

September 25, 2009

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Subject: Response to *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities: Participatory Peer Review Report on Workshop No. 3.*, dated September 18, 2009.

Dear Carl and Walter,

Thank you for your letter summarizing the Participatory Peer Review Panel's review of Workshop No. 3 for the CEUS SSC project. The letter reflects a clear understanding of the purposes of the workshop in the context of the SSHAC Level 3 process. In the spirit of a participatory peer review process, we welcome timely, insightful, and constructive reviews and suggestions that will assist the TI team in achieving a successful conclusion. One mechanism for that interaction is this correspondence between the PPRP and the project management.

We appreciate the kind words given in the General Observations regarding the management and TI team preparations for and success of the workshop. It is heartening to know that the PPRP recognizes the considerable efforts made over the months leading up to the workshop to ensure its success. Further, the comments demonstrate that the PPRP understands the preliminary nature of the SSC sensitivity model and how WS-3 provides a starting point for the development of the SSC model.

To provide the PPRP with insights into our intentions relative to the specific recommendations made in the letter, we provide below a response to the recommendations that have been underlined in your letter to draw attention to their priority. We also value the perspectives provided in other parts of the letter and these will be given serious consideration during the course of the project activities leading up to and including the development of the project report.

1. *The Principal SSHAC Goal for a PSHA:* We appreciate Dr. Coppersmith's informative presentation of the background and context of the principal SSHAC goal for a PSHA: ***“to represent the center, the body, and the range of technical interpretations that the larger technical community would have if they were to conduct the study.”*** His description of the historical context of the treatment of uncertainties in seismic regulation practice illustrates the critical importance to safety decision making of proper treatment of uncertainty, which formed the basis for the SSHAC's evolution of this important goal as well as the process that the SSHAC defined for achieving it. The SSHAC assessment process defines roles for participants as well as process activities that when properly implemented provide reasonable assurance that the goal for a PSHA established by the SSHAC is achieved. Based on Dr. Coppersmith's presentation and the follow-on discussions during the workshop, we concur that the assessment process activities being implemented for the CEUS SSC Project satisfy

the SSHAC guidance. We recommend that this important presentation be developed in the form of a white paper suitable for inclusion as a section in the project final report and that the white paper be distributed among the project participants, including the PPRP and sponsor technical representatives, for early review.

Dr. Coppersmith's presentation was developed in response to the PPRP's previous suggestion that the conceptual framework for the SSC evaluation process be documented. As such, the TI team plans to include the discussion in the project report. The PPRP will have ample opportunity for review of the draft project report.

2. *USGS Open-File Report on Maximum Magnitude:* Although briefly mentioned during the workshop, it was not clear to us how the soon-to-be issued USGS Open-File Report on estimation of maximum magnitude for seismic sources in the CEUS will be considered by the TI Team. We recommend that the report be considered as part of the information base for assessment of the CEUS SSC model.

Several members of the TI team were in attendance at the workshop and the report has been available in draft form—along with a transcript of the meeting—for the use of the TI team. The recommendation to include the report as part of the information base is accepted.

3. *CEUS Earthquake Catalog:* The development and attendant analyses of the updated CEUS Earthquake Catalog are important contributions of the CEUS SSC Project that could potentially have high value for use in future PSHAs. The work summarized by Dr. Youngs on the catalog reflects a tremendous amount of work and represents a significant advancement in this important hazard data base. In order to be assured of the catalog's continuing high value, arrangements should be made to continually maintain this consensus catalog, and the analyses should be periodically updated as warranted by the addition of new data. Because multiple agencies and organizations will use the SSC Model, we recommend that the Project suggest a plan for keeping the CEUS Earthquake Catalog current into the future as a companion product for use of the SSC Model.

We agree that the CEUS Earthquake Catalog will be a significant product developed as part of the CEUS SSC project. It is envisioned that the project report will include a section devoted to recommendations for the future implementation of the products of the study. This discussion will include recommendations regarding plans for keeping the catalog current into the future.

