1998 SCEC Progress Report
Project Title: Completion of Phase III and Beyond
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In the past year most of the SCEC supported work on phase III has been in the form of organizational meetings and revisions of the existing phase III draft, to produce a more integrated and coherent report. While there have been some minor modifications, and recalculations of results with slightly different twists, the main conclusions have not changed from the previous year. The document is scheduled to be submitted for publication in early 1999. We will briefly describe the main findings from the site response section of the phase III report and then move on to a discussion of the "beyond" part of this project which deals with the application of site characterization studies to ground motion modeling and prediction.

SCEC Phase III work

The focus of the site response section of the Phase III report has been on looking for measurable and/or mapable local site parameters that can be used to reduce the uncertainty in predicting future ground motion when using attenuation relations in probabilistic seismic hazard analysis (PSHA). Using both detailed and general digital geologic maps, measured shear-wave velocity data, and a depth to basement parameter, we examine the correlation between these parameters and site response determined from empirical strong- and weak-motion data recorded in Southern California. Average site response factors relative to rock attenuation (Sadigh et al., 1994) are the final result from this study. These results are then incorporated into probabilistic hazard maps which include the site response. While there are some clearly significant affects in using these site response factors in the seismic hazard calculations when compared with standard rock and soil models, they are mainly for the factors which are based on fewer observations and may not be reliable. The statistical significance of using these factors in the PSHA is still to be determined in the early part of 1999.

The main conclusions of the SCEC phase III work are summarized below:

• A trend towards larger site response factors with younger geology seen in all the various site classification used.

• At short periods (0.1 & 0.3 second) on Quaternary geology, there is a decrease in the site response factors at high levels of input motion which suggests nonlinear soil behavior.

• Independent weak-motion studies produce similar average amplification factors for the same geologic site class.

• Average weak-motion site response is relatively consistent with of the low-input strong-motion site response, especially in the Los Angeles & San Fernando basins.

• At 3.0 second period there remains a trend towards larger amplifications with increasing depth to basement even after the site class average amplification factor has been removed, suggesting 3-D basin effects.

• At short periods, there is a trend towards larger amplification factors with lower near-surface shear wave velocity however, there is large variability about this trend.

Beyond Phase III-
Application of Site Characterization Studies to Ground Motion Modeling and Prediction

The recent phase III results (Steidl, 1998) show the need to take a closer look at the effect of the average shear-wave velocity in the upper 30 meters on site response. This is a very critical issue since the Uniform Building Code (UBC) is using shear-wave velocity in the upper 30 meters as a means to define site class. The large variability in the trend between site amplification and average shear-wave velocity in the upper 30 meters raises questions about the usefulness of this parameter.

The Van Norman Dam Complex (VNDC) in the Northern San Fernando Basin, California (Figure 1) is an ideal site for the analysis of the effect of the average shear-wave velocity in the upper 30-100 meters on site response. Several accelerograms of near-source strong motion during the 1994 Northridge earthquake were recorded all within a few km of each other within the VNDC. The variability over such small distances in the observed ground motion (Bardet and Davis, 1996; Archuleta et al., 1998) gave rise to an intensive site characterization study of the VNDC strong motion sites (Gibbs et al., 1998; see Figure 2), and analyses of the nonlinear behavior of soils (Cultrera et al., 1998). In the process of the site characterization, many of the sites were left with a 3” cased hole that we have used in this project for deployment of a downhole package.

In order to examine more closely the relationship between near-surface shear-wave velocity and ground motion amplification, we use a 2.5" diameter borehole instrument package that uses a Wilcoxon accelerometer. This package is to deploy in multiple 3" diameter cased holes left by the USGS after logging for velocity at the Los Angeles Dam complex in the San Fernando valley, and in the future at other cased borehole sites throughout Los Angeles (Gibbs et al., 1998). An inflatable coupling system used to secure the instrument package in the borehole has been designed and makes the system portable, so that we can retrieve the package and move on to the next borehole after recording enough events.

