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April 7, 2010 Via e-mail

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Dear Mr. Salomone:

Reference: *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities:* Feedback on CEUS SSC Preliminary Model.

This letter constitutes the report of the PPRP[1] ("the Panel") providing feedback on the CEUS SSC Preliminary Model. Our feedback is based on a one-day *PPRP and USGS Briefing Meeting* ("the Briefing Meeting") held on March 24, 2010, at EPRI headquarters in Palo Alto, California, and on materials provided to us beforehand. These materials included Draft Data Summary and Data Evaluation Tables, a Hazard Input Document for the CEUS SSC Preliminary Model, and a Draft CEUS SSC Report Outline.

All eight members of the PPRP (J. P. Ake, W. J. Arabasz, W. J. Hinze, A. M. Kammerer, J. K. Kimball, D. P. Moore, M. D. Petersen, and J. C. Stepp) attended the Briefing Meeting. On the following day (March 25), all eight members of the PPRP met privately for a half day to discuss observations and plan this feedback report.

General Observations

The Briefing Meeting was well organized, the TI team members were well prepared, and the Team members' respective presentations effectively stimulated discussion, all of which resulted in a successful meeting. The atmosphere of open discussion that prevailed throughout the briefing significantly enhanced the Panel's participation. We observed, however, that several elements of the model had not reached the stage of completeness of analysis and assessment that we had expected. These will be addressed more completely by Specific Comments.[2]

We commend the Project Manager and TI Team leader for their continuing effective leadership of the Project. This leadership continues to stimulate and maintain productive interactions among TI Team members and between the Project Team and the Panel. Actions required to complete the Project identified in "Path Forward" discussed at the end of the meeting appear to be well formed and achievable. The Panel noted, however, that the actions do not include a feedback interaction following completion of the Panel's review of the Draft Project Report to be delivered on September 1, 2010. We recommend

[1] Acronyms are explained in the Appendix.
[2] As in earlier PPRP reports, recommendations are underlined for emphasis and ease of recognition.

that a process for resolving the Panel's comments and recommendations aimed at completing the Final Project Report be identified and scheduled.

Specific Comments and Recommendations

Provided below are comments and recommendations for consideration and follow-up action by the TI Team. The comments are not ranked in order of priority. We realize that this report is intended to represent the Panel's last formal opportunity to comment on the CEUS SSC Model before it moves ahead from "Preliminary" to "Final." However, because parts of the Model are still incomplete, some additional interactions between the TI Team and the Panel are desirable in the coming weeks to ensure the Panel's "buy-in" to the Final Model.

Among the diverse comments and recommendations contributed by the Panel members, two common themes will become apparent:

- Part of the Panel's responsibility in reviewing the Draft Technical Report in August will be to address the clarity and completeness of documentation of the SSC. So in this document we have included early advisories about potentially confusing terminology, missing pieces, and some expectations of what needs to be documented.
- The Master Logic Tree has progressively been contracted to characterize seismic sources in the CEUS in a way that eliminates elements that, in the judgment of the TI Team, do not contribute significantly to the resulting hazard—thus providing a simpler conceptual framework and allowing efficient computation of hazard. Where credible views of the Informed Technical Community ("ITC") do not appear to be included in the Master Logic Tree, there is a clear burden on the TI Team to address and document how those views have been considered and duly accounted for in the Model.

Because the Master Logic Tree includes major changes in characterizing earthquake potential in the CEUS, compared to past PSHAs, the Panel believes that the TI Team will need to be aggressive and pre-emptive in explaining these changes.

1. *Availability and completeness of work products for review:* The review period for the final report documentation is very short. It is critical that the PPRP be provided a complete final draft on August 2 so that Panel members can submit a set of complete and meaningful review comments. (Because of schedule constraints, some PPRP members need to begin their review immediately upon receipt of the Draft Technical Report on August 2.) In addition, the PPRP would find it beneficial to evaluate certain products that are finalized (after April 30) and at an early stage prior to the submittal of the Draft Final Project Report on August 2. Of particular interest would be the Mmax distribution and summary information used to develop the distribution for each seismic source zone (largest observed event, N, prior). Summary rate maps for individual source zones would also be useful for PPRP assessment prior to August 2.