4. *Comments on Smoothing:*

- We consider the alternative procedures for smoothing seismicity that were presented and discussed during the workshop to be valuable tools for the TI Team to use to express uncertainty in its tectonic-based assessments of the spatial variation of seismicity. Accordingly, we recommend that the use of these tools (i.e., the choice of smoothing method, the use of anisotropic kernels, priors on parameters, and so on) be justified in terms of the Team's evaluations of tectonic processes governing earthquake occurrence.

It is agreed that the justifications for the choice of smoothing tools should be made in terms of tectonic and other technical arguments. For example, if an adaptive kernel is used that varies the

smoothing distance as a function of data density, the technical basis for the use of such a kernel will be documented in terms of the expected future spatial distribution of seismicity.

6. *Data Summary Table and Data Evaluation Table:* The **Data Summary Table** appears to be a highly valuable means of documenting the current range of the larger technical community's technical interpretations. We believe that the **Data Evaluation Table** also is an important part of the documentation of the CEUS SSC assessment that can serve the important need for transparent documentation of the TI Team's evaluations supporting its assessments of the center and body of uncertainty in the larger technical community's technical interpretations. The **Data Evaluation Table** also is potentially useful as a record of lessons learned and as such will be valuable in considering the need for and planning future investigations of the CEUS. This includes not only the utility of the various data most important in the SSC assessment, but also the nature and quality of data which imposed limitations on their use in identification and characterization of the seismic source zones. A summary of the various documents, their contents, and relationships would likely prove helpful and increase clarity for future implementation of the SSC Model. We recommend that the Project and TI Teams give careful consideration to these important potential uses of the **Data Evaluation Table** as the assessment goes forward.

It is agreed that the data evaluation and data summary tables provide a valuable means of documenting the use and considerations of data made by the TI team. In the project report, the tables will supplement the detailed discussions of the technical bases for the SSC model (i.e., documentation of the bases for the branches and weights on the final logic trees). The TI team will give due consideration to the potential uses for the tables given in the PPRP comment.

7. *Sensitivity studies:* We consider the sensitivity studies to be highly valuable for providing insights and gaining understanding of the sensitivity of PSHA at a specific site to various elements of the SSC model. Additional sensitivity studies at a range of distances from the sources of frequent large earthquakes could add value for future use of the SSC model. However, we recommend that the sensitivity studies not be used to justify devoting a reduced effort to assessing any fundamental element of the SSC model. (See also Comment 11.)

See response to Comment 11.

8. *Lack of Consideration of Focal Depths:* There was a lack of discussion of earthquake focal depths in the workshop presentation on the updated CEUS seismicity catalog. This omission should be rectified. Because focal depth is a potentially important contributor to our knowledge of seismic hazards, useful in characterizing and defining the limits of seismic source zones, and helpful in assessing potential ground motion, we recommend that greater consideration be made of this parameter in the CEUS SSC.

We agree that seismic sources are three-dimensional and the vertical dimension is to a large extent constrained by the depth of earthquake hypocenters. The accuracy of focal depths varies

considerably throughout the study region. The project report will include a discussion of earthquake focal depths and their use in characterizing seismic sources for the CEUS SSC project.

9. *Plan for use of gravity and magnetic data.* Gravity and magnetic anomaly data and a variety of maps processed from these data are important in mapping largely hidden geological structures of the CEUS that may be useful in identifying seismic source zones and their geographic boundaries. We note that the contract for preparing the gravity anomaly data and associated maps has been let to the University of Oklahoma, but the contract has not been executed for preparing and processing the magnetic anomaly data. Furthermore, the Expanded Schedule for the CEUS project (7/14/09) set the completion date for both of these contracts as October 30, 2009, which we learned at WS-3 has now been delayed until December 31, 2009. Despite the lack of the products from these contracts, the work of the TI team including the identification and delimiting of source zones must continue. As a result, we recommend that after December 31, 2009, once the new data sets and maps are available, a thorough review be conducted of decisions on identification and bounding of source zones that were reached prior to the availability of the gravity and magnetic anomaly data and related maps. This review may lead to modification of previous decisions.

