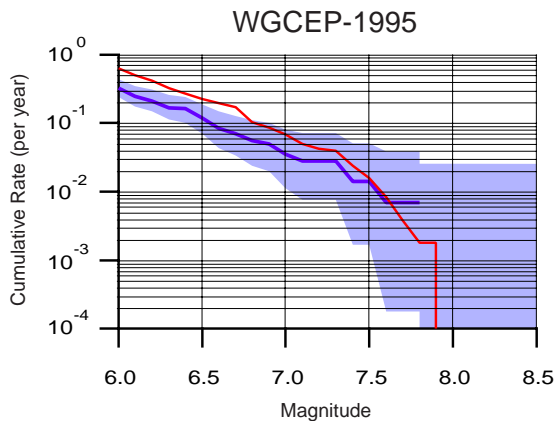


# Annual Report, 1998

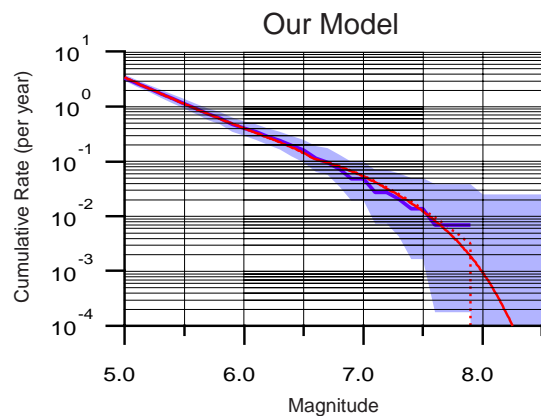
Edward (Ned) H. Field

## PSHA Source Model for Southern California

SCEC's Phase II report (WGCEP, 1995) represented the first attempt to combine seismic, geodetic, and geologic constraints into an integrated seismic-hazard source model. By far the most contentious aspect of the study was that it predicted a rate of magnitude 6 to 7 earthquakes significantly greater than that observed historically (Figure 1). One explanation was that the discrepancy, or apparent earthquake deficit, is an artifact of the upper magnitude limit built into the model. This was controversial, however, because removing the discrepancy required earthquakes larger than are seen in the geological record, and larger than implied from empirical relationships between fault dimension and magnitude. Although several papers have addressed this issue, an alternative, integrated source model without an apparent deficit has not yet appeared. We present a simple geologically based approach for constructing such a model which agrees well with the historical record and does not invoke any unsubstantiated phenomena (Figure 2).



**Figure 1.** The WGCEP-95 observed (blue) and predicted (red) cumulative rate of earthquakes for southern California. The shading on the observed cumulative rate represents the 95-percent confidence region. Note the factor of  $\sim 2$  discrepancy at  $M \leq 7$ .



**Figure 2.** Same as Figure 1, but for the catalog and model presented by Field et al. (1999). The preferred model rate is plotted with the red line. The red dotted line is the variant where no earthquakes larger than  $M$  7.9 are allowed.

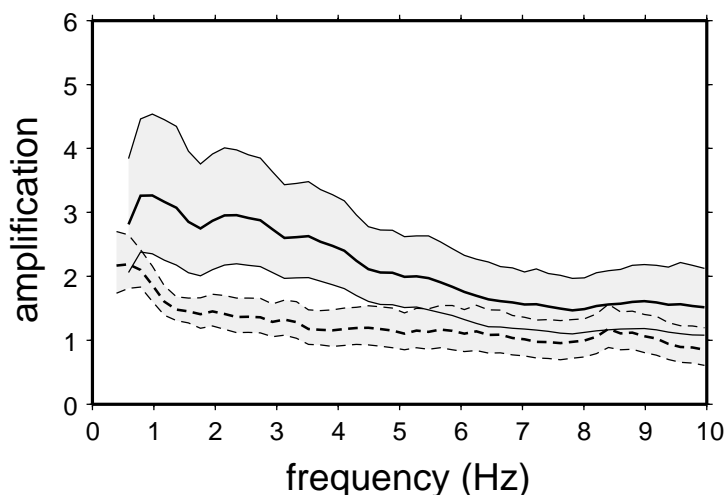
The following factors are found to be influential: the  $b$ -value and minimum magnitude applied to Gutenberg-Richter seismicity; the percentage of moment released in characteristic earthquakes; a round-off error in the moment-magnitude definition; bias due to historical catalog incompleteness; careful adherence to the conservation of seismic moment rate; uncertainty in magnitudes estimates obtained from empirical regressions; allowing multi-segment ruptures

(cascades); and the time dependence of recurrence rates. The previous apparent deficit is shown to have resulted from a combination of these factors. None alone caused the problem, nor solves it. The model presented here is relatively robust with respect to these factors. An in-depth discussion of this paper can be found in Field et al. (1999) available upon request from the first author.

I have initiated an effort to revisit this problem (SCEC Working Group 2000) by the end of SCEC's current incarnation. Virtually all data that went into the previous report are being revised, and we will test several different, viable models of southern California seismicity (rather than producing one consensus model). We hope to publish the report as a special issue of the *Bulletin of the Seismological Society of America*.

### Nonlinear Response of Sediments

A previously published study (Field et al., 1997, *Nature*. **390**, 599-602) claimed to have identified the first widespread evidence of nonlinear sediment response in southern California (Figure 3). This observation, which has subsequently been supported by other more extensive analyses (e.g. Field et al., 1998a; several others), was surprising to many seismologists. At the same time, engineers expressed surprise that sediment sites had behaved more linearly during the Northridge earthquake than they had expected. Thus, it appears that the traditional gulf between seismologists and engineers on the significance of sediment nonlinearity is narrowing.



