

Research Program: Hazard Definition

Project Title: Synthetic Earthquake Hazard

MAE Project Number: HD-1

Start Date: 01/02 **End Date:** 12/07

Project Goals and Objectives:

- The goal of HD-1 is to develop methods for synthesizing ground motions for earthquakes in areas where a lack of observed strong ground motions hinders loss estimation and mitigation efforts. More specifically, the objectives are:
 - Develop methods for defining seismic hazards for evaluating risk and potential losses across regional systems and networks. Estimates of seismic hazards including peak ground motion parameters, response spectra, and synthetic time histories will be incorporated directly into MAEViz.
 - Develop peak ground parameters, response spectra, and synthetic time histories for use in other MAE Center projects including the Memphis Test Bed for use in developing vulnerability functions and evaluating retrofit strategies.

Budget
(\$1000)

YEAR

NSF

Matching

Leverage

	1	2	3	4	5	6	7	8	9	10
NSF					49	45	45	30	30	30
Matching					41	41	41	30	30	30
Leverage										

Project Personnel:

PI: G.J. Rix

Graduate RA's: Alfredo Fernandez-Leon

Undergraduates: Daniel Acosta

External Collaborators: C.H. Cramer, U.S. Geological Survey; W.J. Silva, Pacific Engineering and Analysis, El Cerrito, CA; G. Toro, Risk Engineering, Inc., Boulder, CO

Project Scope:

- Scope of the project initially is focused on using existing source, path, and site models to develop hazard estimates for the NMSZ. These hazard estimates are continually refined and updated by incorporating results from other HD projects and pertinent research external to the MAE Center. Examples of these results include new information on dynamic material properties, source models and parameters, path effects such as attenuation relationships, and methods of modeling site response in deep unconsolidated sediments such as those found in the Upper Mississippi Embayment.

Project Methodology:

- Peak ground motion parameters, response spectra, amplification factors and attenuation relationships are calculated using RASCALS, a computer program developed by Dr. Walt Silva that integrates source, path, and site components. Rock motions are modeled using the stochastic method (Boore, 1983; 2003). Site response is modeled using an equivalent linear approach that utilizes random vibration theory to estimate peak values. Seismological parameters are selected based on a comprehensive evaluation of previous studies conducted in the Central and Eastern U.S. and the results of other HD projects.
- Synthetic time histories are generated using (1) artificial ground motions based on band-limited white noise and (2) actual ground motions scaled to match the desired response spectral shapes.

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Project Methodology:

Project Tasks:

Task	Planned		Deliverable
	Start	Finish	ID #
Task 1: Ground motion simulations for Upper Mississippi Embayment	10/1/04	12/31/04	
Task 2: Perform regression analyses on simulated ground motions to determine attenuation relationship coefficients	11/1/04	3/15/05	HD-1-1
Task 3: Calculate uniform hazard spectra for select cities in the Upper Mississippi Embayment	5/1/05	6/15/05	HD-1-2
Task 4: Calculate suites of ground motion time histories for select cities in the Upper Mississippi Embayment	7/1/05	11/1/05	HD-1-3
Task 5: Calculate regional probabilistic hazard maps for the Upper Mississippi Embayment	10/1/05	12/31/05	HD-1-4
Task 6: Develop method of synthesizing time histories that incorporate basin response.	1/1/06	12/31/06	

Dependency on Other MAE Center Projects:

Other MAE Center Project	Necessary Input from Other Projects	Affected Tasks in this Project
HD-2	Weak motion observations recorded in the Upper Mississippi Embayment for validating ground motion calculations.	Task 4
HD-3	Updated near-surface soil attenuation properties	Task 6
HD-4	Updated PSHA-NL framework with finite-fault model and nonlinear soil properties for the Upper Mississippi Embayment	Task 6
HD-5	Site resonance measurements and site-specific shear wave velocity profiles for ground-motion validation studies	Task 6

Project Deliverables:

Deliverable ID #	Project Deliverables	Planned Delivery Date	Other MAE Center Projects Requiring this Deliverable
HD-1-1	Soil attenuation relationships for site conditions in the Upper Mississippi Embayment	3/15/05	MAEViz
HD-1-2	Uniform Hazard Spectra for Select Cities in the Upper Mississippi Embayment	6/15/05	Memphis Test Bed
HD-1-3	Suites of ground motion time histories for select cities in the Upper Mississippi Embayment	11/1/05	CM and DS Projects
HD-1-4	Regional probabilistic hazard maps for the Upper Mississippi Embayment	12/31/05	MAEViz

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How project differs from similar work done elsewhere:

- Previous estimates of synthetic ground motions for the Central U.S. produced for the MAE Center by Wen and Wu (2001) are based on an approximate method for local site effects and do not include the effects of non-linear soil behavior on ground motions, and do not include the effects of epistemic and aleatory uncertainty in source, path, and site response parameters. These limitations are removed in this study.
- Current efforts to account for local site response in code-based approaches (i.e., IBC2000) are based on the use of generic site coefficients. In this study, more rigorous and region-specific models are used to account for site effects to yield more accurate ground motion estimates that reflect the unique geologic conditions in the NMSZ.

