

Consequences Resulting from a Major Earthquake in the Central U.S.

for the

New Madrid Seismic Zone Conference

Wednesday August 13, 2008

Rolla, Missouri

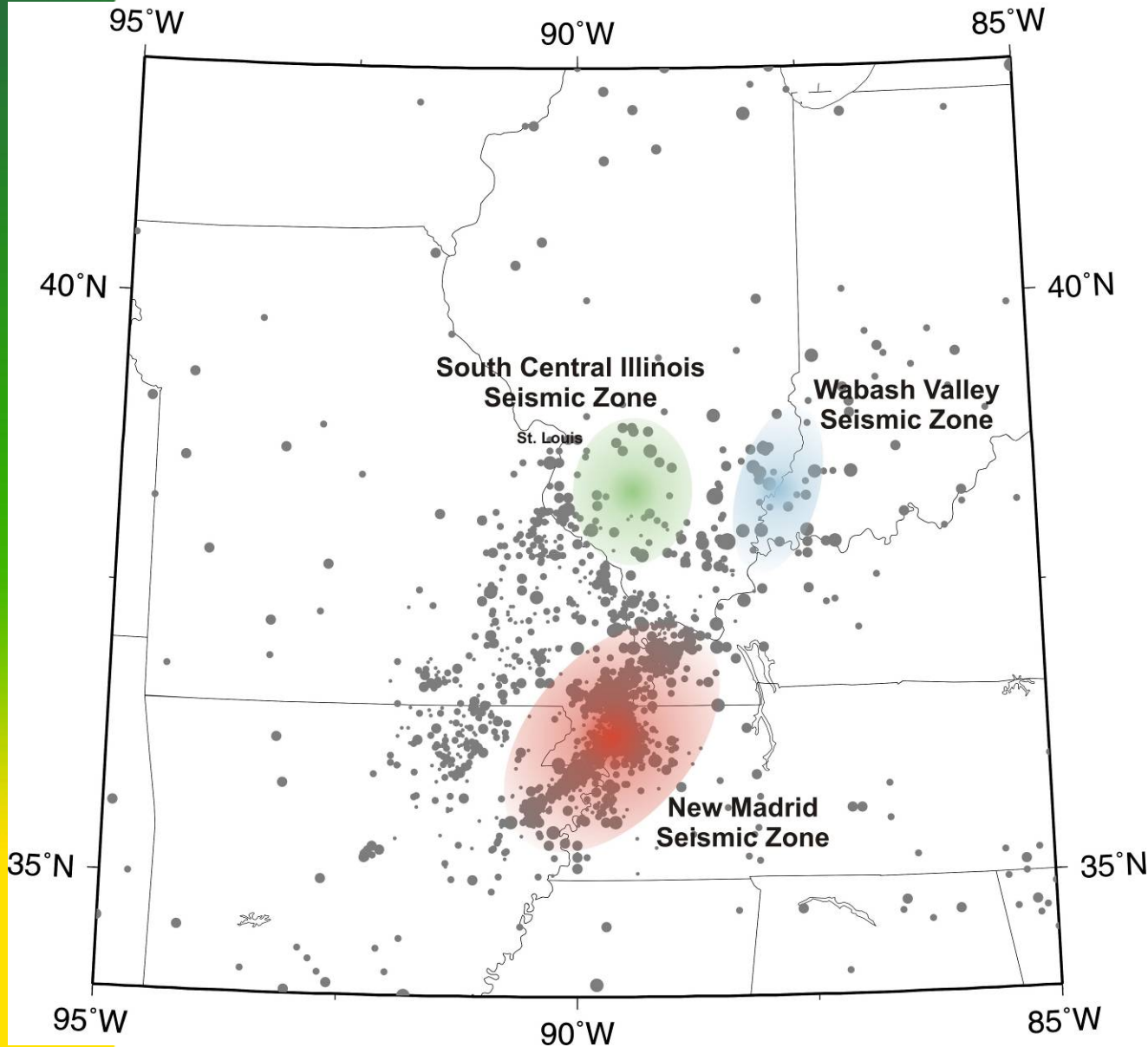


J. David Rogers

Missouri University of
Science & Technology

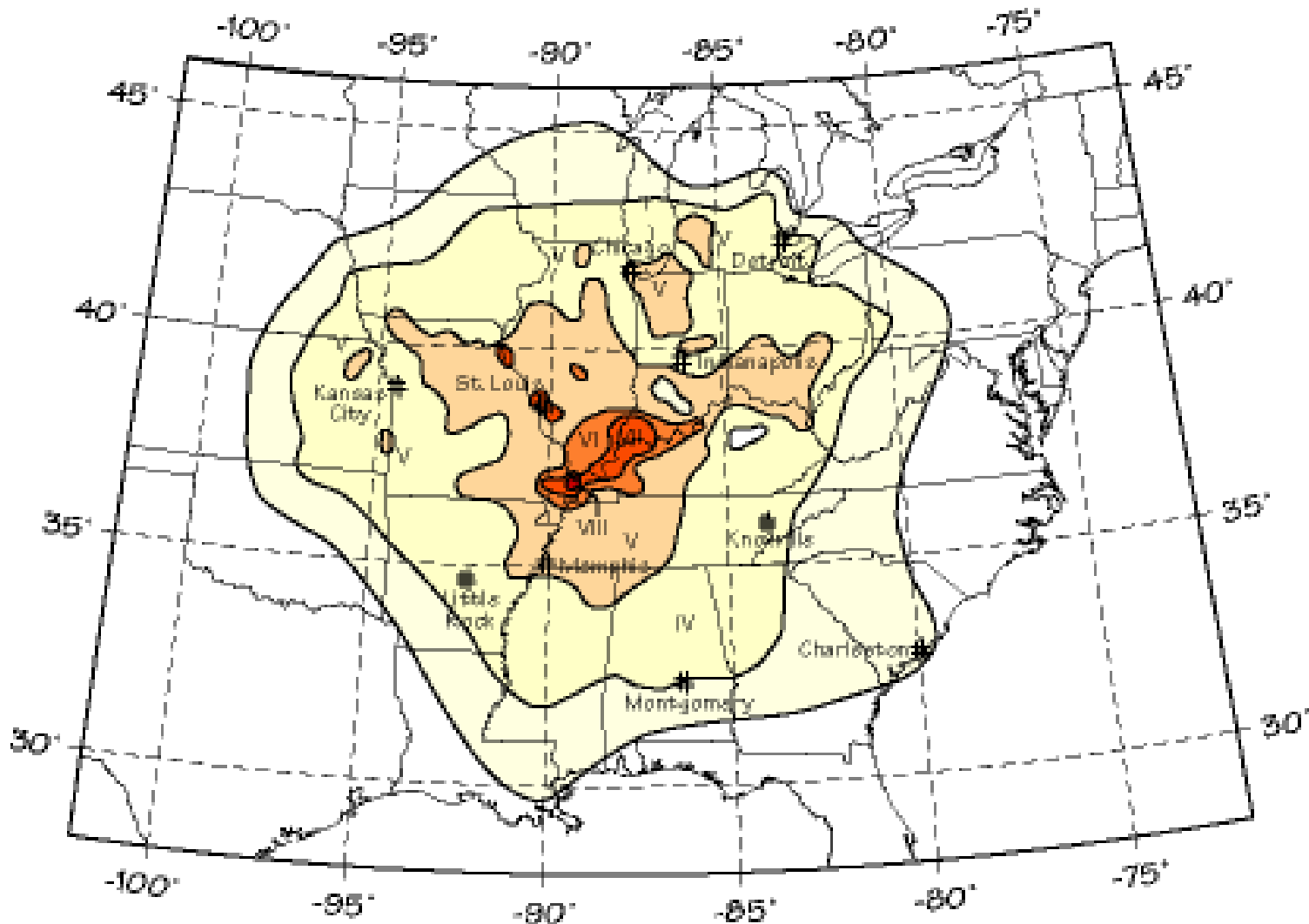


Active Midwest Seismic Zones



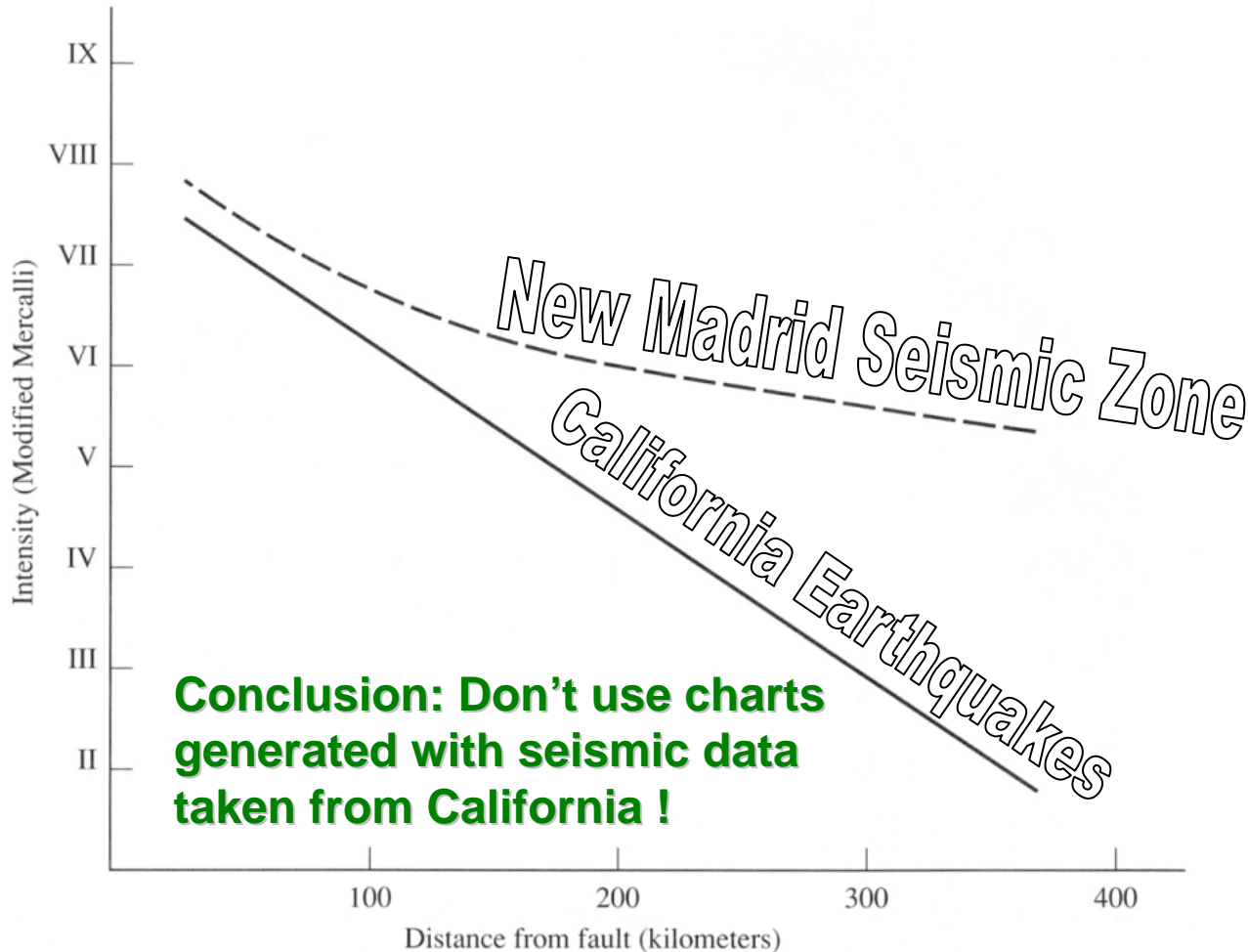
- ⌚ **New Madrid Seismic Zone rediscovered in 1973 NRC study of West Memphis power plant**
- ⌚ **Wabash Valley Seismic Zone generated M 5+ quakes in 1968, 1987, and 2008.**
- ⌚ **South Central Illinois spawned a M 5+ quakes in 1838, 1857, and 1891. Initially recognized in 1999.**

