

Recommendations for Probabilistic Seismic Hazard Analysis: **Guidance on Uncertainty and Use of Experts**

Senior Seismic Hazard Analysis Committee (SSHAC)

SHARE Iberia Workshop on Seismogenic Sources

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SHARE POSITION

- SHARE has adopted a uniform SSHAC Level-3 procedure, adapted to the needs of the present project.
- In SHARE, both the Work Package Leaders (in their roles as Technical Integrators) and the experts will share the responsibility and intellectual ownership of the results.

Introduction

- Probabilistic Seismic Hazard Analysis (PSHA) has become an increasingly important tool for aiding design and decision-making at all levels in both the private sector and government.
- The level of sophistication applied to PSHA has increased dramatically over the past three decades since the technique was first introduced. As PSHA is implemented more and more in different forms, it became clear to the sponsors of SSHAC that the time had arrived to establish more uniform and up-to-date guidelines for future studies.

Introduction (cont.)

- In order to improve the overall stability of the PSHA process, the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE); and the Electric Power Research Institute (EPRI) co-sponsored the SSHAC Project to provide methodological guidance on how to perform a PSHA.
- The project was carried out by a seven-member Senior Seismic Hazard Analysis Committee (SSHAC) supported by a large number other experts.
- In 2009, "Implementation of the SSHAC Guidelines for Level 3 and 4 PSHAs – Experience Gained From Actual Applications" was published by the USGS.

PSHA Objectives

- The most important and fundamental fact that must be understood about a PSHA is that the objective of estimating annual frequencies of exceedance of earthquake-caused ground motions can be attained only with significant uncertainty.
- SSHAC believes that the following should be sought in a properly executed PSHA project for a given difficult technical issue:
 - 1) A representation of the legitimate range of technically supportable interpretations among the entire informed technical community, and

PSHA Objectives (cont.)

- 2) The relative importance or credibility that should be given to the differing hypotheses across that range.
- As SSHAC has framed the methodology, this information is what the PSHA practitioner is charged to seek out, and seeking it out and evaluating it is what SSHAC defines as technical integration.

Consensus

- SSHAC identifies four different types of consensus, and then concludes that one key source of difficulty is failure to recognize that
 - 1) There is not likely to be "consensus" (as the word is commonly understood) among the various experts; and
 - 2) No single interpretation concerning a complex earth-sciences issue is the "correct" one.

Types of Uncertainty

There are two different classes of uncertainties:

- Those that we will call *epistemic* are lack-of-knowledge uncertainties arising because our scientific understanding is imperfect *for the present*, but are of a character that in principle are reducible through further research and gathering of more and better earthquake data.
- Those that we will call *aleatory* — "random" in character — are uncertainties that for all practical purposes cannot be known in detail or cannot be reduced (although they are susceptible to analysis concerning their origin, their magnitude, and their role in PSHA).

Types of Uncertainty (cont.)

- The division between the two types of uncertainty is somewhat arbitrary. This is because, conceptually, some of the processes and parameters; whose uncertainties we will characterize here as aleatory ("random") maybe partially reducible through more elaborate models and/or further study.
- A PSHA that follows the SSHAC guidance but that does not deal appropriately with both the epistemic and the aleatory uncertainties must be considered inadequate.

Example: Probability of Activity

- For many faults, even in areas that are well studied, the evidence is not definitive that a specific fault is active and seismogenic.
- Thus whether a fault is seismogenic is also a seismic source parameter that has epistemic uncertainty.
- This epistemic uncertainty can be parameterized as the probability of activity.
- Is probability of activity being considered in SHARE?



Criterion for a Successful PSHA

- When independently applied by different groups, would yield "comparable" results, defined as results whose overlap is within the broad uncertainty bands that inevitably characterize PSHA results.
- For this to be true, we believe that the uncertainties in the methodology must be confronted and dealt with head-on. No PSHA analyst should attempt less, and no PSHA sponsor should accept less.

Criterion for a Successful PSHA (cont.)