Treatment of Uncertainty

- Epistemic uncertainties in source, path, and site parameters are included via the use of alternative models for each aspect of the earthquake process. Aleatory uncertainties are included via Monte-Carlo simulations using random variations in source, path, and site parameters to yield median ground motion values and their associated uncertainties.

Source Models Atkinson and Boore (1995), Frankel et al. (1996), Silva et al. (2003)	Stress Drops Medium case, 2x higher, 0.5x lower
Soil Profiles Lowlands, Uplands	Nonlinear Soil Properties EPRI (1993), Peninsular Range (EPRI, 1993)
Sediment Depth Bins 6 – 15 m, 15 – 30 m, 30 – 61 m, 61 – 152 m, 152 – 305 m, 305 – 610 m, 610 – 1220 m	

Potential Impact of Project:

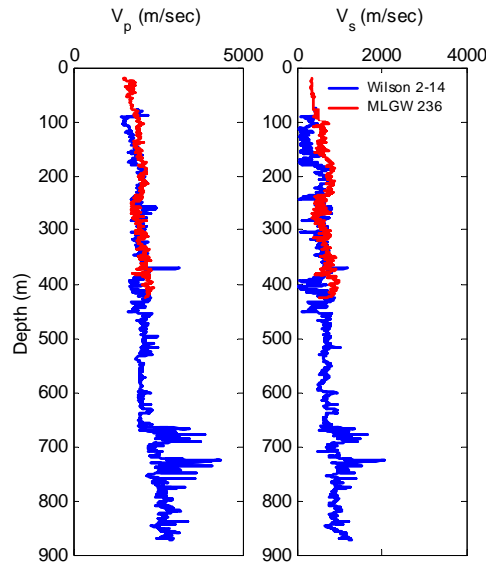
- Project results will impact estimates of seismic hazard in the Central and Eastern U.S. Specifically, the project will demonstrate that it is possible to improve regional estimates of seismic hazard by incorporating more detailed aspects of site response than is currently the practice and by including explicit estimates of uncertainty arising from epistemic and aleatory uncertainty in site response parameters.
- By expressing the results of ground motion simulations in the form of attenuation relationships, the results can be easily incorporated into deterministic and probabilistic seismic hazard analyses using a variety of programs including EZ-FRISK and OpenSHA.

Stakeholder Benefits

- Stakeholders will benefit from results describing the development of region-specific ground motions and simplified site coefficients for use in existing code-based approaches for seismic hazard evaluation and the inclusion of improved seismic hazard estimates into MAEViz.

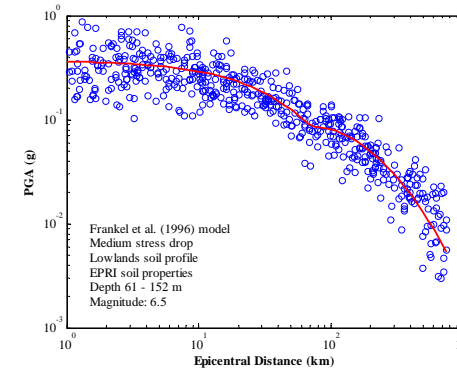
Project Accomplishments

- The first direct measurement of the shear wave velocity profile in the deep sediments of the Upper Mississippi Embayment.



Project Accomplishments

- Attenuation relationships for the soils in the Upper Mississippi Embayment have been developed that explicitly account for the unique conditions in this area including differences between Holocene-age and Pleistocene-age deposits, the presence of deep (up to 1 km thick) deposits of unconsolidated soils underlain by stiff Paleozoic bedrock; and varying levels of input motions.



Publications Resulting from This Project:

- Romero, S., and G. J. Rix, "Regional Variations in Near-Surface Shear Wave Velocity in the Greater Memphis Area," *Engineering Geology*, 62, 137-158, 2001.
- Rix, G.J., G.L. Hebler, and M.C. Orozco, "Near-Surface V_s Profiling in the New Madrid Seismic Zone Using Surface Wave Methods," *Seismological Research Letters*, 73(3), 380-392, 2002.
- Romero, S., and G.J. Rix, "Site Response in the Upper Mississippi Embayment," *Proceedings, Seventh U.S. National Conference on Earthquake Engineering*, Boston, MA, July 2002.
- Fernandez, J.A. and G. J. Rix, "Soil Attenuation Relationships and Seismic Hazard Analyses in the Upper Mississippi Embayment," submitted to the Eighth U.S. National Conference on Earthquake Engineering, San Francisco, CA, April 2006.

Project Accomplishments

- Uniform hazard response spectra and time histories have been developed for select cities in the Central and Eastern U.S.

