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APPENDIX H

CORRESPONDENCE

H.1 EPRI Decision Point 2 Letter to Nuclear Regulatory Commission (NRC) August 24, 2012

H.2 Participatory Peer Review Panel (PPRP) GMM Report

H.2.1 PPRP GMM Report #1 (Project Plan) April 20, 2012

H.2.2 PPRP GMM Report #2 (Decision Point 2) August 20, 2012

H.2.3 PPRP GMM Report #3 (Feedback Workshop) October 23, 2012

H.2.4 PPRP GMM Report #4 (PPRP Closure Briefing Action Items) March 6, 2013

H.2.5 PPRP GMM Report #5 (GMM PPRP Closure) April 5, 2013

H.2.6 PPRP GMM Report #6 (Review of Draft Project Report) May 21, 2013

August 24, 2012

Letter # PT-082412-024

Dr. Nilesh Chokshi
Deputy Director, Division of Site & Environmental Reviews
Office of New Reactors
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: EPRI (2004, 2006) Ground Motion Model (GMM) Review Project

Dear Nilesh:

The purpose of this letter is to inform you of our decision to proceed with Phase 2 of the GMM review project, which will result in an update of the EPRI (2004, 2006) GMM for the Central and Eastern United States (CEUS). Consistent with NRC guidance, this update is being conducted using the Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 methodology.

The EPRI (2004, 2006) ground motion model review project is divided into two phases. The purposes of Phase 1 were to a) review the EPRI (2004, 2006) GMM, which is based on data, models and methods compiled and evaluated from 2002 to 2004, in light of current (2012) data, models and methods, and b) determine whether the EPRI (2004, 2006) GMM should be updated before it is used to calculate ground motion response spectra (GMRS) at existing nuclear power plants in the CEUS in response to the NRC Request for Information (RFI) 50.54(f) letter dated March 12, 2012. The purpose of Phase 2 is to update the EPRI (2004, 2006) GMM integrating up-to-date data, models and methods.

The Technical Integration (TI) Team and Project Manager (PM) presented the Phase 1 results to the project Participatory Peer Review Panel (PPRP), the Senior Technical Advisors and the NRC staff during a working meeting held on August 14, 2012. At this working meeting, the TI Team, together with the PM, recommended that industry proceed with Phase 2 based on the compilation and evaluation of new data, models and methods completed in Phase 1. The PPRP and Senior Technical Advisors for the Project concurred with this recommendation. The PPRP Decision 2 letter is enclosed. In summary, the basis for this recommendation, as presented during the August 14, 2012 working meeting and the August 16, 2012 public meeting, is as follows:

- Ground motion experts, who developed seven (7) of the thirteen (13) ground motion prediction equations (GMPEs) used in the EPRI (2004, 2006) GMM, recommended that their GMPEs be updated with newer models developed during the last ten (10) years.
- There are three new GMPEs developed by ground motion experts during the past ten (10) years that should be evaluated and possibly integrated into an update of the EPRI (2004, 2006) GMM.
- A new ground motion database for the Central and Eastern North America (CENA) is now available with nearly 28,000 earthquake recordings. Eighty percent (80%) of the earthquake records are from earthquakes that occurred after the development of the EPRI (2004, 2006) GMM in 2004.

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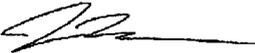
- Comparison of these new data to the predictions by the EPRI (2004) GMM indicates that updating the EPRI (2004, 2006) GMM is warranted to better support the NTTF Recommendation 2.1 effort.

As stated above, this letter serves as notification of the industry conclusion that it is appropriate to update the existing EPRI (2004, 2006) GMM to incorporate current data, models and methods before it is used to calculate GMRS at existing nuclear power plant sites for the purpose of addressing NTTF Recommendation 2.1 for seismic. For this purpose industry is implementing Phase 2 of the approved EPRI (2004, 2006) GMM Review Project Plan¹.

Proceeding with the update will not impact the schedule for the CEUS hazard responses to the 50.54(f) letter provided that the use of the update EPRI GMM can commence in February 2013. The updated EPRI (2004, 2006) GMM will be available in February 2013 and the updated EPRI (2004, 2006) GMM Final Report in April 2013. We request that the NRC review and endorse the updated GMM by February 2013. A draft version of the model and supporting text will be available in January 2013 to facilitate the NRC review and approval by the February 2013 Closure Briefing. In addition, the implementation of Phase 2 of the project will be discussed at multiple NRC Recommendation 2.1 public meetings, which will facilitate appropriate public interactions.

As we have proceeded using the appropriate SSHAC methodology, we anticipate that, upon completion of the project, the updated EPRI (2004, 2006) GMM will be acceptable for responding to the NRC Request for Information (RFI) 50.54(f) letter dated March 12, 2012 and be suitable for use to address other seismic regulatory issues, pending completion of the NGA-East Project. It is expected that the NGA-East Project will provide a replacement ground-motion model for the CEUS when it becomes available.

Sincerely,



Jeffrey F. Hamel
EPRI Program Manager

¹ *EPRI (2004, 2006) Ground-Motion Model Review Project: Project Plan*. EPRI, Palo Alto, CA: 2012. 1025770

Cc

L. Salamone
K. Keithline (NEI)
S. Flanders (U.S. NRC)

April 20, 2012

Via e-mail

Lawrence A. Salomone
WorkforceLogic
19080 Lomita Avenue
Sonoma, CA 95476

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project*, Draft Project Plan
(Rev. 1, dated March 30, 2012): Participatory Peer Review Report

This letter constitutes the report of the Participatory Peer Review Panel (PPRP)¹ providing review comments on the referenced document (herein referred to as the “Draft Project Plan” or “draft Plan”). The designated members of the PPRP are: Walter J. Arabasz (chairman), Brian Chiou, Richard Quittmeyer, and Robert B. Whorton. The latter, who was recently added to the PPRP on April 10, 2012, did not participate in this review of the Project Plan.

Background Information

The following relevant information, not explicitly included in the Draft Project Plan, was considered by the PPRP in its review: (1) A document titled, *Review, EPRI (2004, 2006) Ground Motion Prediction Equations (GMPEs)* (Prepared by L. Salomone, 12/9/11), referred to by the Project Team as the “Conceptual Plan”; and (2) discussion with the Project Team during a telephone conference, more than 2-1/2 hours in length, on March 8, 2012, identified in the Project Schedule as Working Meeting #1. Two members of the PPRP (W. J. Arabasz and R. Quittmeyer) participated in Working Meeting #1 (B. Chiou was added to the PPRP at a later date on March 14, 2011).

Preliminary PPRP feedback on the Draft Project Plan was provided to the Project Team on April 5, 2012, in the form of consolidated review comments. The written document containing those review comments is appended here as Attachment 1. Because members of the PPRP did not have time to jointly review individual comments made by others before our April 5 deadline, we have subsequently revisited those comments and have edited some parts. Hence, Attachment 1 does not correspond exactly to what we submitted on April 5.

This report provides the Panel’s unified views, both on technical details of the draft Plan and its suitability in terms of implementation guidelines for a SSHAC process.² We proceed to offer *General Comments*, followed by *Specific Comments and Recommendations* for consideration and follow-up action by the Project Team. Recommendations are underlined for project

¹ All acronyms used in this report are defined in the Appendix.

² A structured process, originally described and formalized by the Senior Seismic Hazard Analysis Committee (SSHAC) in NUREG/CR-6372 (1997), for the treatment of uncertainty and the use of experts in Probabilistic Seismic Hazard Analysis. Key SSHAC concepts—including the goal to “capture the center, body, and range of technically defensible interpretations” at a particular point in time—are discussed in NUREG-2117 (2012), an updated and amplified treatment of SSHAC guidelines.

tracking. Other comments, including many editorial suggestions for improving the draft Plan, are contained in Attachment 1.

General Comments

The presentation of the Draft Project Plan as a formatted technical report usefully gives it a structured and well-organized form that is reader-friendly. In its parts, the draft Plan is reasonably written but will require efforts to improve its clarity and completeness. Apart from its review by the PPRP and other external reviewers, the document should be checked by a technical editor before finalizing it.

What needs to be done to revisit the EPRI (2004, 2006) Ground Motion Model (GMM) in light of new data, models, and methods since the GMM was developed has been carefully thought out by the Project Team—notably in meetings and conference calls with expert ground motion practitioners that led to the shaping of the “Conceptual Plan” in late 2011 and during Working Meeting #1 on March 8, 2012. However, the Draft Project Plan, in its present form, fails to describe the envisioned project in an effective way.

We are mindful that the EPRI (2004, 2006) Ground Motion Model Review Project is inherently motivated by a request for information from the U.S. Nuclear Regulatory Commission (NRC) and that it has regulatory implications for industry. Appropriately, we focus on technical and process aspects of the draft Plan, consistent with our SSHAC role. Where any of our review comments touch on wording involving regulatory issues, it should be understood that it is not our intent to be influencing policy considerations by the Project relating either to NRC or industry.

Specific Comments and Recommendations

Most of the following review comments address issues of clarity and completeness. Specific Comment #1 is overarching, and Comments #2–#7 relate to individual sections of the draft Plan. Some specific technical issues relating to the Work Plan are addressed in Comment #6.

1. *Clearer Explanation of the Flow of Steps and Tasks:* One significant shortcoming of the draft Plan, in terms of clarity, is inconsistency in the wording and description of steps to be taken, which will confuse most readers. Parts of the report clearly specify the need first to evaluate whether the EPRI (2004, 2006) GMM should be updated and revised (“Decision Point 2”). But other parts leap ahead and refer to use of the “updated” EPRI (2004, 2006) GMM. Given the conditional logic of the conceptual plan, we recommend that a schematic flow chart of various steps and tasks be included to help guide the reader; the flow chart could also serve to provide a clearer road map for the labeling of the steps and tasks. Adding timing elements to such a flow chart would also help the reader better understand the relations between tasks and milestones in the Project Schedule as well as the Project’s relation to other industry milestones outside the Review Project.

In the interest of clarity, we also recommend that the Project Team adopt the definitions used in Chapter 6 of NUREG-2117 regarding “Updating: Replacing, Revising, and Refining Probabilistic Hazard Assessments.” In particular, note that the end action of *updating* an existing hazard study is either to *replace* (completely set aside), *revise*

(modify), or *refine* (incorporate site-specific information into) the existing study. In this project, if the process of assessing the EPRI (2004, 2006) GMM reached the conclusion that the GMM were not “acceptable for a current and specific use” (see the definition of *Update or Updating*), then the GMM would be “revised” and best described as a revised model—or an updated and revised model. An “updated” model ambiguously could be a replaced, revised, or a refined one.

2. *Product Description—Describing the Decision Making at Major Decision Points*: In the Product Description and elsewhere, there is a lack of clarity in describing what decisions will be made at the three major Decision Points and the basis upon which decisions will be made. We recommend attention to these descriptions of decision making, with special attention to the criteria for decision making at Decision Point 2—whether or not to revise the EPRI (2004, 2006) GMM—which will be particularly important for all parties interested in the Review Project to understand.
3. *Section 1 (Introduction and Context of the Study)*: Section 1 places the EPRI (2004, 2006) Ground Motion Model Review Project in the context of efforts over the past 25 years to characterize seismic sources and ground motion for the Central and Eastern United States (CEUS). The section also relates the Review Project to the request by the NRC for utilities to update the ground motion response spectra (GMRS) for existing nuclear power plants, taking into account the recently completed revision of seismic source characterization (SSC) for the CEUS (EPRI/DOE/NRC, 2012). With respect to the NRC request, the section points out that an on-going SSHAC Level 3 study—the NGA-East Project (being carried out under the auspices of the Pacific Earthquake Engineering Research Center)—to develop new GMMs for Central and Eastern North America will not provide results in a timeframe to meet the NRC’s schedule. While the overall discussion in section 1 is useful and provides an appropriate level of detail, it would benefit from clarification in three areas:

First, we recommend that the Introduction clarify the intended use of the reviewed and/or revised EPRI (2004, 2006) GMM that the Project aims to achieve, and that wording in other parts of the Project Plan be consistent with the stated purpose. To be clear, the perspective of the Project Team may change at the end of the Project, depending on their findings, conclusions, and other circumstances. But for the purposes of the Project Plan, there needs to be a clear communication of intended applicability of the resulting GMM, especially if it is intended for a specific and limited use. Misunderstanding and unintended consequences can be avoided by carefully stating in the Project Plan what the envisioned GMM will be, will not be, and perhaps may be (if the Project Team chooses to venture there).

Second, we recommend that the schedule for the Review Project, relative to the schedule imposed by the NRC for updated GMRS, be clarified.

Third, we recommend that the Introduction emphasize that the NRC’s request does not explicitly require a review and possible update of the EPRI (2004, 2006) GMM, but that this approach is prudent in light of new data, models, and methods that have become available since the existing EPRI GMM was developed.

4. *Product Description and Section 2 (Objectives)*: The Product Description, which effectively serves as a distilled executive summary or overview of the proposed project, and section 2 (Objectives)—a terse counterpart contained in the main body of the report—are intertwined, and both need improvement. Much of the logic underpinning the Review Project is framed in the Product Description along with the outline of efforts needed to accomplish the objectives and the corresponding steps that the project will follow, which map into section 4 (Work Plan). We recommend careful attention to improving the construction and description of the “road map” for the Review Project put forward in the Product Description and in section 2. This is the heart of the entire Project Plan. It must be logical and easily grasped by the reader.
5. *Section 3 (Selection of SSHAC Study Level)*: In general, we find that Section 3 is not effectively focused for the purposes of describing the process that the Project Plan will follow, and we recommend that Section 3 be revised, considering suggestions provided below and in Attachment 1. The subsection on Background omits references to key SSHAC-related documents, and it doesn't take advantage of referring to extensive background information summarized in Chapter 2 of the CEUS SSC report (EPRI/DOE/NRC, 2012) and in NUREG-2117. The case for not considering a Study Level 4 (cost and schedule) can be stated more briefly. As a central point, the compelling case for a Study Level 2 should be brought front and center: In our understanding, the Review Project will re-assess a SSHAC Level 3 study, potentially updating and revising it, consistent with guidance in NUREG-2117, and it will be constrained by a deadline.

The various SSHAC Study Levels can be characterized more succinctly, noting the key differences between a Level 3 and a Level 2 process. Importantly, we suggest emphasizing that the Review Project will involve a quasi-Level 3 process: It will have a Technical Integrator (TI) Team and a PPRP, not required for a Level 2 process; the only difference with a Level 3 process will be the absence of multiple workshops. Oversight by a PPRP will ensure that the TI Team appropriately engages resource and proponent experts and carries out the type of evaluation activities that otherwise would occur in workshops under a Level 3 process.

We point out that participation in ground motion workshops associated with the USGS National Seismic Hazard Mapping Program is not viewed by the PPRP as equivalent to conducting a workshop following the SSHAC guidelines. That said, we agree that the TI Team's proposed interactions with resource and proponent experts at the planned USGS workshop can be a productive part of the project's SSHAC Level 2 process, and one or more members of the PPRP will participate in the workshop as observers. (Among various comments in Attachment 1, we have attempted to clarify that the primary role of PPRP members in the setting of a workshop or a working meeting is that of *observers*.³ If requested by the TI Team, and if willing, an individual PPRP member may occasionally play the role of a resource expert in such settings—with his dual role clearly identified and transparent.)

³ The term “observers” is used here in a general sense and should not be confused with the project role of “Observers,” described in section 5 of the draft Project Plan. The latter play a much more restricted role in terms of their ability to participate in discussions and interact with the TI Team during any project meetings.

6. *Section 4 (Work Plan)*: Similar to other sections, this section requires effort to improve its clarity and completeness. A description of the proposed approach for identifying key issues would provide useful background for some of the tasks and help clarify the relationship with the NGA-East project and the utility of hazard sensitivity analysis.

The Draft Project Plan calls for the incorporation of site response in the testing of the EPRI GMM against observed ground-motion data, which were recorded at a wide range of site conditions. The draft Plan describes the possible approach of incorporating site response but fails to deal with the potentially important issue of uncertainty in site response estimates. We recommend that Task 4 include subtasks to characterize site response uncertainty and to incorporate this uncertainty into the testing of the EPRI GMM and its subsequent use in other tasks, such as model revision. Such effort should also cover the effect of near-surface anelastic attenuation.

7. *Section 7 (Schedule)*: The scheduling of dependent activities needs to be reviewed to remove inconsistency. As an example, completion of the draft report (Task 9) presumably has to precede the Closure Briefing meeting. If so, the scheduling of completion of Task 9 in January 2013 is inconsistent with the scheduling of the Closure Briefing on November 29, 2012.

Table 7-1 alone is not effective in showing the timing and duration of all project activities. In the interest of clarity of the Project Schedule, we recommend that, in addition to Table 7-1, the Project Team consider including a Gantt chart to illustrate the start and finish dates of all tasks and tracking milestones. Inclusion of Decision Points in such a chart would also help illustrate their dependencies on the other project activities. Alternatively, the inclusion of timing elements in the schematic flow chart recommended in Comment #1 would similarly serve this purpose, but not fully.

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

For the PPRP,



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Copy: PPRP Members
R. P. Kassawara (EPRI)
J. F. Hamel (EPRI)

References Cited

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- EPRI/DOE/NRC, 2012. Technical Report: Central and Eastern United States Seismic Source Characterization for Nuclear Facilities, EPRI Report 1021097, DOE Report DOE/NE-0140, NRC NUREG-2115, EPRI, Palo Alto, CA, U.S. DOE, and U.S. NRC.
- NRC, 2012. Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies, NUREG-2117, NRC.
- SSHAC: R. J. Budnitz, G. Apostolakis, D.M. Boore, L.S. Cluff, K.J. Coppersmith, C.A. Cornell, and P.A. Morris, 1997. Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts, NRC NUREG/CR-6372, University of California UCRL-ID-122160.

APPENDIX**ACRONYMS**

CEUS	Central and Eastern United States
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GRMS	Ground Motion Response Spectrum (or Spectra)
NGA-East	Research project to develop a new ground motion characterization (Next-Generation Attenuation) model for Central and Eastern North America
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC Nuclear Regulation Report
NUREG/CR	NRC Nuclear Regulation Contractor's Report
PPRP	Participatory Peer Review Panel
SSC	Seismic Source Characterization
SSHAC	Senior Seismic Hazard Analysis Committee
TI	Technical Integrator
USGS	U.S. Geological Survey

ATTACHMENT 1

Consolidated PPRP Review Comments on EPRI (2004, 2006) GROUND MOTION MODEL REVIEW PROJECT PROJECT PLAN (draft April 2012)

To: Lawrence A. Salomone

From: Walter J. Arabasz (PPRP Chairman), Brian Chiou, and Richard Quittmeyer

Date: April 5, 2012 (rev. April 20, 2012)

This document consolidates the separate review comments from the three individual members of the Participatory Peer Review Panel (PPRP) for the draft Project Plan. The intent is to provide timely first-stage feedback to the Project Team. A formal PPRP letter report, to be submitted later, will integrate the individual comments and provide the Panel's unified views, both on technical details of the Project Plan and its suitability in terms of implementation guidelines for a SSHAC process.¹

I. Review Comments by Walter J. Arabasz

General Comments (Last paragraph of original comment substantially edited)

The presentation of the Plan as a formatted technical report usefully gives it a structured and well-organized form that is reader-friendly. In its parts, the draft Plan is reasonably written but will require efforts to improve its clarity and completeness. Apart from its review by the PPRP and other external reviewers, the document should be checked by a technical editor before finalizing it.

What needs to be done to revisit the EPRI (2004, 2006) Ground Motion Model (GMM) in light of subsequent developments has been carefully thought out by the Project Team—notably in meetings and conference calls with expert ground motion practitioners that led to the shaping of a “Conceptual Plan” in late 2011 and during Working Meeting #1 on March 8, 2012. However, the draft Plan, in its present form, fails to describe the envisioned project in an effective way.

One significant shortcoming of the draft Plan, in terms of clarity, is inconsistency in the wording and description of steps to be taken, which will confuse most readers. Parts of the text clearly specify the need first to evaluate whether the EPRI (2004, 2006) Ground Motion Model (GMM) requires updating or modification (“Decision Point 2”). But other parts leap ahead and refer to use of the “updated” EPRI (2004, 2006) GMM. Given the conditional logic of the conceptual plan, a schematic flow chart would help to guide the reader and could provide a clearer road map for the labeling of steps and tasks.

Another shortcoming of the draft Plan is lack of clarity in describing what decisions will be made at the three major Decision Points and the basis upon which decisions will be made. The criteria for decision making at Decision Point 2—whether or not to update and modify the EPRI (2004, 2006) GMM—are particularly important for the reader to understand.

¹ SSHAC: Senior Seismic Hazard Analysis Committee (see NUREG/CR 6372 and NUREG-2117)

Specific Comments

1. Front Matter: Given the numerous acronyms in the report, a listing should be included.
2. Product Description, pp. v–vii:
 - a. Understandably, this section is probably a required part of a standard EPRI report. But for most readers, this section will effectively serve as a distilled executive summary for the proposed project. To alert the reader to that effect, it would be helpful either to give this section a title something like, “Product Description and Project Overview” or at least add a subtitle after Product Description.
 - b. At the outset of this project (and the report), it will be useful for the TI Team to agree upon consistent use of key acronyms. EPRI (2004, 2006) GMM for the Ground Motion Model defined in footnote 1 seems pretty well established; correspondingly one would write “EPRI (2004, 2006) GMM Review Project.” Also, if pursued, distinction could be made between the original version of the EPRI (2004, 2006) GMM and an updated version—say, version 2 or the EPRI (2013) GMM.
 - c. The schematic flow chart described under *General Comments* above could be introduced either here or in section 2. Logically, such a flow chart would first appear within the body of the Plan in section 2. Many readers will likely be challenged to understand the various bullets on pages v and vi. The logic and wording in these bullets needs to be improved for better understanding. One option would be to place the schematic flow chart in section 2 and refer the reader to it here when describing the bullets.
 - d. On page v, because the bulleted “tasks” do not simply correspond to those later listed in Section 7, confusion can be avoided by describing the bulleted items here as “actions” or “efforts.”
 - e. In the second bullet on p. v, following discussion during Working Meeting #1, include the word *reliable* to specify “with reliable site characterization information.”
 - f. In the second bullet on p. v, the rationale for identifying a “subset” of data from the new NGA-East Project is unclear. Is it to find data for which corresponding site characterization information already exists (as the syntax implies)? Or is there some other unspecified reason (see second bullet on p. vi, where there is confusing mention of using “a subset of the NGA-East database” judged to be complete)?
 - g. In the fifth bullet on p. v, there is terse mention of “taking into account new information on site conditions.” The reader should be informed more clearly—somewhere in the Product Description section—of the strategic step of acquiring V_{S30} information (described under Task 3) as part of this project.
 - h. The third bulleted step on p. vi introduces the important concept of “the consensus state of knowledge database”—against which the EPRI (2004, 2006) GMM will be tested. Presumably, information described in the early bullets on p. v enters into “the consensus state of knowledge database.” Just what the latter is, in terms of its general content, should be clearly spelled out.
 - i. In the first bullet on p. vi, there is no wording to explain what type of decision is involved in “DECISION POINT 1.”