- Regardless of the scale of the PSHA study, the goal remains the same: to represent the center, the body, and the range of technical interpretations that the larger informed technical community would have if they were to conduct the study.

Roles in a PSHA

- Project Sponsor
- Project Leader
- Technical Integrator (TI)
- Technical Integrator Facilitator (TFI)
- Experts – Proponents, Evaluators, and Resources Experts

Technical Integrator

- TI is a single entity (individual, team, company, etc.) who is responsible for ultimately developing the composite representation of the informed technical community for the issues using the TI approach.
- This could involve deriving information relevant to an issue from the open literature or through discussions with experts.

Experts

- A *proponent* is an expert who advocates a particular hypothesis or technical position. The proponent role is common in science, whereby an individual evaluates data and develops a particular hypothesis to explain the data. The proponent's position is then, challenged technically by his peers in professional debates and in the literature to see if it stands up to a variety of observations.

Experts (cont.)

- An *evaluator* is an expert who is capable of evaluating the relative credibility of multiple alternative hypotheses to explain the observations. The evaluators are expected to evaluate all potential hypotheses and bases of inputs from proponents and resource experts and provide 1) their own input and 2) their representation of the community distribution.
- A *resource expert* is a technical expert with particular knowledge of a particular data set of importance to a PSHA. Commonly, a resource expert will have site-specific experience that will be of use to the evaluators.

Degrees of PSHA Issues and Levels of Study

ISSUE DEGREE	DECISION FACTORS	STUDY LEVEL
<p>A Non-controversial and/or insignificant to hazard</p>	<ul style="list-style-type: none"> ➤ Regulatory concern ➤ Resources available ➤ Public perception 	<p>1 TI evaluates/weights models based on literature review and experience; estimates community distribution</p>
<p>B Significant uncertainty and diversity, controversial, and</p>		<p>2 TI interacts with proponents and resource experts to identify issues and interpretations; estimates community distribution</p>
<p>C Highly contentious, significant to hazard, and highly complex</p>		<p>3 TI brings together proponents and resource experts for debate and interaction; TI focuses debate and evaluates alternative interpretations; estimates community distribution</p>
		<p>4 TFI organizes panel of experts to interpret and evaluate; focuses discussions; avoids inappropriate behavior on part of evaluators; draws picture of evaluators' estimate of the community's composite distribution; has ultimate responsibility for project</p>

