PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Central and Eastern North America Ground-Motion Characterization

NGA-East Final Report Appendices

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PEER Report No. 2018/08
Pacific Earthquake Engineering Research Center
Headquarters at the University of California, Berkeley

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Contents

List of Tables

Appendix C

Appendix D

Appendix E

Appendix G

Appendix H

Appendix I

List of Figures

Appendix D

Appendix F

Appendix G

Appendix H

Appendix I

Appendix A Participatory Peer Review Panel (PPRP) Correspondence on Final Report and Project Plan

This appendix contains the Participatory Peer Review Panel (PPRP) correspondence with the Technical Integration (TI) team. Section A.1 contains the PPRP letter expressing their acceptance of the Final NGA-East Report (this document). Section A.2 provides the PPRP comments and TI team responses to draft versions (revisions 0, 1 and 2) of the Final NGA-East Report. Sections A.3 and A.4 contain the NGA-East Project Plan and associated correspondence between he PPRP and the TI team.

A.1 PPRP Report Acceptance Letter

This material is included in the following pages.

December 20, 2018

Dr. Yousef Bozorgnia
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Dear Dr. Bozorgnia:

This letter summarizes the activities and conclusions of the participatory peer review panel (PPRP) during the course of the NGA-East ground motion development project. Consistent with the expectations described in NUREG-2117 for a Senior Seismic Hazard Analysis Committee Level 3 study, the PPRP was engaged throughout the course of the project, as documented below.

Introduction

The objective of the Next Generation Attenuation for Central and Eastern North America project (NGA-East) has been to develop a new ground-motion characterization (GMC) model applicable for use in Central and Eastern North America (CENA, east of approximately 105 degrees west). The GMC model consists of the following two parts, for use in probabilistic seismic hazard analysis (PSHA) for nuclear facilities in central and eastern North America (CENA):

1. A set of new ground-motion models (GMMs)—also known as ground-motion prediction equations (GMPEs)—for the median ground motions and their associated weights in the associated logic-trees.
2. A set of new models for the aleatory standard deviations of ground motion, and their associated logic tress.

The NGA-East Project was conducted in a manner consistent with the Senior Seismic Hazard Analysis Committee (SSHAC) framework (Budnitz et al., 1997). The SSHAC guidance describes four levels of study with increasing scope and rigor proceeding from Level 1 to 4. Higher-level SSHAC studies have greater regulatory assurance, which is defined as confidence on the part of the regulator that (1) the data, models, and methods available to the larger technical community have been properly considered; (2) that the resulting model adequately represents the center, body, and range of technically defensible interpretations; and (3) that the process is documented in a manner that ensures transparency and reproducibility. The NGA-East project was conducted to satisfy the requirements of a Level 3 study. At the time this study was conducted the applicable guidance on conducting a Level 3 project consistent with the SSHAC framework was later published in NUREG-2117. Subsequently an update to NUREG-2117 was developed (NUREG-2213). However, none of basic framework guidance for a Level 3 study differs in the new guidance document.

The following sections summarize the specifics of PPRP engagement throughout the course of the project, the panel's assessment of the technical adequacy of the final product as well as its conformance to the applicable SSHAC guidance, and a description of the review of the documentation of the project.

PPRP Engagement and Organization

In order to evaluate if the project has satisfied the requirements for technical adequacy and conformance to the SSHAC process, a significant degree of engagement and involvement by the PPRP is required. As described in NUREG-2117, participatory peer review includes observation, interaction, review and comment by the panel throughout the course of the project. This allows feedback from the PPRP to be actively evaluated and addressed by the TI Team during the conduct of the study. The Panel was fully engaged in peer-review interactions with the TI Team and the Project Manager of the NGA-East Project throughout the course of the Project, including a thorough review of the Project Plan, attendance to the formal Project Workshops (including daily debriefings and formal written feedback to TI Team), attendance at some of the Working Meetings, and review of three drafts of the final Project Report, including its appendices and attachments. The Panel was given appropriate and adequate opportunity to question the TI Team concerning details of their analyses, and provided feedback verbally and in writing. The TI Team was responsive to the technical input from the Panel. The TI Team's responses included undertaking additional analyses to address specific Panel technical questions or concerns, and examining and assessing alternative technical approaches suggested by the Panel.

The level of PPRP involvement in the NGA-East Project has been substantial. The PPRP attended each of the formal project workshops as summarized in the table below.

Workshop Number (Date)	**Activity**
Workshop 1 (November 15-18, 2010)	Review of Project Plan and Data Needs Workshop Written comments provided by PPRP
Workshop 1b/2a (October 11-13, 2011)	PPRP attendance and written comments provided to TI Team
Workshop 2b (July 14-16, 2014)	PPRP attendance and written comments provided to TI Team
Workshop 3a/2c (October 29-30, 2014)	PPRP attendance and written comments provided to TI Team
Workshop 3b (March 4-5, 2015)	PPRP attendance and written comments provided to TI Team
Workshop 3c (June 17-18, 2015)	PPRP attendance and written comments provided to TI Team

In addition to formal workshop attendance, the PPRP participated in several teleconferences and attended several working meetings that occurred during the course of the project. This engagement allowed the PPRP to better understand the technical work as it proceeded, and to ultimately perform the PPRP review of the project documentation. At times, several members of the PPRP were also actively engaged as resource experts supporting some of the working groups.

The membership of the PPRP evolved with time. At various times the following people participated on the PPRP: Julian Bommer (Lead), John Adams, Jon Ake, Trevor Allen, John Ebel, Aybars Gurpinar, Jeff Kimball, Richard Lee, James Martin, Leon Reiter, and Frank Scherbaum. The final PPRP is comprised of Gabriel Toro (Lead), Adams, Ake, Ebel, Kimball and Lee. This six-member PPRP was responsible for the review of a majority of the project's activities and of the final report. The members of the initial and final Panels collectively met all requirements in terms of subject area expertise, knowledge of PSHA, and experience from other projects carried out following SSHAC guidance.

SSHAC Process Review

The NGA-East Project was unique among SSHAC studies in that it began as a project that was not specifically identified as following the SSHAC guidance. The project was initially structured in a manner similar to the NGA-West efforts, with a more de-centralized and research-oriented project organization. However, since the sponsors, and likely users of the product, were owners and/or regulators of nuclear or other critical facilities, the decision was made to re-orient the project so it would follow the SSHAC guidance. Further, rather than simply assemble and evaluate existing data, models and methods, the NGA-East Project explicitly undertook the task of conducting new and original research as well as the development and application of new methodologies. For these reasons, the application of the SSHAC Process to the NGA-East Project has been unique. However, the PPRP finds that the TI Team has been diligent in applying the overarching principles of Evaluation and Integration to capture the Center, Body and Range of Technically Defensible Interpretations (CBR of TDI) in developing a new GMM for CENA.

To support the research-oriented project work scope, several technical working groups were formed that included a large number of researchers. Because of this, the framework for the conduct of the formal SSHAC workshops deviated from the three workshops described in NUREG-2117 (Workshop 1-Significant Issues and Data Needs, Workshop 2-Proponent Data, Models and Methods, Workshop 3-Feedback and Alternative Interpretations). In addition, because the technical scope of this project was broad and complex, more than three formal SSHAC workshops (with some of them blending the themes of Workshops 1, 2, and 3), were required to perform the necessary activities of Data Compilation, Evaluation and Integration. As can be observed from the Table above (and Section 2.3 and Appendix B of the final project report), in the interest of ensuring that all significant technical activities were conducted in an open workshop environment, there was some overlap between the goals of the workshops. However, the TI Team was always diligent in describing the goals for each section of the workshops and ensuring that those goals were met.

Technical Review

The first major technical phase in a SSHAC project is the compilation of available data, collection of new data, if needed, the uniform processing of these data, and the dissemination of these data to the entire project team.

The collection and processing of ground-motion data covered a significant amount of new data, which were not available to the previous SSHAC Level 3 ground motion study for CENA (EPRI, 2004). These new data included a large number of records from the Transportable Array, as well as recent records from regional and strong-motion networks in CENA. The important ground-motion data from the 2011 Mineral, VA, and Sparks, OK, earthquakes are included in this database, but no post-2011 earthquakes are included. All data were processed in a consistent manner. A significant effort was also made to obtain earthquake and station metadata. A particular challenge in this regard was the collection of information on site conditions (parameterized by Vs30) at the recording stations. In most instances, direct geotechnical or geophysical measurements were not available, and indirect "proxy" methods had to be utilized for this purpose (some of them developed by the project). Ground motion data from other regions were also obtained and used for certain tasks, such as the quantification of the aleatory standard deviation.

In addition to the set of earthquake data compiled in the database, several well-validated numerical simulation methods were used to generate synthetic ground-motion data for earthquakes in the region. These synthetic data complement the CENA data described above, because they cover a broader range of magnitudes than do the recorded data.

The project also sponsored the compilation of crustal-structure data by the USGS. These data, together with data from earlier EPRI work and from recent work by other researchers, provided the basis for the definition of two distinct crustal-structure regions within CENA.

The next task was the compilation of existing GMPEs that can explain the data described above and may be used as the starting point for the integration phase. In addition to compiling and summarizing existing GMPEs in the literature, the project sponsored the development of 20 new GMPEs for CENA. The GMPEs were developed by independent researchers with TI Team guidance, including two of the models developed by PEER that were authored by TI Team members. These independent researchers had access to the databases described above and were familiar with the goals of the project. Of the candidate proponent GMMs, 19 models were ultimately used as seed GMMs. From a lessons-learned perspective, it is suggested that stronger guidance in a) setting the reference rock velocity, b) establishing a uniform method of correcting site observations to reference rock, and c) specifying rupture distance and rupture depth (Z_{TOR}) as explanatory variables would have improved the usability of the seeds.

Overall, the Panel considers that the data collection effort and the development of new GMPEs were appropriate and sufficient for the intended purpose, and are properly documented. In particular, the CENA ground-motion database and the development of new seed GMMs represent important scientific contributions to the understanding and quantification of earthquake ground motions in CENA. Given that the project duration extended to 2018, it would have been desirable to include post-2011 data (which were collected as the Transportable Array continued to move East), but this was not feasible due to budget and schedule constraints.

The second major technical task in a SSHAC project is the evaluation of the data and GMPEs collected in the first phase. In the evaluation phase, the TI Team determines the quality and usefulness of these data, models, and methods. The documentation of this phase must include both the evaluation steps followed and the technical bases for all decisions made regarding the quality and usefulness of these data and GMMs. In this project, the most challenging portion of the evaluation step was the evaluation of the 19 new seed GMMs.

The evaluation of the seed GMMs included the development of criteria that were used to reject all existing GMMs and assess each seed GMM. This evaluation resulted in the decision to retain all 19 of the seed GMMs, although some of them just for a limited range of spectral frequencies. From a lessons learned perspective, the PPRP notes that this evaluation step presents a number of technical challenges. From a planning perspective this requires time to interact with each GMM proponent to ensure that GMM inputs do not result in any unintended bias that would challenge having the GMM produce viable median ground motions. Sufficient time becomes a priority for ensuring success in the evaluation phase. In the end, the PPRP concludes that the evaluation phase was performed in a defensible manner and is properly documented.

The third major technical task in a SSHAC project is integration, in which the results of the previous two phases are combined to construct a new model that represents the CBR of the TDI. The TI Team developed and applied an entirely new approach (using a continuous multivariate representation of the ground motions together with Sammon's maps) to capture the CBR of the TDI for estimating median ground motions from future earthquakes, using as inputs the 19 seed GMMs and a subset of the ground-motion data. The seed GMMs are used to develop a continuous distribution of ground motions from which several thousand GMMs were sampled to obtain a fine-grained representation of the epistemic uncertainty. One of the key steps in the process executed by the TI was to develop GMM physicality constraints that were used to identify sampled GMMs that should not be used to develop the final discretized sets of GMMs. Sammon's maps were then used to visualize and finally re-discretize the sampled ground motions to develop the final 17 GMMs and obtain their weights.

Because this mapping approach is novel, it necessitated significant interaction between the PPRP and TI Team before the PPRP was able to conclude that the approach was technically defensible for this application as well as clearly explained in the project documentation. Based on extensive review and discussions, the Panel concluded that a number of sensitivity analyses carried out by the TI team demonstrated that the Sammon's maps approach is robust with respect to the most critical choices made during their implementation.

The PPRP made several requests/suggestions during the final stages of model development and documentation. The TI Team was responsive to those requests. For example, the PPRP suggested the exercise of applying the Sammon's mapping approach to developing median ground motion models utilizing as input the nine models that were used as "seeds" in EPRI (2013). The use of EPRI seed models in the Sammon's map approach was to assess the sensitivity of the results to the integration approach (Sammon's vs. EPRI, 2013). This required a substantial amount of work on the part of the TI Team. The project undertook this effort and the results provided enhanced confidence in the robustness of the approach and of the final model. Throughout the course of the study the TI Team maintained a strong emphasis on including hazard feedback in the evaluation and integration process. This allowed both the TI Team and PPRP to assess the importance of alternative model choices.

In addition to the development of a model for the median GMM and its epistemic uncertainty, the TI Team also performed a parallel data evaluation, and integration effort to develop a model for the aleatory standard deviation, using data from CENA and from other regions with more abundant recordings. The TI Team developed two models for the aleatory uncertainty; namely, an ergodic model and a "single-station" model. The Panel also finds that the approach followed and the resulting models are defensible and well documented.

The Panel reiterates that significant new research was conducted outside the SSHAC process to support the NGA-East final report. Much of this research is anticipated to have utility beyond the scope of the NGA-East project. The project and the TI Team should be commended for their efforts.

Documentation

A critical task in a SSHAC Level 3 study is the development of the project documentation, which is vital to the successful completion of any project. The need for comprehensive documentation is especially important for studies conducted within a regulated environment. The original SSHAC guidelines document devotes a full chapter to the type and required level of documentation (Budnitz et al. 1997). The need for comprehensive and clear documentation is further elaborated in NUREG-2117.

As described in the previous sections, the NGA-East Project was unique in that it had a number of research working groups conducting research that supported the technical bases for much of the integration portion of the project. Hence, in addition to producing a final technical project report, the project also documented the supporting research in a number of PEER technical reports. While these reports were reviewed by the PPRP during the study, no formal peer review comments were provided as they were intended to be "stand-alone" technical research reports supporting the SSHAC evaluation phase. However, the informal review of these documents facilitated the PPRP's understanding of many aspects that underlie the technical basis of the final report.

For the NGA-East project, the overall project documentation included the following:

- The set of PEER reports documenting the research portion of the NGA-East project (as described in Chapter 1 of the final project report)
- The project plan (provided in Appendix A of the final project report)
- SSHAC workshop agendas and presentations (Section 2.3 and Appendix B of the final project report)
- The set of comments provided by the PPRP and the project resolutions to the comments (contained in Appendix A of the final project report)
- The final report.

During the review of the three draft versions of the final report the PPRP submitted more than 1,200 comments to the TI Team. All of the comments were considered by the TI Team and disposition of the comments is documented in Appendix A of the final report.

The numerous electronic attachments generated by the project constitute an important element of the project documentation and a valuable resource for future research. The Panel recommends that these attachments be archived by PEER and made available to the research community in a convenient form (for instance, by creating durable links for these attachments in https://peer.berkeley.edu/thrust-areas/data-sciences/databases or a similar page). The draft report contains Dropbox links, which are perishable. The final report should reference the new durable links. It is recommended that archival DVDs also be created.

Conclusion

On the basis of its review of the NGA-East GMC project the PPRP finds that the project meets the expectations for a **SSHAC** Level 3 study, in terms of process, technical defensibility, and documentation. Specifically, the project assembled, evaluated and integrated available and new data, models and methods in order to capture the center, body and range of technically defensible interpretations of ground motions for future earthquakes in the CENA region. The PPRP has been actively involved during the course of the study and has provided comment and feedback throughout.

The PPRP wishes to thank the TI Team for all of the constructive discussion during the process and to commend the TI Team and all of the NGA-East project participants for their significant contributions to the characterization of earthquake ground motions in CENA.

Sincerely,

Gabriel R. Toro
Chair, PPRP

John Adams
Member, PPRP

Jon Ake
Member, PPRP

John Ebel
Member, PPRP

Jeffrey Kimball
Member, PPRP

Richard C. Lee
Member, PPRP

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U.S. NRC. 2018. NUREG-2213: "Updated Implementation Guidelines for SSHAC Hazard Studies." Washington, DC: U.S. Nuclear Regulatory Commission.

A.2 Participatory Peer Review Panel Comments on Report Drafts and Technical Integration Team Responses

The comments from the PPRP are tabulated in the following pages, along with the TI team responses. We identify the comments to Rev.0 (no fill, regular font) to those from Rev.1 (grey fill, italic font) and those obtained after Rev.2 (blue fill. Italic font) using the format in parentheses above and by the first and third columns in the table itself.

This material is included in the following pages.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
CHAPTER 1								
Rev.0	1	G1-1.				Given that this should have been a simple chapter the PPRP is concerned that readers/users will not see the forest for the trees. This chapter does not clearly summarize what steps were taken to implement the SSHAC process. Rather it randomly summarizes the science component without providing a clear picture of what the objective was for each piece of work, what was done to achieve that objective, the outcome of the work, and what specifically was used (as data or model) by the TI Team. Lots of detailed comments follow but the overall message intended to be provided by the Chapter and Sections is just not clear.	General	We have reworked Chapter 1 extensively based on all the PPRP comments.
Rev.0	1	G1-2.				The summary of the science component found in section 1.3.2 lacks focus; each sub-section should clearly articulate the key data or models which are subsequently used to develop the NGA-East GMM. Each sub-section should start with describing the objective of the work relative to what the project team wanted from the effort. Why was the work done? Then summarize what was done to meet the objective and the key findings from the effort. Lastly, clearly state what outcome (data or model) is being used by the TI Team, with a brief discussion of how it is being used.	General	Ageed, we elaborated on the contributions of each task/report.
Rev.0	1	G1-3.				There is inconsistency in naming. “MEM” is being used together with “Gulf Coast”. Geologically MEM is a very small part of Gulf Coast (<10%, if it is indeed part of Gulf Coast in the first place), and there appear to be major differences like sediment thickness between MEM and the rest of the Gulf Coast. The PPRP would prefer that some form of Gulf Coast, perhaps “GCR” or “GCM”, be used. Where “MEM” is used (because specific conclusions relate to or arise from it) is should be just for the immediate source area around the New Madrid seismic zone. If MEM conclusions are generalized to Gulf Coast, that should be made clear, and justified. Finally if MEM is retained against our advice, the combined entity should be defined as MEM= Gulf Coast/Mississippi Embayment and not the reverse. [Acronyms list gives MEM = Mississippi Embayment/Gulf Coast Region].	General	We have changed the nomenclature for the whole report with MCR and GCR used for mid-continent region and Gulf Coast region, respectively.
Rev.0	1	1-1	1.1	1-1	1st paragraph	Consider using the notation used in EPRI (2013) for GMM, vs. GMPE (where GMM refers to the entire package and GMPE refers to one individual function or table). It is a good idea to use one (and only one) term for each concept in the report (except perhaps where the concept is introduced). Comment applies to entire report.	NR	GMM is ued in replacement of GMPE as in this project there is no "Equation". The GMC model is the "whole package" with the GMMs and the weights.
Rev.0	1	1-2	1.1	1-1	1st paragraph	Delete hyphen in North-America; add spaces around em dash "-"	ED	Corrected.
Rev.0	1	1-3	1.1	1-1	2nd paragraph, line 4	Coordinated ’developed. SSHAC process involves more than coordination; it carries procedural, scientific, and documentation implications.	NR	Corrected.
Rev.0	1	1-4	1.1	1-1	2nd paragraph, Line 10	Suggested wording change. "An overview of the SSHAC process, as it was implemented in this project, is presented in Chapter 2"	ED	Corrected.
Rev.0	1	1-5	1.1	1-1	2nd par	Suggest adding section or paragraph with table describing the goals/accomplishments of the "scientific component" of NGA-E here or elsewhere.	NR	Corrected.
Rev.0	1	1-6	1.1	1-1	3rd paragraph, line 6	Change "was also under" to "was also developed under"	ED	Corrected.
Rev.0	1	1-7	1.1	1-1	3rd par	Suggest stating here or elsewhere that this NGA-E GMPE product is intended to supersede earlier EPRI/NRC efforts particularly the EPRI 2013 GMPEs	NR	That is a decision to be made by the regulators.
Rev.0	1	1-8	1.1	1-1	5th paragraph	Unless done elsewhere, CEUS and CENA should be defined more precisely and/or mapped. Perhaps add a reference to Figure 1-1 here. Fig 1-1 should then show CENA and CEUS, and either drop subdivisions of CENA on the current figure or add labels to each of the sub-regions shown on the figure. Alternatively, add a second figure showing the sub-regions, and then discuss Figure 1-1 here and the new Figure 1-2 in Section 1.3.2.4.	NR	Agreed. We have changed the figure and simplified the caption.
Rev.0	1	1-9	1.2	-	Entire sub-section	Please indicate kinds of earthquakes covered: aftershocks? Induced? Is earthquake type a predictor variable?	RE	Agreed
Rev.0	1	1-10	1.2.1	1-2	1st paragraph, line 2	Meaning of "average" not clear. More precision needed. Does it refer to components of motion? Does it refer to epistemic uncertainty? Becomes clear in 1.2.5, BUT language should be made more precise in both places	NR	Agreed
Rev.0	1	1-11	1.2	1-2	1st paragraph	Goulet et al. (2013) is missing from the reference list.	ED	Agreed
Rev.0	1	1-12	1.2.1	1-2	2nd paragraph,	This section needs much more in-depth discussion of what the SSHAC Level 3 process entails. Alternatively, provide a summary of the process, using some of the SSHAC key terms, and point to Chapter 2.	RE	Agreed
Rev.0	1	1-13	1.2.1	1-2	2nd paragraph,	Please change "empirical data" to "data" or something else. The terms "empirical data" and "empirical database" are used in several other places in report and should be changed.	ED	Agreed

