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Review of Electric Power Research Institute Report "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities" # 1016756, draft July 31, 2010., R.P. Kassawara and J.F. Hamel,

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For Dr. Stephen McDuffie
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Proposed mission and purpose of the subject report:

The Executive Summary and Introduction of the subject report states that the mission and purpose of the report is to provide a regional seismic source model for use in probabilistic seismic hazard analyses (PSHAs) for high hazard NRC and DOE regulated nuclear facilities in the central and eastern United States (CEUS). The intention of this study is to replace previous regional seismic source models conducted for this purpose, including the Electric Power Research Institute-Seismicity Owners Group (EPRI-SOG) model (EPRI, 1986, 1989) and the Lawrence Livermore National Laboratory (LLNL) model (Bernreuter et al., 1989, 1991). The report states that the study was conducted using Senior Seismic Hazard Analysis Committee (SSHAC) Study Level 3 methodology (Budnitz et al., 1997) in order to provide high levels of confidence that uncertainties had been considered and that the center, body, and range of views of the informed technical community have been captured and represented. The report notes that the regional seismic source characterization (SSC) model can be used for site-specific PSHAs, provided that "appropriate site-specific assessments are conducted as required by current regulations with the focus provided by regulatory guidance." "The current recommended ground motion models for use at nuclear facilities are those developed by EPRI (2004, 2006)."

Scope of Review:

This review was conducted for the DOE and consequently is focused on SSC model impacts, sensitivities and uncertainties that may impact DOE facilities and existing and planned nuclear power plants. Because the development of the SSC model was conducted as a SSHAC Level 3 study and is likely to replace other existing regional hazard studies for these applications (e.g., EPRI-SOG, LLNL, and the USGS National Map model (USGSNM)), another area of review is the SSHAC process that was followed. This review did not include checking of mathematical formulations or calculations contained in the report and did not focus on editorial changes or recommendations except as otherwise noted. This reviewer is familiar with tectonic issues relative to hazards in the southeastern United States (SEUS). Although the documentation for all of the RLMEs appears to be thorough and complete, the DOE should consider additional careful review of the non-Charleston RLME models documented in this study on a facility specific or local geographic basis. This additional review could be completed on an as-needed basis in the course of a DOE site-specific investigation.

Comments relative to the seismic hazard for specific DOE facilities in the CEUS is important for a review for the DOE, but unfortunately those results were not contained is the report and were not available for comparison or review.

General Comments:

This is a timely and critically important study that will likely impact critical facility development for many years. The documentation, especially the methodology is generally well written and thorough. The three workshops were held with a wealth of expert breadth and participation and appear to be well documented. The selected staff, TI team and PPRP members assigned to complete this study are likely the most experienced team that could have been assembled for the task. The DOE should make every effort to see that this study is vetted and receives the support of the scientific and engineering community.

SSHAC Methodology:

The report states (Section 2.1.2.3) that "Based on the evidence presented in this report (Section 2.1), each of the methodology steps in the SSHAC guidelines was addressed adequately on the CEUS SSC Project… It is therefore concluded that the current standards of practice have been met for a SSHAC Study Level 3 process-both those that are documented in the SSHAC report and those that resulted from precedents set by projects conducted since the SSHAC report was issued. Accordingly, it is concluded that the preponderance of evidence provides reasonable assurance that the center, body, and range of views of the informed technical community have been captured and represented in the CEUS SSC final model."

As cited in Section 2, many of the requirements for a SSHAC Level 3 study have been completed in this report. However, there appears to be important aspects of the SSHAC Level 3 requirements that are missing, or were inadequate to complete a SSHAC Level 3 study. These omissions may need to be corrected to achieve the very important and community-wide endorsement that it was conducted as a SSHAC Level 3 process according to Budnitz et al., 1997.

The SSHAC report (Budnitz et al., 1997) points out that "expert buy-in" on technical issues does not apply directly as in the Technical Facilitator/Integrator (TFI) approach, however SSHAC states that "expert buy in" does apply indirectly. "Specifically, if the TI develops a controversial interpretation that represents an integration of diverse technical views of differing experts, it is very important that an attempt be made to obtain the views of the specified advocates of the various technical positions involved. The peer reviewers can verify that this contact has been fulfilled and that the various interpretations are properly represented. In SSHAC's opinion, if these experts can "buy into" the process that the TI has used to integrate the different views, the credibility of the ultimate result of the TI's effort will be significantly strengthened." There are many controversial developments made in the study, including the background rate model, the exclusion of the fixed b-value and kernel approach, and the development of RLME models. Therefore expert buy-in is critical to acceptance of this study as a SSHAC Level 3 process.

