SITE-AMPLIFICATION MAPS FOR THREE QUADRANGLES IN THE ST LOUIS AREA, MISSOURI AND ILLINOIS

Deniz Karadeniz
J. David Rogers

Department of Geological Sciences & Engineering
University of Missouri-Rolla

UMR

Introduction - 1

- In 2005 USGS-CEUS office organized a St. Louis Area Seismic Hazard Mapping Project Technical Working Group (SLAHMP-TWG).
- The SLAHMP-TWG convenes four times a year to discuss mutual goals and assignments for the 5-year NEHRP earthquake hazards program (EHP) study, focusing on evaluating relative seismic risks and ground shaking hazards posed to the St. Louis Metropolitan area
- The study area encompasses about 4,000 km^2 across 29 USGS 7.5-minute quadrangles.

UMR

Introduction - 2

- Our pilot feasibility study has selected three 1:24,000 scale quadrangles: 1)Granite City, 2) Monks Mound and, 3) Columbia Bottom, encompassing downtown St Louis and the area immediately to the east and north, including the Mississippi River floodplain.
- These seismic hazard maps are based on accurate assessments of site-amplification that incorporate considerations of actual geologic conditions underlying these areas.

UMR

What information do we need to estimate site amplification?

1) Characterize the bedrock properties below the surficial materials

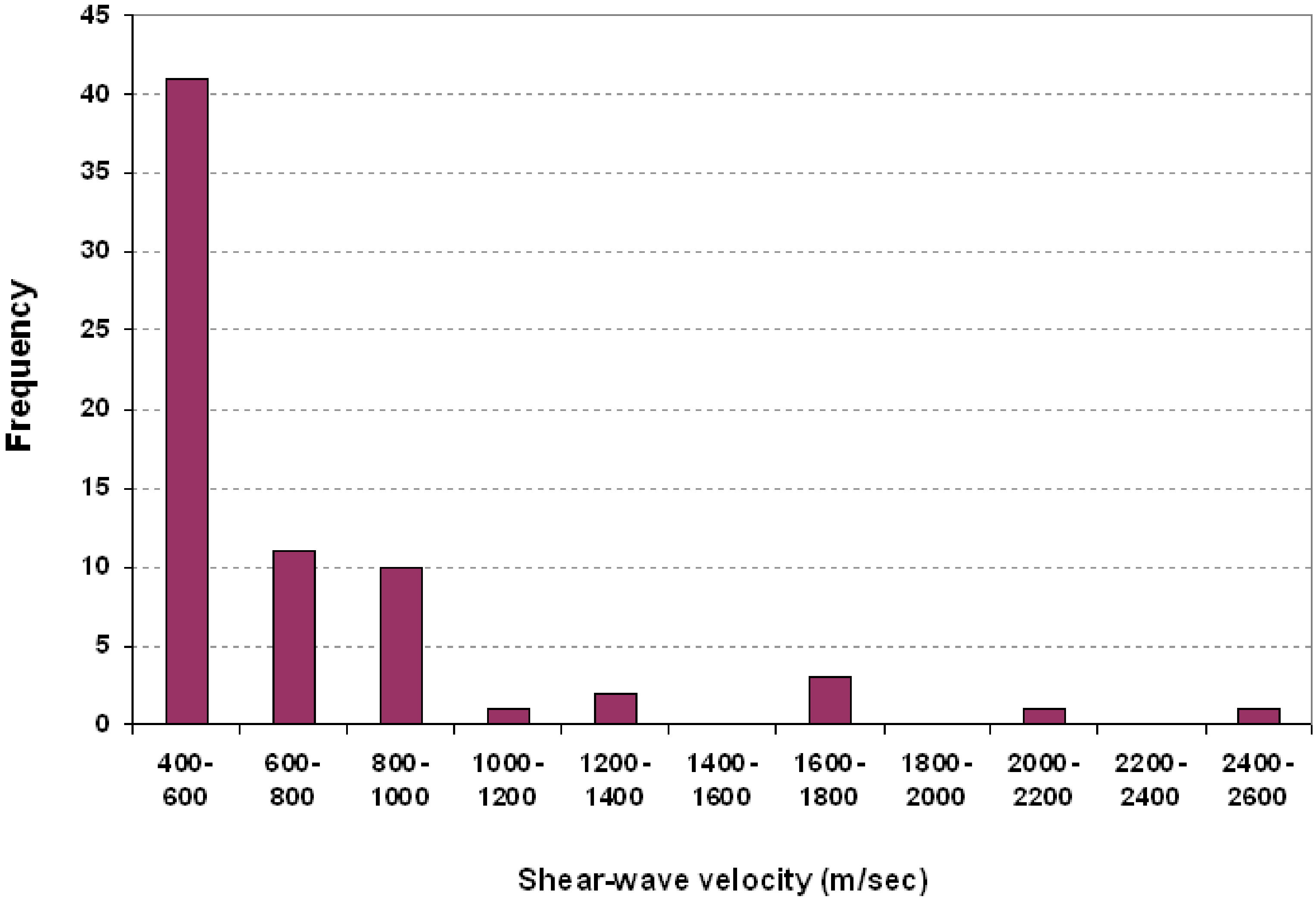
2) Characterize the bedrock acceleration

3) Characterize the shallow geology overlying the bedrock
   - Surficial geology maps
   - Depth to Bedrock

4) Characterize the properties of the surficial materials (soil cap)
   - Physical soil properties
   - Dynamic soil properties (Shear modulus and damping, Shear-wave velocity)

UMR

Shear wave velocity of the weathered bedrock interface



Data below surficial materials

- **We used 2000 m/sec for the weathered bedrock shear-wave velocity as suggested by Bob Hermann, St. Louis University.**
- **We have selected 50 m thickness of the weathered bedrock.**
- **We used 2800 m/sec for the half-space below the weathered bedrock.**

UMR

What do we need to know to estimate the amplifications?

1) Characterize the bedrock properties

2) Characterize the bedrock acceleration

3) Characterize the shallow geology

   Surficial geology maps

   Depth to Bedrock

4) Characterize the soil properties

   Physical soil properties

   Dynamic soil properties (Shear modulus and damping, Shear-wave velocity)

UMR

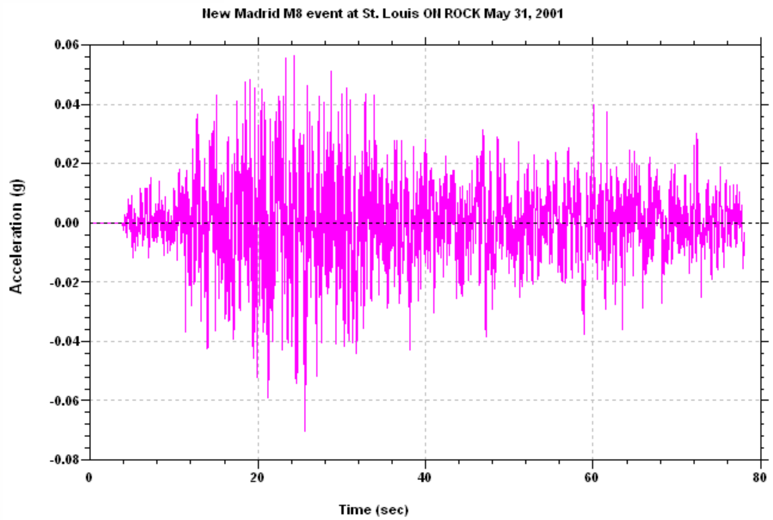
Earthquake time-series on Rock used in Amplification analysis

Year	Mw	Dist	Earthquake	Components
1992	M7.3	194 km	Landers, CA	200, 290
1999	M7.1	184 km	Duzce, Turkey	E, N
1999	M7.6	183 km	Chi Chi, Taiwan	N, W
1999	M7.1	194 km	Hector Mine, CA	360, 90
2002	M7.5 M8.0	200 km	Atkinson and Beresnev	
2002	M7.0 M7.5	200 km	Boore's SMSIM Code	

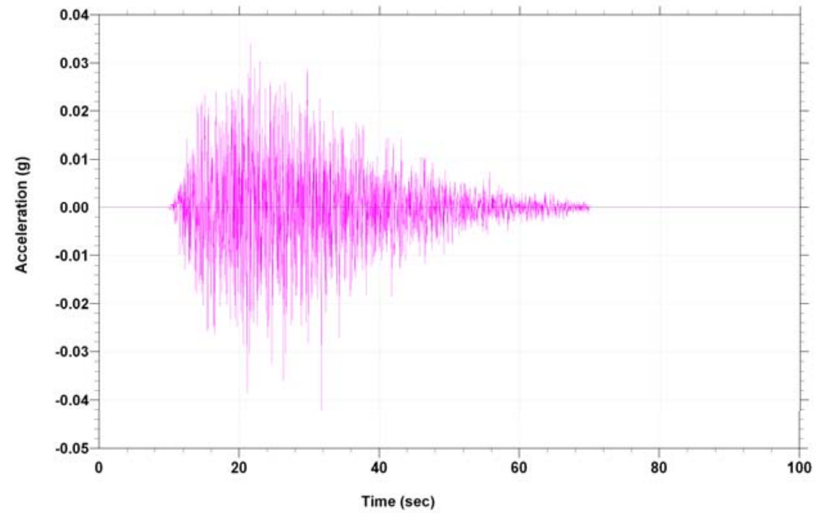
UMR

Acceleration-time histories

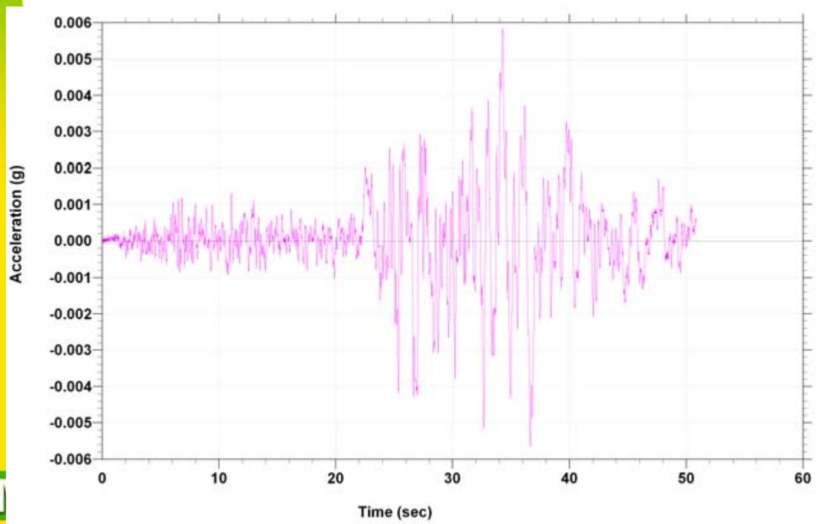
Atkinson and Beresnev, 2002
Distance = 200 km, Mw = 8.0



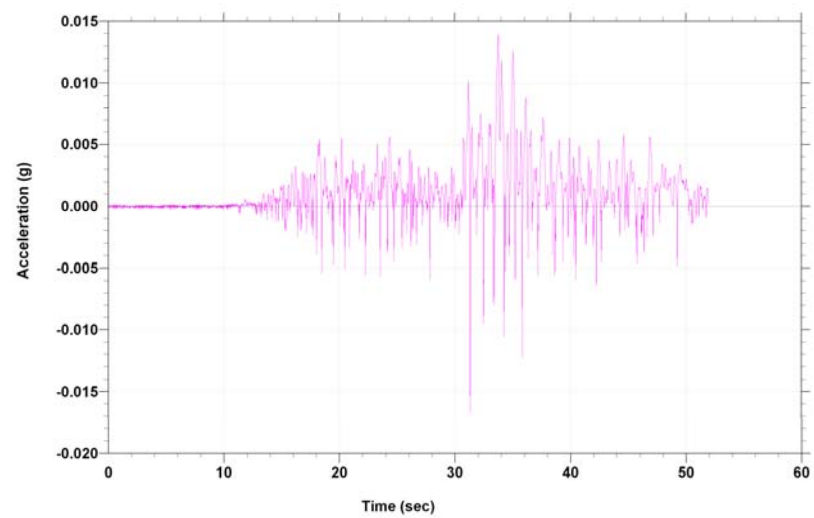
SMSIM v2.2 Distance = 200 km, Mw = 7.5



1999 Duzce Earthquake
Distance = 184 km, Mw = 7.3



Hector Mine, CA Earthquake
Distance = 194 km, Mw = 7.1



- **6 different earthquakes are selected. With the components, 14 different scenarios were used in the analysis.**
- **The amplification depends on the amplitude and frequency of the ground motion.**
- **Distribution of site amplification are built at a particular amplitude and frequency.**
- **The real ground motions are "scaled" to input rock motions at ten different shaking levels (0.01, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8 and 1.0g).**

UMR

What do we need to know to estimate the amplifications?