In the past year weak-motion data from local earthquakes have been recorded at the VNDC and preliminary analysis on the contribution of the upper 30-100 meters on site response has begun. The initial deployment of the first downhole package took place in March of 1998. The instrument was installed at the Jensen Filtration plant at the Generator building borehole site, a stiff soil site with shear-wave velocities in the upper 100 meters between 450 and 700 m/s (Figure 2). The station has recorded over 25 events from March 1998 to present, ranging in magnitude from 1.6 to 4.8. The ability to record small local earthquakes from within the Northridge aftershock zone as well as larger regional events on the downhole accelerometer was a surprising success. In addition to the downhole station at the generator building, during the summer of 1998 a larger deployment at all the stations within the VNDC took place with the help of a SCEC summer Intern. An example of the high quality digital data recorded during this deployment is shown in Figure 1.

Large variability over short distances can be seen in the recordings of weak motion (Figure 1) similar to the Northridge mainshock observations (Bardet and Davis, 1996; Archuleta et al., 1998). The same sites that showed larger ground motion during the Northridge mainshock also show larger ground motion for the aftershocks. These differences in the ground motion are not so surprising once we look at the variability in the shear-wave velocity profiles from these sites (Figure 2). There is a clear correlation between larger ground motions and lower shear-wave velocity.

Using the downhole ground motion as the "reference" site we calculated spectral ratio estimates of site response at each site by averaging over all recorded events at each site (Figure 3). The average site response estimates are smoothed whole record estimates (10 seconds of data). The station at the Jensen Filtration Plant Administration building lawn (solid curve) and the Sylmar Converter Station West (dash-dot curve) show the largest spectral amplifications, exceeding a factor of 4 over a wide frequency band. Some of the larger high frequency peaks are related to sub harmonics of the electrical noise from all of the power conversion and transmission equipment, and not related to the soil response. The surface station at the Jensen Filtration Plant generator borehole site (dotted curve) and the Sylmar Converter station East site (long dashed curve) show less spectral amplification, between a factor of 2 to 3 over a wide frequency band. The Los Angeles Dam site (short dashed curve) has almost no spectral amplification relative to the borehole station at lower frequency. This site is also has the largest shear-wave velocities (LAD-Figure 2) of all the sites.

It is encouraging that the average weak-motion site response and the observed strong ground motion at these sites can be correlated with the measured shear-wave velocities, and that the variability over such short distances can be explained. It is less encouraging to think that the velocity profiles can change so quickly from site to site, since defining the near-surface shear-wave velocity profile on such a small scale over a large region such as the Los Angeles basin is extremely cost prohibitive.

Our plan for the future is to double out efforts in obtaining uphole/downhole records of ground motion at both the VNDC and other sites in the Los Angeles basin. These observations will then be used to search for the best parameter that correlates site amplification with some range of near-surface shear-wave velocity and also with surface geology. This task is of critical importance to including local site response in maps of seismic hazard over a regional scale in a probabilistic sense. In addition these observations will be used in calibrating and validating both linear and nonlinear numerical methods for ground motion prediction. The data from this project will be made available to the engineering seismology and geotechnical engineering community for testing numerical wave propagation techniques. A workshop will be held in 1999 in conjunction with the ROSRINE project, where a blind prediction experiment to generate synthetic surface ground motions from the borehole data is evaluated, and the various numerical methods are compared.

References

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UCSB/SCEC Temporary Array at the Van Norman Dam Complex Includes 5 Surface and 1 Downhole Sensors