- j. Technical edits:
- Par 1, 1st sentence: for consistency with the title of the project elsewhere, change “Review project” to “Review Project”
 - Extra period at end of par. 1
 - In footnote 1, suggested change of last sentence to read, “For brevity we term the combined models the EPRI (2004, 2006) Ground Motion Model, abbreviated as the EPRI (2004, 2006) GMM.”
 - Par. 2, 2nd sentence: change “EPRI (2004/2006) model” to “EPRI (2004, 2006) GMM,” and in line 3 change “models” to “model”
 - Par. 4, 1st sentence: “stability and longevity” of what?
3. Results and Findings, p.vi: This paragraph is awkwardly worded—hinging on “if necessary”—and potentially misleading. In EPRI-speak, the immediate “product of this report” apparently is the Project Plan itself. But most readers will likely interpret “Results and Findings” as relating to the Review Project and what can be anticipated. Clearly, even if there is a downstream decision not to pursue an updated ground-motion model as part of the project, there will be a large body of information to be reported, including a description of “the consensus state-of-knowledge database,” the results of testing the EPRI (2004, 2006) GMM against the latter, and so on.
4. EPRI Perspective, p. vii:
- a. The qualifier relating to pursuit of an updated ground-motion model (“if appropriate”) invites comparison to terminology elsewhere (“if necessary”). Because there is a regulatory implication, uniform language is desirable, throughout the report, to describe that decision.
 - b. For more consistency with wording elsewhere in the report—and to avoid the red herring of “informed”—consider revising wording in the last sentence to read: “. . . and because this project will solicit and evaluate input from acknowledged experts in the larger technical community through a SSHAC process, it can confidently be used until . . .”
5. Acknowledgements, p. ix:
- a. It seems both appropriate and of value to acknowledge Norm Abrahamson for his contributions to developing the plan for this project. His contributions during Working Meeting #1 were evident. Also, the “Conceptual Plan” distributed by Larry Salomone prior to Working Meeting #1 [“Review, EPRI (2004, 2006) Ground Motion Prediction Equations (GMPEs) (Prepared by L. Salomone, 12/9/11)”] describes the involvement of individuals not mentioned in the *Acknowledgements* in: (1) a conference call on November 8, 2011; (2) subsequent interviews (for three individuals unable to participate in the conference call); and (3) a meeting at the offices of the USGS on November 30, 2011.
 - b. Technical edits:
 - In the CEUS SSC final report, the standard American spelling (acknowledgments) is used, rather than the British spelling (acknowledgements)

- 1st sentence: Awkward wording—“The authors of the report [who presumably wrote it] wish to acknowledge the contributions from other members [of the TI Team] who prepared the report . . .”
- In the last sentence, suggestions: change “The agreement from this distinguished group . . . to participate” to “The willingness of these distinguished subject-matter experts to participate”; delete “landmark” [pretentious] or replace with “important”

6. (Section 1) Introduction and Context of the Study:

- a. 1st par., 3rd sentence: Stating that “The EPRI (2004, 2006) Ground Motion Model will be updated before determining ground motion response spectra . . .” is inconsistent with paragraph 4 and leaps ahead of Decision Point 2. (See also technical edits, below.)
- b. 4th par., ending on p. 1-2: To conclude this paragraph, the last sentence needs to be better worded. Suggestion: “Given industry needs to meet the NRC’s 18-month deadline, this Review Project, including possible updating of the EPRI (2004, 2006) GMM, will have to be completed on schedule.”
- c. The last three paragraphs need to be rewritten to deal with the problem of leaping ahead of Decision Point 2. Without dictating text, an example rewording of the first full paragraph on p. 1-2 would have revisions something like:

The CEUS SSC project replaced the SSC component of the EPRI-SOG study, and the results of this Review Project will provide a defensible, pre-NGA-East ground motion model—either in the form of the existing EPRI (2004, 2006) GMM or an updated version. Completing an update for the EPRI (2004, 2006) GMM one year after development of the CEUS SSC model would put these two important inputs for Probabilistic Seismic Hazard Analysis (PSHA) on approximately the same time schedule for updates [the rest of this original sentence doesn’t make sense]. As is the case for the CEUS SSC model, the EPRI GMM endorsed by this project would be applicable to any site within the CEUS and could be used to calculate seismic hazard at any site of interest. Long-term efforts to develop SSHAC Level 3 GMPEs for the CEUS are in progress as part of the NGA East Project, but results are not expected until after the NRC’s 18-month deadline.

[Note: The above text, offered as an example, should be revised for consistency with other parts of the report after the Project Team clarifies the intended use of the reviewed and/or revised EPRI (2004, 2006 GMM). —April 13, 2012.]

d. Technical edits:

- 1st par., 1st sentence: Suggested revision of second half of sentence: “. . . which will review the EPRI (2004, 2006) GMM and potentially update it, based on new data, models and methods.”
- 1st par., 2nd and 3rd sentences: Suggested revision: “The EPRI (2004, 2006) GMM Review Project will take full advantage of data and findings from the NGA-East Project, available at this time, and from the U.S. Geological Survey (USGS) Seismic Hazard Mapping Project. Other data and information developed over the past 10 years will also be evaluated.

- 3rd par., line 2: Change “requests that . . . are computed” to “requests that . . . be computed”; change “in eighteen (18) months” to “within eighteen (18 months)”
- 4th par., line 5: GMRS not previously defined
- Last par. on p. 1-2, last line: Consider changing “milestone” to “deadline” [but be consistent with references elsewhere to the NRC’s 18-month date]

7. (Section 2) Objectives:

- a. General comment: The framing (and terseness) of this section could be improved by the use of a schematic flow chart, described earlier in the General Comments and in Specific Comment 2c, together with corresponding explanation.
- b. 1st par., last sentence: Clarify “the program”
- c. 2nd par., last sentence: Stability and longevity of what? Consider, “Experience has shown that stability and longevity of seismic hazard models (whether SSC or GMM) are best achieved through a proper characterization of existing knowledge and uncertainties, coupled with . . .”
- d. 3rd par.: The first sentence isn’t topically related to the content of this paragraph and should be deleted. It could be retained by moving it to the end of the preceding paragraph—but clarifying exactly which issue NUREG 2117 “specifically addresses.”
- e. 3rd par.: This paragraph reads like pasted text with unclear relevance to Objectives. One fix would be to revise and amplify the existing fourth paragraph. Again, without dictating text, an example rewording would be the following:

For the EPRI (2004, 2006) GMM Review Project, evaluation and integration activities will be implemented as part of a SSHAC Level 2 assessment process (see section 3). In a first step, the activities will lead to a decision whether the EPRI (2004, 2006) GMM requires modification/updating to meet NRC requirements for calculating GMRS at existing nuclear power plant sites. If modification/updating is needed, then evaluation and integration activities will be an essential part of developing the revised GMM. In any case, the SSHAC process will ensure an appropriate approach that is structured, transparent, and fully documented.

If the EPRI (2004, 2006) GMM is revised, then this Review Project will entail another key component. The revised GMM will be used to conduct hazard calculations at seven (7) demonstration sites representative of different hazard environments. The reason for doing this is . . . [elaborate].

f. Technical edits:

- 1st par., 1st sentence: Change “EPRI (2004/2006)” to “EPRI (2004, 2006)”
- 2nd par., 1st sentence: Consider, “(2) a structured and systematic evaluation of the range of diverse technical interpretations from the larger technical community”

8. (Section 3) Selection of SSHAC Study Level:

- a. General comment (Minor changes/corrections made to original comment): The subsection on Background isn't effectively focused for the purposes of this report, it omits references to key SSHAC-related documents, and it doesn't take advantage of referring to extensive background information summarized in Chapter 2 of the CEUS SSC report and in NUREG-2117. The case for not considering a Study Level 4 (cost and schedule) can be stated more briefly. As a central point, the compelling case for a Study Level 2 should be brought front and center: In our understanding, the Review Project will re-assess a SSHAC Level 3 study, potentially updating and revising it (consistent with guidance in NUREG-2117), and it will be constrained by a deadline.

The various SSHAC Study Levels can be characterized more succinctly, noting the key differences between a Level 3 and a Level 2 process. Importantly, we suggest emphasizing that the Review Project will involve a quasi-Level 3 process: It will have a TI Team and a PPRP, not required for a Level 2 process; the only difference with a Level 3 process will be the absence of multiple workshops. Oversight by a PPRP will ensure that the TI Team appropriately engages resource and proponent experts and carries out the type of evaluation activities that otherwise would occur in workshops under a Level 3 process.

- b. 4th par., p. 3-1, 1st sentence: In section 3, exactly who made the decision to use a SSHAC Level 2 assessment process should be unambiguous—EPRI project management? The Project Manager? The TI Team? All of the above?
- c. SSHAC Level 2 Assessment Process, p. 3-2: The first paragraph is out of place. It's not a relevant lead-in to this subsection. For a topical first sentence, one can invert the first sentence of the second paragraph to read: "A SSHAC Level 2 assessment process will be implemented for this project, following the guidelines provided in Chapter 6 of NUREG-2117."
- d. 3rd full par., p. 3-2, line 5 (Minor changes/corrections made to original comment): Change "PPRP members may also participate as resource experts, if requested" to "PPRP members may occasionally participate as resource experts, if requested" to help place more emphasis on the PPRP's review and observer roles.
- e. Last par., p. 3-2, 1st sentence: Purpose of the USGS October 2012 workshop needs to be clarified.
- f. Last par., p. 3-2f: The last two sentences of this paragraph address the justification for selecting a Level 2 process and should be integrated into the preceding subsection.
- g. Technical edits:
- Throughout, make sure that previously undefined acronyms are defined (e.g., PM, PPRP)
 - 3rd full par., p. 3-2, line 2: change "will be lead" to "will be led"

9. (Section 4) Work Plan:

- a. General comment: If a schematic flow chart is used to provide a road map for the project (see Comment 2c), the labeling of tasks, keyed to the flowchart, might conceivably change. As with the Product Description section, many readers will be confused by the

wording of various tasks without an understanding of conditional decision making and timing of the tasks.

- b. 1st par., 2nd sentence: To avoid confusing the reader, consider, “The Plan is based on the assumption that a SSHAC Level 2 process will be used to address most ground motion issues. Some decisions, however, may follow the findings of the NGA-East Project, which is being performed as a SSHAC Level 3 process.”
- c. Task 5, 1st sentence: For clarity (if a flowchart is not used), insert “, contingent upon Decision Point 2,” after “The goal of this task”
- d. Task 6, descriptor: Consider expanding the descriptor of this Task 6 to be more informative, e.g., “Interaction with Technical Community at USGS Workshop.” The avowed purpose is to “present and discuss” and get feedback from other ground motion experts on a preliminary updated GMM. Explicitly mentioning “USGS Workshop” precludes ambiguity about whether an EPRI workshop is to be planned (for those who miss details in the text).
- e. Task 10, title: Add “and other Reviewers” to the title
- f. Task 10, 2nd sentence: Change this sentence to read: “One or more members of the PPRP will attend each of the working meetings and the USGS workshop, primarily as observers, and participate in conference calls. The full PPRP will also meet with the TI Team in a Project Closure Briefing . . .”
- g. Task 10, 2nd full sentence at the top of p. 4-6 (Minor changes/corrections made to original comment): The sentence beginning, “Members of the PPRP” should be deleted or revised, eliminating mention of the PPRP.
- h. Task 13, text: A revised listing of the responsibilities of the PPRP is provided in Comment 11, below. Here, to avoid repetition in section 5, consider an abbreviated description akin to that for Task 14. Example text:

This task includes the activities that fulfill the PPRP’s key responsibilities, under SSHAC guidelines, for reviewing both the technical and process aspects of the EPRI (2004, 2006) GMM Review Project. These activities are detailed in section 5.

- i. Technical edits:
 - Under Task 1, line 7: Insert a comma after “Observers” to read “Senior Technical Advisors and Observers, and comments will be . . .”
 - Under Task 1, next-to-last line, and also under Task 2, line 3: Change “project team” to “Project Team”
 - Under Task 8: Add a verb to the last sentence
 - Under Task 9, second bullet: Change “GMM model” to “the GMM”
10. Table 4-1: Insert a page break to separate this table from the text of section 4.
11. (Section 5) Project Organization: With an eye on the scope of work and task descriptions for PPRP members in the EPRI contractual arrangements, the following revised text is suggested for the functions of PPRP members:

PPRP Members: PPRP members will have the primary responsibility for reviewing the technical and process aspects of the project. Additional duties will include, but not be limited to :

- Attending working meetings of the TI Team and the USGS workshop, and participating in conference calls, to observe the process and monitor progress of the project;
- Interacting occasionally with the TI Team as resource experts if requested;
- Providing written review comments, in the form of a single consensus letter report, on the Project Plan and the draft and final versions of the Project Report;
- Providing oral or written review comments, as required, on interim technical assessments or other products made by the TI Team at key points during the project;
- Participating in the PPRP Closure Briefing in Palo Alto, CA;
- Providing a written closure report to the Project Manager for inclusion in the final Project Report
- Performing other functions, as feasible, requested by the Project Manager (the PPRP, for example, will be asked to review the list of resource and proponent experts invited to the USGS workshop for interaction with the TI Team).

12. (Section 5) Observer [sic], p. 5-3: Change “Observer:” to “Observers:”

13. (Section 6) Lines of Communication and Points of Contact: In the third sentence, the requirement that “EPRI Management and the Project Manager shall be copied on all correspondence and work products” should be clarified. Copied on all project-related e-mails, even informal ones? Is the intent (e.g., for the EPRI Management) to be copied on all *formal* correspondence?

14. (Section 7) Schedule:

- a. Table 7-1: There is an inconsistency in scheduling the milestone for Task 9 (Draft Report) for January 2013 and the proposed PPRP Closure Briefing on November 29, 2012. Presumably completion of the draft report has to precede the Closure Briefing.
- b. Quality Assurance: There is no mention of the SSHAC Level 2 assessment process.
- c. Technical edits:
 - In the 1st par., next-to-last sentence, revise the ending of the sentence to read: “. . . and the availability of participant becomes known.”
 - In the 1st par., last sentence, consider revision to avoid awkward wording at the end of the sentence: “Additional meetings and/or teleconferences with the PPRP and the Project Team, not shown, will be scheduled as the project progresses.”
 - In the listing of Key project milestones, if the suggestion in Comment 9d is adopted, change the wording of Task 6.
 - Consider inserting a page break before Table 7-1.

15. Last page of report, B-18: Presumably, this EPRI boiler-plate page should not be part of Appendix B (with Appendix B header and pagination)

II. Review Comments by Brian Chiou

2. Objectives

- Hazard calculation at seven demonstration sites: Is this calculation part of the project objectives? If no, consider taking it out.

3. Selection of SSHAC Study Level

- On page 3-2, 3rd paragraph: “. . . and any necessary action would be revision of the EPRI (2004, 2006) GMM to provide adequate assurance that the evaluations . . . will be sustained upon the projected future replacement of this currently accepted model.” My sense is that this statement imposes an important constraint on the project deliverable, but I am not sure if it is the intention of the project management. If so, then it needs to be elevated to a much higher position so it is clearly communicated to the project team. Also, consider rewording the sentence to be specific about what it meant by ‘future replacement’ so that one can put the term ‘sustained’ in a clear and proper context.
- The project plan anticipates that the project will benefit from the up-to-date data and the proponent-model database that NGA-East project has compiled. Has the project management officially secured the cooperation of the NGA-East project?
- Page 3-1, last paragraph: “The identification of key issues will be based on experience from the NGA-East Project and sensitivity analyses that are deemed appropriate for this study”. This is an important statement pertaining to the project approach. Consider reiterating it in the Work Plan (Section 4).

4. Work Plan

It will be helpful to clarify that the order in which tasks are presented in the Work Plan is not necessarily the chronological order by which they will be executed.

Task 1: Development of Project Plan and Approved by Participatory Peer Review Panel

- Sensitivity Analysis: Given its role in identifying the key issues, including a general timeframe and a scope of sensitivity analysis in the Work Plan and Schedule is essential. The place for it is preferably Task 4 or Task 5.

Task 2: Obtain Ground-Motion Database and Identify New CEUS GMPEs

- Consider adding a short description of ground motion data from the Nov 5, 2011 Oklahoma M 5.6 earthquake, similar to the one given for the Mineral VA earthquake.

Task 3: Obtain Shear Wave Velocity Measurements at Recording Stations

- It is implied in Task 1 that the project TI team determined the 33 stations for site investigation, but here it states that the NGA-East project selected the stations. This

seems to be an inconsistency. If the latter is true, has the project TI team reviewed the list to determine if it satisfies the needs of the project?

- Consider adding text to explain the basis of the section.

Task 4: Test EPRI (2004, 2006) Ground Motion Model

- Will the TI team quantify the uncertainty in site amplification factor (due to, say, variability in measured Vs profile by different geophysical methods and the use of different computational method of soil amplification)? Will the TI team consider such uncertainty in the evaluation of EPRI (2004, 2006) GMM?
- On page 4-4, the ‘epistemic uncertainty’ bullet: it is not clear how the discretization of GMPEs relates to epistemic uncertainty.

Task 5: Update the EPRI (2004, 2006) Ground Motion Model

- Consider rewording the first sentence.

Task 6: Workshop Feedback

- Is the USGS Ground Motion Workshop dedicated entirely to the EPRI update study? If not, how much of the meeting will be used to discuss the EPRI update and is it sufficient to achieve the goal of this task?

Task 7: Calculate Seismic Hazard at Seven Demonstration Sites

- It was stated in Task 1 that these seven sites will also be used in sensitivity analysis. Why is sensitivity analysis not mentioned in the Task 7 description?

Task 8: Finalize Updated EPRI (2004, 2006) Ground Motion Model

- This task includes ‘Decision Point 3’. What decisions are to be made at ‘Decision Point 3’?

5. Project Organization

The project plan closely follows that of a Level 3 study (without public workshops), while the project is declared a Level 2 study. In instances where they differ in rules or approaches, it becomes unclear as to which of the two SHHAC Levels we are supposed to follow. For example, the NUREG 2117 specifies a late-stage peer review for a Level 2 study, not a participatory review. It is not clear if the term ‘Participatory Peer Review Panel’ can be used in this project, a Level 2 study. Does using the term ‘PPRP’ in project plan imply that all the rules regarding PPRP’s participation in a Level 3 study (for example, attending working meetings as observers) also apply to this study? The project plan should include clear instruction (preferably in Section 3 and Section 5) on which to follow when ambiguity or conflict arises.

- Project Manager: PM will support PEER’s and TI team’s efforts to obtain shear wave velocity measurements. In the Task 2 description of Section 4, there is no mentioning of PEER’s direct participation in the site investigation effort.

7. Schedule

- Table 7-1 is helpful but not the best way to illustrate the (overlapping) timeline of all tasks and to show the temporal relationship between milestones, decision points, working meetings, and review activities. Consider adding a Gantt chart to convey such information.
- The proposed schedule of Task 5 is very aggressive; there is only 1 week between the decision on the overall approach (September 7) and the completion of the draft model (September 13). Is it realistic? Is ‘September 7’ a typo?
- In Task 5, the 3rd tracking milestone refers to the ‘Final model’. Consider using a different term to avoid potential confusion with the real final model of Task 8.
- What is “epistemic mean” in Task 5 description?
- Meetings in August and September are conference calls. Is such arrangement by design? In-person meeting is typically more effective than conference call in resolving issues and reviewing work. Consider holding an in-person working meeting in August or September to discuss/review progress of task 5.

III. Review Comments by Richard Quittmeyer

1. In the “Disclaimer of Warranties and Limitation of Liabilities” statement it says, “Organization(s) that prepared the document” are Lettis Consultants International and AMEC. In the “Citations” section on the next page it says, “This report was prepared by” Lettis Consultants International and WorkforceLogic. This apparent inconsistency should be clarified.
2. Product Description, 1st paragraph (Minor changes/corrections made to original comment): The document being referred to is unclear. Is the intent to cite "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (ADAMS Accession No. ML 111861807, July 12, 2011) or the NRC letter dated March 12, 2012 (“Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident” (ADAMS Accession No. ML12053A340)? Or both?
3. Product Description, 1st paragraph (Minor changes/corrections made to original comment): Provide the basis for stating that the project is “necessary” for resolving Recommendation 2.1. In the March 12, 2012 NRC letter, the NRC indicates that use of the existing EPRI (2004, 2006) Ground Motion Model is acceptable for resolving the request for information.
4. Product Description, 2nd paragraph (Original comment substantially edited): Clarify the objective “to evaluate whether the EPIR (2004/2006) model requires modification/updating for application to address NTTF Recommendation 2.1 for seismic” in light of the NRC statement in its March 12, 2012 letter that use of the existing EPRI (2004, 2006) model is acceptable (Attachment 1 to Seismic Enclosure 1, Step 1, first bullet).

5. Product Description, 3rd paragraph: Consider “will be carried out” instead of “will be required.”
6. Product Description: There seems to be a significant amount of overlap between the first set of bullets and the second set of bullets. Consider consolidating them into a single list of project tasks and decision points.
7. Product Description: Is the “product” being described the “project” or the “project plan?” If the “product” is the “project plan,” consider significantly reducing the content of this section.
8. Product Description, 2nd set of bullets, 2nd bullet: If the database is a subset of the NGA-East database isn’t it by definition incomplete? Clarify what is intended by “completeness of the database.”
9. Product Description, 2nd set of bullets, 3rd bullet (Minor changes/corrections made to original comment): As discussed in Comment 3, the NRC has stated that it is acceptable to use EPRI (2004, 2006) to address Recommendation 2.1. Clarify use of the word “acceptable” in light of the NRC statement.
10. Product Description, 2nd set of bullets, 6th bullet (Original comment substantially edited): Mention of USGS Ground Motion Workshop is given without context. Consider adding a bullet describing the step in which the EPRI model, if updated, will be presented at the USGS Ground Motion Workshop to provide an opportunity for feedback from the technical community.
11. Product Description, 2nd set of bullets, last bullet (Original comment substantially edited): Consider modifying the bullet to focus on interaction with the NRC regarding the possible update of the EPRI GMM rather than the broader issue of the approach to addressing NTF Recommendation 2.1
12. Project Description, Results and Findings: Consider “this report” instead of “the product of this report.” Also, consider an alternate word to “necessary” (e.g., “appropriate”). Consider putting “and” before “assessment.”
13. General: Spell out acronyms the first time they are used and then consistently use the acronyms in the remainder of the text.
14. Project Description, Applications, Values, Use (Original comment deleted):
15. Project Description, EPRI Perspective (Original comment substantially edited): Clarify if the “evaluation of adequacy” for the EPRI (2004, 2006) GMM is limited to adequacy for use in addressing the NRC request for information in their March 12, 2012 letter.
16. Project Description, EPRI Perspective (Minor changes/corrections made to original comment): Use caution with the term “informed scientific community.” In the context of the SSHAC guidance, members of the scientific community are not “informed” unless they have followed the SSHAC process. Also, clarify the connection between involving the scientific community and the duration for which the updated ground motion model can be used.

17. Acknowledgements (Minor changes/corrections made to original comment): the last sentence could be deleted. Not sure a SSHAC level 2 study rises to the level of “landmark.”
18. Introduction, 1st paragraph (Original comment deleted):
19. Introduction, 1st paragraph, last sentence (Original comment deleted):
20. Introduction, 2nd paragraph, last sentence: Statement that EPRI (2004, 2006) is the “most current” ground motion model for the CEUS should be clarified, as more recent models are available.
21. Introduction, 5th paragraph, 1st sentence: Although most readers will know what is being referred to, consider providing a more formal reference for the CEUS SSC project.
22. Introduction, general (Original comment substantially edited): Clarify the motivation for the project in light of the NRC statement that use of the existing EPRI (2004, 2006) GMM is acceptable to address their request for information (“Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,” Attachment 1 to Seismic Enclosure 1, Step 1, first bullet [ADAMS Accession No. ML12053A340]).
23. Objectives, 1st paragraph (Minor changes/corrections made to original comment): Here and throughout the report, consider whether use of words like “require” and “necessary” should be used. In a regulatory environment, a reader may expect use of such words to flow from regulatory requirements or direction, while in the context of this study they are used in a more general, looser sense. Clarify if required actions have a technical or a regulatory basis (or both). [Specific comments with respect to this issue will not be made for the remainder to the draft plan, but the issue should be addressed throughout the document.]
24. Objectives, 2nd paragraph: Here and elsewhere in the draft plan, consider using “assessment” instead of “full assessment.” One could argue that “full assessment” requires an SHACC Level 3 or 4 process.
25. Objectives, 2nd paragraph (Minor changes/corrections made to original comment): While this is paraphrased from the NUREG, it is not clear how item 1 differs from item 2. Consider “(1) assessment of the center, body and range of technically defensibly ground motion interpretations for the CEUS”.
26. Objectives, 3rd paragraph: Should NUREG-2117 be referred to as “draft NUREG-2117?” Has it been formally issued yet? I don’t find it on the NRC internet site.
27. Objectives, last paragraph (Minor changes/corrections made to original comment): Clarify whether it is intended that an updated EPRI GMM is specifically for use in addressing the NRC request for information in its letter regarding Recommendation 2.1 or more generally. This paragraph makes a broad statement that it is to be used to develop GMRS for existing nuclear power plants without tying it specifically to the NRC’s request related to Recommendation 2.1. For example, will it be appropriate for use in updates to existing COL

applications? Will it be appropriate for use in the USGS National Seismic Hazard Map development?