1) Characterize the bedrock type

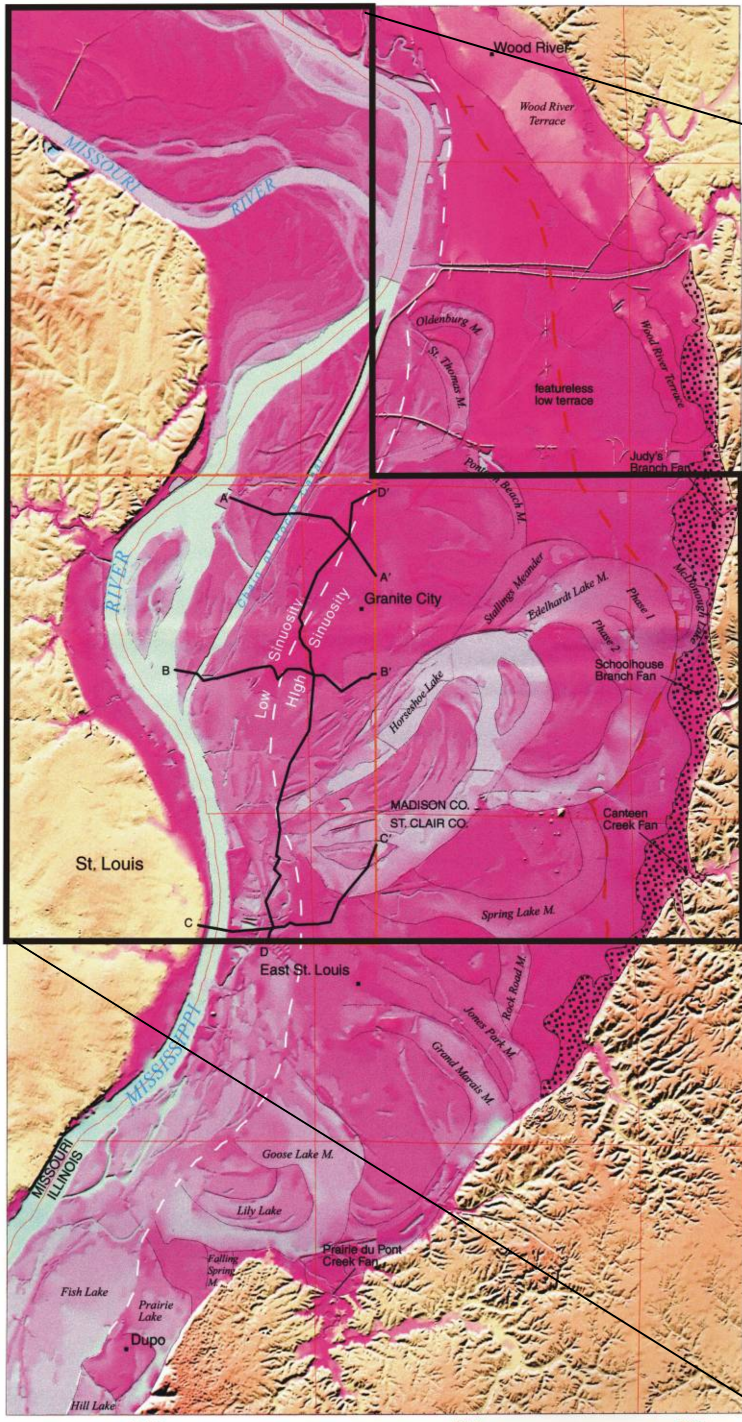
2) Characterize the bedrock acceleration

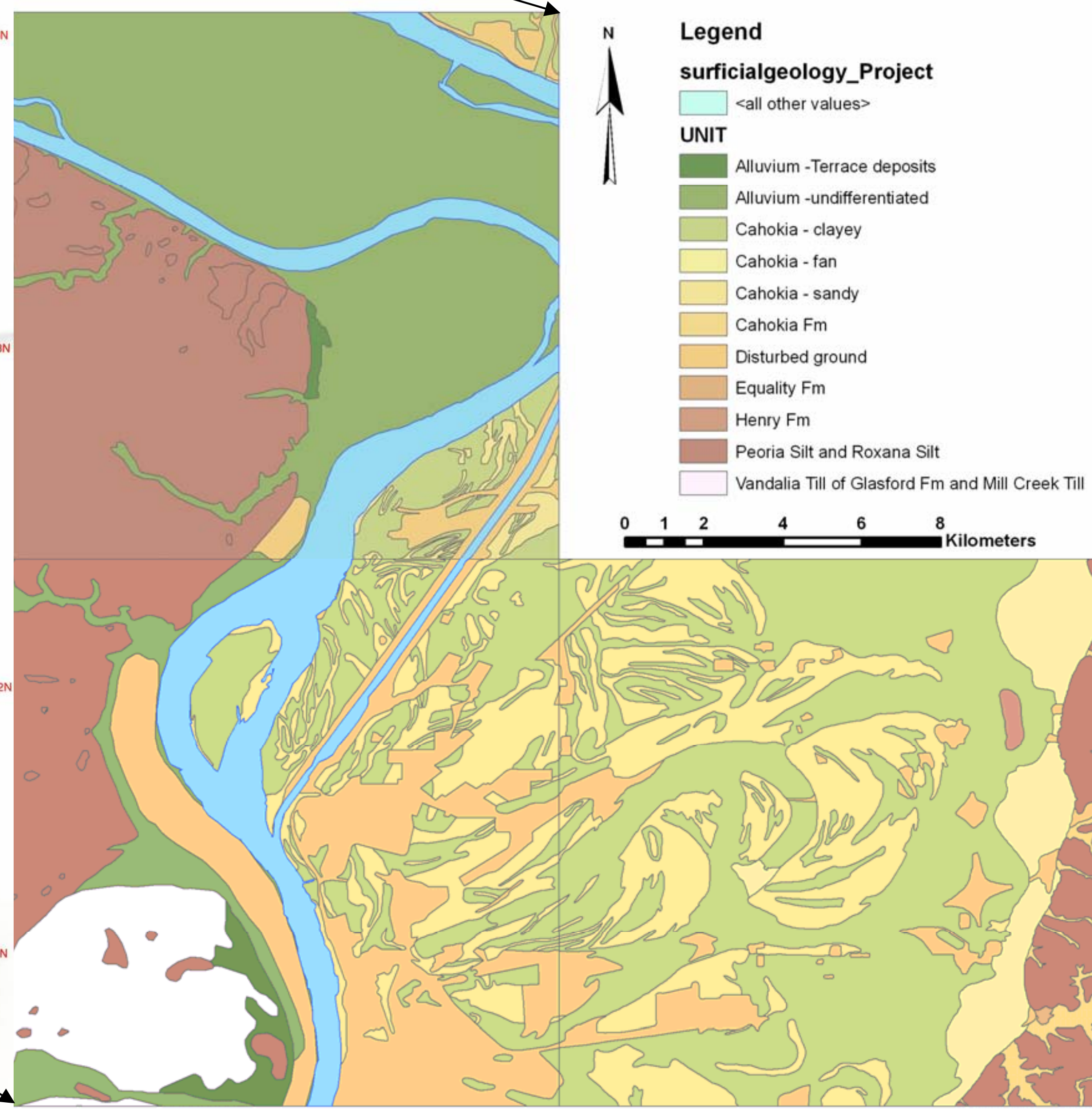
3) Characterize the shallow geology
   - Surficial geology maps
   - Depth to Bedrock

4) Characterize the soil properties
   - Physical soil properties
   - Dynamic soil properties (Shear modulus and damping, Shear-wave velocity)

