Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Next Generation Attenuation (NGA) Models, WUS Shallow Crustal Earthquake*—**1L01**		
Start/End Dates	8/1/02 – 6/30/04	Budget/ Funding Source	$352,630 / Caltrans
Project Leader (boldface) and Other Team Members	**Power (Geomatrix)**		

1. Project goals and objectives

The overall goal of the project is to develop Next Generation Attenuation (NGA) relationships for shallow crustal earthquakes in the western United States. These attenuation relationships will have a substantially better scientific basis than current relationships because they are developed through the efforts of five selected attenuation relationship developer teams working in a highly interactive process with other researchers who are: (a) developing an expanded and improved data base of strong ground motion recordings and supporting information on the causative earthquakes, the source-to-site travel path characteristics, and the site and structure conditions at ground motion recording stations; (b) conducting research to provide improved understanding of the effects of various parameters and effects on ground motions that are used to constrain attenuation models; and (c) developing improved statistical methods used to develop attenuation relationships including uncertainty quantification.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

The assessment of the damage that earthquakes can cause to electrical systems and other lifelines depends significantly on how well the vibratory ground motions can be predicted as a function of the seismic environment characteristics, including earthquake magnitude and other earthquake source characteristics, source-to-site-distance and other travel path characteristics, and the stiffness and depth of the geologic media in which lifelines are founded. This project greatly improves the reliability and the quantification of uncertainty associated with ground motion predictions, thus allowing more reliable assessments of damage to, and design of, lifelines.

3. Brief description of the accomplishments of the project

The project accomplishments to date are summarized as follows.

(1) The PEER data base of ground motion recordings and supporting information, which is vital for developing attenuation relationships, has been substantially improved through the addition of a large number of recordings, evaluation of the characteristics of recordings (e.g. better understanding of the usable period range for response spectra of the recordings), and research and quality assurance that has resulted in more accurate and increased information about the earthquake source, path, and recording station parameters. The additions of records to the PEER data base is shown in Figure 1.

(2) Selected research and synthesis of current and previous research by PEER, PEER-LL, U.S. Geological Survey, Southern California Earthquake Center, and others, has been conducted to develop increased understanding of the various earthquake source, travel path, and site factors affecting earthquake ground motions and thus provide better constraints on empirically-based attenuation relationships. The research synthesis includes findings from the following projects:

(a) rock motion simulations; (b) basin response simulations; (c) site response simulations; (d) attenuation at moderate distances; (e) effects of rupture directivity on ground motions; (e) and synthesis of empirical studies on site response.

(3) Six two-day NGA workshops have been held in 2003 and 2004 following a two-day kickoff meeting on October 2002. These workshops, each attended by approximately 40 to 45 researchers and stakeholders in the NGA project, have facilitated review of interim results for the project. Presentations from the workshops have been placed on the PEER web site. In addition to the workshops, a number of less formal meetings of NGA working groups and of the NGA developers have been held for project review and interaction. The working groups have been an integral part of the project for review of selected research and data base findings. Six working groups, each consisting of five to thirteen scientists and engineers involved in various project activities have been active: #1Strong Ground Motion Data Processing; #2 Validation of Ground Motion Database; #3 Validation of 1D Rock Motion simulations; #4 Source and Path Effects; #5 Site Classification and Site Effects; and #6 Statistical Modeling of Data.

(4) Preliminary results for effects modeled in NGA relationships were presented by the five NGA attenuation developer teams at Workshop #6 in July 2004. Examples of analysis of effects of soil type and soil depth on ground motions are shown in Figures 2 and3. Results are scheduled to be finalized during October and presented at a final workshop for this phase in November 2004. In addition to preparation of comprehensive project reports covering the new attenuation relationships, the new data base, and the supporting research, it is planned that the new attenuation relationships will be presented at special sessions at conferences and published together in a special issue of a widely read professional journal.

4. Describe any instances where you are aware that your results have been used in industry

The final project results are not yet available. When available later this year, extensive use of the new attenuation relationships is anticipated in engineering practice, including in the development of future ground motion maps for California, the United States, and in national building codes, as well as for site-specific ground motion definition. The data base developed for the project will be a major resource to the entire engineering and seismological community as a source of well documented strong motion records and supporting information. Reports of supporting research for the NGA project will similarly be used to advance the practice of ground motion definition for new construction and retrofit projects.

5. Methodology employed

The methodology developed and its implementation is summarized in items (1) and (3) above.

6. Other related work conducted within and/or outside PEER

The NGA project is unique in providing a focused, coordinated, and highly interactive effort involving participation of five selected expert attenuation relationship developer teams, development of an improved and expanded data base of ground motion recordings and supporting data required for attenuation relationship development, conduct and synthesis of supporting research on the processes of earthquake generation, seismic wave propagation, and site response to provide better physical constraints on attenuation relationships, development of better statistical methods for attenuation relationship development, and integration of all project

elements through a series of workshops and meetings of working groups and attenuation relationship developers.

