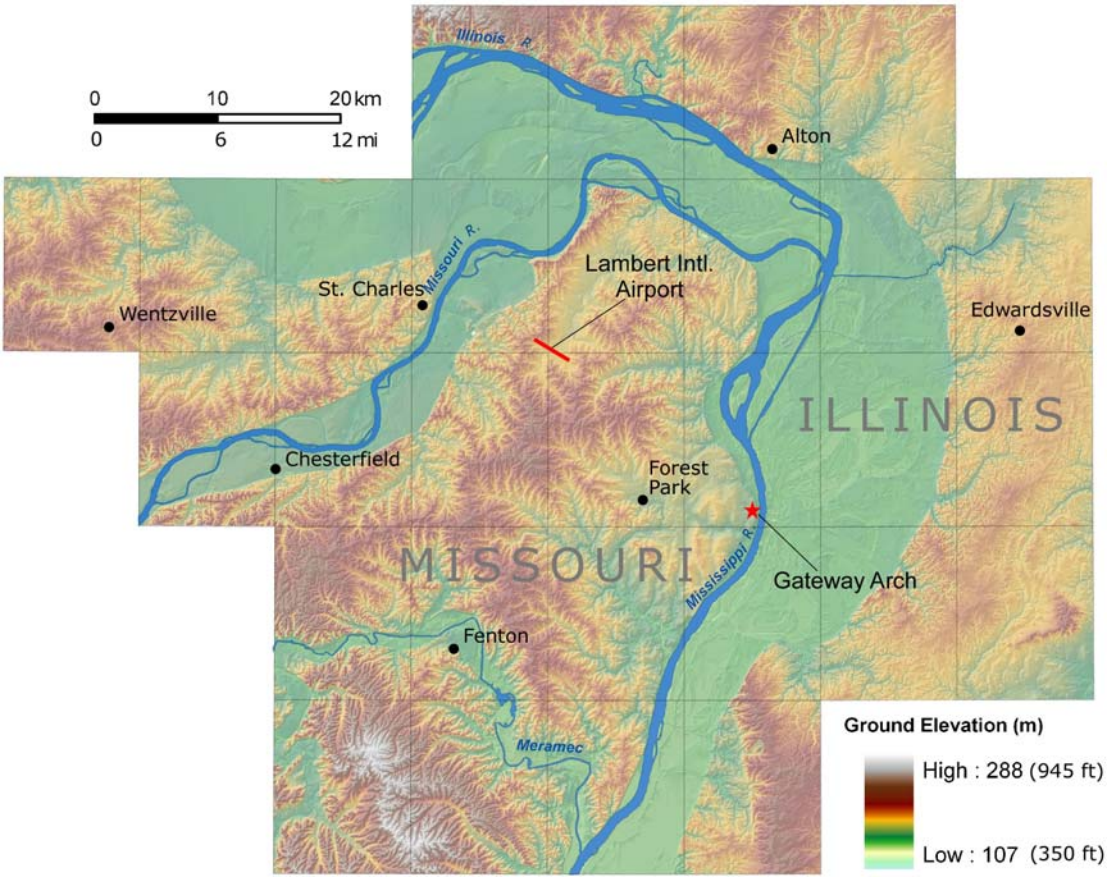
St. Louis Area Earthquake Hazards Mapping Project–A PowerPoint Presentation

By Robert A. Williams

In collaboration with the St. Louis Area Earthquake Hazards Mapping Project (SLAEHMP)



Open-File Report 2009–1198

U.S. Department of the Interior
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Cover: St. Louis metropolitan study area encompasses 29 USGS quadrangles shown on a shaded relief map.

St. Louis Area Earthquake Hazards Mapping Project—A PowerPoint Presentation

By Robert A. Williams

Introduction

This Open-File Report contains illustrative materials, in the form of PowerPoint slides, used for an oral presentation given at the Earthquake Insight St. Louis, Mo., field trip held on May 28, 2009. The presentation focused on summarizing the St. Louis Area Earthquake Hazards Mapping Project (SLAEHMP) justification, goals, achievements, and products, for an audience of business and public officials. The individual PowerPoint slides highlight, in an abbreviated format, the topics addressed; they are discussed below and are explained with additional text as appropriate.

Slide Content

Slide 1 – This slide shows the partners involved in the SLAEHMP. The USGS is spearheading the project, but the success of the project depends on the collaboration of the many agencies shown here. Some funding for the project comes from the USGS through the National Earthquake Hazards Reduction Program (NEHRP). The map shows the study area and its location relative to the New Madrid Seismic Zone (NMSZ). The shaded relief map shows that the study area consists of 29 USGS quadrangles. Topography is key to understanding the areal distribution of the ground-shaking hazard in the study area. Here, modeling and measurements of earthquake observations support a difference in ground motions between the alluvial valleys and the uplands that meet our general expectations. The SLAEHMP wants to learn about the expectations and needs of potential users of this information.

Slide 2 – **What is Earthquake Hazard Mapping?** Earthquake hazard mapping refers to a measure of the shaking, or ground motion, sustained during earthquakes, that can cause building damage. The hazard depends on the magnitudes and locations of likely earthquakes, how often they occur, and the properties of the rocks and sediments that earthquake waves travel through. In the central United States, earthquakes are concentrated along the New Madrid and Wabash seismic zones and, more diffusely, in an area scattered across southern Illinois and eastern Missouri.

Who Uses Earthquake Hazard Maps? Public and private groups can use hazard maps for earthquake preparedness planning, hazards mitigation, and event response to minimize losses resulting from earthquake shaking. Portfolio managers in the lending, insurance, and wealth management industries can use the maps to better manage risk exposure. Planning and zoning professionals can use the maps for hazard considerations in designing and locating new development, critical facilities, and transportation corridors. Business continuity managers can use the maps to anticipate and prepare for earthquake-related losses to their facilities, supply networks, and market share. The scale of the maps does not allow them to be used in a site-specific manner, but rather as a guide as to where more detailed studies are needed.

Slide 3 – Earthquake hazard mapping in St. Louis involves analyzing earthquake ground motions and potential liquefaction. Scientists can't predict when an earthquake will occur, but we can

estimate how much the ground will shake during future earthquakes. The influence of the local underlying soil conditions on the amplification of earthquake shaking is called the site effect. We are using proven methodologies that are consistent with those of the USGS National Seismic Hazard Map (NSHM), which are used to map the nation. Unlike the NSHM, the St. Louis maps include the effects of local differences in geology.

Slide 4 – The fundamental data needed to produce earthquake hazard maps are local geology and regional earthquake information. Geologic mapping for St. Louis is supplemented by thousands of well borings and hundreds of subsurface measurements that have been compiled for the study area. However, to fill in data gaps, we need additional measurements and new, more-detailed geologic mapping. For regional earthquake history and information, we depend on the decades of work that have gone into the USGS NSHM.

Slide 5 – Earthquakes produce effects which can cause property damage and loss of life. In general, the effect that produces the most widespread hazard is ground shaking because it can cause building failure and collapse hundreds of kilometers from the earthquake. Recent research has focused on producing national and regional maps of probabilistic earthquake ground shaking. These maps integrate the results of historical seismicity, paleoseismology, strong motion seismology, and site-response studies. The maps take into account all the known possible earthquake locations and magnitudes that can occur. These maps have been produced since the early 1970s by the USGS, in cooperation with engineers and building officials involved in developing building codes that incorporate earthquake resistance.

Slide 6 – Shows proximity of St. Louis to seismically active areas nearby.

Slide 7 – The USGS NSHM does not take into account local and regional geological structures and soil conditions, which may have strong amplifying or damping effects on ground shaking. NSHM assumes a moderately stiff uniform ground surface. SLAEHMP products include the effects of variations in local geology.

Slide 8 – Study area showing regional cultural landmarks and the main geographic features.

Slide 9 – Study area showing a subset of borings that reach bedrock. Defining the depth to this surface is crucial for characterizing ground motions accurately. USGS quadrangle names are shown.

Slide 10 – Study area showing status of detailed geologic mapping of surficial materials.

Slide 11 – A deterministic liquefaction hazard map for a hypothetical M7.5 earthquake. Result taken from Chung (2007). The map shows higher liquefaction hazard in the lowlands.

Slide 12 – A probabalistic ground motion hazard map at 0.2 second spectral acceleration for the three quadrangle pilot study area (Columbia Bottom, Granite City, and Monks Mound) by Karadeniz (2007). At this frequency (5 Hz) the map (right figure) shows higher hazard in the uplands.

Slide 13 – Summary of project status indicating that the compilation of data and construction of the geologic model phases are the foundation on which subsequent products are based.

Slide 14 – Maps showing the location of the 18 April 2008 M5.4 Mt. Carmel, Ill., earthquake (left) and the Advanced National Seismic System (ANSS) station array in the St. Louis area, including stations STIL and SLM, which recorded the earthquake.