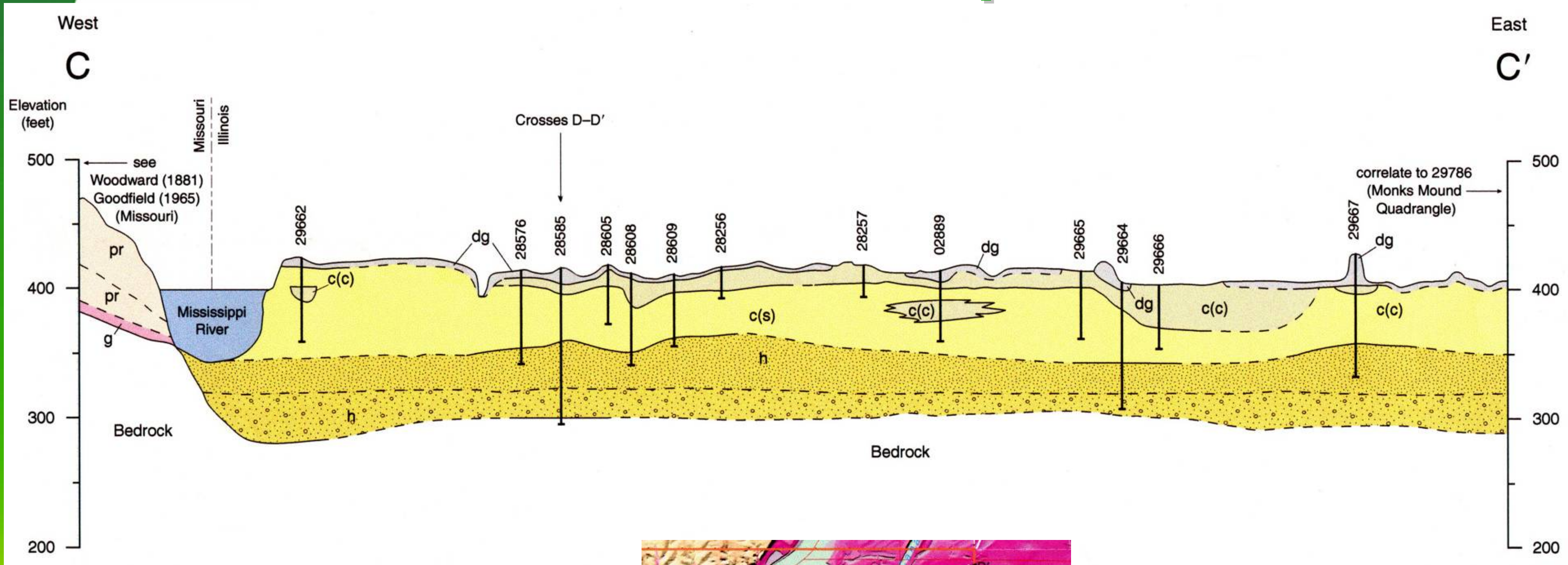
UMR

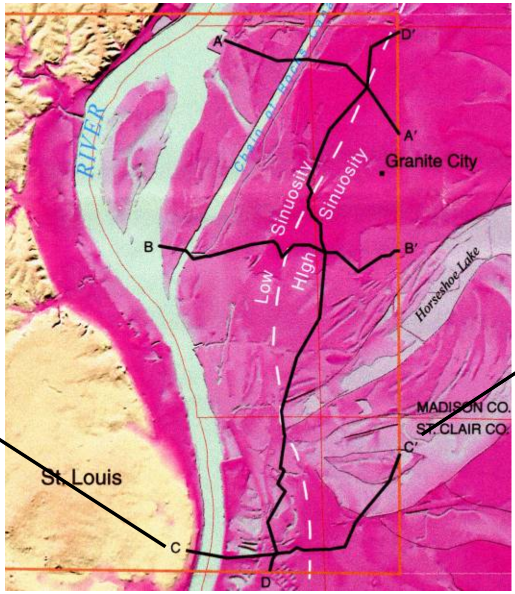
Geology Interpretation





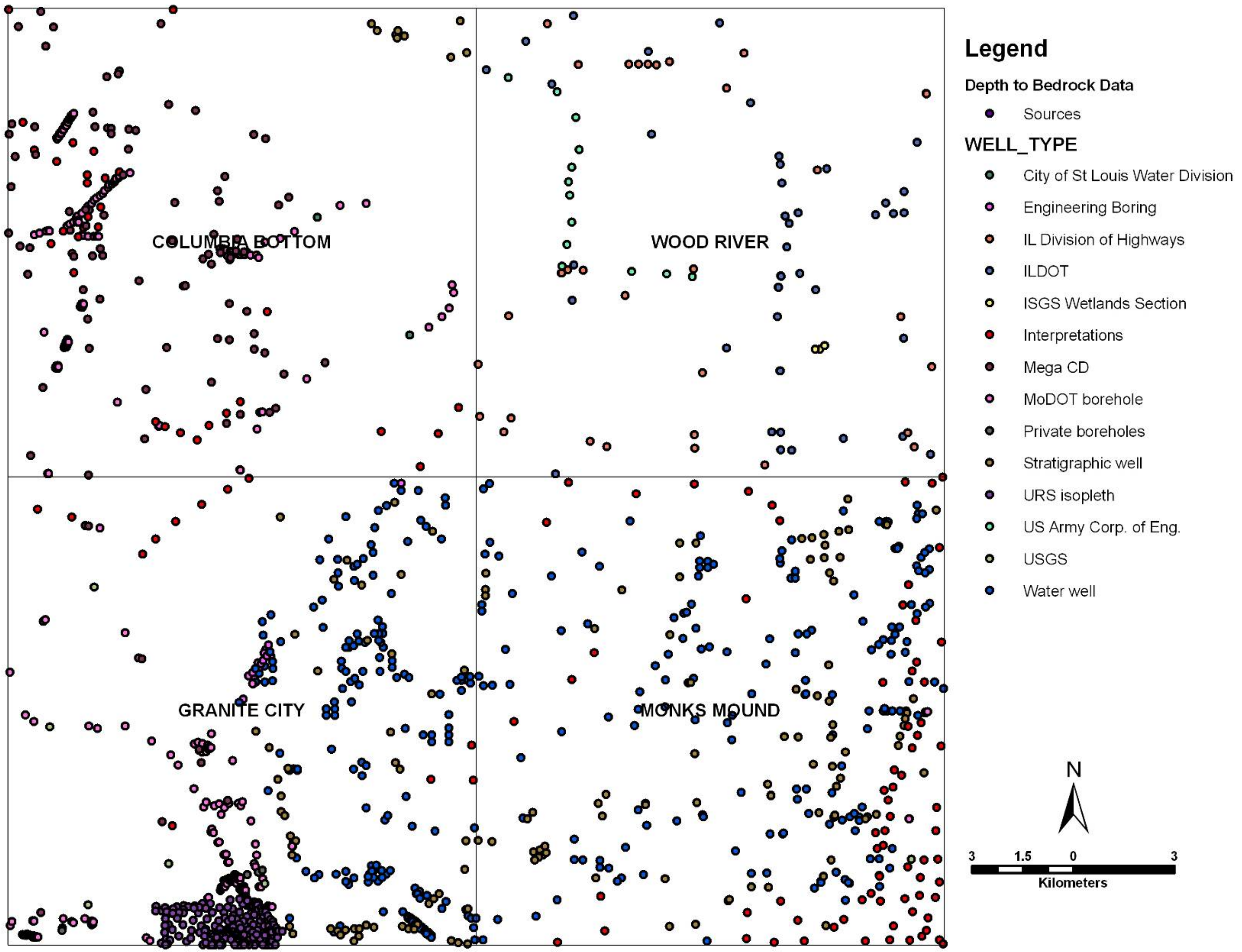
Geological Cross-sections and Subsurface Interpretation





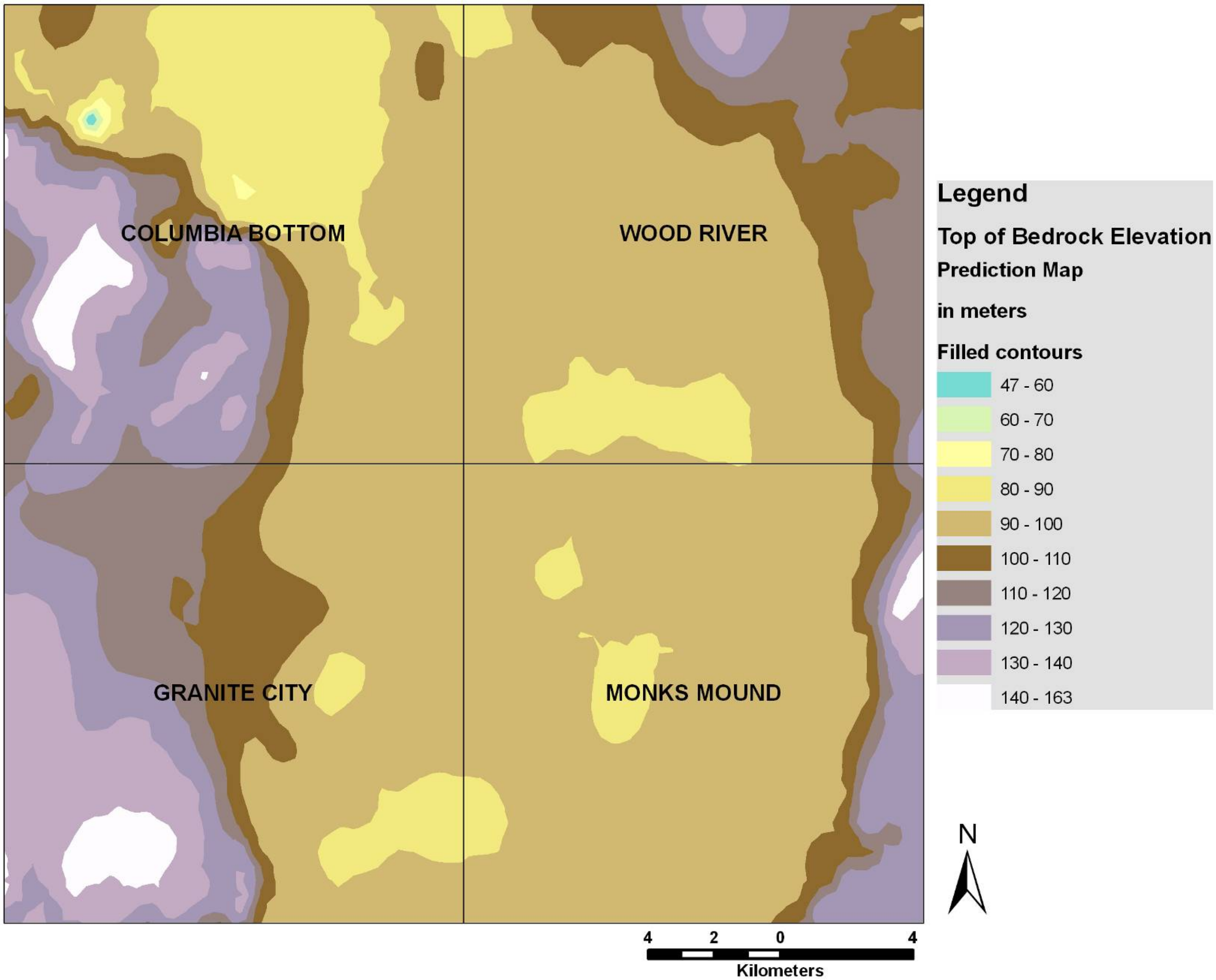
Cross section interpretation by Illinois State Geological Survey

