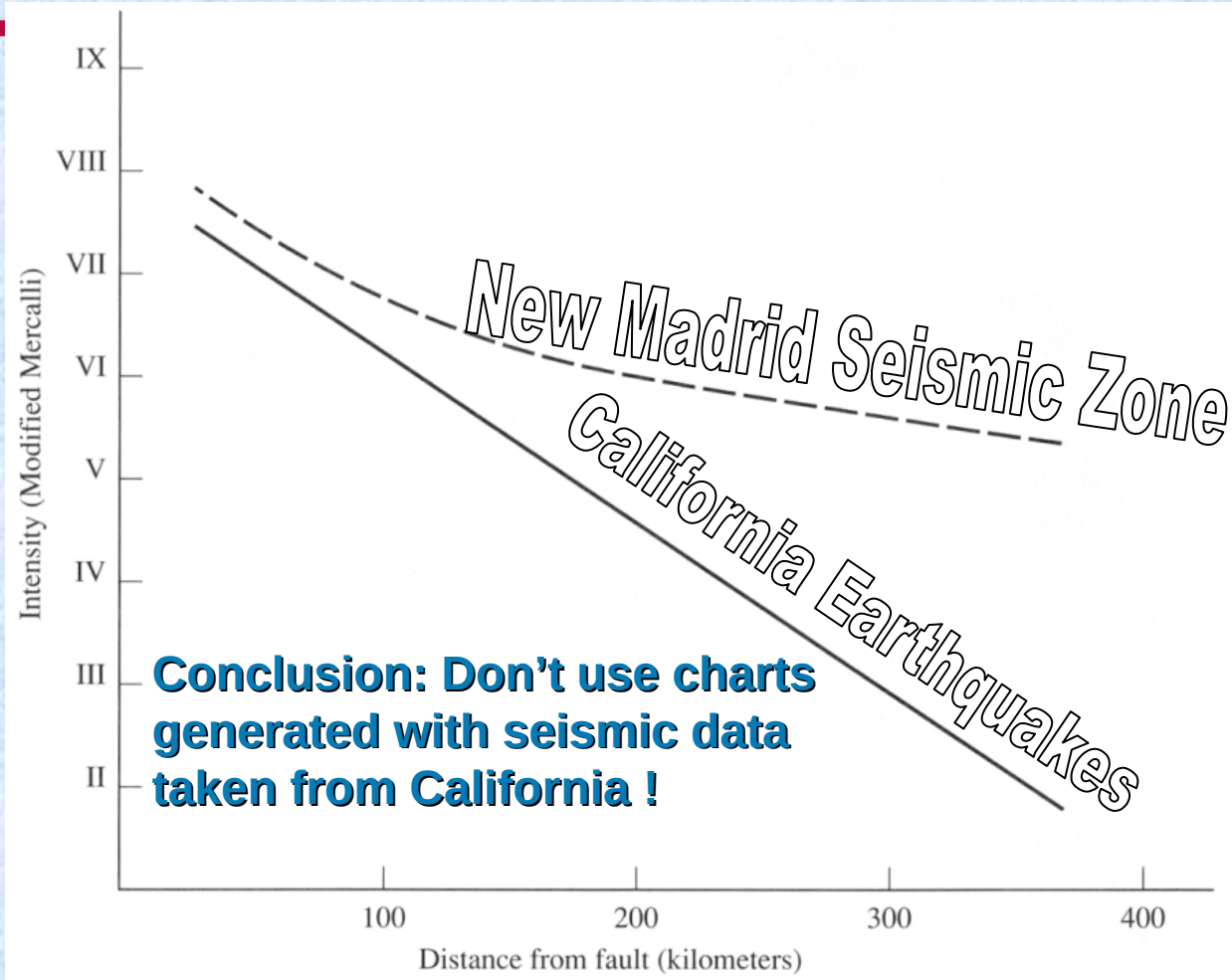
SHAKING INTENSITY versus DISTANCE



Midwest quakes are less frequent, but much more lethal than California quakes because there is <u>less damping</u> of seismic energy.

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Question #3

What is the Most Likely Earthquake We Can Expect in the Here and Now; not 300 years from now?

Recurrence Intervals for New Madrid Earthquake Events*

Magnitude	Recurrence Interval
4.0	14 Months
5.0	10 – 12 Years
6.0	70 – 90 Years
7.0	254 – 500 Years
8.0	550 – 1200 Years

* based on existing data; always subject to update and revision

MOST LIKELY QUAKE

- In our lifetimes, the most likely earthquake to impact St. Louis would be something similar to the **Magnitude 6.0 Charleston, MO quake of 1895**, which has a recurrence frequency of 70+/- 15 years (overdue since 1980).
- It could emanate from either the **New Madrid Zone** or the **Wabash Valley Fault Zone**, or from **South Central Illinois.**

Question #4

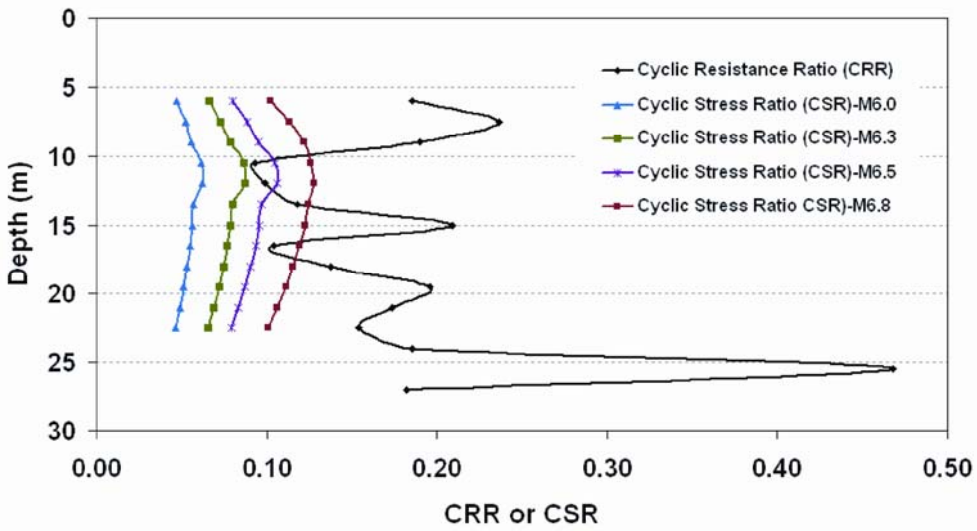
What is the Economic Impact of Soil Liquefaction?

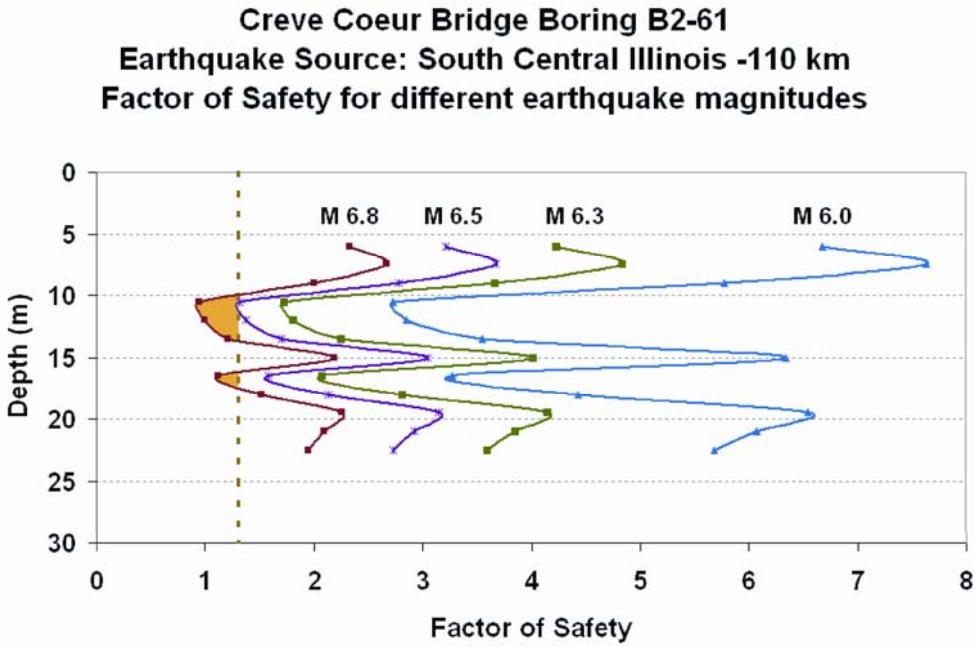
Recent sand blows dot the landscape surrounding New Madrid, MO, testifying to massive liquefaction

LIQUEFACTION or "QUICK SAND" CONDITION

Liquefaction is a failure mechanism by which cohesionless materials (sand and silt) lose shear strength when the pore water pressure equals the effective confining stress. It is usually limited to the upper 50 feet and typically occurs in silt, sand and fine gravel.

Liquefaction Potential





Liquefaction is predicted in the Missouri River Flood Plain for a Magnitude 6.8 quake from South Central Illinois and Wabash Valley Seismic Zones.

Liquefaction to depths of 18 m predicted for Magnitudes > 6.5

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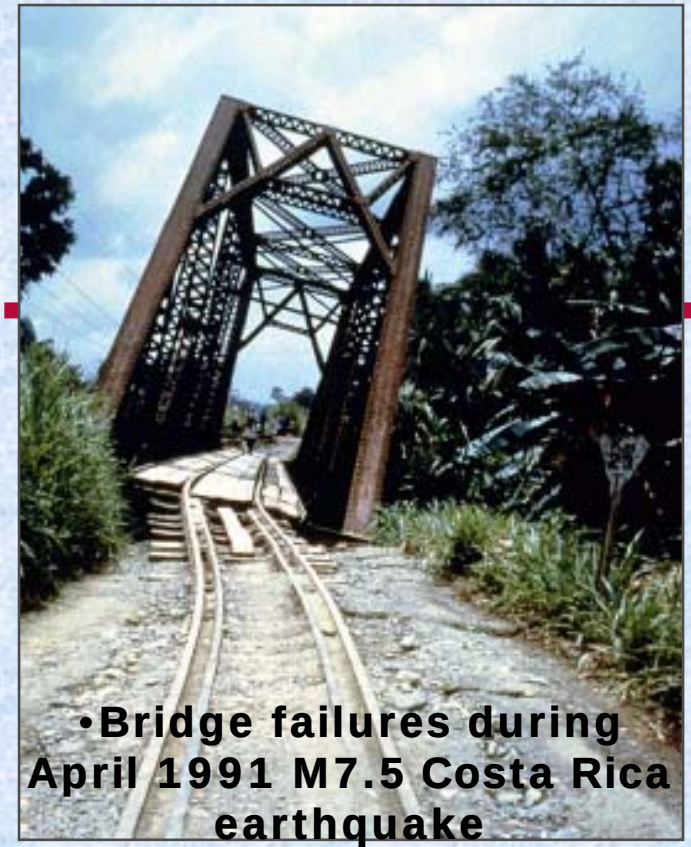
Liquefaction Often Impacts Bridges



•Bridge failures during April 1991 M7.5 Costa Rica earthquake

- Though supported on steel and concrete piles respectively, these bridges both failed due to liquefaction of foundation materials, which tilted the piles
- Fiber optic cables strung across bridges would also be severed

Question #5

Why Are Old Lakes and Filled Ground Important Factors in Predicting Ground Shaking Intensity?

This 1796 map shows the spatial distributions of oxbows, cutoffs, and islands in the river floodplains around St. Louis.

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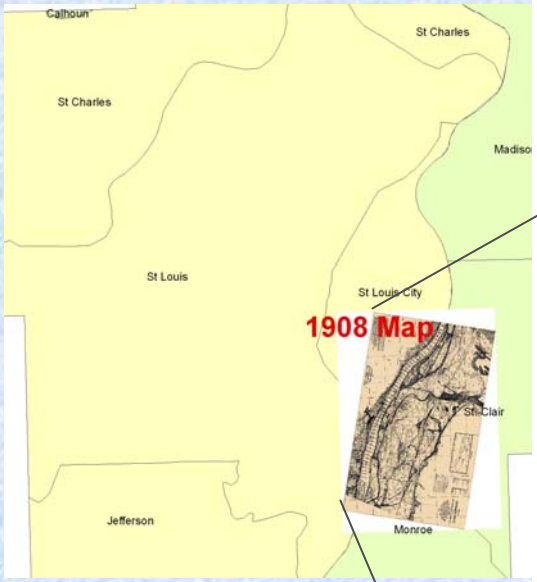
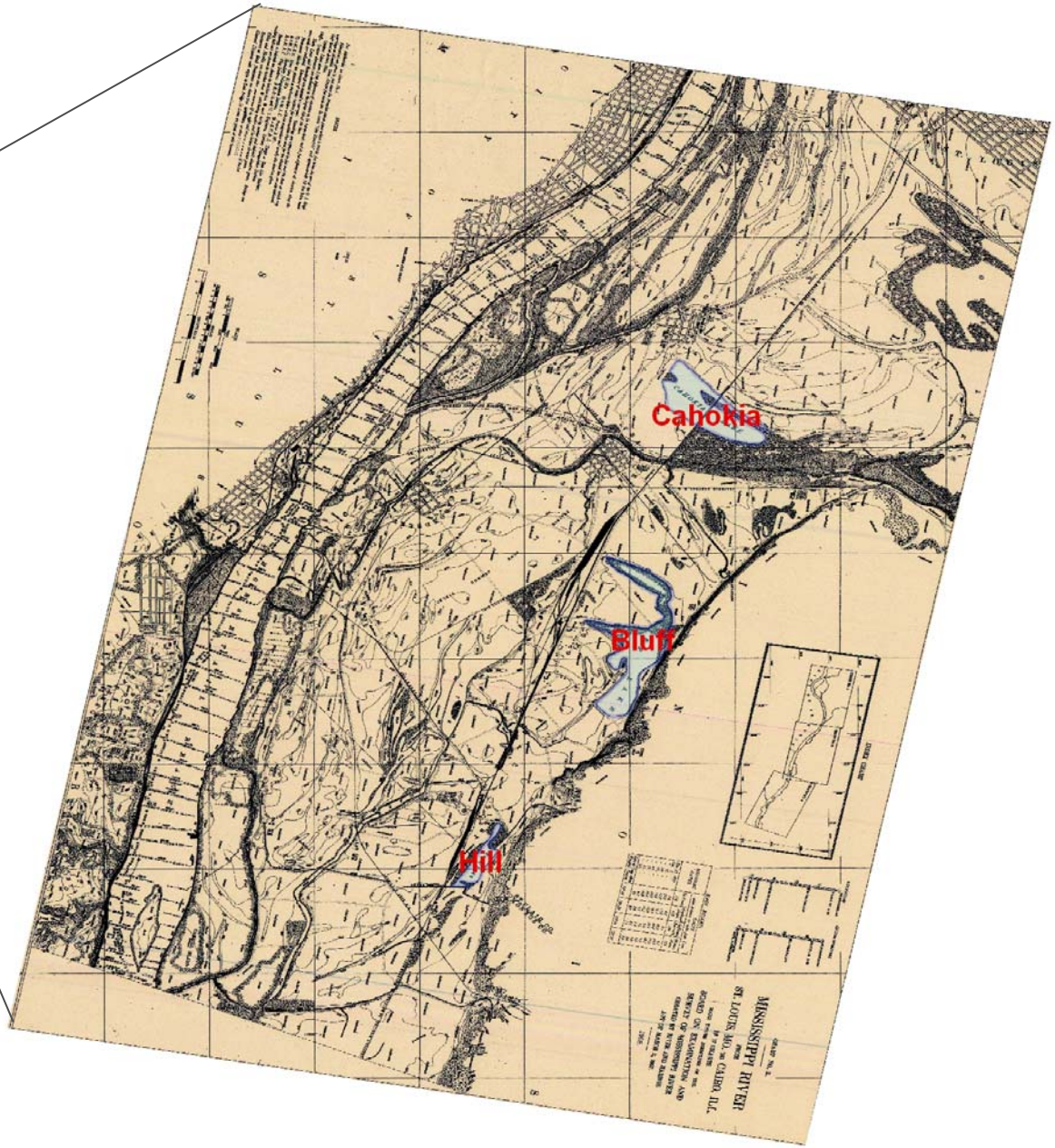
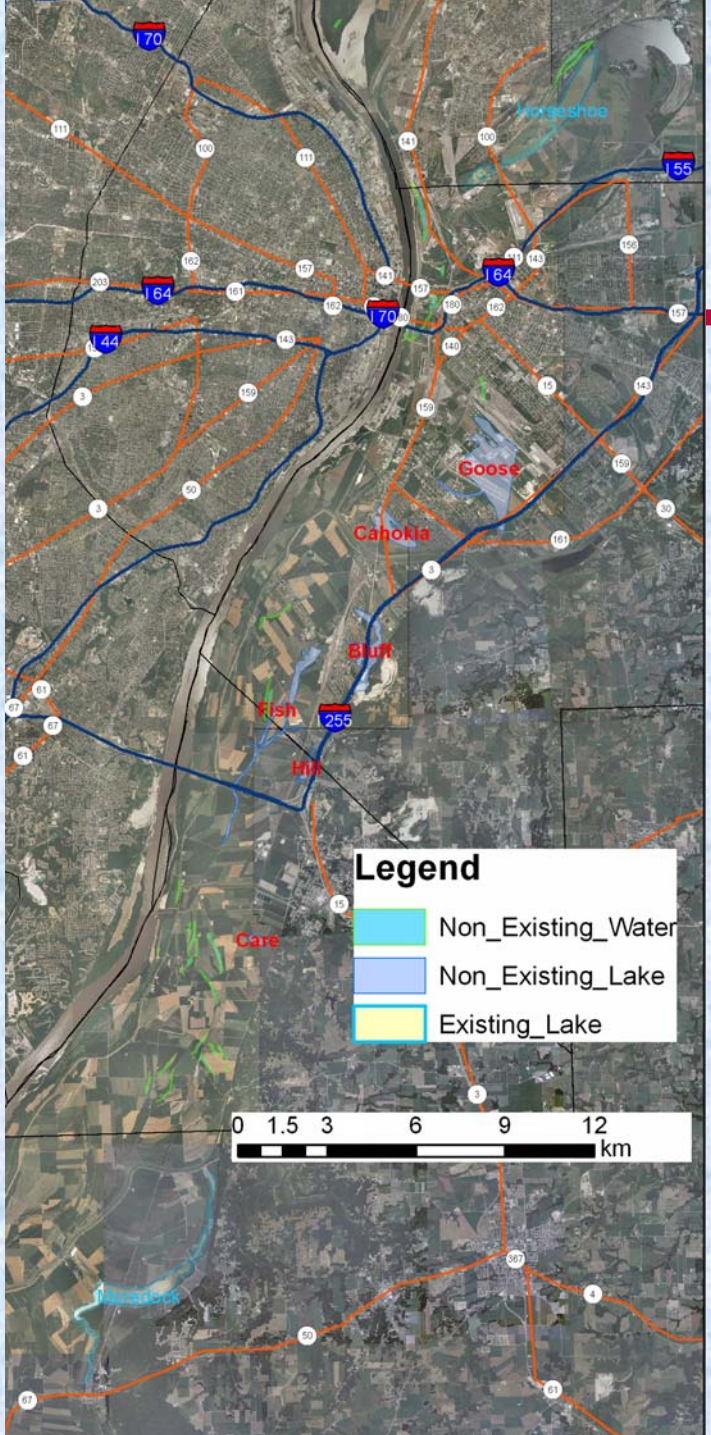
Overlay of 1908 Mississippi River Map



