# Final Project Summary — PEER Lifelines Program

| *Project Title*—**ID Number** | *Design Ground Motion Library*—**1F01/1F01a** | | |
|---|---|---|---|
| **Start/End Dates** | 7/01/02 – 6/30/04 | Budget/ Funding Source | $95,520 / PG&E/CEC & Caltrans |
| **Project Leader (boldface)** and Other Team Members | **Power (Geomatrix)** | | |

### 1. Project goals and objectives

The objective of the Design Ground Motion Library (DGML) project is to form an electronic library of recorded acceleration time histories suitable for use by engineering practitioners for the time history dynamic analysis of various facility types in the western United States, including lifelines, buildings, bridges, dams, base isolated structures, and other infrastructure facilities. The DGML is distinctly different from a ground motion data base. Data bases contain large numbers of time history records but no guidance on how to select records for specific applications. On the other hand, the DGML contains small groups of time histories considered by the expert project team to be suitable for use for defined categories of the seismic environment and structure characteristics.

### 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.

To accurately predict the damageability and performance of lifelines and other infrastructure facilities when analyzed using time history analysis methods, the time histories must be representative of the seismic environment with respect to those time history characteristics most important to causing structural damage. This project applies knowledge gained through research by PEER, PEER-LL, and other research of the time history characteristics that correlate with structure damage and selects time histories that, in aggregate, represent the variability in these characteristics to be expected for the design earthquake for a facility.

### 3. Brief description of the accomplishments of the project

In the current phase, the project has focused on developing criteria for the selection of time histories and quantification of their characteristics. The implementation of the criteria and finalization of the DGML will be accomplished using an expanded and improved data base of ground motion records, which has just been completed as part of the Next Generation Attenuation (NGA) project (project 1L01). Elements of the criteria include: (1) definition of magnitude (M)-distance (R)-site (S) condition bins (M-R-S bins) and period-range sub-bins for which key time history characteristics are evaluated and sets of time histories are selected (Tables 1 and 2); (2) detailed criteria for selecting time history record sets based on capturing the variability of ground motion response spectral shape and, for near-source record sets, the variability of pulsive ground motion characteristics; and (3) definition of ground motion parameters and supporting information to be quantified and tabulated for selected time history records (Tables 3 and 4).

Ground motion response spectral shape over a period range of significance to structural response has been found to be correlated with inelastic response and behavior in research by PEER and PEER-LL. The period range of significance includes periods shorter than the structure fundamental period because of higher mode effects and periods longer than the fundamental period because of structure softening as inelastic response occurs. Therefore, the development of quantitative measures to evaluate the variability of response spectral shape from a median spectral shape for each M-R-S bin and period range sub-bin has been an important element of criteria for time history selection. Figures 1 and 2 illustrate how the variability in response spectral shape of a larger data set can be captured in a smaller set of time histories through quantitative analysis of spectral shapes. Research has also indicated that the time-domain pulsive characteristics (pulse velocity, pulse period, and number of pulses) associated with near-fault ground motions can be damaging to structures. Therefore, criteria has been developed to include these ground motion characteristics and their variability for near-source record sets.

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

When the selection of time history record set is fully complete, it is expected that the library will be used in practice to select records for the analysis of a wide range of facilities.

## 5. Methodology employed

The methodology broadly consists of, first, development of criteria for forming time history sets and identifying parameters and information to be quantified and tabulated for selected time history records; and, second, implementation of these criteria for records selected from an expanded and improved ground motion data base. A key element of the overall approach to forming the DGML has been to utilize a multi-disciplinary team of structural engineers, geotechnical engineers, and seismologists who are expert both in selecting time histories and in utilizing these time histories in analyses for new and existing facilities. The team develops the criteria for the DGML and selects and reviews the time history record sets.

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

It is believed that similar projects are not being conducted outside PEER. In contrast to the collection of large numbers of records in a ground motion data base, the DGML focuses on the identification of sets of smaller time history records that are judged to be appropriate for time history analyses of different types of structures.