More specifically, under Section 2.1.2.2 Evidence that CEUS SSC Project Has Captured the Informed Technical Community. Item #6, page 2-20 states: "Conduct Sensitivity Analyses and Submit Feedback to Experts. " "The feedback results from the Sensitivity SSC model were presented at workshop #3- Feedback (Appendix F), where conclusions were drawn regarding the most important contributors to the mean hazard at seven demonstration sites throughout the study region. This information provided a basis for focusing the subsequent effort on significant issues." The next paragraph goes on to note that expert feedback was sought and provided to the PPRP. Note that expert feedback is not required for a SSHAC Level 3 assessment; however, it is strongly recommended by SSHAC for controversial issues. Appendix F indicates that there was hazard model and weight "buy-in' from the proponent model experts on sensitive or critical issues related to the hazard feedback. This process was completed on earlier regional studies, such as the update of the LLNL (1990) PSHA and USGS National Map workshops conducted over the last 10 years, and is a very positive attribute of this study. However, there were inadequate data necessary for the TI, experts and the PPRP to make hazard informed decisions. The inadequate data includes gridded mean and fractile hazard as discussed below.

In the SSHAC report Table 7-1 "List and Description of Standard PSHA Results", required results include: (a) Fractile and Mean Hazard Curves; and (b) Uniform

Hazard Response Spectra. Optional results include: ground motion contour maps. These SSHAC requirements and recommendations apply to facility applications; however, the overall purpose of the requirements is to allow the developer and user to make informed decisions on the technical basis, sensitivities, uncertainties and weights used in the PSHA. Therefore, these SSHAC requirements and recommendations apply to this study.

There is no documentation that this study included computation of fractile hazard, uniform hazard spectra or hazard deaggregations (M, R, ε) for the TI, experts or the PPRP for the purposes of sensitivity analysis for the seven illustration sites. More critically, there is no documentation that mean and fractile hazard contour or gridded hazard analysis or maps were prepared for sensitivity analysis by the TI, experts, or the PPRP. Gridded hazard, when incorporated in sensitivity analyses, provides essential critical information required to understand model sensitivities for a regional hazard study. Mean hazard was computed for seven illustration sites, however the necessary computational results to make hazard informed decisions (gridded mean and fractile hazard) were not provided to the TI team, proponents/experts and the PPRP to adequately perform their assignments. Consequently, from a SSHAC perspective, this study needs significant additional work before the community, users and owners can confidently accept that the study was conducted as a SSHAC Level 3 study.

A cost effective approach of this regional SSC was to combine regulatory accepted COLA models into one CEUS model with expert and topical workshops for a TI to incorporate expert opinions to achieve the body center and range of the informed technical community. However, for a model of this importance, the critical missing supporting data necessary to make hazard-informed judgments related to background seismicity and RLME source geometries (and development of corresponding model weights) are of such importance that the report should be revisited and revised prior to this study being used.

Because gridded hazard is necessary for both development of the SSC model and is useful for potential applications of the study, it is not sufficient that gridded hazard be developed as a follow-on to this study but rather that the process of model development, weight selection and user buy-in should be revisited with gridded and fractile hazard made available to the TI, experts and PPRP to complete the study.

Regional vs Site-Specific

There are several areas in the report, including the Executive Summary that appropriately note that the source characterization is regional in nature and not site-specific. The course of action needed for a user to develop a site-specific PSHA is only weakly touched on (see specific comments below) and is generally stated as "The regional seismic source characterization (SSC) model defined by this study can be used for site-specific PSHAs, provided that appropriate site-specific assessments are conducted as required by current regulations with the focus provided by regulatory guidance." This sentence underemphasizes an important and potentially costly caveat that is not adequately treated in the Executive Summary or elsewhere in the report. To make the study site-specific requires an intensive investigation of potential seismic sources within 40-km of the critical facility, an evaluation of potential impacts and possible incorporation of additional sources in the hazard evaluation. This application caveat should be made very clear in the Executive Summary. The report should then state very clearly the necessary steps that the user can be expected to take in order to make a site-specific assessment. These steps should be enumerated in the Executive Summary and Introduction.