2. *Differences Between Seismic Source Zones:* The TI Team stated that the conceptual approach used to define distributed seismic sources, specifically those defined on a seismotectonic basis, focused on four key factors: (1) earthquake recurrence rates; (2) maximum magnitude; (3) expected earthquake characteristics; and (4) tectonics. The Data Evaluation Tables provide information on some of these factors indicating some differences between seismic source zones. However, because the TI Team had not completed development of the final earthquake catalog, implementation of the approach to defining maximum magnitude and spatial smoothing of earthquake recurrence rates for each of the distributed seismic sources had not been finalized. As a result it is difficult for the PPRP to have high confidence that the preliminary seismic source characterization model captures the center, body, and range of the ITC. While some significant differences between distributed seismic sources may be anticipated (e.g., Mmax differences between Non-Extended crust relative to differences between the Illinois Basin Extended Basement (IBEB) and Mid-continent Crust seismic sources), it is not intuitive that such differences will fully support the seismotectonic zones that subdivide the Mesozoic Extended crust, and as a result the conceptual approach used to define distributed seismic sources. The PPRP had expected that the Hazard Input Document would have included information to justify the approach being used. The PPRP recommends that the TI Team provide this information for PPRP review concurrent with providing hazard input to the project's hazard analyst.

   We recommend the following with respect to maximum magnitude: (1) The TI Team should describe how paleoliquefaction evidence was used to define seismic source likelihood functions. (2) The TI Team should provide specific likelihood functions and posterior distributions for each of the Hybrid and Seismotectonic source zones, for each of the prior assumption cases considered.

   With respect to the application of the smoothed seismicity approach, we recommend that the PPRP be provided with sufficient activity rate maps for each hybrid and seismotectonic source zone (such as for M = 5) to appreciate the significance of recurrence rate differences between seismic sources.

3. *Organization of the Logic Trees:* We note that there are significant changes in the organization of the logic trees of the current CEUS SSC from previous PSHAs of the region. The Panel is generally supportive of these changes, but we recommend that the documentation of the design of the logic trees include a clear and detailed explanation of the reasoning involved in making the changes from previous studies. For example, the magnitude of the largest observed events (both historical and inferred from paleoliquefaction) is a major factor in isolating source zones for detailed characterization (the RLMEs), while regions of moderate to intense earthquake activity without moment magnitudes that exceed mid-5 values such as eastern Tennessee, northeastern Ohio, the Humboldt fault zone (Nemaha Ridge), and the Ramapo fault that have been included in earlier studies are not called out as specific seismic zones.

   Furthermore, we have the sense that some lines of evidence used by the ITC in identifying and characterizing the seismic source zones of the CEUS have not received

the attention in the current study that they have been given by some members of the ITC and in former PSHAs of the region. For example, contrary to the present study, some investigators place considerable emphasis on recent strain (GPS) measurements and others give considerable weight to tectonic features of the CEUS that have been mapped directly or indirectly in the identification and characterization of seismic source zones. The project would be well served by documented justification of the reasoning supporting minimization of these elements by the TI team in their decisions—and we recommend that the Draft Technical Report include such documentation.

Lastly, it would be helpful if the TI Team paid particular attention to, and provided an appropriate level of discussion about, areas toward which the technical community is moving. For example, the use of strain rates is an area that will likely expand in the future. So, although these data may not have had a significant impact at this time, it is important for the study documentation to fully discuss the data available and how it was treated now.

4. *Clarity of terms in the Master Logic Tree:* In labeling and discussing branches of the Master Logic Tree, clarity can be improved. The TI Team may want to consider another term for "hybrid" at the very front end of the tree. The term is a vestige from labeling a former three-branch node (now collapsed to two), and many readers would expect a hybrid branch to be a combination of two other branches. Referring to "zoneless" seismicity sources is confusing insofar as these sources lie within demarcated areas of differently affected Mesozoic crust. In general, we recommend that the TI Team examine jargon that has evolved in their internal discussions and evaluate whether terms used in their working discussions now help or hinder clear communication to others. Labeling of Iapetan Extended/Non-extended as a different case from Mesozoic Extended/Non-extended may be confusing to those unfamiliar with the arcane term "Iapetan." Labeling of "Inter-event Times" as a Recurrence Method for the RLME logic tree branches is confusing because the method used in fact involves the use of both inter-event and event-interval paleoearthquake data. In source geometry branches for RLME sources (e.g., Figures 15 and 17 in the HID), "extended trace" should be used instead of just "extended" to avoid confusion with crustal extension.

5. *Assigning Weights to the Logic Trees:* As mentioned during the Briefing Meeting, we recommend that TI Team describe the overall approach to assigning weights to the logic trees, and that this written description be included in the Draft Technical Report. In some cases these weights represent an explicit statistical assumption or distribution while in other cases these weights are the TI's evaluated judgment of the informed technical community views. In these cases it would be useful to have an understanding of how the TI assigned weights from a generic perspective.