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

The present project is limited to formation of time history record sets representative of shallow crustal earthquakes in the western United States. A future project extension is envisioned to develop time history record sets for subduction zone earthquakes such as occur in northwest California, Oregon, Washington, and Alaska. The DGML should be periodically reviewed and updated with records from future earthquakes. The addition of simulated earthquake recordings to fill gaps in the recorded data should also be considered.

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

Authors of the final report will be members of the DGML project team. Project team members and their respective organizations include: Maurice Power, Robert Youngs, Faiz Makdisi, and Chih-Cheng Chin, Geomatrix Consultants, Inc.; Ronald Hamburger and Ronald Mayes, Simpson Gumpertz & Heger; Roupen Donikian, T.-Y. Lin International; Yusof Ghanaat, Quest Structures; Walter Silva, Pacific Engineering & Analysis; Paul Somerville, URS Corporation; Ignatius PoLam, Earth Mechanics; Professor Allin Cornell, Stanford University; Professor Stephen Mahin, University of California, Berkeley.

**Table 1**

**Preliminary M-R Bins for DGML**

| Moment Magnitude, M | Earthquake Closest Source-to-Site Distance, R (km) |
|---|---|
| 5.5 – 5.9 | 0 – 15, >15 – 30 |
| 6.0 – 6.4 | 0 – 15, >15 – 30, >30 – 50 |
| 6.5 – 7.0 | 0 – 15, >15 – 30, >30 – 50, >50 – 100 |
| 6.9 – 7.9 | 0 – 15, >15 – 30, >30 – 50, >50 – 100 |

**Table 2**

**Preliminary Period Range Sub-Bins for DGML**

| (seconds) |
|---|
| 0.05 – 0.5 |
| 0.5 – 5.0 |
| 0.1 – 5.0 |

**Table 3**

**Ground Motion Record Parameters (Intensity Measures) Considered for Quantification in DGML**

| Parameter | Published Attenuation Relationship Available | Presently Proposed to be Quantified for Records in DGML |
|---|---|---|
| • PGA, PGV, PGD | ☐ | ☐ |
| • Elastic response spectra | ☐ | ☐ |
| • Inelastic response spectra | * | ☐ |
| • Duration | ☐ | ☐ |
| • Cumulative Absolute Velocity (CAV) | * | ☐ |
| • Energy | | |
| • Damage indices | | |
| • Arias Intensity | ☐ | ☐ |
| • Housner Spectrum Intensity | | ☐ |
| • Near-source record characteristics | | |
| - pulse velocity | ☐ | ☐ |
| - pulse period | ☐ | ☐ |
| - no. of pulses | ☐ | ☐ |

* Relationships developed, not yet published.

**Table 4**

**Supporting Information about Records Considered for Quantification in DGML**

| **Parameter or Characteristic** | **Presently Proposed to be Quantified for Records in DGML** |
|---|---|
| • Earthquake moment magnitude | ☐ |
| • Faulting mechanism (strike slip, reverse, normal, reverse-oblique, normal-oblique) | ☐ |
| • Hanging wall vs. foot wall | ☐ |
| • Source-to-site distance (closest distance to rupture surface, Joyner-Boore distance) | ☐ |
| • Near-fault directivity parameters: Somerville et al. (1997): s or d, X or Y, cos ☐, cos ☐, X cos ☐, Y cos ☐ | ☐ |
| • Site classification(s): Geomatrix; NEHRP | ☐ |
| • Basin response influence | |