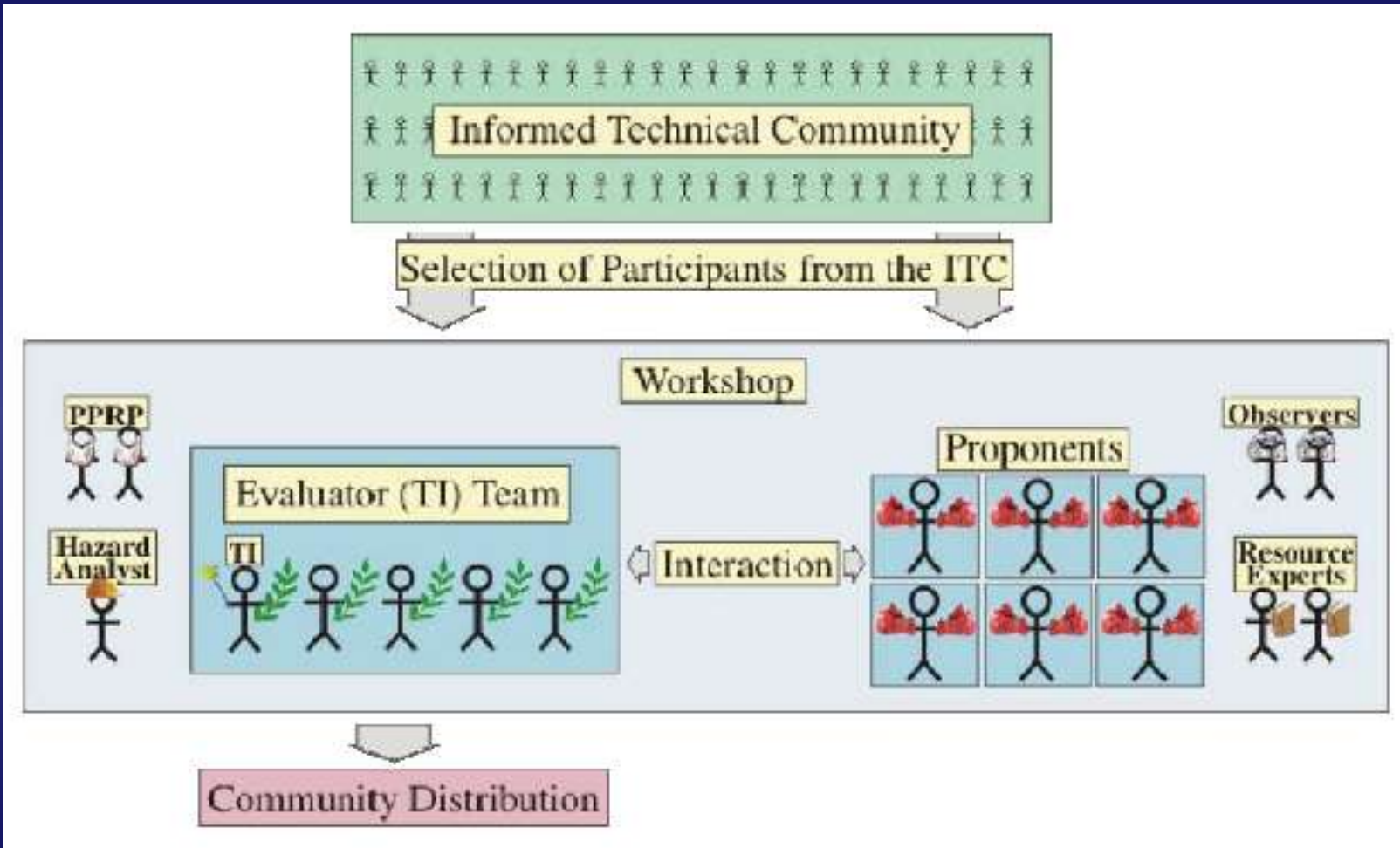


Example Large PSHA Projects That Have Followed SSHAC

PROJECT	LEVEL
Yucca Mtn., U.S.	4
PEGASOS, Switzerland	4
Central and Eastern U.S. Next Generation Attenuation	3
British Columbia Hydro Dams, Canada	3
Central and Eastern U.S. Seismic Source Characterization	3



Expert Interaction for SSHAC Level 3



TI Process

- Step 1. Identify and select peer reviewers
- Step 2. Identify available information and design analyses and information retrieval methods
- Step 3. Perform analyses, accumulate information relevant to issue and develop representation of community distribution
- Step 4. Perform data diagnostics and respond to peer reviews
- Step 5. Document process and results

Peer Review

- The SSHAC guidance gives special emphasis to the importance of an independent peer review. It distinguishes between a participatory peer review and a late-stage peer review, and also between a peer review of the process aspects and of the technical aspects for the more complex issues.
- SSHAC strongly recommends a participatory peer review, especially for the process aspects for the more complex issues.
- In this work package, a Participatory Peer Review Panel is being engaged.

Documentation

- One of the major lessons that the PSHA community has learned in recent years is that documenting the PSHA process and results is as important as carrying out the project in a technically competent way.
- There are at least three reasons why excellent documentation is crucial:
 - Only through adequate documentation can others in the technical community understand or review the analysis and the results.

Documentation (cont.)

- Only through adequate documentation can a later analysis team with new information or improved models utilize a PSHA to update it, revise it, or validate that it does not need an update or revision.
- Only through adequate documentation can the sponsoring organization retain an adequate record of the process it supported.