Chapter 9 of the report contains a section on the necessary studies for site specific application of the study. This Chapter 9 section consists of only two sentences. The necessary studies for a site-specific application of the SSC model are described: "local geologic and tectonic interpretations, topographic data, geophysical data, historical seismicity data, micro-seismicity data, paleoseismic studies, and any other data, interpretations, or investigations that might indicate local seismic sources that could affect the site." This discussion should be expanded so that potential users of the study can clearly understand the steps necessary to meet regulatory requirements. The Executive Summary and Conclusions should also summarize and reference this revised section of the report.

Selected Sites for Hazard Evaluation

Mean hazard is computed for seven sites (Topeka, Kansas, Central Illinois, Houston, Texas, Jackson, Mississippi, Chattanooga, Tennessee, Savannah, Georgia, and Manchester, New Hampshire) using the EPRI (2004, 2006) GMPEs. According to the report, the purpose of the hazard evaluation for the seven sites was for (1) "illustration"; (2) "evaluating the significance of various SSC issues and providing that information as feedback to the TI Team"; and (3) for "comparison with other hazard studies." There was no documentation of other hazard assessments or gridded hazard evaluations conducted for this study, other than the seven hazard assessment locations. The documented hazard assessments are inadequate to assess the impacts of the new model or compare to other hazard results including EPRI-SOG, LLNL and the USGS National Map (USGSNM) at sites of interest to the DOE or NRC.

Because gridded hazard comparisons are not available for review, DOE, utility and other potential users will not understand the ramifications of the SSC-related hazard unless a site-specific evaluation and related sensitivity studies are completed. DOE and the NRC could complete this portion of the study as a follow-on of the report.

Report and Associated Documentation

Much of the report was very well written. Many of the early chapters appear to be carefully crafted, while later chapters appear hastily prepared. Many of the figures and text describing the figures are missing in these later chapters. The documentation and discussion of the RLMEs and Mmax zones appears to be carefully written and well organized. The expert/reference/database appears thorough. The appendices are concise, and except where noted, are well prepared.

The Hazard Input Model (HIM) is reported to be a publically available model/data although digital files are not available for this review. A publicly available HIM is an excellent idea and will immensely improve communication of the hazard models.

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CEUS SSC Longevity

There are a number of instances in the report that mention the expected longevity of the study: “It is expected that the longevity for studies such as the CEUS SSC Project will be at least 10 years before there will be a need for a significant revision.” Rather than presume such an optimistic assessment, why not develop an annual or semi-annual review mechanism for updating the study? The report should be expanded on this topic to include an annual or bi-annual review mechanism so that the SSC database can be reviewed and updated on a regular basis.

CEUS SSC Earthquake Catalog

There were considerable resources expended in updating the CEUS earthquake catalog. The report should document the differences between the updated catalog and other catalogs currently used such as the National Map earthquake database. It is a simple matter to identify missing or duplicate events and illustrate differences in magnitude completeness and magnitude bias. This effort would add considerably to the report and provide insights to the user on the stability of earthquake catalogs.

Spatial b- and a-Value Determinations

The penalized-likelihood approach was developed in this study for the purpose of developing spatial a- and b-value models for background seismicity. Based on the limited comparisons available in Chapter 6 and 7, there appears to be a consistent and significant bias between observed and modeled rates of seismicity, especially for the larger magnitudes (Mw>4). This bias is noted in the report in both chapters: “This is the result of deviations of the data from the exponential magnitude distribution.” It appears that the model predictions for Mw 6 and greater range from 2-6 times the observed mean rates. Also, the rate predictions appear to be too tight as compared to the uncertainty of the data. The “full” and “reduced” magnitude weight rate predictions seem to heavily favor the more numerous lower magnitude earthquakes. The net result seems to be rate predictions that consistently exceed observed data at earthquake magnitudes that drive hazard predictions. A consistent under-prediction of b-values could lead to this result. It appears that the average b-value developed in the model is near 0.8 while the National Map model uses 0.95. A biased-low b-value can result in substantially higher and biased mean hazard. Besides the apparent bias in rates and b-values, the penalized-likelihood approach resulted in disappointingly low variability in both a- and b-values.