Data Points



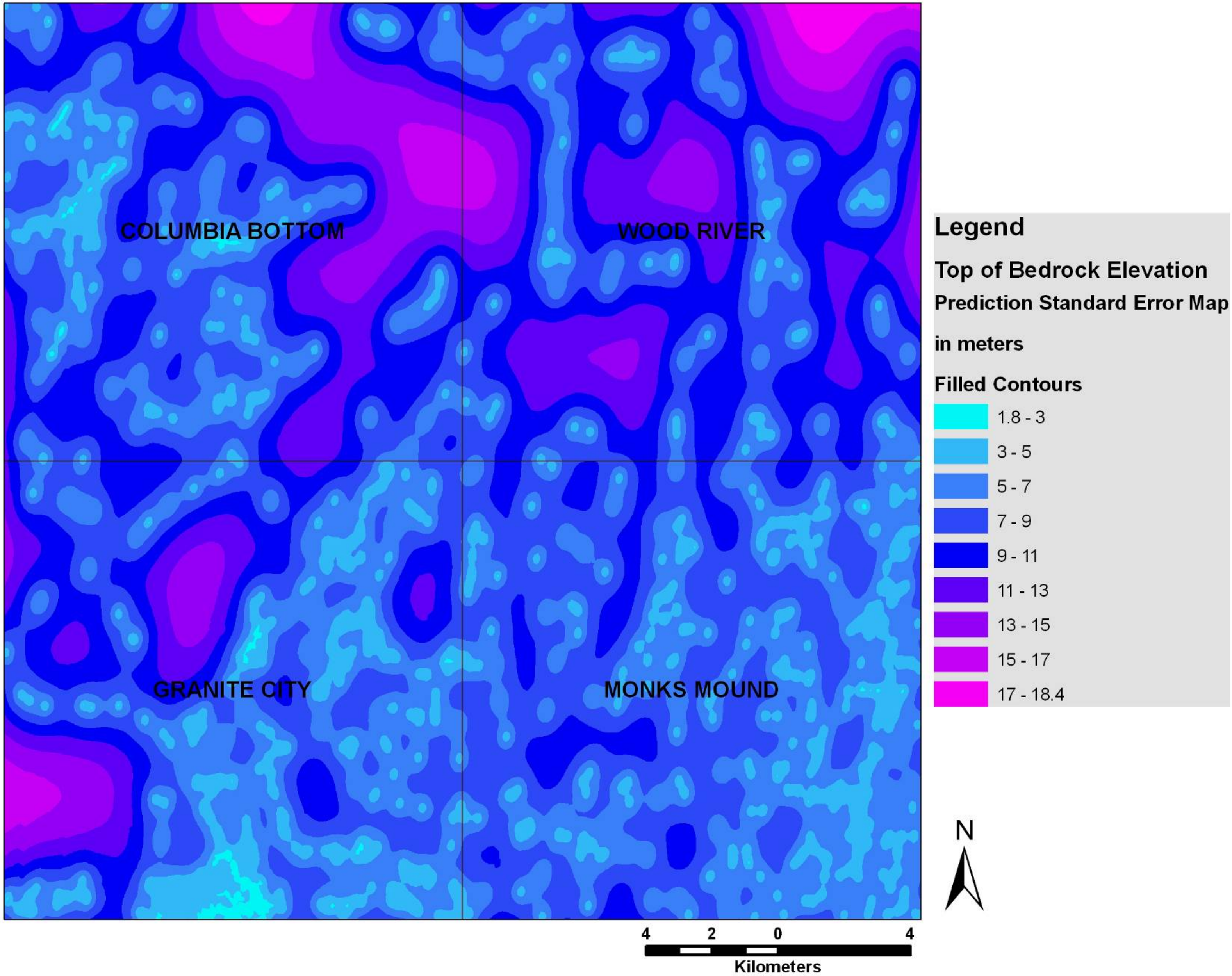
UMR

Estimation of Top of Bedrock Elevations



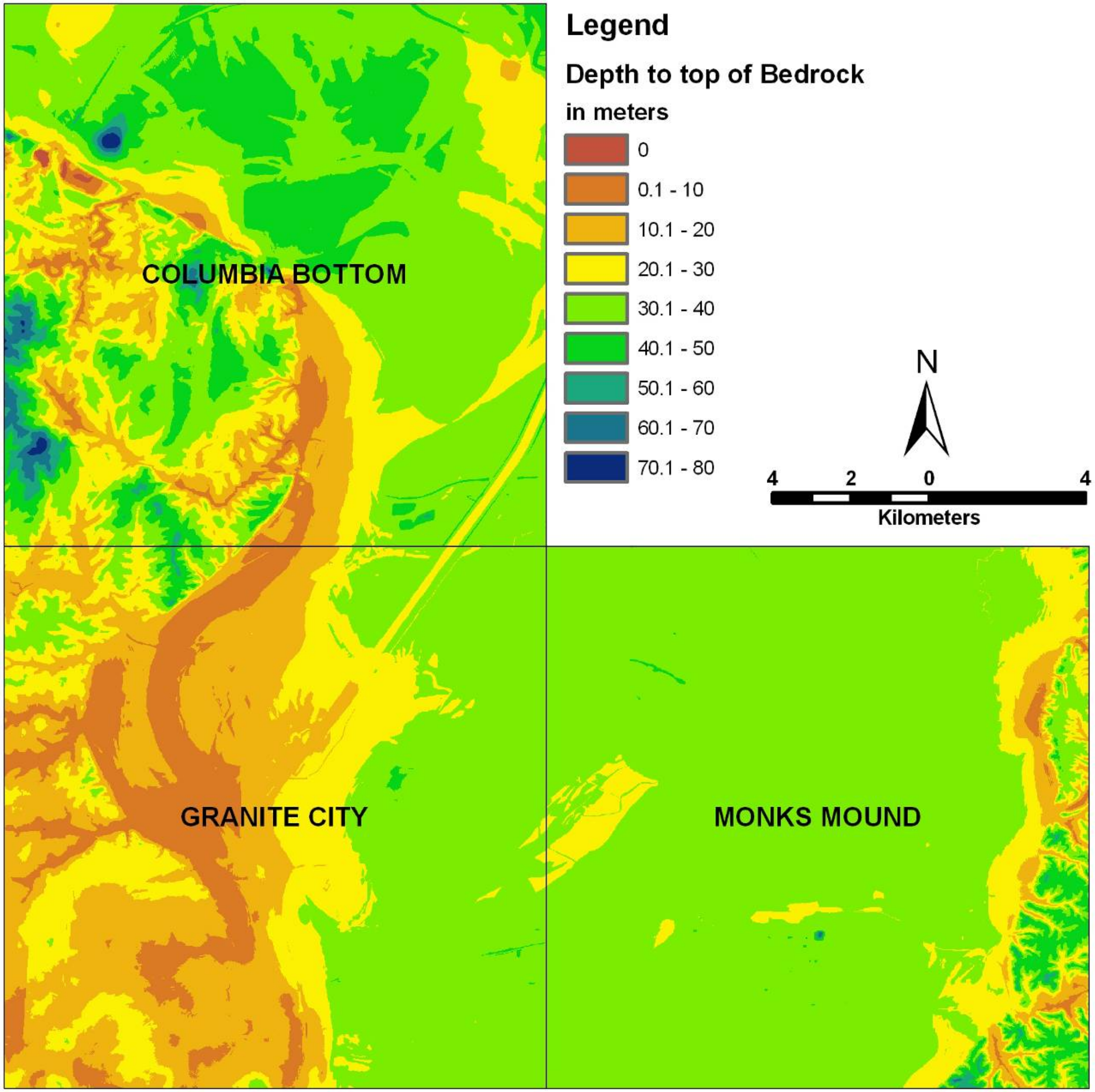
UMR

Standard Error Map Bedrock Elevation



UMR

Depth to Bedrock



UMR

What do we need to know to estimate the amplifications?

1) Characterize the bedrock type

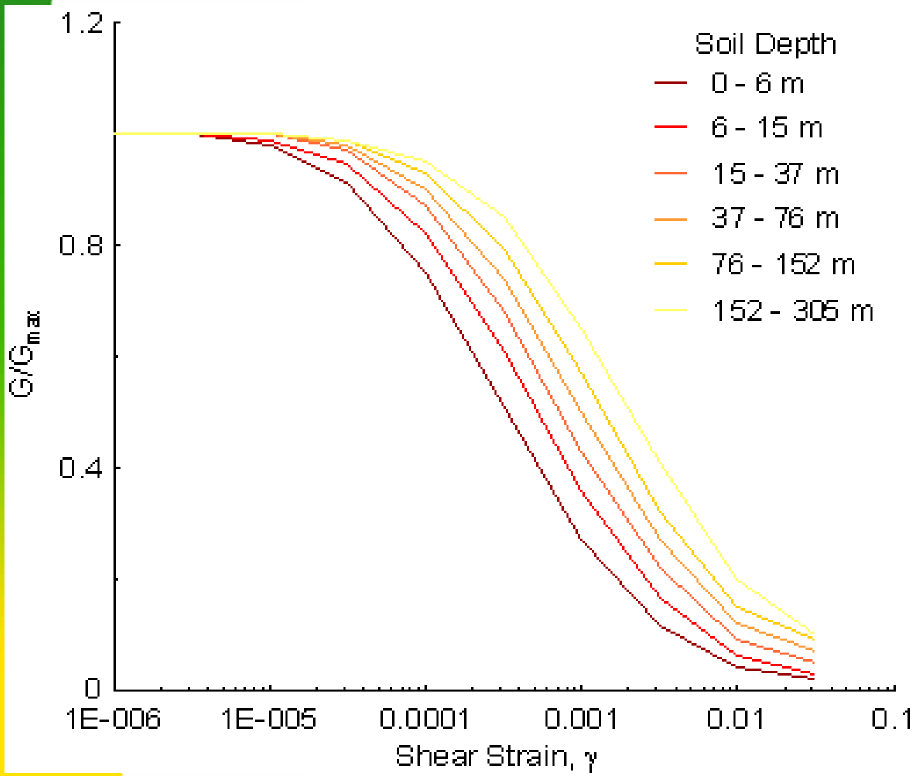
2) Characterize the bedrock acceleration

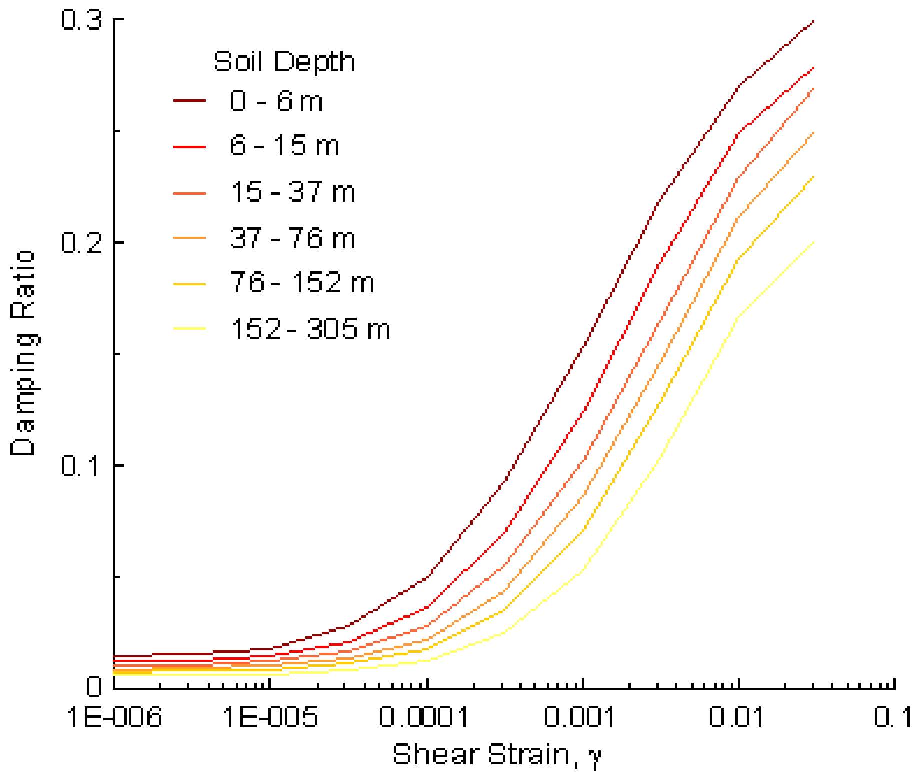
3) Characterize the shallow geology
   - Surficial geology maps
   - Depth to Bedrock

4) Characterize the soil properties
   - Physical soil properties
   - Dynamic soil properties (Shear modulus and damping, Shear-wave velocity)

UMR

Shear Modulus and Damping
EPRI (1993)





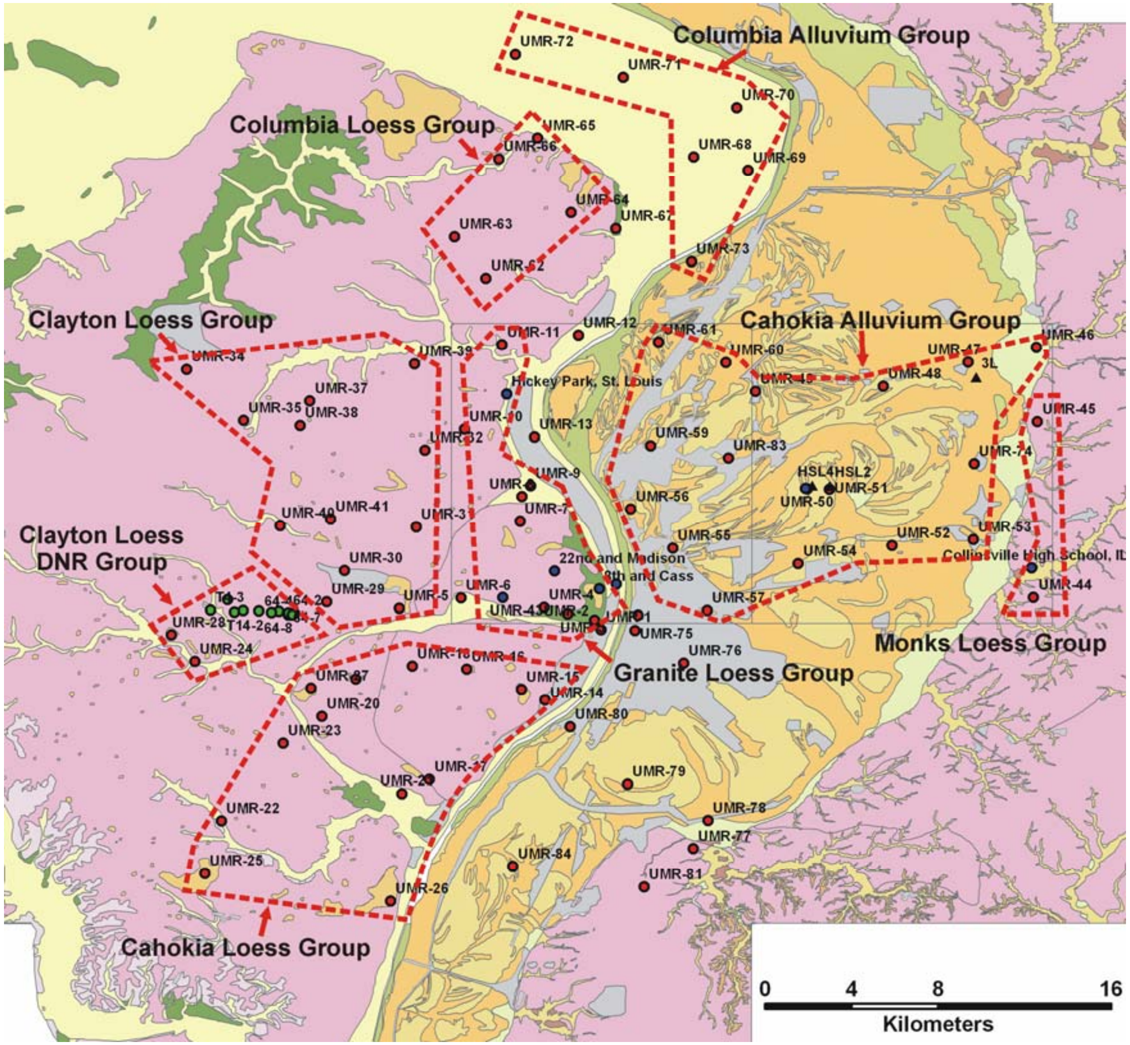
Compilation of shear-wave velocity profiles