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	1	1-14	1.2.2	1-2	Sentence 1	Dreiling reference citation is inappropriate in the text, as it implies Dreiling et al. established the study area. State who did. You can still cite Dreiling in the figure caption if it is appropriate.	ED	Agreed. The text was revised and the figure replaced in response to the related comment above.
Rev.0	1	1-15	1.2.2	1-2	Sentence 2	Consider modifying the title of Section 1.2.2 to "Study Region and Regionalization" and add text to summarize conclusion of regionalization work.	NR	We removed regionalization description from this capter.
Rev.0	1	1-16	1.2.3	1-2	1st paragraph	Is there an implied typical profile beneath this typical 3000 m/s site? Monotonically increasing Vs? What if there are some lower-velocity strata beneath the 3000 m/s material? There are sites in the southeastern US where there is 1 km of sediments with 3000 m/s velocity, underlain by several kilometers of lower-velocity sediments (approximately 2000 m/s). At what depth should the reference conditions be defined in a case like this?	RE	Yes. The profile will be provided with the final hazard input document.
Rev.0	1	1-17	1.2.3	1-2	1st paragraph	Discuss rationale for these values. After all, most CENA sites have Vs<3000 m/s at the surface or even at foundation depth. Hard-rock data? Precedent? Is this the optimal interface point between GMPEs and site-effects in CENA? See also detailed comment 1-50.	RE	We added text to that effect. The concept was to have a reference rock for which the site amplification was unity. Other site conditions will be with respect to this reference condition.
Rev.0	1	1-18	1.2.4	1-2	1st paragraph	Indicate (if this is the case) that more emphasis was placed on 0-500 km in the model development.	NR	No we do not put "emphasis" on 0-500 km . The PSHA process automatically takes care of the significance of contributions of magnitude-distance pairs.
Rev.0		*Rev.2 follow-up*				*One could emphasize the 0-500 km range in the development of the GMC, and in fact you did (to a degree) in the selection of data for the Chapter 9 weights. A clarification in the text would be useful but is not required*	*NR*	*The previous answer still applies. When specific ranges of M and R distances are used, we make statements in the relevant section.*
Rev.0	1	1-19	1.2.4	1-2	1st paragraph	Try: "from an earthquake source, using rupture distance as the distance metric"	ED	Agreed
Rev.0	1	1-20	1.2.5	-	-	Is the sigma definition in chapters 10 and 11 consistent with the RotD50 definition of ground motion?	RE	Yes.
Rev.0	1	1-21	1.2.5	1-2	1st paragraph	Indicate explicitly that vertical motions are not considered by project (although some vertical motions may/will? be included in final version of the database)	NR	Agreed
Rev.0	1	1-22	1.2.5	1-2	5th line	Please comment on the absence of PGD	NR	Agreed
Rev.0	1	1-23	1.2.5	1-2	6th line	Reference to Table 1-1; max frequency on table should be 100 Hz? Section 1.2.1 says 0.02 sec, not 0.01 s, but Section 1.3.2.1 says 0.01 sec. Clarify if 0.01 s data was collected (section 1.3.2.9) but not used to produce a GMM for 0.01 s	NR	Table was edited.
Rev.0	1	1-24	1.2.6	1-3	2nd paragraph, line 4	Text seems to imply that CEUS and NGA East will always be used together. This is not necessarily true. Please revise.	NR	The text was edited.
Rev.0	1	1-25	1.2.6	1-3	2nd par, 1st sentence	Delete word "as"	ED	Agreed
Rev.0	1	1-26	1.2.6	1-3	2nd paragraph, line 6	How can you have interaction (which implies two-way communication) if one of the projects had already been completed (except for the "patch" related to depth distribution) when the NGA-East project did most of its work? Please revise entire paragraph; emphasize overlap and communication with CEUS-SSC TI Lead in early phases of work and with other TI team members during the entire project.	NR	Agreed. The text was revised.
Rev.0	1	1-27	1.2.6	1-3	2nd paragraph last sentence	Suggested revision: "NGA-East Project team as described in Chapters 13 and 14 of this report".	ED	Agreed. The text was revised.
Rev.0	1	1-28	1.2.7	1-3	bullets	The nomenclature is spelled out clearly here, but in other chapters this seems to have got lost. See comments made on Chapter 7 and 8 and try to ensure consistency in the entire report	ED	Agreed.
Rev.0	1	1-29	1.2.7	1-3	first bullet	"were to be developed" ' "were developed"	ED	Agreed.
Rev.0	1	1-30	1.2.7	1-3	second bullet	GMIM is spelled out in the heading 1.2.5, but probably wise to spell it out again here. Elsewhere we note that it's easy to misread GMIM as GMM, particularily with sans-serif font.	ED	Agreed. The text was revised.
Rev.0	1	1-31	1.2.7	1-3	Last bullet on page 1-3	Please consider re-writing sentence: "For each of these 29 cells, a process to define a representative model in each cell was defined.." Sentence is very confusion and uses verb "define" twice to mean different things.	ED	Agreed. The text was revised.
Rev.0	1	1-32	1.2.7	1-3	Last bullet on page 1-3	Sampled GMMs were "grouped" into 29 cells. The term "grouped" doesn't seem appropriate. Consider revising.	NR	Agreed. The text was revised.
Rev.0	1	1-33	1.2.7	1-3, 1-4	Last bullet on page 1-3	Unclear. Should indicate that these 29 GMMs and their weights represent the TI Team's assessment of the CBR of the TDI for the median amplitudes. It may also be worth emphasizing that they are intended to be used as a "package" (rather than choosing one or more GMMs from the set). A reference should be provided to the chapter that explains the use of the GMMs in PSHA.	NR	In response to the previous comment, we recised the text

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	1	1-34	1.2.8	1-4	-	Needs to be much more explicit about the limitations, for example results may underestimate the ground motions for shallow M6 events, etc. Please discuss other data-related limitations (perhaps more important than those listed). In particular, very little data for M-R ranges of engineering interest, very little data for high frequencies, very little data on station site conditions, etc. PPRP may have further advice on this section as it gets to the end of its review.	RE	Agreed. The text was revised.
Rev.0	1	1-35	1.2.8	1-4	2nd line	"do not explicitly include" ' "do not explicitly parameterize". Note that such factors are implicitly included in the GMM only to the degree that they exist in the input data set	NR	Agreed. The text was revised.
Rev.0	1	1-36	1.3.1	1-4	1st paragraph	May want to indicate that SSHAC process builds on science component and that science components were needed in order to fill gaps. They were not just interesting science projects: they were strongly focused efforts. The direction for the science component came from the project team with specific objectives; the science component provides valuable input on data and models to be evaluated by the TI Team; a valuable component of the SSHAC process.	NR	Agreed. The text was revised.
Rev.0	1	1-37	1.3.1	1-4	1st paragraph, 3rd line	.."under the "science component of NGA-East have been considered in the SSHAC component". Consider replacing "considered" with "utilized as data, models, or methods" in the SSHAC component. lso see comment 32 in April 7th version.	ED	Changed the wording.
Rev.0	1	1-38	1.3.2	All	All	See General comment G1-2 "The summary of the science "	NR	Addressed above.
Rev.0	1	1-39	1.3.2.1-1.3.2.10	Multiple pages	Entire section	These comments apply to each report description (1.3.2.1 through 1.3.2.10). -Indicate how the results from this report were used by NGA-East SSHAC project. - If applicable, indicate how results from this report affect future usage of the NGA-East model - There should be more consistency in the level of detail of these descriptions. In 1.3.2, cross-references to other science reports should refer to the name and corresponding portion in 1.3.2 rather than to the original science report. (see also comment G1-2).	NR	Changed the wording.
Rev.0	1	1-40	1.3.2.1	1-4	1st paragraph, line 3	"M >2.5, distances up to 1500 km" were not the criteria used at first (they were less inclusive and more nuanced). Please revise to reflect actual evolution of the project	NR	This section refers to the data collected in the database not the ground motion models.
Rev.0	1	1-41	1.3.2.1	1-4	1st paragraph	Indicate here (or perhaps earlier in 1.3) that the SSHAC 3 process has strong-data collection requirements, which are satisfied by NGA East science components. Cross-reference Section 5	NR	Clarified by giving an example.
Rev.0	1	1-42	1.3.2.1	1-4	1st paragraph	a.k.a. not considered acceptable (too informal). It is a good idea to use one (and only one) term for each concept.	ED	Text was revised
Rev.0	1	1-43	1.3.2.1	1-4	1st paragraph	Is RotD50 tabulated in database? If so, please indicate	NR	Text was revised
Rev.0	1	1-44	1.3.2.1	1-4	1st paragraph	Add a cross-reference to Section 5.2	NR	Text was revised
Rev.0	1	1-45	1.3.2.1	1-4	Middle last par	"(SRCs)" should be "(SCRs)"	ED	Text was revised
Rev.0	1	1-46	1.3.2.1	1-4	Next to last sentence	Section quotes oscillator periods of from 0.01 to 10 sec. This range differs from Table 1-1	NR	This was corrected.
Rev.0	1	1-47	1.3.2.1	1-4	Next to last sentence	Need to mention PGA and PGV	NR	Text was revised
Rev.0	1	1-48	1.3.2.1	1-4	Bottom of page	Suggest adding brief description about the site corrections applied in the database. A forward reference to later sections might be appropriate	NR	Text was revised
Rev.0	1	1-49	1.3.2.2	1-5	1st paragraph, 2nd sentence	Sentence is awkward. Not clear why statement about "semi-empirical" is important. Instead of "semi-empirical" try "the final NGA-East"	NR	Text was revised
Rev.0	1	1-50	1.3.2.2	1-5	Entire 1st paragraph	The reference Vs defines where the interface between the GMPE and the site-response analysis takes place. This section should discuss the tradeoffs in selection of reference rock for CENA (e.g., many [all?] of the records come from softer sites and have to be corrected for site response), as well as past choices of reference-rock (unless these issues are discussed elsewhere in SSHAC report).	RE	This is a recommendation of the geotechnical working group which ie very much consistent wuith the previous EPRI studies.
Rev.0	1	1-51	1.3.2.2	1-5	Two bullets in this section	The "reference" P and S velocities given here indicate a Poisson's ratio of about 0.29 or a little higher. This might be acceptable for porous sedimentary rocks, but for bedrock, a value closer to of 0.25 would be expected [Hughes and Luetgert (JGR, 1991) published Poisson's ratios from 0.24 in Vermont to 0.265 in New England to 0.28 in the Adirondacks. Nowhere do they report a Poisson's ratio as high as 0.29. Perhaps higher Poisson's ratios are reported for other parts of the CEUS?] Please explain the discrepancy Also, given the comment above, is it the Vs or the Vp that is the definitive measure? Since most shaking is from S-waves, Vs would be a natural choice. However, we note that most of the analysis in Chapter 4 is performed in Vp instead.	RE	Vs is the measure used to define reference rock adn was adopted by the project. We have reworked Chapter 4 to present a summary and evaluation of proponent regionalization models instead of a "copy" of the Dreiling et al. 2014 report. Dreiling et al 2014 documents one the models.
Rev.0	1	1-52	1.3.2.2	1-5	1st paragraph, line 1	"deals with" is too informal for a technical report. Consider revising all instances of "deals with" in report.	ED	Text was revised.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	1	1-53	1.3.2.2	1-5	2nd paragraph	Please explain why there is an uncertainty associated with the reference velocity. It is reasonable to later indicate the tolerance within which actual rock can be considered to be equivalent to reference rock, but this should not be part of the definition of the reference. Also see comments 1-56 and 1-57.	RE	Text was revised.
Rev.0	1	1-54	1.3.2.2	1-5	2nd paragraph	May want to indicate that report contains some Gulf-region profiles	NR	The study did not provide a reference-rock condition for the Gulf Coast.
Rev.0	1	1-55	1.3.2.2	1-5	2nd paragraph	Are the transfer function for the Gulf Coast region sediment-thickness dependent? Is this discussed anywhere in report?	RE	There was no transfer functions developed for the Gulf Coast.
Rev.0	1	1-56	1.3.2.3	1-5	Entire section	Indicate what are the implications of the Vs range given here (for the project and for the downstream user)? How are results from this report used by project? Also see next comment.	RE	Text was revised to provide a justification for the range. There is no intent of uncertainty propagation. The range should be seen as a tool; it provides the values which leads to a 5% difference in sigte response.
Rev.0	1	1-57	1.3.2.3	1-5	Entire section	Be clear: is reference rock 3000 +/- 0 m/s or 3000 +/- 300 m/s? Why is there an uncertainty associated with the reference (isn't the reference the reference?). If there is an uncertainty, how is this uncertainty to be incorporated by the user (i.e. is the 5% uncertainty to be added to all PSHA models)?	RE	See response above.
Rev.0	1	1-58	1.3.2.3	1-5	Entire section	Indicate what are the implications of the k_0ref value and uncertainties given here (for the project and for the downstream user)? How are results from this report used by project? Regarding downstream users, do the site response analysts need to take these uncertainties into account or are these effects already built into the NGA-East aleatory and epistemic uncertainties?	RE	See response above.
Rev.0	1	1-59	1.3.2.3	1-5	1st paragraph, line 6 (and near end of paragraph)	Reference to "PEER Report 2014-11 (Hashash et al. 2014)", should be changed to the work already described in section 1.3.2.2	ED	Text was revised to point to the previous section.
Rev.0	1	1-60	1.3.2.3	1-5	3rd para line 8	Median is missing the "n"	ED	Corrected.
Rev.0	1	1-61	1.3.2.3	1-5	1st paragraph, line 9 and 10	Indicate the standard deviations are in natural log units.	ED	Text was revised
Rev.0	1	1-62	1.3.2.4	1-6	1st para, last sentence	This information should also be given in caption (OK to also have it in text)	ED	Agreed.
Rev.0	1	1-63	1.3.2.4	1-6	1st para,,last sentence	Label them on the map	ED	Agreed. The map was updated.
Rev.0	1	1-64	1.3.2.4	1-6	3rd paragraph, line 10	Suggested wording change-"were used to show if there were significant". Consider changing "show if" to "investigate if".	ED	Text was revised.
Rev.0	1	1-65	1.3.2.4	1-6	Final paragraph	Nomenclature of "MEM" - see general comment G1-3.	NR	See response above.
Rev.0	1	1-66	1.3.2.6	1-7	First para, line 6	Change "has its own" to something like "documents the work of one"	ED	Text was revised.
Rev.0	1	1-67	1.3.2.7	1-7	1st paragraph, 2nd sentence	Suggestion: write this sentence in terms of extending the model to these three regions in parameter space. Make forward references to where each is discussed (not all are in the same place)	ED	We did not see how to better express this. All three issues are addressed in the report referenced in this section.
Rev.0	1	1-68	1.3.2.9	1-8	3rd par	Section quotes response spectra from 0.01 to 10 sec. This range differs from Table 1-1	NR	This was corrected.
Rev.0	1	1-69	1.3.2.10	1-8	1st para,1st line	Update when report becomes available	ED	OK
Rev.0	1	1-70	1.3.2.10	1-9	2nd paragraph	Most of paragraph (In the contextÉ) is superfluous. Consider removing all but first and last sentence, while respecting the general comment G1-2 and detailed comment 1-38 above.	ED	We removed this section.
Rev.0	1	1-71	1.4	1-9	Middle of page	Suggest adding section that briefly describes the recording site correction applied to the data	NR	We point to Chapter 7 where this is discussed,
Rev.0	1	1-72	1.3.2.10	1-9	3rd paragraph	Paragraph refers to the orientation-independent FAS as the effective amplitude spectrum (EAS). How, or does, this interface with the concept of the RotD50 used for the empirical ground motion response spectra data? Also, consider adding a one-sentence hint on how this FAS is calculated.	NR	There I no one-to-one correspnadance between EAS and RotD50. Reference to EAS was removed.
Rev.0	1	1-73	1.4	1-9	Middle of page	Suggest adding section that includes table describing chronology of important events in the development of GMPEs for example dates/topics for all meetings with PPRP and TI meetings. Alternatively, this list may go in Chapter 2.	NR	A list of events is provided in Chapter 2.
Rev.0	1	1-74	1.4	1-10	4th bullet	Revise to indicate the objective of the three steps described	NR	A reference to Section 1.2.7 is now provided
Rev.0	1	1-75	1.4	1-10	5th bullet	Indicate the relationship between chapters 8 and 9.	NR	In Chapter 9, weights are assigned to the 17 models.
Rev.0	1	1-76	1.4	1-10	Next to last bullet	Consider removing "additional." It is not clear why this guidance is additional.	NR	Text was revised.
Rev.0	1	1-77	1.5	1-11	Boore	The second Boore and Thompson reference uses a different style for date.	ED	This was corrected.
Rev.0	1	1-78	Fig. 1-1	1-15	Fig 1-1	Regions should be consistently identified by the acronyms used in report (CNA, APL, etc.). Caption should define all these acronyms. Ensure all boundaries, including the arbitrary ones in Alberta and near 60N across Hudson Bay, are documented later in the report	NR	In response to comment above, we removed regions from this figure. It is much cleaner this way as there are different candidate models reviewed in Chapter 4.
Rev.0	*1*	*N/A (new)*		*1-6*	*1*	*Consider replacing "were" with "where".*	*ED*	*Fixed.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	*1*	*N/A (new)*		*1-11*		*Consider replacing "consists in electronic " with "consists of electronic ".*	*ED*	*Fixed.*
Rev.0	*1*	*N/A (new)*	*1.2.8*	*1-4*	*entire section*	*We suggest that this section say something about the postulated Rg-wave effects from shallow earthquakes.*	*NR*	*This was not considered or documented in the regionalization report, but by the TI team. The statement is in Chapter 4 which provides the TI tema summary of several studies.*
Rev.0	*1*	*N/A (new)*	*1.3.2.1*	*1-5*	*entire section*	*Please consider adding words like "only a small set of selected data were added after Xmonth, 201X." The text does not indicate an ending date, which would suggest that data to 2018 might have been used.*	*Important*	*Fixed.*
CHAPTER 2								
Rev.0	2	1				Chapter 2 as written does not sufficiently describe the implementation of the SSHAC Level 3 process as carried out for the NGA-East Project. Listed below are several general comments that should be considered as part of revising the chapter.	General	Agreed, text was updated
Rev.0	2	1a				The chapter needs to be written to describe what was actually done versus what may be done in a "typical" SSHAC Level 3 project. The chapter should reflect the actual number of workshops held and should summarize the objective of each workshop and what was accomplished. All future tense language should be avoided. RE: workshop summaries: should be a "distilled summary" (a few paragraphs), not blow by blow minutes. Full minutes should remain in Appendices.	General	Agreed, text was updated
Rev.0	2	1b				The chapter needs to reflect why SSHAC Level 3 was selected for the project. While it is acceptable to use the language from other references such as NUREG-2117 to aid in writing the text, that material should reflect all of the guidance as appropriate. For example the language which refers to "The SSHAC assessment process" is too simplified; it would be more appropriate to reflect all of the objectives for following the SSHAC guidance as articulated in NUREG-2117 (see Section 3.3 in particular). The language from the NUREG-2117 Foreword is provided below to aid in addressing this thought. "The objectives of the additional practical guidance provided in this NUREG are: (1) determination of more accurate and consistent assessments of seismic hazard and the associated uncertainty, (2) standardization and complete and transparent documentation of the assessment process undertaken, the input data, and the basis for the resulting model and findings, (3) increased regulatory assurance based on the transparency of the study's technical basis and, (4) the increased longevity of a study as a result of the ability to assess new data against the existing model and its basis and assumptions. All of these goals lead to greater regulatory assurance and stability." Another factor that affects the choice of SSHAC level is epistemic uncertainty, as discussed in section 3.1.3.5 of the original SSHAC report. In this regard, it may be useful to mention that epistemic uncertainty ground motions is usually the highest contributor to the total epistemic uncertainty in hazard, especially in Stable Continental Regions.	General	Agreed, text was updated
Rev.0	2	1c				The description of the SSHAC Level 3 Process for NGA-East needs to accurately reflect the overall project organization, the roles and responsibilities assigned to the various project participants, the steps taken by the TI Team to perform the evaluation and integration objectives, the various project interactions including working meetings and formal workshops (the actual number of workshops), the steps taken to develop the GMC model, and a summary of how the documentation was developed to support the project.	General	Agreed, text was updated
Rev.0	2	1d				The description of the SSHAC Workshops needs to be written as an accurate representation of what was done including the actual number of workshops held, the objectives for each workshop, how each workshop fit within the overall SSHAC framework, what was accomplished at each workshop, and what, if any major SSHAC process issues were identified by the PPRP that were addressed by the TI Team relative to ensuring that the overall SSHAC objectives were achieved.	General	Agreed, text was updated
Rev.0	2	1e				The description of project documentation should summarize the steps taken by the TI Team to develop the overall project documentation including the project plan, workshop agendas and presentations, the set of PEER reports, the comments from the PPRP and the project resolutions to those comments, and the final report. It would seem appropriate to describe in more detail how the documentation of the proponent models evolved including guidance from the TI Team to the modelers, review of the models by the TI Team, and the final PEER report including electronic information provided by the modelers.	General	Agreed, text was updated
Rev.0	2	1f				Given the important role of the seed models in this project, the interactions between the TI team and the GMM Working Group deserve particular attention. These interactions should be summarized in Chapter 2 and described in more detail in Chapter 7.	General	This was summarized in Chapter 1 and elaborated in Chapter 7
Rev.0	2	1g				Section 2.4.6 needs to be revised so that it describes the interactions with specialty contractors as they happened during this project. Also, their role and the role of the MIA in Section 2.4.7 should not be described using the future tense.	General	Agreed, text was updated
Rev.0	2	1h				Once this chapter is revised, an overall summary statement should be added at the end which clearly states the TI Teams view regarding whether they achieved the intent of meeting the SSHAC Level 3 guidance as found in SSHAC (1997) and NUREG-2117.	General	Agreed, text was updated

