Ground Motion Methods and Results for the 1998 PSHA

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Ground Motion Characterization

The 1998 PSHA use seven experts to develop the ground motion models for the spectral acceleration, peak acceleration, and peak velocity for both the horizontal and vertical components. To allow the ground motion experts to account for the different distance measures, the ground motion experts developed estimates of the median (μ) and aleatory standard deviation (σ) for discrete magnitude distance and style-of-faulting cases. Parameteric models were then fit to the expert's point estimates to give the attenuation relations that are used in the PSHA.

The experts also provided estimates of the epistemic uncertainty for the median and the aleatory variability. The epistemic uncertainty in the median is denoted σ_μ and the epistemic uncertainty in the aleatory standard deviation is denoted σ_σ. Parametric models were used for both σ_μ and σ_σ. The experts were allowed to use asymmetric models for the epistmic uncertainty, but all seven experts chose to use symmetric models for simplicity.

Expert Model Development

The experts developed their models by selecting candidate models from available empirical ground motion models and from numerical simulations conducted for the sites and source conditions at Yucca Mountain (point A). In general, the empirical models were not developed for the site and source conditions at Yucca Mountain. To account for the differences in site and source conditions between the empirical strong motion data and Yucca Mountain, adjustment factors were applied to the empirical ground motion models. These adjustment factors accounted for three main factors: (1) the hard-rock condition at point A (shallow Vs and the kappa), (2) stress-drop for normal faulting earthquakes, and (3) the geometrical spreading in the Basin and Range (crustal velocity structure).

An example of the plots provided to the ground motion experts showing the estimates from the different models is shown in Figure 1 for peak acceleration on the horizontal component.

In addition to the ground motion models, the experts also considered the constraints on ground motions close to large normal faulting earthquakes provided by precarious rock data. The precarious rocks indicated that the median ground motion close to large normal faulting earthquakes should be much lower than predicted by the empirical models. Only one of the seven ground motion experts considered the precarious rock information to be developed enough to be considered: Anderson broadened his epistemic uncertainty in the median ground motion at short distances to account for precarious rock constraints.

To develop the weights for their models, the experts assigned weights to the candidate models. Most of the experts first assigned weights to model classes: empirical models, point source simulation models, and finite source simulation models. Weights were then assigned to the models within a class representing the relative strengths of the altenative models within each class. The total weight for a model was given by the product of these two weights. The weights for both the model classes and the individual models within a class varied as a function of magnitude and distance.

The weights were applied to the ground motion point estimates. The purpose for using point estimates rather than just assigning weights to the models was to have the experts consider the values of the ground motions predicted by the models and not just the merits of the models. Simple parameteric models were then fit to the expert's point estimates for use in the PSHA. The experts reviewed the fitting to be sure that it accurately represented their point estimates.

Feedback and Model Revisions

The experts received three rounds of feedback on their ground motion models during the project. This feedback focused on comparisons of the mu, sigma, sigma-mu, and sigma-sigma values for the point estimates given by the experts. Feedback was also provided on the hazard values, but this focused on return periods in the 10,000 year range.

The feedback lead to three rounds of revisions of the ground motion models. The experts were allowed to make changes until they turned in their final model. One expert, Anderson, made significant changes to his model in the last round of revisions. He significantly increases his epistemic uncertainty for the median ground motion at short distances. This increase was based on the discrepancy between the empirical models and the precarious rock data, and on the uncertainty training that emphasized the tendency to underestimate uncertainties. In particular, he considered that the existing numerical simulation models may not be correct and that significant changes could occur in future developments of numerical simulations. Since these revisions came at the end of the project, they were not reviewed by the other experts. As a result, Anderson's model has much larger epistemic uncertainty than the other expert's models.

Use of Parameteric distributions of Epistemic Uncertinaty

In the 1998 PSHA, parameteric models were used for the epistemic uncertainties. This approach may lead to ground motion models that are outside the range of any existing models (in terms of the median and aleatory sigma). This was an intentional choice by the TFI. If the experts are restricted to available models, then the epistemic uncertainty will tend to increase as more models become available. That is, as more studies are conducted, the estimate of the uncertainty increases, which is contrary to the concept that epistemic uncertainty should decrease as additional data are collected.