Earthquake Shaking Intensity Map



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

EARTHQUAKE SHAKING INTENSITY versus DISTANCE

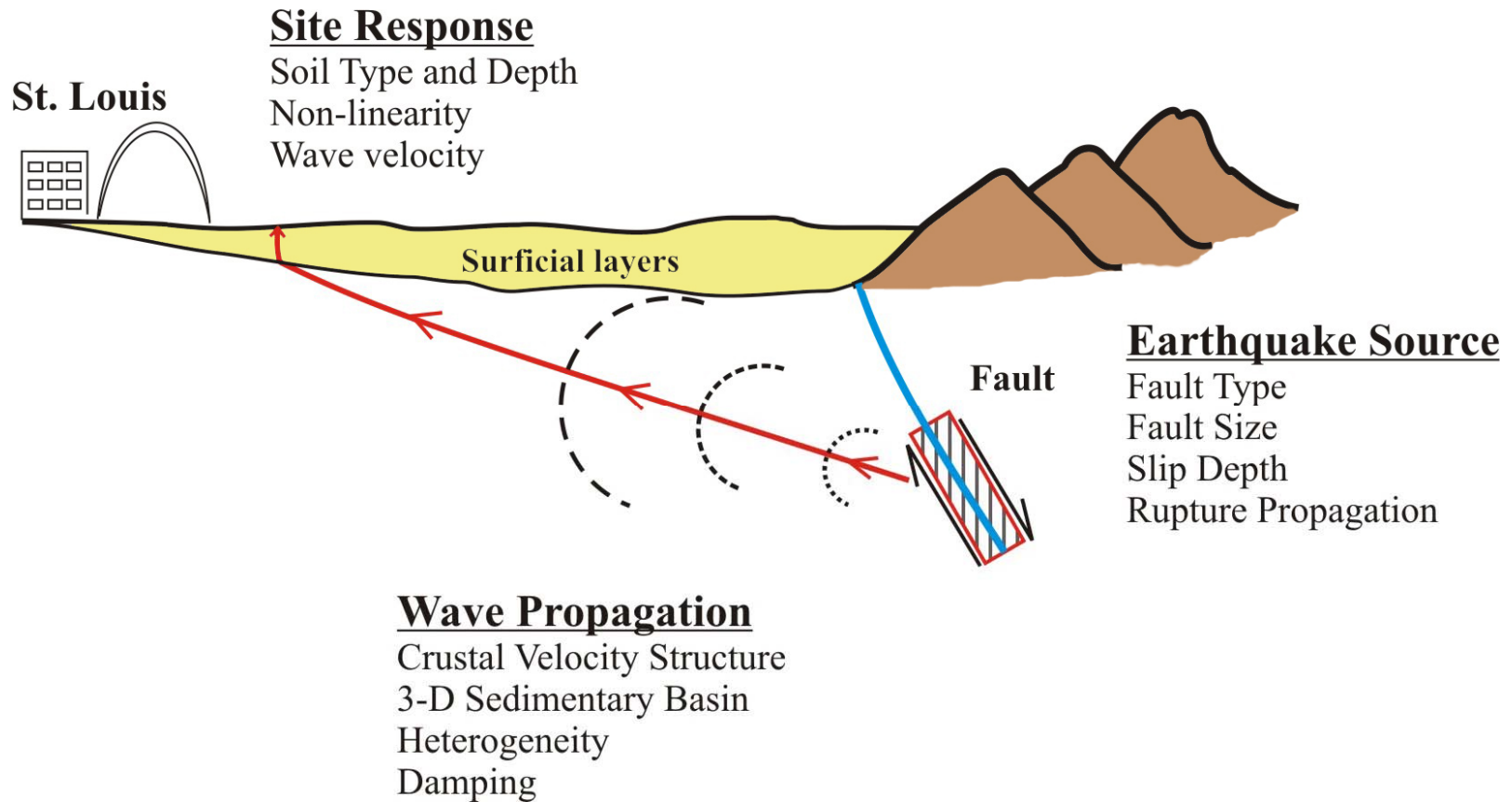


Midwest quakes are less frequent, but much more lethal than California quakes because there is less damping of seismic energy.

Shaking Intensity
also

**Varies from One Area to
Another**

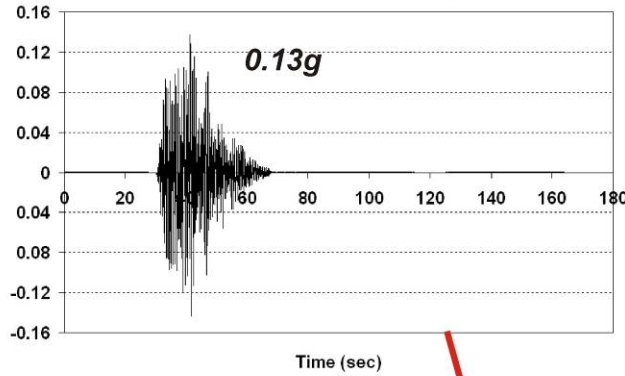
Seismic Site Response



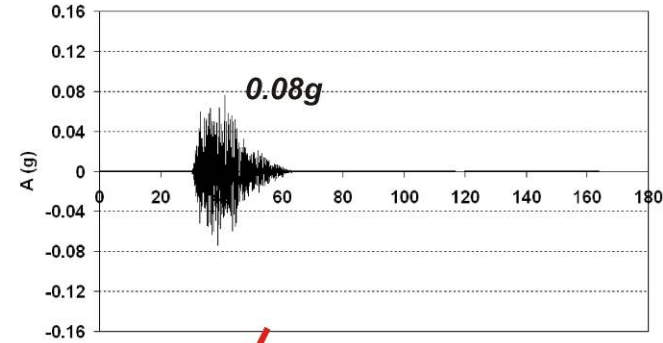
- The type, depth and size of fault, combined with physical properties of crust and geophysical properties of overlying surficial soils, all combine to affect **site response**.

Effect of Soil Thickness on Peak Ground Acceleration (PGA)

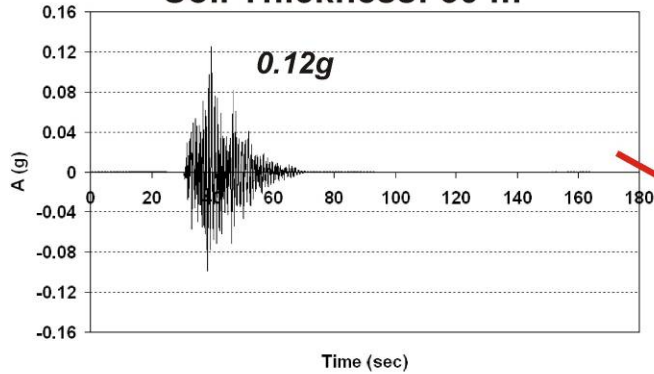
Soil Thickness: 28 m



Soil Thickness: 22 m

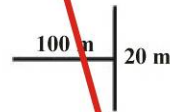


Soil Thickness: 39 m



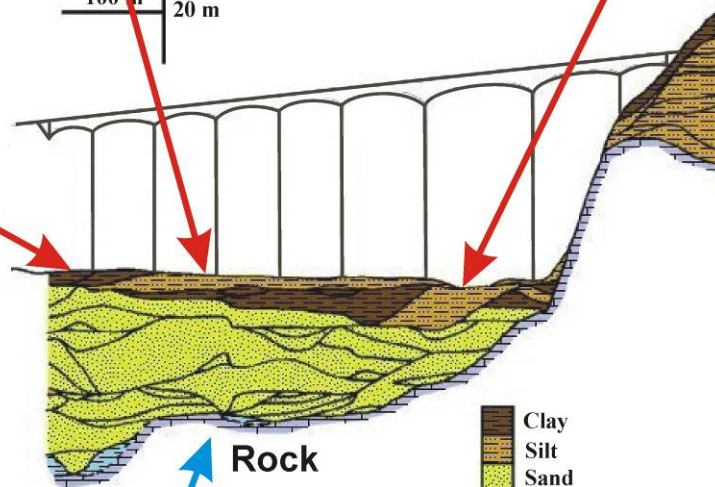
Time (sec)

W



Time (sec)