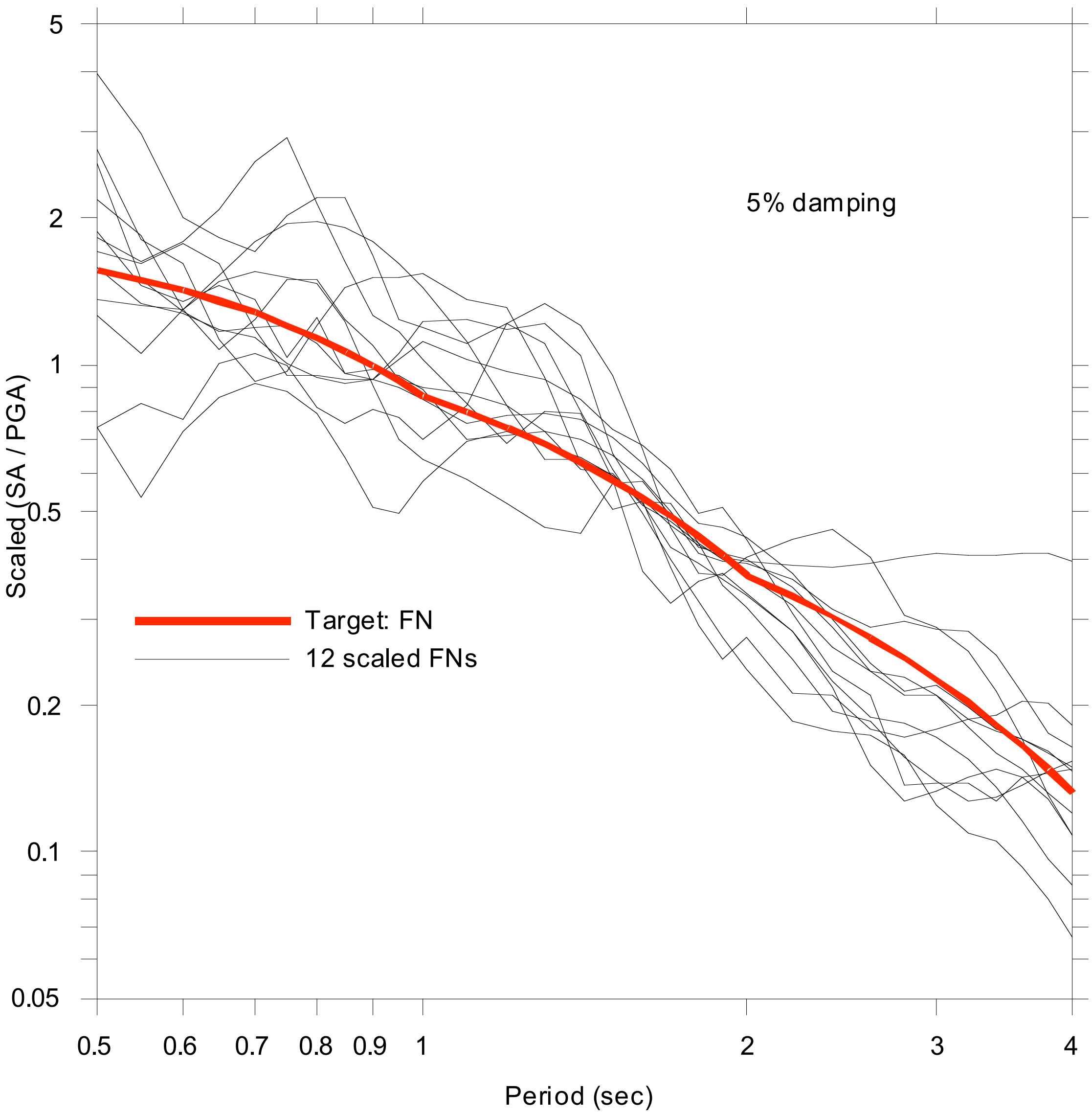


Figure 1 Comparison of response spectral shapes of fault-normal components of 12 records with target median spectral shape for M-R-S bin M ≥ 6.9, R= 0-20 km, rock -- period range 0.5 to 4.0 seconds.