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	2	1i				Once this chapter is revised, an overall summary statement should be added at the end which clearly states the TI Teams view regarding whether they achieved the intent of meeting the SSHAC Level 3 guidance as found in SSHAC (1997) and NUREG-2117.	General	Agreed, text was updated
Rev.0	*2*	*N/A (new after Rev.2 release)*		*2-2*	*2nd par, 5th line*	*Suggest changing "hazard model" to "ground motion prediction model".*	*ED*	*Replaced with "was assigned to the GMC model building tasks "*
Rev.0	*2*	*N/A (new after Rev.2 release)*		*2-12*	*Section 2.8*	*This section seems out of place and makes a concluding statement that is really the domain of the PPRP. Suggest deleting Section 2.8.*	*NR*	*OK. Removed.*
Rev.0	*2*	*N/A (new after Rev.2 release)*		*2-6*		*different font size in middle paragraph*	*ED*	*Fixed.*
Rev.0	*2*	*N/A (new after Rev.2 release)*		*2-6*	*line 1*	*Consider replacing "2930" with "29-30".*	*ED*	*Fixed.*
Rev.0	*2*	*N/A (new after Rev.2 release)*	*2.6*	*2-9*	*entire section*	*It is recommended that the documentation include a code repository, ideally complete enough and sufficiently documented that key parts of the project could be relicated. This would be particularly important for the Sammons map processing.*	*NR*	*This is a very good idea, but that not part of the scope of work. The amount of work required to develop the documentation of code is prohibitive at this stage of the project. This is something to consider for future SSHAC projects.*
Rev.0	*2*	*N/A (new after Rev.2 release)*	*2.6*	*2-9*	*entire section*	*In addition, all electronic attachments should be be made available through links with longevity (hosted by PEER?). Dropbox links may disappear any day without a trace. In the short term, report may provide a generic link to PEER NGA-East page and then project can populate that page with links to the actual attachments.*	*Important*	*Agreed. The temporary hosting was only used for confidentiality reasons during the review process. All the appendices will be on the PEER website.*
						CHAPTER 3		
Rev.0	3	G3-1				It is not clear to the PPRP how useful it is for this chapter to provide so much detail about the CEUS-SSC study (particularly Sections 3.2.2-3.2.4). The PPRP considers it more important for this chapter to provide a very general overview of the CEUS-SSC and focus instead on the interface issues between CEUS-SSC and NGA East (source types, magnitude and distance ranges, distance measures, crustal thickness, representation of seismicity in area sources (points vs. pseudofaults vs. virtual fault), detailed rupture geometries (strike, dip, aspect ratio, etc.)		Details of model reduced, interface issues presented.
Rev.0	3	G3-2				The PPRP had a number of comments and concerns about the example provided. Some relate to the choice of site and the frequencies being de-aggregated. Other relate to clarity of presentation. A well-documented example would be very useful.		Example replaced with trial calculations at demonstration sites.
Rev.0	3	G3-3				It would be useful to provide a final section that points to chapters in the report where the information in this chapter and the CEUS-SSC model will be used.		Added text.
Rev.0	3		3.1	3-1	1st sentence	There should be no expectation that the primary use of the NGA-East GMC model will be in conjunction with the CEUS-SSC model; while that may be accurate in the next few years there is no guarantee that this will be the case. Also, site-specific updates to the CEUS-SSC model may be used in some cases. The focus of this discussion should be to review the CEUS-SSC model to identify key SSC-GMC interface issues to inform the development of the NGA-East GMC model. It is suggested that this section be recast to focus on these interface issues. Interface issues could include use of consistent magnitude, magnitude range, consistent distant measure and ability to use multiple distance measures, distance range, consideration of focal depth, and consideration of style of faulting (see, in particular, Section 5.4 and tables in Appendix H of CEUS-SSC report).	RE	The NRC requested that the project be designed to work with the CEUS SSC. It is understood that new SSCs may be developed in the future. Ok with the comment that that we will focus on the interface.
Rev.0	3	3-2	3.2.1	3-1	bullets	First part of bullet #1 should be a not be part of the bullet	ED	Fixed.
Rev.0	3	3-3	3.2.1	3-1	Para 2 last sentence	Start with "In CEUS-SSC the rate….", as this was a significant choice	ED	Not sure what is being suggested.
Rev.0	3	3-4	3.2.1	3-1	Para 3 line 5	"in the CEUS" "in the CEUS (see Fig 3-4),"	ED	Figure not yet introduced.
Rev.0	3	3-5	3.2		Entire section	This section spends too much time summarizing the CEUS-SSC logic tree. As indicated earlier, we suggest that you make this summary shorter and more focused on interface issues for the different source types defined by the CEUS-SSC study. More importantly, interface issues related to crustal thickness, rupture dimensions, rupture orientation and dip, distance metrics, etc. are not discussed.	RE	Reduced detail and added rupture characterization discussion.
Rev.0	3	3-6	3.2.1	3-1	1st bullet	Text "Two …model:" should not be part of the first bullet. Also, consider changing "included" to "considered"	ED	See response to 3-2, "included" is correct.
Rev.0	3	3-7	3.2.2	3-2	title	Consider adding "CEUS-SSC" to the section title (may apply to other sections, too). Otherwise the words "in CEUS-SSC need to be added at many places (for example in last sentence of para 3 of 3.2.2 to make it clear who did what. Another example is "preferred" in the same paragraph = preferred by TI team, or ??	ED	Added to title.
Rev.0	3	3-8	3.2.4	3-3	1st paragraph last sentence	Consider deleting the last sentence. While it is true that the second set of recurrence parameters (M = 4 and larger) can be used with the CAV filter this is a regulatory issue, not a technical issue. The magnitude range (down to M = 4) simply provides the users of the NGA-East GMC model the flexibility of having a model that extend to lower magnitudes if the user determines that this is necessary.	NR	Deleted.
Rev.0	3	3-9	3.3	3-3	Last sentence	Consider forward referencing where in the report the hazard sensitivity analysis is provided. Replace the "this" as its antecedent might be EPRI 2013	NR	Added and replaced "this".