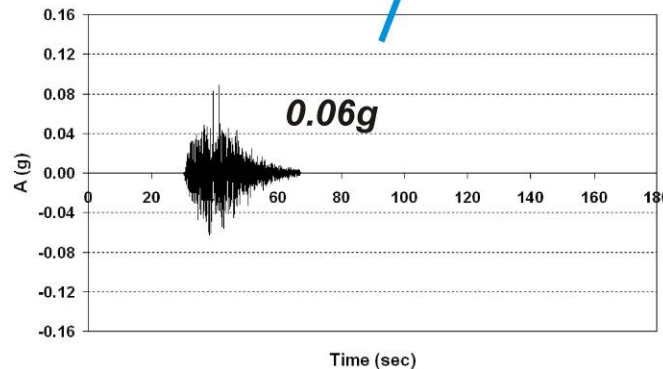
E



- Clay
- Silt
- Sand
- Shale
- Limestone

Rock

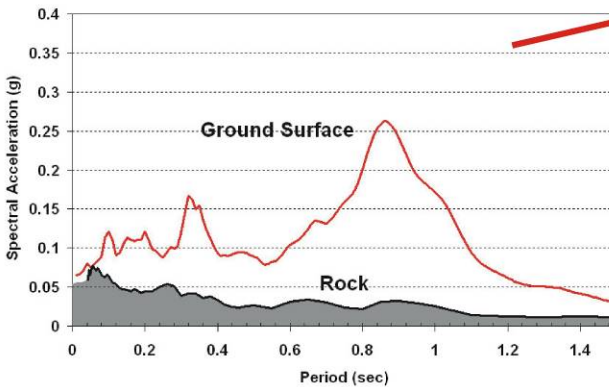
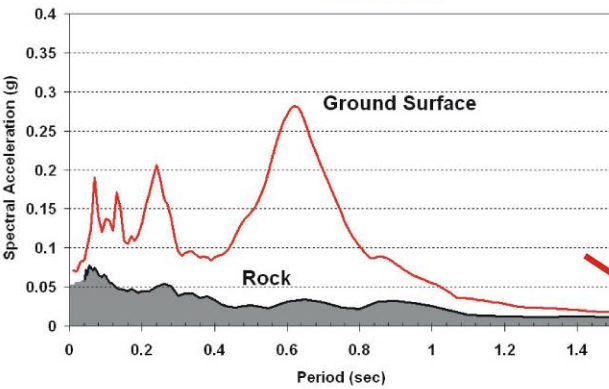
Magnitude 6.8 quake
emanating from
South Central Illinois
at 110 km



Effect of Soil Thickness on RESPONSE SPECTRA

Soil Thickness: 28 m

Peak SA = 0.28 g
Peak Period = 0.62 sec

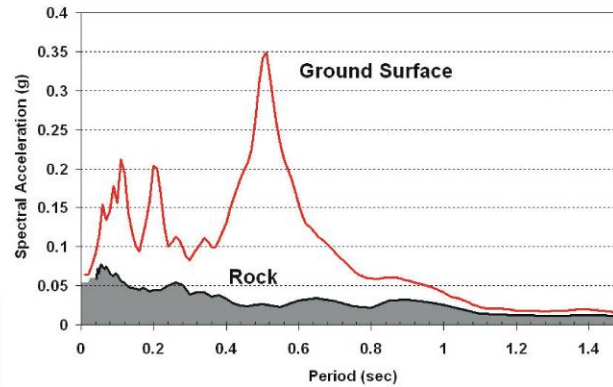


Soil Thickness: 39 m

Peak SA = 0.26 g
Peak Period = 0.87 sec

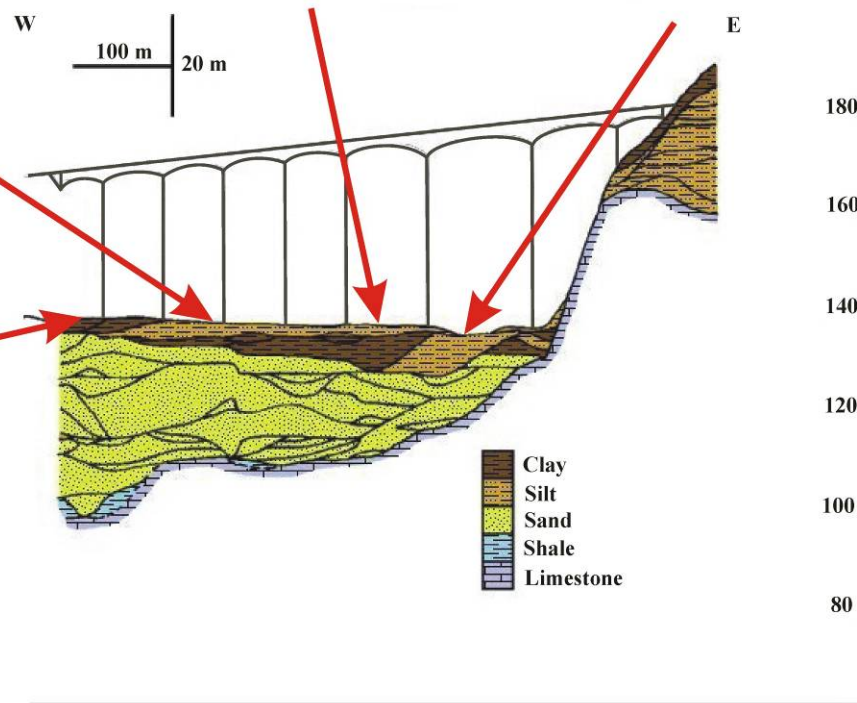
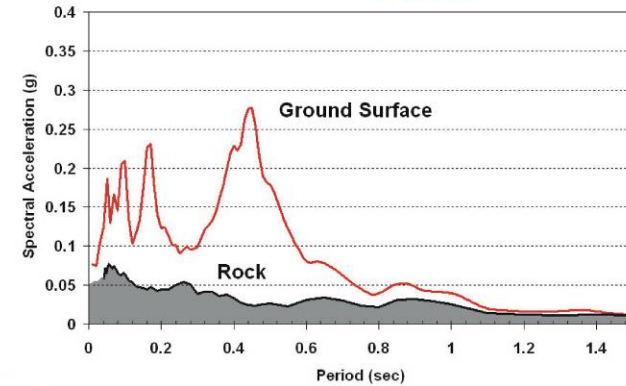
Soil Thickness: 25 m