The zone seismic activity rates indicate that all zones with the exceptions of GHEX, IBEB, OKA and SLR indicate higher predicted rates and lower b-values than suggested from the observed earthquake data. This apparent bias should be resolved by the project and then reviewed before use is made of the study.

Consideration of Constant b-value Kernel Approaches

Although there is some discussion for the rationale of why the constant b-value approaches are not used, there is no definitive documentation of why the constant b-value approach is not credible when a substantial number of the informed technical community uses the constant b-value approach. This decision seems at odds with the SSHAC approach. Also, fully weighting a relatively new and unpublished approach (the penalized-likelihood approach) without direct comparisons of rates and b-values used in other state of practice seismic source characterizations seems contrary to a conservative practice. If the constant b-value approach has no credibility, the report should document that.

Specific Comments

Executive Summary:

1. Page v, 1st par. Spell out clearly what is meant by “regional seismic source model” as it is critical to the summary
2. Page v, 2nd par., 1st sentence. States “The regional seismic source characterization (SSC) model defined by this study can be used for site-specific PSHAs, provided that appropriate site-specific assessments are conducted as required by current regulations with the focus provided by regulatory guidance.” This sentence glosses over an

important and potentially costly caveat that is not adequately treated in the Executive Summary or elsewhere in the report. To make the study site-specific requires an intensive investigation of potential seismic sources within 40-km of the critical facility, an evaluation of potential impacts and possible incorporation of additional sources in the hazard evaluation. This should be made very clear in the ES,

3. Page ix, 2nd par. Evaluation of the mean PGA and 1-hz hazard at seven demonstration sites for the purposes of "demonstration" are not adequate for purposes of application to DOE sites and likely potential reactor sites. This issue is discussed above in the context of how the TI made hazard informed judgments of the RLMEs, usefulness for reviewers and usefulness for utility and the DOE.

4. Page ix, last par. Discussion of level of precision in seismic hazard estimates seems to be void of consideration of the uncertainty in the hazard as depicted by fractiles. Should the discussion center on precision or accuracy?

5. Page ix, last par. Discussion of level of precision in seismic hazard estimates. "Based on the precision model evaluated, if an alternative assumption or parameter is used in a seismic hazard study, and it potentially changes the calculated hazard (annual frequency of exceedence) by less than 25 percent for ground motions with hazards in the range 10-4 to 10-6, that potential change is within the level of precision with which one can calculate seismic hazard." This assessment is made without the availability of fractile hazard nor source deaggregation evaluation at the seven evaluation sites.

Sponsors' Perspectives

1. This reviewer agrees with the specific benefits that a new and vetted SSC model would have.

Chapter 1:

1. Page 1-1, 1st sentence. Be consistent with terminology, change "…a full regional seismic …" to "…a regional seismic …".

2. Page 1-1, second paragraph. "The regional SSC model provided by this study can be used for site-specific PSHAs, provided that the appropriate site-specific refinements-as provided by current regulations and regulatory guidance- are applied." This caveat is provided here and elsewhere in the report and with only one exception, without any discussion of what the caveat entails. The report should state very clearly the necessary steps that the utility or DOE site can be expected to take in order to make a site-specific assessment. These steps should be enumerated in the 1) Executive Summary; 2) Introduction; and 3) Conclusions.

3. Page 1-3, 3rd par. The model will certainty be useful to the utilities and the DOE, however the CEUS SSC report falls short of providing even preliminary hazard results in the vicinity of these facilities using EPRI GMPEs.

4. Page 1-4, 1st par. This paragraph states that the National Map "are focused on AEFs in the range of 10-2 to 10-3/yr…" while this study focuses on the range of 10-4 to 10-6/y. The National Map is a regional study that can be applied to building code requirements using site-specific corrections. The National Map has been previously

applied to DOE PC-3 facilities, has been thoroughly documented, and reviewed in public meetings with expert feedback as input on controversial issues. This section could be simply reworded to something like “The National Map is not intended to be used for nuclear power plants”.