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	3	3-10	3.4	3-3	example	Consider calculating your own example, perhaps using one out of an EPRI report (one of the demonstration sites?; Savannah and Houston might not be good choices, but most others would make good examples). Also, although the deaggregation at 1+2.5 Hz and 5+10 Hz is specified by the NRC for the development of the GMRS, the use of individual frequencies (and perhaps including one additional frequency below 1 Hz) would be more informative for the purposes of this example. Finally, the color scheme would need to be explained in lines 1 and 2 on page 3-4	NR	Replaced example.
Rev.0	3	3-11	3.5	3-4	title	Consider "Influence of the CEUS-SSC project on the NGA-East Project"	NR	Recast section.
Rev.0	3	3-12	3.5	3-4	Line 15	Consider starting a new paragraph with "Past…"	ED	Recast section.
Rev.0	3	3-13	3.5	3-4	Last 2 sentences	Consider enhancing the discussion of the number of spectral frequencies values addressed by the NGA-East GMC model. The current set of GMC models (in particular, EPRI, 2013) are not sufficient to develop a complete assessment of the spectral shape associated with a uniform hazard response spectrum (UHRS). This requires that additional steps are taken to derive the spectral shape from the discrete UHRS; these additional steps are eliminated by the NGA-East GMC model thus representing an improvement in GMC modeling for CENA.	NR	Not sure that more is needed. We believe sentences already make the point.
Rev.0	3	3-14	3.5	3-4	Last line	"simple" do you mean log-log interpolation?	ED	Removed.
Rev.0	3	3-15	3.5	3-4	Entire section	The text shows evidence that ground motions out to 1000 km are needed, and sometimes the ground motions exceeding this distance may be required also. From there, the report indicates that NGA-East needs to provide ground motions out to 1500 km. The Justification for this 1500 km number is missing. Why not 1100 km? Why not out to 1000 km and then extrapolate beyond that distance? The disaggregation figures (i.e., Fig. 3-5 and following) are labeled only out to 400 km, although there are some cells beyond that (with no indication of the epicentral distance of those cells). Thus, those figures are of little use to the reader to judge how important the ground motion are at 1000 km, much less at 1500 km. These figures need to be improved, and the justification for the 1500 km distance needs to be made explicit.	RE	Added example showing contributions out to ~1500 km at sites in areas of very low seismicity.
Rev.0	3	3-16	3.6		New section	As in many other chapters, a conclusion section in SSHAC language is needed to summarize the chapter, and foreshadow how the TI-Team will use the results (e.g. in Chapter 12) in any subsequent chapters	RE	Fixed.
Rev.0	3	3-17		3-9 to 11	Fig 3-5 to 3-8	If example is retained, please insert the source, and name the site in the figure caption. Distance interval appears to be a log-scale – is this so?	ED	Replaced example.
Rev.0	*3*	*N/A (new after Rev.2 release)*		*3-4*	*second last line*	*Consider replacing "0.1-50 Hz" with "0.1-100 Hz". This may not be a typo.*	*ED*	*Fixed.*
Rev.0	*3*	*N/A (new after Rev.2 release)*		*3-4*	*2nd para.*	*Figures 3-5 and 3-6 illustrate deaggregation to 1000 km; suggest increasing range to 1500 km to better illustrate point of section.*	*ED*	*Comment provided after Rev.2 was submitted. Under ideal conditions, we would edit the report as requested, but due to limited resources, this was not done.*
						CHAPTER 4		
Rev.0	4	G4-1				As written, section 4.1(first paragraph) represents a potentially fatal defect in the documentation of this project. This section simply states the TI Team adopted the conclusions of the Dreiling et al. report. There is no discussion of what form of evaluation and integration that the TI Team engaged in to reach the conclusion that the Dreiling et al. results were appropriate for use in this project. During two of the workshops, considerable discussion, questioning and probing of the proposed velocity/Q subdivision of CENA occurred between the TI Team and the authors of the Regionalization Report. There was also substantial feedback from the PPRP. No sense of the content or tenor of those discussions is documented in this section of the report. See also detailed comment G4-2.	General	We have reworked Chapter 4 extensively to represent the TI team evaluation of the regionalization work. The previous version consisted mostly of the PEER report by Dreiling et al. (2014) and did not provide the required evalutation of available regionalization studies. We do not address specific comments regarding the original version of the chapter, which again, consisted of text from Dreiling et al. (2014).
Rev.0	4	G4-1				As written, section 4.1(first paragraph) represents a potentially fatal defect in the documentation of this project. This section simply states the TI Team adopted the conclusions of the Dreiling et al. report. There is no discussion of what form of evaluation and integration that the TI Team engaged in to reach the conclusion that the Dreiling et al. results were appropriate for use in this project. During two of the workshops, considerable discussion, questioning and probing of the proposed velocity/Q subdivision of CENA occurred between the TI Team and the authors of the Regionalization Report. There was also substantial feedback from the PPRP. No sense of the content or tenor of those discussions is documented in this section of the report. See also detailed comment G4-2.	General	See response to first comment.
Rev.0	4	G4-2				This comment applies to more than just this chapter. Some parts of this project are referred to as "part of the science component of NGA-East." These are simply technical tasks or studies that were undertaken as part of the NGA-East project. They can be viewed as data, models or methods. The fact that these studies were conducted outside the SSHAC framework does not obviate the need for the TI-Team to perform assessment and evaluation of the results to ensure they are appropriate for use in the NGA-East model. This includes providing documentation of the evaluation and assessment of the supporting studies. Those studies provide the foundation for the project as a whole. Hence if questions arise as to the adequacy of the evaluation process due to inadequate documentation it calls into question the results of the project as a whole.	General	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	G4-3				Given the lead-in from Chapter 3 there is remarkably little use made of the CEUS-SSC results in Chapter 4. Please consider extensive tying-back of Chapter 4 to the CEUS-SSC report. In particular, the discussion in (current) section 4.2.2.1 should be strongly related back to CEUS-SSC, highlighting similarities and differences. A comparison map might be useful	General	See response to first comment.
Rev.0	4	G4-4				The EPRI (1993) approach to regionalization was heavily adopted in this chapter. The TI reduced the original EPRI-starting regionalization of 16 geologically-based regions to 4 geologically-based regions. The report needs to document how and why this starting approach was taken despite the wealth of peer-reviewed geophysical characterization data that was available (and subsequently used to infer differences between the 4 regions).	General	See response to first comment.
Rev.0	4	G4-5				The documentation and basis for the velocity-models used in the analysis needs to be significantly expanded. Presumably a host of alternate data sources/techniques were combined to evaluate crustal velocity structure including body-wave refraction and reflection surveys and surface-wave studies over a broad range of frequencies and distances. The report should compile the types of investigations used in the regional averages and PSA distributions and provide some justification for combining the alternate techniques used in the analysis. Perhaps this question is partially explained in the selection criteria which should also be fully documented in the report. The report should also justify the choice of a single representative velocity profile for each region, and explain how the representative value for the region was obtained when data are tightly clustered in one part of the region (e.g. 60 out of 86 datapoints are in the Mississippi embayment part of the Gulf Coast, by our count from Dreiling fig 3.13).	General	See response to first comment.
Rev.0	4	G4-6				The documentation and basis for the Q-models used in the analysis needs to be significantly expanded. Specifically: in section 4.2.1.3.1, line 3, please a)Explain how the median was derived (if it were the median of the Q(f) values displayed, it can not be the straight line against frequency depicted); b) Justify the choice of the median instead of the mean values; c) Justify the choice of a single Q(f) relation for each region, and d)Discuss how the uncertainty in each adopted Q(f) listed in Table 4-4 affects the project outcome.	General	See response to first comment.
Rev.0	4	G4-7				A single Q(f) model derived for the Mississippi Embayment is subsequently applied to the entire Gulf Coast even though it is said to be higher than values published for Gulf Coast. Please display your selection of Q(f) for the Gulf Coast, selected as for the other regions, together with the ZP2010 one. Please show the test for "the combined MEM region" that is intended by the words "would not test". There are other models for the Gulf region that should have been included in this comparison, such as Gupta and McLaughlin (1987) and those considered in EPRI (2013), even if they are not chosen for use.	General	See response to first comment.
Rev.0	4	G4-8				Regarding the use of the results in Chapter 4 (or lack thereof). A comparison and cross-walk between Section 4 and Section 7 (actually the PEER Report 2015/04) fails to illustrate significant linkage between the results (as summarized in Tables 4-3 (velocity) and 4-4(Q)) and their use in development of the seed GMPEs. For example, Boore uses a velocity model from Boore and Joyner (1997) to calculate crustal amplification terms and Q models from published references. Frankel uses a velocity and Q-model from Hartzell (1994). Darragh et al., use a slightly modified version of one of the four velocity models but different Q-models. Yenier and Atkinson do not appear to use either the velocity or Q results in their analysis, and so on. Suggest adding additional paragraph in section 4.5 as to how Chapter 4's conclusions are going to be used (or not), as forward-looking aid to the reader. Please also add additional reference/discussion in Chapter 7 as to which GMPEs actually used the results of Section 4 and which did not. [Note: Table 4-3 contains four derived velocity models, but most of the modellers used a single velocity model for the modelling that was done to support GMPE development (Section 7 and the PEER report).]	General	See response to first comment.
Rev.0	4	G4-9				Please check nomenclature for consistency (e.g. on page 4-11 ENA is used rather than CENA or CI or ??) and clarity of meaning. The regions should be identified by their 3-letter acronyms, not by numbers. Please replace various acronyms & numbers (which evolved during the project, but will now be confusing to users) by 3-letter acronyms. Applies to entire report. The PPRP takes exception to the term "MEM" as applied to the entire Gulf Coast (see forthcoming comments on Chapter 1).	General	See response to first comment.
Rev.0	4	G4-10				Small figures and figures annotations with very small fonts is a common problem in this and other chapters and should be corrected in the final version of the report.	General	See response to first comment.
Rev.0	4	G4-11				Technically, the word "data" is plural, so "data is" should read "data are" etc. This problem exists throughout the report.	General	See response to first comment.
Rev.0	4	4-1	4.1	4-1	First sentence	Is it a matter of evaluation, or definition/specification, or both? Also, the regionalization is in terms of crustal effects on PSA for a given magnitude and distance, not in terms of PSA (the latter does not make sense).	NR	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-2	4.1	4-1	Line 4	Be specific: adopted every conclusion, or just based Ch4 on the report? Is the TI team endorsing everything in the report? How much of the material in the report and in this chapter is actually used subsequently? Regionalization? Crustal structures? Q models? See also general comment G4-1	RE	See response to first comment.
Rev.0	4	4-3	4.1.1	4-1	Title	Title of sub-section implies results from 2013 EPRI report, most of the section describes EPRI 1993 results. Suggest renaming as EPRI 1993 or EPRI 1993 and 2013.	RE	See response to first comment.
Rev.0	4	4-4	4.1.1	4-1	2nd Para line 6	The three EPRI Q regions should be named and mapped, ideally together with the new regionalization that is adopted. Also, is the number of regions two or three? The final 1993 model used two regions; the three regions was an intermediate result. Also, please show maps with the final EPRI 1993 regions, as well as the EPRI 2013 regions (which differ from the former in the extent of the Gulf zone). Also, the difference between the 1993 and 2013 regions should be mentioned in the text.	RE	See response to first comment.
Rev.0	4	4-5	4.1.1	4-29	Fig 4-2	Increase figure size and improve resolution. Also, the quantity plotted is not acceleration or PSA, and the meaning of "normalized least-squares" is not clear. Please revise caption accordingly. Also, why is the 1/R line curved? Distance conversion? Assumed Q?	RE	See response to first comment.
Rev.0	4	4-6	4.1.1	4-2	2nd para	Please explain why discussion of focal depths relies on the pre-1993 database rather than material assembled for the CEUS-SSC report. Also, text and Table 4-1 caption are not clear as to where these data come from.	RE	See response to first comment.
Rev.0	4	4-7	4.1.1	4-2	2nd para	Although the report says "focal depth has a strong effect on earthquake ground motions", there is no illustration of trends with focal depth from the simulations (there are also none in the Dreiling et al. report); only results for 5 km depth are given. Please justify this statement, illustrate and discuss the trends with focal depth, and ensure that results in Chapter 13 support the words you use here.	RE	See response to first comment.
Rev.0	4	4-8	4.1.1	4-30	Table 4-1	Caption should reflect that this is pre-1993 data, even though cited by a 2013 publication. Perhaps EPRI (2013) should be Johnston (Johnston et al.?) (1993? 1994?) in the caption.	RE	See response to first comment.
Rev.0	4	4-9	4.1.1	4-30	Table 4-1	Correct (and document) entry for Proterozoic Margin that reads ">25", as shallower earthquakes occur there	RE	See response to first comment.
Rev.0	4	4-10	4.1.1	4-30	Table 4-1	Perhaps change title to "Range of observed focal depths for M>5 earthquakes up to 1993" as in practice some M~5 and all large events will rupture to the surface, depth = 0.	NR	See response to first comment.
Rev.0	4	4-11	4.1.1	4-2	Fig 4-5	Increase figure size and improve resolution. The regions are shown in Fig 4-1, but it is impossible to distinguish the symbols for each on this reproduced figure	NR	See response to first comment.
Rev.0	4	4-12	-	-	Figure 4-6	Figure should be full page width. Latitudes and longitudes are very difficult to read in this map, Small figures and figures annotations with very small fonts is a common problem in this and other chapters and should be corrected in the final version of the report. Also, the regions should be identified by their 3-letter acronyms, not by numbers.	NR	See response to first comment.
Rev.0	4	4-13	4.1.1	4-2	5th par line 4	Replace "it" by explicit mention of who found it reasonable	NR	See response to first comment.
Rev.0	4	4-14	4.1.1	4-2	5th par	Suggest describing in detail (better yet, showing a map of) the three regions identified in EPRI (1993) for comparison to the region selection by NGA-East. Also, please consider changing the number of regions from 3 to 2, as EPRI (1993) effectively used two regions.	RE	See response to first comment.
Rev.0	4	4-15	4.1.2	4-2 and 4-3	Entire section	The reason for the many comments on this section may be that the purpose of this section is not defined very clearly. It appears that it intends to provide a summary of (or an introduction to) the work described in sections 4.2 through 4.5. If this is so, forward references to the corresponding portions in sections 4.2 through 4.5 should be provided so that the reader can correlate the material in 4.1.2 to the more detailed material that follows. In addition, it may be advisable to make 4.1.2 significantly shorter and less detailed.	RE	See response to first comment.
Rev.0	4	4-16	4.1.2	4-2	1st par, 1st sentence	Change to read "extension of the EPRI investigation"	ED	See response to first comment.
Rev.0	4	4-17	4.1.2	4-2	1st par, 3rd sentence	"As such CENA has been subdivided into four regions based on geologic and tectonic setting". No basis for this conclusion is offered, and it is different from the last sentence in Section 4.1.1 (the conclusion of the EPRI 1993 report) that three attenuation groups were appropriate. Additional explanation and justification needed. Suggest deletion of this sentence and all subsequent mentions of "four" in this section. "four" is a judgement, but is given as a bald statement. It is subsequently used as a "known", but how and why four was assumed/chosen is not given. This section should just set out the "How and Why"	RE	See response to first comment.
Rev.0	4	4-18	4.1.2	4-2	Last sentence	"Figure 4-1" should be "Figure 4-6"	ED	See response to first comment.
Rev.0	4	4-19	4.1.2	4-2	final sentence	Delete - reference to "the four regions" is premature as these are only set up in 4.2.1.1	ED	See response to first comment.
Rev.0	4	4-20	4.1.2	4-3	Paragraph 2 on page, line 8	There are no "aforementioned" focal depths. There are four focal depths mentioned in the next paragraph. Are these the focal depths that you mean?	ED	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-21	4.1.2	4-3	middle of second paragraph	Please provide some hint as to how the representative profile and the 18 alternative profiles were developed.	RE	See response to first comment.
Rev.0	4	4-22	4.2.1.1	4-4	1st and 2nd sentences	Suggest deleting first sentence and modifying the 2nd sentence to: "The CENA was subdivided"	ED	See response to first comment.
Rev.0	4	4-23	4.2.1.1	4-4	Entire section	Because of its importance, the material in 4.2.1.1 should be a new section 4.2, before the existing 4.2, not buried below 4.2 DefinitionÉ and 4.2.1 Crustal Seismic Parameters	RE	See response to first comment.
Rev.0	4	4-24	4.2.1.1	4-4	2nd sentence	Explain the reasons why CENA was subdivided into 4 regions and not into 3, or 6, or some other number. How has this choice influenced the final outcome of the project?	RE	See response to first comment.
Rev.0	4	4-25	4.2.1.1	4-4	Entire section	The discussion should be related back to CEUS-SSC, highlighting similarities and differences. A comparison map might be useful. See General comment G4.3	RE	See response to first comment.
Rev.0	4	4-26	4.2.1.1	4-4	2nd Para	Provide the coordinates of the chosen sub-region boundaries in digital form. If they are included in appendix or attachment, please provide the corresponding reference.	RE	See response to first comment.
Rev.0	4	4-27	4.2.1.1	4-4	2nd Para	Too brief. Add at minimum, the reasons for a) the NE ACP-APL boundary near Boston b) the SW ACP-GC boundary near Charleston c) the Atlantic offshore limit to APL and ACP d)the offshore limit to GC	RE	See response to first comment.
Rev.0	4	4-28	4.2.1.1	4-4	Para 2, Line 5	Consider instead whether the western boundary of APL could be defined by the limit of Appalachian thrusting	RE	See response to first comment.
Rev.0	4	4-29	4.2.1.1	4-4	Para 2,Last sentence	Because there are surficial Quaternary sediments over almost all of CNA and APL, this cannot be the definition	RE	See response to first comment.
Rev.0	4	4-30	4.2.1.1	4-4	Last line on page	Delete the comma after "soft"	ED	See response to first comment.
Rev.0	4	4-31	4.2.1.1	4-5	Para 2, line 3	Being an area "dominated by the deposition of young sediments" is a facile reason for including the Mississippi Embayment into the Gulf Coast.	RE	See response to first comment.
Rev.0	4	4-32	4.2.1.1	4-5	Para 3, line 10	Delete irrelevant/unproved statement "since the rate of deposition is lower owing to the smaller source area,"	ED	See response to first comment.
Rev.0	4	4-33	4.2.1.1	4-5	Para 3, last sentence	Unsupported speculation, presupposes outcome. Delete or attribute to Dreiling et al.	RE	See response to first comment.
Rev.0	4	4-34	4.2.1.1	4-5	Paragraph 3, last 3 lines	The sentence states that the factors suggest that the ACP should have high attenuation, but lower than the MEM (Gulf Coast). Neither of these assertions is supported, and furthermore it is essentually contradicted later in 4-4 and 4-14 to 4-18. In Table 4-4, the Q structure of the ACP is virtually identical to that of the CNA. Part of the confusion that arises in this chapter is that there are two different concepts of attenuation that are being used here. Once concept of attenuation is related to the intrinsic anelastic attenuation of the rock of body-wave and surface wave energy. The other concept of attenuation here is the attenuation of strong-motion amplitudes and pseudospectral values. The latter refers to the diminishment of the amplitudes within seismograms with distance, and this dminishment is a superposition of all of the different effects that go into making a seismogram at different distances from a source. This statement on page 4-5 is talking about anelastic attenuation, but it is clearly contradicted later, as noted earlier in this paragraph.	RE	See response to first comment.
Rev.0	4	4-35	4.2.1.1	4-5	Para 4, line 1	Why is there a new term: CI- it was CNA a page earlier. Retain consistent terminology	NR	See response to first comment.
Rev.0	4	4-36	4.2.1.1	4-5	Para 4, line 6	Clarify "young". Do you mean "post-Paleozoic"? as there are thick Paleozoic basins on the basement	NR	See response to first comment.
Rev.0	4	4-37	4.2.1.1	4-6	Para 2, line 1	Replace "strata" (there are many batholiths etc)	ED	See response to first comment.
Rev.0	4	4-38	4.2.1.1	4-6	Para 2, line 5	FYI: There is research suggesting there is differential neotectonic deformation along the fall line (ref?)	NR	See response to first comment.
Rev.0	4	4-39	4.2.1.1	4-6	Paragraph 2 on page, line 8	Suggest the wording "much more resistant to weathering,"	ED	See response to first comment.
Rev.0	4	4-40	4.2.1.1	4-6	Para 3, line 9	Delete "failed". They are rift basins, they just did not succeed to become oceans	ED	See response to first comment.
Rev.0	4	4-41	4.2.1.1	4-6	Paragraph 3 on page, lines 10-11	The perspective in this section does not include the Mesozoic rift basins NE of New York and into Canada (Bay of Fundy); it also does not cover the (successful) passive margin faults off Nova Scotia Also, this sentence about post-rift stability is not correct. There was significant post-rift volcanic activity in Quebec and New England, probably due to the passage of the continent over a hotspot. Western Quebec, the White Mountains in New Hampshire and the offshore New England seamounts are manifestations of this. The rest of the Appalachian region may have been quieter, but not this one area.	RE	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-42	4.2.1.1	4-6	Paragraph 3 on page, lines 11-13	This sentence about the prominent exceptions is rather strange. It lists the east Tennessee seismic zone, which is a long zone of persistent seismicity that has not had an earthquake stronger than about M4.7 in modern times and perhaps earlier. It also lists the central Virginia seismic zone, which was a much smaller zone of no particular note (not large in size, no unusual rate of seismicity there) until the 2011 Mineral earthquake occurred. It ignores the seismicity in Giles County, VA, in the Adirondacks in northern NY, in central New Hampshire (with a pair of M5.5 earthquakes in 1940), and in the Miramichi region in New Brunswick (with events up to M5.8 in 1982). The sentence is also strange because the word "However" suggests a contrast with the previous sentence, which was talking the stability of the Appalachians over the past 180 my or so. All of the seismicity Ilisted here has done such minor deformation to the Appalachians that it would not show up at all over a long geologic time period. This paragraph needs to be broken up, with one paragraph about the geology that seems to be associated with the earthquakes and a separate paragraph about seismicity rates and the stresses that seem to be causing the earthquakes.	RE	See response to first comment.
Rev.0	4	4-43	4.2.1.1	4-6	Para 3 last 3 sentences	Speculative, not helpful, prejudges results. Suggest deletion	NR	See response to first comment.
Rev.0	4	4-44	4.2.1.2	4-7	First bullet	This bullet refers to "a simple "average" models" (sic) but, aside from the obvious grammatical problem, it is unclear what the problem is. Is it OK to find an average model as long as it is not simple? Is it not OK to find a single "average" model, but rather one must find multiple models? If the former question is the problem, then it suggests that the models cannot be a few simple layers but must somehow contain many layers, gradients, and perhaps even lateral variations. If the latter question is the problem, then the adjective simply suggests that one average model is too simplistic to describe the models needed. Putting the word "average" in quotes does not clarify the meaning here at all. In general, the analyses later in this chapter and in subsequent chapters end up using a few simple models (i.e., models with a few constant velocity layers) for their analyses, which in fact were called for in the previous bullet on page 4-6. Thus, as worded this bullet seems to contradict what was done elsewhere in this project as well as the previous bullet. This needs clarification.	RE	See response to first comment.
Rev.0	4	4-45	4.2.1.2	4-7	last bullet	Truncating all profiles so that they have Vs "near" 3 km/s at the top of the profile as the first step in the analysis of the profile statistics may be biasing the results high near the top of the profiles. Because the profiles in each region have considerable scatter, this step guarantees that the velocity of the top layer will be greater than 3 km/s. Comparison of figure 5-15 of EPRI (1993) to figure 4-12 suggest that this is happening (i.e., none of the regional profiles in the latter had velocity between 3 and 3.5 km/s). The very skewed box and whisker plots for Vp at the top of figure 4-25 tend to confirm this suspicion. It is not clear to what extent this apparent error invalidates the conclusions in this chapter (including the conclusions drawn from the ground motion modeling). At a minimum, this apparent bias and its implications should be discussed in the context of "representative rock", and some sensitivity analyses may be necessary. Also, the meaning of "near 3 km/sec" should be defined more precisely.	RE	See response to first comment.
Rev.0	4	4-46	4.2.1.2.1	4-7	Para 2	Irrelevant, delete unless global database influences outcome. Can also delete Fig 4-7a	NR	See response to first comment.
Rev.0	4	4-47	4.2.1.2.1	4-7	Para 4	Start with "North American"	ED	See response to first comment.
Rev.0	4	4-48	4.2.1.2.1	4-7	Para 3	Note that some "shallow crustal structure" profiles probably document the entire crust (especially in the offshore, the blue areas on Fig 4-8)	NR	See response to first comment.
Rev.0	4	4-49	4.2.1.2.1	4-7	Paragraph 4, lines 3-4	When used as adjective, phrases such as "shear-wave" and "compressional-wave" should be hyphenated	ED	See response to first comment.
Rev.0	4	4-50	4.2.1.2.1	4-8	3rd par	The velocity model data source compilation needs significantly more documentation. Simply citing that all peer reviewed publications since the year 1938 was considered for review is not adequate. We suggest that the "entry selection criteria" described in Chulick (1997) be carefully described in the text and that all models that meet that criteria be entered in a table. The tabulations should include geographic region of study, year, complete reference, type of experiment, what parameters were derived (Qs, Vp etc). Profiles that date prior to the 1980s are probably not credible for this study.	RE	See response to first comment.
Rev.0	4	4-51	4.2.1.2.1	4-8	5th par, first sentence	Incomplete; contour accuracy is also related to spacing of the data points. For example there is a large gap in data near 40N,80W. A low in northern South Carolina is defined by one point. How was uncertainty due to the unevenness of the data incorporated?	NR	See response to first comment.
Rev.0	4	4-52	4.2.1.2.1	4-8	5th par, last sentence	Seismic velocities determined to within "a few hundredths of km/sec" is not credible and needs correction.	NR	See response to first comment.
Rev.0	4	4-53	4.2.1.2.2	4-8	1st par	Basis for Vp/Vs ratio of 1.73 needs to be cited or reference provided	NR	See response to first comment.
Rev.0	4	4-54	4.2.1.2.2	4-9	1st par	"Additional literature ( ) were consulted as needed". Meaning? Please provide additional discussion here (or reduce confusion between SSHAC report and science report)	NR	See response to first comment.
Rev.0	4	4-55	4.2.1.2.2	4-9	Fig 4-9	No reason not to also show data used for the other 3 subregions on this figure	RE	See response to first comment.
Rev.0	4	4-56	4.2.1.2.2	4-9	Second to last paragraph line 16	Suggest "in fewer profiles"	ED	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-57	4.2.1.2.1	4-9	Last paragraph	In the first sentence of this paragraph, the comparisons for the ACP and APL velocities is not shown, and this is not convenient for the reader. If a point like this is made, the data need to be shown. The reader should not be forced to look at another reference in order to verify a point like this. Also, the second sentence in this paragraph has no meaning. What does it mean for an occurrence of a P velocity to be "less obvious"?	RE	See response to first comment.
Rev.0	4	4-58	4.2.1.2.2	4-9	Para 6 second sentence	Clarify what "these data" refers to	ED	See response to first comment.
Rev.0	4	4-59	4.2.1.2.2	4-10	Fig 4-12 Table 4-3	Please provide evidence that the Vp 7.3 layer at 30-40 km in the "MEM" model (Dreiling Fig 3-14) underlies the entire Gulf Coast. The PPRP is concerned that because a) 60 out of 86 (by our count from Dreiling Fig 3.13) chosen velocity profiles are in the Mississippi embayment part of the Gulf Coast, and b) Dreiling Fig 3-14 shows a significant minority of profiles with Vp ~6.5, the chosen "MEM" profile may not be representative of 90+% of the Gulf Coast region.	RE	See response to first comment.
Rev.0	4	4-60	Table 4-3	4-23		The ACP has a slower velocity between 4 km and 20.5 km than the MEM (really Gulf Coast), but the attenuation of spectral acceleration is greater for the MEM than for the ACP. It is not obvious from the velocity-depth profiles why the MEM profile generates such different ground-motion values than the other regions, especially if it is the velocity structure and not the Q model that is the primary cause of this. The first sentence on page 4-19 says, "It was found that the seismic velocity structure of the crust, rather than the Q-factor, had the largest effect on the attenuation of ground motions for the site-to-source distances considered here." The velocity structures of the APP and CNA regions are quite similar, but the ACP is rather different than these two, and the MEM model has a deep layer of Vp 7.3 that is not in the other models. Thus the report seems to be saying that the deep crust velocity structure seems to be controling the ground accelerations at the surface (differences in the Moho bounce effect?). Are we correct in concluding that it is the deep Vp 7.3 layer that affects the amplitudes of the ground accelerations with distance? Understanding how the crustal velocities control the ground accelerations is not straightforward from the report.	RE	See response to first comment.
Rev.0	4	4-61	4.2.1.2.2	4-10	Para 1 line 1	Why was the Moho placed at 40 km? Explain how the representative crustal profile with Moho at 40 km was adjusted for places where the Moho is significantly shallower or deeper. What is the effect of Moho depth differences on the outcome?	RE	See response to first comment.
Rev.0	4	4-62	4.2.1.2.2	4-10	Fig 4-10b Right-hand	The tails of mantle-like velocity shallower than 40 km and of crustal-like velocities below 40 km show pervasive effects of Moho depth differences	NR	See response to first comment.
Rev.0	4	4-63	4.2.1.2.2	4-10	Para 2 Fig 4-12	This is the only plot of velocities showing Vs. to facilitate comparison with other figures, please consider showing Vs and Vp in separate panels.	ED	See response to first comment.
Rev.0	4	4-64	4.2.1.2.2	4-10	Para 4 sentence 4	Not SSHAC-like; quantify judgement, what are implications? Also need to see data distribution on a map (see comment above)	RE	See response to first comment.
Rev.0	4	4-65	4.2.1.3	4-10	1st sentence	Suggest deleting word "formula"	ED	See response to first comment.
Rev.0	4	4-66	4.2.1.3	4-10	2nd sentence	Confirm EPRI(2013) was intended to be EPRI(1993), to be consistent with Fig 4-1 caption	RE	See response to first comment.
Rev.0	4	4-67	4.2.1.3	4-10	3rd sentence	Explain why the assignment is being made	RE	See response to first comment.
Rev.0	4	4-68	4.2.1.3	4-10	Table 4-4	Explain why EPRI1993 region 6 appears to be mis-assigned (should be in Gulf Coast region) and why EPRI 1993 region 3 is not assigned to CAN	RE	See response to first comment.
Rev.0	4	4-69	4.2.1.3	4-10	1st paragraph	If Q(f) is correlated to v(h) as shown in EPRI(1993), how is this correlation validated or applied in this study? Were published models that provided both attenuation and velocity profiles more heavily weighted?	RE	See response to first comment.
Rev.0	4	4-70	4.2.1.3	4-10		Please provide clarity whether TI team is reporting on the science report or adopting/endorsing it for the SSHAC report.	RE	See response to first comment.
Rev.0	4	4-71	4.2.1.3	4-10		Please provide details on the selection and examination process, showing it is consistent with SSHAC3	RE	See response to first comment.
Rev.0	4	4-72	4.2.1.3.1	4-10	Entire section	Unless there is a strong reason to the contrary, please always discuss the sub-regions in the same order	NR	See response to first comment.
Rev.0	4	4-73	4.2.1.3.X	4-10 to 4-11	All subsections	The RE comments below need to be addressed for each subsection	RE	See response to first comment.
Rev.0	4	4-74	4.2.1.3.1	4-10	1st sentence	Needs period at end of 1st sentence	ED	See response to first comment.
Rev.0	4	4-75	4.2.1.3.1	4-10	Line 3	See General comment G4-6 "Explain how the median was derived "	RE	See response to first comment.
Rev.0	4	4-76	4.2.1.3.1	4-10	Figs 4-14 thru - 17	Please ensure that grid lines reproduce in printed copy; for these log-log plots intermediate gridlines would be appreciated	NR	See response to first comment.
Rev.0	4	4-77	4.2.1.3.4	4-11	Last sentence of this section	The last sentence of this section makes no sense to me. In fact, we really do not understand this entire section. It sounds like there are Q data for the Gulf Coast but the authors of this report decided to ignore those data in favor of the one study that they cited. Nowhere are we being told that the Q values are for S waves (if indeed they are). Why do you ignore the active source and published Q values for P waves?	RE	See response to first comment.
Rev.0	4	4-78	4.2.1.3.4	4-11		See General comment G4-7 "A single Q(f) model derived.."	RE	See response to first comment.
Rev.0	4	4-79	4.2.2.1	4-11	2nd para	Not ML but perhaps mb or MW? (CEUS-SSC catalog should have been presented in Mw).	ED	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-80	4.2.2.1	4-11	Paragraph 2	Need to recognize that many of the depths are set at a default depth of 5, 10 or 18 km, and that these are not the actual depths (see following discussion). The SLU catalog looks better but still has a suspicious peak at 8 km (possibly a conversion from 5 miles?). The discussion in this paragraph suggests that the authors really do not understand some of the problems and limitations of event focal depths as reported in earthquake catalogs. Computer programs of the HYPOXXXX series (such as HYPO2000) that compute event locations from P and S arrival time data often have a problem constraining focal depth because there is a strong trade-off between focal depth and origin time in the calculation. Furthermore, for sparse regional seismic network coverage which exists throughout most of CENA (even with the TA stations that were left behind), most events do not have one or more seismic stations close enough to the event epicenter to add any real constraint to the focal depth part of the hypocenter calculation. For events for which this is true, the hypocenter location programs will often freeze the focal depth at its starting value in order to maximize the chances of obtaining the best estimate of the latitude and longitude of the event. Most networks in CENA start their earthquake focal depths at 5 km, 10 km or 18 km. The last value typically is used by the Canadians in their hypocenter locations because so many of their events are in the 15-25 km depth range. Thus, the peaks of the depth histograms noted in this paragraph of the report simply reflect this simplifying assumption in the way that hypocenters are computed, and the peaks have nothing to do with the actual depths of the earthquakes. To make matters worse, the hypocenter location programs often also will put an event at a depth that corresponds to the depth of one of the velocity discontinuities in the crustal model that is used in the hypocenter location computation. This is because the derivatives in the computation abruptly change at depths of velocity discontinuities, and so it can be difficult for a program to move the depth through a velocity discontinuity. Because of this, the programs often just move an event upward or downward to a velocity discontinuity in the crustal model and then just leave the event at that depth. This problem does not exist in the same way for most earthquakes in California because they have such a high spatial density of seismic stations in many of the seismically active areas in the state. However, it is a major problem in CENA. All of the depths noted in this paragraph are likely artifacts of the event location data and algorithms and have little to do with the actual event focal depths. For information, the PPRP considers the focal depth distributions that the TI team showed in a powerpoint for CEUS earthquakes	RE	See response to first comment.
Rev.0	4	4-81	4.2.2.1	4-11	2nd para	It would have been preferable to calculate and show the depth distributions by region using a reviewed depth-data set, and then use the resulting information in the simulations.	NR	See response to first comment.
Rev.0	4	4-82	-	-	-	-	-	See response to first comment.
Rev.0	4	4-83	4.2.2.2	4-11	line 4	See General comment G4-9 "ENA rather than CENA or CI.. "	ED	See response to first comment.
Rev.0	4	4-84	4.2.2.2	4-11	Fig 4-19	Hard to agree with the interpretation in the text when based on this figure, which is too small to be useful. Replace with a map of CENA with the subregions outlined. Ensure bars don't overlap too much.	NR	See response to first comment.
Rev.0	4	4-85	4.2.2.2	4-11	line 45	(north) and É (south) ’ improve language like: (in the northern third)É (rest)	ED	See response to first comment.
Rev.0	4	4-86	4.2.2.2	4-12	1st par	"appears to be normal faulting" Disagree - there are lots, but mainly in Mississippi embayment (ME). How do you reconcile the internal difference within MEM (strike-slip and thrust events) and the rest of MEM region (possibly normal)?	NR	See response to first comment.