7. Recommendations for the future work: what do you think should be done next?

The present project is limited to development of attenuation relationships for horizontal elastic response spectral acceleration and horizontal PGA, PGV, and PGD of ground motions for shallow crustal earthquakes in the western U.S. Future phases of attenuation relationships development may be conducted for: (1) vertical ground motions; (2) other ground motion parameters found to be important in determining earthquake damage to structures (e.g. inelastic response spectral accelerations); and (3) western U.S. subduction zone earthquakes. The present project is also limited to the use of ground motion recordings from actual earthquakes in the statistical analyses for attenuation relationship development. Simulated earthquake recordings, although used in the present project to guide the modeling of effects in attenuation relationship development, and not used as data in developing attenuation relationships. Future phases may consider incorporating simulated recorded data directly along with the actual data for conditions that are not well represented in or well constrained by the existing recorded data (e.g. recordings from large earthquake magnitudes at close distances).

8. Author(s), Title, and Date for the final report for this project

The final report will be submitted later in 2004. Final reports will be submitted by each attenuation relationship development team. In addition, the series of a final reports will (a)compare attenuation relationships from all of the development teams; (b) document the data base of ground motion recordings and supporting information developed for the project; (c)document and synthesize research conducted in support of NGA relationship development.

Figure 1
Magnitude – Distance Distribution of NGA Data Base

Previous Data

New EQ Data

- Kobe
- Kocaeli
- ChiChi
- Duzce
- Hector Mine
- Denali
- Moderate magnitude earthquake aftershocks