28. Selection of SSHAC Study Level, 1st paragraph: Consider providing the more general reader an aid by including a reference citation for SSHAC study levels. For example, “NUREG/CR-6372 provides” or “Budnitz et al (1997) provides” or “The SSHAC report (NUREG/CR-6372, Budnitz et al. 1997) provides”
29. Selection of SSHAC Study Level, 1st paragraph (Original comment substantially edited): The first sentence states that “assurance” is related to SSHAC study level. In the second sentence, however, a balance between “stability and longevity” versus project duration rather than “assurance” versus duration is discussed. Consider clarifying the connection between SSHAC study level and the “stability and longevity” of the results before discussing the balance among objectives that led to the choice of a level 2 study for the project.
30. Selection of SSHAC Study Level, 2nd paragraph: Consider “As discussed in Section 2” rather than “As discussed above”
31. Selection of SSHAC Study Level, 2nd paragraph (Original comment deleted):
32. Selection of SSHAC Study Level, 2nd and 3rd paragraph (Original comment deleted):
33. Selection of SSHAC Study Level, general: The discussion under the “Background” heading is less background and more the heart of the study level selection logic. Consider eliminating the “Background” heading or changing it to “Study Level Selection.”
34. Selection of SSHAC Study Level, general: Discussion of the 4 SSHAC levels is uneven. For example, the discussion of Level 4 does not mention the use of workshops to facilitate interactions among evaluator experts and proponent experts, while this is mentioned for Level 3. Time and resources for Study Levels 1, 2, and 3 are not discussed. Also, differences between Study Level 1 and Study Level 2 are not discussed at all.

Consider expanding the Background section to discuss the 4 levels with respect to the time and resources needed to carry them out and how each aims to capture the center, body, and range of technically defensible interpretations (i.e., TI versus TFI and use of workshops to facilitate interactions and feedback). Also, explain why each increase in study level is believed to increase assurance that the center, body, and range have been appropriately represented. In addition, discuss any relevant guidance from draft NUREG-2117. Then, in a “Selection” section, explain how the project objectives lead to a level 2 study (update of an existing level 3 study, schedule constraint, ongoing Level 3 study underway).

35. Selection of SSHAC Study Level, 4th paragraph: It is inappropriate to imply that the USGS Ground Motion Workshop for the National Seismic Hazard Maps is comparable to a SSHAC process workshop. While participation in the workshop may facilitate some interactions with the technical community as needed for the Level 2 process, the structure of a TI team interrogating and probing proponent models will be lacking (at least based on my limited experience with USGS workshops). Consider deleting mention of the workshop here and moving it to the discussion of the tasks in Section 4.

36. Selection of SSHAC Study Level, general (Minor changes/corrections made to the original comment): While the draft plan makes clear that the purpose of the potential update of the EPRI (2004, 2006) GMM is to address the NRC's request in their letter dated March 12, 2012, it is not clear whether the update is intended for more general use. Consider clarifying if there are anticipated limitations on general use of the updated GMM.
37. Selection of SSHAC Study Level, last paragraph (Minor changes/corrections made to the original comment): It is not clear what the connection is between coordination with the USGS workshop and use of NGA-East project interim products and the selection of a SSHAC study level for the EPRI (2004, 2006) GMM update project. Consider moving this material to Section 4 (Work Scope).
38. Work Scope, 1st paragraph: Section 3 indicated that the work would be carried out following a SSHAC Level 2 process. Here the second sentence says that a SSHAC Level 2 process will be used for "most" ground motion issues. Clarify what issues will be addressed using SSHAC Level processes other than Level 2.
39. Work Scope, Task 1: It is unclear why calculation of seismic hazard at the seven demonstration sites used in the CEUS SSC project is mentioned here. Why is this one specific element of the scope mentioned, while others are not? Consider deleting the sentence.
40. Work Scope, Task 1: Consider clarifying exactly what "Decision Point 1" is. In the "Product Description" there is no mention of shear-wave data collection with respect to Decision Point 1, but here the only decision mentioned in the text is to collect shear-wave data. Is the decision to initiate the Project or to initiate collection of shear-wave data?
41. Work Scope, Task 2, 1st paragraph: Can a task including the goal to "obtain agreement among the project team that the database is current and best available" also identify what the database is (i.e., NGA-East ground motion database)? It seems that agreement must already be in place if obtaining the NGA-East database will meet the goal. Consider, "One goal of this task is to obtain a current and readily available ground motion database that is adequate for use in reviewing, and updating if necessary, the EPRI (2004, 2006) GMM. As part of the planning process, the TI Team has determined that the NGA-East ground motion database fulfills that goal." Or else clarify that the NGA-East database will be considered to meet the task goal.
42. Work Scope, Task 2, 1st paragraph: Is it necessary to state that any task will begin at project authorization? If any task begins at project authorization, one would expect it to be Task 1. Can Task 2 begin before the project is planned in Task 1?
43. Work Scope, Task 2, 1st paragraph (Minor changes/corrections made to the original comment): The text states that "the TI team will take an active role in identifying data and data sources," but it seems that the team has already selected the NGA-East database. Clarify if the scope includes supplementing the NGA-East database with other data or whether the NGA-East database will be solely relied upon.

44. Work Scope, Task 2, 2nd paragraph: If the NGA-East database is being obtained, is there a need to design a database to support the review of the EPRI (2004, 2006) GMM? Clarify the relation between the NGA-East database that is to be obtained and the database designed to support review of the EPRI (2004, 2006) GMM. Is it anticipated that the NGA-East database will need to be altered or supplemented?
45. Work Scope, Task 2, 2nd paragraph: Given the schedule, is it feasible for the Project team to consider data collection beyond that carried out for the NGA-East Project? Consider stating that the project will be carried out using the NGA-East ground motion database as of some cut-off date and that incorporation of any additional data beyond that date will be considered on a case-by-case basis, taking into account impact to schedule.
46. Work Scope, Task 2, 3rd paragraph: This paragraph implies that the compilation of the CEUS ground motion papers will be carried out by staff other than the TI Team. Consider discussing in more detail the process that will be used. Consider also providing some discussion of how the TI team will determine that this compilation is “comprehensive” and adequately covers the range of technically defensible interpretations.
47. Work Scope, 3rd paragraph: Instead of providing copies of key papers to the TI team, consider making all papers accessible to the TI team.
48. Work Scope, Task 2, 3rd paragraph (Original comment deleted):
49. Work Scope, Task 2, last paragraphs: The discussion of the Mineral, VA earthquake is interesting, but raises the question of why other significant earthquakes that have occurred since EPRI (2004, 2006) are not discussed in similar detail. Should other events be listed or briefly described?
50. Work Scope, Task 4, 1st paragraph: Consider re-wording the second sentence: “Results of this evaluation will be used to decide whether or not to update the EPRI (2004, 2006) GMM (Decision Point 2).”
51. Work Scope, Task 4, 2nd paragraph: In the fourth sentence, what “issues” are being referred to?
52. Work Scope, Task 4, 3rd paragraph: Clarify what the “two key elements” are. Amplification and attenuation?
53. Work Scope, Task 6: It is not clear that the goals of the USGS Ground Motion Workshop and the goals of Task 6 can be met in the same workshop. As an alternative, consider exploring whether a separate workshop can be piggy-backed before or after the USGS workshop in which the EPRI team will have full control of the process, participants, and schedule.
54. Work Scope, Task 6: It is stated that the workshop is anticipated to last two days. Clarify if this two day duration is for discussion of the updated EPRI GMM or for the USGS consideration of ground motion models for the National Seismic Hazard Maps. Time that can be allocated for discussion of the updated EPRI GMM at the USGS Workshop may not be adequate for the type of feedback discussion that is warranted.

55. Work Scope, Task 6: Clarify if workshop participants would be provided a draft report describing the updated EPRI GMM prior to the workshop or whether assessment of the model would be based solely on a presentation at the workshop.
56. Work Scope, Task 8: Clarify what is to be decided at Decision Point 3. Previous decision points were to decide whether to continue the project based on results to date. Is this a similar “continue or stop” decision?
57. Work Scope, Task 9, 1st bullet: This bullet could be read to mean that different SSHAC Study Levels would be used for different issues. Clarify or consider deleting “for various issues.”
58. Work Scope, Task 10: There is a lot of redundancy in the description of this task. Consider revision to eliminate redundancy.
59. Work Scope, Task 10: This task might be better titled “Review of the Draft Report.” The task discusses review by many entities, not just the PPRP.
60. Work Scope, Task 10 (Minor changes/corrections made to the original comment): The project needs to be careful in involving the PPRP as resource experts or other roles. While PPRP members will provide feedback if they are aware of data or technically defensible interpretations that are not being considered, it would be better to consider them as observers at the working meetings, not participants. Otherwise the line between TI team and PPRP starts to blur.
61. Work Scope, Task 11: Clarify the format in which comments will be responded to. Will there be written comment response or will the report simply be revised as deemed appropriate by the TI team?
62. Work Scope, Task 13: This scope is largely redundant with scope for Task 10. Consider reducing the scope of Task 10 to simply review of the draft Report and describe other PPRP scope in Task 13.
63. Project Organization, Database Manager: The Database Manager function mentions development of ground motion prediction equations, but this is not part of the overall scope of this project. Modify for consistency with project scope.
64. Project Organization, PPRP: As discussed in Comment 60, consider describing PPRP involvement in working meetings as observers rather than as resource experts. While PPRP members may occasionally switch to other roles such as resource expert, their primary role should be as a reviewer to maintain independence.
65. Project Organization, PPRP: In the Work Scope Section, it is indicated that the PPRP is involved in review of the draft report. However, the description of the task to finalize the report (Task 11) does not mention any additional review by the PPRP. In the PPRP section of the Project Organization section, the third bullet mentions reviewing the final report. Clarify the number of reports that will be reviewed by the PPRP (and other reviewers) here and in the Work Scope section.

66. Project Organization, PPRP (Minor changes/corrections made to the original comment): Clarify the difference in scope for bullets 3 and 4. Consider some term other than “Approval” for the final assessment of the PPRP. Perhaps “Endorse.” The PPRP does not need to agree with the model developed by the TI Team, they just need to agree that an appropriate process was followed and that the technical basis for the model is justified. The PPRP provides due diligence that the TI Team has done their job properly, but the TI team is the owner of the result, not the PPRP.
67. Project Organization, PPRP: The third and seventh bullets are very similar. Consider consolidating them to avoid redundancy.
68. Project Organization, Project Manager: Both the TI Team and Project Manager are listed as responsible for ensuring adherence to scope, schedule, and budget. Consider having one be responsible and the other support the function.
69. Project Organization, Project Manager: Clarify the difference between being responsible for all technical products and “owning” the technical products (see, for example, the Executive Summary and section 3.2 in NUREG-2117).
70. Figure 5-1: The text in the Specialty Contractor/Resource Experts box is offset from the box itself.
71. Table 7-1: Consider repeating column headings on each page to facilitate use of the table.
72. Quality Assurance, 3rd paragraph: Consider deleting the word “all” in “The systematic compilation of all pertinent information . . .” It is very difficult to show that “all” pertinent data have been systematically compiled.
73. Quality Assurance, 4th paragraph: Consider “(reflecting the process of participatory peer review)” rather than “(via the process of participatory peer review)”.
74. Quality Assurance, 5th paragraph: Mention is made of a SSHAC Level 3 database. Will the database that is provided to the TI Team be considered final, pending more data becoming available? Will any additional SSHAC process review and evaluation of the database take place after it is provided to the EPRI project? If so, consider describing it as a “draft” SSHAC Level 3 database.

August 20, 2012

Via e-mail

Lawrence A. Salomone
Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project, Decision Point 2—PPRP Agreement with TI Team Recommendation to Update Ground Motion Model*

This letter provides in writing the views of the Participatory Peer Review Panel (PPRP)¹ regarding Decision Point 2 in the Project Plan that was addressed at Working Meeting #5 at EPRI headquarters in Palo Alto, California, on August 14, 2012. All four members of the PPRP (Walter J. Arabasz, Brian Chiou, Richard Quittmeyer, and Robert B. Whorton) attended the working meeting.

General Statement of the PPRP's Position

The PPRP believes that the paramount question at Decision Point 2 is this: Can the EPRI (2004, 2006) Ground Motion Model (GMM) be used with credibility and confidence for the specific purpose of computing ground motion response spectra (GMRS) at existing nuclear power plant sites in response to the NRC RFI 50.54 (f) letter dated March 12, 2012?

Based on our own collective expertise and after carefully monitoring the process by which the TI Team and the Project Manager (PM) have addressed this question, the PPRP fully supports their recommendation² that the EPRI (2004, 2006) GMM be updated for the defined task.

Guidance from NUREG-2117

Four points of guidance from Chapter 6 of NUREG-2117, Rev. 1³ are germane:

1. Overriding Reason for Considering an Update

In section 6.2 on page 115, NUREG-2117 states: “It is important to remember that the overriding reason for considering the update of an existing hazard study is the same as the fundamental reason for employing the SSHAC process in the first place—the need to attain high levels of assurance that the larger technical community’s data, models, and methods have

¹ All acronyms used in this report are defined in the Appendix.

² As presented at Working Meeting #5, the recommendation of the TI Team and the PM states: “It is appropriate to update the existing EPRI (2004, 2006) GMM to incorporate current data, models and methods before it is used to calculate GMRS at existing nuclear power plant sites. The updated EPRI (2004, 2006) GMM should be the ‘appropriate’ EPRI (2004, 2006) GMM referred to in the NRC RFI 50.54 (f) letter dated March 12, 2012.”

³ NRC, 2012. Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies, NUREG-2117, Rev. 1, NRC Office of Nuclear Regulatory Research.

been considered and the CBR of TDI have been represented.” In the case of the EPRI (2004, 2006) GMM, does that assurance continue to exist and does the GMM still have viable technical bases? We believe the answers must be no in light of the assessment by the TI Team, together with the PM, that: (1) seven of the thirteen original ground motion prediction equations (GMPEs) used in the EPRI (2004, 2006) GMM, based on feedback from the original developers, are either no longer supportable or should be updated with newer models based on more recent data; (2) three new GMPEs more recently developed by ground motion experts should be evaluated and possibly integrated into an updated GMM; (3) eighty percent of the 28,000 earthquake records in a new ground motion database for Central and Eastern North America postdate the development of the EPRI (2004, 2006) GMM; and (4) preliminary comparison of the new ground motion data to predictions by the EPRI (2004, 2006) GMM indicate that updating of the GMM would likely improve its predictive reliability.

2. Criteria for What Entails a “Significant” Change

In section 6.2 on page 116, NUREG-2117 provides key guidance for assessing whether an update to an existing hazard study is needed and, in particular, what may constitute a sufficient basis for deciding to update:

“For a reasoned decision to be made, criteria need to be established for what entails a ‘significant’ change to the hazard analysis. For this assessment, it is recommended that two criteria be used: (1) an assessment should be made of whether or not the new information would lead to a change in the estimates of the CBR of the TDI in the major components of the model (e.g., SSC or GMC) and (2) an analysis should evaluate the magnitude of the change in the calculated hazard results and the significance to the subsequent use of the results. Either of these alone may indicate that an update is required [underlining added for emphasis]. Clearly, changes in the calculated hazard results are the most diagnostic criteria that inform a decision on whether or not to update a study. However, much of the credibility and confidence in a hazard study comes from the conclusion that it has appropriately captured the CBR of the TDI.”

3. Availability of Diagnostic Hazard Results

Regarding the availability of diagnostic hazard results at Decision Point 2—considering, for example, that hazard calculations remain to be made as part of Task 7 during Phase 2 of the current project—section 6.3 of NUREG-2117 on page 120 offers relevant guidance:

“Clearly, the exploratory studies carried out to evaluate whether or not a hazard study needs to be replaced must be done in an expedited manner and are not the same as carrying out a complete study. Therefore, the assessment of whether the existing study is viable (as well as the potential changes in the calculated hazard results) must be based on limited evaluations and expert judgment.”

In other words, one can make an appropriate decision to update even if the potential changes in the calculated hazard results are not exactly known at the time.

4. *Involvement of the PPRP, the Sponsor, and the Regulator*

In section 6.2 on page 115, NUREG-2117 states: “Because both the sponsor and regulator need confidence and assurance, the decision whether or not to replace or refine a hazard study should be made in light of communication between the sponsor and regulator.” Clearly, the PPRP is not the decision-maker on whether or not to update. Under SSHAC guidelines, the PPRP in effect is a referee on technical content and process in this Review Project. The TI Team, together with the PM, has had the responsibility to assess whether the technical bases of the EPRI (2004, 2006) GMM remain viable, and they have put forward their recommendation that an update of the GMM is appropriate. The quotation at the beginning of this paragraph intimates the necessary involvement of the regulator, namely the NRC, at least in concurrence with the sponsor on any decision to update. For reasons we go on to explain, we believe that active NRC concurrence is important for Phase 2.

Perspectives Relating to NRC Concurrence and External Observers

We feel compelled to add a few comments relating to the *framework* for deciding whether or not—and how—to update the EPRI (2004, 2006) GMM. We do so for two reasons. First, to help avoid stumbling blocks in interactions with the NRC and, second, to give interested parties outside this project a better understanding of some of the particular circumstances of the EPRI (2004, 2006) GMM Review Project vis-à-vis NUREG-2117.

During Working Meeting #5, in open discussion with attending NRC staff, there was general recognition of shortcomings in language in Chapter 6 of NUREG-2117 as relating to guidance on updating existing hazard studies. In particular, it became apparent that some of the guidance in Chapter 6 was framed with intended application more to updates of seismic source characterizations than to ground motion modeling. Circumstances particular to the current EPRI (2004, 2006) GMM Review Project were not anticipated—such as the potential need to update a GMM for use prior to completion of the ongoing, SSHAC-Level-3 NGA-East Project.

We are encouraged to believe that the guidance in Chapter 6 of NUREG-2117 can be used to inform, but not unduly constrain, the decision-making “between the sponsor and the regulator” about whether or not and how to update the EPRI (2004, 2006) GMM. In its current form, the language in Chapter 6 makes it an imperfect frame of reference for the decision-making. We say this because of changes in language in the final version of the NUREG which eliminated “revise” as one of three possible end actions of updating—leaving only “replace” and “refine.” A strict reader of the current revised version of NUREG-2117 may find problematic wording relating to the concepts of *viable* versus *non-viable*, *replace* versus *refine*, and *site-specific* versus *regional* as they apply to ground motion modeling—including the current proposed revision of the EPRI (2004, 2006) GMM, which is a SSHAC Level 3 product.

We point out, as we did in our review of the Project Plan, that this review project is being carried out as a quasi-Level 3 SSHAC assessment. Comparison with the eleven required elements for a SSHAC Level 3 assessment that are outlined in Chapter 4 (Table 4-1) of NUREG-2117 shows that the only missing element in this project is the minimum of three formal workshops. A feedback workshop is planned in this project for October 17, 2012. However, in place of formal workshops for the identification and evaluation of (a) hazard-significant issues and available data and (b) alternative interpretations, the TI Team followed

less formal but still structured processes. To be clear, we do not wish to overstate the SSHAC rigor of the current project, but it certainly is more than a Level 2 assessment.

The following comment is for any readers who may revisit the June 2012 Project Plan for this EPRI (2004, 2006) Ground-Motion Model Review Project. When the PPRP reviewed the Project Plan, we urged the TI Team to explicitly define the criteria they would use for Decision Point 2—that is, whether or not to update the EPRI (2004, 2006) GMM. They did so, but not with full clarity in terms of the guidance of NUREG-2117 that we outlined earlier. We believe that the latter should provide the appropriate terms of reference for the decision-making, not the imperfect statements in the Project Plan, which includes different wording in the Executive Summary (p. viii–ix), the body of the text (p. 7), and in the flowchart of Figure 4-1 (p. 15).

Conclusions and Recommendation

The PPRP is favorably impressed with the execution of this project in terms of adherence to schedule and the timely completion of tasks that have led to the key project milestones of reaching Decision Point 2 and concluding Phase 1, as scheduled, by the end of August 2012.

Restating our consensus position, the PPRP fully supports the TI Team’s recommendation that the EPRI (2004, 2006) GMM be updated before it is used to calculate ground motion response spectra at existing nuclear power plant sites in response to the NRC RFI 50.54 (f) letter dated March 12, 2012. Regardless of its impacts on hazard calculation, we expect that this update will result in an improved GMM that better reflects the CBR of current technical interpretations relating to earthquake processes and ground motion attenuation in Central and Eastern North America and better represents the available observations.

Finally, in order to ensure timely NRC concurrence with *how* the TI Team updates the GMM in Task 5—that is, to ensure that the methodology used for updating be acceptable to the NRC in terms of NUREG-2117 guidance, we recommend that the TI Team outline the methodology it now proposes to use and provide it in written form at an early date to the PPRP and the NRC for review.

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

For the PPRP,



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Copy: PPRP Members
R. P. Kassawara (EPRI), J. F. Hamel (EPRI)

APPENDIX

ACRONYMS

CBR	Center, Body, and Range
EPRI	Electric Power Research Institute
GMC	Ground Motion Characterization
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GMRS	Ground Motion Response Spectrum (or Spectra)
NGA-East	Research project to develop a new ground motion characterization (Next-Generation Attenuation) model for Central and Eastern North America
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC Nuclear Regulation Report
PM	Project Manager
PPRP	Participatory Peer Review Panel
SSC	Seismic Source Characterization
SSHAC	Senior Seismic Hazard Analysis Committee
TDI	Technically Defensible Interpretations
TI	Technical Integrator

October 23, 2012

Via e-mail

Lawrence A. Salomone
Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project*, PPRP Report on October 17, 2012, Workshop: Interactions with Technical Community

This letter constitutes the report of the Participatory Peer Review Panel (PPRP)¹ on the Workshop, “Interactions with Technical Community,” held on October 17, 2012, at EPRI headquarters in Palo Alto, California. All four members of the PPRP (Walter J. Arabasz, Brian Chiou, Richard Quittmeyer, and Robert B. Whorton) participated in the workshop in order to be informed and to review both its procedural and technical aspects.

General Observations

We observed that the workshop successfully achieved two key goals, among other aims. First, the TI Team presented its *draft* update of the EPRI (2004, 2006) Ground Motion Model (GMM), including the steps taken to develop the update. Second, they obtained important feedback on this preliminary GMM from seven subject-matter experts who are active practitioners in earthquake ground-motion modeling in central and eastern North America (CENA).

A one-day workshop has inherent limitations. Nevertheless, we believe the workshop was effective—within the context of a SSHAC Level 2 assessment project—in gaining critical feedback from the technical community of ground-motion modelers as part of assessing the center, body, and range of technically defensible interpretations of available data, models, and methods. The “roundtable” format of the workshop enabled interactive discussions between the invited experts and the TI Team throughout the workshop.