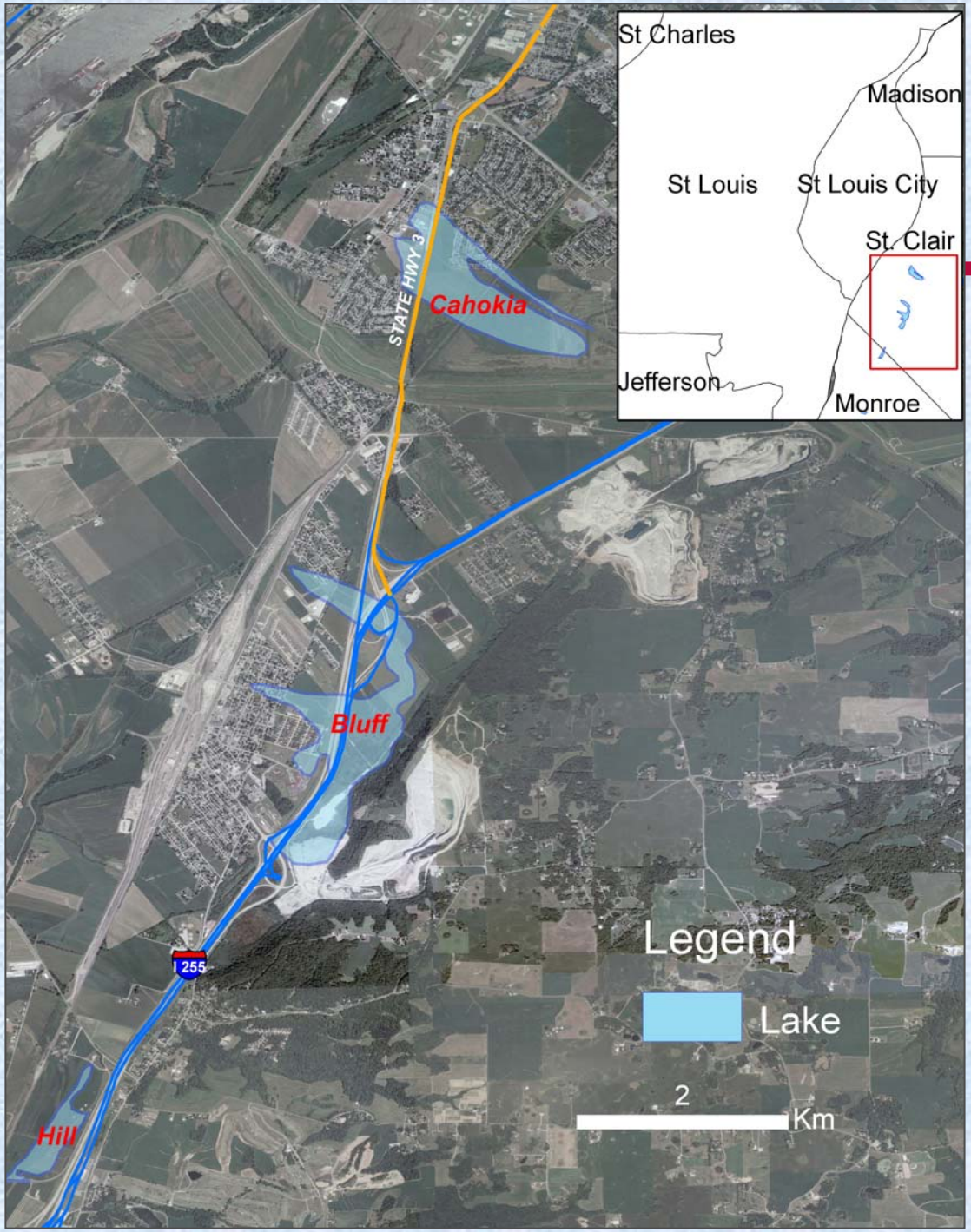
Overlay information on historic maps – in this case, old oxbow lakes and cutoffs that have since been infilled





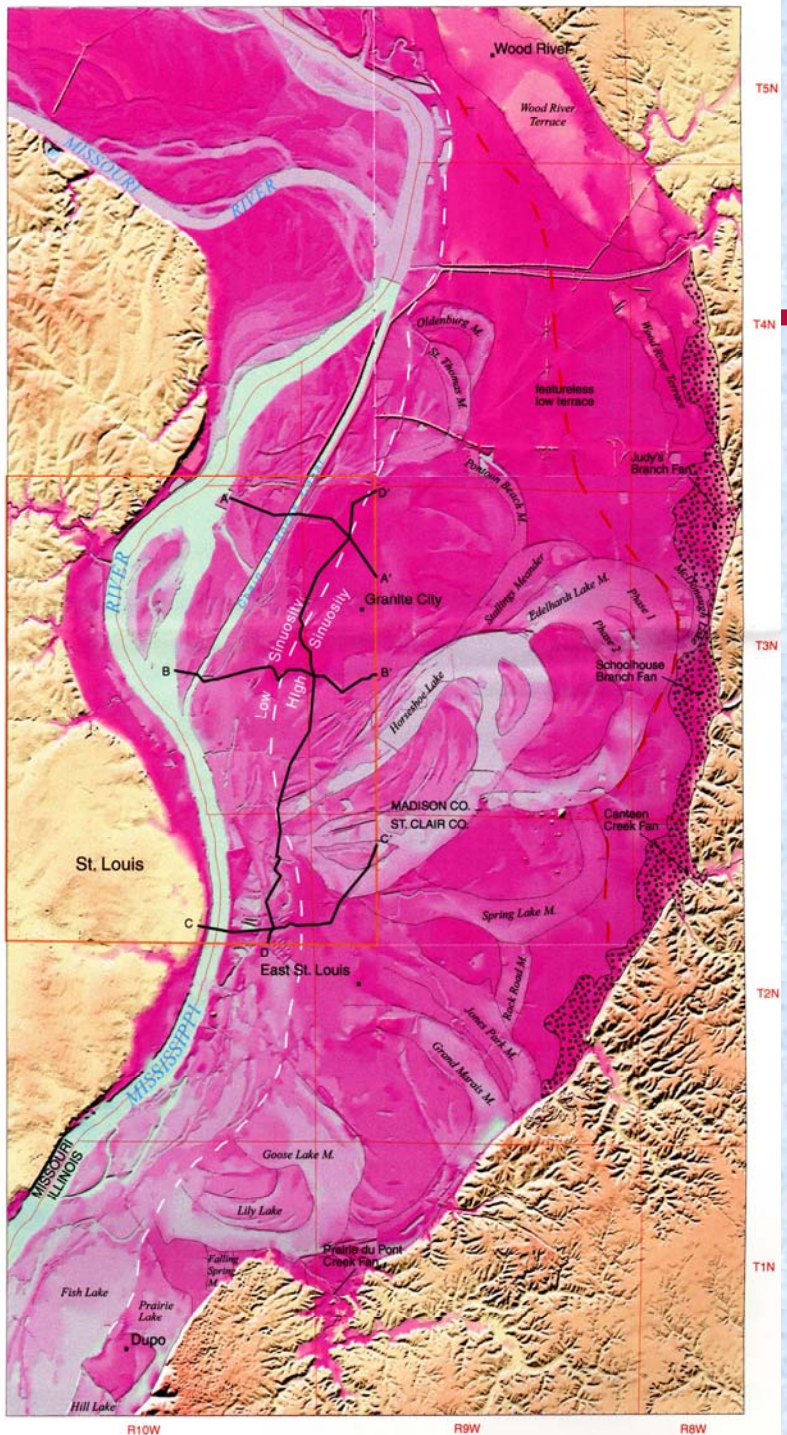
Map Overlays Using Geographical Information Systems

- The spatial positions of the 1908 lakes in the Mississippi River floodplain are overlain on modern maps of the area, to gain a better perspective on which areas are on filled ground; which might be subject to asymmetric site response



Detail of Overlay

- About half of the freeway interchange between Interstate 255 and Illinois Route 3 plots over one of the old cutoff lakes shown on the 1908 map.
- The different geologic conditions beneath either side of the interchange could be expected to foster asymmetric site response problems



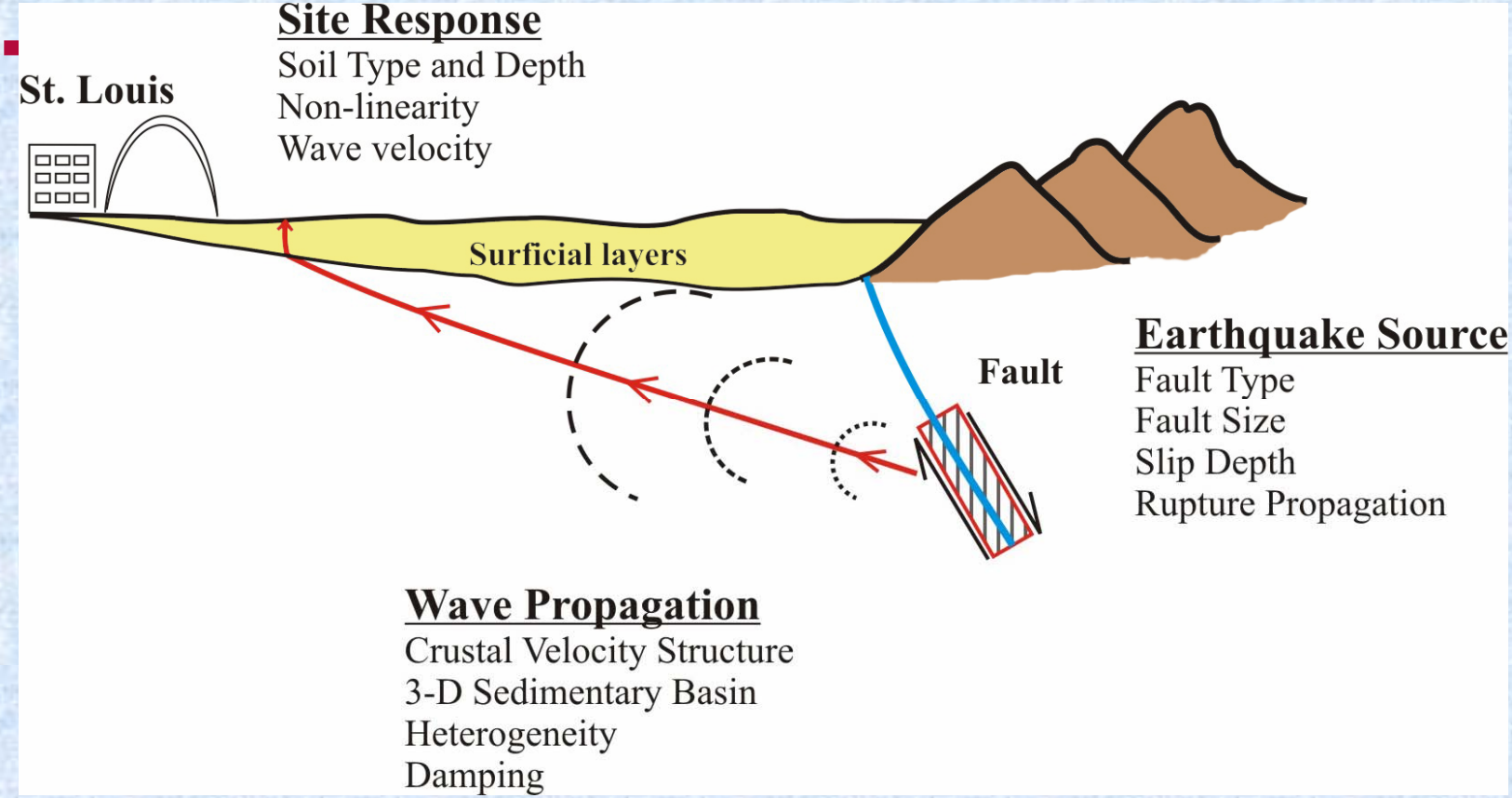
Mississippi River Flood Plain

- One of the most important GIS map products in flood plains along major channels is a rendering of prehistoric channels
- These channels tend to develop one upon another, in spatially complex patterns
- Note bedrock narrows at Carondelet and position of the main channel, hugging the western bank

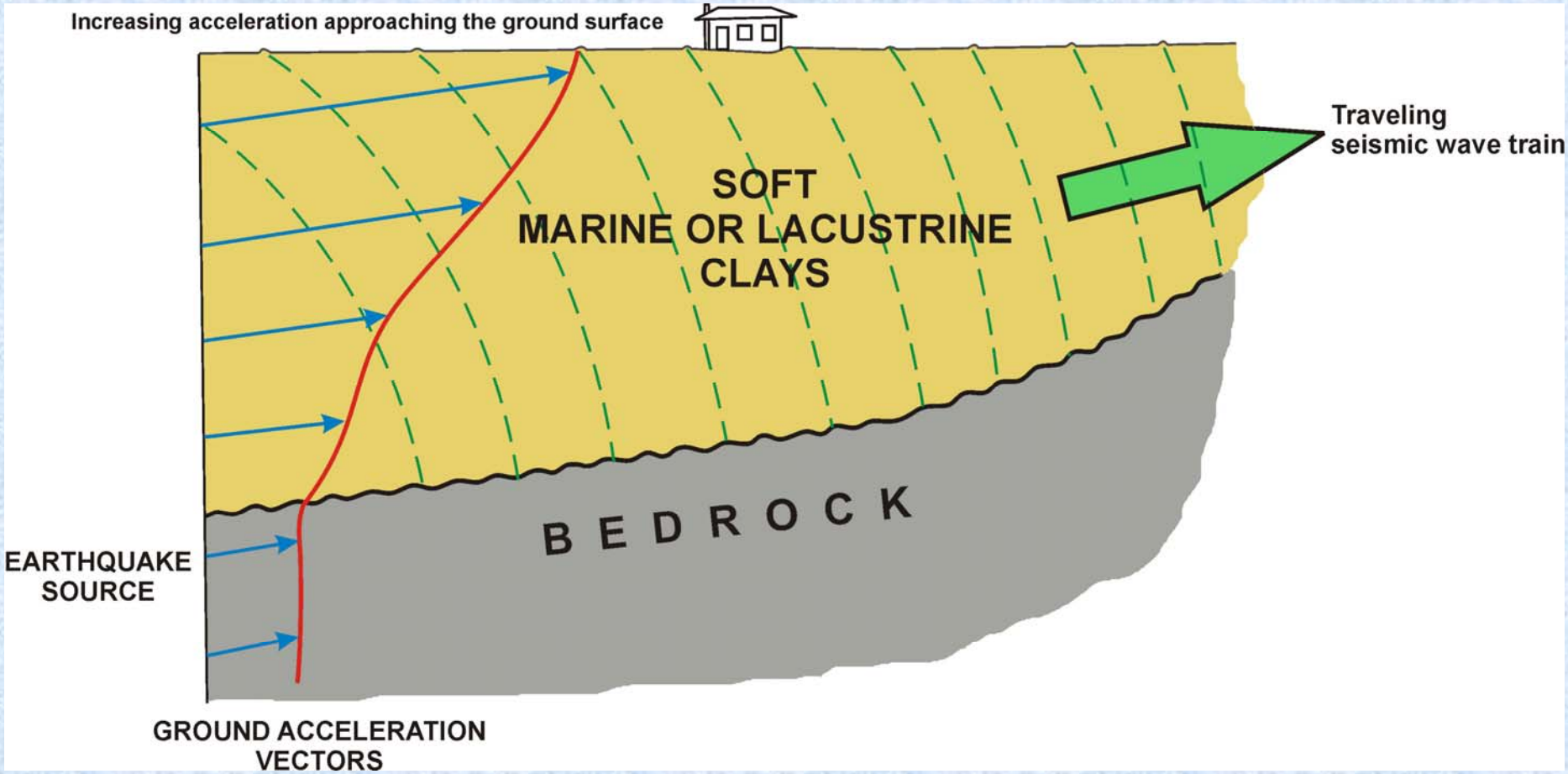
Question #6

How Will the Intensity of Shaking Vary From One Area to Another Around St. Louis?