Slide 15 – A generalized geologic cross section showing the site conditions at two St. Louis ANSS stations (STIL, SLM). The distance between these stations is small (about 6 km) compared to the distance from these stations to the earthquake epicenter (about 215 km), so differences in ground motion between STIL and SLM are most likely due to the unique near-sruface geologic site conditions beneath these stations. Based on the site conditions, we expected and observed significant differences in ground motions. Critical infrastructure such as pipelines, power plants, bridges, and port facilities are located in the lowlands (floodplains).

Slide 16 – Time histories from the Mt. Carmel earthquake recorded at SLM and STIL. We observed significantly larger ground shaking at STIL by a factor of about five.

Slide 17 – The difference in ground motions also shows up when comparing the amplitude spectra for these stations. We see strong site resonances in the floodplains (lowlands) at 1 to 10 Hz. STIL ground motions are as much as 10 times higher than those recorded at site SLM at certain frequencies. For very strong shaking in a larger earthquake, the amplitudes of ground motion at the floodplain sites could be reduced because of nonlinear behavior of the loose deposits.

Slide 18 – Similar ground responses have been observed at these two stations in previous earthquakes and at other stations in the central United States located on similar geologic structures. This repeatability gives us confidence that these ground motions are somewhat predictable, although we have only a limited number of cases so far.

Slide 19 – Summary of SLAEHMP accomplishments.

Slide 20 – Summary of future plans for the project.

Slide 21 – Summary of SLAEHMP products that are available on the project Web site.

References Cited

Chung, J., 2007, Development of a geographic information system-based virtual geotechnical database and assessment of liquefaction potential for the St. Louis metropolitan area: Rolla, Missouri University of Science & Technology, Ph.D. dissertation, 169 p.

Karadeniz, D., 2007, Pilot program to assess seismic hazards of the Granite City, Monks Mound, and Columbia Bottom quadrangles, St. Louis metropolitan area, Missouri and Illinois: Rolla, Missouri University of Science & Technology, Ph.D. dissertation, 290 p.

Williams, R.A., Odum, J.K., Stephenson, W.J., and Hermann, R.B., 2007, Shallow P-and S-wave velocities and site resonances in the St. Louis region, Missouri-Illinois: Earthquake Spectra, v. 23, no. 3, p. 711–726.

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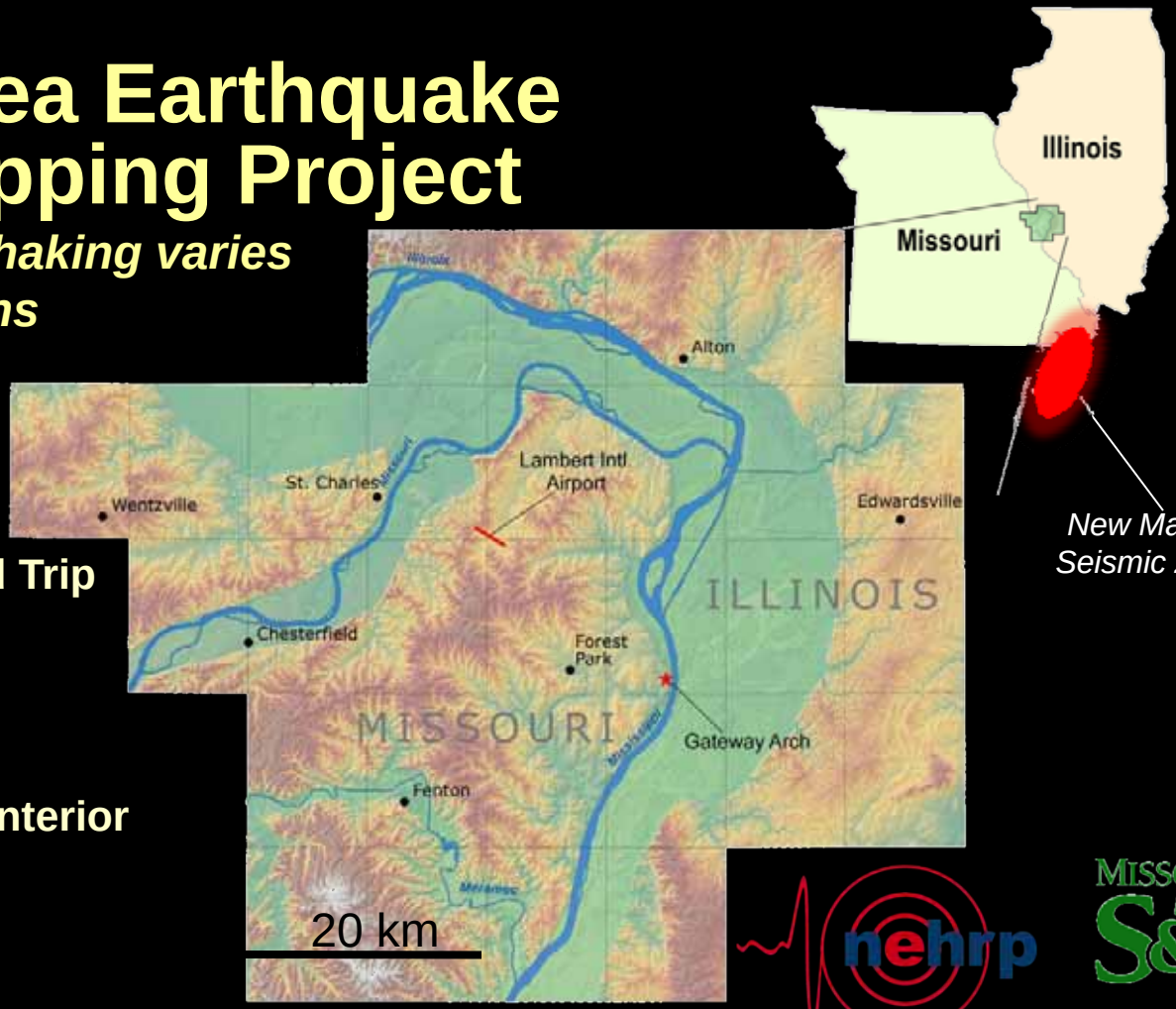
St. Louis Area Earthquake Hazards Mapping Project

Earthquake ground shaking varies with ground conditions

Robert A. Williams
U.S. Geological Survey

Project Overview
Earthquake Insight Field Trip
St. Louis, Missouri
May 28, 2009

U.S. Department of the Interior
U.S. Geological Survey



Missouri Department of Natural Resources

THE UNIVERSITY OF MEMPHIS. Center for Earthquake Research and Information

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SAINT LOUIS UNIVERSITY EARTHQUAKE CENTER

ISGS Illinois State Geological Survey

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St. Louis Area EQ Hazards Mapping Project (SLAEHMP)

- What is earthquake hazard mapping and who uses it?
  - *A measure of the severity of earthquake ground shaking*
  - *Used by engineers, city planners, and the insurance and banking industry*
  - *Note: The scale of the maps do not permit site-specific assessments.*

- Why study St. Louis earthquake hazard?
  - *New Madrid, Wabash, and southeast Illinois earthquakes could affect the area.*
  - *Varying geological conditions affect earthquake ground motions.*
  - *Priority task among State and Federal Governments*

- Status and results of the St. Louis effort
  - *Products from the St. Louis area earthquake hazard project*
  - *A look at ground motions in St. Louis from the M5.4 Mt. Carmel earthquake*

- Where are we headed?
  - *St. Louis hazard maps will support commemoration of the 2011-12 New Madrid Bicentennial.*

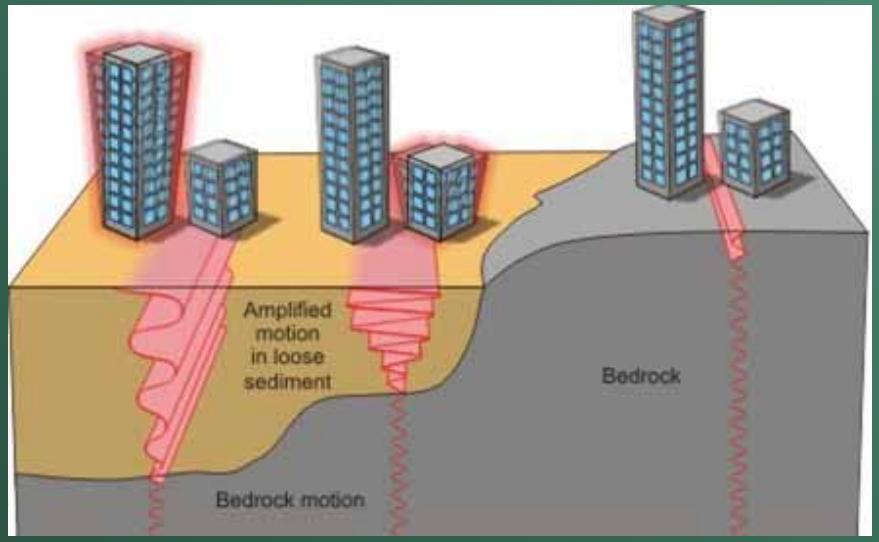
USGS

Earthquake hazards mapping for St. Louis

Includes estimating Earthquake ground shaking and Liquefaction potential

Earthquake ground shaking

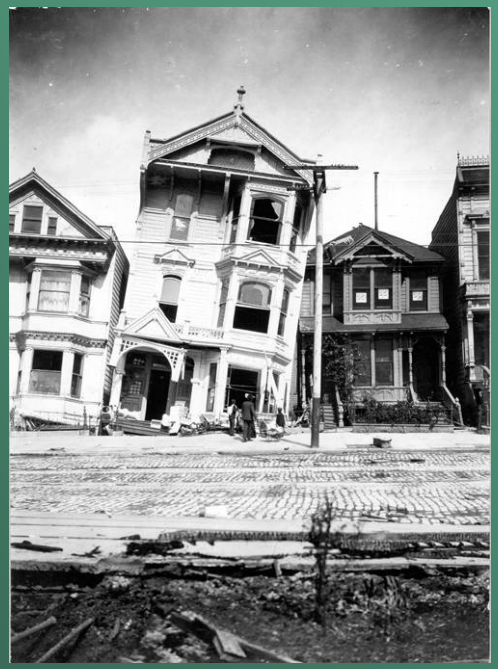
Local soil conditions affect the intensity of shaking. Soft gravels, sand, clay, and silt tend to amplify ground shaking.