6. *Spatial Smoothing:* Conceptually, the PPRP endorses the direction the TI team is taking with respect to spatial smoothing approach and implementation. However, thus far there has been no written documentation provided to us that: (1) describes the

method in detail as it is being applied in this project, (2) describes the bases for choices of parameters of the model, or (3) justifies reliance entirely on the penalized likelihood method. We recommend that the eventual documentation not only describe the adopted technique in detail but also document any perceived advantages of this technique relative to simpler kernel techniques. Some discussion of "floor" values in regions of very low rates should also be included. It would benefit our review to receive this section for review as soon as is practicable.

7. *ALM Area Characterization:* The TI Team presented its independent evaluation of published field data, including original field copies of trench logs and field photographs of features that Randy Cox had described in WS #2 and interpreted as liquefaction features. "Project-specific *Criteria for Identifying Earthquake-Induced Liquefaction Features Used in Development of Paleoearthquake Chronologies"* were used to perform the evaluation. Discussions during the TI Team's presentation identified that these criteria are current state of practice for determining whether observed features are earthquake-induced liquefaction features or properly explained as depositional or due to another geologic process. First, given that the criteria are identified as representing the state of practice of the informed technical community, the "project-specific" qualification is confusing and misleading. We recommend that these criteria be clarified or removed.

   Second, the Team's evaluation appears to reasonably support their conclusion that the features do not satisfy the informed community's criteria for reasonably assessing that the features are earthquake-induced. However, this evaluation appears inconsistent with the highly qualified ALM area model assessment conclusion: "the paleoliquefaction data from the ALM region are immature and highly uncertain and, at the present time, do not provide strong evidence for a source of RLME in the ALM area." This highly qualified conclusion clearly conveys a level of uncertainty that would support giving some assessed weight to an interpretation that the ALM should be modeled as a RLME. Perhaps what is meant is that the information in the current dataset, when assessed using the criteria for determining whether features are indeed liquefaction features consistent with current state of practice, does not support the interpretation that these are paleoliquefaction features. We strongly support the TI Team's decision, as stated during the discussion, to revisit and clarify this assessment—and we recommend that the TI Team do so.

   To support this last point, it would be helpful if the discussion of the criteria include not only what the specific criteria are but the scientific and technical basis of each criterion. This would support not only this assessment, but would provide a valuable tool for projects in the future when datasets are not clear, or even as new information becomes available in the ALM area.

8. *Data Summary and Evaluation Tables:* The Panel finds the Data Summary and Data Evaluation tables to be highly important in supporting and annotating the decisions regarding identification and characterization of the seismic source zones of the CEUS. Every effort should be made to include in these tables documentation for the current,

complete center, body, and range of the ITC by seeking feedback from appropriate current investigators prior to finalizing the tables. A full description is warranted of the procedures used in selecting material for the Data Summary table. Additionally, both tables are essential in reviewing the basis for, and the assessments regarding, seismic source zones—but there remains the need for a full narrative that will allow the user of the CEUS SSC Model to completely understand the data evaluations that support the assessments made by the TI Team. We recommend that the Draft Technical Report include such a full narrative for the Data Summary and Data Evaluation tables.

9. *Earthquake Model for RLME Sources:* In the Master Logic Tree, full weight is given to the maximum-moment model as the "Earthquake Model" applicable to RLME seismic sources. In the western U.S., where detailed data are available to assess earthquake behavior on major active faults, increasing attention is being given to a variable-slip model—which allows the slip, rupture location, and length to change with each earthquake (see, for example, K. Scharer, "Changing views of the San Andreas fault": *Science*, vol. 327, 26 February 2010, p. 1089–1090). To defend a weight of 1.0 for the maximum-moment model vis-à-vis the ITC, the TI Team clearly has to demonstrate (if correct) that the choice is one of simplified methodology, which considers and accounts for other credible models of earthquake behavior.

10. *"Other" Reviews of the CEUS SSC Model:* At the Briefing Meeting, the Project Manager showed tracking milestones including "Review of Draft [Technical] Report by PPRP, USGS, and Sponsor Reviewers—August 2, 2010 to September 1, 2010." It seems appropriate to call attention to the following statement in *Implementation of the SSHAC Guidelines for Level 3 and 4 PSHAs—Experience Gained from Actual Applications* (USGS Open-File Report 2009-1093, p. 35:

> The PPRP is the only legitimate review panel recognized by the SSHAC Guidelines; there is only one PPRP for a SSHAC Level 3 or 4 study, and its sole and unique obligation is to provide on-going commentary to TI/TFI as the project develops. All other "review panels" should be considered as observers, unless the project leadership agrees in advance to a different role/format for them.