Importantly, the workshop was the culmination of more expansive efforts by the Project Manager (PM) and the TI Team, during the course of this review project, to engage and interact with the technical community of earthquake ground-motion modelers in CENA, beyond the seven resource and proponent experts who participated in the workshop.² These efforts included:

- In late 2011: a conference call, interviews, and a face-to-face meeting cumulatively gaining input from about a dozen resource experts regarding the continued viability of

¹ All acronyms used in this report are defined in the Appendix.

² The following resource and proponent experts participated in the workshop: Gail Atkinson, Jack Boatwright, Dave Boore, Chris Cramer, Shahram Pezeshk, Walt Silva, and Paul Somerville.

the EPRI (2004, 2006) GMM (see Table 1-1 in *EPRI (2004, 2006) Ground-Motion Model Review Project, Project Plan*, June 2012).

- During June to September 2012: telephone or e-mail interviews with 11 resource and proponent experts, including the seven attendees at the October 17 workshop, who are working on ground motions and related topics in CENA. These interviews were carried out as part of Task 2—“Obtain Ground-Motion Database and Identify New CEUS GMPEs.”
- Leading up to this workshop: interactions with, and the providing of advance information to, the invited experts.³

Also, all the invited resource experts are being given the opportunity to provide additional written feedback to the TI Team during the week following the workshop.

In the afternoon session of the workshop, when individual feedback was solicited from the resource and proponent experts on the draft update of the EPRI (2004, 2006) GMM, the feedback was relatively brief and uniformly supportive. We believe this reflects the success of the larger *process*, described above, of multiple interactions with the invited experts.

The PPRP commends the PM and TI team for incorporating into the project this interactive workshop with the technical community, which goes beyond the minimum elements typically associated with a SSHAC Level 2 study. In this case, the interaction was positive and beneficial; it enhances confidence in the product being developed by the TI team, complementing the role of the PPRP. The resource and proponent experts who assisted the TI Team throughout the described interactive process deserve special thanks for their willing help.

Specific Comments and Recommendations

1. Proposed Methodology for an Updated GMM

Following the August 2012 determination that the EPRI (2004, 2006) GMM needs to be updated (Decision Point 2), the heart of the matter now is agreement on *how* to update the GMM. At the PPRP’s request following Working Meeting #5, the TI Team produced a written document describing the methodology it proposed to follow.⁴ (The PPRP provided oral feedback to the TI Team during conference calls on September 19 and 20, 2012—chiefly affirming the suitability of the proposed approach and providing some minor technical suggestions.)

The TI Team’s proposed methodology for updating the EPRI (2004, 2006) GMM and a resulting *draft* update of the GMM were described during the first half of the workshop. For their part—recognizing the scope, schedule, and purpose of this project—the invited technical experts unanimously agreed with the general approach being taken by the TI Team. Following up on constructive suggestions made by the invited experts during the workshop, the PPRP offers the following comments on the proposed methodology.

³ In addition to the seven experts listed in footnote 2, Norm Abrahamson and Bob Herrmann were also invited to the workshop; they were unable to attend but provided feedback to the TI Team and PM prior to the workshop.

⁴ *Draft outline of Task 5—“Update the EPRI (2004,2006) Ground Motion Model (Rev. 3-9/12/2012).*

The proposed methodology relies solely on available CEUS rock data (which were obtained mostly from earthquakes of magnitude 5 or smaller) to assign the relative weights of component GMPEs. While the invited technical experts agreed with this general approach, a few experts raised concern about its utility as an indicator of the reliability of a GMPE in the larger magnitude range. Previous studies (for examples, Bommer and others, 2007, and Chiou and others, 2010) have provided counter examples of the usefulness of small-magnitude data in active tectonic regions as a diagnostic tool for predicting ground motions of large-magnitude earthquakes. The PPRP recommends that the TI Team conduct necessary evaluations to determine if this concern is valid and important to hazard analysis in the central and eastern United States (CEUS) and, if yes, to implement a feasible and sound approach to address this issue.

As an aside, during open discussion in the afternoon part of the workshop, the PPRP alluded to the necessary concurrence of the NRC on the matter of how the EPRI (2004, 2006) GMM is updated (see PPRP report⁵ on Working Meeting #5). Although the NRC does not plan to comment in writing at this time, the PPRP was encouraged in hearing NRC observers at the workshop stating that they were favorably impressed with how the TI Team is proceeding with the update.

2. Evolution of Updated GMM and PPRP Tracking

The GMM being updated by the TI Team will evolve, in the first instance, from the draft version presented at the workshop to some version incorporating suggestions made during and immediately after the workshop. Methodology for developing the models of aleatory variability and epistemic uncertainty was presented at the workshop, and draft models are to be completed afterward. It is our understanding that a revised version of the GMM, for both median motions and uncertainties, will be given to Robin McGuire soon after the end of October for calculating seismic hazard curves at seven test sites. The version of the GMM used by Robin will later be subject to further revision in early 2013, when a final version of the updated GMM will be shaped.

Given the evolutionary nature of how the EPRI (2004, 2006) GMM will be updated, understandably the PPRP can now only endorse the draft updated GMM in a qualified way. We recommend that the TI Team provide an information update to the PPRP regarding the proposed GMM it gives to Robin McGuire for his calculations. A project conference call scheduled for November 12, 2012, may be the opportune time. Further, to the extent possible, we ask that the TI Team provide interim documentation on the updated GMM, between now and the end of the year, so that members of the PPRP can gain a fuller understanding of technical details (e.g., data selection, incorporation of site adjustment factors and their uncertainties, and rationales for assigned relative weights) that were provided in summary fashion at the workshop. Our PPRP review would also be aided by early receipt of plots of comparisons between updated and old models for both median predictions and variances.

⁵ EPRI(2004, 2006) Ground Motion Model Review Project, Decision Point 2—PPRP Agreement with TI Team Recommendation to Update Ground Motion Model (PPRP letter report to Lawrence A.Salomone dated August 20, 2012).

3. *Anticipating Convergence of Information and Decision-Making in Early 2013*

Because the PPRP is committed to helping ensure that the project schedule is maintained, we are concerned about the short time frame between December 31, 2012, when the seismic hazard curves are to be completed for seven test sites, and the issuance of the draft updated EPRI (2004, 2006) GMM with accompanying text before the end of January 2013. The PPRP recommends that, if possible, early Task-7 results (any available comparisons of seismic hazard curves using the old and updated EPRI GMM) be provided upon their completion to the PPRP for early review—ideally prior to December 31, 2012.

4. *Comments on V_{s30} Task 3 Report*

Although the August 2012 report by GEOVision Inc. on V_{s30} measurements at 33 instrument sites in the CEUS was only a peripheral part of the workshop, the successful completion of Task 3 of the project (“Obtain Shear-Wave Velocity Measurements at Recording Stations”) warrants mention. (The PPRP offers kudos to the contractors and partners who were involved in these efforts for enabling the timely completion of Task 3.)

Because the level of ground motion experienced at a site is related to the conditions at the site (e.g., shear-wave velocity of underlying materials, local attenuation characteristics), use of the existing database of accelerograms recorded in CENA is enhanced if information on the site conditions at each recording station is known. This knowledge enables site-specific adjustments to be made to the observed ground motions such that they can be compared with respect to a reference site condition. Ground motion prediction equations (GMPEs) for CENA are developed for the reference site condition.

Taking advantage of initial input from the NGA-East Project and the planning carried out as part of the EPRI (2004, 2006) GMM Review Project, recording sites were targeted for shear-wave velocity measurements taking into account the volume of data recorded at each site and geographic distribution. Results from Task 3 at 33 sites are supplemented by results from a similar program carried out by the U.S. Geological Survey at other high priority sites in CENA. The combined results of the shear-wave velocity surveys enable the current *EPRI (2004, 2006) Ground Motion Model Review Project* to explore an approach to ground motion data adjustment based on site-specific data. Alternatively, adjustments are made based on generic site conditions related to broad site classifications (i.e., soft rock, rock, hard rock). The adjustments are carried out before comparing the observed data to values determined from GMPEs being considered as part of the updated ground motion model.

The PPRP commends the PM and TI team for pursuing and successfully obtaining a high-quality dataset of shear-wave velocity measurements to support the update of the EPRI (2004, 2006) ground motion model.

References Cited

Bommer, J. J., Stafford, P. J., Alarcón, J. E., and Akkar, S., 2007, The influence of magnitude range on empirical ground-motion prediction: *Bulletin of the Seismological Society of America*, v. 97, no. 6, p. 2152–2170.

Chiou, B., and Youngs, R., Abrahamson, N., and Aldo, K., 2010, Ground-motion attenuation models for small-to-moderate shallow crustal earthquakes in California and its implications for regionalization of ground-motion prediction models: *Earthquake Spectra*, v. 26, p. 907–926.

This concludes our current PPRP feedback. Please contact us if you wish to discuss any of our observations, comments, or recommendations.

For the PPRP,



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APPENDIX

ACRONYMS

CENA	Central and Eastern North America
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GMRS	Ground Motion Response Spectrum (or Spectra)
NGA-East	Research project to develop a new ground motion characterization (Next-Generation Attenuation) model for Central and Eastern North America
NRC	U.S. Nuclear Regulatory Commission
PM	Project Manager
PPRP	Participatory Peer Review Panel
SSHAC	Senior Seismic Hazard Analysis Committee
TI Team	Technical Integrator Team

February 22, 2013 (rev. March 6, 2013)

Via e-mail

Lawrence A. Salomone
Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project*, PPRP Report on February 13, 2013, PPRP Closure Briefing (PPRP Report #4)

EXECUTIVE SUMMARY

This letter constitutes the report of the Participatory Peer Review Panel (PPRP)¹ on the PPRP Closure Briefing held on February 13, 2013, at EPRI headquarters in Palo Alto, California. In this report we address two primary expectations from the PPRP related to the Closure Briefing: (1) feedback regarding the preliminary updated EPRI (2004², 2006³) Ground-Motion Model (GMM) and the January 18, 2013, Intermediate Document⁴ and (2) our recommendation regarding the use of the updated EPRI (2004, 2006) GMM for industry response to NRC Request for Additional Information dated March 12, 2012.

For reasons explained herein, we do not provide in this report a recommendation on the use of the updated GMM. This will be addressed in a separate PPRP report, following our receipt of responses by the Technical Integrator (TI) Team to recommendations underlined in this report.

In carrying out an *update* rather than *replacement* of the EPRI (2004, 2006) GMM, the TI Team has adopted an approach that aims to be consistent with the conceptual framework of the existing GMM. This circumstance is central to our review of the methodology used to update the existing GMM and how we appraise whether the center, body, and range (CBR) of technically defensible interpretations (TDI) have been appropriately represented.

The Intermediate Document provided for our review is incomplete and generally provides limited information to help the reviewer understand the cause of different results produced by the updated GMM compared to the existing GMM and to appraise the technical soundness of the updated GMM. It was only at the Closure Briefing that we were able to arrive at sufficient

¹ All acronyms used in this report are defined in the Appendix.

² EPRI (2004), *CEUS Ground Motion Project Final Report*, EPRI Technical Report 1009684, Electric Power Research Institute, Palo Alto, CA.

³ EPRI (2006), *Program on Technology Innovation: Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern United States*, EPRI Technical Report 1014381, EPRI, Palo Alto, CA and U.S. Department of Energy, Germantown, MD.

⁴ *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project Draft Report* dated January 18, 2013 and including Sections 6.1, 6.2, 6.3 and Chapters 8 and 10 [to facilitate discussion and decision making at the Closure Briefing] plus Introductory Materials, Chapters 1, 2, 4, and 7, and Appendices B, C, and F.

understanding. After careful deliberation in the aftermath of the Closure Briefing, we concluded that we had sufficient information upon which to base a sound technical evaluation of the updated GMM.

The exemplary implementation of a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 process in this project allows us to confidently endorse its procedural aspects. The multi-stage involvement of experts from the larger technical community, and particularly the direct comments made by ground motion experts at the October 2012 interaction workshop, gives us confidence that the TI Team has carried out an appropriate *evaluation* of all available data, methods, and models that are relevant.

Our formal judgment about whether the updated GMM appropriately represents the CBR of TDI—that is, our appraisal of the TI Team’s *integration* of the information considered during the *evaluation* process—awaits two actions: (1) the TI Team’s revision of the updated model and (2) their response to our request that it re-examine the within-cluster weights, the cluster weights, and the confidence weights underpinning the updated GMM, together with providing justification for the final weights it decides to adopt and results of re-assessing whether epistemic uncertainty is adequately characterized.

The PPRP emphasizes that its role in reviewing the technical and procedural aspects of the *EPRI (2004, 2006) Ground Motion Model Review Project* is separate and distinct from any communications and decision-making between the sponsor and the NRC.

INTRODUCTION

This letter constitutes the report of the PPRP on the PPRP Closure Briefing held on February 13, 2013, at EPRI headquarters in Palo Alto, California. All four members of the PPRP (Walter J. Arabasz, Brian Chiou, Richard Quittmeyer, and Robert B. Whorton) participated in the briefing in order to be informed by the TI Team and to give the PPRP’s feedback on the preliminary updated EPRI (2004, 2006) Ground-Motion Model (GMM). For convenience, we will refer to the latter herein as the “updated GMM” (understood to be preliminary), and we will refer to the original EPRI (2004, 2006) GMM as the “existing GMM.”

Two goals listed on the agenda for the Closure Briefing define the expectations from the PPRP:

- Obtain feedback from the PPRP regarding the preliminary Updated EPRI (2004, 2006) Ground-Motion Model (GMM) and the January 18, 2013 Intermediate Document
- Obtain PPRP Recommendation regarding the use of the Updated EPRI (2004, 2006) GMM for industry response to the NRC Request for Additional Information dated March 12, 2012

In this report we first offer some general observations on the Closure Briefing. We next give some background information relevant to our evaluation of the updated GMM. Then we use the two goals described above to structure the PPRP’s specific comments and recommendations on the updated GMM. For convenient attention by the TI Team, our recommendations are underlined.

GENERAL OBSERVATIONS

During the morning and early afternoon of the Closure Briefing, following an overview by the Project Manager, the TI Team: (1) reviewed the basic steps followed in the development of the updated GMM;⁵ (2) provided additional information to help the PPRP better understand the updated GMM, including results of selected sensitivity analyses for the calculation of weights and a graphical exploration of the updated GMM; and (3) presented selected hazard results obtained with the updated GMM at seven test sites used in the Central and Eastern United States Seismic Source Characterization (CEUS-SSC) study recently completed in 2012⁶.

We observed that the Closure Briefing had the nature of a “feedback workshop” (see NUREG-2117, Rev. 1, section 4.6.3) in the sense that both the PPRP and the TI Team (as evaluators and integrators) benefited from the presentation and discussion of sensitivity results and hazard calculations derived using the preliminary updated GMM. This feedback helps to mature the assessment process prior to final decision-making.

The interactive discussions with the TI Team were particularly helpful for the PPRP to gain an understanding of the causes of different results produced by the updated GMM compared to the existing GMM—both in terms of predicted ground motions and of calculated hazard results based on using the CEUS-SSC model with both the existing and updated GMMs. The understanding that we gained is crucial to our evaluation of whether the updated GMM appropriately represents the center, body, and range (CBR) of technically defensible interpretations (TDI).

Some new information and perspectives arose during the Closure Briefing, both as a result of the sensitivity analyses and graphical exploration of the updated GMM that were presented and from technical comments made during the afternoon discussion session by the PPRP and designated Observers. Results of at least one of the sensitivity analyses prompted the TI Team to consider whether to modify their weighting scheme for the updated GMM. These developments during the Closure Briefing have a bearing on our recommendations.

SOME BACKGROUND INFORMATION RELEVANT TO THE PPRP’S EVALUATION OF THE UPDATED GMM

One of the expectations from the PPRP is that we make a recommendation “regarding the use of the Updated EPRI (2004, 2006) GMM for industry response to the NRC Request for Additional Information dated March 12, 2012.” The circumstances of this project provide a specific context for our evaluation. They have influenced how we have reviewed the methodology used to update the existing GMM and how we appraise whether the CBR of TDI has been appropriately represented. The circumstances we refer to include the following:

⁵ This was the second opportunity for the PPRP to become informed on this matter; the PPRP had earlier observed (via Webinar) a presentation by the Project Team to the NRC on the “CEUS ground motion model update project” at an NRC public meeting on January 23, 2013.

⁶ EPRI/DOE/NRC (2012), *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities*, EPRI Report 1021097, Department of Energy (DOE) Report DOE/NE-0140, NRC NUREG-2115, EPRI, Palo Alto, CA, DOE, Washington, D.C., and NRC, Washington, D.C.

- The TI Team has used a SSHAC Level 2 assessment to review and update, if appropriate, the existing EPRI GMM, developed as a SSHAC Level 3 product. The use of a SSHAC Level 2 assessment is justified in the revised Project Plan.⁷
- With agreement from the PPRP, the TI Team decided that it is appropriate to update the existing EPRI GMM in order to incorporate current data, models, and methods before it is used to calculate ground-motion response spectra (GMRS) at existing nuclear power plants in response to the NRC Request for Information (RFI) of March 12, 2012 (see PPRP Report #2 for supporting details).⁸
- In updating the existing GMM, the TI Team has intentionally followed the conceptual framework used to develop the EPRI (2004, 2006) GMM, without any radical change in methodology. The adoption of an approach deemed appropriate for *updating*, as opposed to *replacing*, the existing GMM is a fundamental part of the project.
- When a decision was made to update the existing GMM at Working Meeting #5 in August 2012, the PPRP recommended that the TI Team outline in written form the methodology it proposed to use for the update so that it could be reviewed at an early date by the PPRP and the NRC in the light of NUREG-2117 guidance (see PPRP Report #2, cited in footnote 8). The TI Team distributed their proposed plan⁹ on September 12, 2012, and their approach was discussed: (1) during a project conference call, including the PPRP and NRC observers, on September 20, 2012; (2) at the October 17, 2012, interaction workshop with the technical community; and (3) during subsequent project conference calls, again including the PPRP and NRC observers, on November 12 and December 19, 2012.

The above circumstances are relevant to a central part of our PPRP review, namely our examination of how the TI Team handled two critical elements of the SSHAC process: (1) their *evaluation* of all available data, methods, and models proposed by the larger technical community that are relevant and (2) their *integration* of the information considered during the evaluation process and whether it represents the center, body, and range (CBR) of technically defensible interpretations (TDI) (see NUREG-2117, Rev. 1, section 3.1, p. 35).

SPECIFIC COMMENTS AND RECOMMENDATIONS

At the Closure Briefing, we explained why the expectation for the PPRP to make a recommendation on the use of the updated GMM was a challenging request. We had a relatively short amount of time between receiving the Intermediate Document on January 19 and the Closure Briefing. Further, because of the project's structure, we are faced with an inverted process—first, a recommendation on the use of the updated GMM and, later, a critical review of a complete Project Report that fully documents and justifies the technical bases for the updated GMM. Shortcomings of the time frame for our review were mitigated by our observing the NRC public meeting on January 23, 2013 (see footnote 5) and by continual

⁷ EPRI (2004, 2006) *Ground Motion Model Review Project—Project Plan* (Final, May 29, 2012).

⁸ PPRP letter to Lawrence A. Salomone dated August 20, 2012; Reference: EPRI (2004, 2006) *Ground Motion Review Project*, Decision Point 2—PPRP Agreement with TI Team Recommendations to Update Ground Motion Model, 5 p.

⁹ *Draft outline of Task 5—“Update the EPRI (2004, 2006) Ground Motion Model”* (Rev. 3, 9/12/2012).

efforts made by the Project Manager and the TI Team, following the October 2012 interaction workshop, to keep us informed on the development of the updated GMM (see last bullet on page 4).

After careful deliberation in the aftermath of the Closure Briefing, we conclude that we have sufficient information upon which to base a sound technical evaluation of the updated GMM. We proceed with our feedback in three parts:

1. PPRP feedback on the January 18, 2013, Intermediate Document
2. PPRP feedback on the preliminary updated GMM
3. PPRP's position regarding the use of the updated GMM for industry response to the NRC RFI of March 12, 2012

1. PPRP FEEDBACK ON THE JANUARY 18, 2013, INTERMEDIATE DOCUMENT

General Remarks

After receiving the Intermediate Document on January 19 and in the lead-up to the Closure Briefing, we focused our review primarily on appraising the updated GMM rather than on a detailed critique of the document. We did this so we could be prepared to make a timely recommendation for use of the updated GMM. The Intermediate Document includes key chapters and sections that describe the data, models, and methods upon which the updated GMM is based. While these materials describe the underpinnings of the updated GMM, they are incomplete and generally provide limited information to help the reviewer (1) understand the cause of different results produced by the updated GMM compared to the existing GMM and (2) appraise the technical soundness of the updated GMM. It was only at the Closure Briefing that we were able to arrive at sufficient understanding.

The PPRP understands its responsibility to complete a critical review of the Draft Project Report, when it is completed, to ensure clear and complete documentation of the technical bases supporting the updated GMM—particularly regarding (1) data, models, and methods that were used and (2) justification for the models included or excluded, and for the weights applied to elements of the GMM. We expect that the level of detail provided in the Project Report relating to these matters will be significantly greater than provided in the Intermediate Document. The Intermediate Document has made a good start in describing the procedural aspects of the project relating to SSHAC guidance. We earlier reviewed and helped shape the table of contents and organization of the Project Report, which will make our later review easier. We offer the following specific comments on the Intermediate Document at this time.

Checking Exercise

The TI Team noted that in development of the Intermediate Document, an inadvertent error was discovered (footnote 4 on p. 6-9 of the Intermediate Document), where an amplification factor used in the analytical adjustment for recording-site conditions was discovered to be underestimated by 30% or less. At this time, the PPRP has been provided only limited examples of analyses that allow it to spot-check calculations. In view of the potential for inadvertent errors in the TI Team's analyses (such as the example noted in the Intermediate

Document), the PPRP recommends that a checking exercise be undertaken immediately to verify the key analyses supporting the updated GMM.

Analytical Adjustment for Recording-Site Condition

Both the PPRP and other observers had difficulty in fully understanding the development of shear-wave velocity profiles for the analytical adjustment process, illustrated in the Intermediate Document for site ET.SWET in Tennessee (Figures 6.2.1.1-1 to 6.2.1.1-3). The combination of measured shear-wave velocity profiles with template profiles from W. Silva as documented in Appendix B of *Seismic Evaluation Guidance* (EPRI, 2013)¹⁰ needs to be clarified. Discussion during the Closure Briefing indicated that, although not described in the Intermediate Document, profile smoothing was carried out. In the Final Report, the description of profile development should be expanded to include all steps, thus enhancing the transparency of the procedure used, and the inclusion of illustrations using other sites would be helpful. If development of velocity profiles differs from that described in Appendix B of EPRI (2013), sensitivity of the analytical adjustment to alternative approaches (e.g., smoothing versus not smoothing) should be discussed, and any implications for the intended use of the updated GMM should be noted and addressed.

For immediate attention, we recommend that the TI Team re-examine how it implements the analytical adjustment for recording-site conditions to ensure that the procedure used is consistent with the intended use of the updated GMM.

Ground Motion Database

Comparison of Table A-3 from EPRI (2004, cited in footnote 2) with Table 6.1.1-1 from the Intermediate Document shows that approximately half of the earthquakes from the EPRI (2004) database (ten earthquakes) are not included in the database for the updated GMM. If information is available, comments should be added in the Final Report on why the earthquakes are not included in the NGA-East database, the percentage of records they represent, and whether their absence reflects an additional motivation to update the existing GMM.

2. PPRP FEEDBACK ON THE PRELIMINARY UPDATED GMM

Key Questions

Observers at the Closure Briefing questioned whether the preliminary updated GMM represents the CBR of TDI—given that it contains only three new ground-motion prediction equations (GMPEs), that the TI Team’s weights put large emphasis on two models by the same developers, and the paucity of close-in data for large-magnitude earthquakes. In the same vein, another observer raised concern whether epistemic uncertainty was adequately characterized in the updated GMM. These are legitimate concerns that the TI Team, as well as the PPRP in our review, must reckon with. We will present our evaluation of the preliminary updated GMM by asking two different questions. First, does the preliminary updated GMM appropriately

¹⁰ EPRI (2013), *Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, EPRI Technical Report 1025287, Electric Power Research Institute, Palo Alto, CA, November 2012 draft.

represent the CBR of TDI? Second, does the preliminary updated GMM better represent the CBR of TDI than the existing GMM?