After J.D. Rogers, Missouri Univ. of Science & Tech.

Liquefaction

Loose sand and silt that is saturated with water can behave like a liquid when shaken by an earthquake.



Public domain photo by G.K. Gilbert
U.S. Geological Survey
San Francisco photo taken in 1906

Public domain photo by J.C. Tinsley
U.S. Geological Survey
Photo taken 10/17/1989 in Watsonville, Calif.

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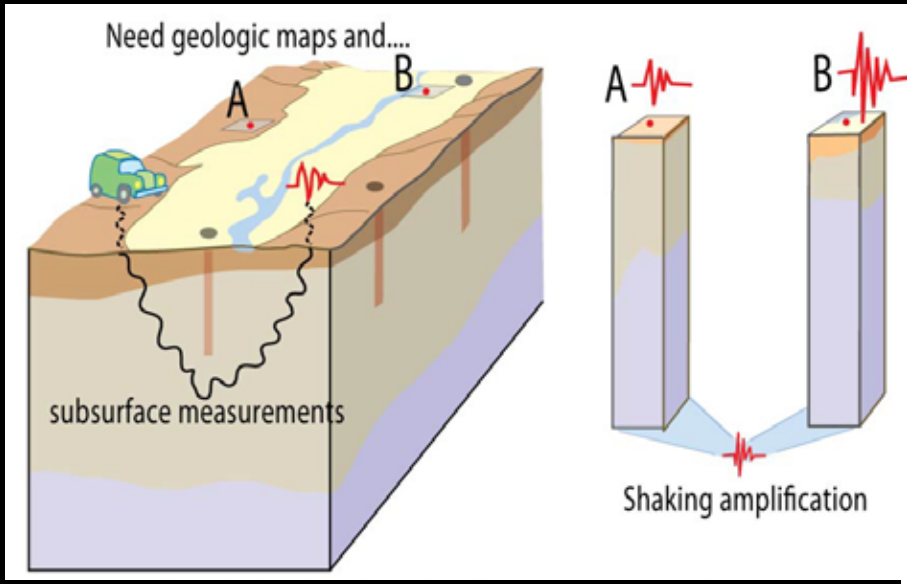
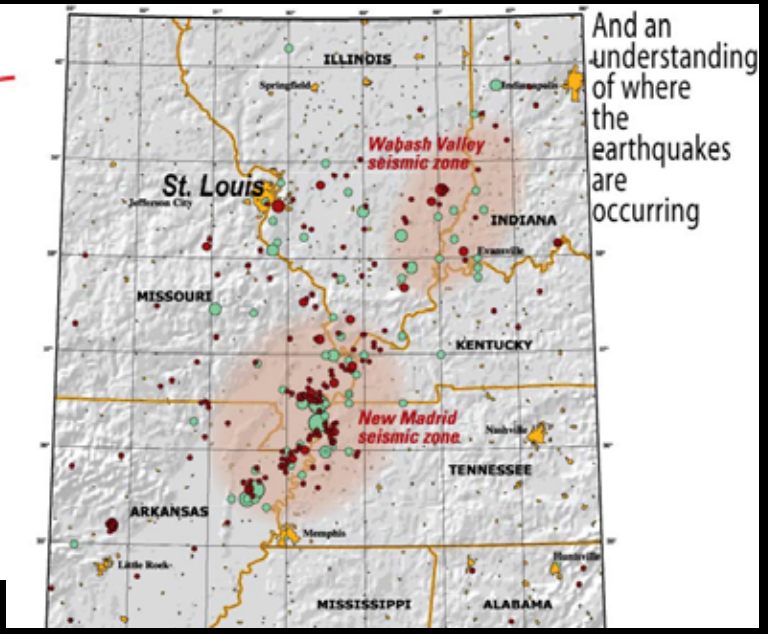
Two basic components to earthquake hazard mapping:





Topographic map showing earthquakes greater than magnitude 2.5 (circles) of the central United States. Red circles are earthquakes that occurred after 1972 (U.S. Geological Survey Preliminary Determination of Epicenters (PDE) catalog). Green circles are earthquakes that occurred before 1973 (USGS PDE and historical catalog). Larger earthquakes are represented by larger circles. Yellow patches show urban areas.

1) **Geology**
2) **Earthquake information**

USGS

Why study St. Louis earthquake hazards?

USGS National Seismic Hazard Map showing relative shaking hazard in the United States during a 50-year time period.

Warmer colors show areas of higher hazard. Blue dots show the locations of major historical earthquakes.

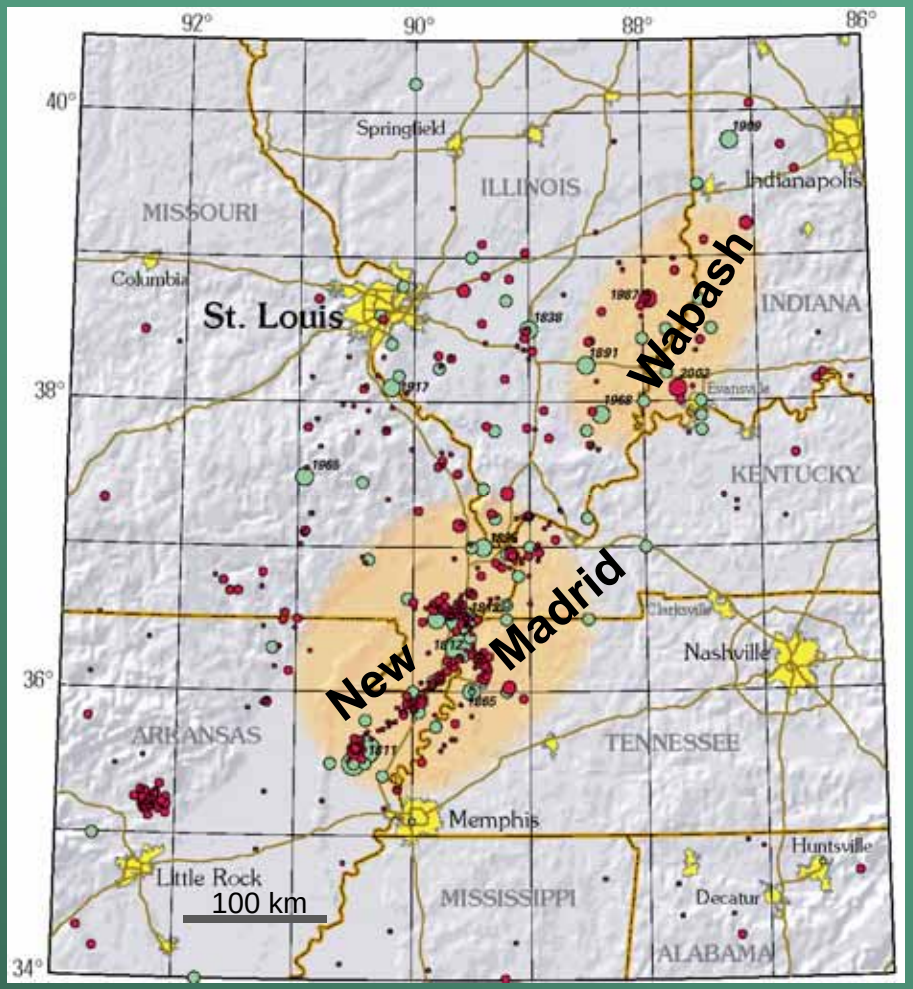
USGS

SLAEHMP

Why study St. Louis earthquake hazards?

Proximity to seismic zones:
New Madrid and ***Wabash Valley***.
Scattered seismicity east and south of St. Louis.