- Five main sources are used:
  - University of Missouri Rolla
  - United States Geological Survey
  - Illinois State Geological Survey
  - Missouri Department of Natural Resources
  - Local Private Companies
- Total of 76 shear wave velocity measurements are used.

UMR

Local Vs Analyses

- **Total of 9 sites were selected for the assessment of the uncertainty in determining Vs for various surficial geology and for the generation of the local characteristic Vs profiles**



Characteristic Profiles

Floodplain (Alluvial) deposits

Vs = 134 m/s
σ = 33 m/s

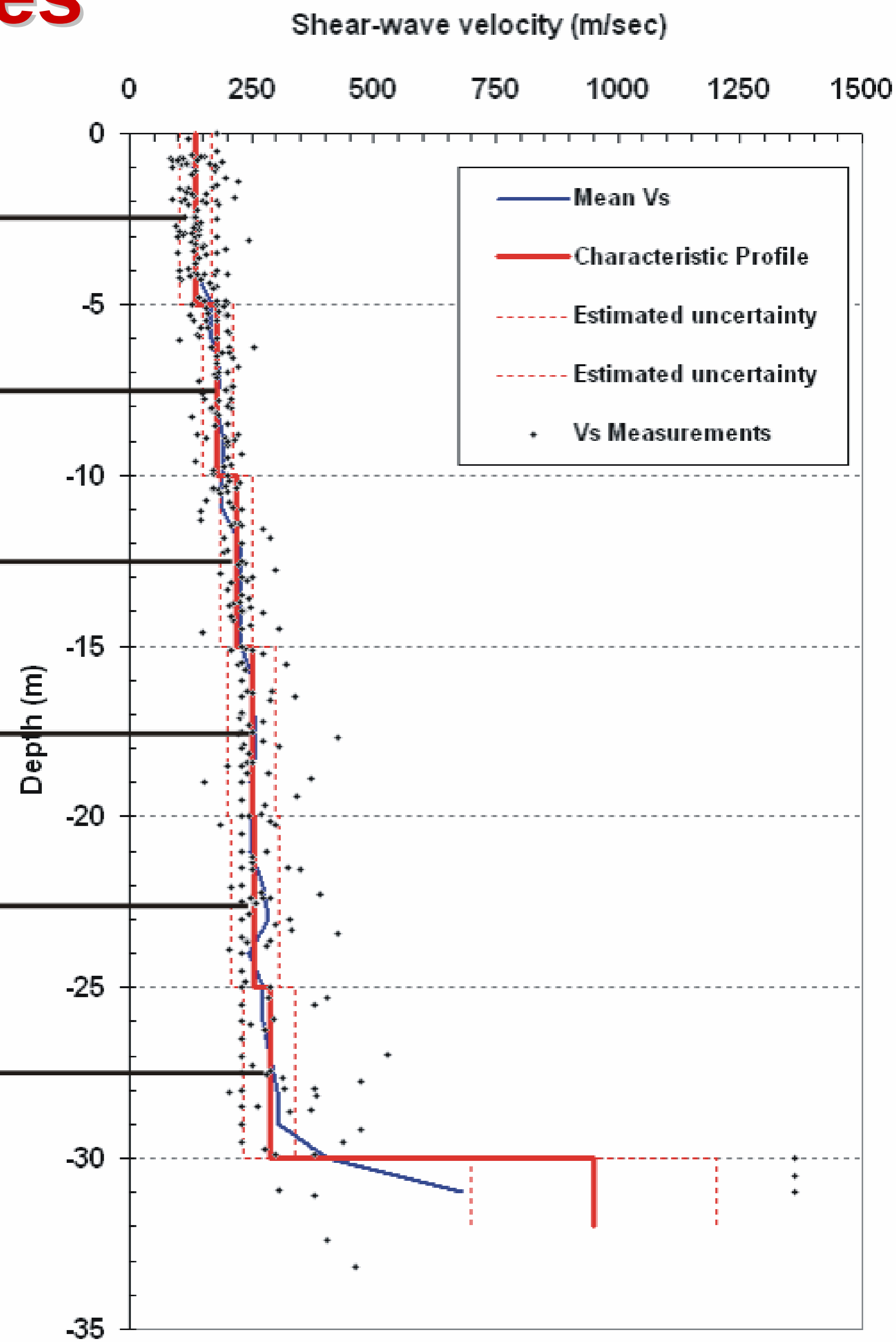
Vs = 180 m/s
σ = 30 m/s

Vs = 218 m/s
σ = 34 m/s

Vs = 250 m/s
σ = 50 m/s

Vs = 256 m/s
σ = 50 m/s

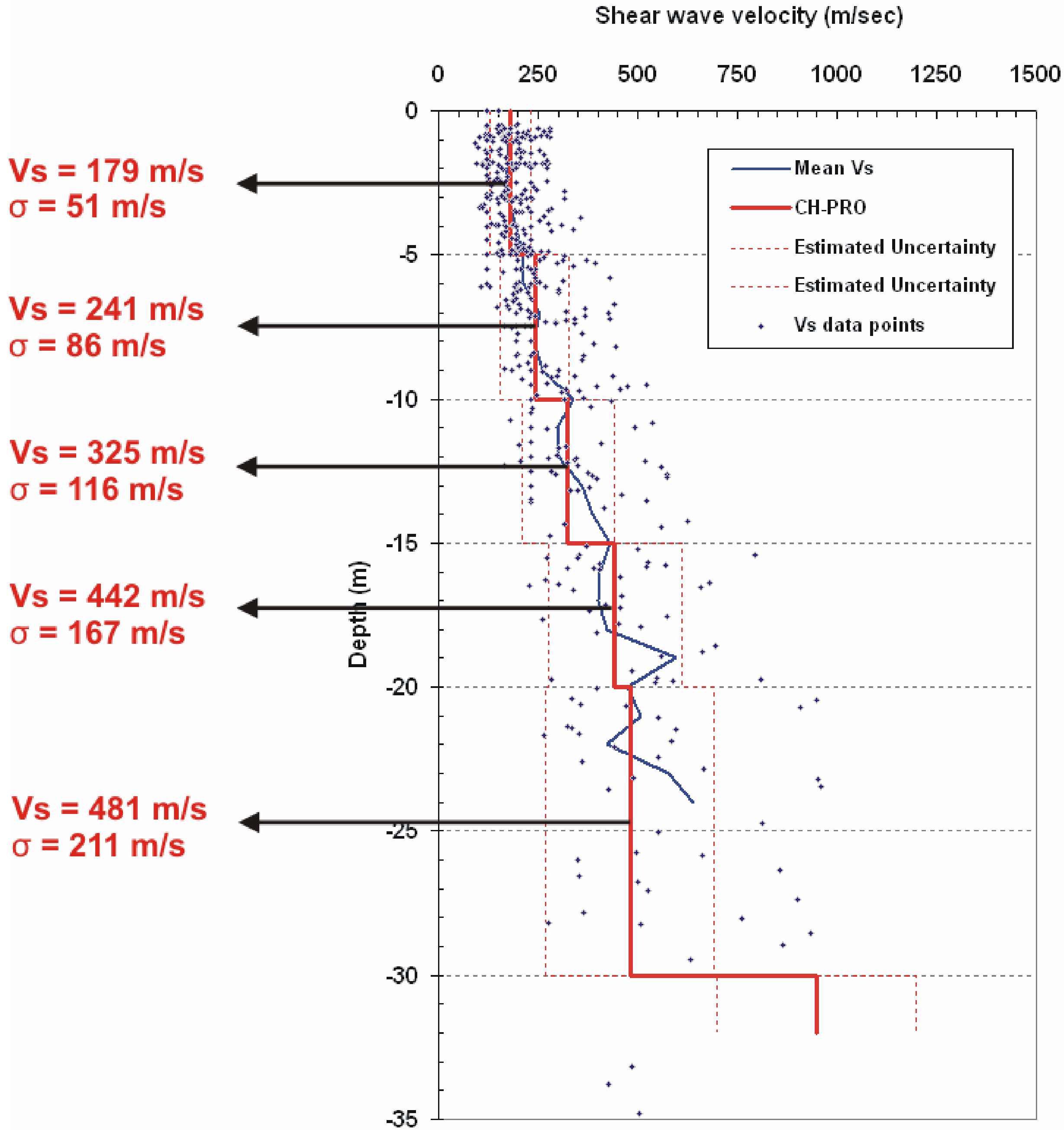
Vs = 286 m/s
σ = 53 m/s



UMR

Characteristic Profiles

Loessal Upland deposits



UMR

Amplification calculations

- Uncertainties are present in all components of the site-amplification calculation.
- Uncertainties present due to
  - Variations in the shear-wave velocity
  - Variations in density values and dynamic soil properties
  - Estimation of the depth to the top of bedrock
  - Differences in time-histories.
- These may cause large differences in amplification calculations when combined.

UMR

Amplification calculations

- State-of-the-art completely probabilistic approach is applied.
- This approach is the same approach taken by Chris Cramer for Memphis Seismic Hazard Maps.
- The properties of sediments are selected randomly
  - From a suite of Vs profiles.
  - From dynamic soil properties.
  - From estimated thickness distributions.
  - From suite of acceleration-time histories.