The advantage of this approach is that it does not limit the ground motions to the available models. In this sense, it could be providing a more accurate assessment of the true scientific uncertainty. The disadvantage of this approach is that it can lead to ground motion models that predict much higher ground motions than are supported by the existing data.

As an example, the epistemic uncertainty in the median PGA from Anderson and Boore are shown in Figures 2 and 3. This difference in the epistemic uncertainty has a large impact on the hazard at the 1E-8 level.

Maximum Ground Motions

No limits on the ground motion or on the applicability of the log-normal distribution at high numbers of standard deviations were elicited. The feedback at the workshop focused on the 1E-4/yr hazard, not on the 1E-8/yr hazard. As a result, the ground motion experts did not review their models for the 1E-8/yr hazard level. If they had feedback focused on the 1E-8 hazard level, then there would likely have been additional revisions to their models.

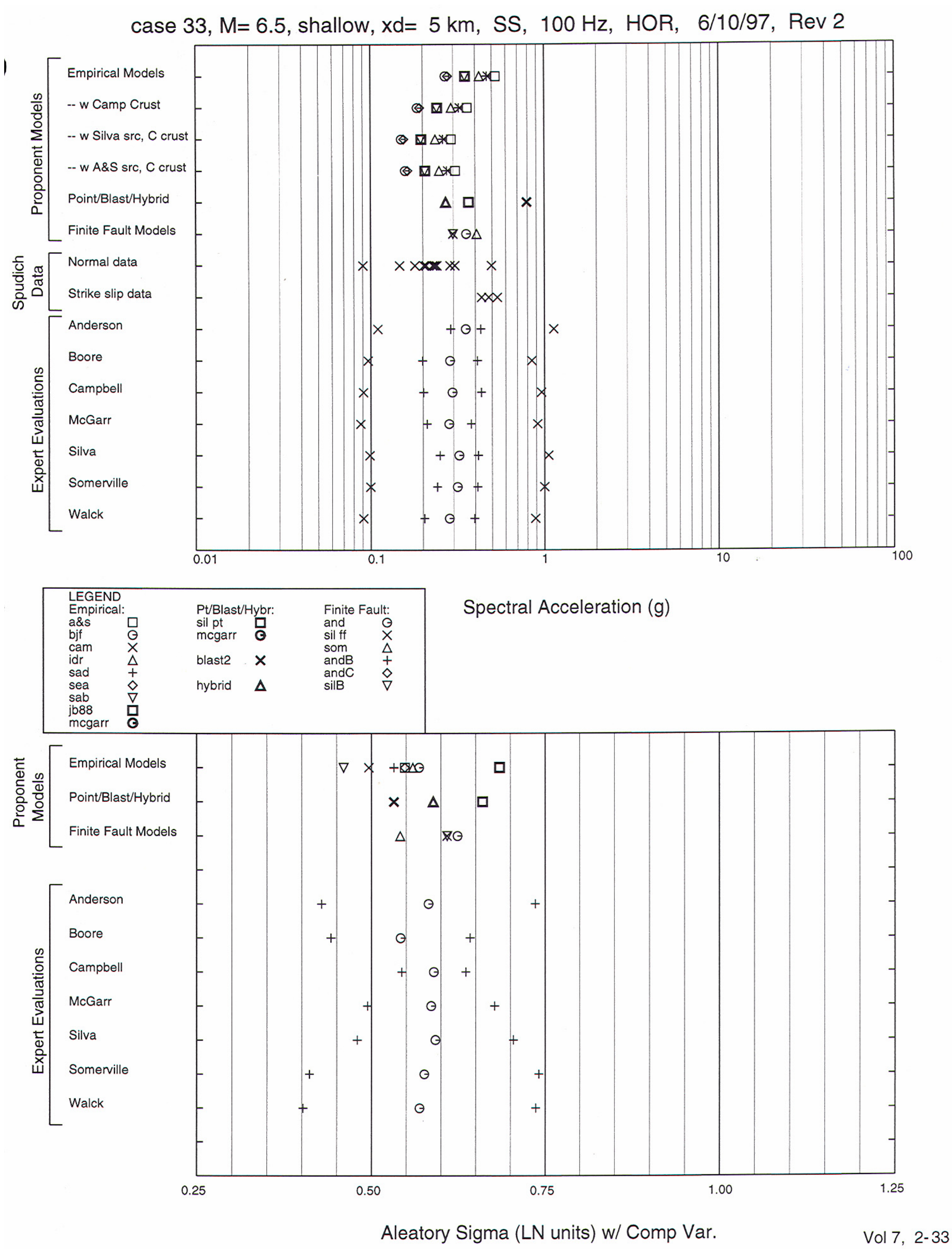

Figure 1. Example of proponent ground motion models.