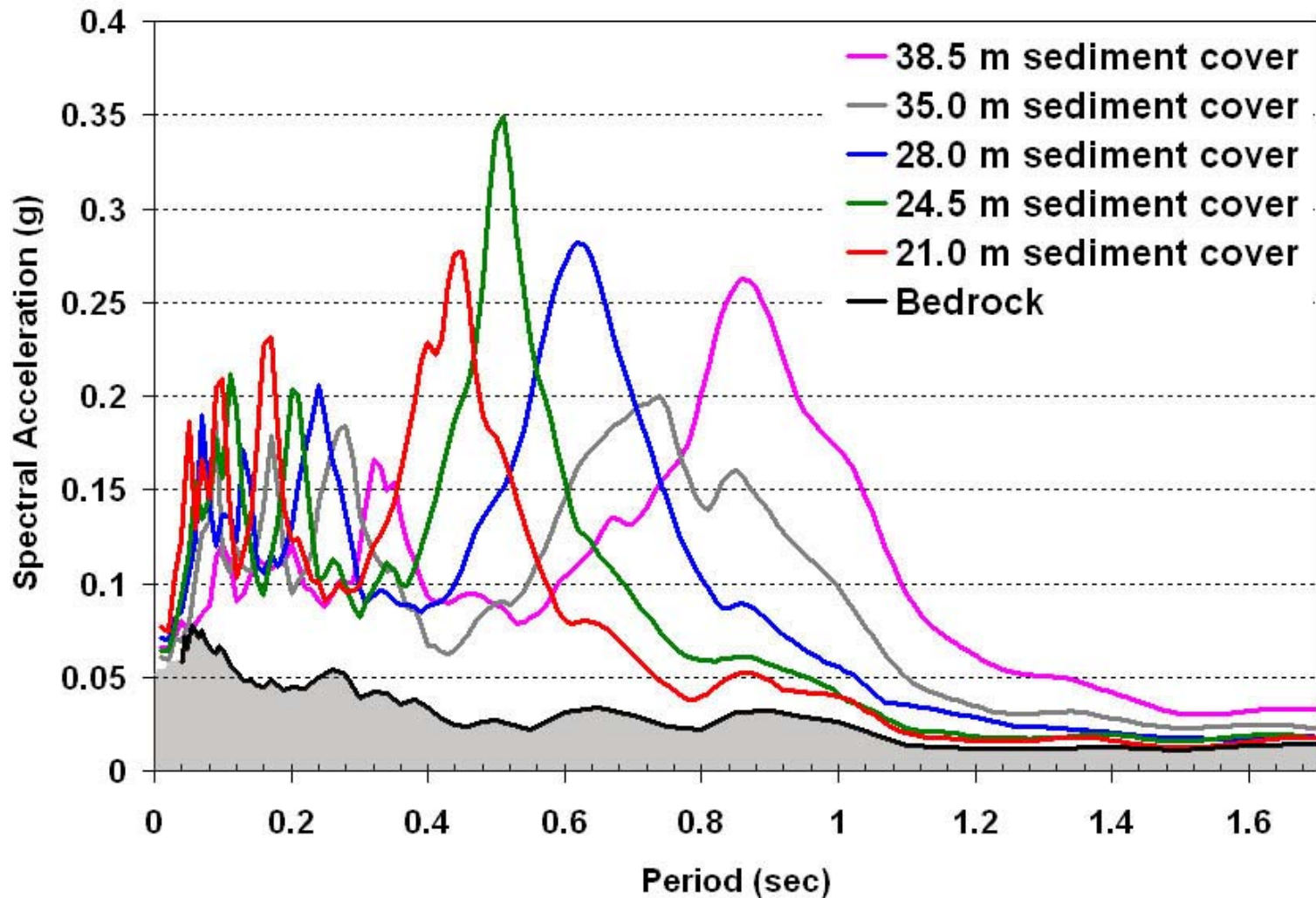
Peak SA = 0.35 g
Peak Period = 0.51 sec



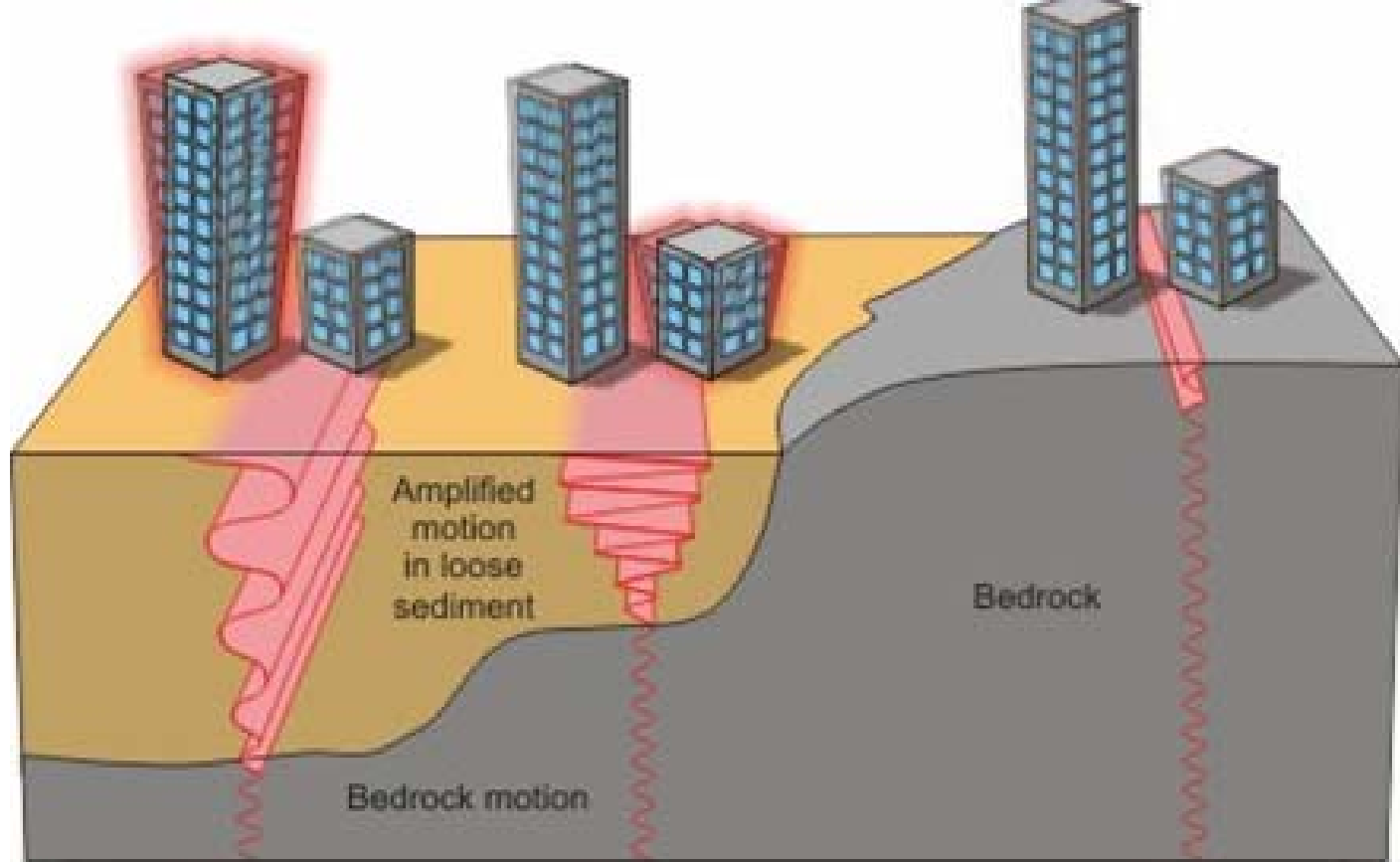
Soil Thickness: 22 m

Peak SA = 0.28 g
Peak Period = 0.45 sec



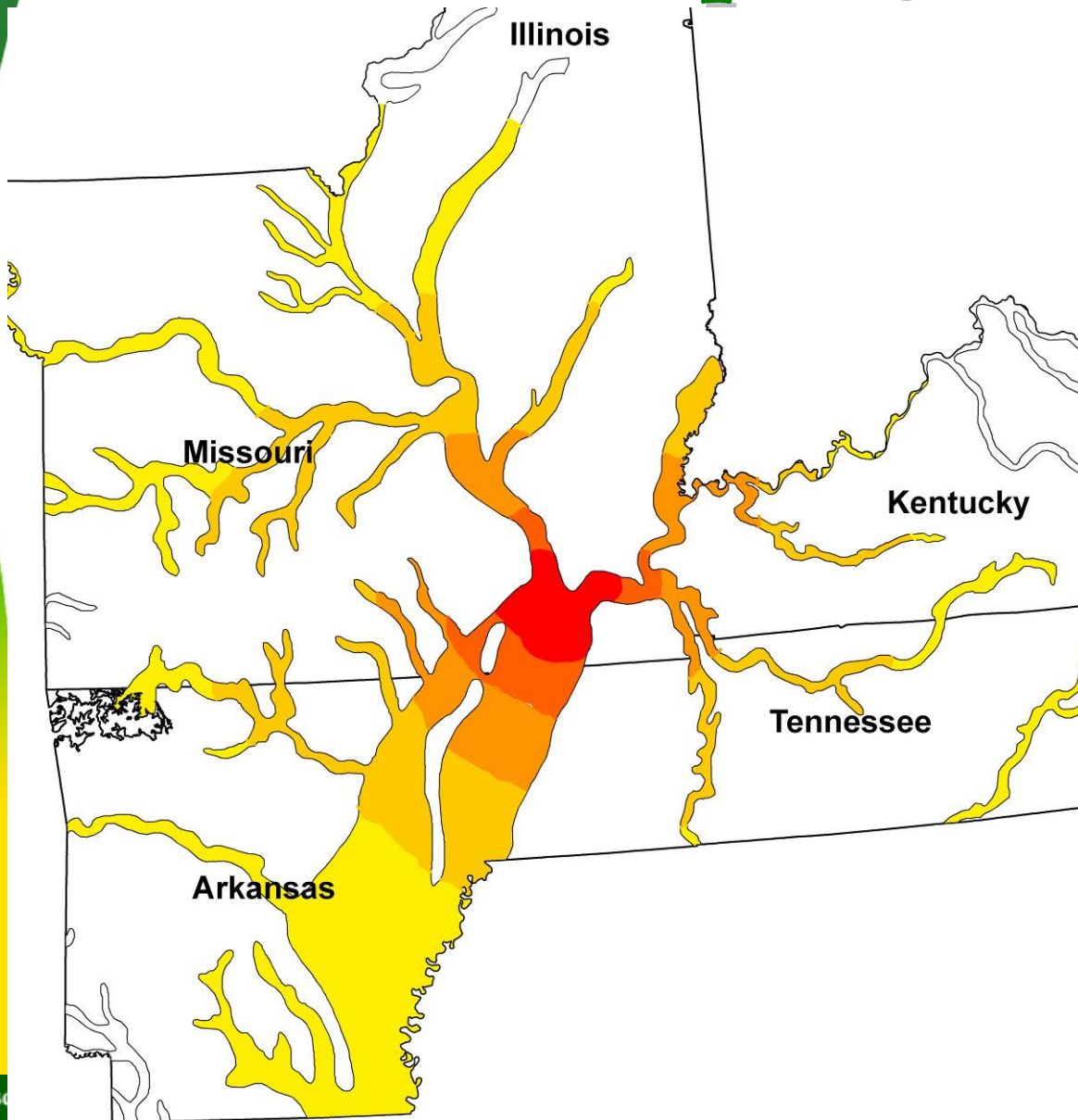


- Variation in expected *spectral acceleration* with *alluvial thickness* in the St Louis, MO area



- **Left – Deeper alluvial cover (~31 m) tends to magnify long period (SA 1.0 sec) motions**
- **Middle – Medium alluvial cover (~18 m) tends to magnify motions for 0.2 sec SA**
- **Right – Upland sites mantled by loess tend to magnify bedrock motion because of impedance contrast between bedrock and soil cap.**

Future Earthquake Hazard Maps



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

**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 Infrastructure 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 (many unknowns, but lateral spreads likely)**
- **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 tanks and water distribution systems**