Shaking Intensity is Controlled by a factor called 'Seismic Site Response'

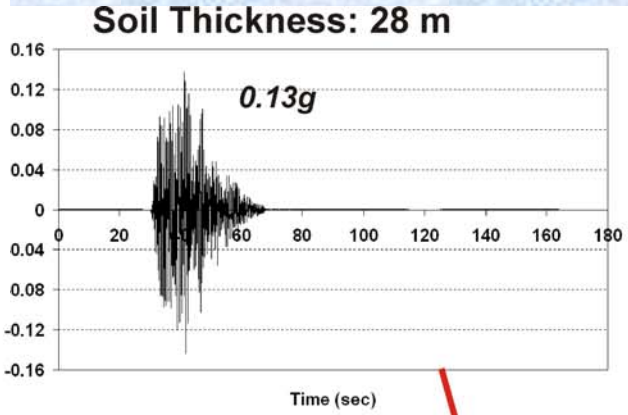


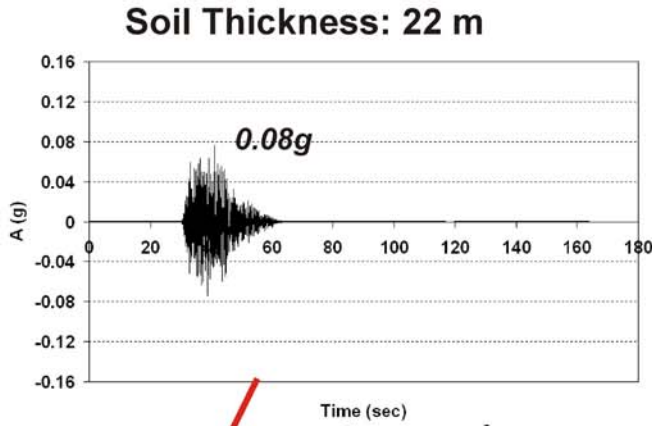
The type, depth and size of fault, combined with physical properties of crust and geophysical properties of overlying surficial soils, all combine to affect site response.

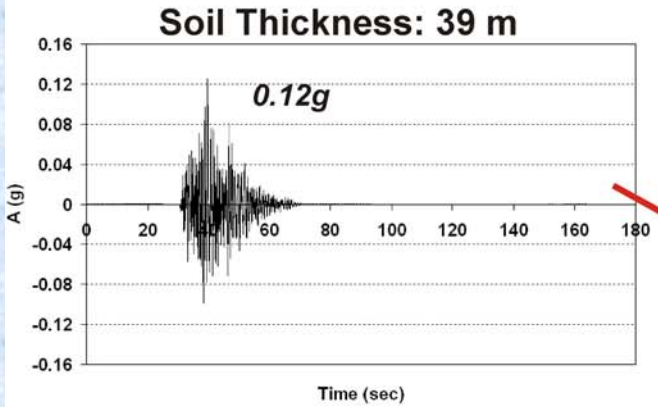


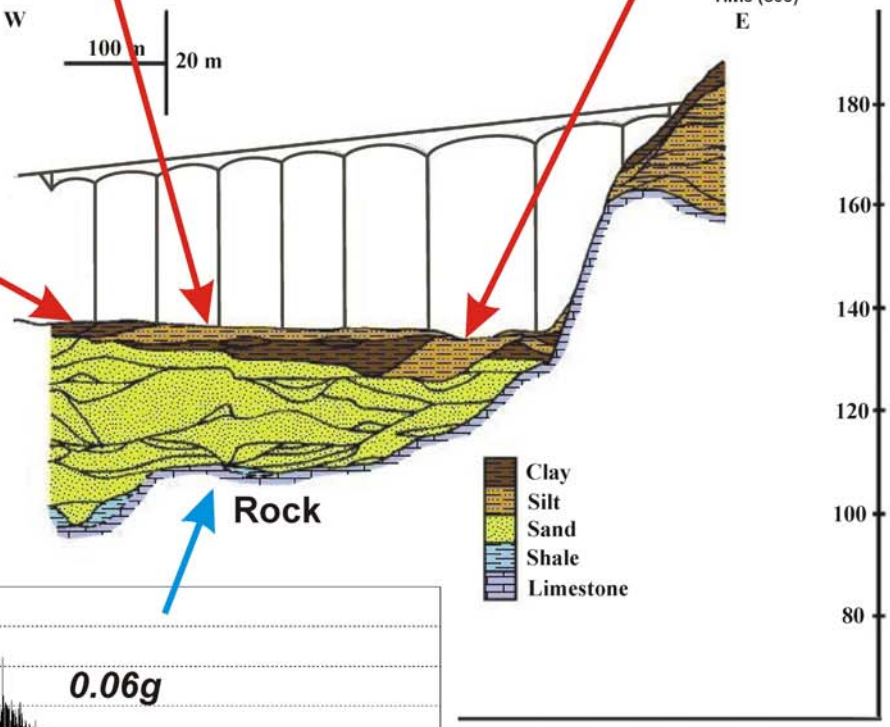
Site response is used to describe the fundamental period of vibration and lateral forces generated by a typical earthquake at any particular site.

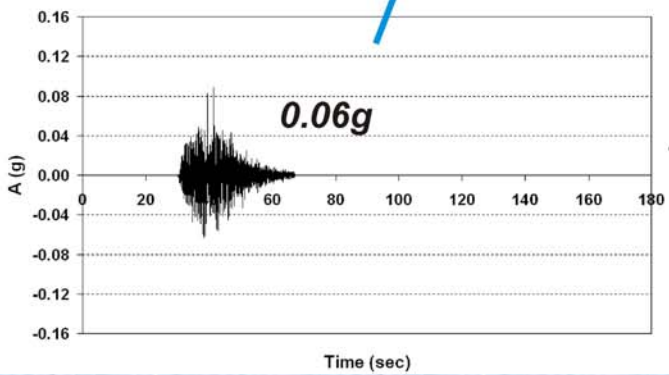
Effect of Soil Thickness on Peak Ground Acceleration (PGA)