Does the preliminary updated GMM appropriately represent the CBR of TDI?

For reasons described in our earlier section on “Some Background Information Relevant to the PPRP’s Evaluation of the Updated GMM,” the specific context in which we appraise whether the CBR of TDI is represented in the updated GMM is the conceptual framework of the EPRI (2004, 2006) GMM.

Implementation of SSHAC Guidelines

Part of establishing confidence that the data, models, and methods of the larger technical community have been considered and that the CBR of TDI has been appropriately represented lies in the implementation of SSHAC guidelines. The SSHAC Level 2 process implemented for this project has been exemplary, in our judgment, and there has been an effective multi-stage involvement of experts from the larger technical community. A summary of the project to date presented by the Project Manager at the start of the Closure Briefing contains an executive overview that reflects evident attention to ensuring compliance with SSHAC guidelines.

The efforts made by the TI Team to perform the SSHAC *evaluation* activity of considering the complete set of relevant data, models, and methods proposed by the larger technical community have been repeatedly described. These include multi-stage interactions with the technical community (due-diligence interviews, conference calls, and meetings; literature review; TI Team interviews; and the interaction workshop held on October 17, 2012).

At the October 2012 interaction with the technical community, the TI Team presented a preliminary version of an updated GMM. Recognizing limitations imposed by the scope and purpose of this project, the invited technical experts unanimously agreed with the general approach being taken by the TI Team. Based on our observations of the process involved in this project—and particularly the direct comments made by ground motion experts at the October 2012 workshop—we are confident that the TI Team has appropriately evaluated all available data, methods, and models that are relevant. That leaves the TI Team’s *integration* activity (i.e., representing the CBR of TDI in light of the evaluation process) to critically review.

Sensitivity analyses

At the Closure Briefing, the TI Team presented results of four sensitivity analyses:

- Effect of giving zero weight to data with $M < 4.75$
- Effect of down-weighting Oklahoma-Arkansas data
- Effect of considering only 10 Hz and 1 Hz weights for within-cluster weights
- Effect of [limiting the weight for any individual GMPE within a cluster to 2/3]

After presenting the sensitivity analyses, the TI Team said it was undecided whether to use the results to change the updated GMM. If one looks closely at the effect on combined weights for

each of the four clusters (see slides #130, #147, #165, and #184)¹¹, one can see that giving zero weight to data with $M < 4.75$ has the greatest effect on the cluster weights, particularly for Clusters 2 and 3. This suggests the importance of re-visiting the cluster weights (see next subsection).

Weighting decisions and the CBR of TDI

SSHAC guidance states that, “In terms of technical review, a key responsibility of the PPRP is to highlight any data, models or proponents that have not been considered. Beyond completeness, it is not within the remit of the PPRP to judge the weighting of the logic-trees in detail but rather to judge the justification provided for the models included or excluded, and for the weights applied to the logic-tree branches” (NUREG-2117, section 3.6.8, p. 49).

For the updated GMM, given the context of the conceptual framework of the EPRI (2004, 2006) GMM and the PPRP’s endorsement of the TI Team’s *evaluation* activity, the PPRP’s ability to appraise whether the updated GMM represents the CBR of TDI hinges largely on the TI Team’s justification of the within-cluster weights, the cluster weights, and the confidence weights.

The PPRP recommends that the TI Team carefully re-examine the within-cluster weights, the cluster weights, and the confidence weights underpinning the updated GMM, considering: (1) the results of the sensitivity analyses, (2) the small number of new GMPEs since completion of the EPRI (2004, 2006) GMM, and (3) the appropriateness of the large weights of Clusters 2 and 3 on predicted ground motions in the updated GMM, particularly in the large-magnitude range (do small-magnitude data have diagnostic power on large-magnitude ground motion?). The TI Team should also assess whether epistemic uncertainty is adequately characterized. We further recommend that the TI Team provide to the PPRP the outcome of this exercise, including justification for the final weights it decides to adopt.

We believe it should be feasible for the TI Team to complete this exercise in a short amount of time, thus enabling the PPRP to make a timely recommendation on the use of the updated GMM for industry response to the NRC RFI 50.54(f) letter dated March 12, 2012.

Treatment of data from earthquakes occurring in OK and AR

Responding to feedback from a ground motion expert at the October 2012 interaction workshop, the TI Team treats data from earthquakes occurring in Oklahoma (OK) and Arkansas (AR) as potentially not representative of the ground motion that the updated GMM is intended to predict. The TI Team should clarify in the Final Report if there are limitations on the types of earthquakes (e.g., shallow, low stress drop) that the updated GMM is intended to represent. Given that the sensitivity-analysis results presented at the Closure Briefing suggest the updated model is insensitive to the inclusion of data from the OK and AR earthquakes, the TI Team may wish to simplify the updated GMM to always include (or exclude) such data. Alternatively, the TI team should document whether, based on published studies, regionalization of ground motion within the midcontinent is warranted.

¹¹ Technical Integration Team (2013), *Overview of EPRI (2004, 2006) GMM Review Project*, Visual slide presentation, Closure Briefing, February 13, 2013.

Preliminary hazard results

In the afternoon of the Closure Briefing, the TI Team presented rock hazard curves at selected frequencies showing total mean hazard together with contributions from important sources at the seven (7) CEUS test sites. All seven sites showed a reduction in seismic hazard when comparing results from the updated and existing GMMs, and the TI Team concluded that the hazard differences were consistent with comparisons of ground-motion estimates from the two GMMs. Because the reductions in hazard are consistent at each of the test sites, this gives the PPRP some assurance that the updated GMM is not biased from site-to-site.

Causes of lower median ground motions (and corresponding hazard)

When asked at the Closure Briefing to explain why the updated GMM was resulting in lower ground-motion estimates and lower hazard results, the TI Team offered the following explanations:

- More data are now available than there were for the existing GMM, allowing an expanded evaluation of GMPE performance for certain magnitude and distance ranges
- The old Cluster 2 and Cluster 3 GMPEs are superseded or not included in the updated GMM, based on the recommendation of their developers, which results in the prediction of lower ground motions for larger magnitudes. [In the following subsection, the PPRP notes that the new Cluster 2 and 3 GMPEs have Western U.S. (WUS)-like magnitude scaling.]
- The adjustment of ground-motion recordings to reference site conditions, which was not part of the approach used in developing the existing EPRI GMM, leads to some lowering of observed ground-motion values that are used to assess weights for the updated GMM
- Data-driven down-weighting of single-corner stochastic models (six of which made up Cluster 1 in the old GMM) lowers ground motion estimates at low frequency
- An updated aleatory variability model (now including magnitude-dependent aleatory variability) results in aleatory variability at large magnitudes that is lower than for the existing GMM.

Magnitude scaling

In the updated GMM, Clusters 2 and 3 receive the highest final combined weights. A companion observation is that, unlike the GMPEs in the existing GMM, the GMPEs in Clusters 2 and 3 of the updated GMM have WUS-like magnitude scaling, which leads to the prediction of lower ground motions for larger magnitudes. Given these observations, a pertinent question is: Does the TI Team have confidence, in general, that WUS-like magnitude scaling represents the mode of current TDI of magnitude scaling for the CEUS? During the Closure Briefing, the TI Team intimated that the answer is yes—based on inferences from replies to related questions made by the ground-motion experts they interrogated. In order to bolster the TI Team's ability to defend the point that the updated GMM appropriately represents the CBR of TDI of the larger technical community, the PPRP recommends that the TI Team make an effort to confirm their position by posing the question directly to CEUS ground-motion experts. This action

would augment the information already obtained through interactions with the technical community.

To clarify our intent, our endorsement of the updated GMM will not depend on having the TI Team first implement the above recommendation. Rather, the matter is one of prudence for defending the updated GMM in the future.

Does the Preliminary Updated GMM Better Represent the CBR of TDI than the Existing GMM?

The question we now ask here is: Does the preliminary updated GMM, whose development was constrained to follow, in general, the methodology and approach used in EPRI (2004, 2006), better represent the CBR of the TDI than the existing GMM?

To begin, the PPRP concludes that the TI Team successfully implemented its planned approach to follow, in general, the methodology used in 2004. As emphasized earlier, the updated GMM does not represent a replacement of the existing GMM.

The PPRP has evaluated the TI team's implementation of the update, noting what elements of the update follow the methodology used to develop the existing GMM and what elements are modifications of that methodology. Modifications are assessed with respect to the technical basis provided by the TI team showing that they reflect the current CBR of TDI. In its present form, the updated GMM incorporates the following (see also Table 1):

- Consistent with the methodology for the existing GMM, an up-to-date database of strong ground motions from earthquakes in central and eastern North America (CENA) was obtained to serve as a basis for evaluating viable GMPEs. While the updated database is considerably expanded relative to that used for the existing GMM, it is still subject to limitations in coverage of magnitude and distance ranges of engineering interest. Both the existing and updated GMM are developed taking into account this issue.
- Consistent with the methodology for the existing GMM, the larger technical community of ground-motion experts was solicited for their views on currently viable GMPEs for CENA. In keeping with a SSHAC Level 2 process, solicitation of views from the larger technical community was carried out through individual interviews with key proponent and resource experts. In addition, the TI team reviewed relevant scientific literature published since the existing GMM was developed. The TI team has performed a high quality and comprehensive evaluation of the current state of knowledge regarding ground motion prediction for CENA. Additionally, other technical observers at the Closure Briefing confirmed their understanding that all available GMPEs have been evaluated as part of the update.
- Consistent with the methodology for the existing GMM, GMPEs were grouped in four clusters according to their characteristics. Two of the clusters (1 and 4) retain the same basis as was used for the existing GMM. For these two clusters, updated GMPEs are unavailable and the previous GMPEs are retained, except that two GMPEs from Cluster 1 for the existing GMM are removed as they are no longer considered viable by their primary developer. Based on a technical evaluation of the remaining GMPEs, the

defining bases for the remaining two Clusters (2 and 3) were revised. For the updated GMM, these two clusters are populated by one GMPE from the existing GMM to which are added three GMPEs that are considered to supersede or supplement previous GMPEs. The PPRP observes that the TI team has provided adequate technical justification for the updated cluster definitions and the updated suite of GMPEs.

- The updated GMM, in comparing GMPEs to observed data, recognizes that site conditions at which strong motions are recorded may differ from the reference site condition used in developing CENA GMPEs. An important new component of the updated GMM is adjustment of recorded ground motions to the GMPE reference site condition for comparison with other GMPEs. Two approaches are used: analytical and empirical, depending on available site data. The PPRP views this new component of the methodology as an improvement that will tend to reduce bias in GMPE evaluation and GMM development. The PPRP also notes that uncertainties in the analytical adjustment approach are taken into account. As mentioned elsewhere in this report, some aspects of the adjustment need to be clarified and checked.
- Consistent with the methodology for the existing GMM, intra-cluster GMPE weights are based on comparison of the median predictions with the available data. The approach used for the existing GMM is expanded to reflect additional considerations as follows:
 - Comparisons are made on the basis of relative likelihood values.
 - Comparisons of data from earthquakes with $3.75 \leq M < 4.75$ and with $M \geq 4.75$ are addressed separately to provide information on differences in the agreement for the two magnitude ranges.
 - Weights are developed separately for six magnitude and distance bins to reflect possible differences in GMPE performance. The importance of the bins with respect to evaluating GMPE performance in the magnitude and distance ranges of engineering interest are also incorporated in the evaluation.
 - Weights are adjusted for sample size to avoid giving greater emphasis to magnitude-distance bins with many recordings. The issue of sample size was also addressed in the existing GMM.
 - Weights are developed separately for high (25, 10, and 5 Hz) and low (2.5, 1, 0.5 Hz) frequency ranges to reflect possible differences in GMPE performance.
 - For Cluster 1, two versions of the Silva et al. stochastic, single corner GMPE are treated as a single GMPE in terms of their combined weight.
 - Weights are developed separately for the analytical and empirical approaches to ground motion adjustment for site conditions
 - Weights are developed separately for alternative cases that include or exclude data from earthquakes in OK and AR, which were identified by a resource expert as potentially distinct from ground-motion recordings in the rest of the midcontinent region.

- The PPRP believes that the expanded approach provides additional flexibility and insight in evaluating the performance of the GMPEs. As discussed elsewhere in this report, the technical basis for consideration of data from earthquakes in OK and AR as potentially unrepresentative of the ground motions to be predicted should be strengthened.
- Consistent with the methodology for the existing GMM, epistemic uncertainty was included in the updated GMM. The approach used for the updated GMM is a modification of the approach from the existing GMM. The updated approach takes the maximum of the intra-cluster variability and a data-based estimate of uncertainty. Additional uncertainties related to source and path characteristics are not explicitly included because of their correlations. Uncertainty due to misfit of the functional form used to represent median ground motion for each cluster is negligible and thus also not included. The PPRP notes that, although the ground motion database is significantly expanded from that available for the existing GMM, data are still sparse in the magnitude and distance ranges of engineering interest. The PPRP recommends that the TI Team consider whether additional epistemic uncertainty may be appropriate to reflect the limited ability to test the GMPEs against data in poorly sampled magnitude and distance ranges.
 - Consistent with the methodology for the existing GMM, cluster weights are based on consistency of the cluster median ground motion models with the available data and also on subjective considerations reflecting the limitations in data-consistency weight because of the lack of large-magnitude events in the ground motion database. For the updated GMM, the subjective consideration explicitly reflects the judgment of the TI team as to the relative ability of the clusters to predict ground motions when they are extrapolated to magnitude and distance ranges that have little or no data in the CEUS database.
 - Consistent with the methodology for the existing GMM, the assessment of aleatory variability is based on observations from regions of active crustal tectonism. Empirical results for event-to-event variability are increased slightly for application to CENA. For the existing GMM, preliminary results for NGA-West were used. For the updated GMM, preliminary results from NGA-West2 are used. The preliminary results for NGA-West did not include magnitude-dependency in ground motion variability. Consistent with the final results from NGA-West and the preliminary results from NGA-West2, in which some GMPEs include magnitude-dependent variability, the model for CENA shows magnitude-dependency. An alternative from the existing GMM in which within-earthquake variability is slightly reduced for CENA, is dropped in the updated GMM to simplify hazard calculations. The PPRP concurs with the updates in characterization of aleatory variability for the updated GMM.
 - Consistent with the methodology for the existing GMM, ground motion for the Gulf Coast region is scaled from the midcontinent model. For the existing GMM, scaling was based on random-vibration-theory (RVT) based point-source simulations that took into account differences in crustal attenuation (Q), site attenuation (κ), and crustal

structure. The extent of the Gulf Coast region was taken from EPRI (1993)¹². For the updated GMM, scaling is accomplished using an inverse RVT (IRVT) method that takes into account differences in crustal attenuation (Q) based on updated information. The extent of the Gulf Coast region is updated based on current information. In contrast to the existing GMM, the updated GMM for the Gulf Coast region is determined for the reference site condition with a shear-wave velocity of 2830 m/s. Effects related to site-specific kappa and crustal structure are left to site response analyses planned as part of the response to the NRC RFI. The PPRP concurs with the use of updated information on the extent of the Gulf Coast region, on Q, and the modified implementation approach. The PPRP notes that treatment of epistemic uncertainty and aleatory variability for the Gulf Coast region needs to be documented.

Based on our evaluation of the steps taken by the TI Team to update the EPRI (2004, 2006) GMM, the PPRP has no hesitation in supporting the position that the updated GMM better represents the CBR of the TDI than the existing GMM. As stated in a preceding section, we are confident that the TI Team has appropriately evaluated all available data, methods, and models that are relevant, appropriately completing its SSHAC *evaluation* activity. We await the TI Team's responses to our underlined recommendations in this report to enable us to evaluate the conclusion of their *integration* activity—in order to comment on whether the CBR of TDI is suitably represented in the updated GMM.

3. PPRP'S POSITION REGARDING THE USE OF THE UPDATED GMM FOR INDUSTRY RESPONSE TO THE NRC RFI OF MARCH 12, 2012

At the Closure Briefing, the PPRP said it was not prepared to make an immediate recommendation regarding the use of the updated GMM for industry response to the NRC RFI 50.54(f) letter dated March 12, 2012. We are prepared to do so, however, upon receipt of responses by the TI Team to recommendations underlined in this report, together with feedback from the TI Team regarding any revisions they decide to make to the updated GMM.

Because the updated GMM we have reviewed will generally result in lower calculated hazard and lower GMRS at most sites in the CEUS compared to the existing GMM, confidence in use of the updated GMM requires a good understanding of the causes of these reductions. Also, a strengthened case needs to be made that the updated GMM represents the CBR of TDI; hence, our recommendations herein.

We are optimistic about being able soon to endorse an updated GMM for the following reasons: (1) After careful deliberation in the aftermath of the Closure Briefing, we concluded that we had sufficient information upon which to base a sound technical evaluation of the updated GMM, which has resulted in our recommendations herein. (2) Based on our technical evaluation, we have found no fatal flaws and believe that any deficiencies identified in the updated GMM can be remediated with relatively minor effort. (3) The exemplary implementation of a SSHAC Level 2 process in this project allows us to confidently endorse its procedural aspects. (4) The multi-stage involvement of experts from the larger technical

¹² EPRI (1993), *Guidelines for Determining Design Basis Ground Motions*, EPRI Technical Report 102293, Electric Power Research Institute, Palo Alto, CA.

community, and particularly the direct comments made by ground motion experts at the October 2012 interaction workshop, give us confidence that the TI Team has appropriately evaluated all available data, methods, and models that are relevant. (5) Pending the TI Team's response to our request that it re-examine the within-cluster weights, the cluster weights, and the confidence weights underpinning the updated GMM, together with providing justification for the final weights it decides to adopt, we anticipate being able to affirm that an updated GMM appropriately represents the CBR of TDI.

This concludes our current PPRP feedback. Please contact us if you wish to discuss any of our observations, comments, or recommendations.

For the PPRP,



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Copy: PPRP Members (Brian Chiou, Richard Quittmeyer, Robert B. Whorton)
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APPENDIX — ACRONYMS

AR	Arkansas
CBR	Center, Body, and Range
CENA	Central and Eastern North America
CEUS	Central and Eastern United States
CEUS-SSC	Seismic Source Characterization for the CEUS
DC	Double-Corner [spectral stochastic ground motion model]
DC-S	Double-Corner with Saturation [spectral stochastic ground motion model]
EPRI	Electric Power Research Institute
ET.SWET	ID Name for Seismic Station in Eastern Tennessee
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GMRS	Ground Motion Response Spectrum (or Spectra)
IRVT	Inverse Random Vibration Theory
NGA-East	Research project to develop a new ground motion characterization (Next-Generation Attenuation) model for Central and Eastern North America
NGA-West	NGA research project for Western North America
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC Nuclear Regulation Report
OK	Oklahoma
PGA	Peak Ground Acceleration
PPRP	Participatory Peer Review Panel
RFI	Request for Information
RVT	Random Vibration Theory
SA	Spectral Acceleration
SC-CS	Single-Corner Constant Stress [spectral stochastic ground motion model]
SC-CS-S	Single-Corner Constant Stress with Saturation [spectral stochastic ground motion model]
SC-VS	Single Corner Variable Stress [spectral stochastic ground motion model]
SSHAC	Senior Seismic Hazard Analysis Committee
TDI	Technically Defensible Interpretations
TI Team	Technical Integrator Team
WNA	Western North America
WUS	Western United States

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Item	Existing EPRI GMM	Updated EPRI GMM
Ground Motion Database	<p>Compiled available strong-motion data from resource experts:</p> <ul style="list-style-type: none"> • 20 earthquakes • 12 earthquakes with $4 \leq M \leq 5$ • 5 earthquakes with $5 \leq M < 6$ • 3 earthquakes with $6 \leq M \leq 6.76$ 	<p>Compiled available strong-motion data primarily from NGA-East:</p> <ul style="list-style-type: none"> • 91 earthquakes • 11 earthquakes with $2 \leq M < 3$ • 33 earthquakes with $3 \leq M < 4$ • 29 earthquakes with $4 \leq M < 5$ • 29 earthquakes with $5 \leq M < 6$ • 4 earthquakes with $6 \leq M < 7$ • 2 earthquakes with $7 \leq M \leq 7.6$ <p>Note: 10 earthquakes from the EPRI 2004 database are <u>not</u> included in the 2013 database</p>
Ground Motion Prediction Equations	<p>13 GMPEs considered viable at the time of the evaluation are included</p>	<p>9 GMPEs considered viable at the time of the evaluation are included</p> <p>Some GMPEs included in the existing GMM are removed in response to recommendations from their developers and/or other ground motion experts</p> <p>Three new GMPEs are included along with minor updates to the three Silva GMPEs that are retained</p>
Ground Motion Model Clusters	<p>Four clusters identified on the basis of model type:</p> <ol style="list-style-type: none"> 1. Spectral, single corner 2. Spectral, double corner 3. Hybrid empirical 4. Finite source/Green's function 	<p>Four clusters identified on the basis of model type, but the basis for clusters 2 and 3 differ from the existing GMM:</p> <ol style="list-style-type: none"> 1. Spectral, single corner 2. Complex/empirical with R^{-1} geometrical spreading to 100 km 3. Complex/empirical with $R^{-1.3}$ geometrical spreading to 70 km 4. Finite source/Green's function

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Item	Existing EPRI GMM	Updated EPRI GMM
Site Correction	<p>Data from rock sites used:</p> <ul style="list-style-type: none"> • All rock sites treated as characterized by the reference rock profile • No site correction applied 	<p>Data from rock sites used:</p> <ul style="list-style-type: none"> • Data categorized as from soft ($500 \text{ m/s} \leq 1000 \text{ m/s}$), intermediate ($1000 \text{ m/s} \leq V_{s30} < 1890 \text{ m/s}$), or hard ($V_{s30} \geq 1890 \text{ m/s}$) rock sites. Categorization used as basis for empirical site correction to ground motion. Based on analysis of residual models, correction made for soft rock sites only. • For sites at which measured V_s profiles were available, an analytical site correction was developed • Both empirical and analytical approaches used to adjust ground motion data prior to comparison with GMPEs
Within Cluster Model Weights	<ul style="list-style-type: none"> • Based on comparison to observed data ($M > 4$) • Based on variance between a model's predictions and the available ground motion database: Sum of squares of the mean deviation of the model predictions from the data (e.g., mean bias) and the square of the standard error of estimation (e.g. variance) of the mean deviation for each frequency (1, 2.5, 5, and 10 Hz) • Data are compared per earthquake to avoid over-weighting earthquakes that generated more recordings 	<ul style="list-style-type: none"> • Comparison based on observed data ($3.75 \leq M < 4.75$ and $M \geq 4.75$ considered separately) • Based on likelihood values for six structural frequencies, 6 magnitude-distance bins, both adjustment approaches and (with and without OK-AR data) • Weights combined to give final model weights for high (25, 10, 5 Hz) and low (2.5, 1, 0.5 Hz) frequency ranges • In Cluster 1, weights for two Silva models are halved because of the similarity in the different model versions • Weights are adjusted for "importance" and sample size