A Note about Experts and Uncertainties

- Experts tend to underestimate uncertainties. They tend to act as proponents rather than evaluators.
- There are several reasons why this is the case. One reason is that experts are so invested in their own model and convinced that their model is correct, they have not or will not evaluate alternative models and interpretations and all sources of uncertainties.
- This process is called “anchoring”.

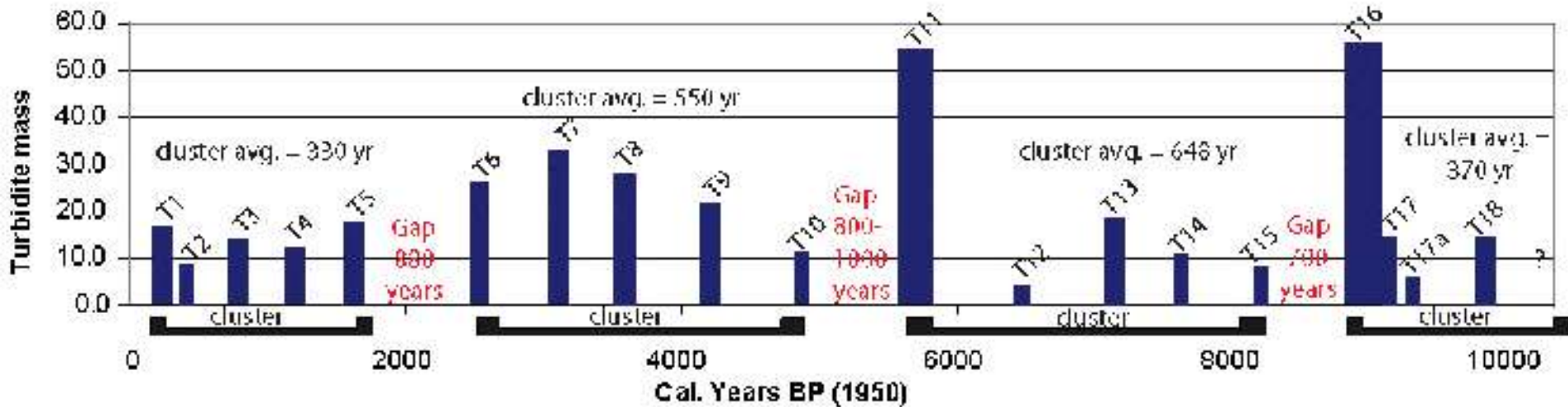
A Note About Experts and Uncertainties

- I often hear the statement from experts that “there is not enough information” to characterize a fault.
- I often find that there is sufficient information but the expert is thinking deterministically and not probabilistically. The lack of information simply results in larger epistemic uncertainty.
- As a result faults are often not characterized and historical seismicity is used solely in PSHAs.
- It is important that faults be included in PSHAs because the resulting hazard can be SIGNIFICANTLY different than just when using seismicity.

Epistemic Uncertainty in Estimating Slip Rates

- Recurrence rates of surface-faulting earthquakes can vary significantly through time. Using short-term and more recent versus long-term rates has clear advantages.
- Temporal clustering of earthquakes can result in large variations in recurrence rates.
- Incorporating these variations in PSHA is obviously very important.

Temporal Clustering Along the Cascadia Subduction Zone, U.S.A.



Source: Goldfinger *et al.* (2009)

Example: Lost River Fault, Idaho, U.S.A.

- For example, the recurrence intervals have varied by more than an order of magnitude during the past 100,000 to 200,000 years.
- During temporal clusters, the recurrence intervals have ranged from a few hundred to 9,000 years.
- Between clusters, the recurrence intervals ranged from 10,000 to 50,000 years.



Conclusions

- Work Package Leaders (TI) – Must capture the center, body and range of Informed Technical Community.
- Experts – Act as resource and proponent experts but in the end must perform as evaluators because in this project, the ownership of the Iberia seismic source model will be shared by both the TI and the experts.
- Participatory Peer Review Panel – Must insure that the process follows the ideas behind the SSHAC guidelines for eliciting experts and that technical issues are satisfactorily addressed and uncertainties properly accounted for.____