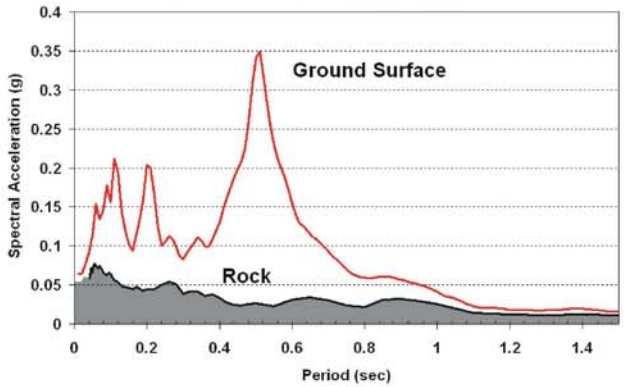


Magnitude 6.8 quake emanating from South Central Illinois at 110 km

Effect of Soil Thickness on RESPONSE SPECTRA

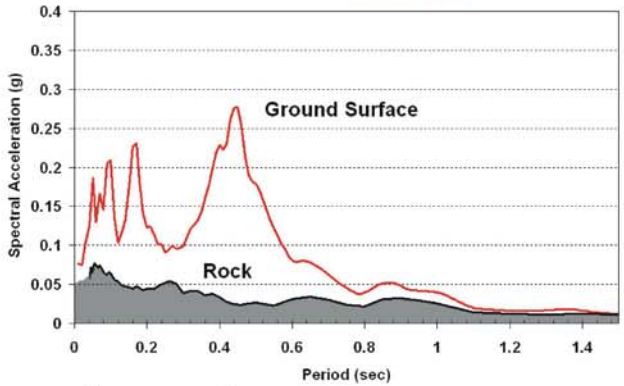
Soil Thickness: 25 m

Peak SA = 0.35 g
Peak Period = 0.51 sec



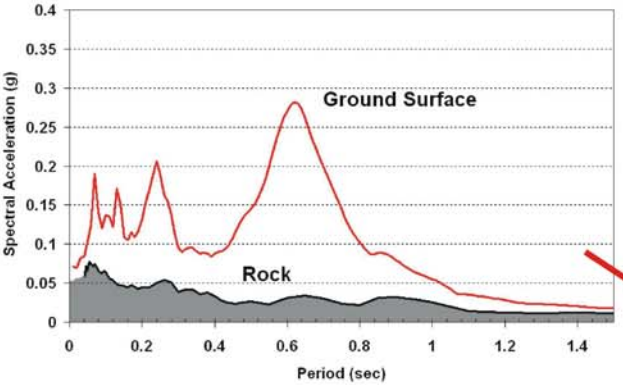
Soil Thickness: 22 m

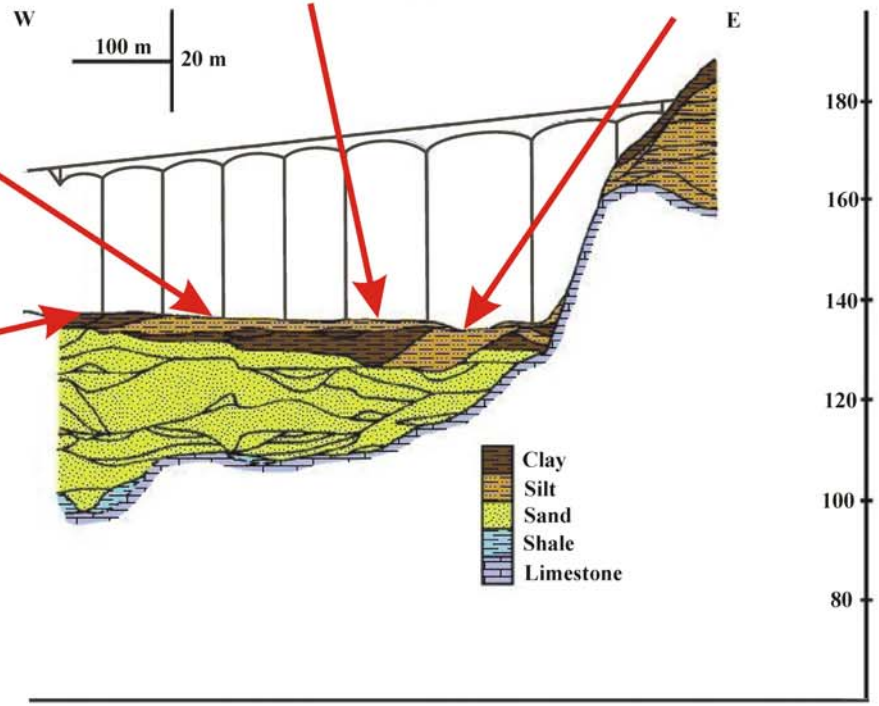
Peak SA = 0.28 g
Peak Period = 0.45 sec

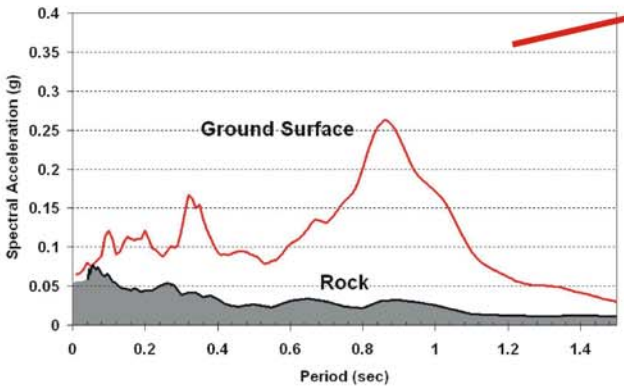


Soil Thickness: 28 m

Peak SA = 0.28 g
Peak Period = 0.62 sec

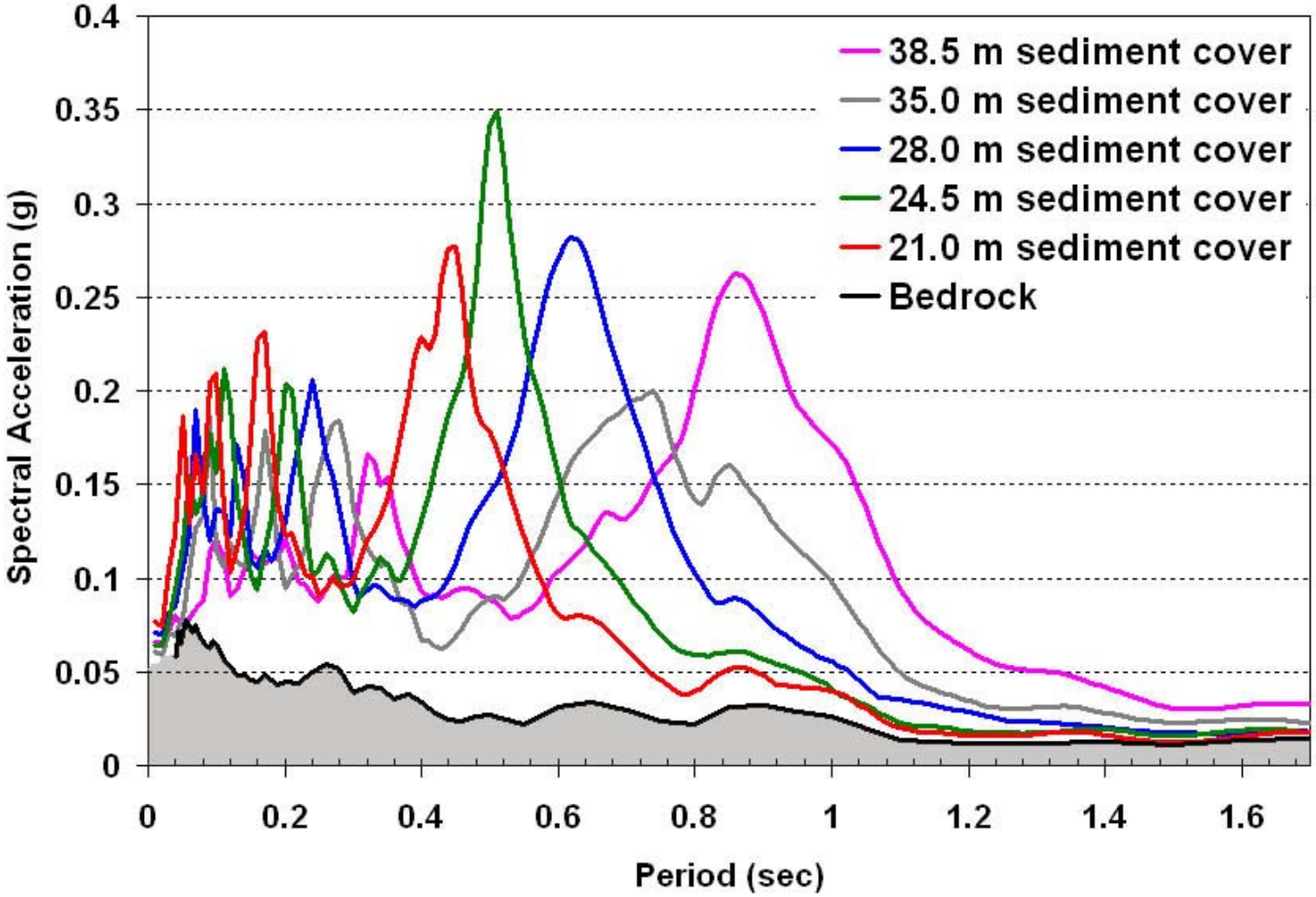






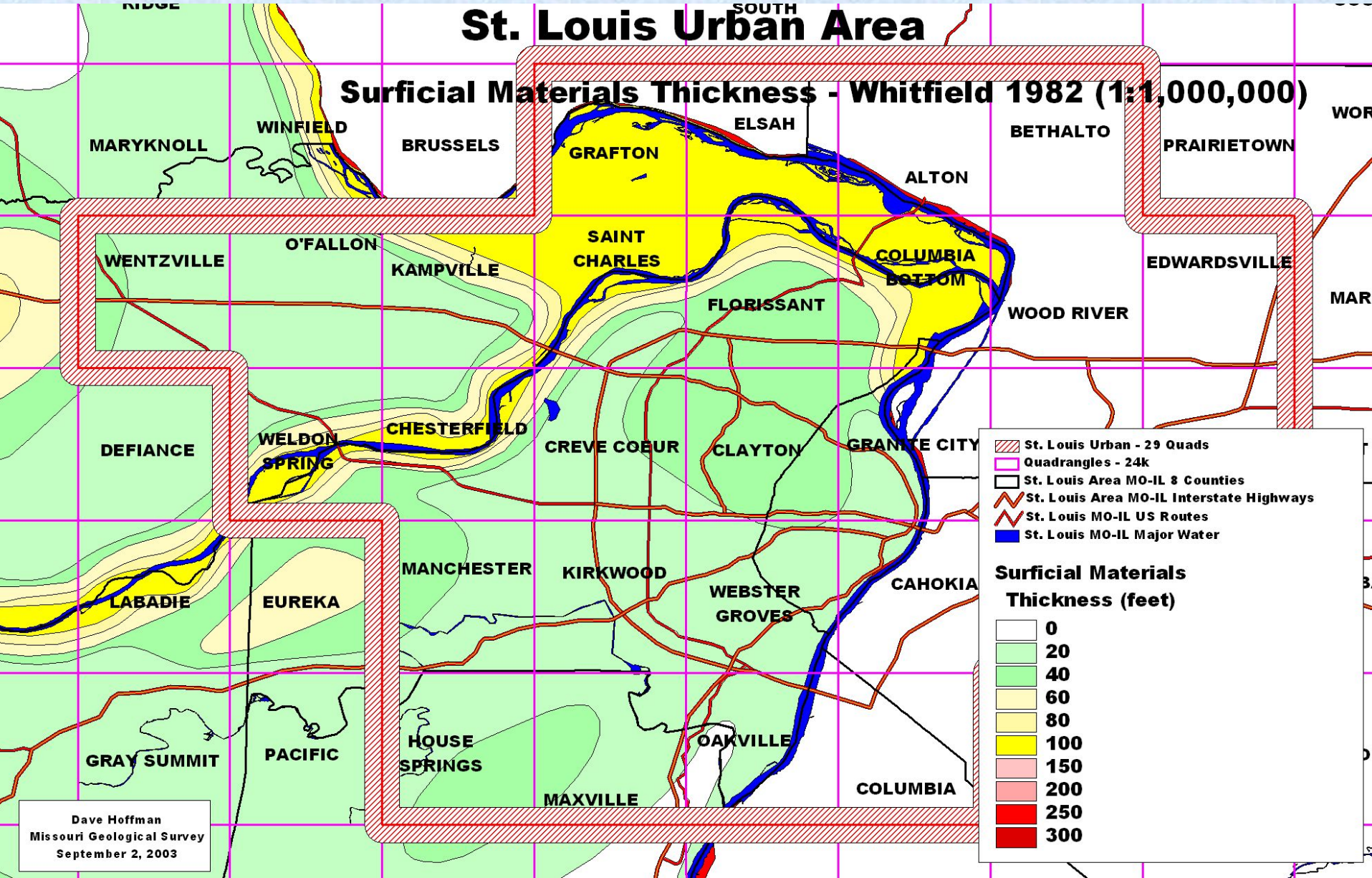
Soil Thickness: 39 m

Peak SA = 0.26 g
Peak Period = 0.87 sec



- **Variation in expected spectral acceleration with alluvial thickness in the St Louis, MO area**

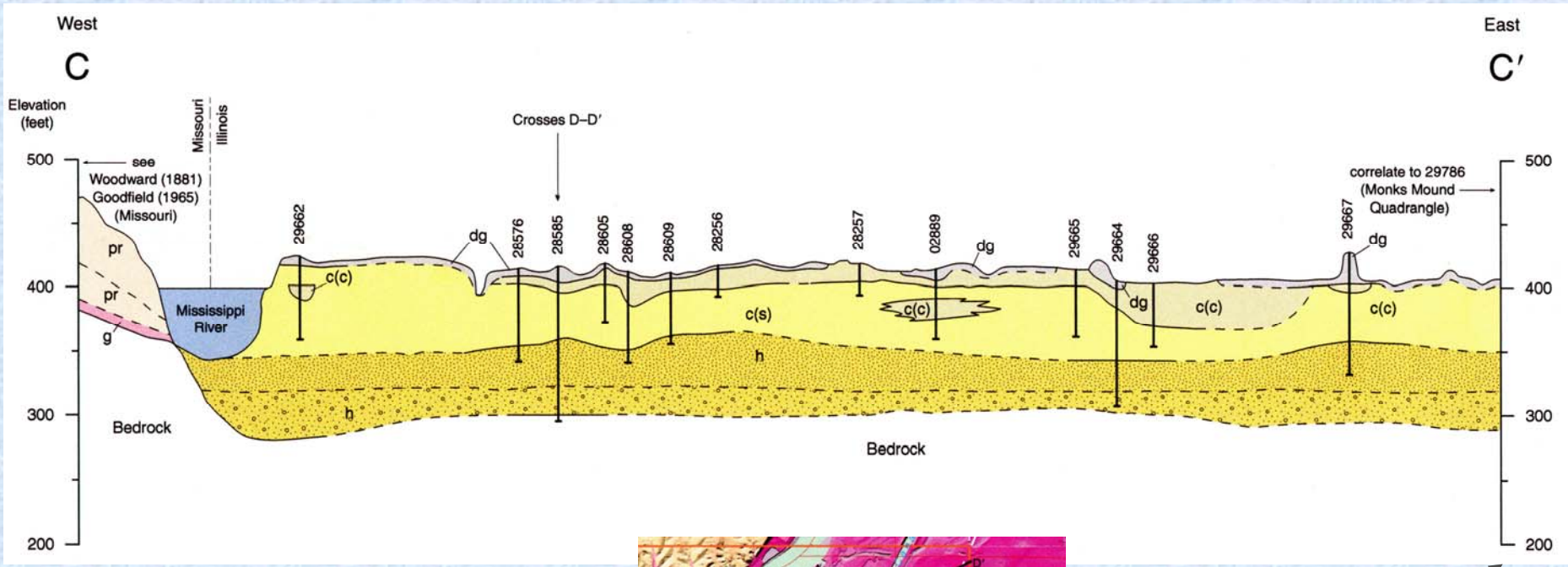
St. Louis Area Surficial Geology Thickness

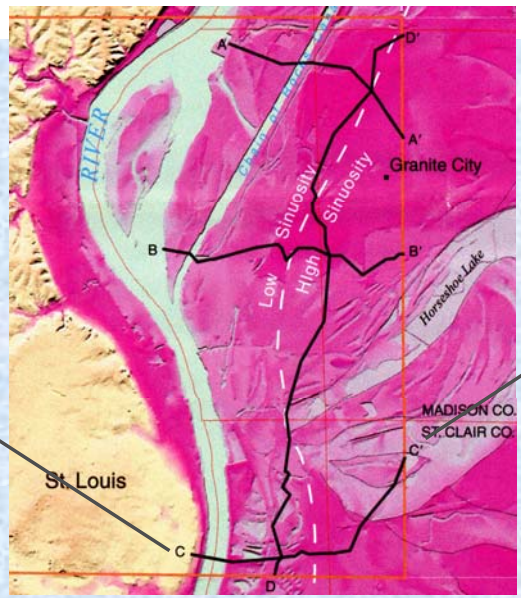


Question # 7

How Will We Construct Seismic Hazard Maps That Can Address the Spatial Distribution of Risk ?

Geological Cross-sections and Subsurface Interpretation





Cross section interpretation by Illinois State Geological Survey

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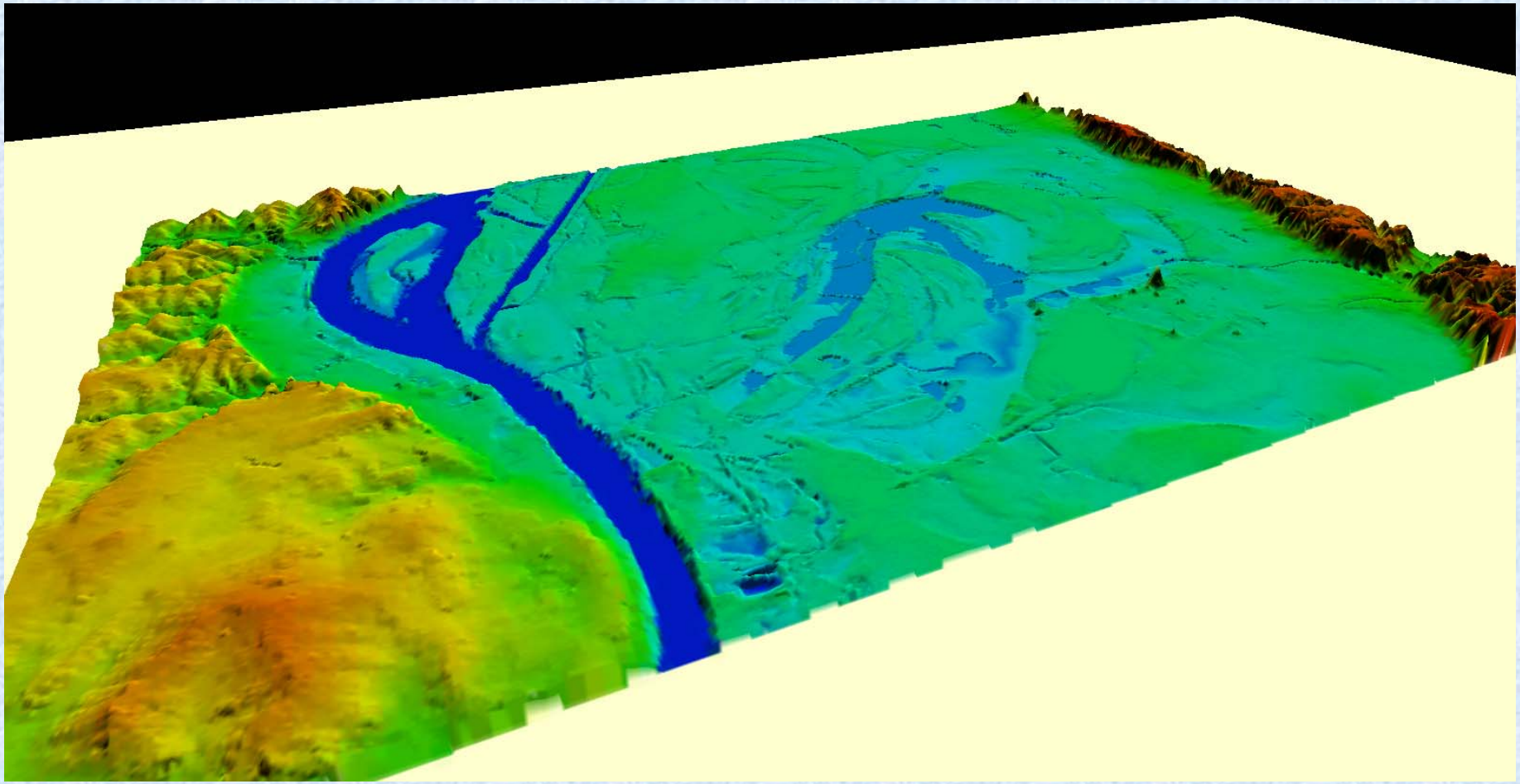
Digital Elevation Model of Granite City and Monks Mound Quadrangles

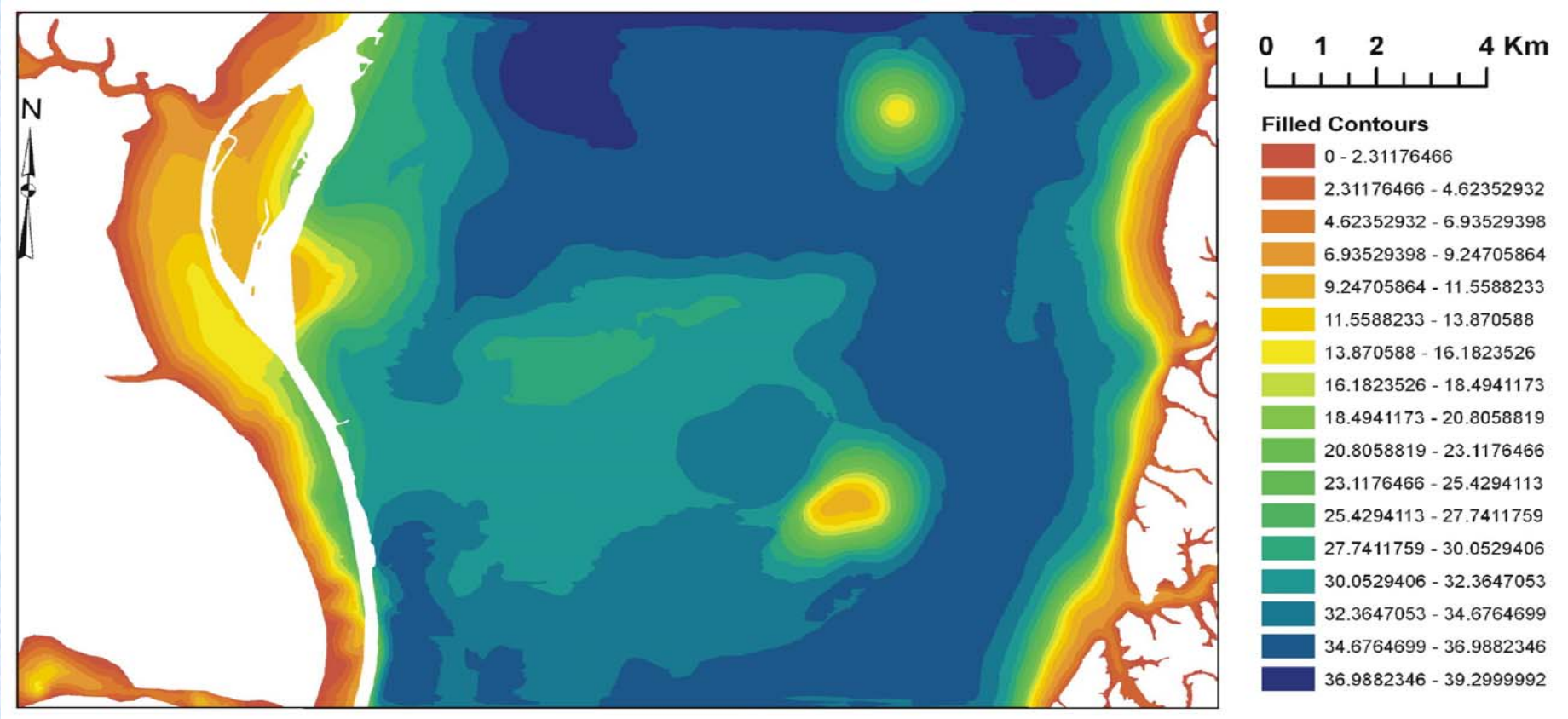


The underlying geology often controls the topography

Surficial Geology of Granite City and Monks Mound Quadrangles

12 kinds of unconsolidated sediment have been mapped on and adjacent to the Mississippi River flood plain.