Rev.0	4	4-87	4.2.2.2	4-12	Line 2 on page	Could some of these normal-faulting events be due to oil/gas withdrawal in producing areas? As written, this sentence implies that that these are tectonic events and thus there must be strong horizontal tension in the Gulf. If these are withdrawal events, they can look like normal faulting events even in a predominantly compressional tectonic regime. This happens at the Geysers in California, where the events are normal faulting (max. principal stress is vertical) whereas throughout the rest of the state the maximum principal stress is horizontal.	RE	See response to first comment.
Rev.0	4	4-88	4.2.2.2	4-12	Paragraph 2, line 9	Suggest rewording to "analysis of the dips of the fault planes of past events is indicated"	ED	See response to first comment.
Rev.0	4	4-89	4.2.2.2	4-12	2nd par	Half the extracted events are strike-slip. These are the ones with the second peak at 75¼ on Fig 4-20. What is the consequence of using only a) the reverse focal mechanism and b) the 45 degree dip?	RE	See response to first comment.
Rev.0	4	4-90	4.2.2.2	4-11	Last paragraph in section	The ground motions simulations are considering only one source to site orientation (90¡). This is not consistent with typical practice in ground-motion simulation, which consider the full range of azimuths. How can one be sure that the conclusions based on this very limited sampling are representative of behaviors for all possible orientations?	RE	See response to first comment.
Rev.0	4	4-91	4.2.3	4-12	-	Please justify the decision that it is sufficient to look at just 2 frequency bands	RE	See response to first comment.
Rev.0	4	4-92	4.3	4-12	-	The computational methods used for this section are not described at all. Suggest that a section be added that describes the methods, justification, required parameters, application and validation (FK and hspec96 are mentioned on page 4-18)	RE	See response to first comment.
Rev.0	4	4-93	4.3	4-12	Last line on page	"In a nutshell" is not appropriate language for a report of this kind	ED	See response to first comment.
Rev.0	4	4-94	4.3	4-13	1st line	"aggregated" Please explain how	NR	See response to first comment.
Rev.0	4	4-95	4.3	4-13	1st para	"regional differences in ground motions given the assumptions"	ED	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-96	4.3.1		Entire section	The statistical approach for evaluating whether the region to region differences in attenuation are statistically significant is rather unconventional. This might have been a good place to use Sammon's maps. At a minimum, an effort should be made to make the material easier to follow.	NR	See response to first comment.
Rev.0	4	4-97	4.3.1.1	4-13	-	"decays" ' "is slower than"?	ED	See response to first comment.
Rev.0	4	4-98	4.3.1.1	4-13	-	In this paragraph the following assertions are made "lower the frequency, the lower the PSA" (a comment which is totally irrelevant to the subject at hand, as it has nothing to do with path effects), "the rate of attenuation is also frequency-dependent" "the Moho reflections become prominent", "effect is more pronounced for higher frequencies", "there is a band of higher energy" Please ensure that this paragraph contains SSHAC-type language, and is not just casual comments. Many of these features are not clearly seen on the figure.	RE	See response to first comment.
Rev.0	4	4-99	4.3.1.3	4-13	Paragraph 1, line 2	See General comment G4-11 "Technically, the word "data" is plural.."	ED	See response to first comment.
Rev.0	4	4-100	4.3.2.1		Para 1 line 1	profile ' profiles	ED	See response to first comment.
Rev.0	4	4-101	4.3.2.1	4-14	first par.	Suggest changing to read "largest number of velocity profiles"	ED	See response to first comment.
Rev.0	4	4-102	4.3.2.1	4-14	Paragraph 1, line 4	data...were aggregated	ED	See response to first comment.
Rev.0	4	4-103	4.3.2.1	4-14	Paragraph 1, last line	"the ground motions are not statistically significant". Meaning that "the differences of ground motions between the regions are not statistically significant". Ground motions themselves cannot have statistical significance, but there can be statistical significance to measures made from those ground motions. We usually use the term "statistical significance" in connect with the testing of a hypothesis or hypotheses about the parameters obtained from some measurement parameters, but here neither the parameters nor the hypothesis is given. That makes this statement meaningless.	RE	See response to first comment.
Rev.0	4	4-104	4.3.2.1	4-14	3rd par.	What is the justification for the -0.2 and +0.4 km/s variations? Are they somehow related to the arithmetic of logarithmic standard deviation in the velocity? Are all alternative profiles given equal weight for the calculation of the standard deviation in ln(PSA)? Is there any cross over between profiles or are the velocity perturbations in the various layers assumed to be perfectly correlated? Is the basecase profile included in the calculation of the standard deviation? If so, what weight is given to it? The number of questions in relation to section 4.3.2.1 make it clear that the process for generating the alternative profiles is not properly described.	RE	See response to first comment.
Rev.0	4	4-105	4.3.2.1	4-14 and 4-15	Last par	Figure 4-24(a) and 4-24(b) indicated layer thicknesses are not fixed, contrary to what is stated in paragraph. One interpretation of Dreiling fig 4.5 is: 2 suites of runs: layer velocities varied + thicknesses fixed, and layer velocities fixed + thicknesses vary. Please confirm.	ED	See response to first comment.
Rev.0	4	4-106	4.3.2.1	4-14	Fig 4-24, Fig 4-25	Please explain the profiles with Vp~7.0 km/s below 40 km and the profiles with Vp above ~7.8 shallower than 40 km on Fig 4-24(a). Are these profiles with the Moho not at 40 km depth? How were different depths for the Moho taken into account? They are not included in Fig 4-25(b).	RE	See response to first comment.
Rev.0	4	4-107	4.3.2.1	4-14	Last par	Suggest new paragraph starting with "Figure 4-24(b)"	ED	See response to first comment.
Rev.0	4	4-108	4.3.2.1	4-15	1st par	Three of the layer thicknesses are varied by +/- 4 km one by +/- 6 km, so the statement +/-6 km is incorrect	NR	See response to first comment.
Rev.0	4	4-109	4.3.2.1	4-15	1st par	Please clarify the number of models. There seem to be only 5 layers, each with 3 alternative thicknesses (=15 cases) and for each of them there are 3 alternative velocities for each of the 5 layers (with the velocities varied one at a time) = 15, so 225 cases in total? Words "only one thickness or velocity modification at a time"	NR	See response to first comment.
Rev.0	4	4-110	4.3.2.1	4-15	1st par	There seem to be only 5 layers, so not 18 models here and in next para?	RE	See response to first comment.
Rev.0	4	4-111	4.3.2.2	4-15	2nd par	Why not just difference the 2 contour plots?	NR	See response to first comment.
Rev.0	4	4-112	4.3.2.2	4-15	4th par	Not 35-70; figure legend says 70-140 km	ED	See response to first comment.
Rev.0	4	4-113	4.3.2.2	4-16	2nd par	Suggest adding table and discussion summarizing all properties and their uncertainties used in the simulations.	NR	See response to first comment.
Rev.0	4	4-114	4.3.2.2	4-16	1st par	"semi-transparent", or "50% transparent"	ED	See response to first comment.
Rev.0	4	4-115	4.3.2.2	4-16	2nd par	Is there a "sigma" missing before the last "CAN"?	ED	See response to first comment.
Rev.0	4	4-116	4.3.2.3	4-16	Paragraph 1, line 3	Éeach of the black linesÉ	ED	See response to first comment.
Rev.0	4	4-117	4.3.2.3	4-16	Paragraph 3, line 1	Éwhether or not the ground motionsÉ	ED	See response to first comment.
Rev.0	4	4-118	4.3.2.3	4-17	1st line	The agreement (or not) is predicated on having used the right Q. Please provide sensitivity tests to reasonable uncertainty in Q. For example Figure 4-15 suggests a range of a factor of 2 in Q estimates at 1 sec for APL	RE	See response to first comment.
Rev.0	4	4-119	4.3.2.4	4-17	5th sentence	Change to read "compute the absolute value of the mean difference"	NR	See response to first comment.
Rev.0	4	4-120	4.3.2.4	4-17	Entire page	Add absolute value brackets on numerator on all equations.	NR	See response to first comment.
Rev.0	4	4-121	4.3.2.4	4-17	Paragraph 3, line 1	Éof the four regions are significantlyÉ	ED	See response to first comment.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	4	4-122	4.3.2.4	4-17	3rd para	Define "majority". Is it 50.1% of the colored area? Was the area above calculated using grid points (as implied by Table 4-8), or determined "by inspection"? If the latter, the figures are not ideal (see comment on Fig 4-30). If by gridpoint, is it reasonable to weight all points equally (i.e. isn't 4Hz at 40 km more important that 20 Hz at 450 km)?	RE	See response to first comment.
Rev.0	4	4-123	4.3.2.4	4-17	Text below Eq. 4 - 1	Shouldn't "Both matrices" be changed to "All three matrices"? Presumably, the denominator in Eq. 4-1 is also matrix.	ED	See response to first comment.
Rev.0	4	4-124	4.3.2.4	4-17	Fig 4-30	Because of the acceptance criteria, Fig 4-30 could be greatly improved by adding strong +1 and -1 contours or changing the color scheme to introduce a clear break in color intensity (note there are +1, -1, +2 and -2 contour labels, but no contours)	NR	See response to first comment.
Rev.0	4	4-125	4.4.2	4-18	-	"Table 4-8" should be "Table 4-7"	ED	See response to first comment.
Rev.0	4	4-126	4.4.3	4-18	-	3 cases of "Table 4-9" should be "Table 4-8"	ED	See response to first comment.
Rev.0	4	4-127	4.4.3	4-18	1st para, line 3	"in means in within" needs correction, ' "in means "Y" is within the 1 sigma range of CNAalt" ?	ED	See response to first comment.
Rev.0	4	4-128	4.4.3	4-18	1st para, line 3	"73%" - 73% is not the lowest value in column \Y\<1 , it is 71% for ACP and 40.8% for MEM	NR	See response to first comment.
Rev.0	4	4-129	4.4.3	4-18	1st par last sentence	Delete "is"	ED	See response to first comment.
Rev.0	4	4-130	4.4.3	4-18	2nd par 4th line	"normalized" & "Table 4-9" should be "Table 4-8"	ED	See response to first comment.
Rev.0	4	4-131	4.4.3	4-18	2nd par 4th line	"Our findings" not appropriate SSHAC language, work was done by Dreiling et al?	ED	See response to first comment.
Rev.0	4	4-132	4.5	4-18	1st line	Description of FK and hspec96 not included in discussion. See comment 4-12 above	NR	See response to first comment.
Rev.0	4	4-133	4.5	4-19	Entire section	Conclusions should include comparison of results to EPRI (1993) given in section 4.1.1 where a subset of the data were used for the same task.	RE	See response to first comment.
Rev.0	4	4-134	4.5	4-19	1st sentence	Substantiate this bald assertion within the chapter and refer back to that section	RE	See response to first comment.
Rev.0	4	4-135	4.5	4-19	3rd sentence	Where is the demonstration that this high velocity layer exists under the entire Gulf Coast?	RE	See response to first comment.
Rev.0	4	4-136	4.3.2.4	4-17		In addition to Figure 4-30, suggest including similar figure illustrating difference of mean PSA between MEM and CNA	NR	See response to first comment.
Rev.0	4	4-137	4.5	4-19	Entire section	Please demonstrate that the observed earthquake motions (from Chapter 5) are (or are not) consistent with the combination of CNA+APL+ACP vs GC (which is based on modelling synthetics) adopted for the regionalization. If not justified/validated in this chapter, please give the section number where this validation will be found.	RE	See response to first comment.
Rev.0	*4*	*N/A (new after Rev.2 release)*		*4-3*	*4.2.6*	*Consider replacing "Q of the R" with "Q of the MCR".*	*ED*	*Fixed.*
Rev.0	*4*	*N/A (new after Rev.2 release)*		*4-8*	*figure*	*expand figure to column width*	*ED*	*Fixed.*
						CHAPTER 5		
Rev.0	5	G5-1				Although the dataset is large compared with previous datasets, it lack some earlier useful data. Please explain the choices that were made, and how the rejection of certain prior data (such as SPZ-only readings) may have changed the outcome.	General	It was a matter of priority and this was defined by the project team early on that the project would focus on horizontal ground motions. The database development was already a large undertaking and the uncertainty in the conversion was a strong deterrent. Additional records have been processed since then, but have not been used for the work described in this report. We added a note in the text.
Rev.0	5	5-1	5.1	5-1	Para 1	Please include the justification for ignoring vertical-only ground motion records. Should note that there is considerable set of eNA vertical-only ground motion records, due to the longer operation of SPZ than 3-cpt stations in ENA; that some workers have "converted" vertical records to be equivalent to horizontal records, but apparently the TI-Team judged that the conversion would have introduced more uncertainty than the extra data was worth.	RE	See previous answer. We added a note in the text.
Rev.0	5	5-2	5.2	5-1	2nd paragraph, second line	Delete the comma after the word "frequency". Possibly use either "return period" or "frequency range" depending on your intentions	ED	Done.
Rev.0	5	5-3	5.2	5-1	2nd paragraph, fifth line	Change "Coda" to "coda".	ED	Done.
Rev.0	5	5-4	5.2	5-1		Please provide references in text to Figures 5-1, 5-2 and 5-3	ED	There were already references to these figures. We added some where relevant.
Rev.0	5	5-5	5.2	5-1	2nd paragraph, sixth line	Change "made the required adjustments" to "set the appropriate requirements". This change is necessary because there is nothing mentioned in the report that can be adjusted.	ED	Done.
Rev.0	5	5-6	5.2	5-2	2nd paragraph, line 1	Text "Table 5-1 lists the earthquakes selected for inclusion" may suggest to the reader that some subjective selection was performed. Please revise text to make it clear that this "selection" was simply an application of the criteria stated above.	ED	Done.
Rev.0	5	5-7	5.2.1	5-2	Para 1, line 7	Note also that the exclusion of vertical-only data removed a fair amount of 1975-2000 data	NR	This was addressed above.
Rev.0	5	5-8	5.2.1	5-2	Para 2	Comment on any records that were originally analog and were digitized;	NR	We didn't digitize records ourselves; we used what was available from various sources.
Rev.0		*Rev.2 follow-up*				*still useful to point out in report that some records started as analog (Saguenay, Nahanni, among others) as the digitization process can introduce artefacts*		*Added a note.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-9	5.2.1	5-2	Para 2	Relocate sentence "All earthquakes.." to after 1st sentence to avoid breaking up flow	ED	Done.
Rev.0	5	5-10	5.2.1	5-2	Para 2	Consider being more explicit in discussion of including Bhuj and Gazli. Why?	ED	Done.
Rev.0	5	5-11	5.2.1	5-2	Para 2 Sentence 2	Use additional introductory words to introduce sentences 2 & 3 which are the important exceptions to the rules in para 1; perhaps combine with para3 on p 5-3	NR	We rearranged the paragraphs based on comments above, so the order is now different.
Rev.0	5	5-12	5.2.1	5-3	1st line	"Geological" not Geologic	ED	Done.
Rev.0	5	5-13	5.2.1	5-2	2nd bullet	"Centre" not Center	ED	Done.
Rev.0	5	5-14	5.2.1	5-4	Para 2	Swap last 2 sentences	ED	Did not understand the need for that change.
Rev.0	5	5-15	5.2.2	5-4	Line 3	Change "Coda" to "coda".	ED	Done.
Rev.0	5	5-16	5.2.2	5-4	Line 3	Put a comma after "For example"	ED	Done.
Rev.0	5	5-17	5.2.2	5-4	Lines 4-5	I do not know what the sentence "The collection of these data is optimal when working with instrument-corrected time series rather than with raw time series." means. I don't know what is optimized, and I don't know what work you are talking about. This sentence needs to be replaced with a clear statement of the ideas you are trying to get across to the reader.	RE	This sentence was confusing and removed.
Rev.0	5	5-18	5.2.2.1	5-4	Line 4	I am confused by the phrase "...the potential for successfully retrieving the time series". The previous sentence describes instrumented and time corrected time series derived from the original data, but no other processing done to the seismograms. In this sentence the time series must be retrieved successfully. What time series? The original seismograms uncorrected for instrument response or time shifts? Why do you need to do that? If the processing was done correctly, how can you not retrieve the original time series. I think you are trying to describe some other process here or test here, but I have no clue what it is. To make matters worse, the next sentence talks about this being a criterion for accepting or rejecting the time series. Accepting or rejecting it from what? I can't figure out what the acceptance or rejection criteria are. This entire paragraph is describing something that I do not understand and could not replicate if I had to.	RE	We clarified this section.
Rev.0	5	5-19	5.2.2.2	5-5	Line 6	Change "Coda" to "coda".	ED	Done.
Rev.0	5	5-20	5.2.2.2	5-5	Line 7&8	"entire recording". This is reasonable, but the illustration of the blue box on Fig 5-4 shows it represents boxes 1-4, but not the entire series	ED	Rephrased.
Rev.0	5	5-21	5.2.2.2	5-5	Line 9	I suggest changing "FAS were computed for all the time windows for each of the recordings" to "FAS were computed for each time window for all of the recordings"	ED	Done.
Rev.0	5	5-22	5.2.2.2	5-5	Line 11	I suggest "on visual inspection"	ED	Done.
Rev.0	5	5-23	5.2.2.3	5-5	Line 7	The statement here about acausal filters is not wrong, but it does not state the real reason why zero padding is needed. The ideal is to use linear convolution for all filtering, but when filtering is done on a computer, particularly when the filtering is done in the frequency domain, wrap-around effects show up. This is true for causal as well as acausal filters. The wrap-around is due to the fact that the filtering actually employs circular convolution and not linear convolution. Zero padding the filtered signal with a sufficient number of zeros allows a circular convolution to produce the same output as one would have gotten if one had applied linear convolution. The acausality of the filter has nothing to do with wrap-around effects.	NR	OK.
Rev.0	5	5-24	5.2.2.3	5-5	Line 7	Change "Coda" to "coda".	ED	Done.
Rev.0	5	5-25	5.2.2.3	5-5	Line 8	The time windows were all increased to a duration of 50 min. (3000 sec)? Do you really need time series this long to avoid wrap-around effects? I have never done any processing of seismograms that require that much zero padding.	RE	This was done for this specific database to allow records to be used for seismological studies as well. The decision was to ensure the same df for the FAS computations.
Rev.0	5	5-26	5.2.2.3	5-5	Line 10	Remove the comma in this line	ED	Done.
Rev.0	5	5-27	5.2.2.4	5-5	Paragraph 2, lines 3-4	The sentence "The FAS calculated from the accelerations in the pre-event noise window also helps in the selection of corner frequencies." seems incomplete to me. I don't see how the FAS of the pre-event noise helps with the measurement of the corner frequency in the later event signal. Another clause explaining this would be really useful here.	RE	We clarified the statement.
Rev.0	5	5-28	5.2.2.4	5-5	Paragraph 3, lines 1-2	I suggest making this read "The high-pass corner frequency" to make clear what frequency you mean here.	ED	It already said that or maybe we didn't understand this comment.
Rev.0	5	5-29	5.2.2.4	5-5	Paragraph 3, line 3	"spectrum" ' "entire window spectrum" (which is what I think is meant)	ED	Done.
Rev.0	5	5-30	5.2.2.4	5-5	Paragraph 3, lines 4-5	The sentence "It is also the intercept with the increasing noise spectrum as decreasing the frequency below 0.1 Hz." has problems. An intercept is a point on an axis (x axis or y axis), and "as decreasing the frequency below 0.1 Hz" makes no sense. This sentence needs to be reworded to make clear what you are trying to say.	ED	This was rephrased.
Rev.0	5	5-31	5.2.2.4	5-6	Second line on page	Above you explained how you determined the high-pass filter frequency, but you never explain how you determine the low-pass filter frequency. In the example you give, you state that you do not need to use a low-pass filter. Thus, there is no method given in the text to explain how to determine the low-pass filter frequency. For this reason, the statement "All the records in NGA-East database were processed following this method of determining fc-HP and fc-LP" is not true since "this method" was not given for fc-LP.	RE	We added a sentence to this effect.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-32	5.2.2.4	5-6	Third line on page	I have no clue what "The usable frequency is also calculated with a multiplicative factor of 1.25 inward" means. I teach time-series analysis and I have never heard or read a statement like this. I have no idea what it means. Perhaps "frequency range" was intended? Also, to be clear "factor of 1.25 inward" means 1/1.25*fc-HP and 1.25*fc-LP? If so, give this in brackets as an clarification.	RE	We clarified the statement.
Rev.0	5	5-33	5.2.2.5	5-6	1st para, line 2	When (& How) were the velocity seismograms turned into acceleration? Most instrument-corrected seismometer records would be velocity records	RE	This was part of the pre-processing performed using SAC, as perfomed by Cramer's team and document in Cramer [2013]. The detailed processing documented in the chapter was completed by PEER, starting from acceleration time series.
Rev.0	5	5-34	5.2.2.5	5-6	Third paragraph, first line	I would drop the first word "However". You are starting a new paragraph with a new thought here, so the word however is in appropriate.	ED	Done.
Rev.0	5	5-35	5.2.2.5	5-6	End of third paragraph	I suggest adding a sentence telling the reader that the method that was used to ensure that these initial values can be assumed to be zero is given in the next paragraph. When I read this sentence and the paragraph ended, I thought it was the processing that you had previously described was the processing where you assumed that the initial values are zero. But I was confused because you had just shown an example where the baseline obviously drifted. Adding this sentence connects the previous text with the next paragraph.	ED	We removed the sentence about the assumption that the initial values were zero. The rest of the text describes the correct process.
Rev.0	5	5-36	5.2.2.5	5-6	Paragraph 3, line 2	Change to "which is then integrated"	ED	We didn't see the need for this change.
Rev.0	5	5-37	5.2.2.6	5-6	Paragraph 1, lines 3-4	I suggest changing "Note that by comparing the FAS for the entire window to the noise window, the time series is affected by microseisms" to "A comparison of the FAS for the entire window to that of the noise window shows that the time series is affected by microseisms".	ED	Done.
Rev.0	5	5-38	5.2.2.6	5-7	Line 2	useable frequencies	ED	Done.
Rev.0	5	5-39	5.2.2.6	5-7	Line 3	look up	ED	Done.
Rev.0	5	5-40	5.2.2.6	5-7	Line 5	Delete the comma after "analyses"	ED	Done.
Rev.0	5	5-41	5.2.2.6	5-6	Line 9	change "Coda, thus, this features becomes a deliberate choice at the project level and is not from an oversight in processing" to "coda because this feature is a deliberate choice at the project level and not an oversight in processing". Explain what "this feature" is, as it appears to have no antecedent	ED	We deleted that whole sentence. It was confusing.
Rev.0	5	5-42	5.2.3	5-7	Para 2 line 3	"developed and documented" explain how developed and where documented (in a PEER report? In the database itself? In this Chapter?)	ED	We clarified the statement.
Rev.0	5	5-43	5.2.3.1	5-7	Line 1	Note also that a rectangular rupture (not ellipse) shape is assumed	ED	Correct. We added a statement to that effect.
Rev.0	5	5-44	5.2.3.1	5-7	Lines 2-4	I agree that all of these parameters describe the fault geometry, but one also needs to know the fault rake (or slip) direction in order to know what kind of earthquake one has. For example, I would expect the hanging-wall effects to be different for strike-slip earthquakes than for thrust earthquakes (the radiation patterns are quite different). Isn't the fault slip part of the geometry?. Note that the strike is redundant if you have the endpoints	NR	The rake and slip are not part of the geometry of the fault plane. That information is included in the Earthquake Source Table (Electronic Appendix).
Rev.0	5	5-45	5.2.3.1	5-7	Line 6	I don't know what "references below" you are talking about. If you are not going to give the references here, be more specific about where "below" is (e.g. give section numbers). I looked around the rest of this paragraph, but I was not sure the references given later are the ones that you mean. Are you talking about the reference list? Please tell me where to look.	ED	Fixed.
Rev.0	5	5-46	5.2.3.1	5-7	Line 7	I suggest rewording this line to say "areal extent of a rupture was the main issue"	ED	Not sure what is being suggested.
Rev.0	5	5-47	5.2.3.1	5-7	Line 8	"collected and systematically evaluated" Table 5-3 appears to represent only the chosen models (for example Haddon's model for Saguenay is not listed), so please provide details of the evaluation that led to those chosen in Table 5-3. There was lots of discussion of this during the workshops, but it is not reflected here.	RE	We have removed that short section as the information was outdated - a relic of earlier plans. The PPRP is correct: several source models were collected and they are summarized in the source table. Finite-fault models were generated for the purpose of computing distance metrics and only considered the geometry of the source (and not, for exmaple, the distribution of slip or stress drop). For most sources, randomized source geometry realization were used to obtain distance values, as described in Section 5.2.3.3. However, for Saguenay, Riviere-du-Loup, Mineral and Nahanni, fixed finite fault models were used. We have added the description of the source parameters selected in Appendix C.1.
Rev.0	5	5-48	5.2.3.1	5-7	Table 5-3	Other models were available, so change title to read "Chosen" or "selected"	ED	OK.
Rev.0	5	5-49	5.2.3.1	5-7	Line 8	If I am interpreting the text correctly, I think you want to say " and an additional one" Name which one (?Nahanni?) - it is not apparent.	ED	Not sure what is being suggested.
Rev.0	5	5-50	5.2.3.1	5-7	Line 12	I think you want to say "a low level of slip"	ED	We removed that sentence and refer to the source for this kind of detail.
Rev.0	5	5-51	5.2.3.1	5-7	Line 11-14	It is unclear here or on Table 5-3 what trim level was used for the other three ruptures (i.e. was it 70 cm, or xx% of the maximum slip, or ??), and therefore what the consequence for the fault dimensions was; perhaps add the equivalent information given for Nahanni to each earthquake in the table.	NR	We removed that sentence and refer to the source for this kind of detail.
Rev.0	5	5-52	5.2.3.2	5-8	Para 1 Line 6	Appendix B is PPRP interactions - do you mean D? or A in PEER2014-17?	ED	Updated the reference.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-53	5.2.3.2	5-8	Para 4 Line 3	" in most cases" this would not represent standard practice in Canada; is the confusion due to the default depths in many catalogs? PPRP concurs that the MT centroid depth is the appropriate choice	NR	This is correct.
Rev.0	5	5-54	5.2.3.3	5-9	Paragraph 1, last sentence	Although I know what you are trying to say here, I think the wording is confusing. You talk about "other path data", but follow that with a parenthetical list of source items. These are not path data, but rather source parameters that are used to compute path parameters. For the items in the parentheses, I think you need to indicate that these are source parameters, but they are necessary to compute path parameters for finite fault models. That removes the ambiguity that source parameters are path parameters.	RE	Fixed.
Rev.0	5	5-55	5.2.3.3	5-9	Para 2 line 2	Appendix B is PPRP interactions. Should Appendix B be inside the preceding bracket?	ED	Updated the reference.
Rev.0	5	5-56	5.2.3	5-9	Para 2, line 6	The sentence refers to Table 5-5 which references Somerville (2001) for rupture area. Wasn't that investigated and updated as part of this project? (PEER 2014-14) Should this reference be updated?	NR	Fixed.
Rev.0	5	5-57	5.2.5	5-10	Para 1, last line	The last sentence seems like an awkward transition.	ED	Unclear, not addressed.
Rev.0	5	5-58	5.2.5	5-10	Para 2, Line 6	"Section 5.4" ?? of Goulet et al.???	ED	Updated the reference.
Rev.0	5	5-59	5.2.5	5-10	Bullet item 4	I do not know what the parenthetical expression "site visited" means. What are you trying to tell me?	ED	Added a clarification.
Rev.0	5	5-60	5.2.5.2	5-12	3rd sentence	Where is the "The small number of strong motion sites with geophysical measurements" given or displayed?	NR	Added. the number.
Rev.0	5	5-61	5.2.5.2	5-12	Line 5	recordings ' recording	ED	OK.
Rev.0	5	5-62	5.2.5.3.1	5-12	Paragraph 1, line 3	I suggest changing "considered recording stations" to "recording stations in the database"	ED	OK.
Rev.0	5	5-63	5.2.5.3.1	5-12	Paragraph 1, last sentence	The Kim et al. 2015 reference is shown as "in press" in the reference list. Probably no longer "in press".	NA	Yes. We corrected that reference.
Rev.0	5	5-64	5.2.5.3.1	5-12	section	Recent communications with Eric Thompson indicate that the Thompson-Silva Vs30 values in the NGA-East database are not the ones obtained using slope-geology, but the ones using slope alone. This should be verified and the text should be modified (if necessary) to reflect what was actually used by the project.	RE	Our intent was to use the geology-slope proxy from Thompson and Silva and we received the estimates from the 2nd author of that report. We have only now learned that the values provided were actually the slope proxy without geology. This is noted in the text.
Rev.0	5	5-65	5.2.5.3.1	5-12	section	Methods 3, 4, and 5 have their own paragraphs, suggest consistently discussing each of 1-5 in a paragraph and referring back to a list in the first paragraph. Also consider giving the methods a letter designation, as you later use numeric codes on page 5-13-14.	ED	OK.
Rev.0	5	5-66	5.2.5.3.1	5-12	Para 2 & 3	Where is the discussion from the workshops at how these methods do not give values of Vs30 > ~1200 m/s? That is, the limitations of the methods should be mentioned.	RE	It is true that very few sites in the profile database have Vs30 > 1200 m/s. There are also limitations at low Vs30.
Rev.0	5	5-67	5.2.5.3.1	5-13	4th para	Please explain why the Kim et al. method was not applied to every recording site supplying data used in the database.	RE	Most sites don't have enough recordings with high enough S/N to use the method. Records beyond 300 km generally eliminated on this basis.
Rev.0	5	5-68	5.2.5.3.2	5-13	Fig 5-13	Please keep the order of the figures consistent with the order of the methods in the text and in Fig 5-14.	ED	Not clear on this comment.
Rev.0	5	5-69	5.2.5.3.2	5-13	Para 1 line 7	Is enough information included to identify the 84 sites? Also are these all strong-motion, or are some of them weak-motion (seismometer) sites?	NR	The 84 sites are from strong ground motion stations.
Rev.0	5	5-70	5.2.5.3.2	5-13	Fig 5-14	Grid lines are very faint. Consider adding a band to represent ACR standard deviations	ED	No time or resources to generate new plots.
Rev.0	5	5-71	5.2.5.3.2	5-13	Para 2	Given the large biases in 3 of the 5 methods and their high standard deviations, please explain why you didn't spend more effort to improve the Vs30 determinations .	NR	We did not have sufficient time and budget to improve these proxy methods at the time of publication of this report. However, that work was subsequently completed and is presented in a journal article (Parker et al. 2017, BSSA).
Rev.0	5	5-72	5.2.5.3.2	5-13	Para 2	The bias in methods 2-4 is about 0.3 log units. Were the assigned Vs30 value corrected for this bias when methods 2-4 were the ones used? If the bias is not removed, please explain why the project chose not to remove it and instead chose to down-weight the high-bias proxies.	RE	We left the bias because we didn't think our very small database was large enough to shift these existing methods.
Rev.0		*Rev.2 follow-up*				*Please indicate this reasoning in the report text.*		*Done.*
Rev.0	5	5-73	5.2.5.3.2	5-13	Para 2 last sentence	While "the P-wave seismogram estimates of VS30 have the smallest dispersion.", even so their dispersion is at the top of the range for ACRs	NR	True, the east has higher dispersion, although as shown in the Parker et al. paper, that high dispersion is mostly for previously glaciated sites.
Rev.0	5	5-74	5.2.5.4.1	5-13, 5-14	Items 2 and 3	By "specifically" do you mean 'exclusively"? Please explain	RE	Replaced with "exclusively".
Rev.0	5	5-75	5.2.5.4.1	5-14	Para 1 line 7	Appendix B is PPRP interactions.	ED	Updated the reference.
Rev.0	5	5-76	5.2.5.4.1	5-14	Para 2 2nd sentence	"fast" re-express	ED	Removed.
Rev.0	5	5-77	5.2.5.4.1	5-14	Para 2 3rd sentence	Explain "special considerations"	RE	Rephrased.
Rev.0	5	5-78		5-14	Equation 5-3	By including the mean in the denominator here, this means that sites with low mean velocity are weighted higher than sites with high mean velocity. Is this intentional? When one weights only by 1/sigma^2, then the elements with the smaller sigma values get higher weights. Your scheme seems to be different, although you offer no explanation for this. I suggest an explanation to clarify this.	RE	The mean here is the mean of residuals, not the proxy mean. It is included so that proxies with bias get less weight.
Rev.0	5	5-79	5.2.5.4.1	5-14	Final sentence	"Figure 5-16 shows the distribution of the recommended values." Please explain how you have >1000 estimates for Sln(V); this is nearly the same as the number of samples (!). Use consistent notation like "sigmalnV" instead of Sln(V).	RE	Each site has an assigned mean and standard deviation. This figure is showing the distribution of each quantity. We agree notation should be consistent and we corrected the figure.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-80	5.2.5.5	5-15	Entire section	Please foreshadow how the log standard deviation (sigmalnV) values are going to be used in the later chapters. I'm confused why this work is being done.	RE	A discussion of the use of uncertainty sigmalnV has been added.
Rev.0	5	5-81	5.2.5.5.1	5-15	Line 4	To aid the reader I suggest you also express the sigmalnV values as percentage error, so sigmalnV of 0.1 is +/-10%	NR	Change made.
Rev.0	5	5-82	5.2.5.5.2	5-15	Line 2	You say engineering judgment, but I suggest that you be more specific here. Is it the judgment of the TI team, of the engineering working group, of the compilers of the database, or of someone else? You offer no reference to any other study here, so I assume it is someone or some group who worked on this project. It would be good to source this opinion in some way.	RE	Clarified. The judgement of the Geotechnical Working Group.
Rev.0	5	5-83	5.2.5.5.2	5-15	Line 2	Some context for sigmalnV of 0.3 should be given, perhaps by an example. "E.g. sigmalnV of 0.3 is +/- 35% which means a value given as 2000 m/s has a 1 sigma range of 1480-2700".	NR	Having given an example of the meaning of sigmalnV for Code 0 (in response to comment above) we don't think the same explanation needs to be provided here.
Rev.0	5	5-84	5.2.5.5.3	5-15		I think the values 0.57 and 0.46 need to be swapped, but admit I'm confused by Code 2 vs method 5 etc	ED	This is correct, the numbers have been swapped. Fixed.
Rev.0	5	5-85	5.2.5.5.4	5-15	Table 5-2 and 5-3	References in text should be to Table 5-7 and 5-8	ED	Fixed
Rev.0	5	5-86	5.2.6	5-15	Paragraph 2, last line	I am confused by the phrase "Arias intensity timing information". Arias intensity is a measure of cumulative acceleration, and time only shows up as the length of time for which the integration is carried out. This seems like a strange parameter to include here without including the Arias intensity itself.	ED	We didn't provide Arias intensities or durations based on Arias intensity in the database released for GMM development. References to that have been removed in the text.
Rev.0	5	5-87	5.2.6.1	5-16	Paragraph 1, line 2	I suggest "associated with"	ED	Fixed.
Rev.0	5	5-88	5.2.6.1	5-16	Bullet 5	Here the phrase "Arias intensity timing" shows up. See the comment above about Arias intensity. Why tell us about the timing when it is the Arias intensity value that engineers want to know?	ED	We didn't provide Arias intensities or durations based on Arias intensity in the database released for GMM development. References to that have been removed in the text.
Rev.0	5	5-89	5.2.6.2	5-16	Lines 1-2	I suggest rewording to "has selected the rotated ground motion described by Boore (2010) as the ground motion for the GMMs developed in this project."	ED	Fixed.
Rev.0	5	5-90	5.2.6.2	5-16	Lines 2-4	The second sentence of this paragraph makes no sense. It has two "is" verbs in the sentence, and I could not untangle it enough to suggest how to correct the wording.	ED	Fixed.
Rev.0	5	5-91	5.2.6.2	5-16	Line 6	Change "independence" to "independent"	ED	Fixed.
Rev.0	5	5-92	5.2.6.2	5-16	Line 7	Update "initial database release" to represent the final configuration. Is only PSA given (not PGA, PGV etc) or is the "only" intended to relate to the 5% level (not 2% or 7%)?	ED	Rephrased.
Rev.0	5	5-93	5.2.6.2	5-16	Lines 7 through 9	Last sentence not clear. May want to change "relative to" to "based on" and needs to be more specific about what duration measures were used (5-75%?)	NR	We didn't provide Arias intensities or durations based on Arias intensity in the database released for GMM development. References to that have been removed in the text.
Rev.0	5	5-94	5.2.6.2.2	5-17	Line 4	Change to "100%"	ED	We didn't provide Arias intensities or durations based on Arias intensity in the database released for GMM development. References to that have been removed in the text.
Rev.0	5	5-95	5.2.6.2.2	5-17	Line 6	I suggest "normalized Arias intensity values"	ED	We didn't provide Arias intensities or durations based on Arias intensity in the database released for GMM development. References to that have been removed in the text.
Rev.0	5	5-96	5.3	5-17	First line	"This section is based on PEER 2015". Which 2015 PEER report?	ED	The one listed in this chapter's references as PEER 2015. We added the report number (2015-04) in the text in case that wasn't clear.
Rev.0	5	5-97	5.3	5-17	Paragraph 1, lines 1 and 6	I think you want "simulation" in both of these lines	ED	Fixed.
Rev.0	5	5-98	5.3	5-17	4th par, 1st sentence	Suggest adding or summarizing simulation modeling approach acceptance criteria.	NR	
Rev.0	5	5-99	5.3.1	5-18	Section title	I suggest adding "(BBP)" after "Broadband Platform"	ED	Fixed.
Rev.0	5	5-100	5.3.1	5-18	Paragraph 1, line 2	I would delete the comma	ED	Fixed.
Rev.0	5	5-101	5.3.1	5-18	Paragraph 2, line 1	which account	ED	Fixed.
Rev.0	5	5-102	5.3.1	5-18	Paragraph 3, line 1	compares	ED	Fixed.
Rev.0	5	5-103	5.3.1	5-18	1st bullet	Typo in Atkinson	ED	Fixed.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-104	5.3.2	5-18	Entire section	This is not stand-alone section – you need to read Dreger et al. Also it doesn't document the extent of discussions at the workshops, nor the PPRP feedback (some of the earlier of which may have influenced the final version of Dreger et al.). TI-Team should clearly state that it accepts the validation exercise as published in SRL completely, and considered it sufficient to use some of the methods in NGA-East. At the end of the section, we had the questions: What were the results of the validation? Why should we trust them? Why are only some of the methods used subsequently?	RE	We have adeed a summary of the process and results. We felt it would be redundant to provide all the details from Goulet et al. (2015) and Dreger et al. (2015) in the current report, especially given their limited use in the project. In the end, the simulation data were shared with the GMPE developer WG, but only two groups made direct use of it. First, the PEER team used the FAS ratios from EXSIM, GP and SDSU to generate their models. The PEER team retracted their model based on SDSU due to concern about the scaling inferred from this model. Second, Graizer explained that he checked against the simulation results for extrapolation to large magnitude. This work was performed as a Science task and the TI team indeed accepted all the conclusions from Dreger et al. We added the summary requested which should address the PPRP concerns.