5. Page 1-6, last sentence of Section 1.2.3. “It is expected that the longevity for studies such as the CEUS SSC Project will be at least 10 years before there will be a need for a significant revision.” Rather than presume such an optimistic assessment, why not develop an annual or semi-annual review mechanism for updating?
6. Page 1-10, Section 1.4.4.1. These summaries contribute nicely to the documentation of the report and set the standard for reference documentation for future SSHAC Level 3 studies.
7. Page 1-10, Section 1.4.4.2. The geologic, geophysical and seismological database that will be available on a public website is an excellent idea and will be extremely helpful to future CEUS updates.
8. Page 1-11, Section 1.4.4.4, 1st sentence. Delete phrases like “emerging use” with regard to paleoseismic data as it has had profound impact on EUS seismic hazard since the early 1990s.
9. Page 1-11, Section 1.4.4.5. This section clearly states that the results of this study are not a CEUS PSHA but the source portion of that evaluation. Further, hazard is computed for seven sites using the EPRI (2004, 2006) GMPEs (Topeka, Kansas, Central Illinois, Houston, Texas, Jackson, Mississippi, Chattanooga, Tennessee, Savannah, Georgia, and Manchester, New Hampshire). According to this section, the purpose of the hazard evaluation for the seven sites was for (1) “illustration”; (2) “evaluating the significance of various SSC issues and providing that information as feedback to the TI Team”; and (3) for “comparison with other hazard studies.” Item (1) was achieved, but (2) and (3) were not adequate for the TI or the experts.

Chapter 2:

1. This chapter provides a very nice historical perspective on implementation and development of the SSHAC process.
2. Page 2-38, 2nd par., last sentence. “No new data were collected…as part of the CEUS SSC Project.” This is an important point and should also be mentioned in the Executive Summary and Introduction.
3. Page 2-38, last sentence under 2.4.2 Identification of Significant Issues. “…throughout the project an effort was made to keep the project ”hazard informed” in the sense that highest priority would be given to the issues having the most significance to the hazard results.” See general comment above.
4. Page 2-43, 4th paragraph. “It was concluded that that the calculated overall level of precision in mean hazard estimates corresponds to a precision in ground motion of +- 8 percent.” This precision estimate is stated in terms of hazard in other parts of the report…
5. Page 2-43, last par. I have been unable to locate Workshop #3 CD or its contents on the EPRI website.

Chapter 3:

1. Where is the SSC update catalog compared to say the USGS NM catalog?
2. How do the number of earthquakes and final magnitudes compare to other catalogs? This would seem to be an easy comparison and I cannot find it in the documentation. For example, how many earthquakes are missing or double counted in the old vs new catalog and how do the magnitudes compare?

Chapter 4:

1. This chapter provides a useful and thoughtful introduction to the analysis.
2. Chapter 4, page 4-1. This section states that nearly all PSHAs developed for nuclear facilities in the CEUS have been conducted by members of the TI Team. This is a positive and necessary attribute in the sense that the TI has experience and knowledge of the issues and has knowledge of NRC accepted COLAs. Thus the COLA proponents were well represented. How were other model proponents incorporated in the assessments? There is certain worth in developing SSC models that are in line with COLAs, however the goals of the program seemed higher in that the SSHAC Level 3 effort would capture the body and range of the informed technical community.
3. Section 4.3 Methodology of Identifying Seismic Sources, page 4-9. Criteria for regional vs. site-specific is defined. “Sources within 40 km (RG 1.208) are too site-specific to be included on systematic basis in the CEUS SSC source model”. “A more reasonable criterion that was applied…the CEUS SSC model provides the regional characterization of sources on a consistent basis throughout the study region, including those special areas that have been the subject of considerable scrutiny in the past. Consideration of site-specific refinement of the CEUS SSC model would be required by current regulatory guidance and would occur only if such refinement would lead to significant differences in the hazard.” This criterion is appropriate and acceptable and should be clearly identified in the first sections of the report.
4. Page 4-8 and 4-9, Section 4.3 Methodology for Identifying Seismic Sources, last sentence: “The CEUS model provide the regional characterization of sources on a consistent basis throughout the study region, including those special areas that have been the subject of considerable scrutiny in the past. Consideration of site-specific refinement of the CEUS SSC model would be required by current regulatory guidance and would occur only if such refinement would lead to significant differences in the hazard.” Earlier in the same paragraph, ”Clearly, local tectonic features that lie entirely within the 8 km (5 mi.) radius site area, and likely the 40 km (25 mi.) radius site vicinity, as defined in RG 1.208, would be too site-specific to be included on a systematic basis in the CEUS SSC source model.” These words may be also appropriate in the Executive Summary and Conclusions.
5. Page 4-9 through 4-11, under Hazard-Informed Approach, specifically, page 4-11, 2nd par.: “To further identify and understand the issues of most hazard significance, seismic hazard calculations were conducted using the SSC sensitivity model prior to Workshop #3 for a review of sensitivity cases. The issues identified as having the most hazard significance were as follows:”. There are an inadequate number of site hazard evaluations to make a hazard informed opinion of on source geometry