UMR

Amplification uncertainty analysis

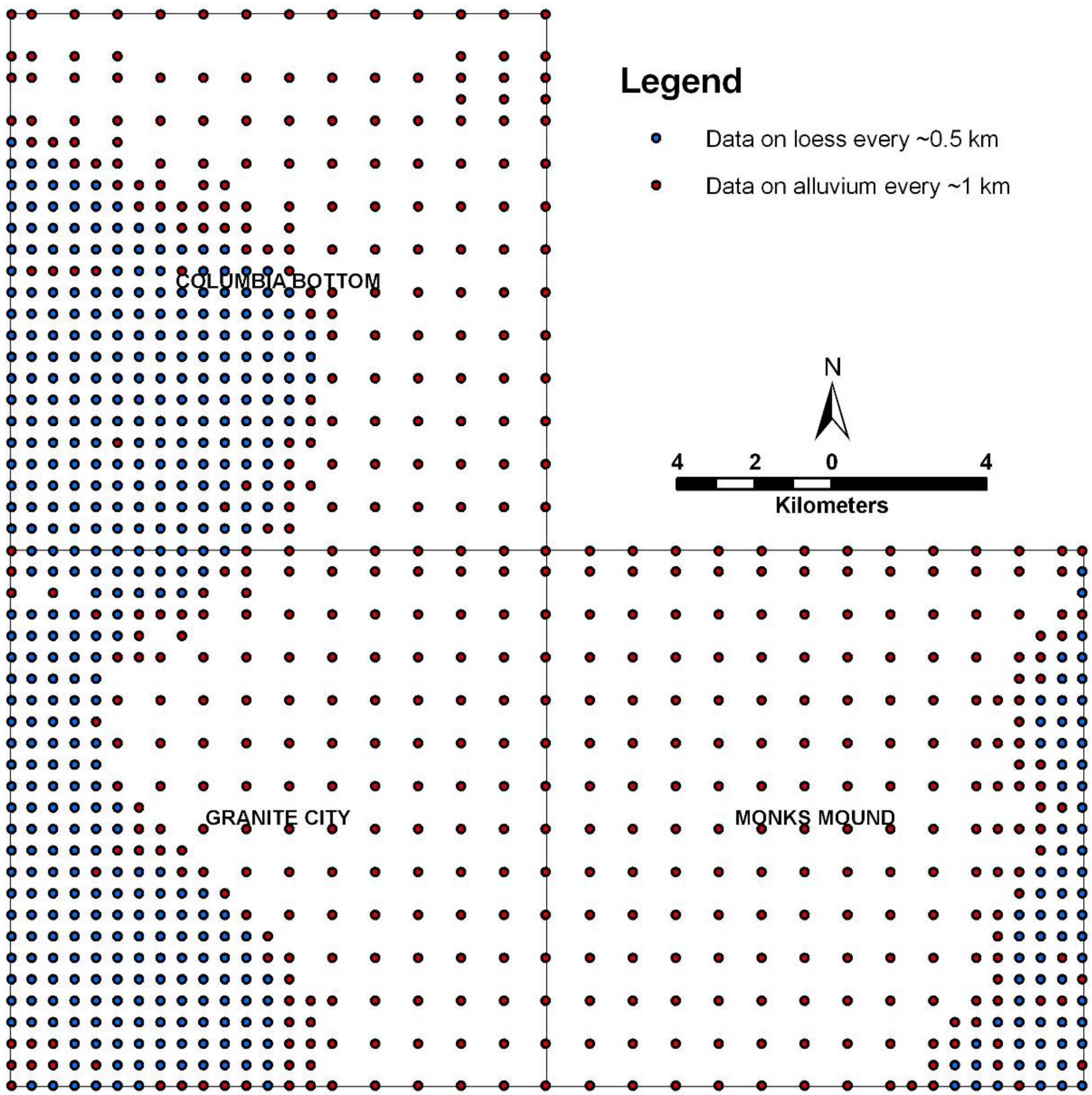
- For each frequency and amplitude, the process of randomly choosing a ground-motion record and scaling it, randomly choosing a set of sediment properties, and calculating the response to the scaled input motions is repeated by 100 times.
- SHAKE91 is used to calculate the response.

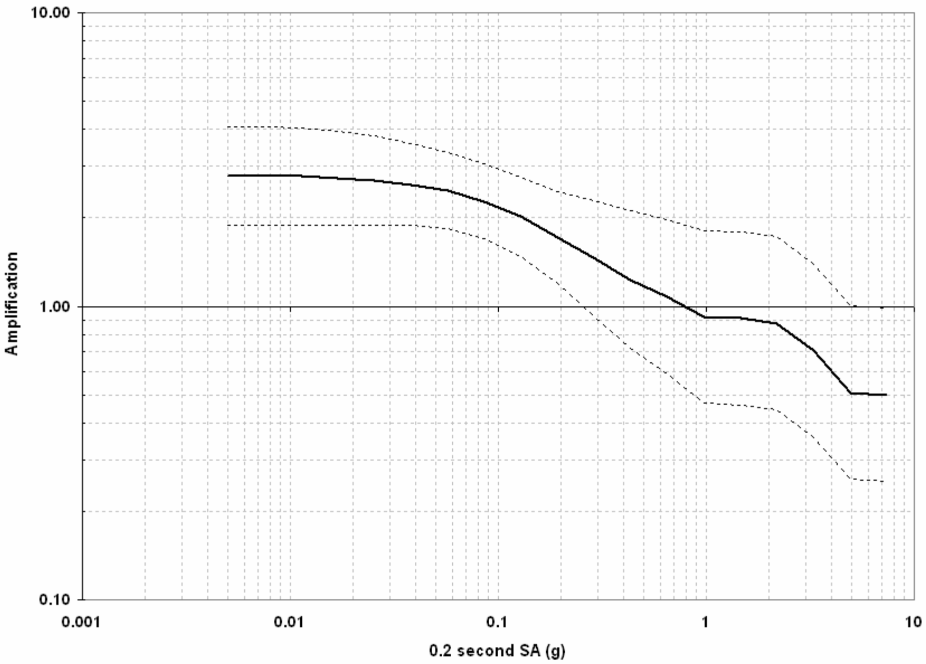
UMR

Amplification uncertainty analysis

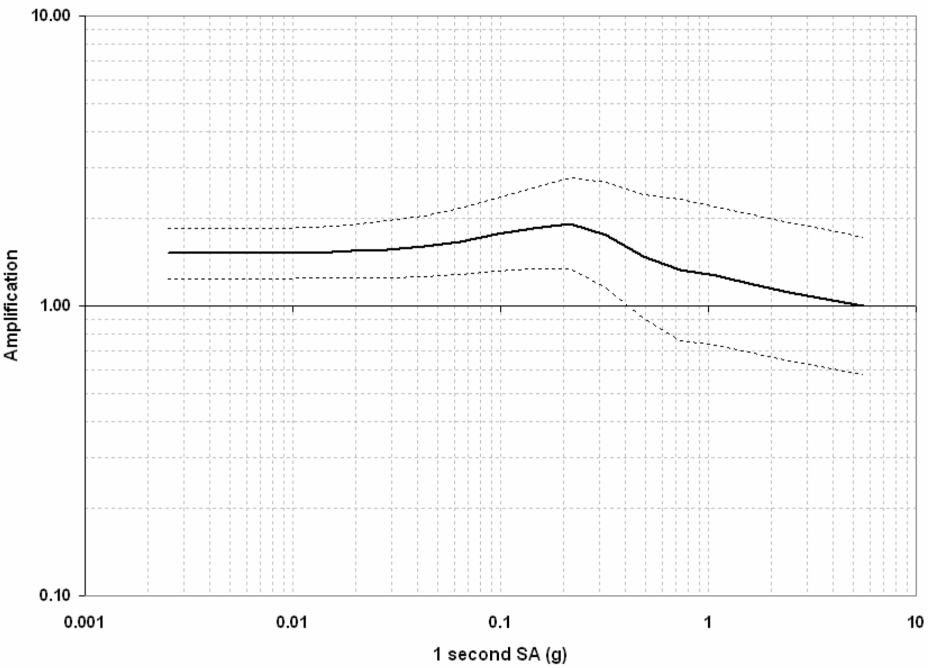
- The amplification factor distributions are represented by mean values and their standard deviations.
- These amplification distributions are calculated on a grid for every 0.005 degree for loess and 0.01 degree for alluvium.
- Total of approximately 1000 grid points.

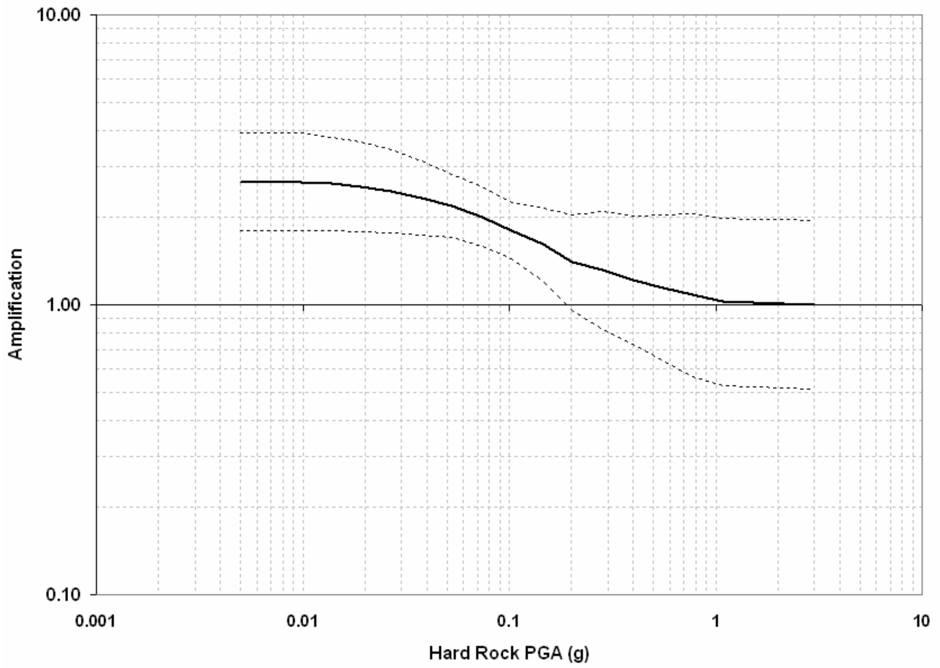
Grid points


Legend
Data on loess every ~0.5 km
Data on alluvium every ~1 km
COLUMBIA BOTTOM
GRANITE CITY
MONKS MOUND
N
4 2 0 4
Kilometers