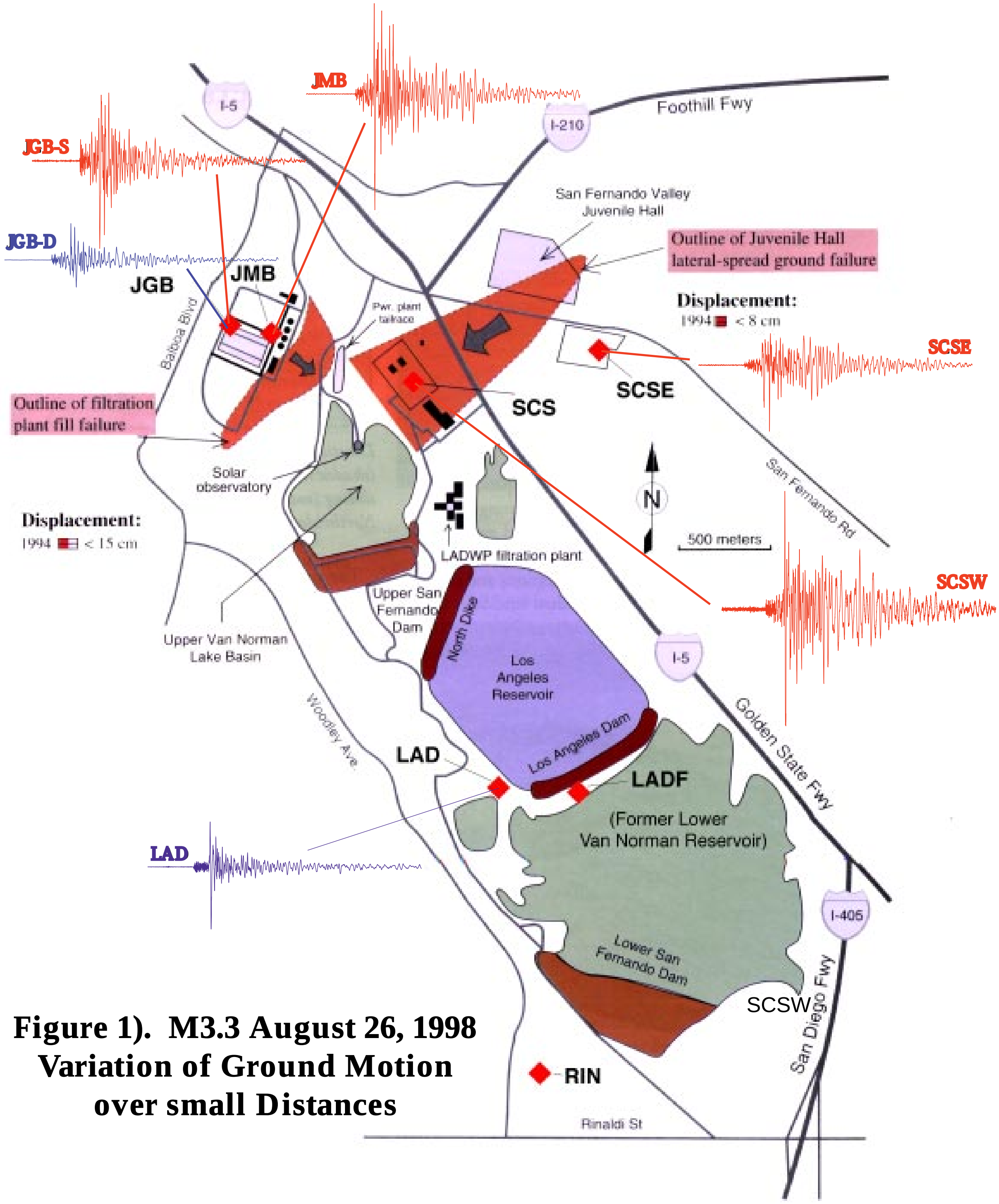

Figure 1). M3.3 August 26, 1998 Variation of Ground Motion over small Distances

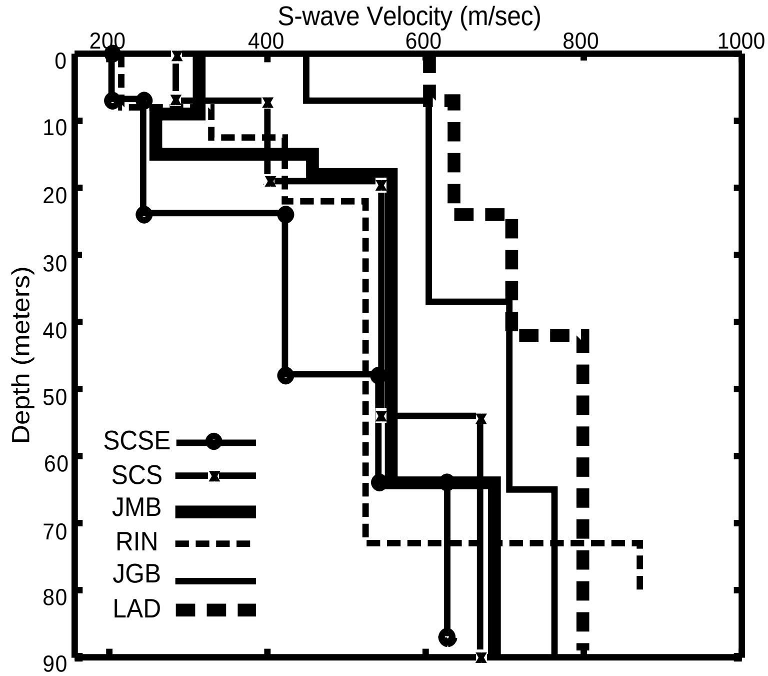

Figure 2).Shear wave velocity profiles for six VNDC sites.