sensitivities for RLMEs, source geometries and smoothing for moderate magnitude sources and smoothing and probability of activity for background sources.
6. Page 4-18, 3rd sentence. Table 4.4.1.1-3 should be Table 4-6.
7. Page 4-19, 4th sentence. The reference to the next 50-yr engineering application seems irrelevant to source characterization.
8. Page 4-22, 3rd par. Figures 4.4.1.3-6 and 7 are missing from the report.
9. Page 4-22, 3rd and 4th par. Discussion for second node in Figure 4.4.1.3-1 "Rough Creek Graben Association" is missing.

Chapter 5:

1. page 5-3, 3rd par. Why is it tempting to apply non-Poissonian models to non-RLME sources? This paragraph is confusing. Excluding RLMEs, what seismic data support non-Poisonian models?
2. page 5-6, "approaches to Mmax estimation…". Consideration and weighting of both the Bayesian and Kijko approaches to Mmax seems appropriate, but where are the comparisons? There would be an expected difference in how the prior distributions are handled but what are these differences?
3. Page 5-10, reference to Appendix K. It would be helpful to incorporate global maps w/ SCR identified to describe contents of this appendix.
4. Page 5-18, 3rd paragraph. Please provide additional explanation of why the Kijko approach results in a zero weight for the NAP case? I'm confused with what is going on with the magnitude distributions in this case.
5. Page 5-19, Section 5.3 Earthquake Recurrence Assessment. This section is difficult to follow. Because the methodology has not been published the section may benefit from additional graphics or flow charts.
6. Page 5-29, next to last paragraph. Why is the prior b-value (0.81) and spatially determined b-values appear to be so low as compared to b-values used in other studies (0.85-0.95)? Why so different from fixed b-value models such as the USGS National Map?
7. Page 5-30, 2nd and 3rd paragraphs. Explain why the new recurrence formulation results in apparently wildly differing variability on ν (both higher and lower) as compared to EPRI/SOG while variability is larger in β and also exhibits a bias as compared to EPRI/SOG.
8. Page 5-30, 4th and 5th paragraphs. The provided perspective plots in Figures 5.3.2-6 through 9 are not adequate to read a- or b-values. I recommend that contour plots be provided for both parameters and these be provided for each source zone.
9. Page 5-30. A comparison of average a and b-values rates for each of the zones as compared to EPRI/SOG and USGSNM would be helpful
10. Page 5-31, par 3, reference to Figure 5.3.2-16. Map of mean recurrence parameters suggest very low b-values as compared to the USGSNM…
11. Page 5-31 through 5-33, Section 5.3.2.3 Exploration of Model Results in Parameter Space. Referenced Figures 5.3.2-20 and 21, appears that the derived b-values are too low for E. Tennessee and too high for Nemaha Ridge Area Figures 24 and 25.

12. Figure 5.3.2-19 caption should read "Map of geographic areas considered in the comparison of simulated and observed earthquake counts."
13. Page 5-32, 2nd par. Figures 5.3.2-20 and 21do not appear to show good agreement between model and data as mentioned in text. See comment above.
14. Page 5-32, last par. Change "The penalized-likelihood approach developed here does not have this problem". To read "In a mean sense, the penalized-likelihood approach developed here does not have the problem of low or zero seismicity rates".
15. Page 5-33, 1st par. Figure 5.2.3-16 should be 5.3.2-16.
16. Page 5-33, 1st par. Reference to Figure 5.3.2-26 is comparing earthquake occurrence rates to spatial maps of ground motion hazard. This comparison does not seem appropriate.
17. Page 5-33, Section 5.3.2.4 Consideration of Constant b-value kernel approaches. Although there is some discussion for the rationale of why the constant b-value approaches are not used, the rejection (zero weight, no credibility) to a fundamental modeling approach used in the USGS National Map and other PSHAs for critical facilities appears to be counter to the SSHAC goal of capturing the range of the informed technical community. Also, fully weighting a relatively new approach (the penalized-likelihood approach) without direct comparisons of rates and b-values used in other state of practice seismic source characterizations seems contrary to conservative practice.
18. Page 5-43, Section 5.4.1.5, Fault Rupture Area. SSC model uses only the Somerville model for fault rupture area, because others "leading to very similar results". Can this be documented in the report?
19. Page 5-43, Section 5.4.1.7, Relationship of Rupture to Source Zone Boundaries. If earthquake epicenters are constrained to lie at the midpoint of the rupture length, would that assumption be unconservative for sites lying outside "strict" boundaries?