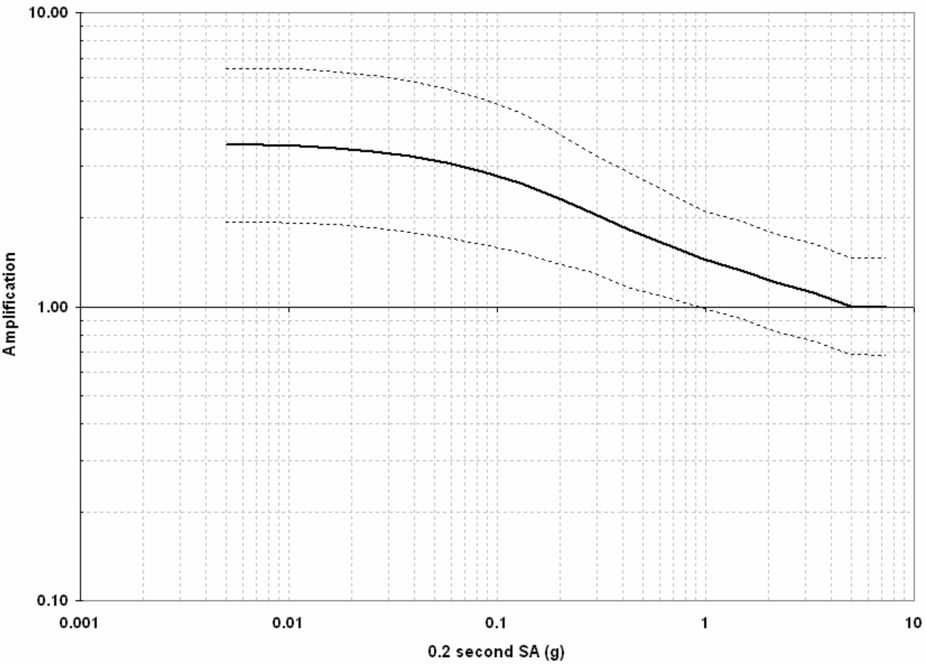


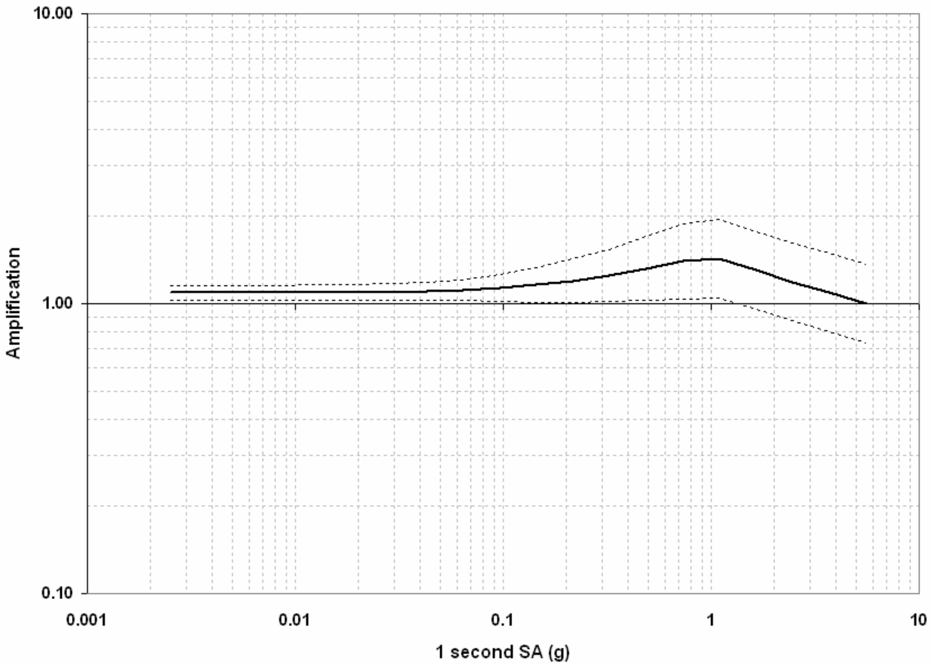
Amplification distribution in Alluvium

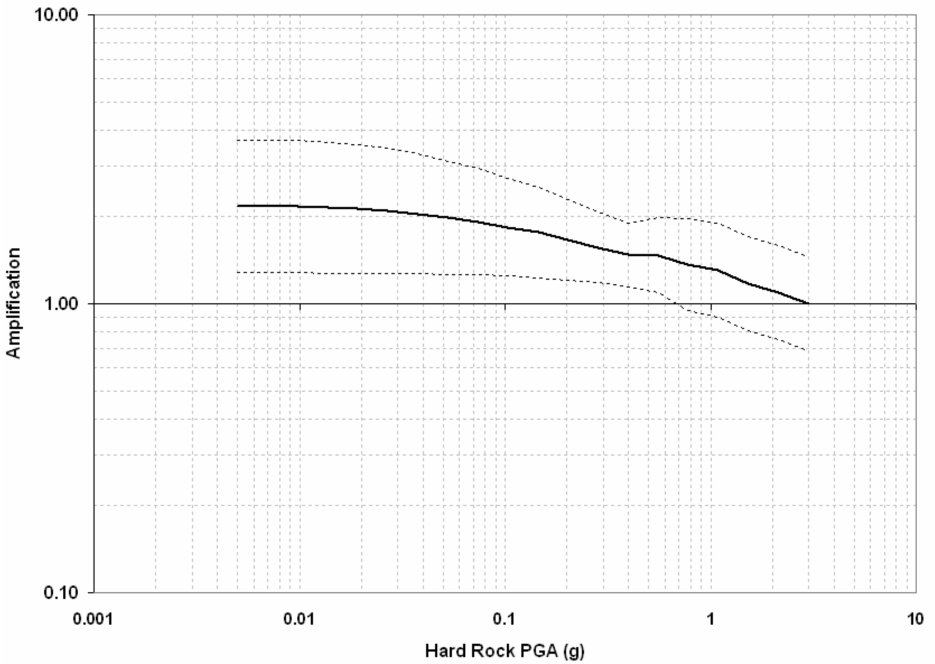




Amplification Distribution in Loess





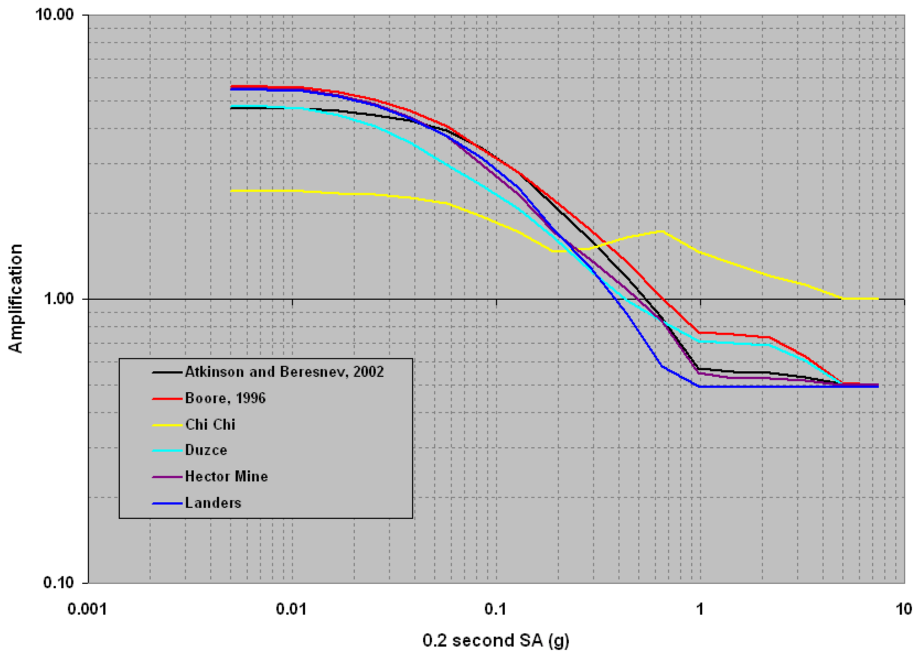


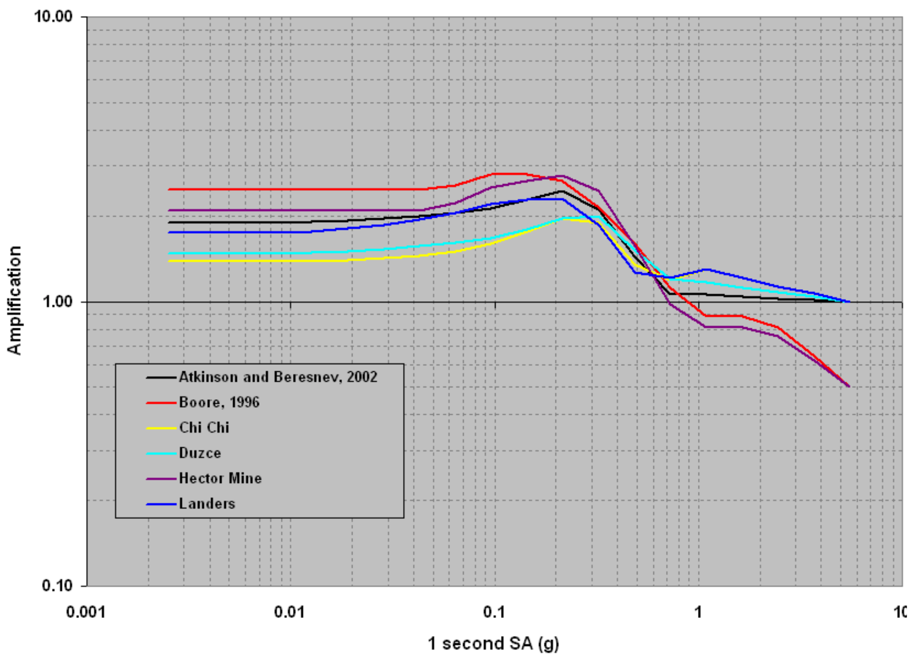
Site-Amplification Sensitivities

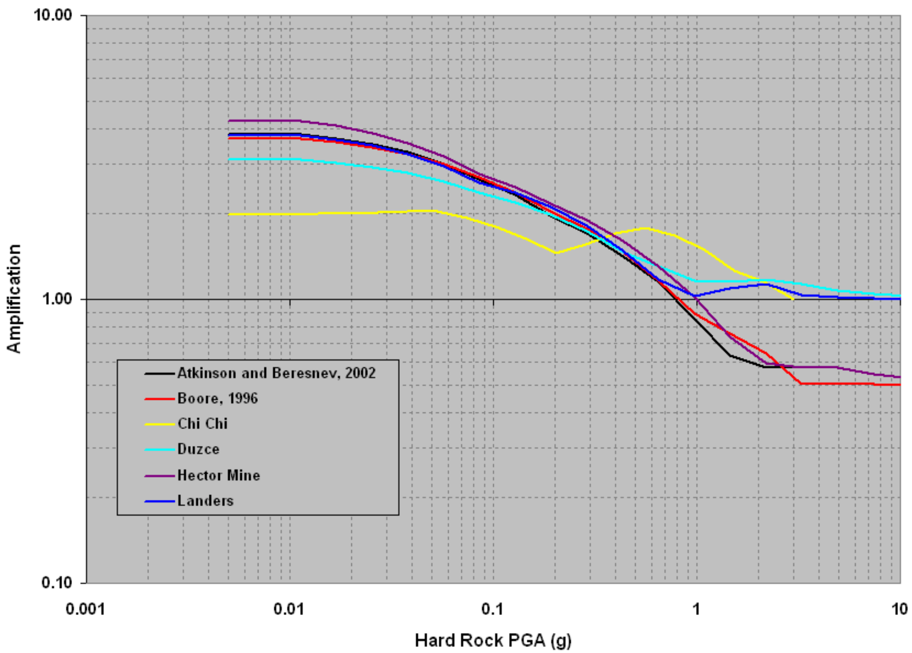
- **We have conducted an uncertainty and sensitivity analysis for the site-amplifications generated.**
- **The Monte Carlo randomization procedure used in generating the site-amplification distributions provides an estimate of uncertainty.**
- **We examined the sensitivity to a specific parameter by fixing the Monte Carlo choices for all parameters.**