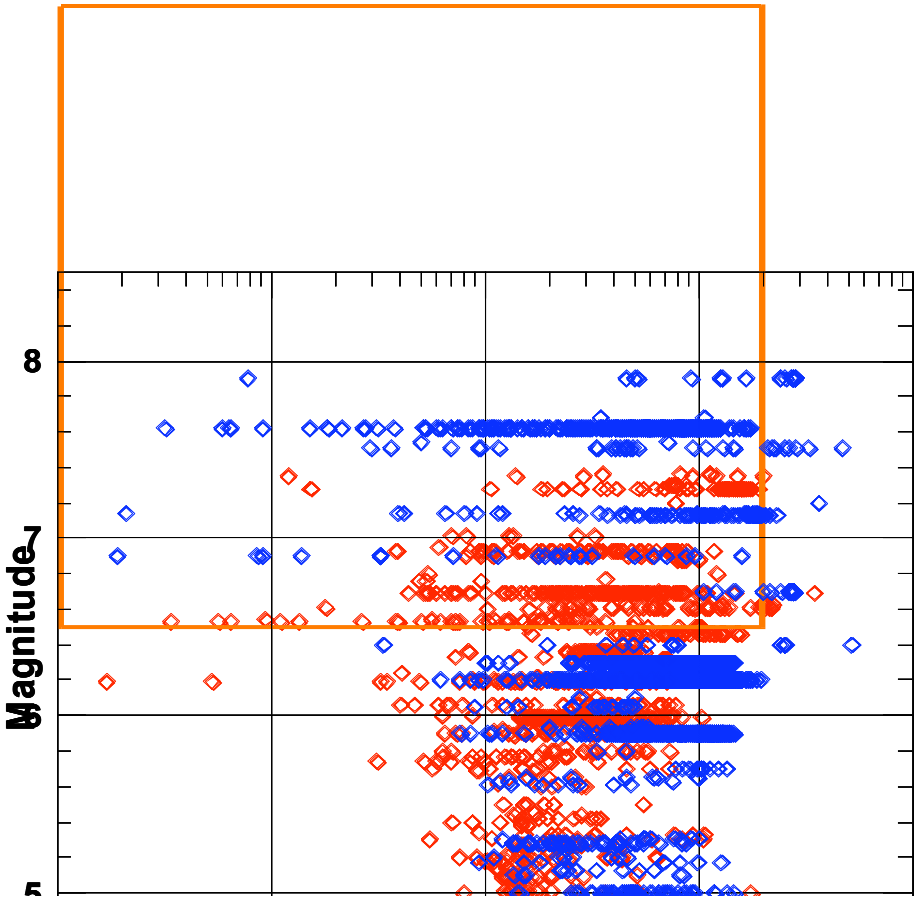


Figure 2
Effects of NEHRP Soil Type on 3-Sec Spectral Acceleration

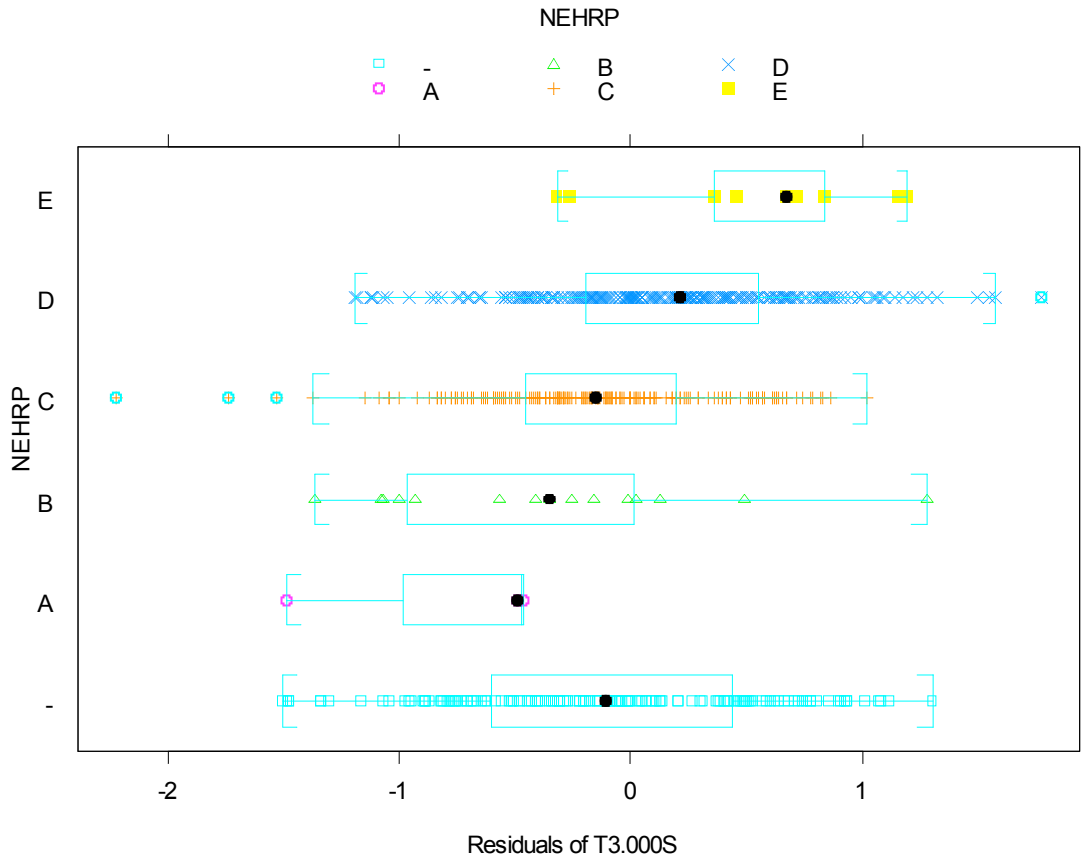
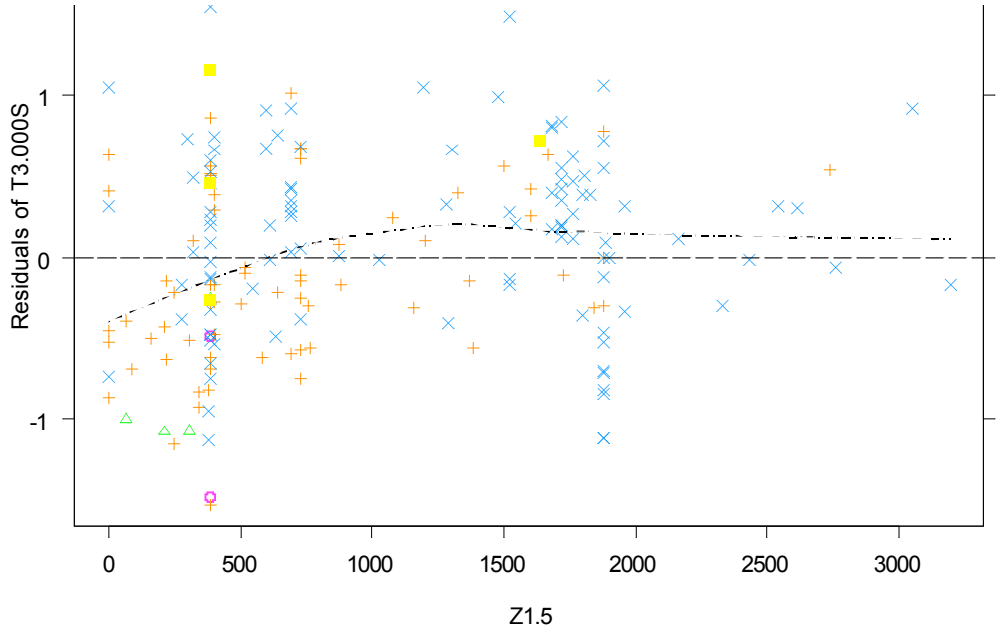


Figure 3
Effects of Depth to Bedrock on 3-Sec Spectral



Depth to Bedrock (taken as depth to rock with V_s = 1.5 km/sec)