Chapter 6:

1. Page 6-61, last par. Figures 6.2-1 and 6.2-2 should be reversed, captions stay the same.
2. Page 6-70, 1st and 3rd par. "Figures 6.3-1 through 6.3-6" should be "Figures 6.4-1 through 6.4-6" and "6.3-7 through 6.3-16" should be "6.4-7 through 6.4-16"
3. Page 6-70, Section 6.4.1 and Figures 6.4-1 through 6.4-6. Please explain why the apparent resolution of the rate maps appears to be greater for full magnitude weights vs. reduced magnitude weight cases. Also explain why the b-value maps are much lower (~0.8) as compared to the fixed b-value maps developed by the USGS (~0.95).
4. Page 6-70, Section 6.4.2 and Figures 6.4-7 through 6.4-16. The bias between the model rates and data is noted in this section with the statement that "This is the result of deviations of the data from the exponential magnitude distribution." It appears that the model predictions for Mw 6 and greater range from 2-6 times the observed mean rates. The rate predictions appear to be too tight as compared to the data. Also the "full" and "reduced" magnitude weight rate predictions seem to heavily favor the more numerous lower magnitude earthquakes. The net result seems to be rate predictions that consistently exceed observed data at earthquake magnitudes that

drive hazard predictions. A consistent under-prediction of b-values could lead to this result.

5. Charleston Source: Mmax, recurrence rate models and weights seem appropriate and well justified. The three selected and weighted source zones are not sufficiently justified. Recent Chapman papers suggest greater basis for “local” zone. The “regional” zone is diluted because 1/3 of zone is in the Atlantic with no corresponding historic or paleoseismic basis for doing so other than a single and likely poorly located earthquake on an offshore feature defined by seismic reflection work and is considered inactive (Helena Banks fault zone). The technical justifications of this zone may be risky to the users of the model because if may appear that relatively “weak” data are used to reduce inland hazard and other earthquakes that have historically occurred inland and over Miocene structures are ignored.

Chapter 7:

1. Section 7.3.1. There is only one figure accompanying the detailed nine page geologic discussion on the St. Lawrence Rift. The section reads as though it was cut and paste with figures omitted from the source. I think this section could be improved by adding descriptive figures. If detailed figures cannot be added, it may be more desirable to remove most of the text and simply reference the source document.
2. Section 7.3.2 Great Meteor hotspot. Same general comment as 1. (Section 7.3.1), except Figures 7.3.2-3 and 7.3.2-4 are referenced but missing from the document.
3. Section 7.3.3 Northern Appalachian. Same general comment as 1. (Section 7.3.1).
4. Section 7.3.4 Paleozoic Extended Zone. Same general comment as 1. (Section 7.3.1).
5. Section 7.5.1 Rate and b-value Maps for single zone and two zones. Same comment as in Chapter 6: explain why the apparent resolution of the rate maps appears to be greater for full magnitude weights vs. reduced magnitude weight cases. Also explain why the b-value maps are much lower (~0.8) as compared to the fixed b-value maps developed by the USGS (~0.95).
6. Section 7.5.1. Comparison of gridded hazard for these rate cases would have been extremely helpful for the TI team and the reader.
7. Section 7.5.2 Comparison of Recurrence Parameters to Catalog. Similar comment as in Section 6.4.2: The bias between the model rates and data is noted in this section with the statement that “This is the result of deviations of the data from the exponential magnitude distribution.” It appears that the model predictions for Mw 6 and greater range from 2-6 times the observed mean rates. The rate prediction models appear to be too close as compared to the data. Also the “full” and “reduced” magnitude weight rate predictions seem to heavily favor the more numerous lower magnitude earthquakes. The net result seems to be rate predictions that consistently exceed observed data at earthquake magnitudes that drive hazard predictions. A consistent under-prediction of b-values could also lead to this result.