Rev.0	5	5-105	5.3.2	5-18	Paragraph 1, sentence 3	"Four" the Table has 5 entries	ED	Fixed.
Rev.0	5	5-106	5.3.2	5-19	Paragraph 1, line 1	"selected" - How and why? Use SSHAC language to explain why the other 2 methods in Table 5-9 were rejected.	RE	We expanded on this section and provided a justification.
Rev.0	5	5-107	5.3.3	5-19	Paragraph 1, line 3	I think you want "simulation" here	ED	OK.
Rev.0	5	5-108	5.3.3	5-19	Paragraph 2, lines 4-5	I think you should say "ground-motion"?	ED	Fixed.
Rev.0	5	5-109	5.3.3	5-19	Paragraph 2, line 10	Do you mean "additional motions"?	ED	Fixed.
Rev.0	5	5-110	5.3.3	5-19	Paragraph 4, line 4	I suggest "2 horizontal components"	ED	Fixed.
Rev.0	5	5-111	5.3.4	5-19	Line 2	The BBP outputs are. If you want to use the "The BBP output", the verb should be "is". I recommend "outputs are".	ED	Fixed.
Rev.0	5	5-112	5.3.4	5-20	Line 2	I think you want "(PSA and FAS ratios)"	ED	Clarified.
Rev.0	5	5-113	5.3.4	5-20	Line 3	Insert a comma, "developers,"	ED	Fixed.
Rev.0	5	5-114	5.4	5-20	Last sentence	"This .." mistakenly points to NGA-East db	ED	Fixed.
Rev.0	5	5-115	5.4	5-20	New Section?	Please say something about other data sets used in Chapter 10 for the sigma model. Also, some justification must be provided as to why these data are relevant.	RE	We added a description and motivation for these data.
Rev.0	5	5-116	5.5	5-20	New section	Chapter just peters-out. Needs a clear SSHAC-like conclusion - what was done, why is was done, why it was accepted and how it is going to be used	RE	We added a Summary conclusion.
Rev.0	5	5-117		5-26	Table 5-1	Ordering by EQID may be pragmatic and represent the history of data additions, but does not serve readers/users well. Consider ordering by date instead, or if not date then by magnitude	ED	Agreed. Not a high-priority change relative to other requests.
Rev.0	5	5-118		5-26	Table 5-1	Event 91 "Sparks" - isn't this usually referred to as the "Prague" earthquake?	ED	This reflects the file name and directory structure develop during early database building. Earthquake names sometimes change over the years.
Rev.0	5	5-119		5-26	Table 5-1	Title is "Earthquakes considered for inclusion". Please add a column indicating which ones were retained (included). Please also add a column indicating which ones will be considered PIE events (even if this distinction is not made until later, you can cite the future section). Also consider adding column with hypocentral coordinates.	RE	We added a Comment column to flag rejected events and PIEs. All the other information is tabulated in the Source table (Appendix C.2).
Rev.0	5	5-120		5-29	Table 5-2	Add as a footnote to the table "* = records that were already instrument corrected"; consider also this note adding to Table caption. [currently users reading the table first can't find what the * means]. Also "*" in a sequence of channel codes is usually taken to be a wildcard, representing all such channels, and so it is doubly misleading here, consider using a different symbol. Also what is the "short-dash" in many of the instrument types? It is not identified in a footnote.	ED	We removed that reference in the text and the asterisks in the table. It didn't provide information that was very useful for the documentation and was indeed confusing with the typical use of the wildcard *.
Rev.0	5	5-121		5-35	Table 5-5	Typo "GCS' ' GSC	ED	Fixed in Table 5-6.
Rev.0	5	5-122		5-37	Table 5-10	Column head for column 5 should instead use a footnote to explain the "*" Column head for column 7 suggests contents will be of the type 14(11), or explain "actual" and "final"	ED	Fixed.
Rev.0	5	5-123		5-44	Fig 5-8	There is almost no difference in the curves, but it is possible that color might make the point better.	ED	It may be a figure resolution issue. The image is not very convincing - in some cases differences are more important, in most cases, they are not. No change made.
Rev.0	5	5-124		5-46	Fig 5-11	Appear to be many missing lines on this figure. Add angle to show dip; add angle to show rake; strike symbol partially hidden; Nrth'north; might help to add Ztor and Zbor	NR	That was an issue in the PDF conversion - the figure is fine in Word. We resaved the figure into a new format and imported it again.
Rev.0	5	5-125		5-13	Fig 5-13	Keep in same order as discussed in text on page 5-12; consider adding bar to indicate the mean residual (or was it zero?)	ED	Not clear on the comment. These show the distribution of residuals, the mean is not always at zero.
Rev.0	5	5-126		5-49	Fig 5-16	Consider using colour to indicate the code contribution to each velocity bar. It would be ok to make this figure larger	NR	Not clear on this comment. We fixed the horizontal axis label.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	5	5-127		5-52	Fig 5-19	Top pair of figures are too low resolution; in axis labels F ' f (Capital F is conventionally Force)	ED	We do not have the resources to redo these figures at this point. The units should make the quantity clear.
Rev.0	5	5-128		5-46		Issues with Figure 5-11.	ED	Fixed as mentioned above.
Rev.0	5	5-129		5-49		Caption on x-axis. Should be sigma not s.	ED	We assumed this was for Figure 5-16 and we made the correction.
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-2*	*5.2.1*	*Consider replacing "not all the all" with "not all".*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-2*	*5.2.1*	*Consider replacing "Teresa" with "St. Teresa".*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-2*	*5.2.1*	*Consider replacing "However, not all the all M4+ CENA earthquakes have been included due to poor station coverage, e.g.,, the Teresa, Mexico, earthquake; this has led to gaps in the EQID sequence after events were rejected." with "However, due to poor station coverage (e.g., the St. Teresa, Mexico, earthquake) and other factors not all the all M4+ CENA earthquakes have been included; this has led to gaps in the EQID sequence after events were rejected.".*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-8*	*last sentence*	*Consider replacing "NRCAN" with "NRCan".*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-15*	*3rd par, line 4*	*Change to read "Tables 5-6 and 5-7"*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-16*	*2nd par, 3rd line*	*Change to read "Tables 5-6 and 5-7"*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-17*	*next to last line*	*change "modeling" to "models"*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-23*	*3rd par, last line*	*change to "500 m"*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*Table 5-1*	*caption*	*aretained*	*ED*	*Fixed.*
Rev.0	*5*	*N/A (new after Rev.2 release)*			*Table 5.1 and Section 5.2.1*	*The text and table indicate that the 1925 Charlevoix, 1929 Grand Banks, 1935 Timiskaming, 1944 Cornwall-Massena, and 2001 Bhuj earthquakes are included. Actually, ground-motion data from these earthquakes are not in the version of the lat file accompanying the report. Please clarify in report.*	*Important*	*We added comments in the table for the events older than 1945. There was already a note regarding Bhuj.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-2*	*next to last par*	*The basis for inclusion of very important data from analogous regions seems worthy of more than two sentences. Suggest adding some material here from Workshop 1 or WG meetings.*	*ED*	*Added a reference to Appendix B.*
Rev.0	*5*	*N/A (new after Rev.2 release)*		*5-2*	*last par, 3rd line*	*suggest changing "assumed" to "considered"*	*ED*	*Fixed.*
CHAPTER 6								
Rev.0	6	G6-1	G6-1			The main problem with this chapter is the lack of technical rigor in the language. As a consequence, the chapter fails to give the reader the intended historical perspective about approaches used in the past. May terms are used before they are defined the terminology is used too loosely. The 1-D preview of the material in Chapters 7-9 is a valiant attempt to explain difficult concepts and techniques, but suffers from the same problems.	GENERAL	We have reworked the chapter based on the PPRP comments. We have cleaned up the 1D example and created a 2D example to help the understanding of concepts described in Chapter 8 and 9.
Rev.0	6	?	6.1	6-1	Entire section	You may want to mention that epistemic uncertainty in ground motions is usually the largest contributor to the epistemic uncertainty in the hazard.	NR	Done.
Rev.0	6	6-1	6.2	6-1, 6-2	First two Paragraphs	These paragraphs are confusing and should be revised for the sake of clarity. The reader doesn't get a clear idea of what this section is trying to say. These paragraphs appear to be highlighting the limitations of the conventional approach of choosing some existing GMPEs and assigning weights to them, but this objective is not achieved. Here is a (non-exhaustive) list of examples of problematic text in the paragraph: a. The phrase "A discrete number of scalars" is confusing, considering that one is referring to a discrete number of GMPEs (which are not scalars, but functions of at least two quantities). b. What is a "well-defined distribution"? Do you mean a well-known continuous distribution? Discrete distributions can be well-defined as well. c. Meaning of "Because logic trees were used to represent the epistemic uncertainty, it became automatic to think about them as the end product with the basis for the underlying distribution forgotten" is not clear. d. The text is not very clear about the violation of the MECE condition and its practical implications. One way to think about this issue (which at least one member of the PPRP finds useful in the TI team may also find useful) is the following: • ME is violated when two or more of the GMPEs may be partial clones of each other because they use the same data on similar assumptions (in contrast to other GMPEs in the logic tree, which are more distinct). This violation complicates the assignment of weights and makes equal weights difficult to justify. • CE violations always occur (in a strict sense) if one uses a finite number of GMPEs (and no sigma_mu) because intermediate values of ground motion amplitudes are artificially excluded. For instance, a Rice-Miller discretization of a normal distribution of epistemic epsilons violates the CE assumption, but may yield adequate numerical results. In practice, these CE violations may not create a serious problem as long as one avoids the following two pitfalls: (1) a discretization that his too coarse and does not provide a representation of the CBR of the TDI (and may lead to inaccurate mean or fractile values of the hazard), and (2) unjustified exclusion of tail values (e.g., values higher than those predicted by the highest seed GMPE even though they belong to the CBR of the TDI).	RE	Comments addressed. a. Corrected. b. Corrected. c. Sentence removed as we reworked the section. d. We incorporated a version of the suggested text in the section.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	6	6-3	6.2	6-1	1st paragraph, line 5	It is not clear that Figure 6-1 clearly illustrates the intended point.	ED	Correct, we removed the figure when reworking this chapter.
Rev.0	6	6-4	6.2	6-2	Last line, 2nd paragraph	Consider rewriting the sentence, "We present a very short summary of each approach and conducted ..".	ED	Done.
Rev.0	6	6-5	6.2.*	6-2 through 6-7	Entire sections	These sections, as written, are not clear and fail to provide the intended historical perspective about past studies and the lessons learned from them. Common problems that detract from the clarity of this presentation are lack of precision in the terminology used and the use of concepts that have not been yet defined in the report. The comments that follow point out a number of those problems. It is suggested that significant effort be spent in improving the clarity of these sections.	NR	We revised the text. The intent of this section was to provide the background and motivation for the selected approach and was not meant to be exhaustive. Each project is summarized in about 1/2 page to achieve this purpose. We have changed the section title to reflect this intent. We added a sentence to that effect at the beginning of Section 6.2.8 as well.
Rev.0	6	6-6	6.2.2	6-3	Last paragraph	Meaning of "straying away from the concept of probability" is not clear. Perhaps you may want to say something such as "straying away from the objective of providing estimates of median logarithmic standard deviation for 540 scenarios".	NR	Done.
Rev.0	6	6-7	6.2.3	6-3	End of first paragraph	Suggested changes to last sentence: "The epistemic uncertainty was captured within each cluster and in the cluster to close the difference."	NR	We did not find that sentence.
Rev.0	6	6-8	6.2.3	6-3	Last paragraph	Paragraph is not clear and does not provide an accurate representation of what was done. Please revise.	NR	We revised the text.
Rev.0	6	6-9	6.2.4	6-4	Third paragraph	The text uses the sentence: "The distributions were again vectors of ground motions with (M, R) and f correlated through GMMs," similar to what was used in the previous section. This is not a very intuitive way to think about a set of parametric GMMs with associated weights, especially considering that this section is providing a historical overview. The concept of one GMMs as vector is a new one and is only introduced in Chapter 8, so it should not be used here.	NR	We added a sentence to the first instance (previous section) to clarify our statement.
Rev.0	6	6-10	6.2.5	6-4	First paragraph	What is the meaning of "discretized probabilities" in the middle of the paragraph? Consider using "discretized distributions"	NR	Done.
Rev.0	6	6-11	6.2.5	6-4	Second paragraph	This statement "representing discrete probabilities of a continuous distribution of ground motions" is also problematic. Consider using "representing discrete approximations of a continuous distribution of ground motions." Also, consider changing "doesn't allow different correlations of ground motions" to "doesn't allow for partial correlation of ground motions (i.e., GMMs that cross each other)." By the way, the concept of correlation between median ground motions at different magnitude-distance scenarios has not been introduced at this point in the report, but is mentioned in a number of places in 6.2 *. Maybe it should be introduced in 6.2 (and it may be worth mentioning that this correlation does not affect the mean hazard but does affect the hazard fractiles).	NR	Done. Done. We added a sentence in Section 6.2.3 that introduces the concept.
Rev.0	6	6-12	6.2.6	6-5	First paragraph	Please consider changing "Ground motion logic trees" to "Separate ground motion models". Also, it is probably incorrect to say that the scaled backbone approach was used for crustal earthquakes, because the resulting GMPEs crossed each other. Also, backbone models have not been defined at this point in the report. Perhaps this is another item that should go in section 6.2. Alternatively, please provide the forward reference to section 6.2.8 where they are defined.	NR	We revised the text. The concept of backbone approach is summarized in Section 6.2.5.
Rev.0	6	6-13	6.2.6	6-6	sentence at top of page	Should emphasize that SWUS proceeded in parallel to NGA-East and concepts were shared, though implemented differently in NGA-E	NR	Done. That's in Section 6.2.7.
Rev.0	6	6-14	6.2.7	6-5	Second paragraph	"alternate" is perhaps not the appropriate word here consider changing to "arbitrary". This word appears to be heavily misused throughout the report; in most cases "alternative" is probably a better choice.	ED	This sentence was removed when we reviesed the text.
Rev.0	6	6-15	6. .2 .7	6-6	Second paragraph	This sentence "We can imagine computing GMM-distances between points for more than three dimensions in a curved Euclidian space" will be very confusing to most readers. How was the space defined? How many dimensions does it have? (the next sentence indicates it is 2, but it is not clear at all at this point). Please rewrite this in a more clear and intuitive manner (perhaps the sentence is not needed at all). In the sentence "By taking the …", please indicate that the mapping into two dimensions is approximate in the sense that the distances between models are not preserved exactly. Also in this paragraph, you don't make each branch of the logic tree MECE, you make the set of all branches MECE.	NR	We prefer to leave that in, for readers who may understand. We refer to Chapter 8 for an explanation. We also added the definition of the 3 dimensions as ground motions for three different (M, R) scenarios and the reader can now make that parallel. We added a sentence, although this type of detail seems a bit premature at this stage. Corrected.
Rev.0	6	6-16	6.2.8	6-6	1st paragraph	Suggested rewording of 1st sentence- "Presented above was an overview of different approaches previously employed for quantifying .."	ED	Rephrased.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	6	6-17	6.2.8	6-6	Middle of last paragraph	Contrary to what the text indicates, the use of logic trees with alternative GMPEs is much older than the Yucca Mountain study. It was used by EPRI-SOG and LLNL in the late eighties, and in some earlier studies. Please change "started to use" to "went back to use"	NR	Rephrased.
Rev.0	6	6-18	6.2.8	6-7	First paragraph	The text "but the concept of 'weight as a probability' is lost. In other words, on the one hand, two GMMs may represent the same ground-motion space, or range, and not be mutually exclusive, allowing for some double-counting of the occurrence of certain ground-motion values" is very confusing. Also, it is not clear why a problem is created simply because two GMMs predict similar ground motion values; the problem occurs only if the two GMMs have too many common elements so they are clones of each other.		Rephrased.
Rev.0	6	6-19	6.2.8	6-7	Second paragraph, second line	Please consider changing "principled" to a different word, or rewrite sentence.	ED	Rephrased.
Rev.0	6	6-20	6.2.1-6.2.7		Entire section	Please include the Thyspunt (South Africa) SSHAC Level 3 study in the historical review of previous SSHAC studies. There is no reason why that study should not be included here. Their approach for ground motions is summarized in several conference and Journal papers.	NR	The intent of this section was to provide the background and motivation for the selected approach and was not meant to be exhaustive. We have changed its title to reflect this intent. We added a sentence to that effect at the beginning of Section 6.2.8 as well. The selected projects were summarized in various forms in NGA-East workshops and the Thyspunt was not. We do not see the added value of adding the summary of that project after the fact. However, we have added a section on the Canadian National Seismic Hazard Maps as it was an important project including a large CENA component. Not including in the write-up was an oversight.
Rev.0	6	6-21	6.3.1	6-7	Paragraph 2, line 4	Delete the comma after "GMMs"	ED	Done.
Rev.0	6	6-22	6.3.1	6-8	4th par	The visualization tool to collapse the high-dimensional vector to a point in 2-D is a critical element in the approach. The statement "These tools provide a way to assess the samples in a global sense- as opposed to a single scenario at-a-time- and allow a more intuitive definition of the center, body and range of P(Y)". How the results of the projection represent the CBR needs to be explained. Please elaborate.	NR	We added a forward reference to Chapter 8. Trying to explain this in Chapter 6 without the proper background would only detract the reader. We make the statement and it will be explained later.
Rev.0	6	6-23	6.3.2	6-9	all	The 1-D example is a very good start at explaining the process to be followed. However, the extension from 1-dimension to >140-dimensions may be an intellectual "bridge-too-far" for many or most readers. Strongly suggest adding a second example with 4-dimensions that includes example covariance matrices.	RE	We considered the suggestion of adding a 4D example, and tried to develop the appropriate narrative. However, it would require numerous concept that are only explained in Chapter 8, which defeats the purpose of Chapter 6. We added a 2D examplee that should help understanding the approach. The leap from the 2D example to the real high-dimensional case relies on understanding and accepting the Sammon's maps, which are explained in Chapter 8. This new 2D example provides a stronger parallel to the NGA-East approach for covering all the steps of the epistemic uncertainty quantification (ground motion space, discretization, residuals and likelihood, weights, etc.), which should be beneficial to the reader.
Rev.0	6	6-24	Step 2	6-9		May want to indicate in last sentence that there is no need to calculate correlation coefficients in this 1D case.	ED	Done.
Rev.0	6	6-25	Step 4	6-9	1st paragraph	Eliminating the tails outside the +2-sigma range will under-estimate the uncertainty. Should this be a concern? Is it compensated for? Saying that it is a TI-Team decision does not provide enough justification.	NR	This is only an example to illustrate the process. We added a comment to this effect.
Rev.0	6	6-26	6.3.2	6-9	2nd par	Test indicates 20 models while Figure 6-4 caption indicates 18 models	ED	Fixed.
Rev.0	6	6-27	6.3.2	6-9	5th par, last sentence	Please explain why seven models?	NR	This is only an example to illustrate the process. We added a comment to this effect.
Rev.0	6	6-28	Step 5	6-10	Equation 6-1	Why is the differential in the integral "d(y)"? Why not "dy"? I have the same question about Equation 6-6 on page 6-11, where there is a factor "d(y)" in the summation. The equations are more readable without the redundant parentheses.	ED	Those were typos. Fixed.
Rev.0	6	6-29	Step 5	6-10	Paragraph after equation 6-1, line 2.	The sentence here ends with ",." Delete the comma.	ED	Done.
Rev.0	6	6-30	Step 5	6-10	Paragraph after equation 6-2, 4th line	Indicate where 0.5 in equation comes from. Perhaps you should add "say," or "for example," after the parenthesis and before the equation.	ED	We changed that sentence and this is no longer part of it.
Rev.0	6	6-31	6.3.2	6-11	3rd para	"It was now.." consider re-expressing. Tenses don't make sense, and the subject doesn't fit with the example.	ED	Rephrased.
Rev.0	6	6-32	Step 2	6-12	Second paragraph	Paragraph is confusing. Consider re-writing.	ED	We simplified this paragraph.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	6	6-33	6.3.3	6-13	2nd par	The statement "The underlying assumption is that the 2D projection calculated in the previous step is a reasonable representation of the ground-motion space and hence P(Y)". How are we assured that this projection produces models or a model space that is mutually exclusive and collectively exhaustive? The SSHAC process should move this approach from an assumption to a validation. This chapter should identify the report sections that demonstrate the validation.	RE	We added a reference to Chapter 8, where this is detailed. Chapter 6 is emant to cover the conceptual approach at a very high level.
Rev.0	6	6-34			general	The SSHAC process as noted on page 6-1, is intended to make assessments of epistemic uncertainty "transparent and defensible." Step 3 needs to be significantly expanded from an assumption to a process that improves the visualization of the mutually exclusive and collectively exhaustive model space and helps the transparency of the process.	RE	We added a reference to Chapter 8, where this is detailed. Chapter 6 is emant to cover the conceptual approach at a very high level.
Rev.0	6	6-35		6-17	Fig 6-1	Make larger; add label to Y-axis	ED	Figure removed. See comment above.
Rev.0	6	6-36		6-17	Fig 6-2	Make larger; add label to Y-axis; trim lower decade	ED	We don't have access to the source; this is from Addo et al. 2012. The axes appear to have been selected to work directly with Figure 6-3.
Rev.0	6	6-37		6-18	Fig 6-3	Make much larger; increase label font size; perhaps move legend to left or right, In caption perhaps "preserved"→ "captured"? Figure caption is for PGA, text indicates PSA, make consistent.	ED	We don't have access to the source; this is from Addo et al. 2012.
Rev.0	6	6-38		6-18	Fig 6-4	Make larger; is Y-axis label p(y) or P(Y)? is X-axis label y or Y?	ED	Figure replaced.
Rev.0	6	6-39		6-20	Fig 6-8	Make larger; improve legend	ED	Figure replaced.
Rev.0	*6*	*N/A (new after Rev.2 release)*		*6-13*	*4th par, last line*	*change M,R scenaroios to "(6, 200 km)"; "(8, 200 km)"*	*ED*	*Fixed.*
Rev.0	*6*	*N/A (new after Rev.2 release)*		*6-36*	*figure caption*	*ble*	*ED*	*Fixed.*
Rev.0	*6*	*N/A (new after Rev.2 release)*		*6-13*	*mid-page*	*Consider replacing "6200 and 8200" with "200 and 200".*	*ED*	*Duplicate comment. Fixed.*
Rev.0	*6*	*N/A (new after Rev.2 release)*		*6-22*	*7th row*	*backbonde*	*ED*	*Fixed.*
						CHAPTER 7		
Rev.1	**7**	**G7-0 (new)**				The TI Team made substantial changes to the Chapter to address PPRP comments. o Section 7.1 was expanded o Sections 7.2.x were improved o Additional figures were added to 7.5.1 and 7.5.2.x sections, and Appendix D, and o Section 7.6 was added (comparing seed models to data). Review of comment resolutions indicates that the vast majority of comments were addressed.	**NR**	
Rev.1	**7**	**G7-0a (new)**				It appears that some of the general (critical) comments were only partially addressed – this pertains to the "evaluations" of the seed models completed by the TI Team related to use. Some text illustrates the issues. o Section 7.5 it is stated "Again, the objective of this process was not to make a critical assessment of individual models". In critical assessments were made (as required by the SSHAC process). o Section 7.5.1 it is stated "To ensure a practical, efficient and consistent model- building process, the TI team excluded models that could only be used over a subset of M and/or R ranges". o Section 7.5.2 "The majority of the candidate GMMs exhibit reasonable behavior over the complete range of magnitudes, distances, and frequencies considered in the evaluation process". o In Section 7.5.2.1, it is stated that a model "cannot be invalidated by the available data." This seems a strange statement, applied specifically here (to ensure inclusion) but would probably also apply to Grazier F<0.2 s and other excluded parts of the 4 conditionally-accepted GMMs. We suggest the TI team review the flagged wording and intersperse phrases like "in the judgement of the TI team… because …." into the discussion of the conditionally-accepted models. In summary, the documentation of the evaluation process is uneven and lacks consistency in language.	**RE**	As described in the introductory text preceding Section 7.1, the evaluation of the candidate models presented in Chapter 7 is a screening process to determine which models will be used as seeds in the development of the final GMMs. In the revisions, we have removed the term "critical assessment" as this may imply a stricter set of criteria than was used in the screening process. Also, as stated in several places in Chapter 7, a primary goal of the screening process was determine a set of technically defensible models apprpriate for CENA. We have made several modification to help clarify the evaluation process and selection of seed models presented in Chapter 7. This includes adding text in Introductory section preceding Section 7.1 to clarify the goals of the screening process presented in Chapter 7, and to emphasize that this process does not explicit weight individual seed models (that occurs implicitly as part of the selection of parameters to describe the continuous distributions, which is presented in detail in Chapter 8). The statment about "...invalidated by available data..." must be viewed within the context of the full sentence. This statement is specific to the published R^(-1.3) models, and the TI-Team judgement that they be included as candidate models in order to adequately sample the range of epistemic uncertainty. We modified the text for added emphasis and clarity. We have also modified the text describing the Graizer model in order to emphasize the role of interaction between the TI-Team and developer when making decisions to exclude portions of the model.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	**7**	**G7-0a (new)**				In the PPRP's view, the TI Team position of not making critical assessments of individual seed models is not consistent with the evaluation process required by SSHAC Level 3. One could also argue that critical assessments were actually made. Also there is little to explicitly indicate how model constraints were or were not considered (i.e., SMSIM and PEA point source models depend on the subsets of the earthquake data that were chosen by these developers for inversions). Some models were in fact used over a subset of magnitudes or distance (Graizer model was used over a subset of spectral frequencies and PEER models were used over a subset of spectral frequencies).	**RE**	See preceeding comment.
Rev.0	7	G7-1				The development of a suite of seed ground-motion models (GMMs) is a critical step in the NGA-East Project. As described below the PPRP believes that significant improvement is needed with the documentation for Chapter 7 to meet the expectations for a SSHAC Level 3 project. The comments provided in the table below focus on these expectations; the general SSHAC Level 3 expectations can be expressed as follows: • Chapter 7 should explain the steps taken by the TI Team to carry out the activities of evaluation and integration with respect to selecting the final set of seed GMMs to be used. The documentation should be of sufficient detail for the PPRP to conclude that the TI Team can explain why , in light of the evaluation process, the set of seed GMMs are a technically defensible interpretation of available models.. • Chapter 7 should include sufficient description and explanation of the decisions of the TI team with regard to the basis for the inclusion or exclusion of seed models. The PPRP expects a clear defense and rationale for the TI choices made. • Chapter 7 should describe the steps taken to objectively examine the seed models. This should include how the TI Team worked with seed model developers to understand the seed model technical bases, underlying model assumptions, and as appropriate, test the seed models against data. Other expectation for Chapter 7 include:	General	We have updated Chapter 7 to provide additional information on the evaluation process that was followed in selecting the seed GMMs. These updates consist of the following: 1) expanding discussion in Section 7.1 on the relative roles of the TI-Team and the GMM developers and their interactions during the GMM evaluation process, including the roles of Dave Boore and the PEER groups in the GMM development process, 2) specific definition of the target ranges of magnitude, distance, and frequency and site condition expected of the seed GMMs, 3) providing summary descriptions of the candidate GMMs in a consistent format including how each developer treated site response effects (section 7.2), 4) expanded discussion of the GMM evelation criteria and process (sections 7.3 - 7.5) including additional comparison plots from the plotting tool, 5) addition of section 7.6 describing the use of data residuals as a consistency check on the seed GMMs, and 6) addition of plots of the candidate GMMs and also plotting tools in Appendix D. Note that further description of the interactions between the TI-Team and the GMM developers has been added in chapter 1.
Rev.0	7	G7-1				• When a seed model is included, the TI team should justify the weight given to that model with respect to other models included. Giving equal weight to all models is a weight-assignment decision like any other, and must be justified. Situations where one developer provides many model variants are even more delicate, especially when the expert himself expresses lower confidence on some of them. • The interactions between the TI team and the developer(s) of candidate GMPEs must be documented. Such interactions may include: (1) participation in workshops 1 and 2 when data and alternative models were being presented, (2) responding to guidance provided by the TI Team, (3) describing the limits of applicability of their models, and (4) any model modifications based on TI Team evaluation of draft models. • Expectations from the TI Team regarding how much of the data documented in Chapter 5 should be used by the developers and how site-effect adjustments to the data should be addressed. Based on these expectations, steps taken by the TI Team to understand what each modeler did with available data and site-effects adjustments in terms of developing and evaluating these models. • The PPRP appreciates that the TI Team has the difficult task of addressing the concept that the final set of seed models serves as appropriate input into the next step of the process followed by the TI Team. Based on the documentation provided, insufficient information exists to determine if all of the seed models taken into the next step should be considered as defensible median GMMs with equal weights.		See response above.
Rev.1	*7*	*Rev.1 follow-up*				*See comment below regarding weights.* *Also, see comment G7-0a above regarding model screening.*		*See response to G7-0a above.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	G7-1				In general the PPRP is supportive of the TI Team Plan to respond to Chapter 7 comments. We note that the TI Team choose the word "rework" versus "revise" for some of the responses; the PPRP understands that the set of actions being taken by the TI Team could result in changes to which seed models are selected for use, or the weights applied to these seed models. It is not simply a matter of revising the text, the TI Team is expected to revisit the assessment and selection of seed models. A few follow-up points are provided. The general expectation from the PPRP is that after reading Chapter 7 the level of documentation will be sufficient to explain why the final set of seed models being taken into Chapter 8 represents viable median ground motion models. With regards to screening criteria the PPRP observes that for the 20 possible seed models only two criteria are used to evaluate the set of seed models; (5) The model is not based on applicable data or utilizes data that is too uncertain to be diagnostic, and (6) The model exhibits magnitude (M), distance and/or frequency scaling that appears unphysical or is inconsistent with the applicable data. For both of these the use of "data" needs careful thought and explanation. The PPRP supports your commitment to expand the discussion of how comparisons to recorded ground motion data and the use of residuals aided in the selection of seed models. We note, however, that it may be important to look into more detail for each seed model regarding what data was used by the modeler to ensure that the resulting ground motion model is a viable median model. While the TI Team may have explicitly requested which Q and geometrical spreading to be used by Dr. Boore, the data actually used to set the stress parameter appears to have been selected by the modeler, and does impact the resulting median ground motions for each of the six "Boore" models.		With regard to the weighting of the seed GMMs, this is not part of the evaluation process described in Chapter 7. The weighting of the models is described in Chapter 8.
						The same is true for other modelers; they selected the earthquakes for inversion or other data that impact the resulting ground motions. For any models that explicitly assessed depth, that should be noted. In the end it is incumbent on the TI Team to evaluate each of the seed models in some detail, and to appropriately document this evaluation in Chapter 7 to achieve a successful NGA-East final report. We note, however, that it may be important to look into more detail for each seed model regarding what data was used by the modeler to ensure that the resulting ground motion model is a viable median model. While the TI Team may have explicitly requested which Q and geometrical spreading to be used by Dr. Boore, the data actually used to set the stress parameter appears to have been to have been selected by the modeler, and does impact the resulting median ground motions for each of the six "Boore" models. The same is true for other modelers; they selected the earthquakes for inversion or other data that impact the resulting ground motions. For any models that explicitly assessed depth, that should be noted. In the end it is incumbent on the TI Team to evaluate each of the seed models in some detail, and to appropriately document this evaluation in Chapter 7 to achieve a successful NGA-East final report. September 2016: PPRP added figures comparing the Chapter 7 seed models (see separate file Chapter_7_PPRP_figures.pdf). These figures may be relevant to the question of whether all these models represent viable median models.		
Rev.1	*7*	*Rev.1 follow-up*				*Weights could be assigmed to the seed models. These weights would be used in the resulting median seed model, the variance model, and the covariance matrix, without creating any mathematical or conceptual difficulty. These weights are separate from the weights determined in Chapters 8 and 9 and there is no impediment for using both sets of weights (if the TI Team judges, as part of the evaluation process, that some seed models should receive less than full weight).* *As indicated in our earlier comments, there are many factors that could motivate the assignment of non 0/1 weights, such as: (1) the fact that two developers generated multiple models in order to sample epistmic uncertainty, while others generated one model to capture the median trend; (2) different data-selection criteria; (3) some models that fit the data better than others, etc.*		*Added text in Introductory section preceding Section 7.1 to clarify the goals of the screening process presented in Chapter 7. See response to comment G7-0a.*
Rev.0	7	G7-2				The description of candidate GMMs is not consistent with the PPRPs understanding of what was done for the project. The NGA-East project started with objective of developing a new set of "PEER" GMMs. As the project evolved a decision was made to develop a set of "new" seed GMMs to supplement existing GMMs. There was no original intent for an existing set of published GMMs, including those considered or developed by EPRI (as documented in EPRI, 2013), to be screened down to a set of candidate GMMs. To state that the published models considered by EPRI were screened out because they were superseded by more recent models is inconsistent with the original project plan as this happened during its execution. While the PPRP has requested that the GMM models from EPRI (2013) be used in sensitivity assessments, this was done to better understand the method being used by the PPRP and how the use of this method impacts the assessment of median GMM epistemic uncertainty. The text should be revised consistent with the evolution of project as executed. There is still some disagreement on what was the "original plan" between TI-Team and PPRP, perhaps because some PPRP members have been involved since project inception.	General	All the new GMMs were developed by "PEER" in that the individual GMM developers all performed their work for PEER, with guidance and interaction during the development process facilitated by PEER, and their models are published as PEER reports. Furthermore, the TI-Team did not directly develop any candidate GMMs, rather they solicited outside groups to develop their own models and submit them for consideration (section 7.1).