The TI team will plan to carry out such a review once the gravity and magnetic data are available.

10. *Preliminary Seismic Source Zones:* The seismic source zones used for the sensitivity evaluations and discussions during WS-3 are still tentative, but a cursory review of these zones raises several concerns:

- Where the evidence for the identified seismic source zones and their geographic limits are not described in referenced publications, we recommend that a comprehensive description be provided for the basis underlying the assessments of the source zones and their boundaries.

Descriptions of the bases for all seismic sources will be provided in the project report.

- It is unclear why certain regions were selected as “zones of elevated seismicity.” What is their role? Why was the Clarendon-Linden region identified but not southeastern New York, the Niagara Peninsula, and other CEUS regions of above normal seismicity in the historical record? We recommend that definitive criteria be cited for the selection of elevated seismicity zones.

Zones of elevated seismicity were identified as a means of organizing the data summary tables. That is, the historical literature refers to several seismicity zones (e.g., Central Virginia, eastern Tennessee, Charlevoix) and we use this terminology to assist the reader of the data summary tables in recognizing the geographic distribution used in the literature. In most cases, zones of elevated seismicity—without a clear RLME source—are handled in the SSC model by the use of spatial smoothing. A complete discussion of the manner in which observed seismicity is used in the SSC model will be included in the project report.

- Earlier at Workshop No. 2, a scheduled presentation by Nano Seeber on seismicity and faulting in Ohio, Pennsylvania, New York State, and New York City was canceled and no similar presentation on this topic was made. Has anything been done to fill this void in the consideration and treatment of alternative interpretations? For example, a 2008 paper by Sykes and others<sup>4</sup> suggests an alternative view of seismicity in the New York City area that has not been cited in the Data Summary Table. We recommend that the list of alternative interpretations be updated to include those pertaining to the region that was to be discussed by Dr. Seeber at WS-2.

We appreciate the PPRP providing recommended literature and databases that the TI team should include in its considerations; hence, we welcome the suggestions for inclusion of the cited paper. Despite Dr. Seeber's cancellation of his participation at WS-2 due to illness, the TI team is aware of his models and will ensure that his publications are included in the associated data tables. In addition, representatives from the TI team will be attending the upcoming Eastern Section of the Seismological Society of America and the associated field trip led by Dr. Seeber.

- There may be an inconsistency in the way that "extended zones" are used in the identification of seismic source zones. The area of the extended zone with normal faulting associated with the Iapetan Rift Margin is moved hundreds of kilometers west into the stable craton from the mapped rift margin. However, the limits of the seismic source zone associated with Iapetan (Cambrian) rifting in the midcontinent, including the New Madrid Rift Zone and its extensions, appear to be limited to mapped grabens without consideration of a bordering extended zone. Of particular note is the lack of an extended zone associated with the Grayville graben in southern Indiana. The "wide" interpretation of the seismic source zones is a step in the correct direction, but without further documentation on the factors defining the boundaries of this interpretation, it is difficult to determine if the broader extended zone is being captured in this interpretation. We recommend that the TI Team consider the possibility of an "extended zone" marginal to midcontinent seismic source zones.

The TI team will reexamine the technical bases for defining the extended/non-extended boundary, relative to its potential influence on establishing a *prior* distribution on Mmax consistent with the way that extended/non-extended SCR crust has been subdivided elsewhere. Further, the technical bases for the alternative locations of the boundary will be documented in the project report as a means of expressing the epistemic uncertainty.

*11. Pruning the Logic Tree and Need for Complete, Clear Documentation.* The use of an initial sensitivity model to inform evaluations to support the final model assessments is a sound and efficient approach. However, care must be taken to fully and clearly document the results of the sensitivity study, particularly as it impacts development of the final model and particularly in cases where alternative branches are removed. In a SSHAC level-3 study, the degree of credibility that the technical community grants the final model may be based heavily on the clarity and completeness of documentation and the ability of the technical community to understand the basis of assessments made by the TI team. In addition, robust

documentation can more easily allow for the incorporation of new data and site-specific information into the model. In fact, specific guidance on how new or site-specific data should be evaluated could prove very valuable to the practitioner.