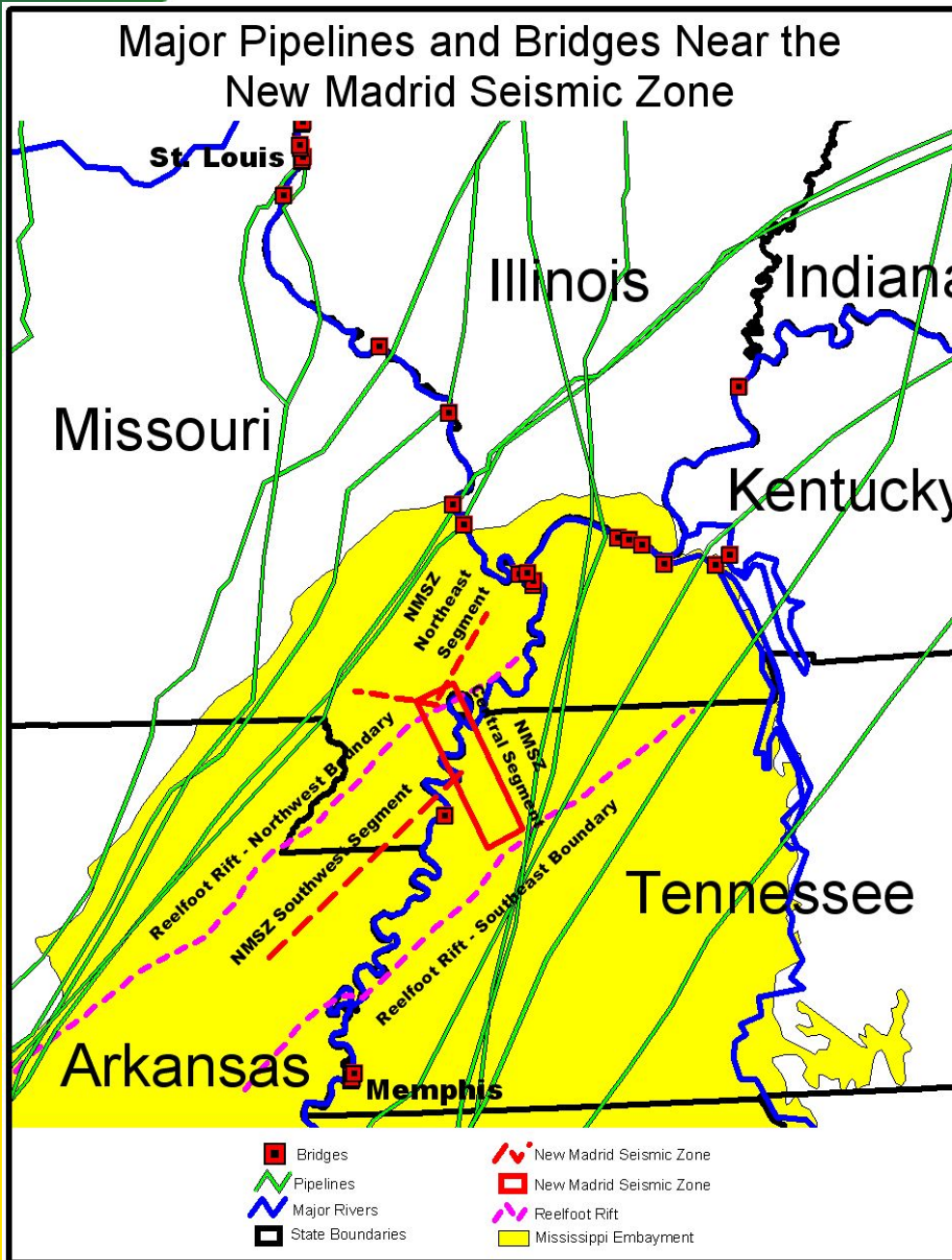
Major Refined Oil Products Pipelines



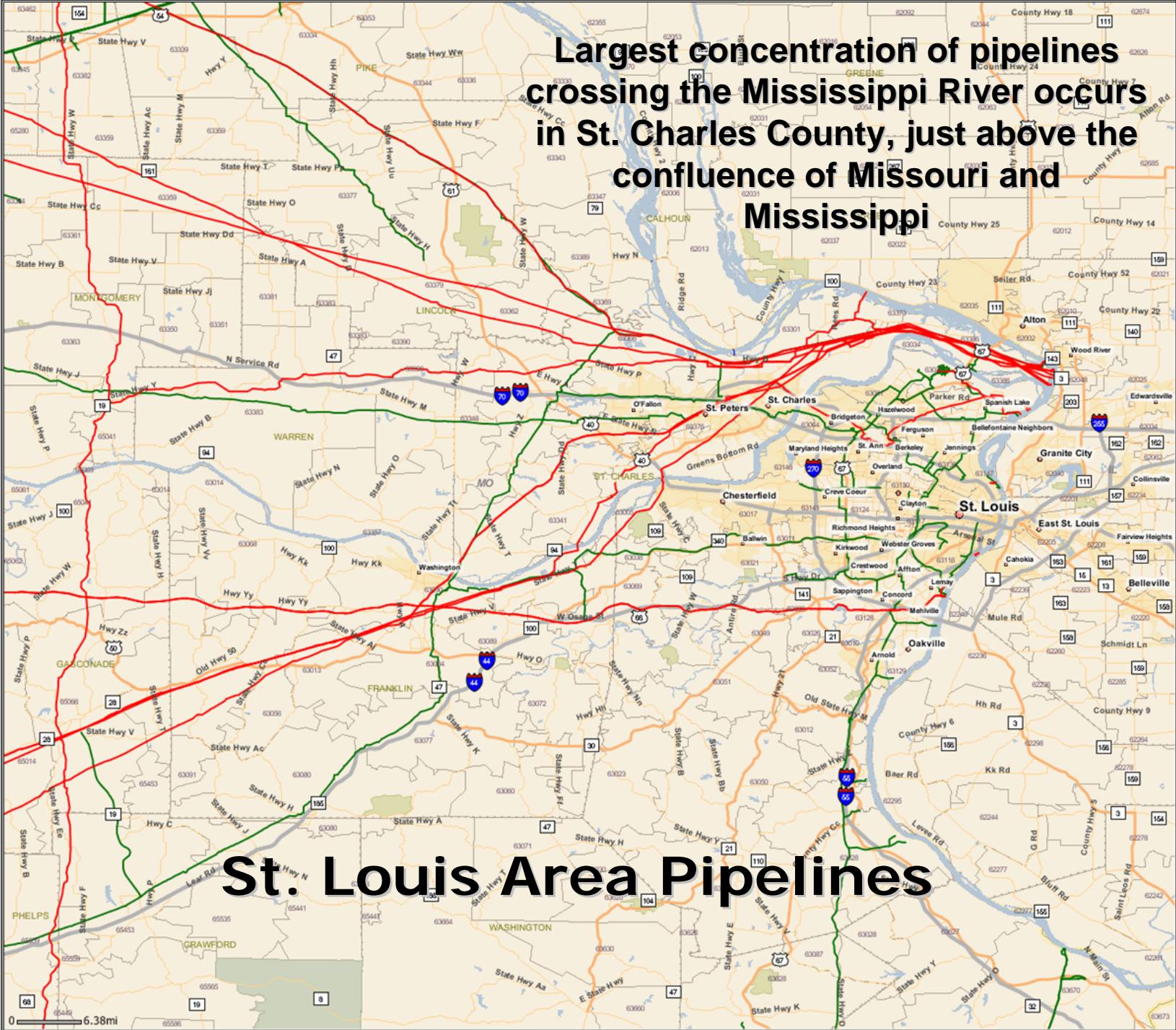
- Refined product service lines convey petroleum products between refineries and major metropolitan markets, from which these products are distributed.
- Significant disruption of the domestic refined product distribution lines has never occurred
- The 'shock factor' of fuel unavailability would be unprecedented,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

Crude Oil and Natural Gas Pipelines

- This map shows the largest crude oil transmission lines in the New Madrid Seismic Zone
- 5 of the 6 main lines crossing the Mississippi River could be compromised in a Magnitude 6.5 earthquake emanating from the NMSZ
- 4 of 9 lines crossing the upper Mississippi Embayment could also be compromised in a Magnitude 6.5 quake



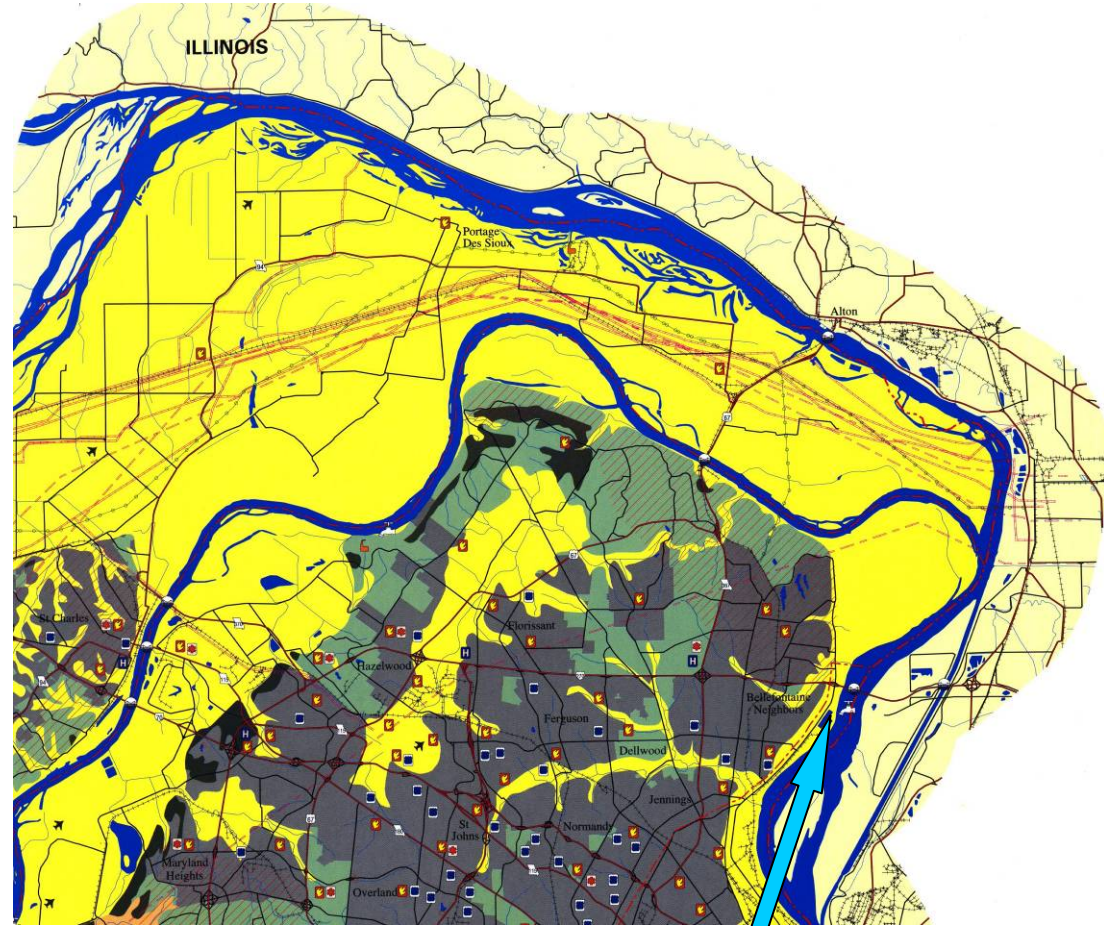
Largest concentration of pipelines crossing the Mississippi River occurs in St. Charles County, just above the confluence of Missouri and Mississippi