**Figure 3.** Average site response estimates (with 95% confidence intervals) for sediment sites during the 1994 Northridge earthquake. That the average amplification for the strong-motion main shock (dashed) is significantly less than that for the weak-motion aftershocks (solid) is evidence of nonlinear sediment response. Details can be found in Field et al. (1997, 1998a).

Given these latest findings, coupled with their significance with respect to seismic hazard estimation, the time was ripe for a comprehensive evaluation of our present understanding of this problem. To that end, in January, 1998 I convened a two-day SCEC/PEER sponsored

seminar/workshop on sediment nonlinearity. Also in attendance were members of the Los Alamos National Laboratory, government officials, members of the private sector, and a representative from the Japanese Ministry of Transportation. Over 60 individuals participated, and the diversity of disciplines in attendance (including physics, seismology, engineering, and practicing professionals) was unprecedented with respect to previous meetings on this topic. A report on this meeting has been published in *Seismological Research Letters* (Field et al., 1998b), and reprints are available from the first author. A summary follows:

We are making rapid advances in our understanding of nonlinear site effects. The degree of sediment nonlinearity appears to reside somewhere between the traditional seismological and engineering perspectives, as each new study seems to make a step toward intermediate ground. We have along way to go, however, and nonlinearity remains as one of the final frontiers in our understanding of site effects. In particular, there is a rich parameter space waiting to be explored in fully nonlinear models, which will presumably give us more insight as to what to look for in our limited observations. Furthermore, we need to conduct more direct and candid evaluations of laboratory results in terms of their ability to reflect *in situ* sediment behavior. Finally, we need more broad-band and wide dynamic-range recordings in order to infer behavior at all frequencies of interest, particularly at downhole arrays which constitute our best hope for understanding the physics of nonlinear site effects.

### **SCEC Phase III Report**

About one year ago the SCEC Phase III report was reviewed by a team of nine experts. At that time it consisted of a collection of related studies, combined in an engineering report, aimed at examining sources of uncertainty in probabilistic seismic hazard assessment. The review team agreed the report contained many important findings, but that it needed streamlining. After subsequent delays, it became apparent this would not happen without a full-time editor, and I was asked to take over in this capacity. The report is well on its way to completion.

It has been decided that rather than producing a document primarily aimed at engineers, Phase III will be published as a collection of scientific papers in a special issue of the *Bulletin of the Seismological Society of America*. The advantage of having the report appear in a peer-reviewed scientific journal justifies the inevitable publication delays associated with this decision.

Sections in the earlier version related to the characterization of seismic sources (updating Phase II) and to computing synthetic seismograms have been removed (and will likely be the topic of separate working groups). The report now focuses exclusively on how, and if, probabilistic seismic hazard assessment (PSHA) can be improved by accounting for site effects.

We have made a diligent search for any characteristics that systematically predispose a site to greater (or lower) levels of ground shaking. We have found some significant attributes, such as surface geology and depth to bedrock in sedimentary basins, that indeed correlate with observed amplification factors. Also, we have tested which of several attenuation relations are most consistent with southern California data and with theoretical considerations where data are

lacking. We are currently in the process of quantifying the influence of these factors on PSHA. A preliminary conclusion is that, except in some specific circumstances, only modest improvements can be made by accounting for site effects. However, even modest improvements may be significant in terms of implied seismic hazard.

Abstracts of the papers currently slated for the special issue of BSSA, as well as the overall status of the report, can be found at: [www.scec.org/research/phase3](http://www.scec.org/research/phase3). Pre-prints of the papers are available from the respective authors.

## **Non-technical Overview of Earthquake Ground Motion and Seismic Hazard Assessment**

I have written a comprehensive, non-technical overview of the factors that influence earthquake ground motion and how probabilistic hazard analysis is carried out (this started as a nontechnical summary of the Phase III report, but has grown into a much more comprehensive overview). Although this paper has been reviewed by several qualified individuals, delays in the Phase III report, and uncertainty on the publication venue, prevented significant progress over the last year. The *Earthquake Engineering Research Institute* has tentatively agreed to produce the document, and we are aiming for publication sometime near the release of the Phase III report.

### **Publications**

- Field, E.H., Y. Zeng, P.A. Johnson, and I.A. Beresnev (1998a). Nonlinear Sediment Response During the 1994 Northridge Earthquake: Observations and Finite-Source Simulations, *J. Geophys Res.* **103**, 26869-26883.
- Field et al. {11 co-authors} (1998). Nonlinear site response: Where we're at (A report from a SCEC/PEER seminar and workshop), *Seism. Res. Lett.* **69**, 230-234.
- Field, E.H., D.D. Jackson, and J.F. Dolan (1999). A Mutually Consistent Seismic-Hazard Source Model for Southern California, *Bull. Seism. Soc. Am.*, In Press.
- Field, E.H. (1996) Understanding Earthquake Ground Motion and Seismic Hazard Assessment: Developing the State of the Art in Southern California; *Under consideration by the Earthquake Engineering Research Institute*.
- E.H. Field & the Phase III Working Group (1999). Accounting for Site Effects in Probabilistic Seismic Hazard Analysis: Overview of the SCEC Phase III Report, *to appear in a special issue of the Bull. Seism. Soc. Am.*, In Preparation.
- E.H. Field & others (1999). Probabilistic Seismic Hazard Calculations: Test of Various Possible Site Response Parameterizations, *to appear in a special issue of the Bull. Seism. Soc. Am.*, In Preparation.