Alluvium thickness distribution

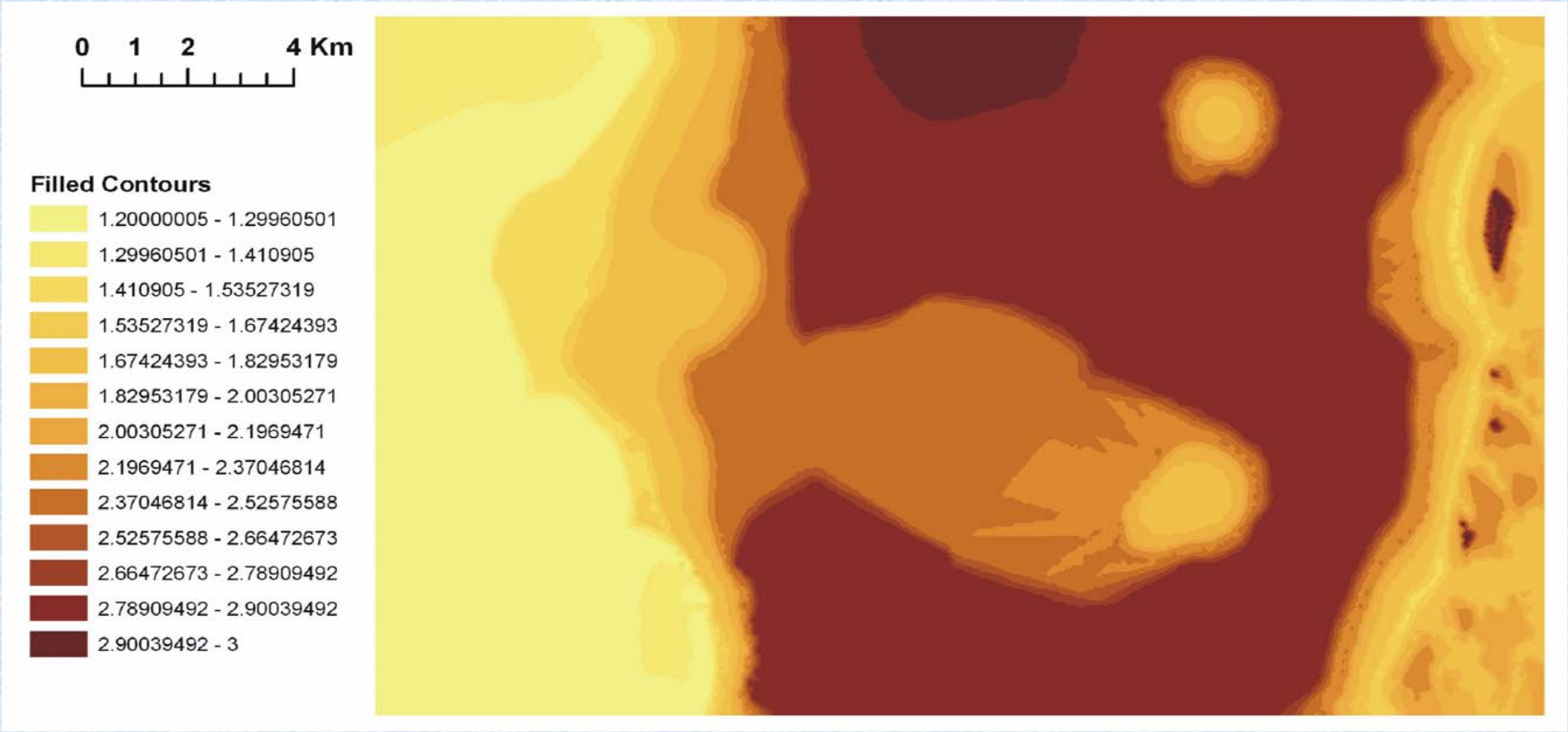


- **The depth of alluvium beneath the Mississippi River flood plain opposite the downtown area varies between 6 and 40 meters.**

Thickness of Wind-blown Loess

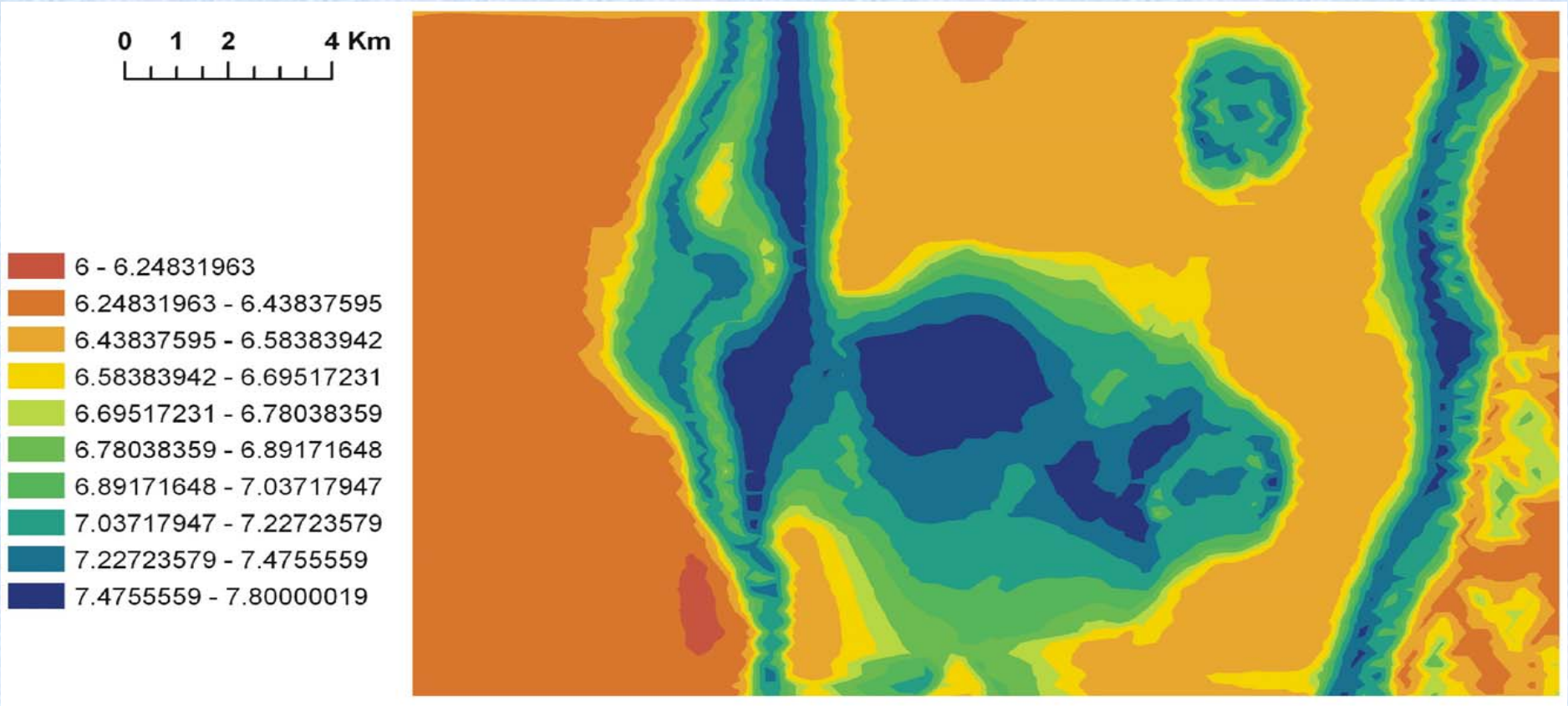
- Loess is wind-blown silt deposited at the end of the last glacial age. It is thickest near the bluffs on the Illinois side of the flood plain

Amplification of spectral accelerations at 1 second period from a Magnitude 6.8 earthquake at a distance of 224 km



- This is the frequency that would more or less match 10 story high structures. Magnification varies between 20 and 300% in the flood plain.

Distribution map of maximum spectral amplifications for a Magnitude 6.8 earthquake at a distance of 224 km



- **The highest amplifications occur along the edge of the flood plain and where the alluvium is 10 to 30 meters thick.**

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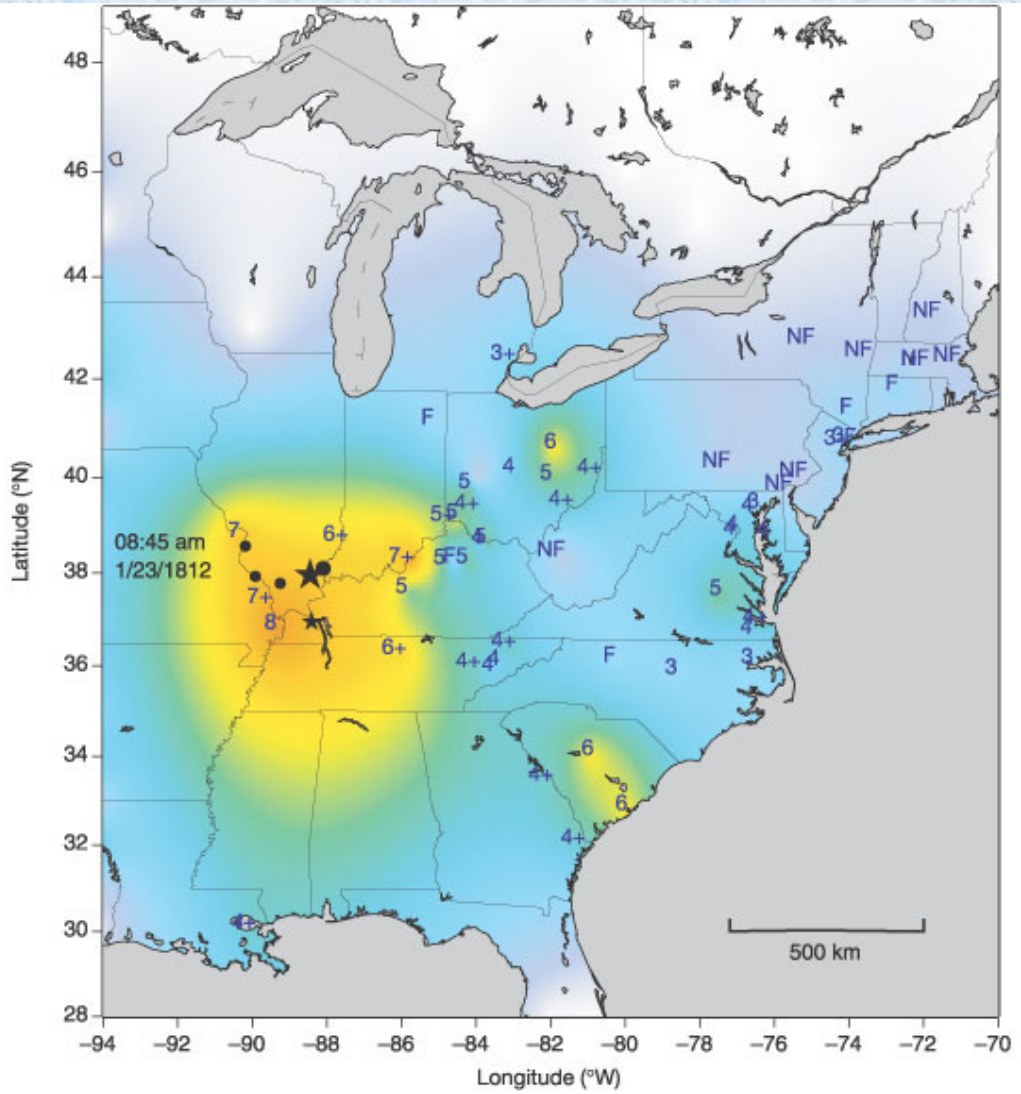
Radiating Patterns

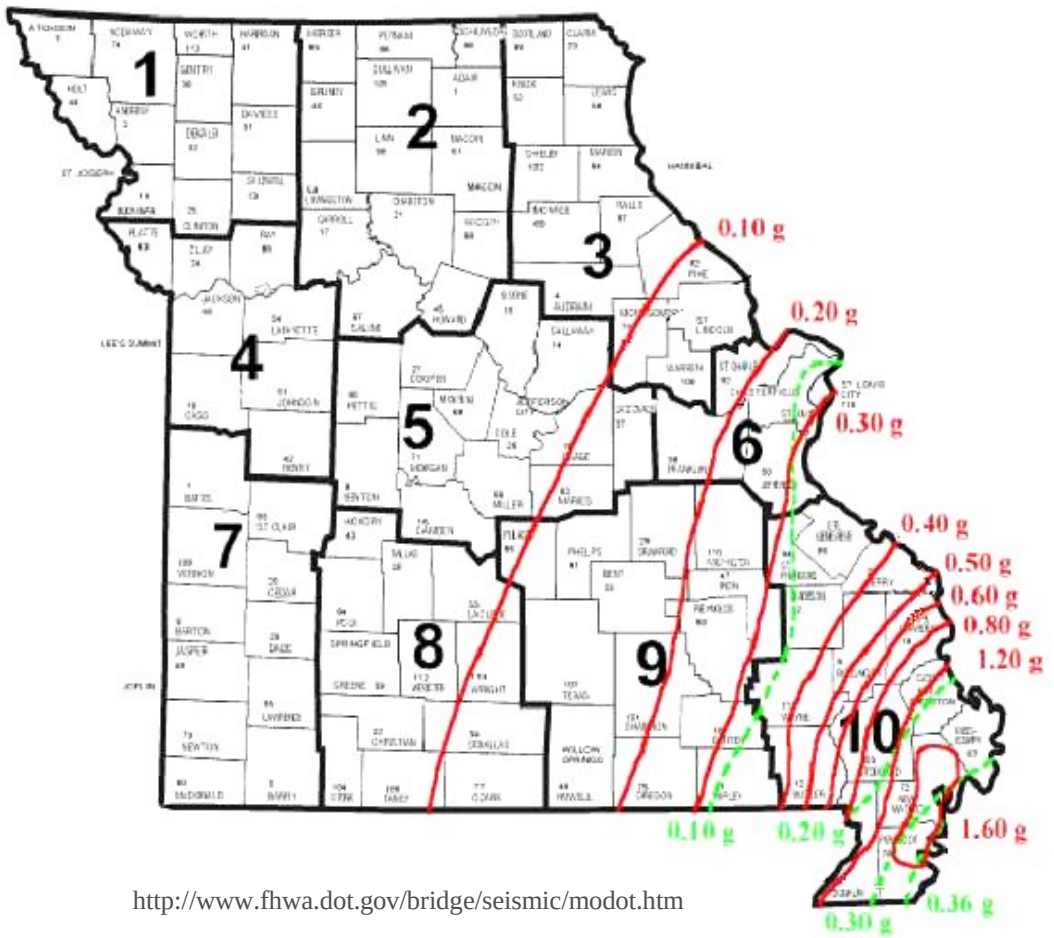


Perceived shaking	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
Potential damage	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
Peak acceleration (% of *g*)	<0.17	0.17–1.4	1.4–3.9	3.9–9. 2	9.2–18	18–34	34–65	65–124	>124
Peak velocity (cm s^{-1})	<0. 1	0.1–1. 1	1.1–3. 4	3.4–8. 1	8.1–16	16–31	31–60	60–116	>116
Instrumental intensity	I	II–III	IV	V	VI	VII	VIII	IX	X+

- Conventional assumptions regarding shaking intensity have assumed radiating patterns of shaking intensity, emanating from the New Madrid area

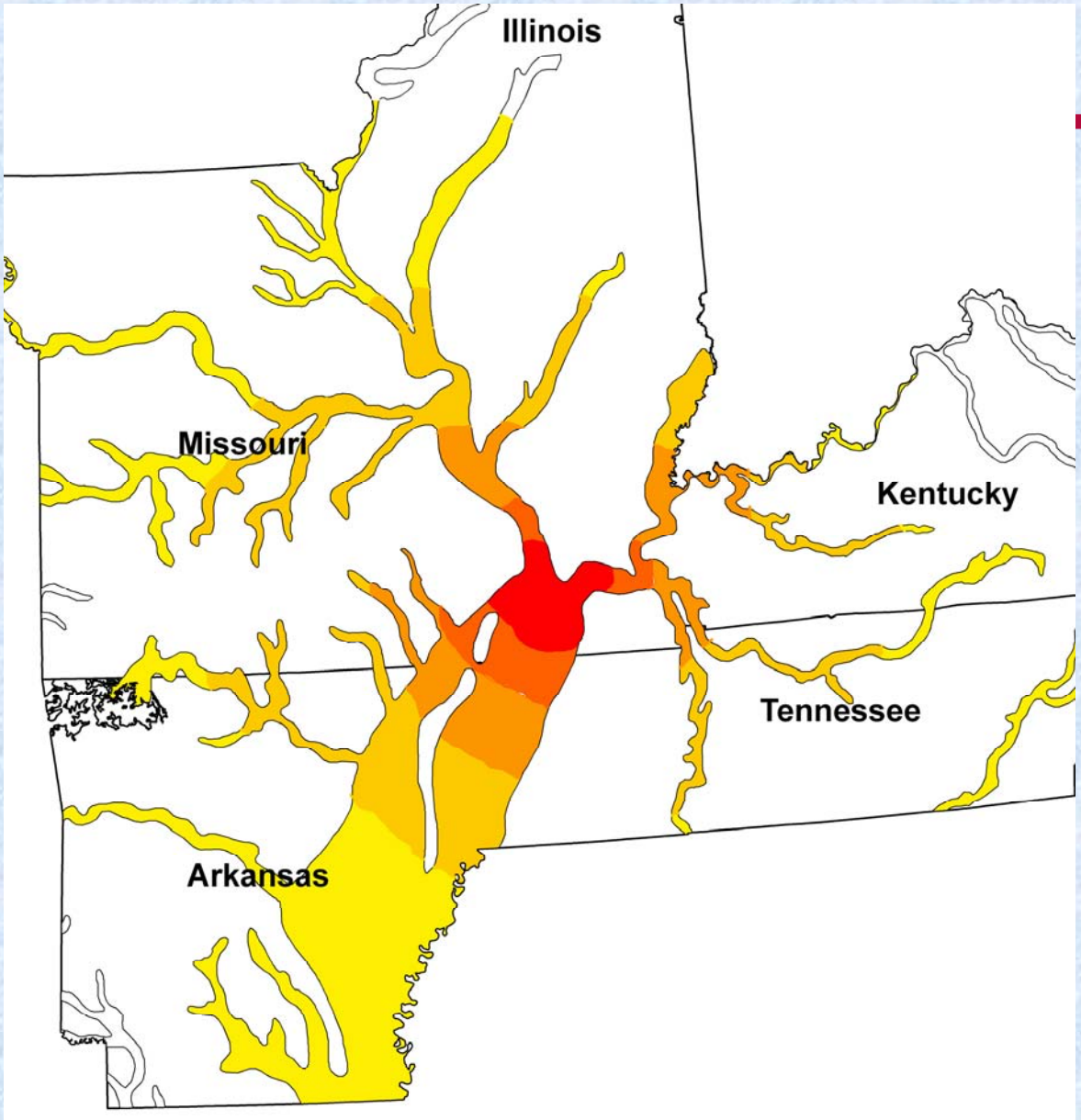
MODOT Standards for Seismic Design Radiate from the New Madrid Zone

- **Green lines** are ASSHTO design parameters using USGS 10% Probability of Exceedance, adopted in 1988
- **Red lines** are new design parameters using 1996 USGS 2% Probability of Exceedance values adopted under federal mandate in 2005



http://www.fhwa.dot.gov/bridge/seismic/modot.htm

Future Earthquake Hazard Maps



- The earthquake hazard map of tomorrow will likely look something like this; highlighting those areas underlain by unconsolidated alluvium, along major river channels

Question #8

So, What Would Be the Economic Impacts of a Magnitude 6.0 to 6.8 Earthquake....
if it happened tomorrow?