St. Louis Area Pipelines

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

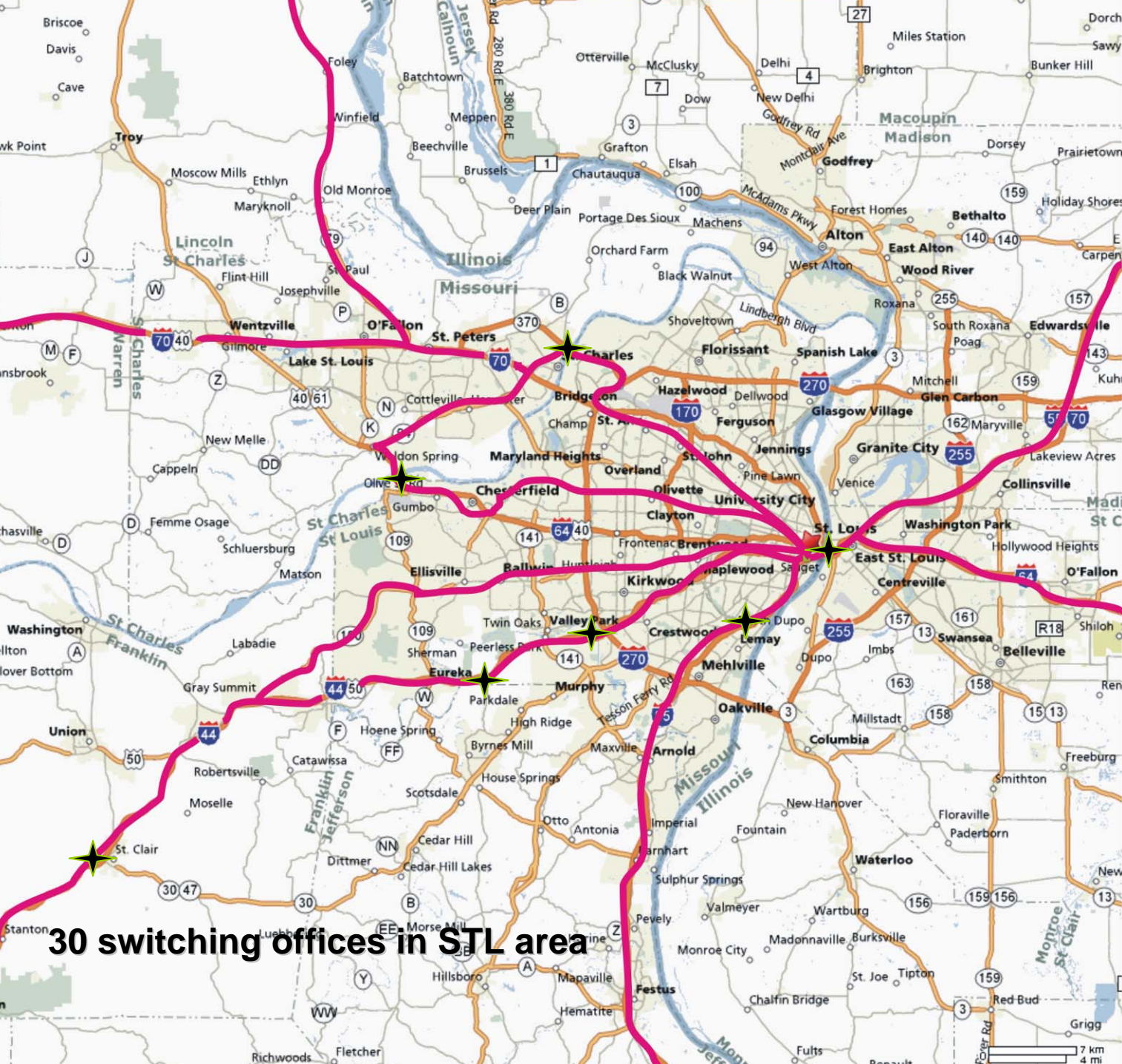


Chain of Rocks Water Treatment Plant

Fiber Optic Cables...



- Are composed of thin strands of glass or plastic bundled together.
 - Transfer laser light through these fibers using the principle of total internal reflection.
- They can transmit tremendous amounts of data when compared to electrical conductors, such as copper wire.
 - Third Generation Fiber Optical Cables can transmit **10 trillion bits per second down a single strand**, using the same cables buried 25 years ago!
 - This is the same amount of data stored on 1,900 full-length audio CDs or 150 million simultaneous phone conversations.



Major Fiber Optic Cable Routes in the St. Louis Metro Area

Major river crossings are marked with black 4 point stars

30 switching offices in STL area

How Vulnerable is our Electric Power Grid in the Midwest?

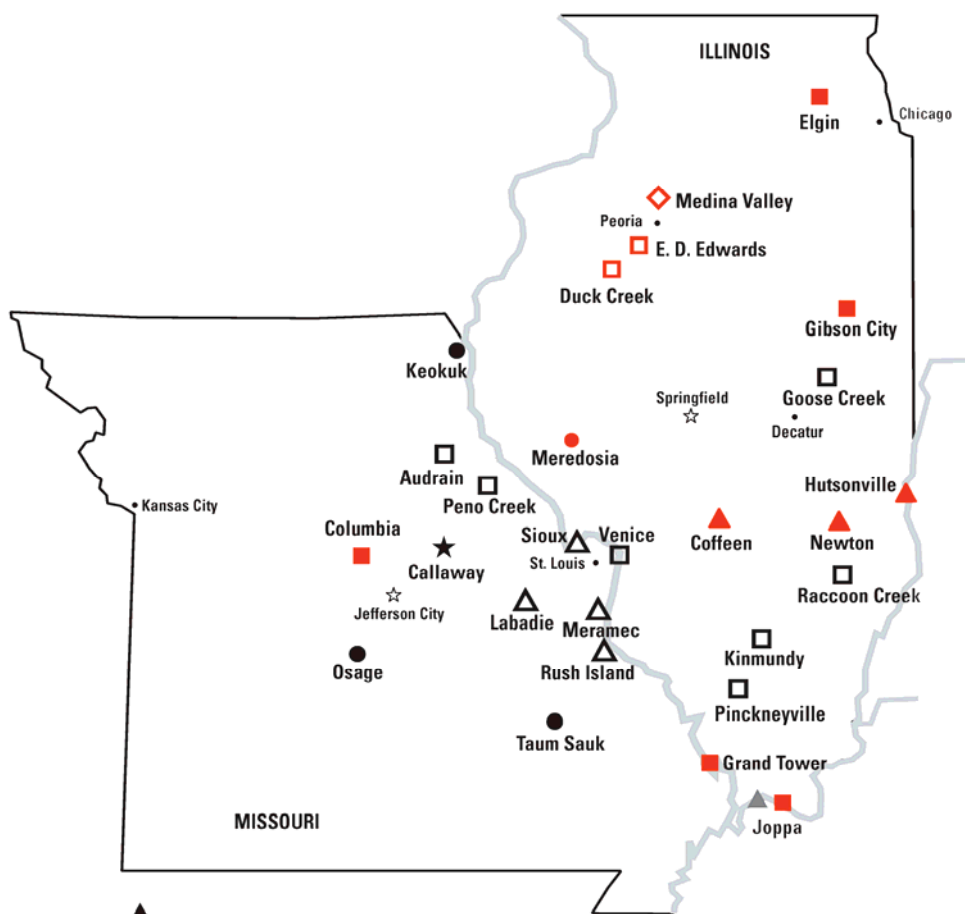
*Is this our
“Achilles Heel”?*

A lot of people have expressed concern about the vitality of the nation's **Electric Power Grid...**

Is there enough energy to meet the needs ?

Answer: There IS sufficient power (e.g. enough generators) available to meet the US national load.....

AmerenUE Power Plants



- Impact of power generation loss depends on a number of factors, including the time of year or decade that 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

- ▲ AmerenUE Coal-Fired Plants
- AmerenUE Hydro Plants
- ★ AmerenUE Nuclear Plant
- AmerenUE CTGs
- ◻ AmerenEnergy Resources Generating Coal-Fired Plants
- ◊ Ameren Cogeneration Plant
- ▲ AmerenEnergy Generating Coal-Fired Plants
- AmerenEnergy Generating CTGs
- AmerenEnergy Generating Coal-, Oil- & Gas-Fired Plant
- ▲ Electric Energy Inc. (80 percent owned by Ameren)

Coal-Fired Plant



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



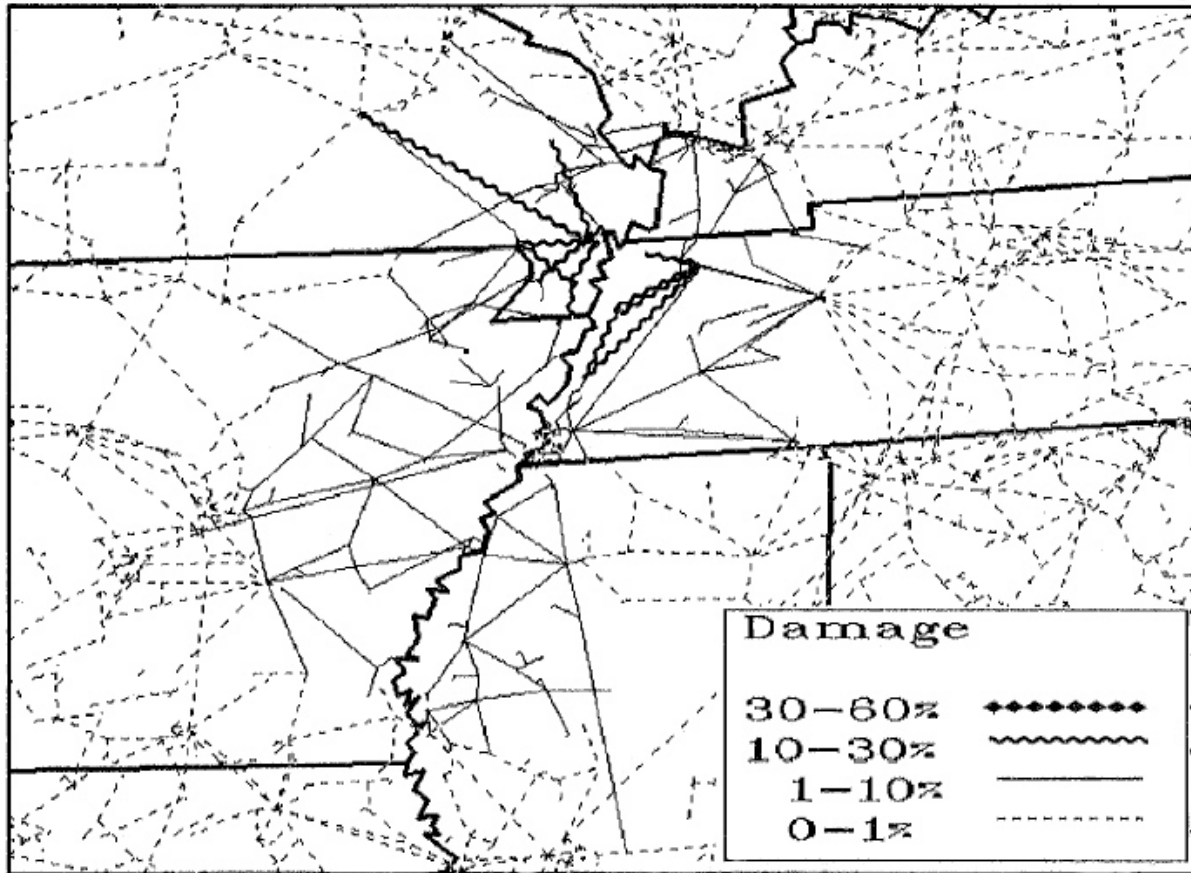
Transmission Network

- The most vulnerable aspect of our power grid is problem we have is **transmission** - getting the power from where it is generated to where the demand centers are.
- Many large plants (coal, nuclear, hydro) are geographically remote from our urban centers –
- If one of the major transportation corridors goes down, then **transmission congestion** occurs and power lines overload – **causing cascading failures.**

Not in My Backyard...