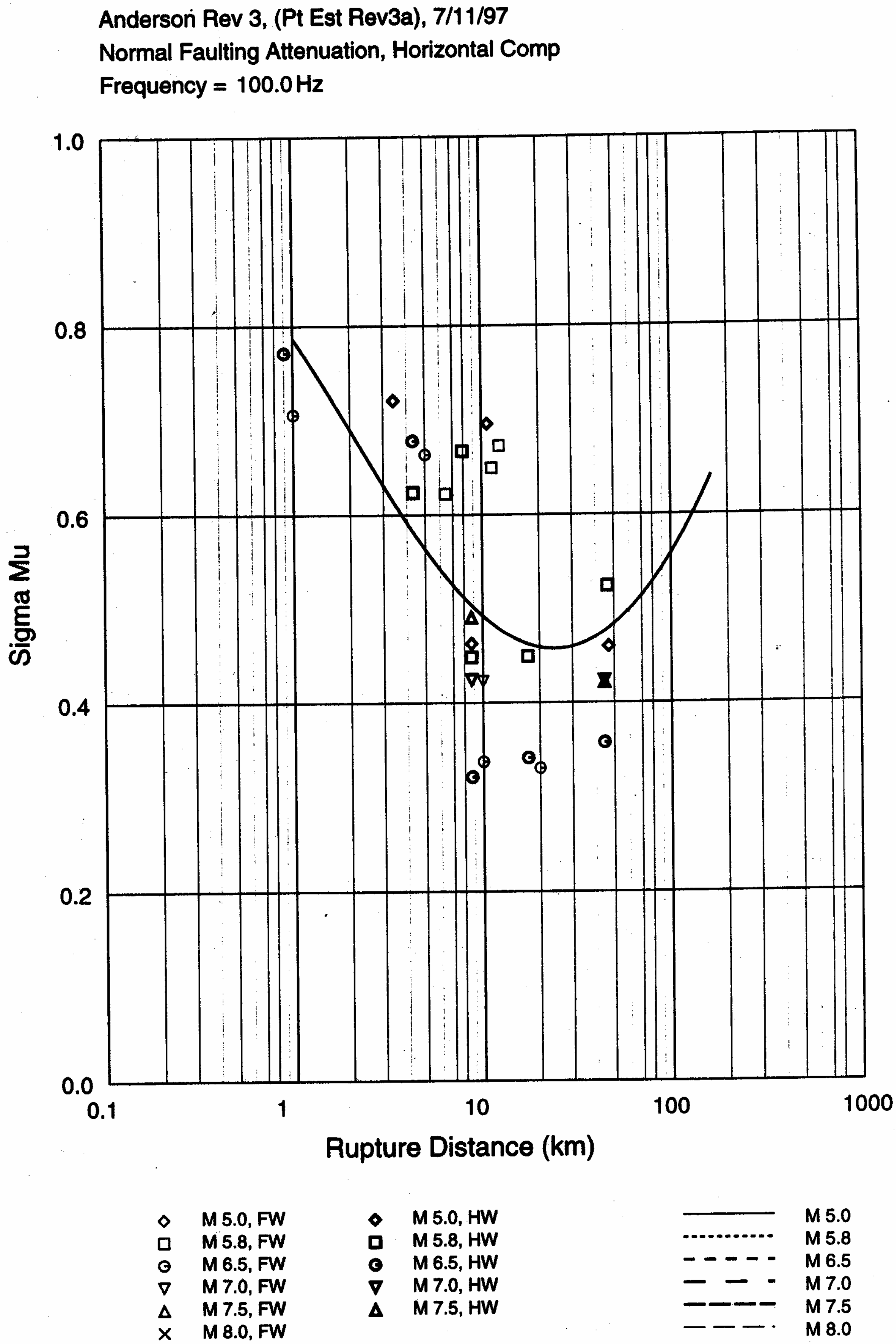

Figure 2. Example epistemic uncertainty in the median PGA from Anderson's model.