The Panel recognizes the prerogative of the Project Sponsors to request comments on the Draft Technical Report from other parties of its choosing for its own purposes. However, we recommend—and believe it is essential—that any comments on the CEUS SSC Model provided to the TI Team that result from a TI Team request be made available to the PPRP for its awareness and consideration.

11. *Comments on Draft Report Outline:* We recognize that the Draft Report Outline dated March 9, 2010, is preliminary (in its present form, the outline is a mix of topical phrases and explanations of what specific subsections will contain). As such, a detailed review is premature, and we only offer some general comments (not exhaustive). We recommend that the PPRP have another opportunity to review the

Draft Report Outline after the TI Team finalizes it. This could avoid some late-stage criticisms of the content of the Draft Technical Report during our August review.

- Because the Project Report will become a legal document with the authority of a regulatory guide, clarity is essential. As examples: do not use "seismicity catalog" for "earthquake catalog"; "event" for "earthquake"; "paleoseismicity" for "paleoearthquake"; "process" for "assessment."
- In providing guidance for future applications of the CEUS SSC Model, adhere to specific terminology of "refinement" for site-specific applications and "revision" for future updates of the Model.
- In section 2.1, consider a discussion of (1) the fundamental goal of safety regulation, i.e., "reasonable assurance based on current knowledge" and (2) the role of technical regulatory guidance for reasonably assuring the goal of safety regulations has been met.
- List of Acronyms needed.
- Need Glossary of key terms (e.g., seismic source, Conceptual SSC Framework, SSC Model, etc.) It will be essential to define "Conceptual SSC Framework" and its role in the assessment process. How does it support or frame the assessment? What weight is it given?
- Labeling section 2, which deals chiefly with process, as an apparent primary "Methodology" section is misleading. Either organize explanations of technical methodology into one section or guide the reader (as in the label for section 3.3) by prominently labeling, "Methodology for _____."
- Make the outline of sections/subsections reader-friendly. For example, the number of subsections in section 4 is too large. Subsections 4.5 and 4.6 appear to be distinct from earlier parts of section 4 (general characterization of seismic sources) and can be broken out into a separate section containing descriptions of specific sources in the logic tree.
- Missing discussion of GIS database, both under section 3.2 and in the Appendices.
- Missing discussion of metadata.
- In section 6, a subsection is needed relating to consideration of new data and/or information and determining when the SSC Model requires revision (updating).
- Declustering of the earthquake catalog was undertaken using methods described in the original EPRI study documentation. Because that study is not broadly accessible, it is important that a full discussion be included in the documentation. It should be complete enough to allow for members of the technical community to understand and repeat the work.
- Section 1.2.2 is currently titled "Conducted using SSHAC Level 3 approach." This section should discuss not only how the project met the standards for a level 3, but also WHY a level 3 was conducted instead of a level 4. It may also be useful to

discuss how this decision was made and what have been the benefits and drawbacks.

- Perhaps the PPRP review documents should be included as an Appendix. The form of the final report has not been clarified; but it could be a summary letter report that has the previous comment sets as attachments.

Closing Comment

The Panel is aware that, at the request of the Project, the USGS is preparing to deliver to the TI team independent feedback on the Project Earthquake Catalog and on the draft HID focusing on completeness of datasets, models, and tools being used in the CEUS SSC assessment. Based on telephone discussions between the PPRP and the Project Team on April 5, 2010, we understand that the TI Team will evaluate the USGS comments and will consider them in its final assessment and in its development of the final HID for the Project. We further understand that the TI Team's evaluation of the USGS comments will be finalized as part of its final working meeting scheduled to be held on April 12-13, 2010, in which one or more PPRP members will participate as observers.

Note: We may choose to provide additional PPRP feedback following the April 12-13 working meeting and receipt of information relating to completion of the TI Team's evaluation of the USGS comments and any modifications the Team may make to its datasets, models, or tools as a consequence.

Please contact us if you wish to discuss any of our observations, comments, or recommendations.

Sincerely,

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Copy: PPRP Members
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APPENDIX

Acronyms

ALM	Arkansas-Louisiana-Mississippi
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
HID	Hazard Input Document
IBEB	Illinois Basin Extended Basement
ITC	Informed Technical Community
Mmax	Maximum Magnitude
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
RLME	Repeated Large Magnitude Earthquake
SSC	Seismic Source Characterization
SSHAC	Senior Seismic Hazard Analysis Committee
TI	Technical Integrator
USGS	U.S. Geological Survey