- Transmission “gridlock” is only going to get worse in the next decade, because while there is sufficient generation, there are not sufficient high voltage transmission lines – *nobody wants a large transmission line going near their property.*
- There was the electromagnetic field scare a few years ago when people thought that the EMF was causing cancer (this was ultimately disproved, but people are still very wary) and besides, transmission lines are unsightly.

High Voltage Electrical Transmission Lines Criss-Crossing the New Madrid Seismic Zone

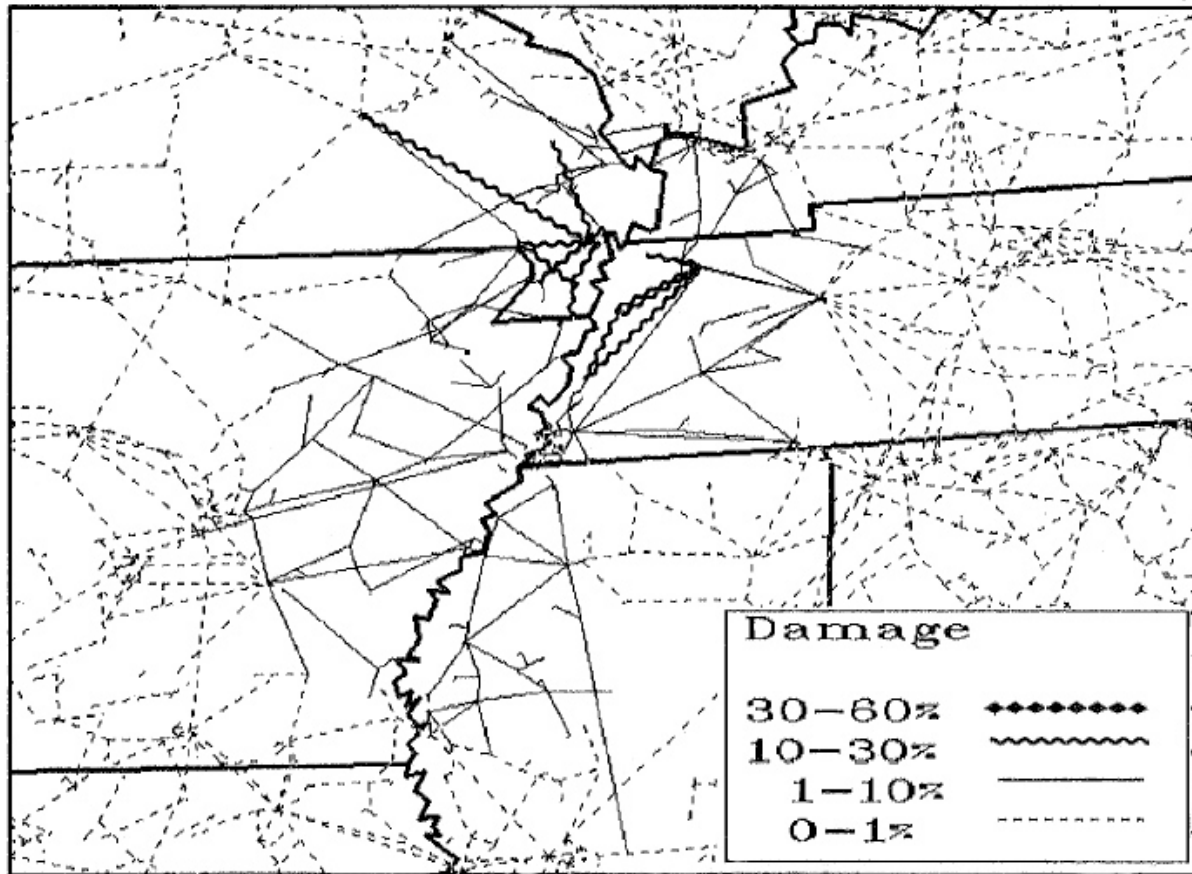


- **Transmission towers founded on >15 m of unconsolidated sediment** in major flood plains can be expected to experience foundation failure, dropping the lines
- **Reconstruction of downed towers will be expensive and time-consuming**

Why does it take so long for power to be restored when outages occur?

- This is a failure of the distribution system (as opposed to the transmission system). When many, many low voltage lines are damaged (such as ice, wind, etc.) they have to be manually repaired.
- The recovery time depends on *manpower availability*. Many major metropolitan areas have similar problems. The only way to protect against this is to put lines underground – but this is more expensive and underground lines are subject to interruptions caused by flooding.

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

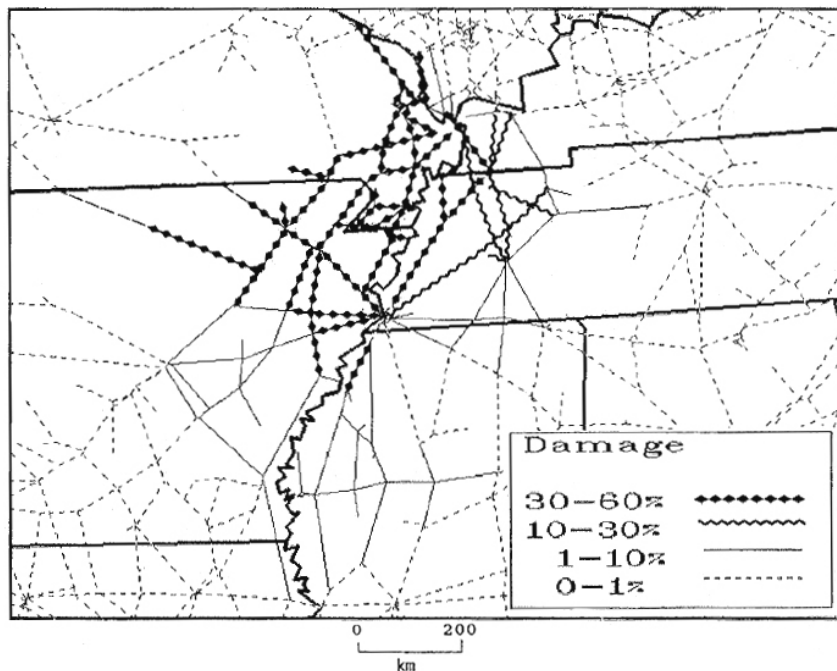
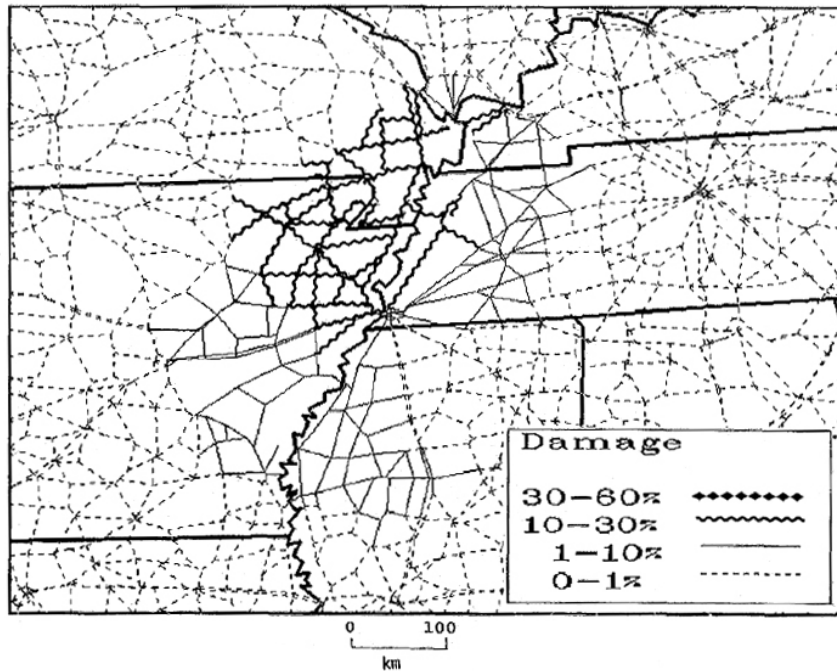
Highway and Railway Bridges