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	G7-3				Section 7.1 should provide a summary for each of the 20 seed GMMs, one at a time. For each seed model sufficient information should be provided to understand the key assumptions and inputs used to develop the model. The summary should make clear how each of the model developers did or did not compare their model against available strong motion data from the NGA-East database, and provide appropriate summary figures of the seed model results at a sufficient scale to understand relevant model results. Small figures of results on log-log plots should be avoided to the extent possible. Where practicable figures should occupy the full width of the page and be labelled in km. To the extent possible the text should focus on explaining the evaluation performed by the TI Team versus simply reflecting assumptions made. In general, the model descriptions should be more detailed, more internally consistent in organization and level of detail, and should use consistent terminology. For instance, the terms PSA, 5% damped pseudo spectral acceleration, and 5% PSA are used in these sections to denote the same quantity. Also, the range of applicability and the site conditions to which they apply are indicated for some models but not for others.	General	Updated GMM summaries have been added to section 7.2. These summaries are presented in a consistent format with standardized sections to aid in cross-referencing and also include a description of site response treatment.
Rev.0	7	G7-4				As written, Section 7.2 is not consistent with the PPRP understanding of the criteria used to review the set of candidate seed GMMs. This section should clearly describe the criteria used by the TI Team to review each of the 20 seed GMMs. Without this description it is not possible to determine if the set of seed GMMs taken into the next steps of the process followed by the TI Team are appropriate. The PPRP understood that an objective set of criteria were to be used by the PPRP to perform this step; if this understanding is not correct then then the PPRP needs to understand the approach followed by the TI Team to ensure that the seed models selected are appropriate for all magnitudes, distances (and focal depths) as viable median models (with the possible exception of the parameter ranges that are explicitly excluded for some of the GMMs). As examples of the lack of clarity in this section, it appears that criteria 5 and 6 were applied in 7.3 but not in 7.2. If this is the case, please revise. In addition, the use of "essentially" at the beginning of 7.2 adds considerable confusion about what was done.	General	We have updated these sections to provide more clarity on the evaluation process. Section 7.3 lists the 6 criteria employed for the evaluation. Section 7.4 describes the application of criteria 1) to 4). Section 7.5 provides a detailed description of the application of ctriteria 5) and 6).
Rev.0	7	G7-5				Given that many of the seed models required extrapolation to shorter and longer distances, the PPRP is interested in learning if the criteria in section 7.2 were applied before or after extrapolation. The text implies that the extrapolations of the models were done after the criteria were applied; the PPRP is concerned that this approach could lead to median ground motions for certain magnitudes and distances that are not technically defensible median motions. The PPRP would like to understand the steps taken by the TI Team to review the ground motions resulting from the seed models as part of determining if these can be considered as viable median ground motions; if this step was not taken the PPRP would like to understand the TI Team's perspective on how the approach being taken is consistent with expectations for a SSHAC Level 3 study. For example, for spectral frequencies greater than 10 Hz two of the seed models were not used; these two models generally represent low ground motions for near source distances. Was equal consideration given to looking at all models including those associated with high ground motions for near source distances? Given that the impact or recommendations for how focal depth should be considered is not known at this time adds some complexity to this discussion; however, the seeds motions must make sense for all possible situations, including shallow focal depths.	General	The evaluation of the candidate models described in setcions 7.3 to 7.5 was done prior to the application of distance extrapolation. However, the distance extrapolation applied to each GMM was 1) checked with the developer to ensure they were OK with the modifications, and 2) back-checked against the 6 acceptance criteria (section 7.9).
Rev.0	7	G7-6				Section 7.3 states that the TI Team performed a more detailed and systematic analysis of the models over a range of magnitudes, distances, and frequencies of interest. The text goes on to state that the objective was to ensure that the models selected were grounded in physically sound and defendable principles. As stated, and as used in the project, this statement may not be complete, and more concerning to the PPRP, may not represent what the TI Team did; the seed GMMs represent median GMMs. Section 7.3.1 should be revised to document in some detail the specific actions taken by the TI Team to perform a detailed and systematic analysis of the models. As currently written this analysis appears to be a general examination for systematically different or unjustifiable behavior with respect to its spectral shape relative to the median of the potential seed models. The PPRP would like to understand any steps taken by the TI Team to compare each of the models to the available data as part of determining if each of the seed models represents viable median models. The PPRP would also like to understand, and have explained in the document, how the TI Team evaluated each of seed models for all spectral frequencies, and for all magnitudes and distances (including near-source distances), and also considering recommendations for how focal depth will be factored in. To what degree did comparison with the data, rather than to other seed models, play a role? To what degree did the developers agree with how their models were adapted? The TI team's role in evaluating these GMMs is especially critical in this project, given that most or all of these GMMs have been developed recently, were developed over a relatively short period of time, have not been used in other projects, and have not been published in peer-reviewed journals	General	The first step of the evaluation process was designed to identify features in the candidate GMMs that warranted further evaluation. This consisted of examining the models both as a group and individually. We have added a more detailed description of this process including a number of additional figures from the plotting tool to help clarify how this was done. Features of the GMMs that were identified in this process were discussed with the developers to ensure that the behavior was intended and is being interpreted correctly. As noted, a GMM being "different" does not in and of itself mean the model should be excluded. The comparison of the individual GMMs to the reference curve is not intended to illustrate how close or far the model is from the median, but rather to provide a consistent reference to aid in the comparison of the models. Section 7.5.2 provides a discussion of the features of each candidate GMM over the subset of magnitude, distance and frequencies considered in this part of the evaluation. Section 7.6 provides an analysis of data residuals computed for each GMM to ensure the proposed models are consitent with the available recordings. A comprehensive set of comparison plots covering a broader range of magnitude and distance is provided in Appendix D. Also, discussion of the near and far distance behavior of the seed GMMs is given in sections 7.7.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	G7-7				Section 7.3.2 notes that to a large extent most of the candidate seed GMMs were "accepted as is". The documentation provided for each of the 20 seed GMMs in sections 7.3.2.x does not provide sufficient information for the PPRP to conclude that the acceptance of the models "as is" represents technically defensible interpretations for median GMMs. Comparisons with available data would seem to be a reasonable expectation in terms of documentation expected in these sections. And there might be an expectation that an accepted model be weighted by its accord with the data. For specific situations (such as near-source distances) other sources of data (e.g. NGA-West 2 data) should be considered to help assess each seed GMM. In the case of the Boore set of models where the modeler expresses a preference for certain models, the TI Team should document how they worked with the modeler, and how they determined that all models should be used "as is" and with weights that differ from Boore's preference.	General	We have expanded the illustration of the GMM features with additional plots both in chap 7 and in Appendix XX. We have added section 7.6 which shows comparison of data residuals for each candidate GMM to ensure the proposed models are consistent with the available recordings. The weighting of the seed models in developing the final GMMs is discussed in Cahpter 8. The role of the SMSIM (Boore) moels has been clarified in section 7.1, and the selection of the 6 attenuation models is described in Appendix D.
Rev.0	7	G7-8				Where proponents used observed ground motions from the NGA-east database to check or adjust their model, to what degree were soil or Vs30 factors used in the adjustments? Was the uncertainty in the Vs30 taken into account?	General	The updated summary descriptions for each GMM contain a section on how site effects were handled. A varieity of approaches were utilized and the TI-Team regards this as part of the epistemic uncertainty of the process.
Rev.0	7	G7-9				Were developers given any guidance regarding the desirability or undesirability of each developer generating alternative models in order to capture the developer's own estimate of epistemic uncertainty in the median amplitudes? Are the results biased if the weights implicit in some developer's views about their validity are ignored? Are the results biased if only some of the developers provide such a range?	General	The TI-team did not provide any explict guidance to the developers as to how they should generate their models. That is, the developers were free to do as they wish. In the case of the SMSIM models, the TI-team asked Dave Boore to generate these models using a set of six published attenuation (Q + geometric spreading) models using a single, consistent methodology. The intent is to capture the epistemic range of uncertainty in these published models in an unbiased manner. Hence, there is no explict weighting of the seed models in the manner referred to here. This is discussed in relation to Dave Boore's comments on the R-1.3 models in sections 7.1 and 7.5.2.1
Rev.0	7	7-1	7.1	7-1	middle of last paragraph	reference to chapter 12 should be chapter 13	NR	OK.
Rev.0	7	7-2	7.1	7-1	Penultimate line	Note usage of "Gulf coast"	ED	OK.
Rev.0	7	7-3	7.1.1	7-2	-	Not clear what depth was used for the modelling by Boore (even from reading PEER2015-04); suggest depth row be added to Table 7-4 and subsequent Although Rrup is the ground motion measure for most of the GMPEs the depth of the event affects the ground motions (that is at Rrup =20 km, ground motions for z=1 are not equal to ground motions at z=20 km). Please indicate what depth(s) were used by various modelers (in cases where depths were used); it be specified in summary tables 7-4 thru -13	NR	Depth is not a parameter in this suite of candidate models. A discussion of the depth range of the seed GMMs and depth adjustments for the final GMMs are provided in Chapter 13.
Rev.0	7	7-4	7.1.1	7-2	-	Not clear what the range of stress parameters was, and whether TI team feels the entire range is acceptable. For example for R^-1.3 models the stress parameters are very large. Also, may consider rephrasing "was inverted for." Sentence is a bit odd	RE	The SIMSM models were generated by Dave Boore at the request of the TI-team. Despite the concerns raised regarding the R-1.3 models, there was not compeling evidence to completely rule out their use. Text has been added in sections 7.1 and 7.5.2.1 to make this clearer. The weighting of the seed models is described in Cahpter 8. If a model is an outlier, or produces unphysical behaviour, the weigthing process will address it accordingly.
Rev.0	7	7-5	7.1.1	7-2	-	PEER Report indicates that Boore had particular issues with two of the models requested by the TI and the "R^1.3 model would not fit the 1 sec and 2 sec data no matter what stress parameter was used". The TI process to prepare the requests of the modeler, the modelers concerns and the TI disposition of the concerns should be included in 7.1.1. (This is in part captured in the general comments above)	RE	See preceeding comment.
Rev.0	7	7-6	7.1.2	7-3	3rd par	Appears that site corrections based on NEHRP category were applied to the data rather than corrections based on Vs30 measurements or assessments? Could this alternate site adjustment introduce bias? In the summary of the models, the TI should address this issue	RE	Section 7.6 has been added to describe the treatment of site response in comparing the data to the seed GMMs.
Rev.0	7	7-7	7.1.1	7-2	last sentence	usage of the word "for each" in this sentence is not clear.	NR	OK.
Rev.0	7	7-8	7.1.2	7-3	3rd para	"..scaling at R > 50 km" ' "scaling at R > 50 km based on NGA-West2 GMPEs"	ED	OK.
Rev.0	7	7-9	7.1.2	7-3	3rd para	"'b' was fixed at -0.03" Why/ is it significantly different from zero?	NR	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-10	7.1.2	7-3	3rd para	"Qo was solved for" Not clear what the value was, and whether TI team feels it is acceptable;); suggest Q row be added to Table 7-4 and subsequent	NR	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-11	7.1.2	7-3	third paragraph	Should reference section 5.2 instead of Goulet et al 2014 (this comment applies to several other sections in this chapter as well); which 53 events were used? Criteria for the selection of these 53 events? Point to a specific table listing those events	RE	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.