Since 1811 at least a dozen earthquakes have caused minor damage in St. Louis.
(Public domain information: Saint Louis University Earthquake Center, St. Louis, Mo., 1999, http://www.eas.slu.edu/Earthquake_Center/EQInfo/Flyers/central_u.html)



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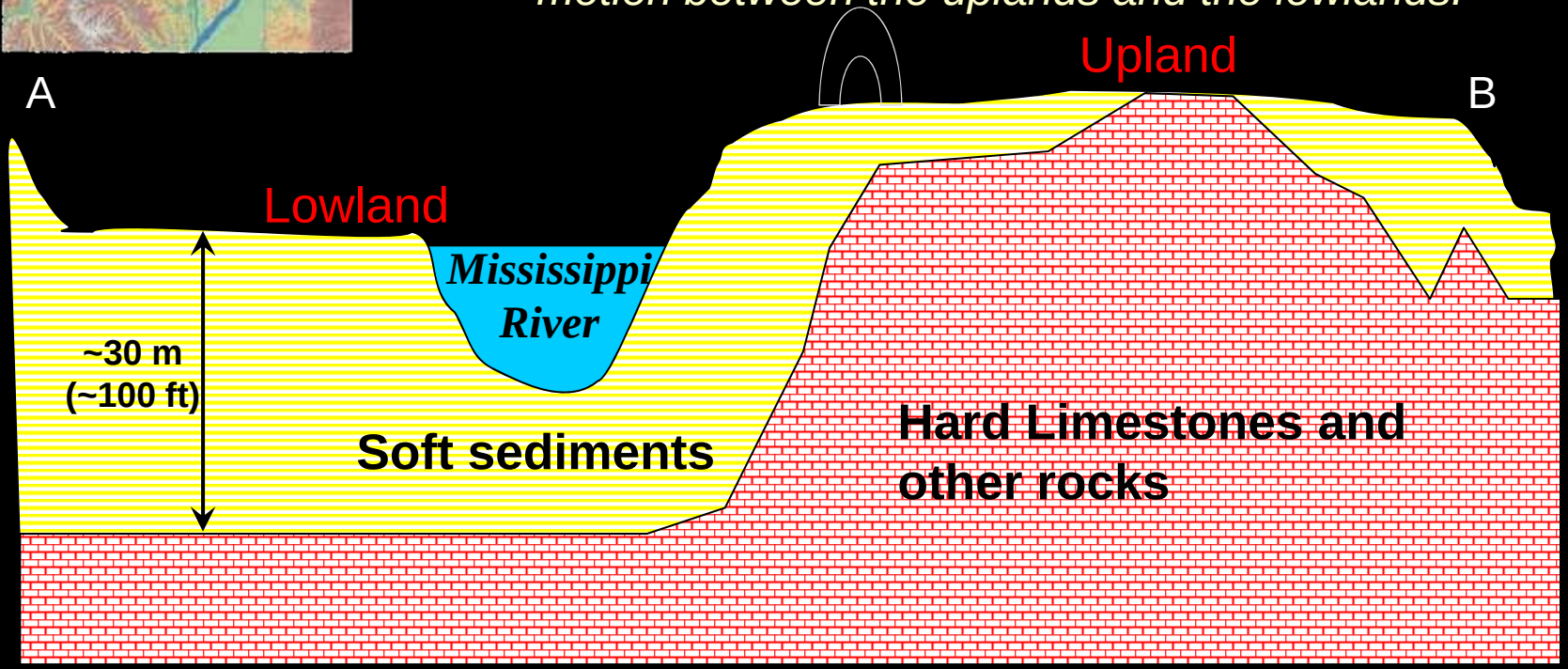
How is the St. Louis area hazards map different from the National Hazard Map?

The SLAEHMP Includes Site Effects

We expect and are seeing differences in ground motion between the uplands and the lowlands.



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St. Louis Area EQ Hazards Mapping Project–Status

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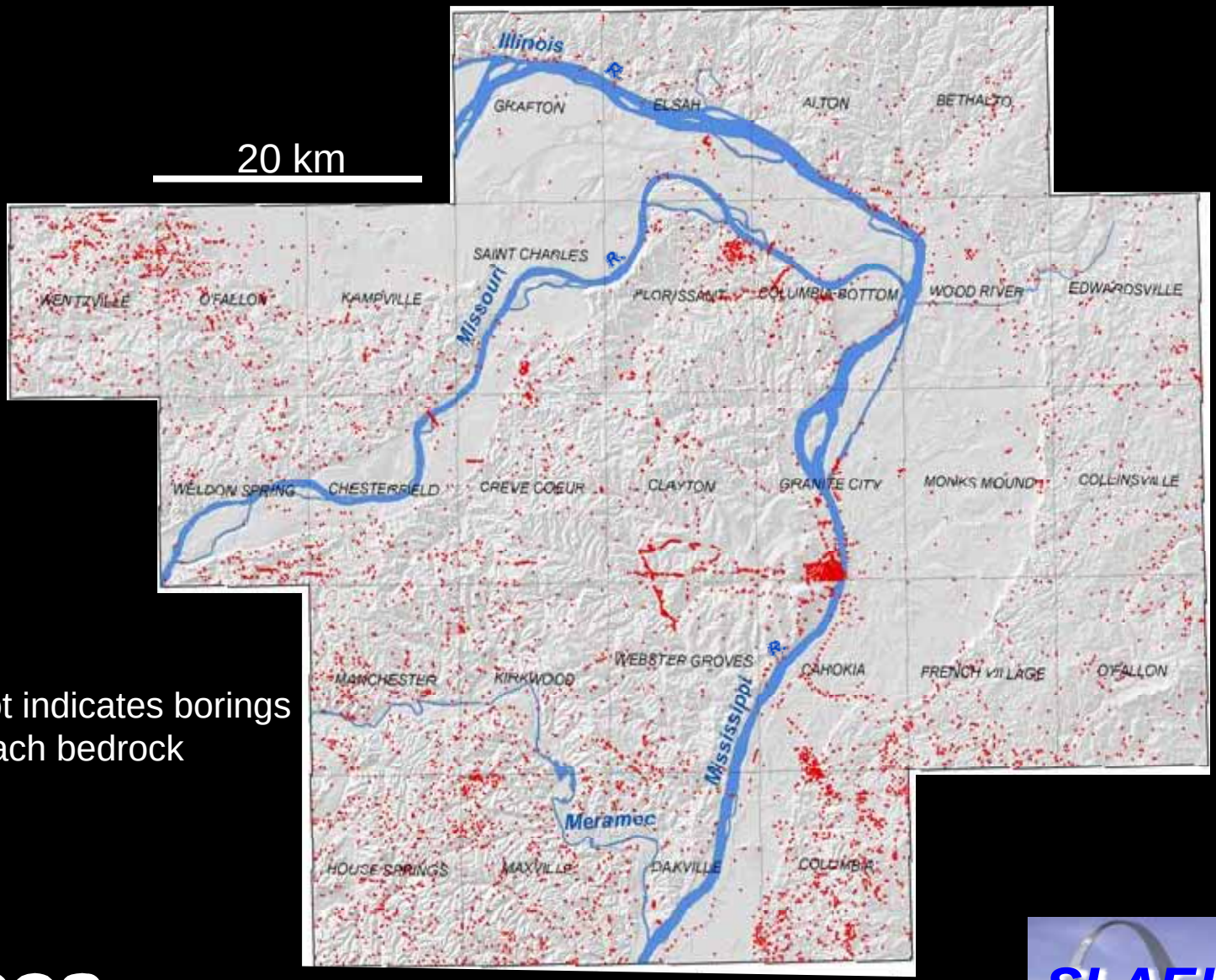
St. Louis Area EQ Hazards Mapping Project–Status