What would get whacked in a Magnitude 6.5 earthquake ?

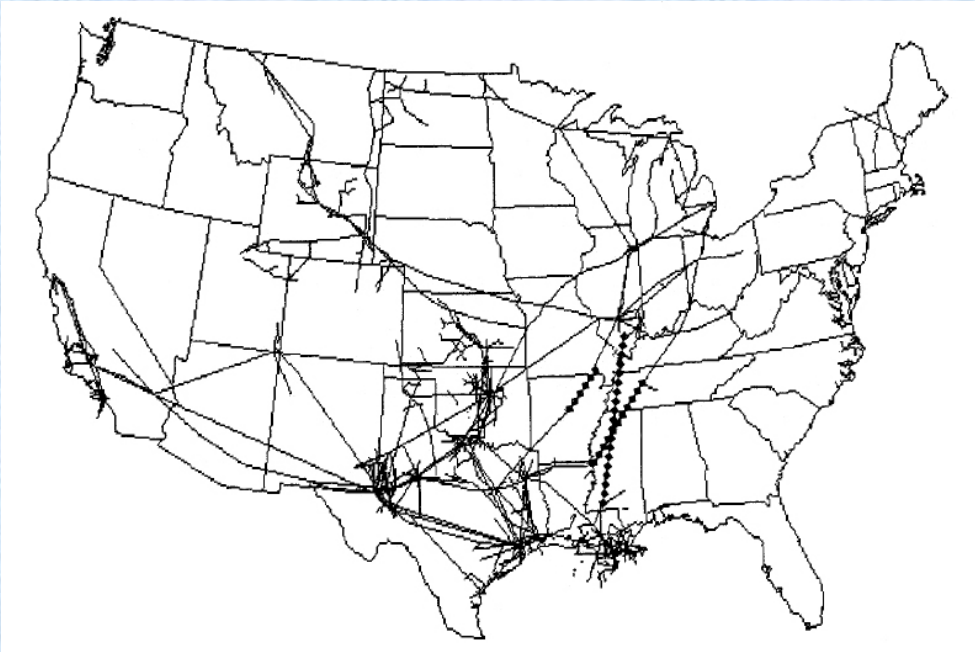
- Structures sitting on alluvium and other unconsolidated materials deeper than about 15 meters (50 feet)
- Structures or improvements situated on filled ground, where fill + alluvium thickness > 15 m
- Taller structures, with fundamentals periods of vibration > 0.70 seconds
- Embankments placed on unconsolidated alluvial materials, where fill + alluvium > 15 m thick
- Tall structures (>8 stories) situated on old soil-filled basins greater than 25 to 35 m thick

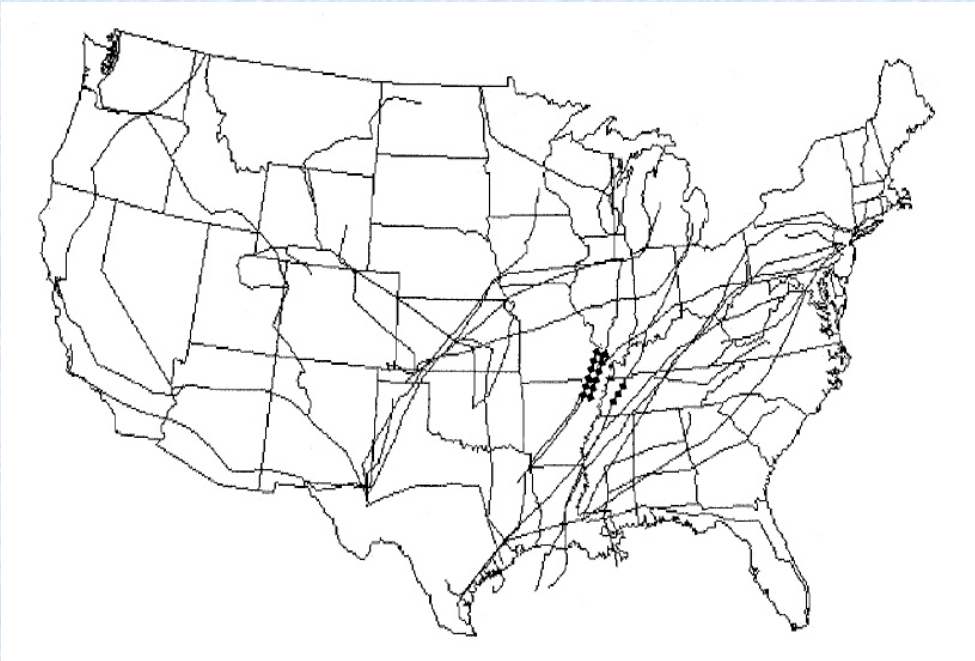
Critical Infrasructure that would likely be impacted by a M 6.5 earthquake

- Multiple span bridges; in particular, tail spans
- Buried oil, gas, coal slurry, water, and sewer pipelines crossing flood plains
- High voltage (tall tower) transmission lines crossing flood plains
- Power plants situated along major river channels
- Water treatment and sewage treatment plants along channels
- Underground storage tanks

Non-critical transportation infrastructure elements that would likely be affected

- Barge traffic on navigable channels
- Fuel pumps made inoperative by loss of electricity
- Drainage ditch network in reclaimed flood plains
- Railroad corridors
- Interstate and secondary highway network
- Airport runways, and fuel handling facilities
- Municipal off-stream water storage

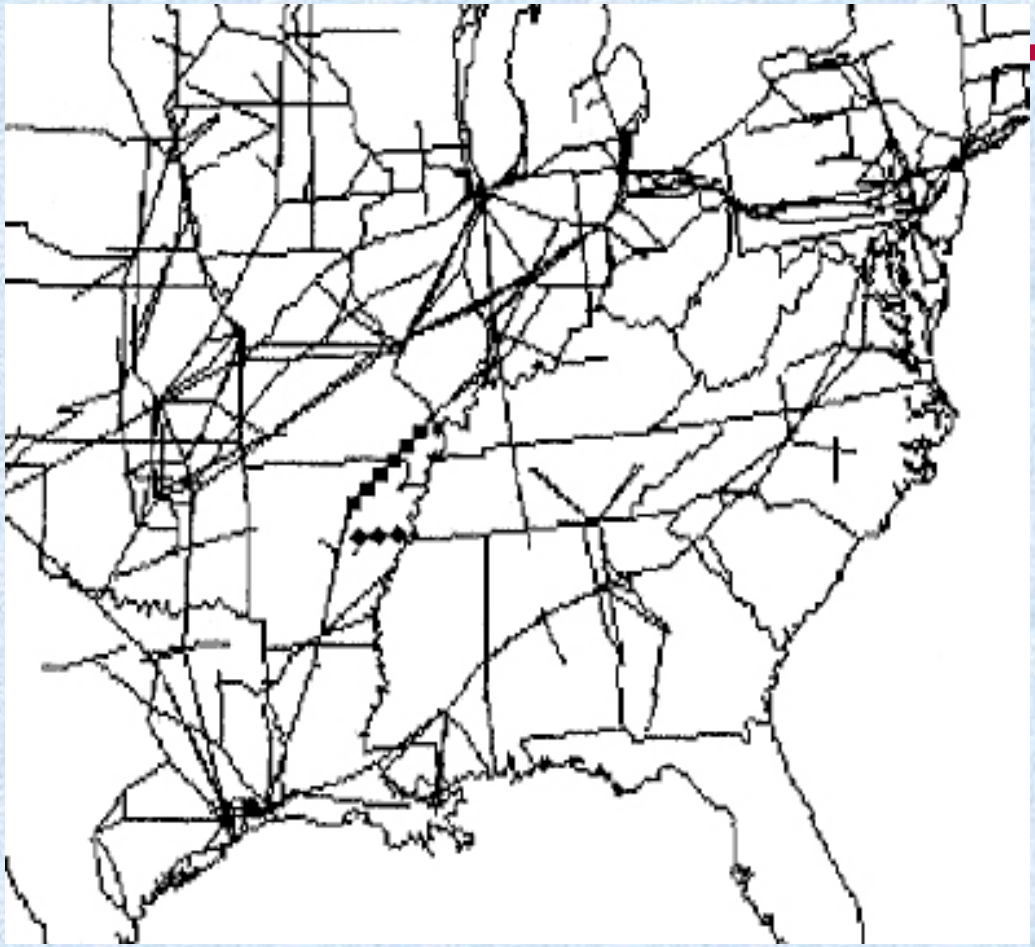




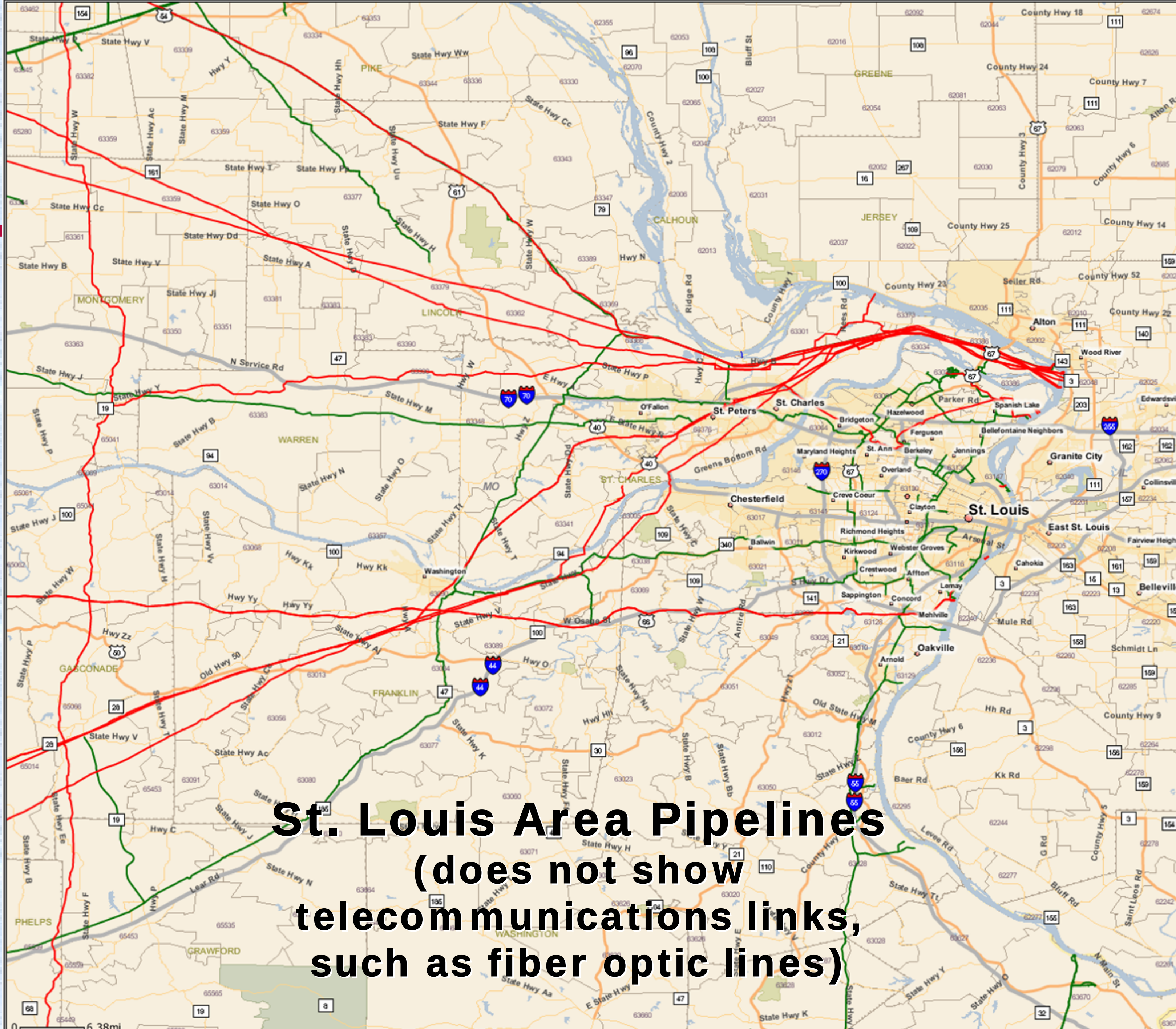
Crude Oil and Natural Gas Pipelines

- Upper map shows the largest crude oil transmission lines in the United States.
- 5 of the 6 main lines crossing the Mississippi River could be compromised in a M. 6.5 earthquake emanating from the NMSZ
- Lower map shows the largest natural gas trunk lines in the United States
- 4 of 9 crossing the Mississippi River could be compromised in a M. 6.5 quake

Major Refined Oil Products Pipelines



- Refined product service lines convey petroleum products between refineries and major metropolitan markets, from which these products are distributed.
- Significant disruption of the domestic refined product distribution lines has never occurred
- The ‘shock factor’ of fuel unavailability would be unprecedented, necessitating rationing



St. Louis Area Pipelines

(does not show telecommunications links, such as fiber optic lines)