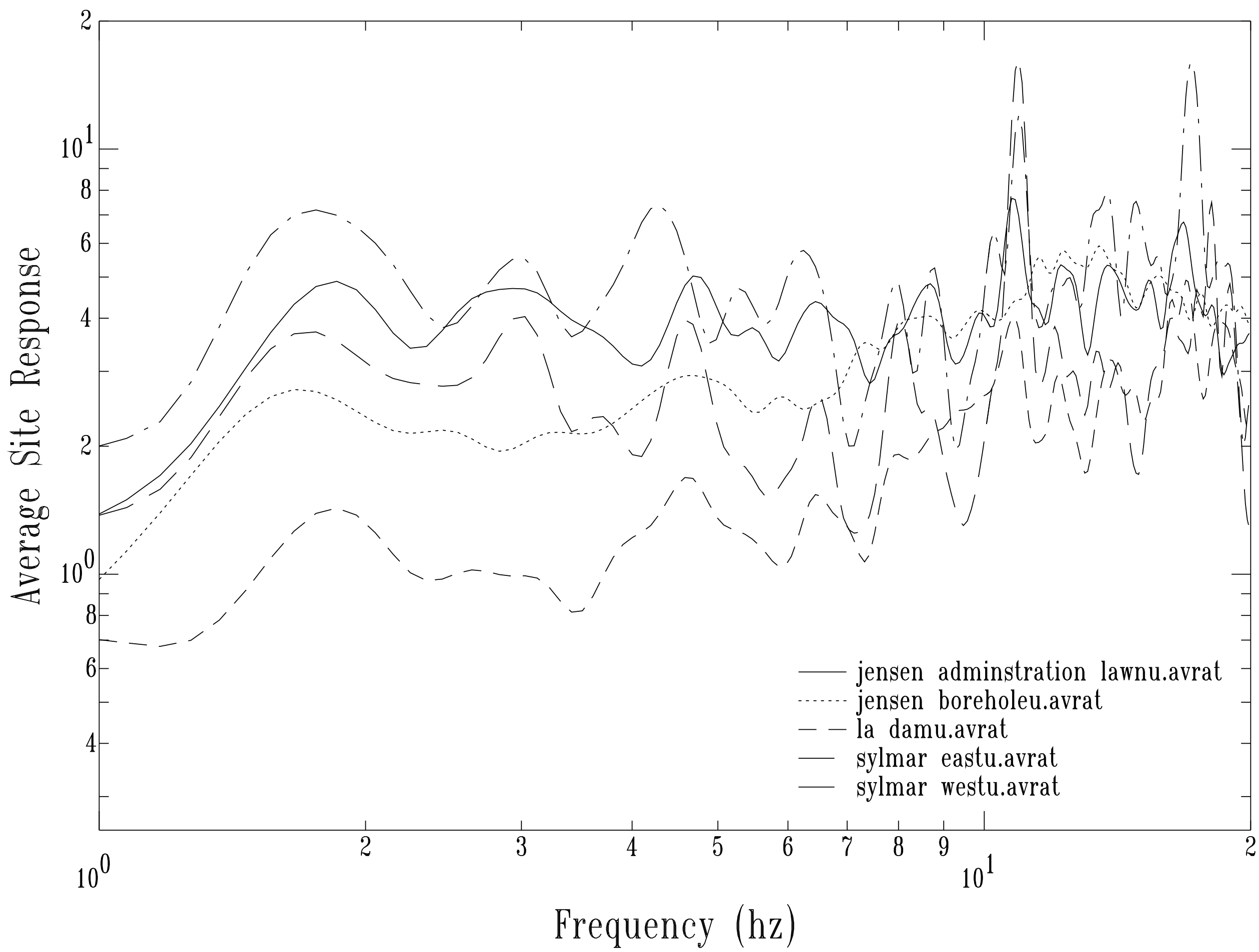

Figure 3). Average Site Response from aftershocks recorded across the VNDC during March-September 1998.