- 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)*

How does the

1) *Speed of Recovery;*

2) *Ease of Recovery;*

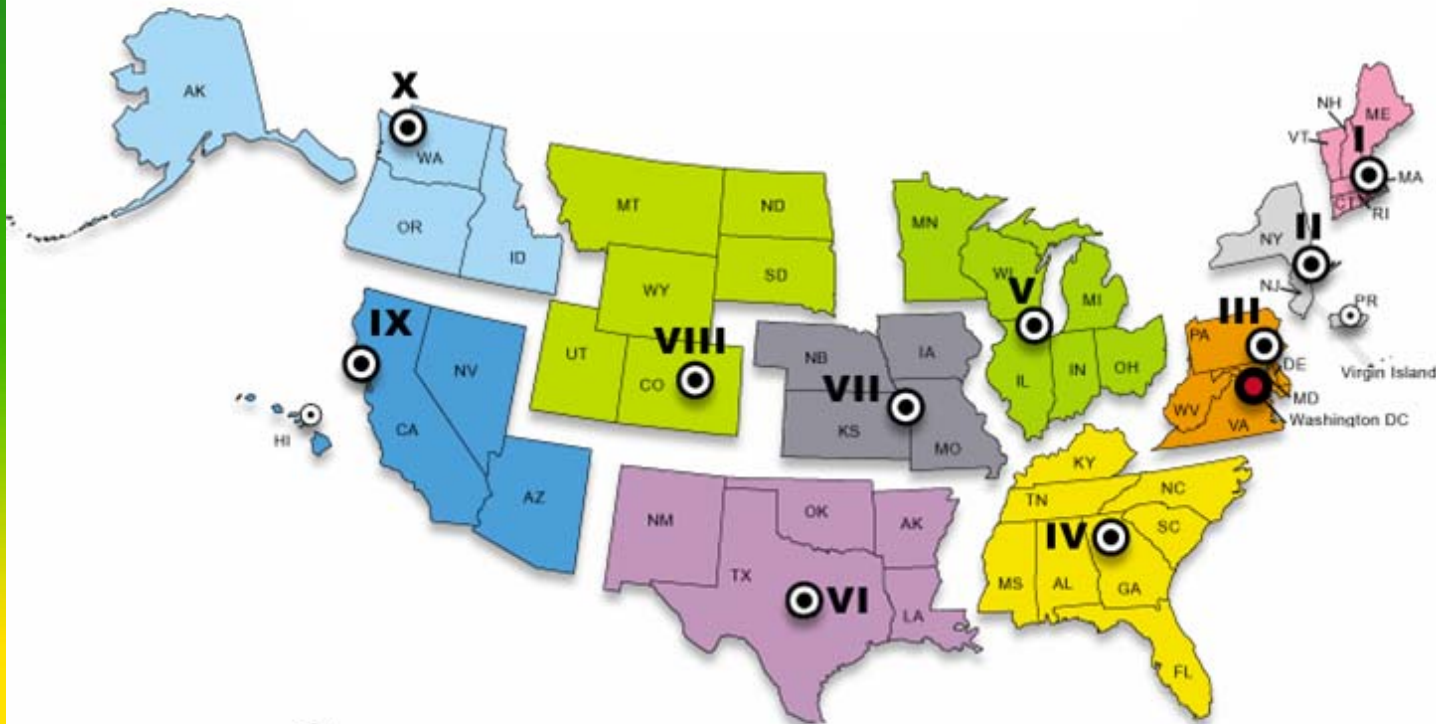
3) *Time Span of Recovery;*

**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



- Headquarters** - Washington, DC
- Region I** - Boston, MA
- Region II** - New York, NY
Caribbean Area Office San Juan, PR
- Region III** - Philadelphia, PA
- Region IV** - Atlanta, GA
- Region V** - Chicago, IL
- Region VI** - Denton, TX
- Region VII** - Kansas City, MO
- Region VIII** - Denver, CO
- Region IX** - San Francisco, CA
Pacific Area Office Honolulu, HI
- Region X** - Bothwell, WA

Disaster Planning that trickles down to the local bus drivers is 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
- **Mobilizing FEMA** doesn't solve any of these problems immediately, it only sets the rescue wheels into motion; e.g. *"calling the cavalry"*

Area Outages

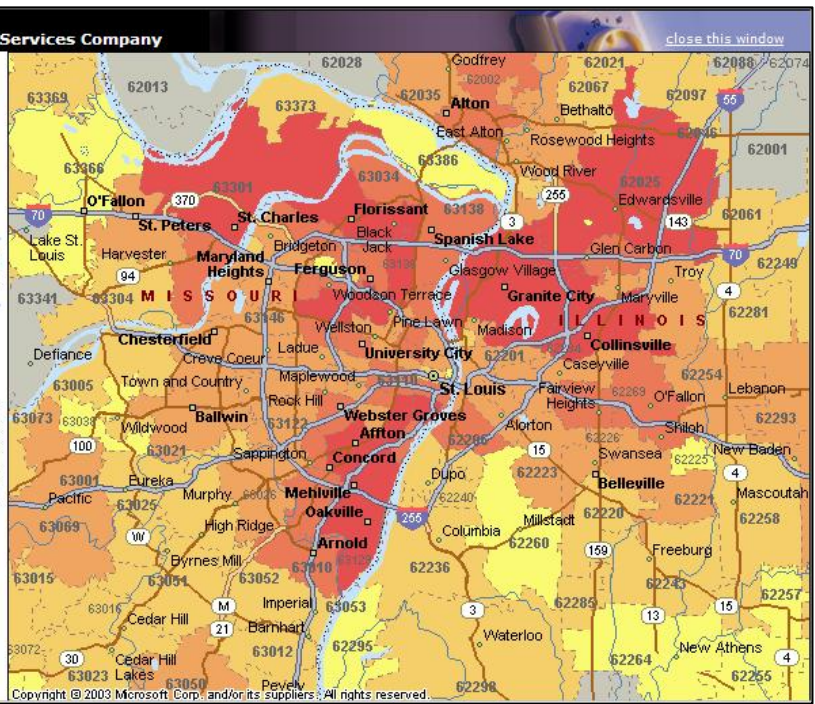
Shaded areas represent ZIP Codes with outages. See legend below for scale.

[Return to System map.](#)

Updated: Jul 21 3:26 PM
Area Outages: 529,063

ZIP	# of Customers	
	Out	Served
63113	5331	7805
63114	10638	18534
63115	5919	11717
63116	10612	23473

# of Customers Out:	
	1-50
	51-1,000
	1,001-5,000
	5,001-10,000
	Over 10,000



Restoration of the Power Grid

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

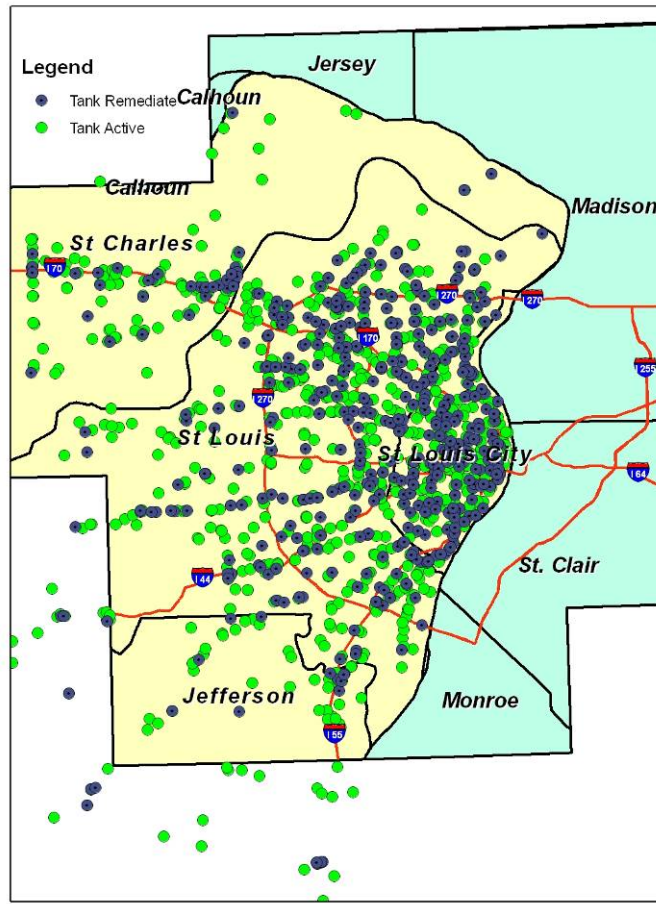


Portage des Sioux power plant near confluence of Missouri and Mississippi Rivers

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



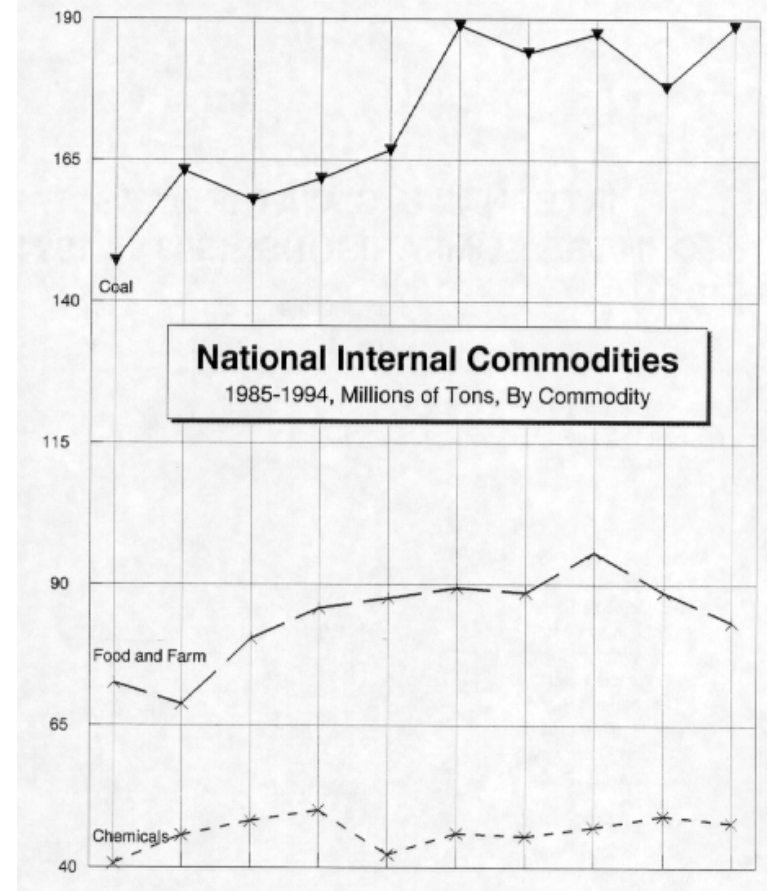
- **Underground fuel storage tanks tend to be lifted out of the ground during earthquakes, if situated close to the permanent groundwater table**
- **This upward movement usually compromises the feeder connections, negating serviceability**
- **These leaks can also promote costly clean-ups**

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 CO₂ emissions per ton-mile) and redundancy from rail and truck transport**

**So, What Will Be the
*'Final 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”**

Actual 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**

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 versus 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.

**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

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.**



Thank You !

**This presentation will be posted
on my website at:**

www.mst.edu/~rogersda

under folder titled

***“Seismic Hazards in the
Midwest”***