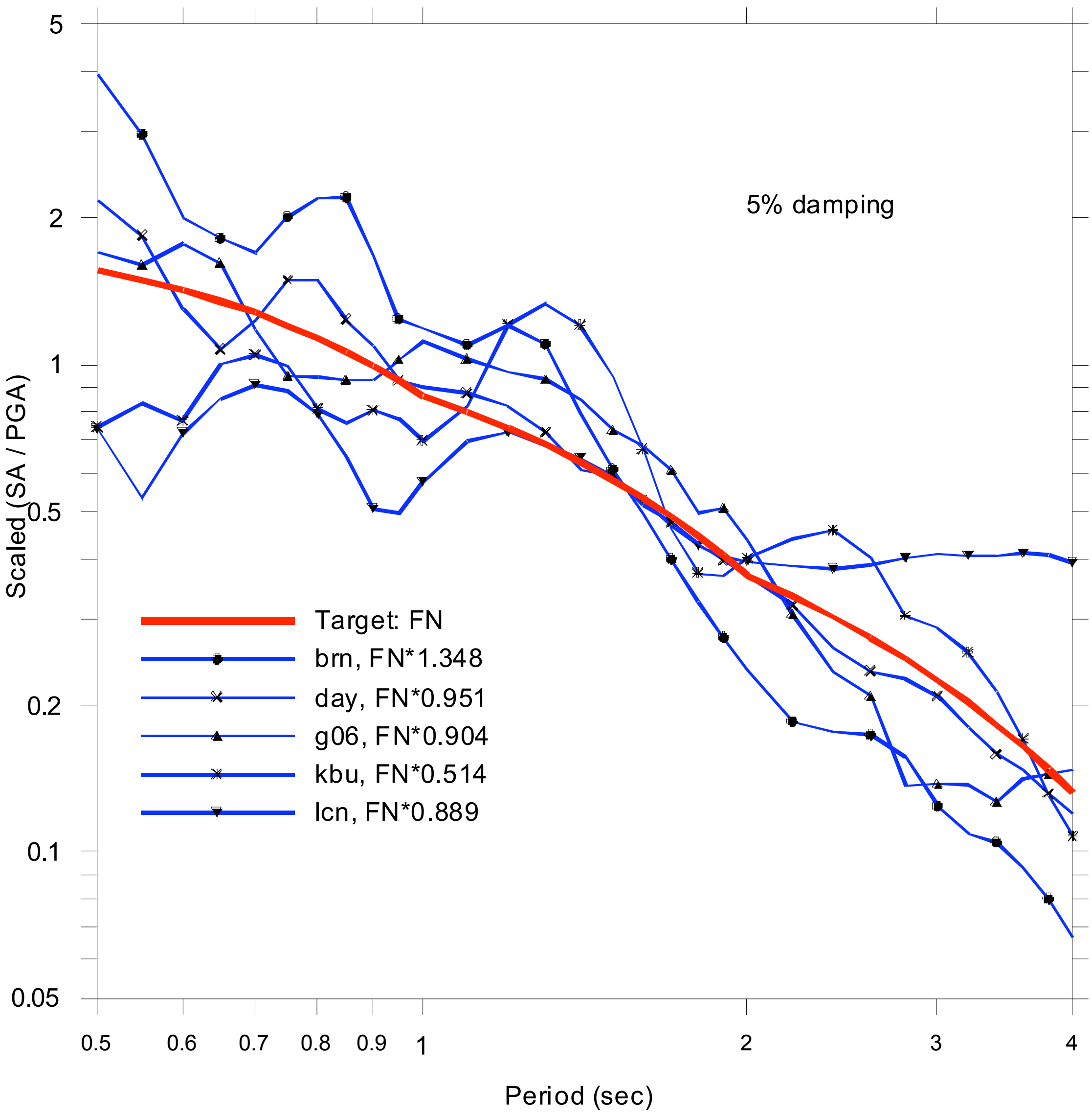


Figure 2 Comparison of response spectral shapes of fault-normal components of 5 selected records with target median spectral shape for M-R-S bin M ≥ 6.9, R= 0-20 km, rock -- period range 0.5 to 4.0 seconds.