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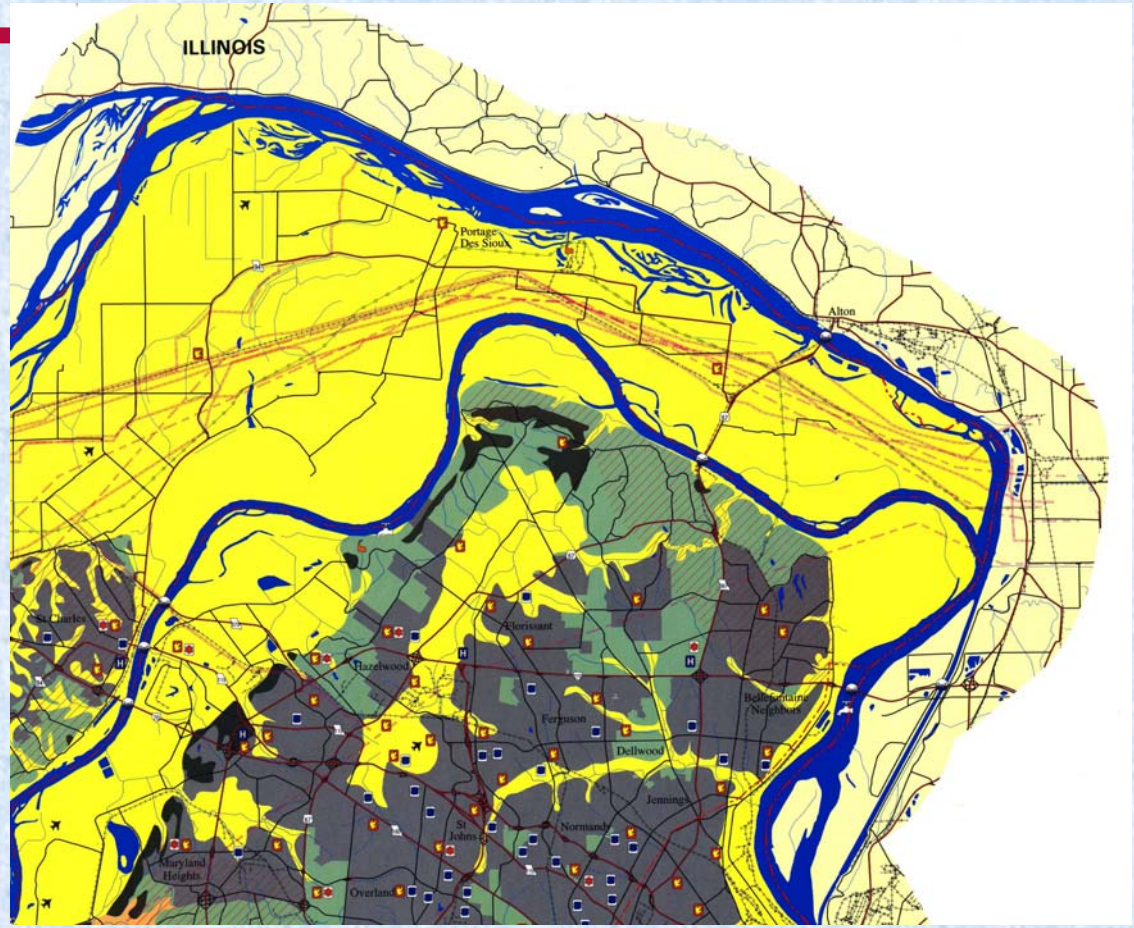
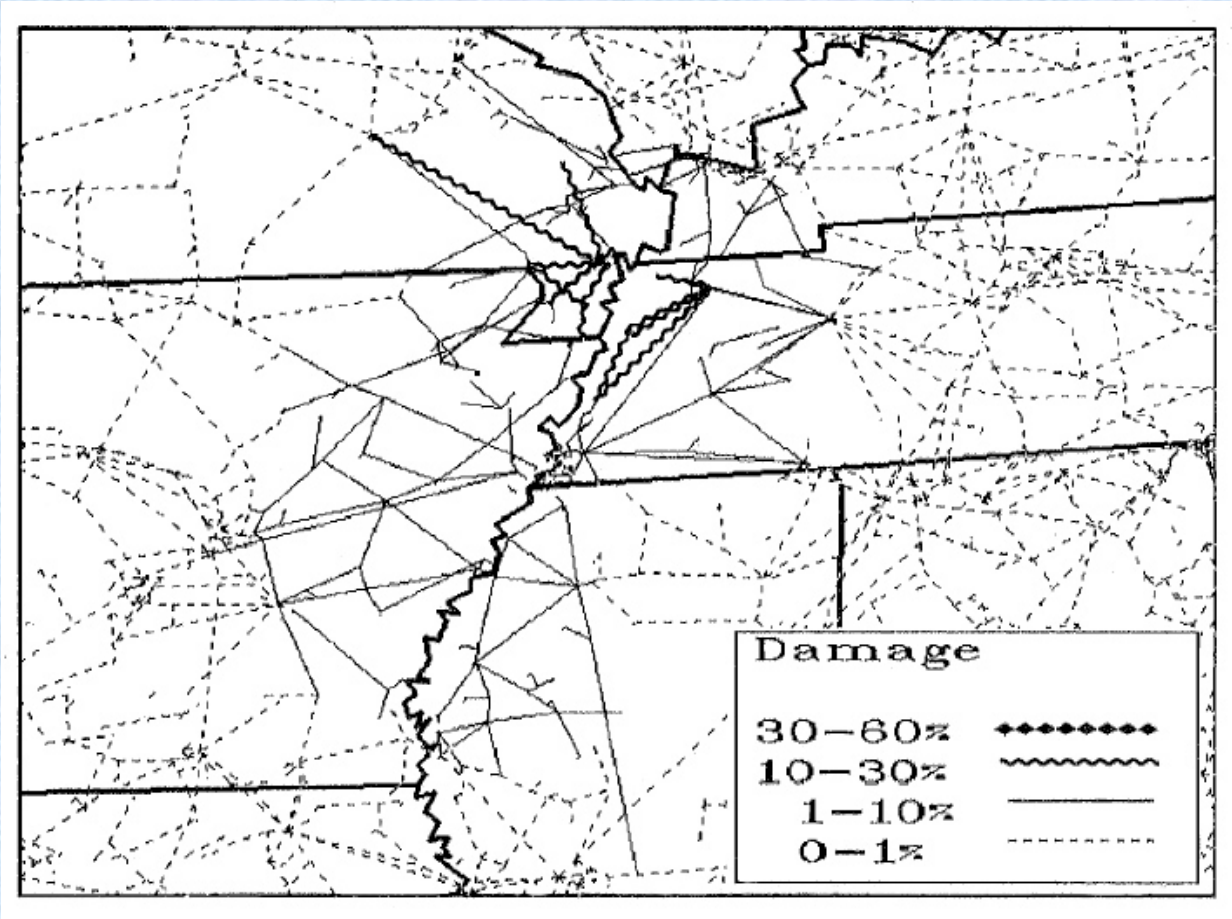
Corridor of Vulnerability: Pipelines in St. Charles County

- There are 7 major pipelines crossing the Mississippi River in eastern St. Charles County
- All of these lines are buried in the loose unconsolidated sediments of the Missouri-Mississippi River flood plain most susceptible to liquefaction
- Spillage would contaminate the municipal water supply for St. Louis



High Voltage Electrical Transmission Lines Criss-Crossing the NMSZ



- Transmission towers founded on >15 m of unconsolidated sediment in major flood plains can be expected to experience foundation bearing failure, dropping the lines
- Reconstruction of downed towers will be expensive and time-consuming

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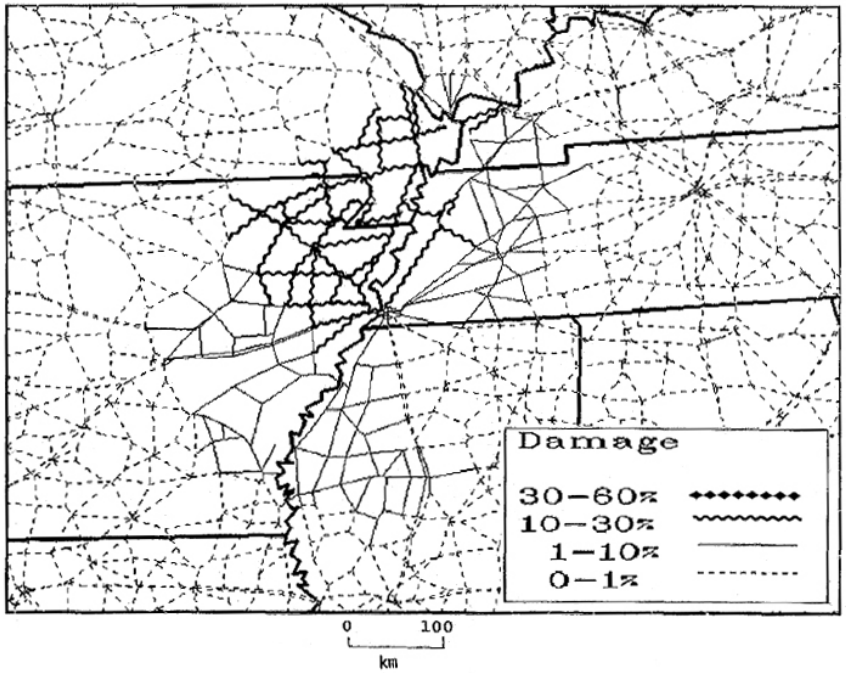
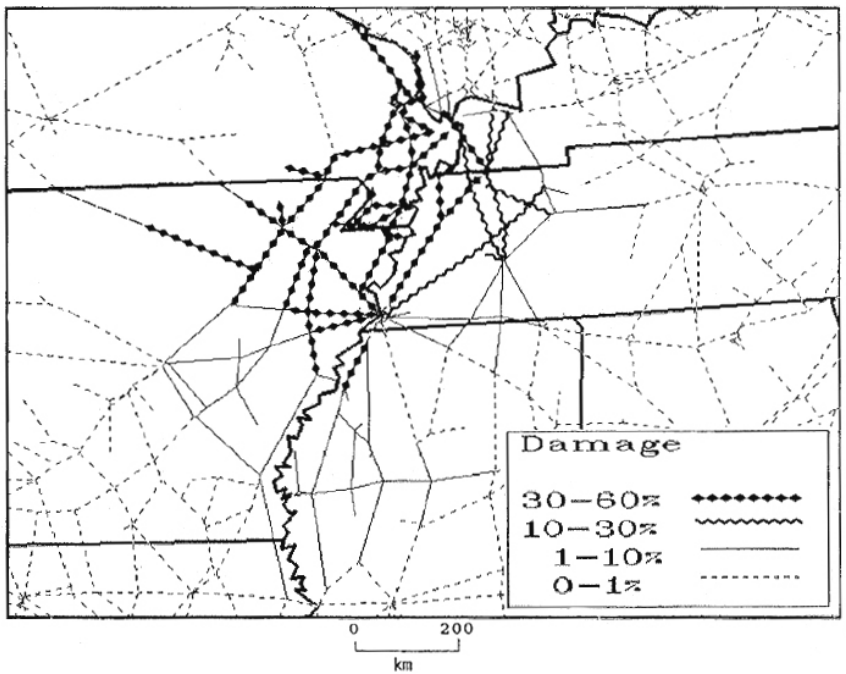
Highway and Railway Bridges

- Only one major highway bridge south of St. Louis has been designed to resist earthquake ground motions
- The newer highway bridges in St. Louis, constructed since 1995, have been designed for seismic loads
- The I-64/US 40 double deck section in downtown St Louis is being retrofitted for seismic loading
- None of the railroad bridges have been designed or detailed for seismic loads



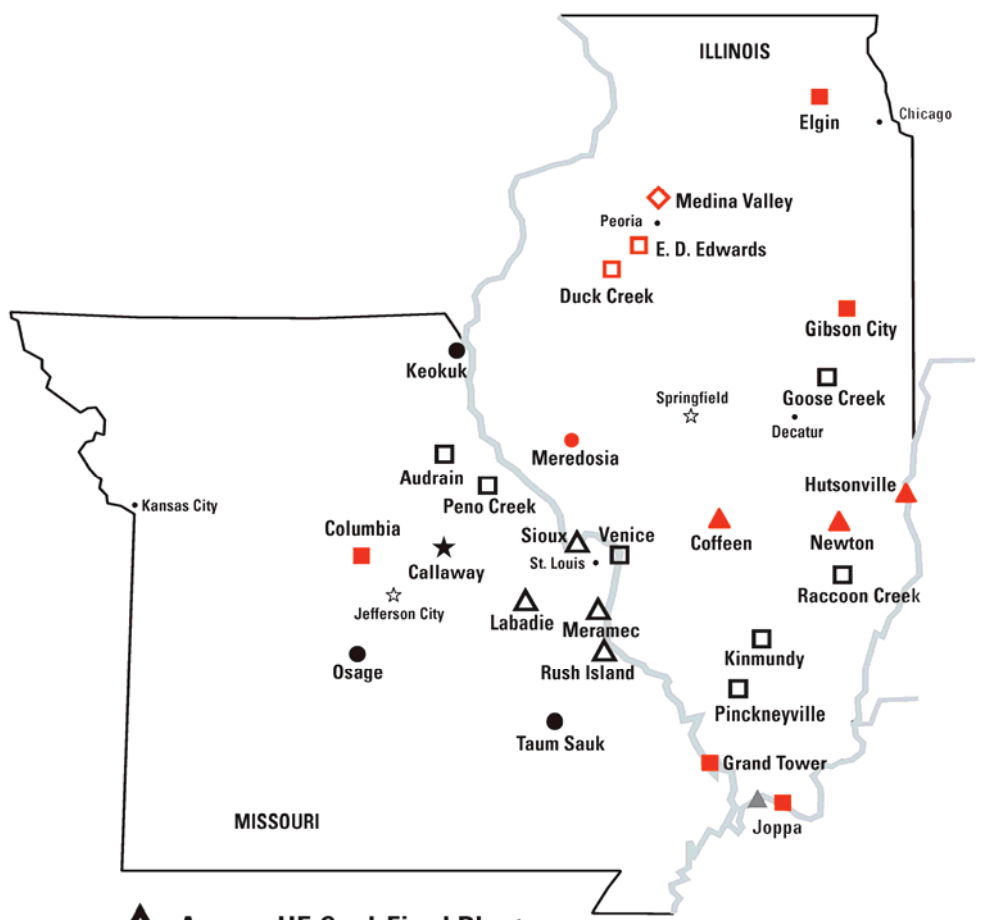


Damage to Highways and Railroads

- Upper plot shows levels of expected damage to highways in the NMSZ area
- The lower plot shows expected damage to the railroad network criss-crossing the NMSZ
- Rail and truck traffic would have to be re-routed to the north and south while restorative work is completed
- Data from FEMA (1994)

Many Power Plants located along rivers

- Most fossil fuel and nuclear power plants are located on unconsolidated alluvium;
- The greatest number of plants are located along the Mississippi and Missouri Rivers
- The New Madrid power plant is shown at upper left



AmerenUE Power Plants

- Impact of power generation loss depends on a number of factors, including the time of year an earthquake strikes.
- Biggest impacts would be on stalling disaster recovery, and some short term overloading of the surrounding transmission grid
- Recovery time is greatest single impact on economic loss

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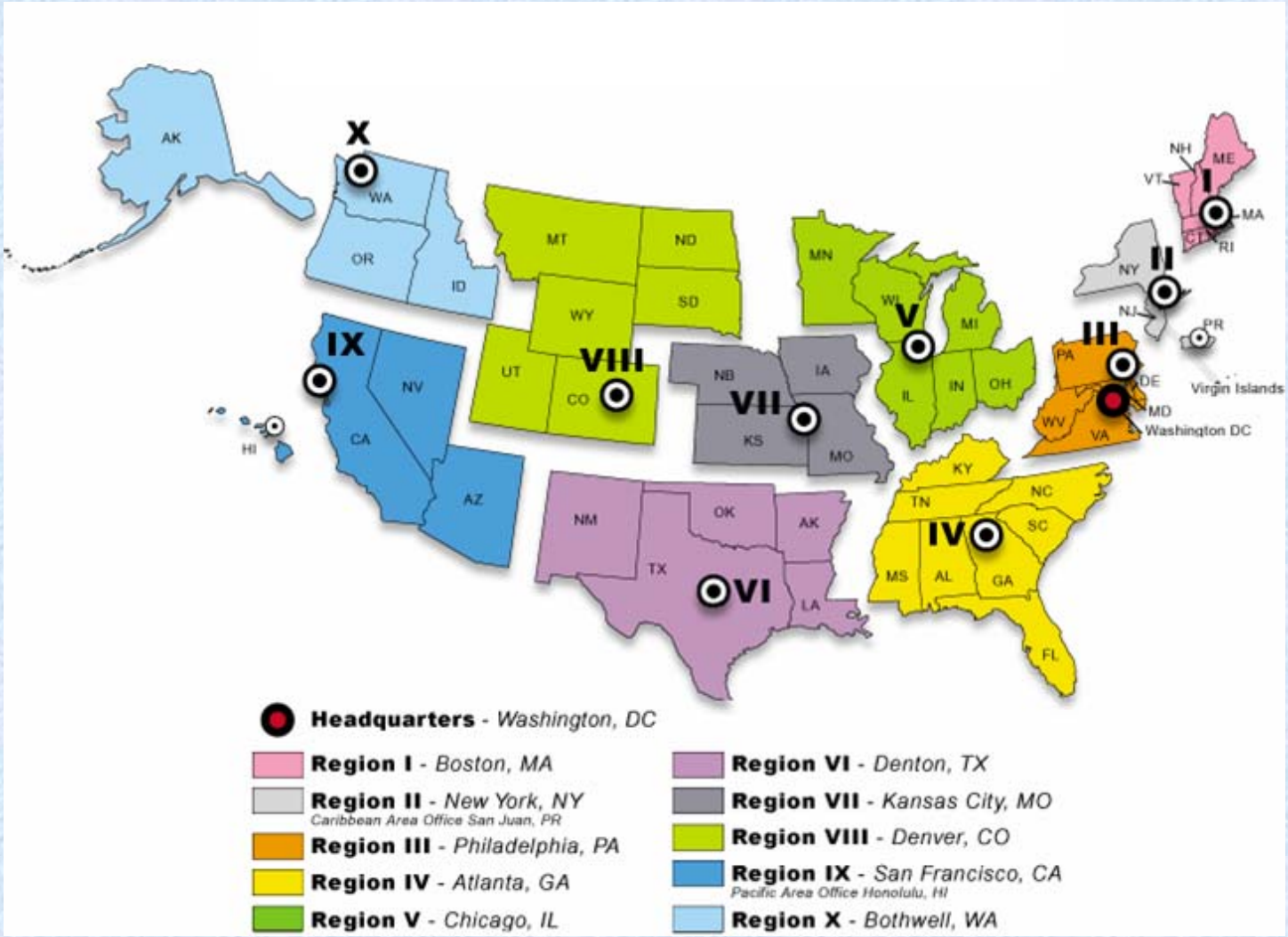
Question # 9

How does the 1) Speed of Recovery; 2) Ease of Recovery; 3) Time Span of Recovery; and, 4) Public Perception of Recovery Success Influence the Economic Impact of the Disaster ?

Public Confidence: Who will be in charge of the recovery, and manage it wisely ?