- Red dot indicates borings that reach bedrock

USGS

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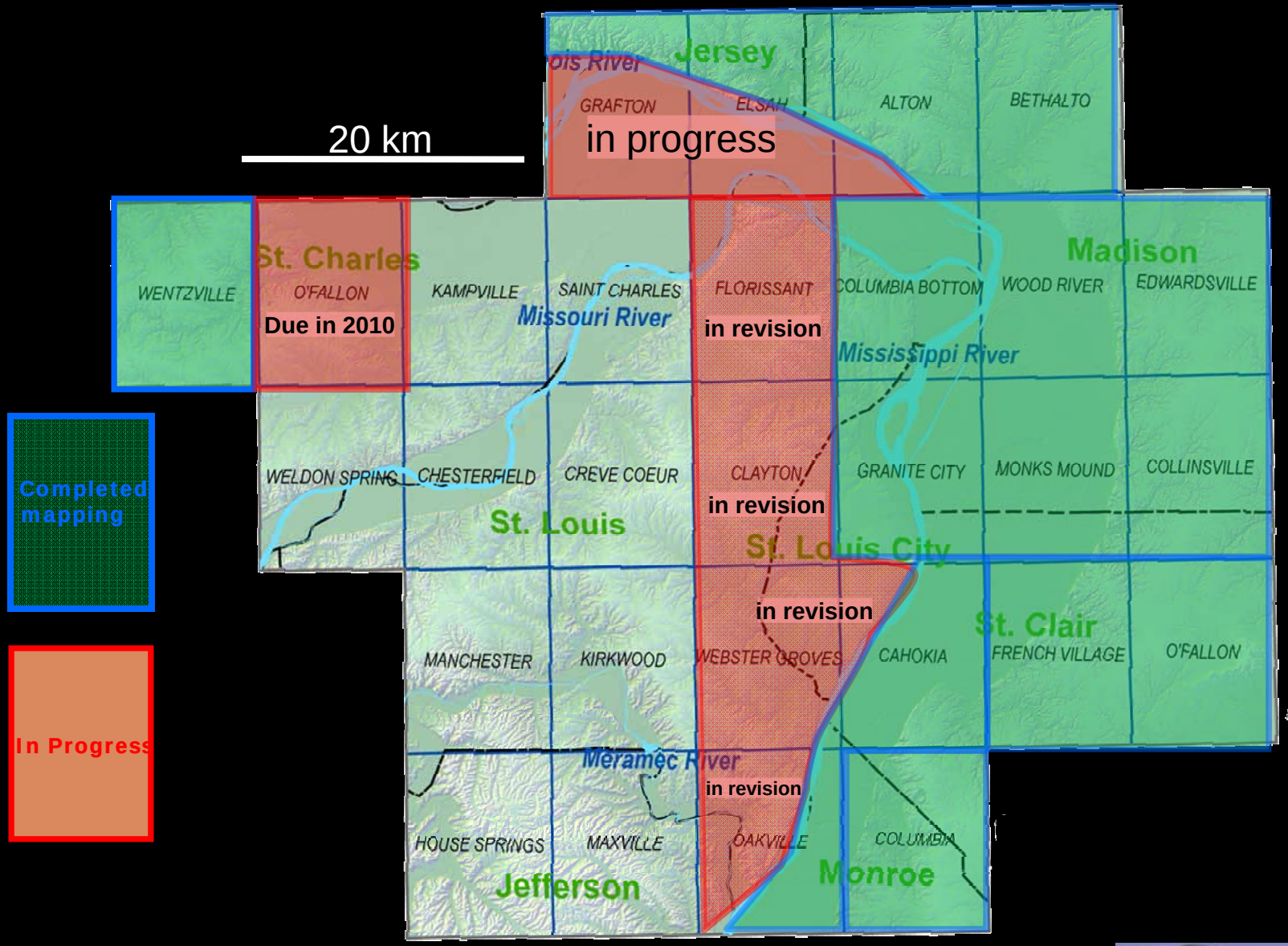
Project Status–Geologic Mapping Progress



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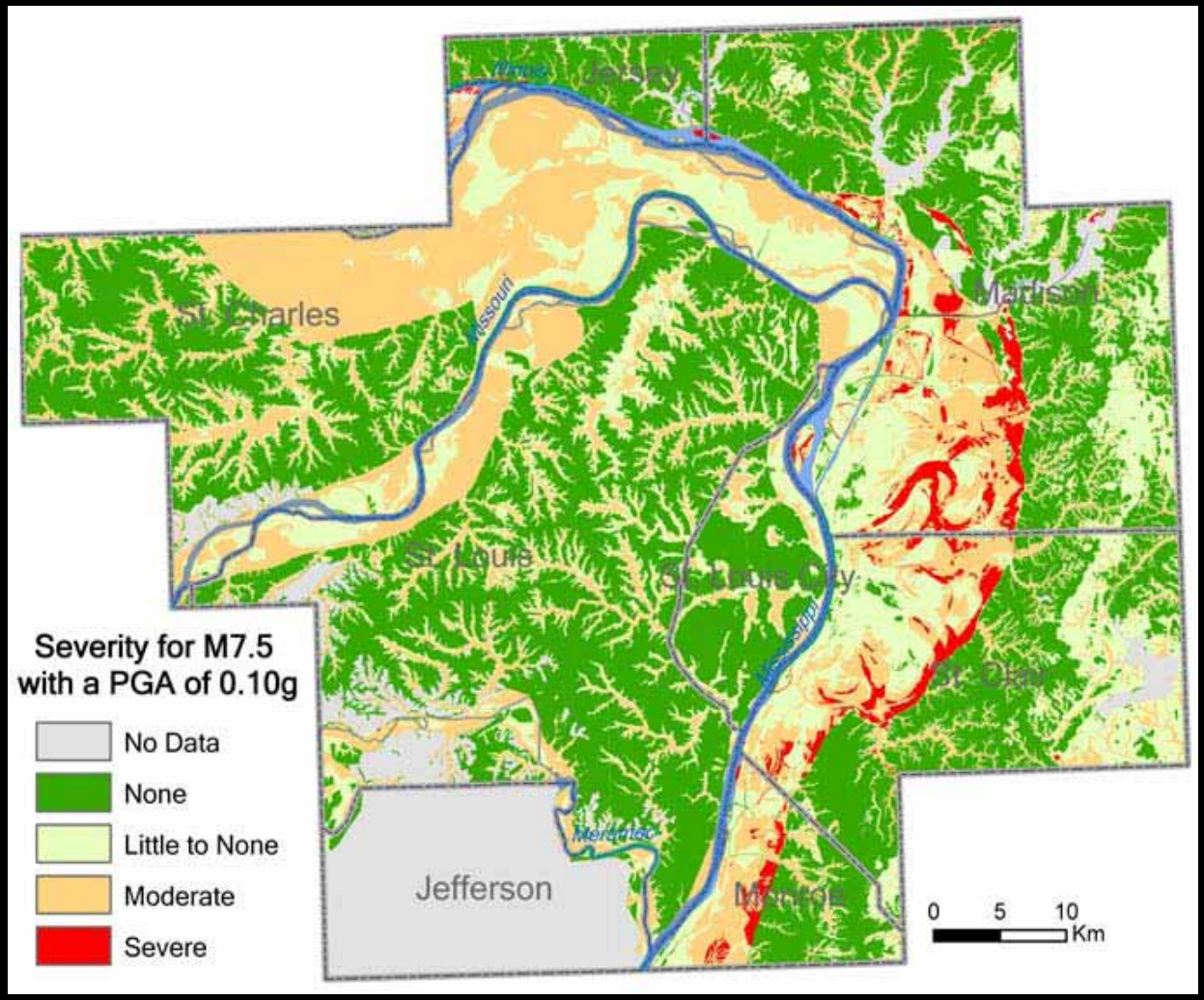
Project Status–Liquefaction Potential Mapping

Higher liquefaction hazard in the Mississippi and Missouri River floodplains



After Chung, 2007

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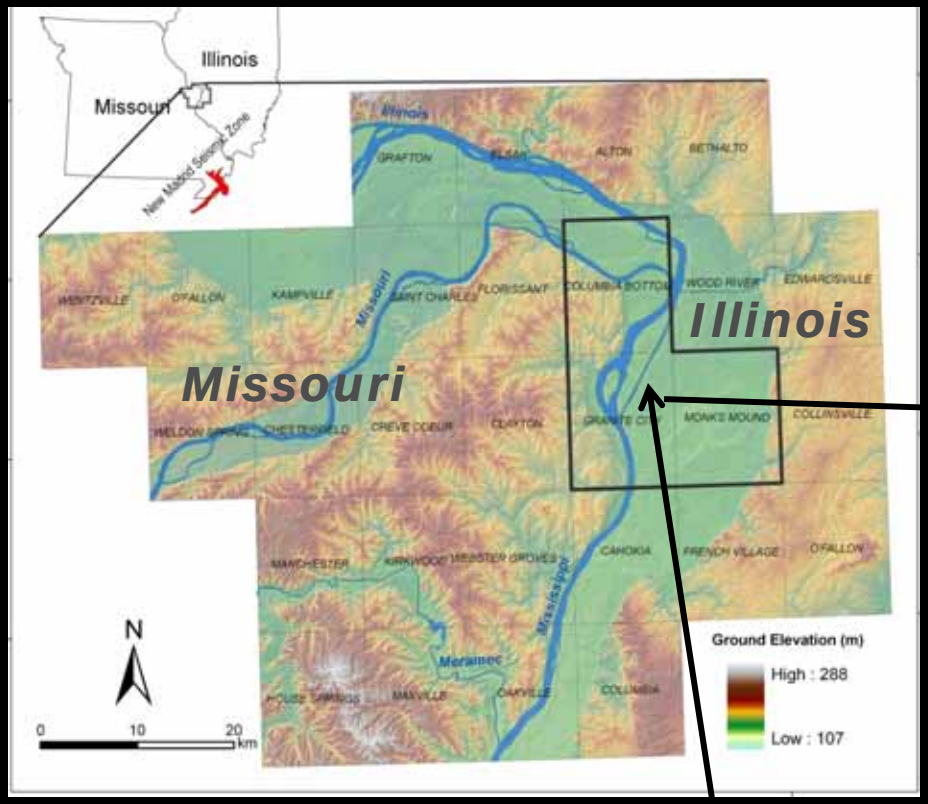
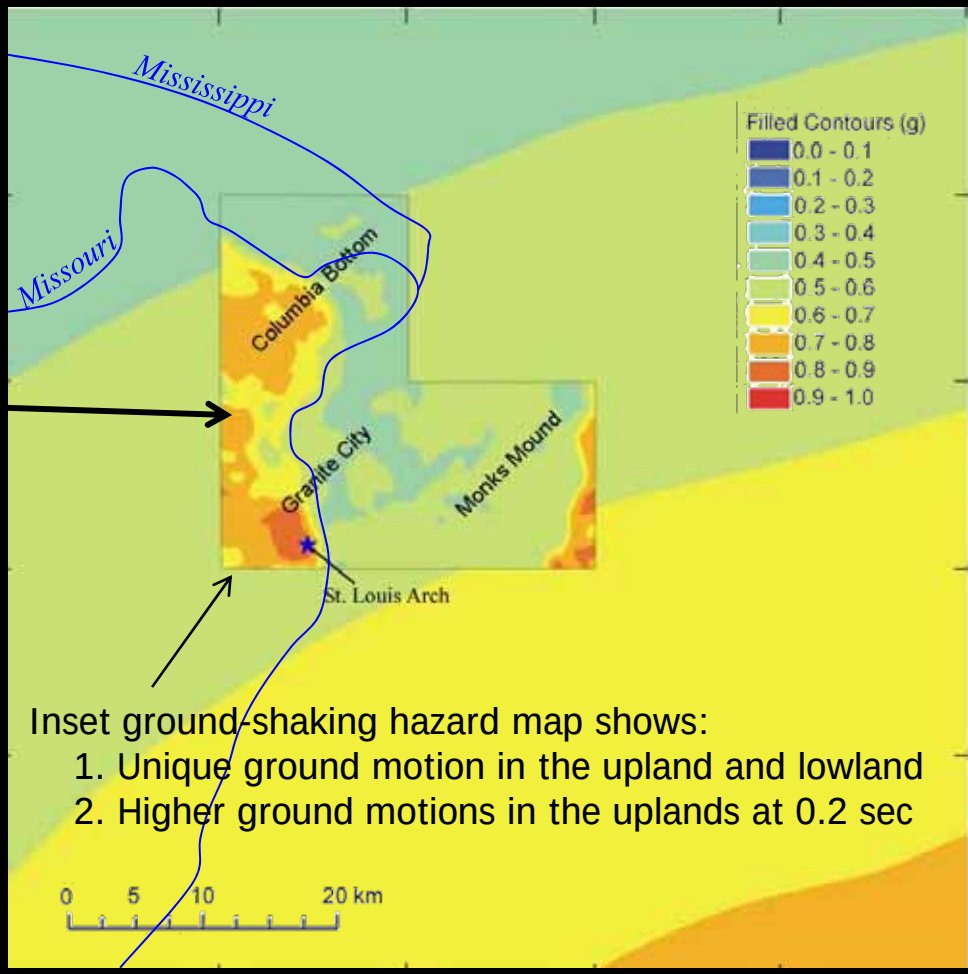
Project Status–Seismic Hazard Mapping Progress