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Item	Existing EPRI GMM	Updated EPRI GMM
Epistemic Uncertainty in Cluster Median Ground Motion	<p>Made up of:</p> <ul style="list-style-type: none"> • Intra-cluster variability • Uncertainty in source parameter values not represented in intra-cluster variability • Uncertainty in path parameter values not represented in intra-cluster variability • Misfit of median ground motions using selected function form <p>Uncertainty due to source parameters for Cluster 1 was also applied to Clusters 2, 3, and 4</p> <p>Uncertainty due to path parameters for Cluster 1 was also applied to Clusters 3 and 4.</p> <p>For Cluster 2, path uncertainty included in the different GMPEs used was determined to sufficiently represent uncertainty</p> <p>Represented by a discrete three-point distribution (median with weight of 0.63, and 5th and 95th percentiles with weights of 0.185)</p>	<p>Made up of maximum of:</p> <ul style="list-style-type: none"> • Intra-cluster variability • Data-based estimate of variability <p>Independent estimates of uncertainty in source and path parameter values are not used as the uncertainties are correlated</p> <p>Misfit in median ground motion using functional form was determined to be negligible</p> <p>Represented by a discrete three-point distribution (median with weight of 0.63, and 5th and 95th percentiles with weights of 0.185)</p>
Cluster Weights	<p>Based on:</p> <ul style="list-style-type: none"> • Consistency with data (0.25 weight) • Seismological principles and uncertainty evaluation (0.75 weight) 	<p>Based on:</p> <ul style="list-style-type: none"> • Consistency with data (0.5 weight) • Robustness as extrapolators to magnitudes and distances of engineering interest (0.5 weight)

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Item	Existing EPRI GMM	Updated EPRI GMM
Aleatory Variability Model	<p data-bbox="653 274 806 302">EPRI (2006):</p> <ul data-bbox="705 315 1272 926" style="list-style-type: none"> <li data-bbox="705 315 1241 414">• Concluded that CENA and active tectonic region (e.g. WNA) aleatory variability should be similar <li data-bbox="705 422 1272 522">• Used average of preliminary NGA West results to develop aleatory model for active tectonic regions <li data-bbox="705 530 1241 629">• Included small increase in event-to-event variability, τ, to account for slightly larger variability noted in data <li data-bbox="705 637 1272 769">• Included a lower weighted (0.3) option for lower within-earthquake variability, ϕ, to represent more uniformity in CENA hard rock sites <li data-bbox="705 778 1272 926">• Increase values for frequencies above 10 Hz (excluding PGA) to equal 10 Hz values to account for greater high frequency content in CENA ground motions <p data-bbox="705 968 1230 1034">Aleatory variability model is independent of magnitude</p>	<ul data-bbox="1346 274 1898 926" style="list-style-type: none"> <li data-bbox="1346 274 1898 373">• Follow EPRI (2006) concept—CENA and active tectonic region (e.g. WNA) aleatory variability should be similar <li data-bbox="1346 381 1881 480">• Used average of preliminary NGA West2 results to develop aleatory model for active tectonic regions <li data-bbox="1346 488 1898 588">• Included small increase in event-to-event variability, τ, to account for slightly larger variability noted in data <li data-bbox="1346 596 1898 769">• For simplicity, drop alternative option for lower within-earthquake variability, ϕ, to represent more uniformity in CENA hard rock sites as impact on mean hazard is small <li data-bbox="1346 778 1898 926">• Increase values for frequencies above 10 Hz (excluding PGA) to equal 10 Hz values to account for greater high frequency content in CENA ground motions <p data-bbox="1346 968 1818 1034">Aleatory variability model is magnitude dependent</p>

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Item	Existing EPRI GMM	Updated EPRI GMM
Treatment of Gulf Coast Ground Motion Prediction	<p>Scaled from the results for the midcontinent based on random vibration theory point-source simulations taking into account differences in attenuation (Q) and crustal structure</p> <ul style="list-style-type: none"> • Extent of Gulf Coast region taken from EPRI (1993) • Q model for the midcontinent taken from Silva et al. (2002) • Q model for the Gulf Coast region taken from EPRI (1993) 	<p>Scaled from the results for the midcontinent using inverse random vibration theory and differences in attenuation (Q)</p> <ul style="list-style-type: none"> • Extent of Gulf Coast region updated based on currently available information including the 2012 CEUS-SSC • Ground motion determined for reference site condition with shear-wave velocity of about 2380 m/s • Q model for the midcontinent taken as harmonic average of Silva et al. (2002) and Atkinson (2004) • Q model for the Gulf Coast region determined from Transportable Array data as part of the Project

TABLE 1. Comparison of Approaches for the Existing and Updated EPRI Ground Motion Models

Cluster	GMPE, existing GMM	Evaluation	GMPE, updated GMM
1 – Stochastic, single corner	Hwang and Ho (1997)		Not included
	Silva et al. (2002) – SC-CS	Silva indicates not updated	Not included
	Silva et al. (2002) – SC-CS-S	Silva indicates not updated	Silva et al. (2003) SC-CS-S
	Silva et al. (2002) – SC-VS	Silva indicates not updated	Silva et al. (2003) SC-VS
	Toro et al. (1997)	Abrahamson suggests not to use (retained upon recommendation of the PPRP)	Toro et al. (1997)
	Frankel et al. (1996)	Frankel suggests the GMPE should continue to be considered	Frankel et al. (1996)
2 – Stochastic, double-corner [for updated GMM, reclassified as complex/empirical models with R^{-1} geometrical spreading to 100 km]	Atkinson and Boore (1995)	Atkinson and Boore suggest replacing with AB06'	Atkinson (2008)+Atkinson & Boore (2011)
	Silva et al. (2002) – DC	Silva indicates not updated	Not included
	Silva et al. (2002) – DC-S	Silva indicates not updated	Silva et al. (2003) – DC-S
3 – Hybrid empirical [for updated GMM, reclassified as complex/empirical models with $R^{-1.3}$ geometrical spreading to 70 km]	Abrahamson and Silva (2002)	Abrahamson suggests not to use	Not included
	Atkinson (2001) + Sadigh et al. (1997)	Atkinson suggests replacing with A08'; also likes Pezeshk et al (2011) as a hybrid empirical model	Atkinson & Boore (2006)+Atkinson & Boore (2011)
	Campbell (2003)	Campbell suggests that Pezeshk et al. (2011) supersedes his GMPE	Pezeshk et al. (2011)
4 – Finite source/Green's function	Somerville et al. (2001)	Abrahamson indicates not working well Somerville indicates not updated and should be included; still works for $M > 6$ and longer period SA	Somerville et al. (2001)

April 5, 2013

Via e-mail

Lawrence A. Salomone
Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project*, PPRP Concurrence with Updated EPRI (2004, 2006) Ground Motion Model (PPRP Report #5)

EXECUTIVE SUMMARY

This letter is a follow-up to an earlier report of the Participatory Peer Review Panel (PPRP)¹ in which formal judgment was suspended about whether a provisional update to the EPRI (2004, 2006) Ground Motion Model (GMM)—presented on February 13, 2013, at the PPRP Closure Briefing—appropriately represents the center, body, and range (CBR) of technically defensible interpretations (TDI) of the larger technical community. The PPRP requested further actions and deliverables from the Technical Integration (TI) Team, and the TI Team has complied with those requests. In particular, the TI Team has provided a revised update to the existing EPRI GMM, referred to herein as the March 28, 2013 version of the updated GMM.

In this letter the PPRP affirms the following at this juncture of the project:

- The exemplary implementation of a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 process in this project allows us to confidently endorse its procedural aspects.
- We concur that the full ranges of relevant data, models, and methods have been duly considered in the TI Team's assessment in the context of updating the EPRI (2004, 2006) GMM.
- We concur that all technical assessments have been adequately defended and documented by the TI Team (this is qualified by noting that because the project report remains to be completed, the PPRP has yet to critically review—for clarity and completeness—the *full* documentation of the technical bases underlying the updated GMM).
- Based on our observation of the implementation of the SSHAC Level 2 process and our review of the technical bases and justifications provided by the TI Team for their representation of the CBR of TDI, the PPRP concurs that the March 28, 2013 version of the updated EPRI (2004, 2006) Ground Motion Model appropriately captures the CBR of TDI.

¹ All acronyms used in this report are defined in the Appendix.

INTRODUCTION

This letter is a follow-up to an earlier report of the PPRP for the EPRI (2004, 2006) Ground Motion Model Review Project. In the earlier report, identified as PPRP Report #4², the PPRP suspended formal judgment about whether a provisional update to the EPRI (2004, 2006) GMM—presented on February 13, 2013, at the PPRP Closure Briefing—appropriately represents the CBR of TDI of the larger technical community.

In PPRP Report #4, the PPRP requested that the TI Team complete two further actions: (1) completion of the provisional updated model and (2) re-examination of the within-cluster weights, the cluster weights, and the confidence weights underpinning the updated GMM, together with providing justification for the final weights adopted and results of re-assessing whether epistemic uncertainty is adequately characterized.

Subsequently, the TI Team has satisfactorily provided information to the PPRP to meet its requests. These include: (1) an illustrated document³ summarizing actions taken in response to PPRP Report #4; (2) a teleconference with the PPRP on March 15, 2013 (~2.5 hours long) explaining changes made to the version of the updated GMM that had been presented at the February 13, 2013, PPRP Closure Briefing; (3) responses by the TI Team on March 23, 2013, to resolve further questions posed by the PPRP following the March 15 teleconference; and, finally, (4) a Hazard Input Document (HID) on March 28, 2013, containing exact specifications for the TI Team's modified update of the EPRI (2004, 2006) GMM for both the Mid-Continent and the Gulf Coast regions of the Central and Eastern United States (CEUS).

PPRP CONCURRENCE WITH THE MARCH 28, 2013 VERSION OF THE UPDATED GMM

At this juncture of the project, consistent with the guidance outlined in section 3.6.8 of NUREG-2117⁴, the PPRP has the responsibility to address the following:

1. Whether the project has conformed to the recommendations of the selected Senior Seismic Hazard Analysis Committee (SSHAC) assessment process—namely, Level 2
2. Whether the full ranges of data, models, and methods have been duly considered in the TI Team's assessment
3. Whether all technical assessments have been adequately defended and documented by the TI Team
4. Whether the updated GMM captures the CBR of TDI⁵

² PPRP letter to Lawrence A. Salomone dated February 22, 2013 (rev. March 6, 2013) ; Reference: *EPRI (2004, 2006) Ground Motion Review Project*, PPRP Report on February 13, 2013, PPRP Closure Briefing (PPRP Report #4), 21 p.

³ Toro, G., Chapman, M., McGuire, R., Youngs, R., and Salomone, L., 2013. EPRI (2004, 2006) GMM Review Project: Actions taken in response to PPRP letter of 2/22/2013 (rev. 3/6/2013), PowerPoint document, 56 slides, March 14, 2013 (Draft) and March 16, 2013 (Final).

⁴ NRC, 2012. Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies, NUREG-2117, Rev. 1, NRC Office of Nuclear Regulatory Research.

⁵ The abbreviations “CBR of TDI” and “CBR of the TDI” are both found in NUREG-2117 and are considered interchangeable.

Items #1 and #2 (process and *evaluation* activity)

In PPRP Report #4, we described in detail our appraisal of Items #1 and #2. We affirmed that the exemplary implementation of a SSHAC Level 2 process in this project allows us to confidently endorse its procedural aspects. We also affirmed our judgment that the TI Team has suitably evaluated all available data, methods, and models that are relevant, thereby appropriately completing its *evaluation* activity. (See PPRP Report #4 regarding discussion of the TI Team's approach to achieve an update consistent with the conceptual framework of the existing EPRI GMM.)

Item #3 (justification and documentation)

Based on the actions taken by the TI Team subsequent to the Closure Briefing and their receipt of PPRP Report #4, we are now in a position to address Item #3. We have challenged the TI Team to defend and justify the technical assessments that support their latest version of the updated GMM, particularly revisions made to the GMM since the Closure Briefing. Our conclusion here must be clearly understood: We have reached a good understanding of the TI Team's technical assessments, and the TI Team has adequately defended those assessments to our satisfaction, providing sufficient documentation for those purposes. However, because the writing of the project report remains to be completed, we have yet to critically review—for clarity and completeness—the *full* documentation of the technical bases underlying the updated GMM. These circumstances are a consequence of the project's structure (see PPRP Report #4).

Item #4 (CBR of TDI)

To clarify the issue at hand: “The SSHAC process seeks to capture the center, the body, and the range on each component of the hazard study. . . . If the correlations between these component distributions are also captured, this in turn will then result in capture of the center, the body, and the range of seismic hazard estimates, which is the ultimate objective of the process” (NUREG-2117, section 3.1, p. 33).

For clarification of terminology, we refer further to NUREG-2117:

Once a group of geological, seismological, and geotechnical experts have made their evaluations of all of the available data, the center of these interpretations can be thought of as the best estimate or central value (median) of the distribution of possible outcomes as determined by that group. The term “body” can be thought of as the shape of the distribution of interpretations that lie around this best estimate and capture the major portion of the mass of the distribution. The term “range” refers to the tails of this distribution and the limiting credible values. (NUREG-2117, section 3.1, p. 33)

With the above guidance in hand, we have carefully examined the material provided to us by the TI Team. At the outset, two points warrant emphasis. First, the TI Team “owns” the updated GMM, and the primary responsibility to justify the capture of the CBR of TDI rests with them. They do so in Slides 55–56 of their PowerPoint document of March 14, 2013 (cited in footnote 4), where their arguments are summarized in seven bullets. Second, the excerpt from NUREG-2117 reproduced above points out how the *center* of TDI is achieved—it results from determinations of the TI Team. Whereas the *body* and *range* of TDI can be compared to the available views of the larger technical community, the *center* of TDI is more fundamentally linked to the TI Team's informed judgment.

Based on our observation of the implementation of the SSHAC Level 2 process and our review of the technical bases and justifications provided by the TI Team for their representation of the CBR of TDI, we concur that the March 28, 2013 version of the updated GMM appropriately captures the CBR of TDI. In particular, we note the following:

- The multi-stage engagement by the TI Team of resource and proponent experts from the larger technical community gives us assurance that the TI Team's decisions to eliminate some older ground motion prediction equations (GMPEs) and to substitute/include more up-to-date GMPEs, which predict lower mean ground motions than the older GMPEs, are well founded and not just reflections of the TI Team's own experience and opinions.
- Despite the great increase in available ground-motion recordings in the CEUS since the development of the EPRI (2004, 2006) GMM, the TI Team's recognition of the limitations of these data for predicting future ground motions in critical magnitude-distance ranges is an important element of their latest updated GMM. Significantly, the TI Team has (1) abandoned an earlier decision to give greater weight to data consistency and (2) added a contribution to epistemic uncertainty that aims to capture increased uncertainty due to the relative lack of empirical data and knowledge of magnitude scaling for earthquakes of magnitude 5 and greater in the CEUS.
- Ground motion data used to evaluate GMPEs are adjusted to take into account site conditions of the recording stations. Uncertainties in the adjustments are incorporated appropriately. The adjustments mitigate a known bias in the use of the ground motion data to test GMPEs developed for a nominal site condition of 2800 m/s.
- The characterization of aleatory variability, updating the approach used for the existing EPRI GMM, is based on the most current information from the NGA-West and NGA-West2 projects.
- The model updates the characterization of ground motion for the Gulf Coast region to incorporate current data and technical results, including NUREG-2115 (2012) and studies based on data recorded by regional network stations of the Advanced National Seismic System (ANSS) and by EARTHSCOPE Transportable Array stations.

RESTATEMENT OF THE PPRP'S POSITION

Based on our observation of the implementation of the SSHAC Level 2 process and our review of the technical bases and justifications provided by the TI Team for their representation of the CBR of TDI, the PPRP concurs that the March 28, 2013 version of the updated EPRI (2004, 2006) Ground Motion Model appropriately captures the CBR of TDI.

This concludes our current PPRP feedback. Please contact us if you wish to discuss any of our observations or comments.

For the PPRP,



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R. P. Kassawara (EPRI)
J. F. Hamel (EPRI)

APPENDIX — ACRONYMS

ANSS	Advanced National Seismic System
CBR	Center, Body, and Range
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
HID	Hazard Input Document
NGA-West	Research project to develop a new ground motion characterization (Next-Generation Attenuation) model for Western North America
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC Nuclear Regulation Report
PPRP	Participatory Peer Review Panel
SSHAC	Senior Seismic Hazard Analysis Committee
TDI	Technically Defensible Interpretations
TI Team	Technical Integration Team

May 14, 2013 (rev. May 21, 2013)

Via e-mail

Lawrence A. Salomone
Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 9430

Dear Mr. Salomone:

Reference: *EPRI (2004, 2006) Ground Motion Model Review Project*, PPRP Review
Comments (PPRP Report #6) on the Draft Project Report

The purpose of this letter is to communicate the review comments of the Participatory Peer Review Panel (PPRP) on the draft project report of April 26, 2013. The PPRP has already concurred with the Updated EPRI (2004, 2006) Ground Motion Model (PPRP Report #5 dated April 5, 2013). Therefore, the primary focus of this review is on (1) the clarity and completeness of the project report and (2) whether all technical assessments made by the Technical Integration (TI) Team have been adequately justified, defended, and documented. Our review comments are appended.

All four members of the PPRP (Walter J. Arabasz, Brian Chiou, Richard C. Quittmeyer, and Robert B. Whorton) participated in the review and jointly discussed the PPRP review comments, including consensus on the labeling of “mandatory” review comments (see below).

General Comments

- The PPRP members agreed that, in general, the documentation in the various parts of the draft project report was significantly improved, better organized, and more complete than the Intermediate Document provided to us on January 18, 2013.
- Having said that, our PPRP review was challenging. It became apparent that many sections of this draft had not received the kind of thorough technical editing by support staff that we had expected. In certain areas, this required us to make many editorial suggestions to ensure clear descriptions of process, technical assessments, and conclusions in the report.
- As requested, we have distinguished “mandatory” and “non-mandatory” review comments. Mandatory comments must be addressed by the TI Team in their final documentation of the project report; non-mandatory comments are intended to help improve the final project report—to be handled by the TI Team as feasible and at their discretion.
- We have attempted to make our written review comments form a stand-alone document. However, to facilitate revision of the draft report, and upon your request, we are also providing companion Microsoft Word markups of individual parts of the report with suggested revisions of text and other editorial notes.
- The draft project report initially provided for our review was, to a minor extent, incomplete. We reviewed the material provided and noted in our comments and markups which tables, figures, and appendices were missing. Some of the items missing from the original material sent on April 26, 2013 (notably Appendix A and parts of Appendix G), were later provided, and comments on those materials have been added to this review.

GMM RP_PPRP #6_final

- We have not assumed responsibility for *comprehensive* technical editing, leaving that task to the Project Team's support staff.
- In some of our markups, replacement text is liberally suggested. All editorial markups should be viewed as indicating suggested alternative wording for improved clarity—not a dictation of how the TI Team should word its report.
- Ordinarily, editorial suggestions would be considered non-mandatory review comments. However, in our review we encountered many cases where we judged that editorial changes or additions were essential either for completeness, accuracy, or clear communication to the reader. In such cases we have made the review comment a mandatory one.

Separate Report on Shear Wave Velocity Measurements

EPRI Report 3002000719, *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project: Shear Wave Velocity Measurements at Seismic Recording Stations, April 2013*, was developed to obtain shear-wave velocity measurements at some of the key stations in the NGA-East ground-motion database. The V_{S30} and velocity profile at each station were determined by non-invasive geophysical methods such as seismic refraction, spectral analysis of surface waves (SASW), and multichannel analysis of surface waves (MASW). The shear wave velocity data were used by the TI Team to develop scaling factors to adjust the recorded ground motion data to be representative of the reference site conditions.

Although the PPRP is not responsible to review EPRI Report 3002000719 in detail, our general review finds that the effort was conducted in accordance with the Project Plan, and the separate report contains thorough documentation of the geophysical conditions and methods used at each recording station for use in developing scaling factors for the ground motion model update. Summary results are adequately presented in Chapter 4 of the draft project report.

This concludes our PPRP feedback on the draft project report. Please contact us if you wish to discuss any of our comments.

For the PPRP,



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J. F. Hamel (EPRI)

PPRP WRITTEN REVIEW COMMENTS:**EPRI (2004, 2006) GROUND-MOTION (GMM) REVIEW PROJECT (APRIL 26, 2013)**

Explanation: For each part of the draft project report, we provide corresponding written review comments, sequentially numbered and keyed to each part of the report and identified as general or specific. The latter are marked as either mandatory or non-mandatory.

FRONT MATTER

(A separate marked-up Word file contains other suggested edits to various parts of the Front Matter, including extensive suggestions for the Abstract and Executive Summary.)

Title Page-1 (specific, non-mandatory). *EPRI Product ID Number and format for citation of report.* The EPRI Product ID Number is the same as for the shear-wave report. (Is this intentional?) On the back of the title page the specified format for citing the report is problematic—e.g., other EPRI reports cited in Chapter 10 (References) in the present report do not follow this format; in a standard list of references, a citation requires some leading indication of authorship or agency attribution.

Table of Contents-1 (specific, mandatory). *List of Appendices.* List of Appendices needs to be added.

Abstract-1 (specific, mandatory). *“High” level of assurance.* In the last sentence of the third paragraph on p. vii, the text states, “. . . the project used an enhanced SSHAC Level 2 assessment process. Therefore, the updated model can be used with confidence . . . with a high level of assurance that the spectra properly represent current technical knowledge.” The authors need to carefully consider whether to claim “a high level of assurance” (which is also used in the Executive Summary). If this is intended to connote “regulatory assurance,” it is arguable whether a SSHAC Level 2 process (albeit “enhanced”) leads to a “high” level (see, for example, Table 4-2, p. 56, and Section 3.3, p. 37 in NUREG-2117). See also Comment **Executive Summary-2**.

Abstract-2 (specific, mandatory). *Total number of stations with V_{S30} data?* In paragraph 4 of the Abstract, the description of the shear-wave velocity data raises the questions, How many stations in total had shear-wave velocity data (V_{S30}) available to enable adjusting for recording-site conditions? And what fraction did this represent of the total number of stations used? The reader will not easily find the answers in the report.

Abstract-3 (specific, non-mandatory). *Suitability of Updated GMM for other seismic regulatory purposes.* In the next-to-last paragraph of the Abstract, the statement is made that “The updated EPRI (2004, 2006) GMM is suitable for use to address the seismic regulatory issues in USNRC, 2012 as well as for other seismic regulatory purposes pending completion of the NGA-East Project.” Is this proposition stated and/or discussed in the main body of the report? (We can’t find it.)

Executive Summary-1 (specific, non-mandatory). *Reader alert needed.* At the very outset of the Executive Summary, in some kind of note, the reader should be informed (a) why the Executive Summary is so long and detailed (consider labeling it “Expanded Executive

Summary”) and (b) that references cited in the Executive Summary are listed at its end for the reader’s convenience. Readers missing the latter information will seek information in Chapter 10 (References). Individual references in both places should be identical—not, for example, CEUS (2012) in the Executive Summary and EPRI/DOE/NRC (2012) in Chapter 10. If a shorthand alias is needed, define one in the text.

Executive Summary-2 (specific, mandatory). *“High” level of assurance (cont’d).* In the fourth paragraph of the Executive Summary, the text states, “The EPRI (2004, 2006) GMM Review Project implemented an enhanced [SSHAC] Level 2 study in order to provide a high level of assurance that” As in the Abstract, the claim of “a high level of assurance” may invite argument in the context of regulatory assurance (again, see Table 4-2, p. 56, and Section 3.3, p. 37 in NUREG-2117). The project needs to anticipate this criticism and be prepared to defend whatever wording it chooses.

Executive Summary-3 (specific, non-mandatory). *SSHAC terminology.* For global technical editing in the report: In various parts of the Executive Summary, and in parts of the body of the report, the phrase “resource experts and proponents” appears. SSHAC guidance defines “resource experts” and “proponent experts” (e.g., NUREG-2117, p. 45). We suggest following the SSHAC terminology, writing for example, “resource and proponent experts.” Also, decide whether to consistently capitalize Resource Expert and Proponent Expert when referring to their SSHAC roles (as in Section 3.2.8).