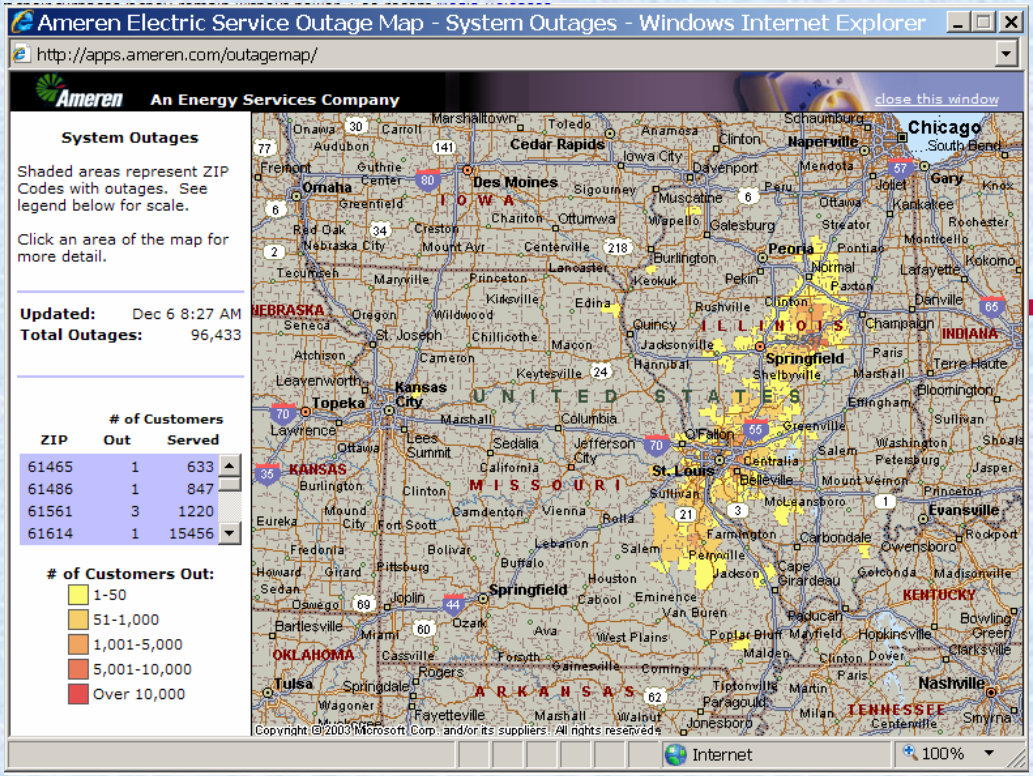


Answer: four separate DHS/FEMA Regions share jurisdiction in the New Madrid Seismic Zone

DISASTER PLANNING ESSENTIAL for RECOVERY

- Local government agencies have to develop coherent disaster plans, posted on the Internet for everyone to see and understand, especially teachers (e.g. 1962 Cuban Missile Crisis)
- Those same agencies need to conduct periodic disaster response exercises
- Every person who will be tapped in an emergency needs to know what will be expected of them; such as bus drivers, medical personnel, law enforcement, etc.
- Disaster plans need to include contingencies for extended loss of: power, vehicle access, fuel availability, sanitation, communications, and lifeline support
- Calling FEMA doesn't solve any of these problems immediately, it only sets wheels of support into motion; e.g. "calling the cavalry"

Restoration of the Power Grid



- In today's culture, the economic impact of being without electrical power is stupendous
- We can't get along for more than a few days without electricity
- Businesses forced to relocate rarely return to their original pre-disaster locations, because of the cost

Portage des Sioux power plant

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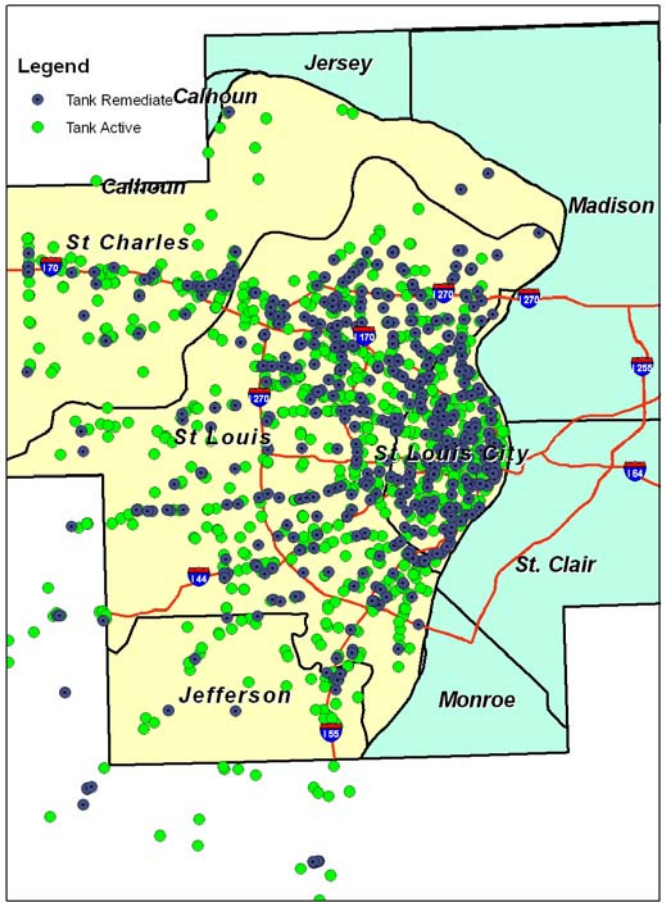
Hidden Costs Lurk Everywhere

- One of the hidden costs of earthquakes is their impact on retail business
- The 1989 Loma Prieta and 1994 Northridge earthquakes saw a record number of business failures occur in the wake of these events. Impact lasted for 10 years.
- Retail businesses cannot survive more than about 6 weeks without meaningful cash flow
- 70% of the downtown businesses in New Orleans has been lost since Hurricane Katrina
- The economic impact will likely extend over several decades.

Underground Storage Tanks



- Underground fuel storage tanks tend to be lifted out of the ground during earthquakes, if situated close to the permanent groundwater table
- This upward movement usually compromises the feeder connections, negating serviceability
- These leaks can also promote costly clean-ups

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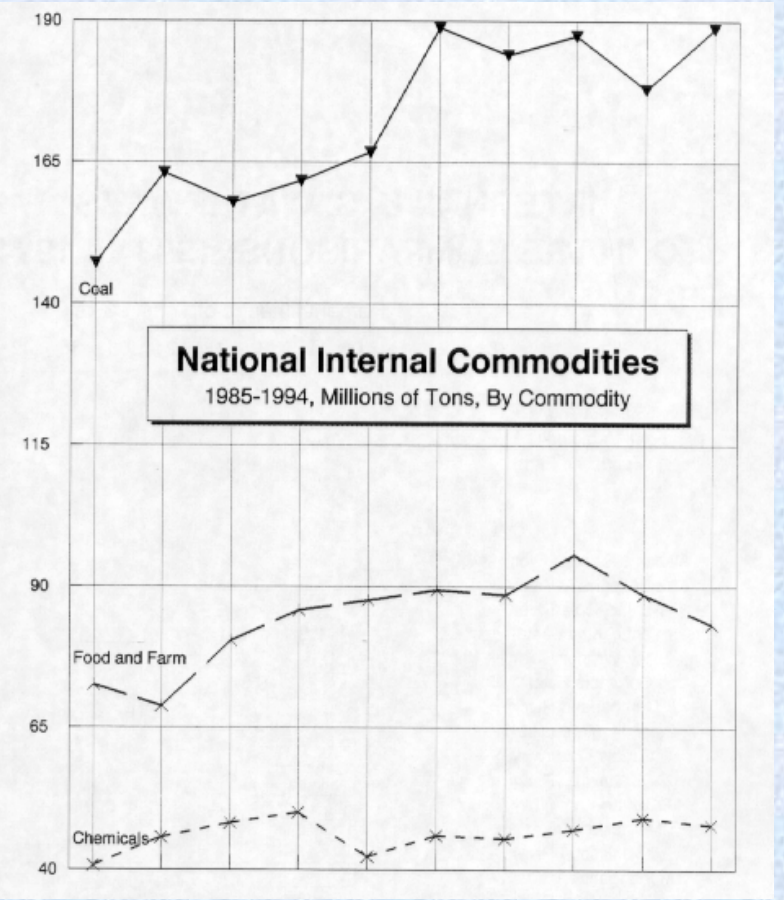
Above-Ground Storage Tanks

• Above-ground storage tanks are also susceptible to earthquake-induced distress, especially partial liquefaction of their foundation soils, shown here.

Barge Traffic



- **Waterborne commerce along the Mississippi River fluctuates with the cost of diesel fuel; but continues to rise through each decade.**
- **Barges provide an environmentally clean alternative (much lower CO_2 emissions per ton-mile) and redundancy from rail and truck transport**

Question # 10

Is There Anything in Our High Tech Arsenal that Can Mitigate Some of the Doom and Gloom?

Identifying Critical Facilities and Components for Disaster Response

- Cellular phone transmission towers
- Fiberoptic data transmission cables
- Redundancy in electrical power grid
- Alternate routes and fuel sources for emergency responders
- Alternate route packaging for commerce
- Realize limitations of shelters, e.g. Louisiana Superdome; London underground during World War II
- Sensor systems using GPS location fixed motes will provide monitoring feedback in future

Lack of Advance Warning Limits Evacuation Mobility

- Unlike atmospheric events, such as hurricanes, **earthquakes strike without warning**. There is no evacuation ahead of the actual event

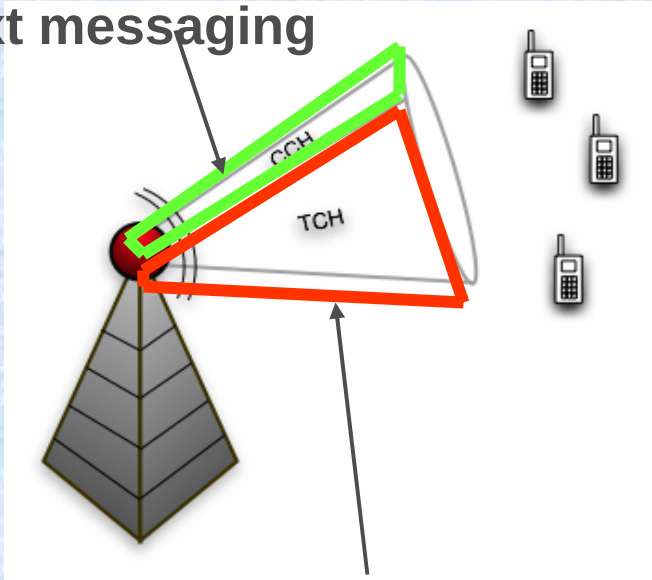
- Gasoline will be unavailable in areas without electrical power

How Can Stranded People Communicate their Peril ?

- We can't send in Army helicopters to rescue stranded victims unless we know WHERE they are
- We can expect that an earthquake will take down a fair number of the cellular repeater towers
- We can also expect that telephone transmission systems will be overtaxed
- Text messaging and GPS receivers will soon emerge as the preferred method of hailing assistance in the wake of disasters, natural or man-caused.

Text Messaging will play an increasing role in disaster response

Amount of bandwidth needed for text messaging



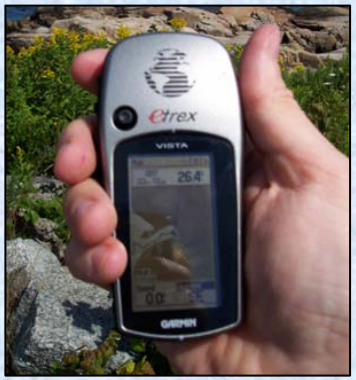
Amount of bandwidth needed for voice calls

- Text messaging does not require as much bandwidth as voice calls.
- If low reception, users are more likely to have a text message go through than a voice call.

http://www.smsanalysis.org/

The future is here: Communicating with the Outside World After a Disaster

- GPS-equipped phones can transmit user's location when calling 911.
- But what if they can't get through? Cell towers may be down.
- They may still be able to text message coordinates or an interstate mile marker taken from phone or external GPS device, if not all towers are completely down.



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People have to be educated about what to do in specific scenarios

- **Extreme events, like combat, are always treacherous because most responders don't have first-hand experience with such catastrophes**
- **Mass evacuations are difficult to plan for without recurring exercises and a through program of public education. Contrast 1960 Chile quake with 2004 Sumatra quake**
- **You're lucky to get 2/3 of any populace to evacuate an area ahead of a natural disaster, if it is the first exposure to the natural peril (1963 Taal Volcano eruption).**
- **People with children more prone to leave than those without children.**

Importance of Exercises and Familiarity with the Real Thing

- Emergency responders should be provided with appropriate training to develop realistic expectations: "*expect the unexpectable*", learn how to innovate (e.g. San Francisco's loss of fire mains in 1989)
- Teaching most effective when done by other responders who have personal experiences to share, lessons learned (just like combat)
- Realistic training is most crucial aspect of preparedness (e.g. military use of live ammunition; fire fighters practicing on real fires).
- Sending responders to other agency's disasters is probably our single best training option; there is no education like experience

Question # 11

So, What Will Be the Cost?

@ to RECENT FEMA studies.....

- A 1994 study estimated that a repeat of a M 7.5 to 7.7 event on the New Madrid Seismic Zone would cause upwards of **$30 billion** in damage
- A 2006 study estimated that a M 7.7 event on the southwest arm of the NMSZ would cause $200 million in hard damage to Memphis alone, and **$50 to $70 billion** in overall damage to the affected region
- Comparisons between projected damages and actual damages are extremely complex, for many reasons, not the least of which is that fickle factor so aptly dubbed **"public confidence"**

Economic Impacts

Local, Regional, and National Impacts

FEMA HAZUS models do not come close to accurately gauging things like:

- **the infrastructure disruption impacts (as opposed to structural damage)**
- **trickle-down economic impacts, such as loss of confidence by consumers**
- **People tend to hold onto their money after any sort of disaster (e.g. 9/11)**
- **e.g. record number of retail business failures following 1989 and 1994 earthquakes in California**

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Other “Spin Off” and “Spin Down” factors

- In Hurricane Katrina, the government is implementing a plan to remunerate those people who lost their homes and personal property…
- This process, along with re-building, will likely take 3 to 10 years, or longer
- Adjacent residents may not have lost their homes, but have lost:

    1) their jobs/livelihood

    2) The ability to sell their homes and relocate

    3) Difficulty getting insurance

Regional and National Economic Impacts

- When raw materials or product stockpiles are suddenly or unexpectedly reduced/or their flow is constricted; the news media reports the POTENTIAL shortages and all sorts of speculation ensues.....
- This speculation can easily lead to inflated prices, which triggers consumer reaction; and
- We may witness unforeseeable consequences, such as a drop in sales of SUVs while everyone waits to see what will happen to the price of gasoline at the pump.

Question # 12

If spin-off and spin-down losses are tied to 'public confidence'…. What Influences this confidence in the wake of a disaster ?

Television and Print Media

- **Media coverage is ESSENTIAL to the success or failure of any emergency response scenario**
- **Media tends to search out stories that elicit emotional responses or show graphic images to spike their viewing audience**
- **Media market consultants recognize that viewers tend to select one channel over all others during any important event, often remaining loyal to that station thereafter**
  (e.g. CNN in 1990-91 Gulf War; Fox News in 2003 Iraq invasion)

The Public Is Informed Through the Media

- The media swiftly deployed their best correspondents into harm's way to report on conditions. Live streaming via satellite and video phone has changed viewer's expectations of being able to witness historic events when they occur
- The media depends on cuing from: 1) government agencies and officials; 2) the public (via cell phones and e-mail); or, 3) from other media outlets (local affiliates, wire services, newspapers)
- They only report what fails; not what remains standing

9/11: An example of good media management

- New York Mayor Rudy Giuliani inspired confidence with his skillful leadership and sensitivity to the emotions evoked by the 9/11 attacks
- Scattered anthrax incidents almost turned the 9/11 aftermath into a national disaster of unprecedented proportions

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Media stories tend to include lots of "maybe" statements

- **Discovery of one incidence of mad cow disease in Yakima, WA in Dec 2003 triggered a sudden decline in beef prices and sales nationwide, and bans on many beef exports.**
- **CNN soon reported that:**
  "*A British Health Department bulletin revealed that fourteen Britons have died of mad cow disease so far this year; scientists say that 500,000 people could die of the disease by 2030"*

Headlines on hold ....

- The potential Avian Flue pandemic remains on the media's radar screen right now
- Every incident is widely reported
- Western governments are developing contingency plans, similar to those developed for chemical and biological warfare scenarios.
- Public anxiety in America remains low...for the time being. One incident could change all that.

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Like it or not, we, as emergency responders, are obliged to court the media

- The television media covers the "breaking news" as never before
- Those stories can install public confidence or hinder it
- We shouldn't forget that news networks are profit-making corporations operating in a highly competitive marketplace
- Courting positive media coverage is not only an essential aspect of disaster response, it will be good for the nation's economy and benefit the recovery, more than most scientists or engineers realize.

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Thank You !

This presentation will be posted on my website at:
www.umr.edu/~rogersda
under folder titled
“Seismic Hazards in the Midwest”