Chapter 8:

1. Many figures that are provided are inadequately described:
2. Hazard fractiles should be computed to understand uncertainties.
3. Figure 8.2-1A. What is the "$STUDY_R$" curve in this and other figures?
4. Figure set 8.2-2 for Chattanooga site is missing.
5. Figure set 8.2-5 Manchester site is missing.

Chapter 9:

1. The Hazard Input Model (HID) (Appendix H) is a critically needed product of this study and unfortunately the digital files were not available for review. I strongly recommend that DOE critically review the HID when it becomes available.
2. Page 9-1, 1st par. Next to last sentence. "In this sense, the SSC model has been "optimized" to include only those assessments that capture the community's views and that are believed to be significant to the hazard. Once this level of uncertainty treatment was reached, there was no further attempt to optimize or reduce the complexity of the model for purposes of subsequent calculational efficiency." What do these sentences mean and how was this concept implemented?
3. Page 9-1, 2nd par. As mentioned above, the regional hazard model conversion to a site specific model needs serious discussion and guidance. This part of the report would be an ideal point to consider these aspects for the potential user.
4. Page 9-3, 2nd and 3rd par. Sensitivity studies conducted by looking at the impacts on hazard of each of the logic tree branches is an appropriate and necessary methodology, however, judging hazard results/impacts from only seven sites in the entire CEUS is totally inadequate technical basis for the TI team. As suggested by SSHAC, gridded hazard is a necessary ingredient for controversial issues. In addition, for a regional hazard map, it should be a necessary requirement. Suggestions for additional SSHAC minimum requirements for a regional hazard model: (1) gridded 1- and 10-hz hazard for 500, 2500, and 10000 years at 10-km spacing. For sensitivity studies, gridded hazard can be computed using mean based parameterizations to improve computational efficiency.
5. Page 9-3, 5th par. This paragraph states that any (hazard) sensitivities to alternative geometries of the Charleston RLME will be accentuated at the Savannah Site. This statement is not demonstrated in the report and cannot be because of the lack of gridded hazard used in the sensitivity studies.
6. Page 9-3, last par. Rupture orientation may be more sensitive at the Savannah site (but was not demonstrated), however RLME source model orientation sensitivity is certainly not a maximum at the Savannah site. The hazard sensitivities completed for the seven sites is likely inadequate for the conclusions made in this chapter.
7. Page 9-3, last through 9-46. The hazard sensitivities completed for only seven sites may be inadequate to support the conclusions made in these sections.
8. Page 9-47, last par. This section consists of two sentences to describe the necessary studies for a site-specific application of the SSC models including: "local geologic and tectonic interpretations, topographic data, geophysical data, historical seismicity data, micro-seismicity data, paleoseismic studies, and any other data,

interpretations, or investigations that might indicate local seismic sources that could affect the site." This section should be extensively expanded so that potential users of the study can understand the necessary efforts to meet regulatory requirements. The regulatory requirements should be identified and summarized in this section. The Executive Summary and Conclusions should also summarize this section and point to this section.

9. Page 9-48, Section 9.4.1 Data available to evaluate the precision of seismic hazard estimates. The estimates of COV derived from other studies are useful, but I don't understand why the COV is not computed directly from the mean fractile hazard evaluations. The contribution to COV from GMPE, background source, RLMEs can be easily resolved.
10. Page 9-53. Figure 9.4-3 should be 9.4-43; all following figure numbers are off by 40.
11. There is quite a detailed section on "precision" in the mean hazard and how close an alternate team of experts might come to the derived mean hazard. The section also asks the question of how stable the mean hazard may be. An inference could also be made by comparing gridded hazard and COV with the USGS National Map results.

Appendix A:

1. A high quality summary of geological, geophysical and seismological databases that the main body of the report indicates will become public.

Appendix C:

1. Provide discussion of table parameters, e.g, quality values and how determined.

Appendix D:

1. A quality collection of reference summaries for this documentation and future reference.

Appendix F:

1. The workshop summaries could be improved by expanding to include copies of all expert presentations and work summaries.