Preliminary results for **pilot study area** covering 3 of 29 quadrangles: Columbia Bottom, Granite City, and Monks Mound.

0.2 sec spectral acceleration, 2% probability of exceedance in 50 years

Comparison to USGS National Seismic Hazard Map



Inset ground-shaking hazard map shows:

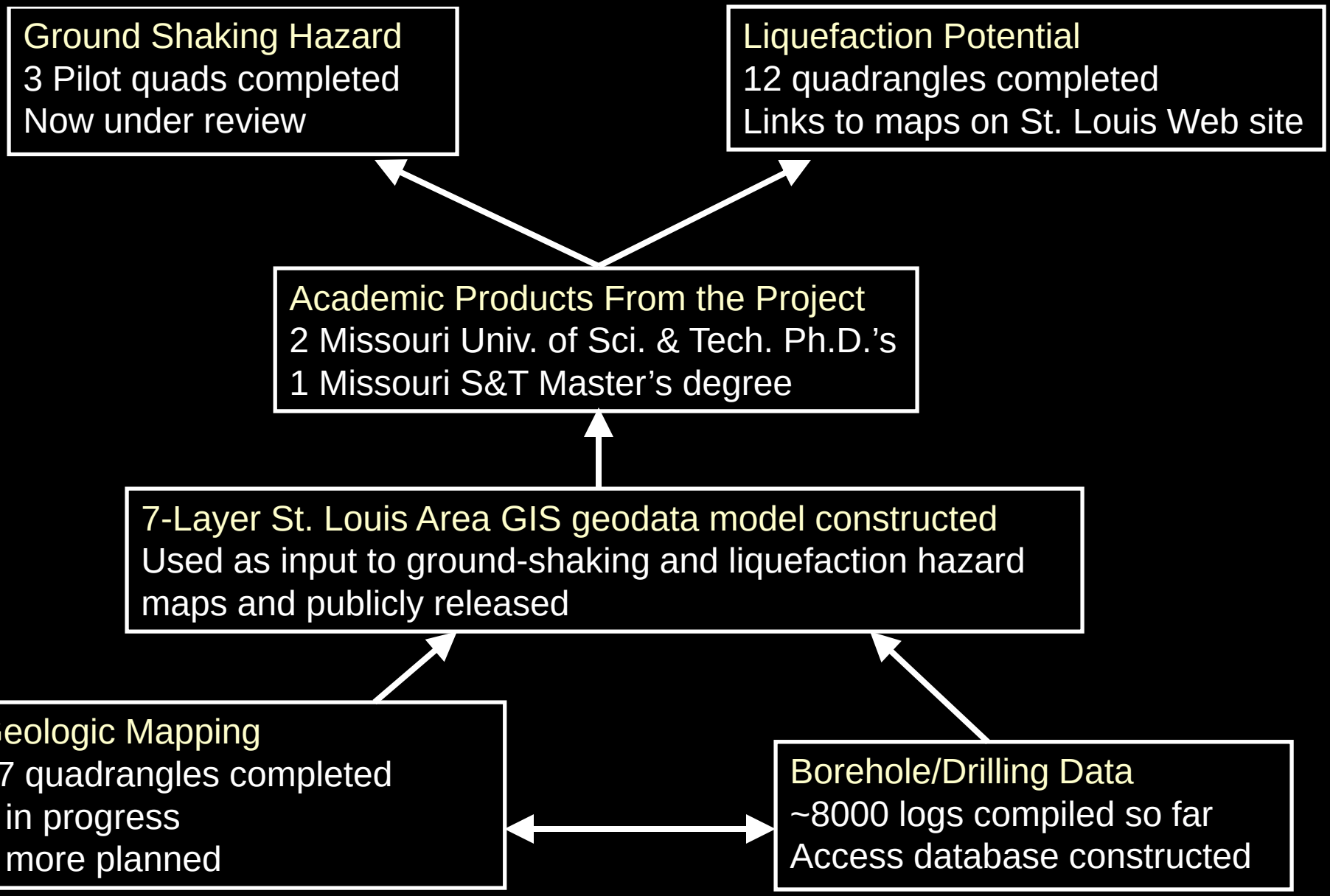
1. Unique ground motion in the upland and lowland
2. Higher ground motions in the uplands at 0.2 sec

After Karadeniz, 2007

USGS

SLAEHMP

St. Louis Area EQ Hazards Mapping Project–Status



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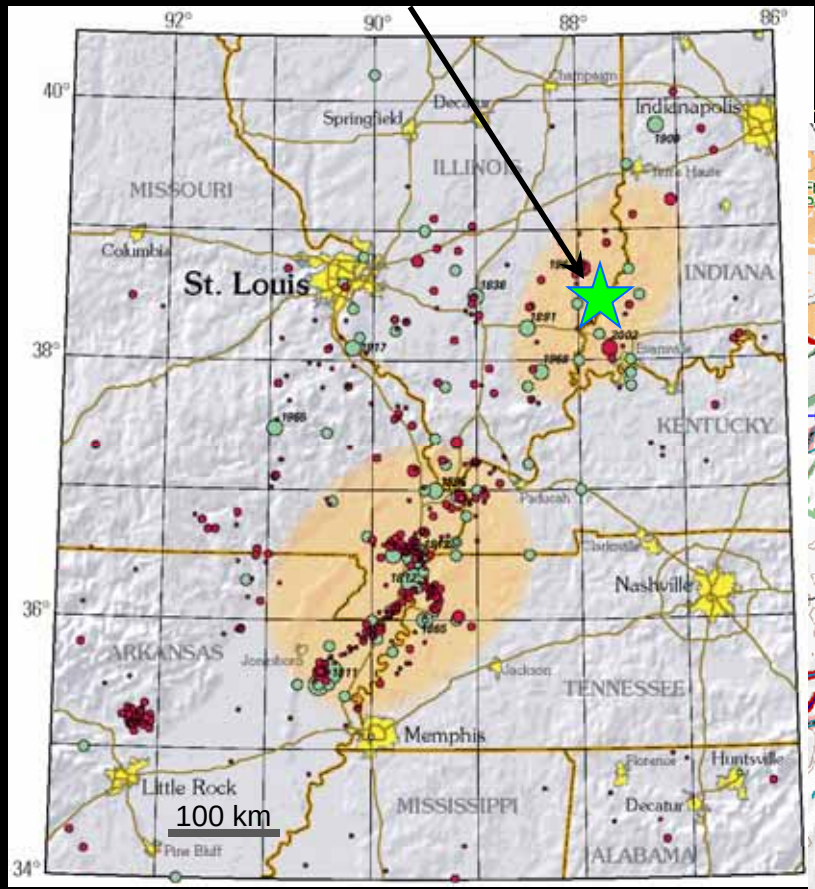
A look at earthquake ground motions in St. Louis:

M5.4 Mt. Carmel Earthquake epicenter–April 18, 2008



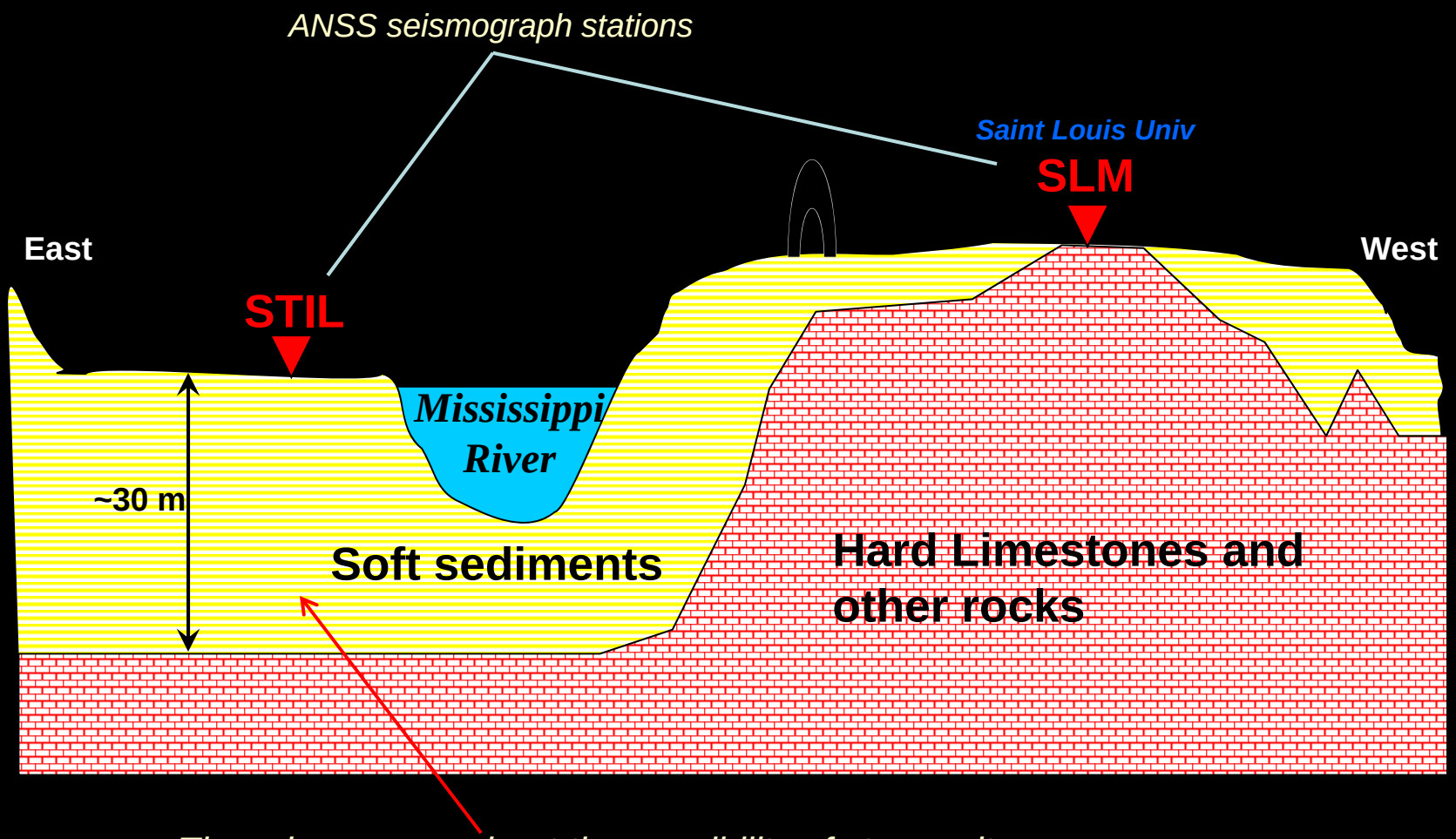
Earthquake travel time to St. Louis: ~30 seconds

The seven Advanced National Seismograph System (ANSS) stations in the St. Louis region

Figure from St. Louis University ANSS Web site information page:
http://www.eas.slu.edu/Earthquake_Center/ANSS/slmmap.html

USGS

Generalized site condition comparison for STIL and SLM



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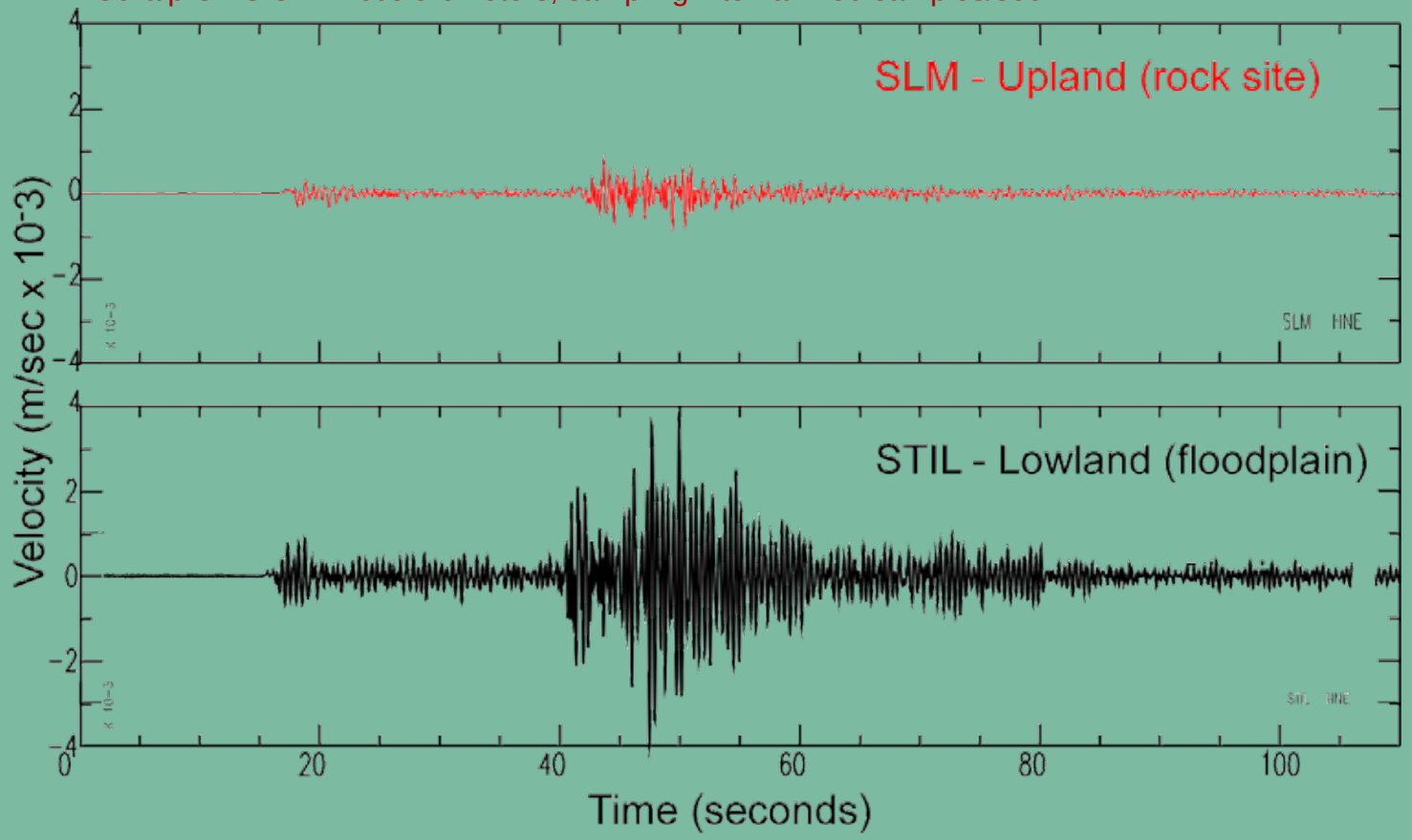
M5.4 Mt. Carmel Earthquake Time History Recordings St. Louis area–April 18, 2008