Executive Summary-4 (specific, mandatory). *Labeling in Table 2.* The title of the table should indicate that cluster weights are included in the table. The parenthetical presentation of the weights is not explained, i.e., (area sources/repeated large-magnitude earthquake sources) and is critical for the reader’s understanding. (Where in the main body of the report does this table appear?)

Abbreviations-1 (specific, mandatory). *Missing and mislabeled entries.* The list of abbreviations and symbols should be checked for completeness. Missing entries for FTP and V_{S30} were noted; besides NGA, it would also be helpful to explain NGA-East and NGA-West. Also, needed corrections were noted for ANSS (Advanced National Seismic Design System) and TI Team (Technical Integrator Integration Team).

CHAPTER 1—INTRODUCTION

(A separate marked-up Word file contains other suggested edits for Chapter 1.)

Ch. 1-1 (general). This chapter is informative, appropriately succinct, and for the most part well written. Some concerns regarding clarity are described in the following specific comments.

Ch. 1-2 (specific, non-mandatory). *Usage of “require.”* Throughout this chapter, care needs to be taken in any usage of the word “require” (particularly given the regulatory context of this project), and all instances should be checked (see marked-up Word file). In referring to NUREG-2117, it should be noted that the latter consistently refers to “recommendations”—including the contents of Table 6-1 in NUREG-2117. NUREG-2117 does, however, notably use the term “require” when referring to circumstances warranting replacement or refinement of an existing hazard study.

Ch. 1-3 (specific, mandatory). *Explicit explanation of “CBR of TDI.”* In Section 1.1.2, which gives the reader background information on “Present-Day NRC Seismic Regulatory Requirements and Guidance,” the text fails to describe for the reader, in a sufficiently explicit way, the fundamental present-day goal of describing the CBR of TDI. The information is admittedly embedded—for the astute reader to find—within the definition of “Integration,” but the terminology needs to be clearly explained to ensure that the reader understands the importance of this key concept. The issue of suitably representing the CBR of TDI arises in later parts of the report and was central to evaluating both the EPRI (2004, 2006) GMM and its updated version in this project. Some significant points that could be mentioned:

- At a minimum: Recast language in NUREG-2117 that emphasizes the CBR of TDI
- The need to capture the CBR of TDI of each component of a seismic hazard study, which should lead to capturing the CBR of the whole
- While the body and range of TDI can sensibly be compared to the available views of the larger technical community, the center of TDI is “the best estimate or central value (median) of the distribution of possible outcomes” as determined by a group of evaluation experts, namely, the TI Team (see NUREG-2117, section 3.1, p. 33).

Ch. 1-4 (specific, mandatory). *NRC guidance for updating seismic hazard models.* In Section 1.1.4 (first paragraph), obsolete terminology is used in referring to guidance in NUREG-2117 regarding the updating of seismic hazard models and needs to be corrected. NUREG-2117 (Rev. 1) contains no language—as did an earlier version of the NUREG—relating to “revise (modify).” The revised version of Chapter 6 in NUREG-2117 addresses “replace” and “refine” as the only actions in updating probabilistic hazard assessments.

Ch. 1-5 (specific, non-mandatory). *Versions of the updated GMM.* In Section 1.4.2, Chapter 1 introduces the Updated EPRI (2004, 2006) GMM. Later in Chapters 2 and 3 a fundamental issue of documentation (and consistent terminology for clarity) arises regarding the versions of an updated GMM that were developed in this project:

- Development of the “preliminary” updated GMM that was presented at the October 2012 workshop
- Development of the “draft” updated GMM that was presented at the February 2013 Closure Briefing (the term “draft” emerges in Section 3.4.6)
- Completion of the “final” Updated GMM after the Closure Briefing and specified in the HID of March 28, 2013

Neither the Abstract nor the Executive Summary introduces the reader to this process, which must be clarified at least in Chapters 2 and 3. It would be helpful to introduce the reader to these points in Section 1.4.2 of the Introduction.

CHAPTER 2—PROJECT PLAN

(Two separate marked-up Word files contain flagged typos and other suggested edits for Chapter 2. Note edit on Table 2.2.6-2 in one of the files regarding the term “Resource Expert Observer.”)

Ch. 2-1 (general). This chapter reasonably describes the Project Plan in a summary way, but improvement is needed in describing some important aspects of the project—notably the steps toward finalizing an updated GMM and the writing of a “draft” project report. There is a

difference between what was anticipated in the Project Plan and what actually happened. Between relevant sections in Chapters 2 and 3, this needs to be sorted out, communicated clearly to the reader, and documented for the future.

Ch 2-2 (specific, mandatory). *Need to include title and date of the Project Plan.* As part of the project's documentation, the title and date (final revision) of the Project Plan should be provided, perhaps in a footnote.

Ch. 2-3 (specific, mandatory). *Updated EPRI (2004, 2006) GMM.* If Chapter 1 does not alert the reader to the various versions of an updated GMM developed in this project—and corresponding descriptors (see Comment **Ch. 1-5**), then this should be done by the time reader encounters Section 2.2.5 (Task 5—Update EPRI (2004, 2006) GMM).

Ch. 2-4 (specific, non-mandatory). *Description of Task 8.* Section 2.2.8 presents bulleted details on the process of how the updated GMM was finalized. These are repeated in Section 3.4.8, which seems a more appropriate place to provide these details. To avoid the repetition in Section 3.4.8, suggested edits are provided in a separate marked-up Word file for abbreviating the discussion—consistent with how other tasks are described in a more general way in Chapter 2.

Ch. 2-5 (specific, non-mandatory). *Draft project report.* The documentation and review of a draft Project Report is addressed in Sections 2.2.9 and 2.2.10 (and later in Sections 3.5.2 and 3.5.3). One of the particular circumstances of this project is that a draft project report was not completed before the Closure Briefing. This is documented in our PPRP reports—because we had to explain how we could concur with an updated GMM without having seen a completely written draft project report. But it also needs to be spelled out in the project report (some suggestions are made in the separate marked-up Word files).

CHAPTER 3—SSHAC LEVEL 2 ASSESSMENT PROCESS AND ITS IMPLEMENTATION FOR THIS STUDY

(A separate marked-up Word file contains other suggested edits for Chapter 3.)

Ch. 3-1 (general). The first several pages of this chapter were carefully written, and we have tried to be sensitive to the need to preserve correct wording in our suggested edits. However, Comment **Ch. 2-1** also applies to Chapter 3, and the corresponding sections need to be clarified, as indicated by our markups.

Ch. 3-2 (specific, non-mandatory). *“CBR of TDI.”* Regarding Section 3.1: As noted in our Comment **Ch. 1-3**, explicit mention of “the CBR of TDI” is desirable. Depending on how our earlier (mandatory) comment is handled in Chapter 1 within the context of NRC requirements and guidance, some comparable but abbreviated mention of the CBR of TDI can usefully be included here.

Ch. 3-3 (specific, mandatory). *Responsibilities—TI Lead vs. TI Team.* In Section 3.2.4, the sentence preceding the bulleted list of responsibilities should be modified to clarify (as we believe to be correct) that these apply to the entire TI Team and not just the TI Lead.

Ch. 3-4 (specific, mandatory). *Description of how the draft and final updated GMMs were completed and reviewed.* Section 3.4.6 is critical for accurate documentation of how the updated GMM was finalized, and the text needs to be clarified. In a separate marked-up Word document we have liberally made numerous suggestions for improving this section (describing our view of what actually happened). As elsewhere, our intent is not to dictate the wording of the report, but the TI Team and PM need to pay particularly close attention to the wording of this section.

Ch. 3-5 (specific, mandatory). *Description of draft project report.* As in our comments on Section 2.2.9, what constituted the draft project report should not be ambiguous for future readers (some suggestions are made in the separate marked-up Word files).

Ch. 3-6 (specific, mandatory). *Title and content of Section 3.7.* The title of Section 3.7—“Consistency of EPRI (2004, 2006) GMM Review Project with SSHAC Guidelines”—is misleading; both the title and content of this section need to be revised or restructured in combination with those of Section 3.8. Section 3.7 includes only an outline of the guidelines, it does not describe how the Review Project was consistent with the guidelines.

CHAPTER 4 — RESULTS: SHEAR WAVE VELOCITY MEASUREMENTS AT SEISMIC RECORDING STATIONS

(A separate marked-up Word file contains other suggested edits for Chapter 4.)

Ch. 4-1 (specific, mandatory). *Introduction.* For the reader to understand this section, the introduction needs more specific reference to the separate EPRI Report 3002000719. Consider the following example introductory paragraph, provided in the Chapter 4 mark-up:

Detailed site characterization studies for the EPRI (2004,2006) Ground-Motion Model Review Project are contained in a separate EPRI Report 3002000719, “EPRI (2004,2006) Ground-Motion Model (GMM) Review Project: Shear Wave Velocity Measurements at Seismic Recording Stations,” April 2013.

Ch. 4-2 (specific, mandatory). *Section 4.3.* The first bullet observation relating “hard” rock sites being below the CEUS reference rock velocity of 2,800 m/s is not appropriate. Suggested wording is provided in the Chapter 4 mark-up.

Ch. 4-3 (specific, mandatory). *Section 4.4.* The described use of USGS shear wave velocity data is not complete. At a minimum, an appropriate reference needs to be cited, along with identification of section(s) within the report where this information is utilized.

Ch. 4-4 (specific, mandatory). *Figure 4-1.* This figure is missing the “overlapping” UT site station symbol in Virginia.

CHAPTER 5—EPRI (2004, 2006) GROUND-MOTION MODEL (GMM): OVERVIEW OF KEY FEATURES

(Two separate marked-up Word files contain other suggested edits for Chapter 5.)

Ch. 5-1 (General). The text in Chapter 5 is reasonably well written, but the chapter would benefit from restructuring and adding identified subsections to better guide the reader. Section 5.3 (beyond its first introductory sentence) inexplicably is a lengthy verbatim repeat of most of Section 2.1

Ch. 5-2 (specific, non-Mandatory). *Suggestions for restructuring subsections and headings.*

- Insert **5.1.1 Historical Background** (or a similarly worded heading) immediately following **5.1 EPRI (2004) GMM Framework** and include the first three paragraphs of existing text.
- On p. 5-2, consider inserting **5.1.2 Grouping GMPEs into Clusters** before the second paragraph and begin, “An important outcome of Workshop 1 in the EPRI (2004) project was consensus . . .”
- On p. 5-2, consider inserting **5.1.3 Methodology Steps** before the third full paragraph beginning, “The EPRI (2004) project used a three-step process . . .” and include the remainder of text on p. 5-2.
- On p. 5-3, consider inserting **5.1.4 Adjustment for Gulf Coast Region** before the first paragraph.
- On p. 5-3 (strongly recommended), consider inserting **5.2 EPRI (2004) Aleatory Model Studies** before the second paragraph beginning, “EPRI (2004) developed models for aleatory variability . . .” and include the remainder of the existing subsection. Clearly separating the descriptions of the 2004 and 2006 aleatory models will be helpful.
- If the preceding suggestion is followed, on p. 5-4 renumber subsection 5.2 to **5.3 EPRI (2006) Aleatory Model Study**.

Ch. 5-3. (specific, non-mandatory). *Independence of the PPRP.* Inclusion of the PPRP in the definition of “Project Team” may lead to confusion regarding the independence of the PPRP in the EPRI (2004) GMM project. Consider re-wording the sentence to state that the Project Manager and TI Team concluded that a SSHAC Level 3 process was appropriate and that the PPRP concurred with that conclusion.

Ch. 5-4 (specific, non-mandatory). *Deletion of Section 5.3.* Because virtually this entire section repeats Section 2.1, we suggest it be deleted. One can simply end Chapter 5 by writing something like, “We refer the reader to Section 2.1 for a description of how the EPRI (2004, 2006) GMM was evaluated before the start of this project, with the help of recognized ground-motion experts, to make a preliminary determination whether the GMM needed updating.”

CHAPTER 6—RESULTS: GROUND-MOTION DATABASE, IDENTIFICATION OF NEW CEUS GMPES, ADJUSTMENT OF RECORDED MOTIONS, AND COMPARISONS OF OBSERVATIONS TO EPRI (2004) GMM

(Two separate marked-up Word files contain other suggested edits for Chapter 6.)

Ch. 6-1 (General). This chapter basically describes the work to complete Tasks 2-4 of Phase 1 of the project, leading up to the August 2012 Working Meeting #5, (described at the end of the chapter in Section 6.5.2), where Decision Point 2 was addressed. Readers will need better guidance in following some details of this chapter, which are a prelude to Chapter 7 where the details of the final Updated GMM are presented.

Ch. 6-2 (specific, non-mandatory). *Chapter title.* Following on Comment Ch. 6-1 (General)—and to contrast with the title of Chapter 7—consider a chapter title such as, “Evaluation of the EPRI (2004, 2006) GMM in Light of New Data, Models, and Methods.” Another reviewer adds, “The decision to update EPRI (2004) GMM is an important outcome of the works described in this chapter, and an important milestone of the project. Why is it not mentioned in the chapter title?”

Ch. 6-3 (specific, non-mandatory). *Careful re-examination of contents of Chapter 6.* Following on Comment Ch. 6-1 (General), we suggest that the entire contents of Chapter 6 be re-examined to ensure clear communication to the reader about the process of Phase 1. Instead of inserting afterthoughts (“it is worth noting”) to alert the reader when preliminary results or methods used in Phase 1 differ from those presented in Chapter 7, it would be useful to have guidance at the front end of the chapter, first, to convey that there were some evolutionary changes during the project and, second, for the reader to understand the contents of the chapter vis-à-vis counter-part information in Chapter 7.

Another reviewer adds, “Reading the same (or similar) material in several different places in the report could hamper readability and frustrate readers. The TI Team needs to carefully examine the necessity for repeating information. This comment also applies to other chapters, particularly Chapter 7.”

Ch. 6-4 (general). Section 6.1.2 is an excellent summary, highly readable and informative.

Ch. 6-5 (specific, mandatory). *Evaluation of current suite of GMPEs.* Section 6.1.2.1: Given the organization of the report, with Chapter 7 describing the updated model and Chapter 6 the compilation and evaluation of new information and its comparison to the existing model, conclusions regarding applicability of GMPEs for an updated model should be discussed in Chapter 7 rather than Chapter 6. Provide the evaluation of the models in Chapter 6, but give the conclusions regarding the suite of GMPEs to be used and not used in the updated model in Section 7.4.1.

Ch. 6-6 (specific, mandatory). *Evaluation of EPRI (2004) GMPEs.* Section 6.1.2.1: The evaluations of the GMPEs included in EPRI (2004) needs to be presented in sufficient detail that they provide the technical basis for including or excluding the GMPEs in the updated GMM described in Chapter 7. During the 2002-2003 evaluation and integration for EPRI (2004), the models were determined, through a SSHAC Level 3 process, to be technically defensible and

viable. For example, Hwang and Huo, with its limited range, was included. For those that are evaluated to no longer be viable or no longer needed to represent the CBR of the TDI, the technical basis determined by the current TI Team needs to be provided. The bases need to show the TI Team's rationale and justification, not just the developer's current judgment. The developer is not part of the TI Team (in most cases) and acts as a resource or proponent, not an evaluator.

Ch. 6-7 (specific, mandatory). *Template profiles.* Section 6.2.1.1: Given the importance of the ground motion adjustments, for completeness of documentation, add a table to Chapter 6 or Chapter 7 that lists the template profile values.

Ch. 6-8 (specific, non-mandatory). *Magnitude range used for comparison* Section 6.3.2.: Consider commenting on why for the analytically adjusted data comparisons to the EPRI (2004, 2006) GMM are made for data from $M > 3.75$ earthquakes, but for the empirically adjusted data, comparisons are made for data from $M > 4.75$ earthquakes.

Ch. 6-9 (specific, mandatory). *Epistemic Uncertainty.* Section 6.4.2 concludes that "the EPRI (2004) GMM is overestimating epistemic uncertainty." This statement needs to be qualified so that the reader does not misinterpret it as applicable to all magnitudes and all distances. Contrary to this statement, as discussed in Chapter 7, serious efforts were made to expand the epistemic uncertainty for $M > 5$, and the updated uncertainty for this M range is now larger than EPRI (2004) GMM.

Ch. 6-10 (specific, non-mandatory). *Bullet #2, page 6-9.* Section 6.5: It would help strengthen the rationale if it is mentioned that their inclusion was also recommended by experts as stated in Section 6.1.2.

Ch. 6-11 (specific, mandatory). *Updated basis for aleatory variability in ground motion.* Section 6.5: The last bullet in Section 6.5 indicates an updated basis exists, relative to that used in the EPRI (2004, 2006) GMM, to assess aleatory variability in ground motion for CENA. However, there is no discussion prior to this of the updated data that were compiled and evaluated to reach this conclusion. Add a section to Chapter 6 that summarizes the compilation and evaluation of new information since 2006 that bears on whether it is appropriate to update the aleatory component of the EPRI (2004, 2006) GMM.

Ch. 6-12 (specific, non-mandatory). *Bullet #2, page 6-9.* It would help strengthen the rationale if it is mentioned that their inclusion was also recommended by experts as stated in Section 6.1.2.

Ch. 6-13 (specific, non-mandatory). *Figures.*

- Figures 6.3.1-1 through 6.3.112 are missing
- The two plots in Figure 6.1.1-1 are identical

CHAPTER 7—UPDATED EPRI (2004, 2006) GMM

(Three separate marked-up Word files contain other suggested edits for Chapter 7. Also, a separate pdf file includes editorial comments on Chapter 7 figures.

Ch. 7-1 (general). Compared to the previous documentation, materials in this chapter are better organized and the explanations are easier to follow, thanks to the translations of mathematically challenging formulations into plain English. More such translation will definitely help improve the readability of this chapter.

Ch. 7-2 (specific, non-mandatory). *Usefulness of a roadmap.* Chapter 7 includes long discussions on complicated and sometimes difficult to understand topics. A roadmap, in an easy to understand manner, describing the steps it took to reach the final updated GMM would help readers navigate through this chapter and usefully help a less technical reader skip the more technical sections in his/her first reading.

Ch. 7-3 (specific, mandatory). *Accuracy of section cross-references.* There are instances in Chapter 7 in which cross-references to other report sections are inaccurate. The report needs to be carefully reviewed to ensure that cross-references are accurate and conform to the final outline of the report. For example, on page 7-8, “As discussed in Section 7.1, the lower limit of 500 m/sec was used . . .” but such discussion was not found in Section 7.1.

Ch. 7-4 (specific, mandatory). *Data used in the analysis.* (a) Because some earthquakes (i.e., Gulf Coast Domain earthquakes) and recordings (i.e., those obtained at stations with Vs30 less than 500 m/s) are excluded from the analysis, but included in the Updated EPRI GMM database, it is important to explicitly note if such earthquakes and data are included in figures and tables that have titles such as Table 7.2.6-1 Number of Earthquakes in Final Ground-Motion Database or Figure 7.2.6-1 Magnitude-distance distribution of rock site ground motion data. Do these numbers/data include or exclude the Gulf Coast Domain earthquakes? Earthquakes with magnitude less than 3.75? (b) Similarly, use of magnitude-distance bins that include distances up to only 500 km implies that data from distances greater than 500 km are not used in assessing the GMPEs and Clusters. Clearly specify in the text or on the Figures and Tables that include data from beyond 500 km whether those data were used in analyses. For figures, consider discriminating visually those data not used in the analyses (e.g., recorded beyond 500 km). For purposes of discussion in the text, it may be useful to refer to a “Project database” that includes all the data compiled for the study and a “Final Analysis database” that includes only those data actually used for development of the Updated EPRI GMM. It is acknowledged that differences between the final project database and the one used to evaluate the EPRI (2004, 2006) GMM make this simple distinction more complicated, but it is important for the reader to understand what data are being used at each stage of the Project and if this differs from the total amount of data compiled.

Ch. 7-5 (specific, mandatory). *Discussion of data selection.* Discussions of data selection (exclusion) are spread throughout Section 7.2. Placing them in one dedicated subsection will be important, as data selection is a frequently asked question.

Ch. 7-6 (specific, mandatory). *Completeness of figures and tables provided for review.* During review of Chapter 7 it was noted that a number of figures and tables were not initially provided

for review. While a few of these were subsequently provided in response to specific requests or are available (at least in draft form) in project presentations made over the past year, some final versions still remain outstanding (e.g., Figures 7.11-XX). The report needs to be thoroughly reviewed to ensure that all cited figures and tables are included in the report.

Ch. 7-7 (specific, non-mandatory). *Candidate GMPEs.* When GMPEs are being considered for inclusion in the Updated EPRI GMM it is appropriate to refer to them as “candidate” GMPEs. Once the TI team has integrated the GMPE evaluations to determine the GMPEs that represent the center, body, and range for the Updated EPRI GMM, they are no longer candidates; they have been elected. Once the final selection of the GMPEs has been discussed in the report, consider no longer referring to the GMPEs as “candidate.”

Ch. 7-8 (specific, non-mandatory). *Distance range for Cluster 2 plots.* Plots for Clusters 1, 3, and 4 generally go to 1000 km, but plots for Cluster 2 often go beyond 1000 km. Is this significant? Consider providing all results as a function of distance consistently for each Cluster.

Ch. 7-9 (specific, non-mandatory). *Rock profiles vs. reference rock profile.* Provide discussion of whether the rock profile specified in each candidate GMPE is the same or similar to the reference rock profile described on page 7-9 for the EPRI GMM model.

Ch. 7-10 (specific, non-mandatory). *Redundancy of Sections 7.1.1 and 7.1.2.* Section 7.1.1 is redundant with a more detailed discussion in Chapter 3. Similarly, Section 7.1.2 is redundant with material presented in Chapters 4 and 6. While completeness is important, excessive redundancy becomes distracting to the reader. Consider deleting these sections.

Ch. 7-11 (specific, non-mandatory). *Need for EPRI (2004, 2006) GMM Update.* Section 7.2.1: It is noted that not all data in the ground motion database used for developing the EPRI (2004) GMM is included in the NGA-East database used for the Updated EPRI GMM. Consider citing the fact that data used in the 2004 GMM do not meet current criteria for inclusion in the NGA-East database as part of the rationale for reaching the conclusion that an update should be considered. Also note that not including vertical-converted-to-horizontal data eliminates an uncertainty and is considered an improvement over the EPRI (2004, 2006) GMM approach.

Ch. 7-12 (specific, non-mandatory). *Use of geometric mean horizontal peak motion.* Section 7.2.2.2: Consider stating whether or not this choice for the Updated EPRI GMM is consistent with the approach used in the EPRI (2004, 2006) GMM.

Ch. 7-13 (specific, mandatory). *Problems with figures and tables.*

- All figures for Section 7.2.4 are missing.
- Table 7.2.6.-1: Explain why the number of earthquake varies across periods.
- Table 7.2.6-2: Explain why the 25Hz PSA data is smaller in size than other frequencies.
- Figure 7.2.6-2: Why the number of earthquakes plotted on this map is less than the number given in Table 7.2.6-1? If easy to do, make the size of symbol proportional to earthquake magnitude.
- Figure 7.3.1.1-1: Figure legend missed three curves (rock profiles).

- Figure 7.3.1.1-2 (optional): Place axis with metric unit on the left side of plot, to be consistent with the other plots.
- Figure 7.7.1-1: Incomplete plot.
- Figure 7.8.1-4f: Wrong plot.
- Tables and Figures for Section 7.10.2 are missing.

Ch. 7-14 (specific, mandatory). *Documentation of station attributes.* Section 7.2.5: The report would benefit from a Table that summarizes the following information: Total number of stations at which data were recorded, number of those stations for which Vs30 is “measured,” number of stations for which Vs30 is “estimated,” for stations with measured and estimated Vs30, how many have Vs30 less than 500 m/s. Also, for the empirical site ground motion adjustments, the number of stations classified as “soil,” “soft rock,” “intermediate rock,” and “very firm rock.” The above information would be further enhanced if, in addition to number of stations for each item, the number of recordings was also provided. Table 7.2.6-2 comes very close to providing the requested recordings information for empirical site classifications. Figure 7.2.5-1 is a useful complement to the requested table for Vs30 data, but does not show the information in the context of the total number of stations.