The final model must represent the range of legitimate interpretations of the informed technical community in a scientifically defensible way. While some pruning of the tree based on the sensitivity study is desirable, we recommend that the sensitivity study not be used to trim branches that represented significant concepts or alternate hypotheses, even if the inclusion of alternate branches does not impact hazard. Some computational efficiencies could possibly be gained for the future hazard analyst if the study provides specific guidance as to the distance from the more significant sources at which the source no longer impacts hazard, and can be trimmed from the model.

The TI team is aware of the need to show that all potentially significant hypotheses have been considered in the course of the evaluations. We are also aware that some hypotheses—although subject to debate within the technical community—may have relatively little significance to hazard at the annual frequencies of interest. Likewise, certain technical issues will have a profound effect on hazard (e.g., those related to rate) and should be given priority in the development of the preliminary SSC model. In this spirit, the feedback gained from the analyses conducted for WS-3 and the follow-on analyses that were identified during the workshop will serve as a means to prioritize the subsequent efforts by the TI team as we move forward. This certainly does not mean that “significant concepts or hypotheses” will be “trimmed from the tree.” However, first priority will be given to the concepts and hypotheses that matter most to hazard. Whether or not the concepts and hypotheses are actually included in the logic trees, evidence that they have been fully considered and evaluated will be included in the project documentation. In addition, consideration will be given to including specific guidance for site-specific application of the SSC model relative to the distances and sources that may need to be included. This guidance would be part of the site-specific implementation guidance anticipated for inclusion in the project report.

*13. Sanity Check for Seismic Sources Defined by Paleoliquefaction: We recommend that the TI Team make a sanity check for those seismic sources defined by paleoliquefaction—that is, whether the source boundaries make sense, given the assumed magnitude versus area (or length) using relationships between magnitude and the maximum distance to liquefaction. For example, the magnitude-versus-area relationship for the CEUS results in an assumed rupture length of ~21 km for M = 6.7. For the currently defined Charleston source options, can ruptures at the far ends of the source (e.g., the southeastern or northwestern corners of the large zone shown on Figure 15 in the HID) explain the observed paleoliquefaction at the opposite end of the source? The TI Team may need to factor in how they are modeling the recurrence of the source relative to the paleoliquefaction—but they need to make sure that the sources for the paleoliquefaction regions do not become too large when considering how rupture length is being modeled relative to paleoliquefaction.*

The TI team will plan to conduct such sanity checks during the development of the preliminary SSC model.

15. *Need for Uniform Rigor in Assessing Rate-Information Inputs.* Examination of the SSC Sensitivity Model shows an apparent unevenness in rigor applied to assessing rate-information inputs in terms of significant figures and assessed distributions. This stands in contrast to the systematic rigor applied, say, to recurrence modeling. Because of the fundamental importance of rate information to hazard, we recommend careful uniform attention to the assessment of rate inputs. Such assessments should meet the basic expectations of a normative expert in a PSHA if one were overseeing the assessments.

The TI team agrees with the comment and will provide uniform attention to the assessment of rate inputs across the entire SSC model.

16. *PPRP Observers in Remaining Working Meetings.* Under the CEUS SSC Project Expanded Schedule (dated July 14, 2009), the next face-to-face meeting of the PPRP with the TI Team will be in March 2010. Because this will be at a relatively late stage of shaping a near-final (albeit still “preliminary”) SSC model, we recommend that the Project Manager facilitate participation of at least two PPRP members as observers in the TI Team’s Working Meeting #6 (October 20–21, 2009) and Working Meeting #7 (January 12–13, 2010).

We agree with the comment and encourage participation by members of the PPRP at the upcoming working meetings.

Thanks again for your insightful review comments, and we are convinced that they will assist us in developing a better product. If you have any questions regarding this letter, please feel free to contact us.

Sincerely,

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