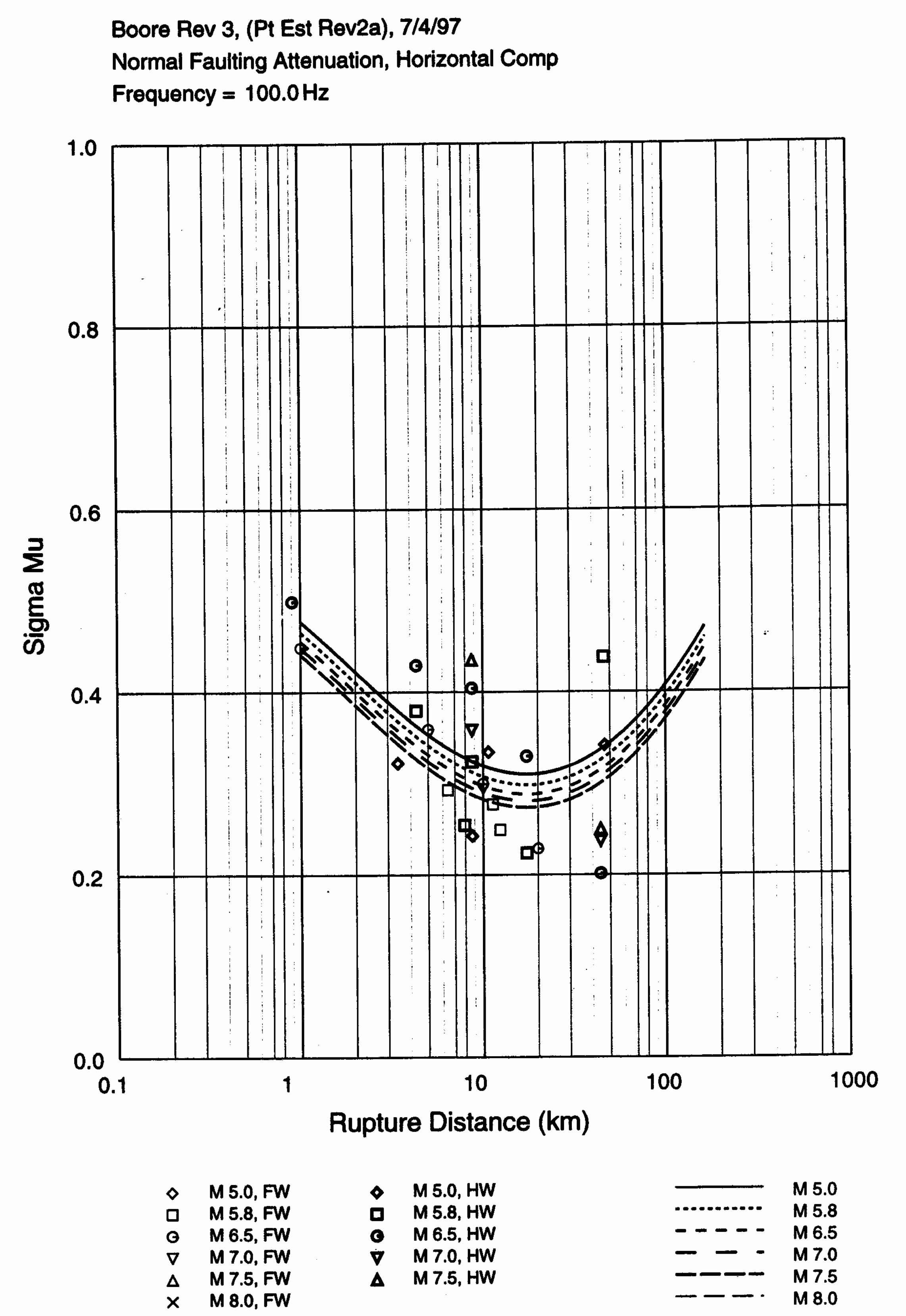

Figure 2. Example epistemic uncertainty in the median PGA from Boore's model.