Ch. 7-15 (specific, mandatory). *Earthquakes excluded from the analysis.* Section 7.2.6: Because data from some earthquakes are excluded from the analysis, provide an indication in Table 7.2.3-1 (and any other tables that summarize the complete set of earthquakes providing data for the project) of which earthquakes were excluded and the reason. For example, a Table Note could be provided.

Ch. 7-16 (specific, mandatory). *Final distribution of the database.* Section 7.2.6: Each panel of Figure 7.2.6-1 looks identical. Check that the appropriate data is being plotted. From the existing figure it is not clear that “the amount of data for 25 Hz PSA is less than half that available for other frequencies.”

Ch. 7-17 (specific, mandatory). *Error in Figure 7.2.6-1.* Identical plots for all frequencies.

Ch. 7-18 (specific, mandatory). *Justification needed.* On page 7-12, provide justification on the sufficiency of using 2 profiles and 2 kappa in capturing the CBR of site correction factor. Explain why the base-case profile was given no weight.

Ch. 7-19 (specific, non-mandatory). *EPRI process versus SPID process.* Section 7.3.1.1: When listing the steps taken to define velocity profiles for the analytical ground motion adjustment approach, clarify (i.e., explicitly state) if the steps are the “slightly different” approach used in the Updated EPRI GMM or the “EPRI SPID (2013)” steps.

Ch. 7-20 (specific, non-mandatory). *Vs profile development.* Section 7.3.1.1: Consider enhancing Figures 7.3.1.1-2 and 7.3.1.1-3 to more completely and explicitly show how the profile development steps are implemented. For example, show the ET-SWET profile plotted along with the template profiles to show where it falls with respect to them. Show what portion of the final profile is based on data and what part is based on use of the template profiles. Show the relation of the two template profiles that bound the composite profile on Figure 7.3.1.1-3.

Ch. 7-21 (specific, mandatory). *Figure 7.3.1.1-3.* There seem to be more short velocity steps in extended profile than in the template profile for 900m/s (shown in Figure 7.3.1.1-1) below 44 m depth. Check the calculations.

Ch. 7-22 (specific, mandatory). *Use of 5 alternative Vs/kappa profiles.* Section 7.3.1.2: It is understood that 5 Vs profiles are run as part of the process for the analytic ground motion adjustment, but only 4 are used in developing the adjustment that is used. Clarify the purpose of running the base-case (best-estimate) profile, but not using its results. When results for the base-case profile are discussed or shown, clarify that they are not used in determining the adjustment.

Ch. 7-23 (specific, mandatory). *Alternative Vs profiles.* Section 7.3.1.2: Under “Typical Results” it states that the profiles used in developing analytical ground motion adjustments for station ET-SWET are shown in Figure 7.3.1.1-1 and 7.3.1.1-2. Neither of these figures shows the base-case and $\pm\sigma$ profiles that were used. Figure 7.3.1.1-3 shows the base-case profile, but not the two profiles that are actually used as the basis for the adjustment. A figure showing the profiles that are the basis for the adjustment, rather than just the base-case which is ultimately not used, should be included.

Ch. 7-24 (specific, mandatory). *Fourier spectrum from IRVT.* On page 7-14, explain why the Fourier spectrum of the recorded motion was calculated by IRVT, not from the acceleration time series. On page 7-15, it was stated that Fourier spectra were also calculated from the time series. This is confusing and needs more elaboration.

Ch. 7-25 (specific, mandatory). *GMPE used to determine empirical adjustments.* Section 7.3.2: The text indicates that EPRI (2004) Cluster 1 median GMPE was used to assess empirical adjustments. Section 7.3.3 implies that final empirical adjustment factors were based on all Cluster median GMPEs (“averaged over all GMPEs”). Clarify that other cluster median GMPEs were also used and that results for Cluster 1 are presented as an example. [Following Equation 7.3.2-3 there is reference to “all of the cases analyzed;” if not other GMPEs, clarify what the “cases” are.] If Cluster 4 was used, note whether the rift or non-rift version was implemented, or both depending on the earthquake.

Ch. 7-26 (specific, mandatory). *Empirical ground motion adjustment.* Section 7.3.2: Values for C_{SR} are shown in Figure 7.3.2-2 for different magnitude-distance ranges. Clarify which results (i.e., for which magnitude-distance range), or combination of results, is used to determine the C_{SR} value used in the actual adjustment. Summarize results in a Table.

Ch. 7-27 (specific, non-mandatory). *New GMPEs that update previous GMPEs.* Section 7.4.1.1: Consider expanding the discussion to indicate why each update of a previous version of a GMPE is an improvement. Expand on the benefits of “second generation” models relative to “first generation” models. While perhaps obvious to the TI team, it would be useful to document for the record that the second-generation changes are in fact improvements.

Ch. 7-28 (specific, mandatory). *Resource Expert input.* Section 7.4.1.1: Clarify whether Resource Experts concurred on the viability of retained models or whether they only commented on GMPEs that they themselves had been involved in the development of.

Ch. 7-29 (specific, mandatory). *Resource Expert judgment on GMPEs.* Section 7.4.1.1: Clarify that Resource Expert judgments on GMPEs were one input considered by the TI team in

determining what suite of GMPEs to use for the Updated EPRI GMM. While the TI team interacted with the technical community to obtain their judgments, the TI team then integrated those judgments along with all other information to arrive at a final set of GMPEs representing the center, body, and range of technically defensible interpretations, given the plan to follow the EPRI (2004) approach. Also, for GMPEs not retained, provide the technical bases.

Ch. 7-30 (specific, mandatory). *New basis for Clusters 2 and 3.* Section 7.4.1.2: Because the re-definition of the bases for Clusters 2 and 3 represents a departure from the approach in EPRI (2004), the reason that the existing bases are no longer supported and why the new ones are appropriate and adequate should be expanded. Is the underlying philosophy of EPRI (2004) retained, but just the outcome different, or was the philosophy used to define clusters updated for the Updated EPRI GMM?

Ch. 7-31 (specific, non-mandatory). *Earthquakes in different regions.* Section 7.4.2: Consider providing a Figure that shows which earthquakes are considered to occur in which regions, or shows the geographic extent considered for each region.

Ch. 7-32 (specific, mandatory). *Inconsistent use of $\sigma^2(m,r,f)$ magnitude scaling.* On page 7-29, Equation (7.4.4-4) and the text above it is inconsistent regarding the use of $\sigma^2(m,r,f)$ magnitude scaling. Also, the write-up on page 7-29 seems to be inconsistent with the text in Section 7.7.1.2. Section 7.4.4 needs to be updated to cover the technical basis for “cluster independent within-cluster epistemic uncertainty.”

Ch. 7-33 (specific, mandatory). *$\sigma_{data\ constraint}$.* It’s not clear how the standard errors of coefficients p_i , $i=1,4$, were used to establish $\sigma_{data\ constraint}$. More explanations are needed in Sections 7.4.4 and 7.7.1.2.

Ch. 7-34 (specific, mandatory). *Functional form for distance dependence of data-constraint-sigma.* Section 7.4.4: Provide the technical basis for the functional form used to describe the distance dependence of data-constraint-sigma. While the form beyond 150 km is described as linear (in distance log-amplitude space) between 150 and 500 km, when results are shown they extend out to 1000 km. Clarify.

Ch. 7-35 (specific, non-mandatory). *Terminology concerning mean residual.* Section 7.4.4: In Figure 7.4.4-1 a curve is shown as a function of log (Rjb distance). This sentence in which the figure is cited in Section 7.4.4 implies the curve shows “mean residual.” In the caption for Figure 7.4.4-1 the term “mean ground motion residual” is used. On the figure itself, the y-axis is labeled as “Bias of residuals.” In Table 7.7.1-1, values for P1, P2, P3, and P4 are described as for “parameters of data-constraint within-cluster standard deviation.” Clarify how all these terms are related and use consistent terminology where possible.

Ch. 7-36 (specific, mandatory). *Magnitude scaling uncertainty.* Section 7.4.4: Consideration of magnitude-scaling uncertainty is referenced to ground motion amplitude for **M** 5. Discuss the use of this approach for the SEL GMPE, which is based on simulations for **M** of 6 and greater and comment on whether or not this results in any limitations.

Ch. 7-37 (specific, mandatory). *Development of cluster weights: subjective weighting.* Section 7.4.5: Section 7.4 is described as providing the technical basis for the approaches used in the

Updated EPRI GMM. However, the technical basis for the subjective “confidence weights” is not provided in Section 7.4.5. As this is an important factor in developing the overall GMM, the technical basis for this aspect of the model should be presented at this point in the report.

Ch. 7-38 (specific, non-mandatory). *Rock categories.* Section 7.5.1: In the legends for Figure 7.5.1 rock categories (soft rock, intermediate rock) are mixed with a rock category criterion ($V_{s30} > 1890$ m/s). Consider consistently using the rock categories or their criteria rather than mixing the two.

Ch. 7-39 (specific, non-mandatory). *Figure 7.5.2.* Rearrange the plots so that they are in the same GMPE order as in Figure 7.5.1, for convenience of comparison between the two site adjustment approaches.

Ch. 7-40 (specific, mandatory). *Magnitude for data-constraint uncertainty.* Section 7.7.1.2: In the paragraph in which Figure 7.7.1-9 is cited, it states that “The total cluster-independent within-cluster epistemic uncertainty is set equal to the sum of the variance from the data-constraint uncertainty, which is considered to apply at M , . . .” It seems that something should follow “ M .” “at $M \leq 5$ ” because most data used to determine it are in that range? Or “at all M ”? Clarify.

Ch. 7-41 (specific, mandatory). *Justification needed.* Justify the use of confidence weight in Equation (7.7.1-3).

Ch. 7-42 (specific, mandatory). *Title of Section 7.7.2.* Title is incomplete.

Ch. 7-43 (specific, non-mandatory). *Magnitude and distance grid used to develop high and low GMPEs.* Section 7.7.2: Consider stating if the magnitude and distance grid used to generate the ground motion values that are fit to give the low and high GMPEs are the same as used for the median GMPE.

Ch. 7-44 (specific, mandatory). *Distance and aleatory variability adjustments.* Sections 7.8.1 and 7.8.2: Section 7.8.1 states that the coefficients for the distance adjustment equation (7.8.1-1) are given in Section 9.2. Section 7.8.2 states that coefficients for the aleatory variability addition equation (7.8.2-1) are also given in Section 9.2. This is not the case. Provide the correct cross-references. Perhaps the HID?

Ch. 7-45 (specific, mandatory). *Figure 7.8.1-4f.* Section 7.8.1: Replace Figure 7.8.1-4f in the review draft with the correct figure.

Ch. 7-46 (specific, mandatory). *Cluster weights for Cluster 4.* Section 7.9.3: Provide the technical basis and describe any limitations for determining the Cluster weight for Cluster 4 using data from earthquakes at magnitude less than M 6. While use of this Cluster is recommended only for seismic sources with earthquakes predominately greater than M 6, the weights for the Clusters, including Cluster 4, are based on data predominately from earthquakes of M 5 or less.

Ch. 7-47 (specific, mandatory). *Weights for high and low frequency.* Section 7.9.3: Weights for high and low frequency are combined for determining Cluster weights. Provide the weights used in combining results for high and low frequency and the technical basis for those weights.

Ch. 7-48 (specific, mandatory). *Basis for confidence weights.* Section 7.9.3: Part of the technical basis for the confidence weights is stated to be that Cluster 1 and 4 have “some degree of credibility.” Clarify if it is “some degree of credibility” (one assumes the GMPEs for Cluster 1 and 4 would not have been included if they did not have some degree of credibility) or a higher degree of credibility relative to Clusters 2 and 3, than the data-consistency weights would suggest. Also, expand the discussion of the technical basis for why weights of 2/3 and 1/3 for geometrical spreading of R^{-1} and $R^{-1.3}$, respectively, represent the CBR of the TDI, and therefore support the assigned confidence weights. [Note that an earlier comment suggests that the technical basis for the confidence weights should be discussed in Section 7.4.5. Section 7.4 addresses the technical basis for the model.]

Ch. 7-49 (specific, mandatory). *Explanation needed.* Above Equation (7.10.2-1), explain how the maximum standard deviation of 0.16 came about.

CHAPTER 8 — DEMONSTRATION HAZARD CALCULATIONS

(A separate marked-up Word file contains other suggested edits for Chapter 8.)

Ch. 8-1 (specific, mandatory). *Section 8.2, Test Sites.* Bullet listing of hazard curves for Houston and Jackson test sites are reversed and need correction. Suggested wording is provided in the Chapter 8 mark-up.

Ch. 8-2 (specific, non-mandatory). *Entire Chapter and Figures 8.2-8 to 10.* This chapter should consistently refer to the project as “Updated GMM”, rather than interchangeably using “Updated EPRI (2004, 2006) GMM”. Suggested wording is provided in the Chapter 8 mark-up.

Ch. 8-3 (specific, non-mandatory). *Figure 8.1-1.* It would be desirable to include (overlay) the Gulf Coast region on this figure for ease of reference with the hazard results. Suggest replacing with Figure 1.3-1 (from Chapter 1).

CHAPTER 9—INSTRUCTIONS FOR THE UPDATED EPRI (2004, 2006) GMM IN PSHA

Ch. 9-1 (specific, non-mandatory). *Both Chapter 9 and Appendix G?* Chapter 9 is short and covers no detailed information on the HID; details are provided in Appendix G and an electronic attachment. The current arrangement makes Chapter 9 seem unnecessary as most of its text is repeated in Appendix G. The TI Team could consider moving Appendix G to Chapter 9 or simply removing Chapter 9.

Ch. 9-2 (general). For comments on the HID, see the PPRP’s review of Appendix G.

CHAPTER 10 — REFERENCES

Ch. 10-1 (Specific, Mandatory). *Entire Chapter.* Need to add more description to the following three references: *Atkinson et al. (2011)*; *Campbell (2009)*; *Silva, 2012, Ch. 4*. Also, correct date of EPRI Report 3002000719 to “2013”.

CHAPTER 11—GLOSSARY OF KEY TERMS

(A separate marked-up Word file contains other suggested edits for Chapter 11.)

Ch. 11-1 (general). The Glossary is generally well written—thanks, in part, to earlier compilation and editing efforts made for the CEUS SSC project report (EPRI/DOE/NRC, 2012), and good efforts have been made to include useful terms for this report. Throughout, keep in mind that the Glossary is aimed at readers generally unfamiliar with the technical content of the report.

Ch. 11-2 (specific, non-mandatory). *Check for Legacy Terms that May Be Out of Place.* Near the very beginning, the reader will encounter a description for “Bayesian Approach” (relating to Mmax), which seemed out-of-place for this report. A global search of Chapters 5–8 failed to find the term, although “Schwartz-Bayesian Information Criterion” was found. This suggests that the members of the TI Team should peruse the Glossary to see if perhaps this and any other legacy terms from the CEUS SSC Glossary ought to be removed from the Glossary for this report.

Ch. 11-3 (specific, non-mandatory). *Project-Specific Definitions.* Where terms are included that are specific to this project (e.g., Senior Technical Advisor, Working Meeting, Workshop), consider beginning the definitions with, “For this project, . . .”

APPENDIX A—DESCRIPTION OF GEOGRAPHICAL INFORMATION SYSTEM (GIS) DATABASE [Provided to PPRP on May 16, 2013]

(A separate marked-up Word file contains suggested edits for Appendix A.)

App. A-1 (general). This appendix, like many other sections we have reviewed, suffers from the lack of prior technical editing. Final revision will require close attention.

App. A-2 (specific, mandatory). *Missing parts.* Table A-1, Attachment A-1, and A-2, all mentioned in the text, are missing.

App. A-3. (specific, mandatory). *V_{S30} available at how many stations?* Section A.1 fails to inform the reader how many stations had available V_{S30} data for project use—either measured or estimated, and from whatever sources.

APPENDIX B—DOCUMENTATION FOR LITERATURE REVIEWS

(A separate marked-up Word file contains other suggested edits for Appendix B.)

App. B-1 (specific, non-mandatory). *Organization.* Traditionally, the Introduction is the first section in a Chapter. Consider moving the Introduction to come before the list of documents that were reviewed. Also, the “References” section could be eliminated and the list simply added at the end of the Introduction.

App. B-2 (specific, mandatory). *Introduction.* The first paragraph of the Introduction reads as if it were from a plan for future work rather than a description of work that is completed. Also, it

is not necessary in every Chapter and Appendix to state the motivation for the project. Eliminate the first paragraph and focus the Introduction on what is contained in the Appendix. An example of text that could be used is included in the Appendix B mark-up. [Note that the example text includes a reference to the Project Plan (EPRI, 2012), which surprisingly is not cited in the rest of the report. If it is cited in Appendix B, as suggested, it should be added to Chapter 10 – References.

App. B-3 (specific, non-mandatory). *Literature Review Tables.* The Literature Review tables use many abbreviations that are not documented in the report (e.g., Calif, Cal, eqns, So, BC, BA-08, atten). While their meaning may be obvious to most readers, for completeness and full transparency, either spell out the words or define the acronyms/abbreviations when they are first used and compile them in the Report list of such items. Also, consider expanding the information in the tables so that it is composed of complete sentences, rather than sentence fragments, which sometimes can be ambiguous.

APPENDIX C—DOCUMENTATION FOR INTERVIEWS

(A separate marked-up Word file contains other suggested edits for Appendix C. Note that the first two comments here are similar to those for Appendix B.)

App. C-1 (specific, non-mandatory). *Organization.* Traditionally, the Introduction is the first section in a Chapter. Consider moving the Introduction to come before the list of interviewees and the questionnaire.

App. C-2 (specific, mandatory). *Introduction.* The first paragraph of the Introduction reads as if it were from a plan for future work rather than a description of work that is completed. Also, it is not necessary in every Chapter and Appendix to state the motivation for the project. Eliminate the first paragraph and focus the Introduction on what is contained in the Appendix. An example of text that could be used is included in the Appendix C mark-up. [Note that the example text includes a reference to the Project Plan (EPRI, 2012), which surprisingly is not cited in the rest of the report. If it is cited in Appendix C, as suggested, it should be added to Chapter 10 – References.

App. C-3 (specific, non-mandatory). *Interview Documentation Tables.* Review and enhance the content of the interview Documentation Tables with an eye to transparency in the future. This could perhaps be accomplished with “Notes” following each table or footnotes. Some items are mentioned by shorthand that may not be obvious in the future or to a non-expert. For example, “Mineral aftershocks” are mentioned. Explain that this refers to the Mineral, VA earthquake of August 2011. As another example, provide the context for “my Blue Castle presentation.” Also, make sure any references cited (or that should have been cited) are included in Chapter 10.

APPENDIX D—COMMENT RESPONSE TABLES

(A separate marked-up Word file contains other suggested edits for Appendix D.)

App. D-1 (general). This appendix appears to have been hastily assembled. It needs thoughtful attention to reorganize it so it achieves the purpose of meaningful documentation. Note: The

provided markups and comments are only a start toward revising the appendix—the appendix can't be fixed without taking it apart and starting over again.

App. D-2 (specific, non-mandatory). *Title.* The title of Appendix D doesn't accurately convey what the appendix contains.

App. D-3 (specific, mandatory). *Appendix needs to be reorganized.* The introductory parts of this Appendix (Sections D.1–D.3) are poorly organized to help the reader navigate through this appendix. A clear and specific roadmap is needed to outline exactly what the appendix contains and in what order. The comment response tables should be grouped and separated from presentation materials. The narrative at the start of the appendix should support what the reader will find—after the reader has the roadmap.

App. D-4 (specific, mandatory). *PPRP Comment Response Table.* The first row of the table is completely misleading and should be deleted. At the outset, clear labeling is needed to identify where the first 1-2/3 pages of comments came from: E-mail from B. Chiou to L. Salomone dated February 8, 2013. The context was PPRP input, prior to the Closure Briefing, “on what the TI Team could add to their presentations to further facilitate PPRP’s technical review.”

APPENDIX E—WORKING MEETING

App. E-1 (specific, non-mandatory). *Title of chapter.* Preferable to title it “Working Meetings.”

App. E-2 (specific, mandatory). *General.* Need to add all documentation from the PPRP Closure Briefing held on February 13, 2013, including meeting notice, slide presentations, meeting summary, etc. [It is recognized that portions of the PPRP Closure Briefing materials are included in Appendix D.]

APPENDIX F—BIOGRAPHIES OF PROJECT TEAM (No comments)

APPENDIX G—HAZARD INPUT DOCUMENT

(A separate marked-up Word file contains other suggested edits for Appendix G.)

App. G-1 (general). Only a PSHA analyst can provide an adequate review of this Appendix for its usefulness and completeness in implementation. If this HID has been field-tested by an analyst in a PSHA study, it would be helpful to say so in Section G.1.

App. G-2 (specific, mandatory). *Equations (G-1) and (G-4).* Similar equations (in a different symbol system) are provided as Equations (7.8.1-1) and (7.8.2-2). Furthermore, on page 7-40, there is a reference to Section 9.2, which in turn references Appendix G. There should be some text (in either Section 7.8.1 or the Appendix) to discuss the relationship between the two sets of equations and to help close the chain of reference started in Section 7.8.1. It appears that the whole Appendix G hasn't caught up with Chapter 7 in terms of equations and their citation.

App. G-3 (specific, non-mandatory). *Tables and figures.* They are not provided in the printed copy of the draft. Some of the missing tables and figures were found in the electronic attachment, but without proper table/figure captions. Since they are referenced in the written text, these figures and tables should also be presented in the report, not in a separate electronic attachment.

App. G-4 (specific, mandatory). *Tables G.2.3-1 through -10 and G.2.4-1 through -16.* [Tables were provided to the PPRP on May 16, 2013.] These tables are not referenced by Sections G.2.3 and G.2.4. Text should be modified to include references to these tables.

App. G-5 (specific, non-mandatory). *Tables G.2.4-1 through -16.* The key word “distance” is missing from the table titles (“Adjustment from Epicentral to Joyner –Boore Distance”).

App. G-6 (specific, non-mandatory). *Tables G.2.4-15 and G.2.4-16.* It is unclear what the adjective “new” in the table titles modifies. It may mislead some readers to think there is a new Cluster 4. Is it necessary to emphasize that the Cluster 4 adjustment presented here is new, relative to EPRI (2004)?

APPENDIX H—CORRESPONDENCE

Note: The only electronic version of Appendix H provided to the PPRP for review was a pdf file, so no markup has been made.

App. H-1 (specific, non-mandatory). *Suggested edits/additions for title page of chapter.*

- The PPRP was informed that this appendix was not intended to contain correspondence between the Sponsor and the NRC, because it was outside the SSHAC process (hence, the exclusion of other such correspondence). Suggestion: Add a footnote explaining why H.1 was singled out for inclusion in this appendix, while other formal “correspondence” between the Sponsor and the NRC is not included.
- Change the description of H.2.5 to read: “PPRP GMM Report \$5 (Concurrence with the Updated GMM) April 5, 20 The PPRP’s ”Closure” letter will be its last—and presumably will be included in the Front Matter of the project report.
- When finalized and submitted, add:
H.2.6 PPRP GMM Report #6 (PPRP Review Comments on Draft Project Report) *date*

APPENDIX I—QUALITY ASSURANCE

(A separate marked-up Word file contains other suggested edits for Appendix I.)

App. I-1 (specific, mandatory). *Section I.3.1.* Need to reference the hazard input document (HID) to Appendix G. Suggested wording is provided in the Appendix I mark-up.

App. I-2 (specific, mandatory). *Sections I.4 and I.6.* In the electronic version of Appendix I, Sections 1.4 and 1.6 have open comments for additional modification by the TI team. (It is noted that these additions were provided to some of the PPRP for review in the hard copies. These modifications are considered acceptable.)