Guralp CMG 5TD Accelerometers, sampling interval = 50 samples/sec



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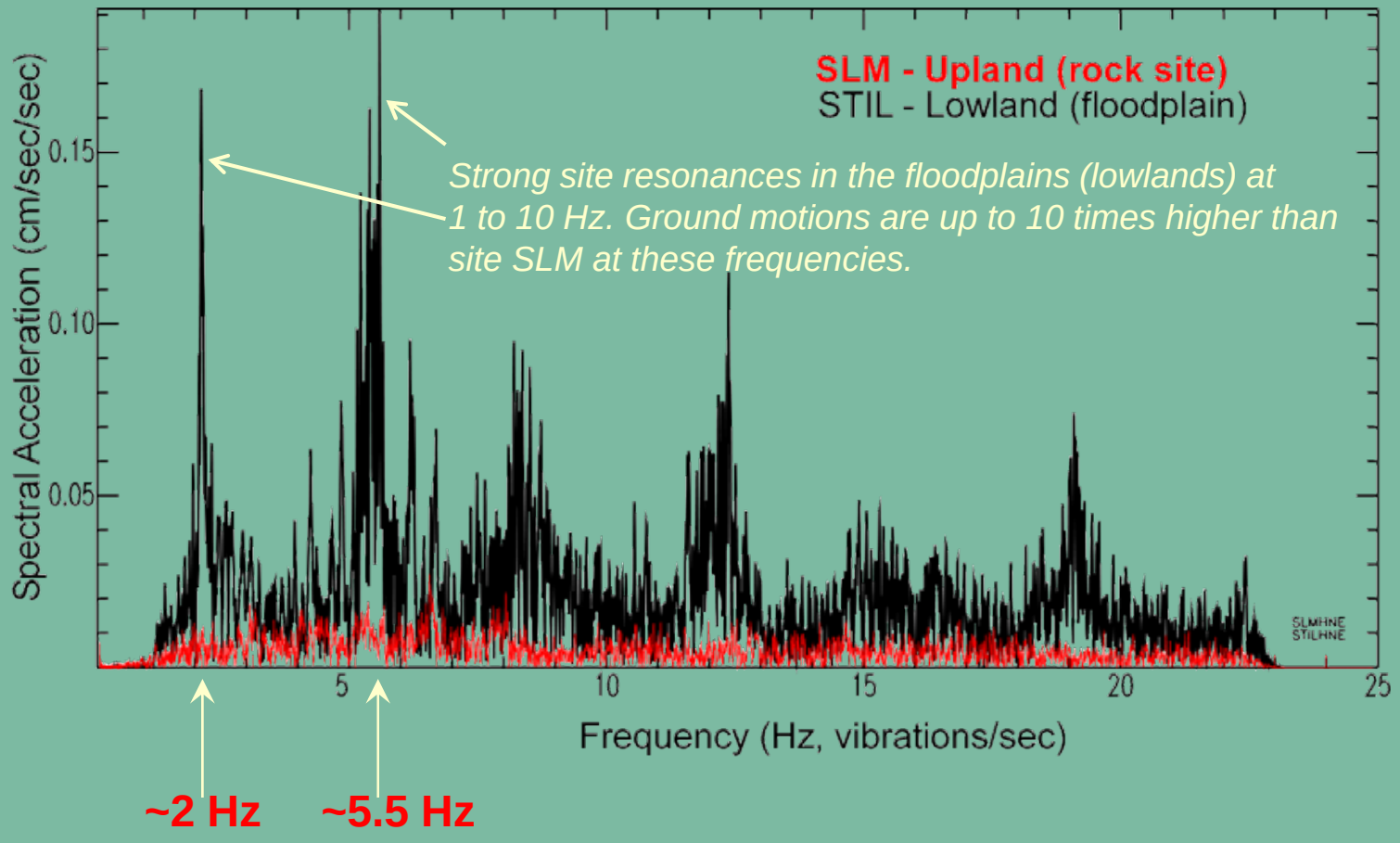
M5.4 Mt. Carmel Spectra Comparison at STIL and SLM

These are so-called "weak" motion (low strain) responses; ground motion behavior will probably be different under stronger ground shaking.



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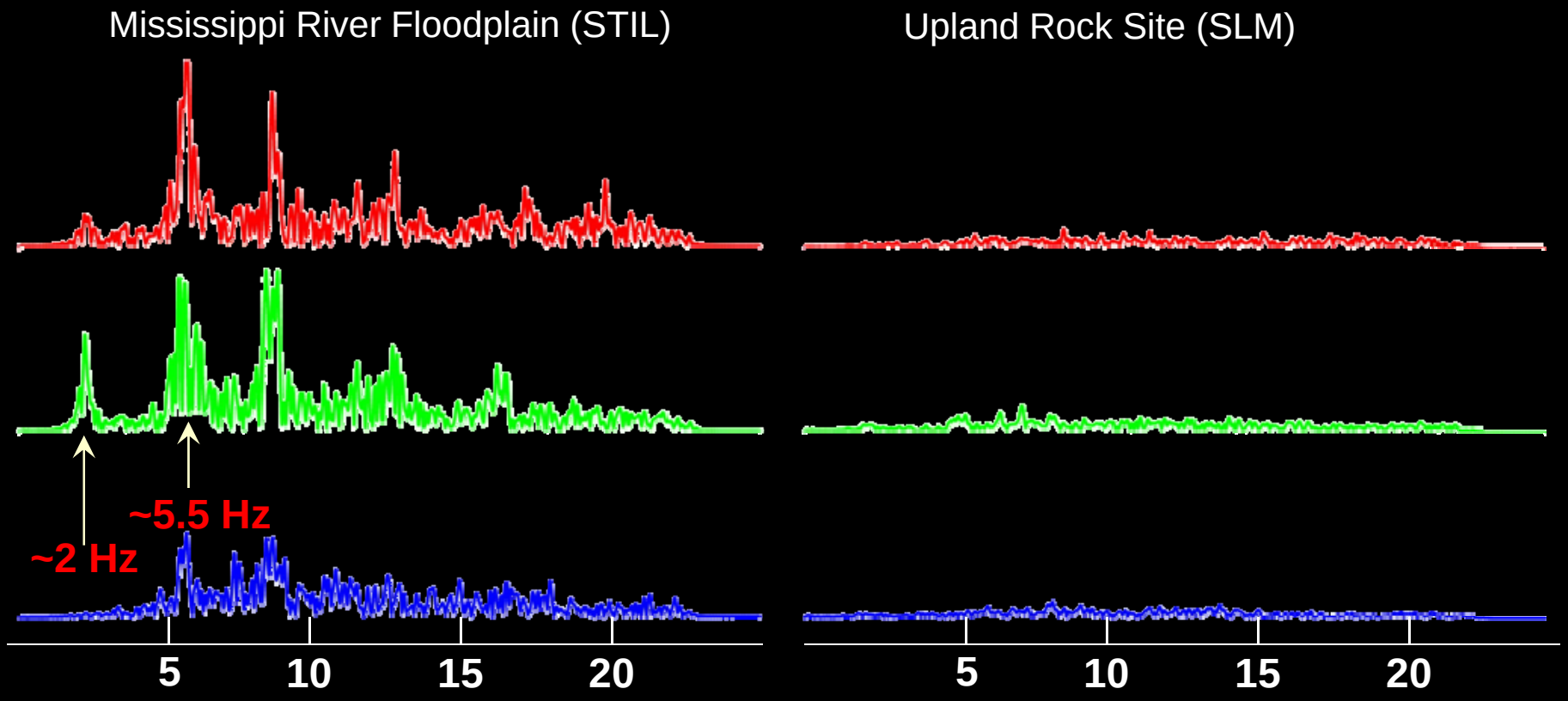
The same site resonances occur in other earthquakes:

January 2006 M3.6 Earthquake in Southern Illinois



Three components of ground motion are recorded at each site: vertical (blue lines) and the two horizontals (green and red lines).

ANSS stations STIL and SLM; after Williams and others, 2006

USGS

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St. Louis EQ Hazard Mapping–Summary

- >8,000 drilling/geotechnical measurements
  Continuing to add new data
- Geologic mapping: 58% of study area completed
  3 more quads under production
- Liquefaction maps: preliminary map completed
  Higher liquefaction hazard in the river floodplains
  Evaluating methodology; considering other scenarios
- Ground shaking hazard map: 10% complete–under review
  Observed ground motions fitting expectations
- Earthquake ground motions observed in St. Louis indicate potentially damaging site resonances in the lowlands.

USGS

SLAEHMP

Where are we headed?

- We are seeking to refine the geologic model and continue to collect and compile new data–especially through donated data and geologic mapping.
- A late-2011 public release of St. Louis earthquake hazard and liquefaction-potential maps
- The 2011-12 New Madrid Earthquake Bicentennial
  Commemorated with scientific meetings and public events

Project data available at: http://earthquake.usgs.gov/regional/ceus/urban_map/st_louis/index.php

USGS

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SLAEHMP products on the Web site:

http://earthquake.usgs.gov/regional/ceus/urban_map/st_louis/index.php

- OF Report 2009-1059: St. Louis Area Earthquake Hazards Mapping Project—A Progress Report
- Comparing the 2002 and 2008 USGS Seismic Hazard Model in the St. Louis Area
- Report describing the St. Louis area surficial materials database
- Download the St. Louis area surficial materials database (Access format - 31Mb)
- Liquefaction susceptibility and probabilistic liquefaction potential hazard mapping, St. Louis
- Creation of a Geologic GIS Database for the St. Louis Metro Area, Missouri and Illinois
- St. Louis, Metro Area Shear Wave Velocity Testing
- Shallow P- and S-Wave Velocities and Site Resonances in the St. Louis Region, Missouri-Illinois

USGS