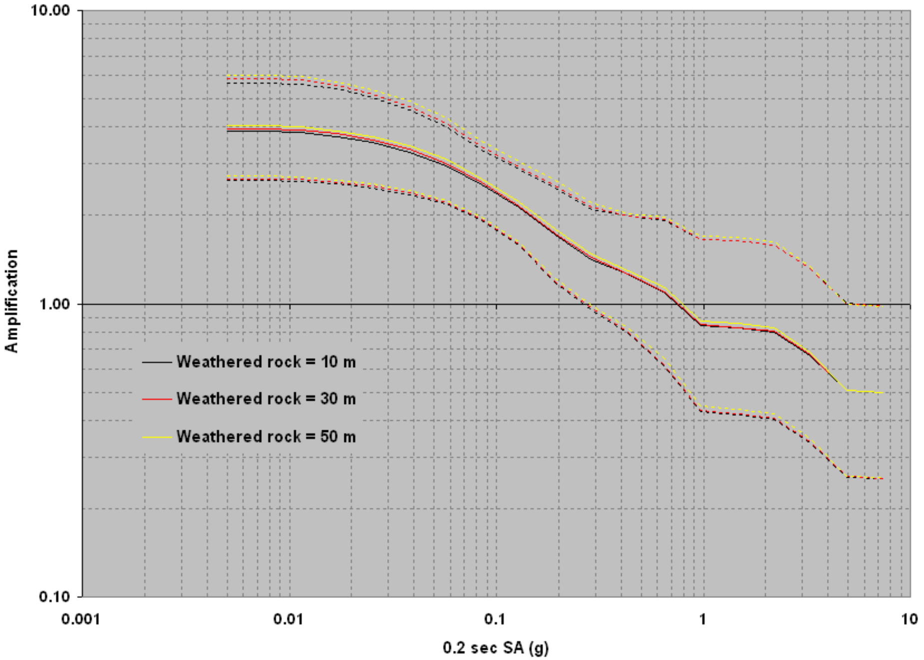
UMR

Input ground motion sensitivity

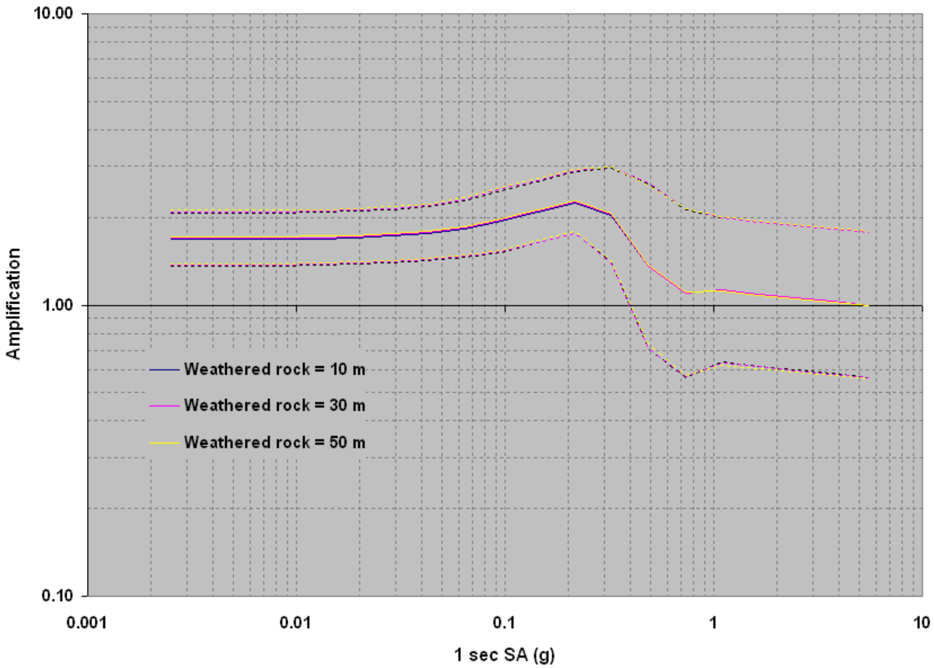


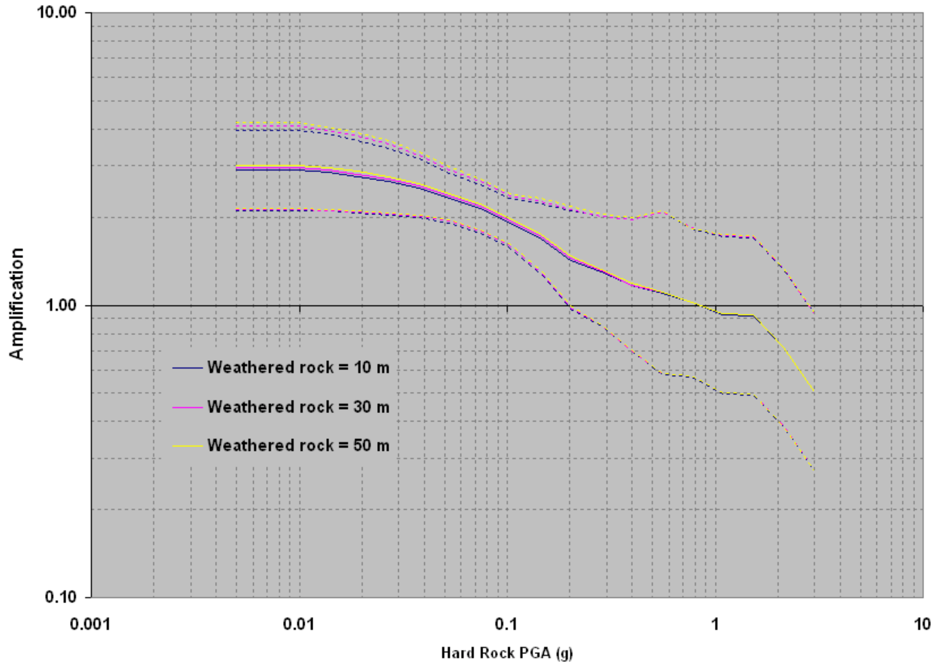




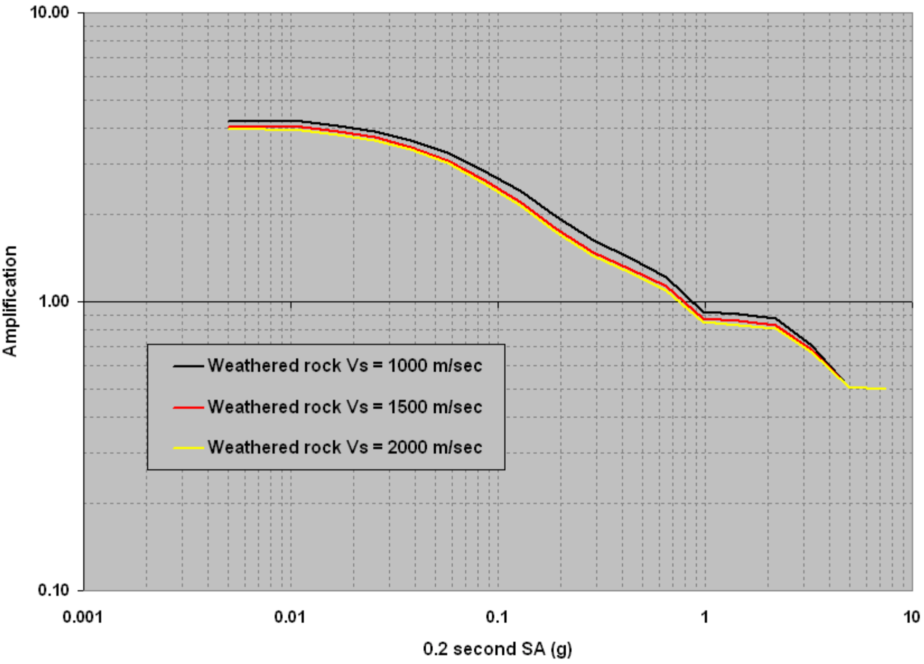


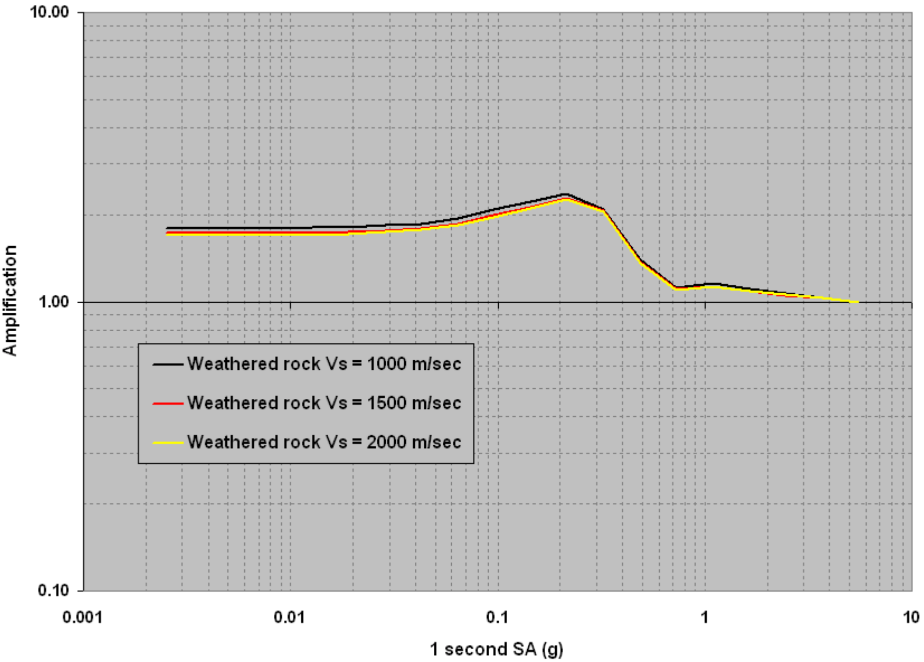
Thickness of weathered bedrock sensitivity

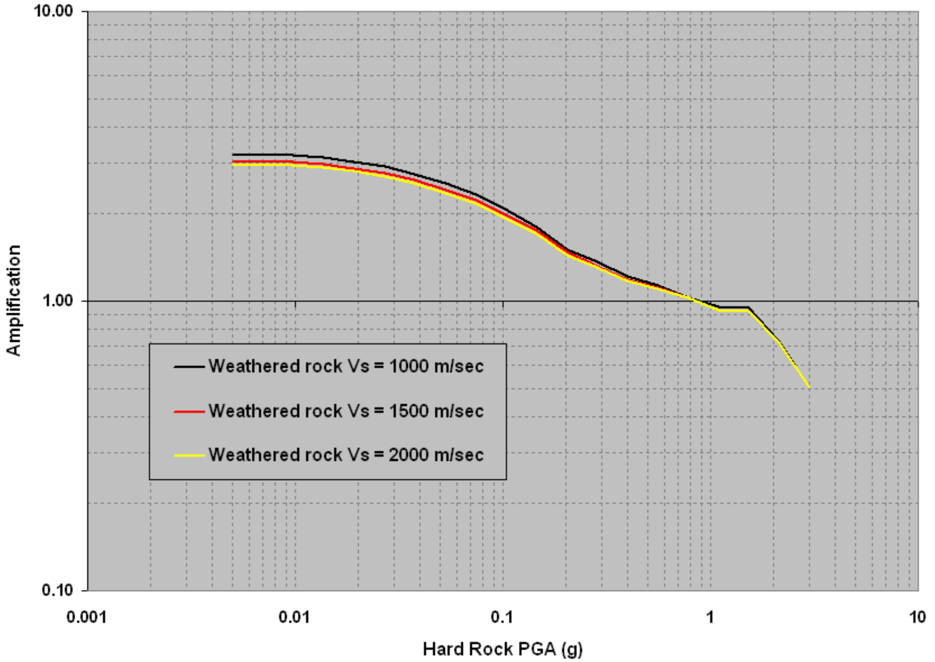




Shear wave velocity of weathered bedrock sensitivity







Conclusions - 1

- This preliminary study calculated the amplification distributions for the St Louis Metro area for different ground motion shaking levels.
- These amplification distributions are calculated in order to estimate hazard in a “fully probabilistic” approach.

UMR

Conclusions - 2

- **Calculations indicate that the greatest sensitivity comes from the choice of the input time-series, at all levels of ground motion.**
- **The thickness and shear wave velocity of the weathered bedrock below the soil profile has little impact on amplification and uncertainties.**

UMR

Conclusions - 3

- **Other uncertainties in site-amplification include;**
  - **The choice of soil-response program**
  - **Dynamic pore pressure changes**
  - **Site-specific dynamic soil properties**
- **Site-amplification uncertainties may range between 20-50% because of the choice of the various input parameters.**

Acknowledgments

- We would like to thank St Louis Earthquake Hazard Mapping Program Technical Working Group for their technical oversight and much of the needed data
- Special thanks to Professor Chris Cramer at the University of Memphis for his recommendations and ongoing review of the hazard mapping process.

UMR