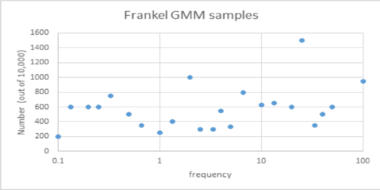
Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	7-12	7.1.2	7-3	4th para	"depths were randomized assuming a log-normal distribution with a mean of 8 km and a standard deviation of 0.6 natural log units" please express uncertainty in km (in addition to the logarithmic standard deviation)	ED	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-13	7.1.2	7-3	4th para	"shows" ' "has"	ED	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-14	7.1.2	7-3	4th para	The constant-stress-parameter model actually has a magnitude-varying stress	ED	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-15	7.1.3	7-4	bottom of second paragraph in section	remove "empirical": Data are always empirical (except for synthetic data, which aren't really data).	ED	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-16	7.1.3	7-4	for paragraph, next to last line	change predictive to predictor	ED	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-17	7.1.3	7-4	near the bottom of last paragraph	Not clear whether this overall calibration factor, converts from site B/C to reference site conditions. Please clarify	RE	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-18	7.1.5	7-6	2nd para	Frankel and Grazier GMMs were produced for 2800 m/s rock; not evident that they were corrected to 3000 m/s. Please indicate somewhere that this difference has negligible effect in practice (was it the result of lack of communication between the TI team and the developers?)	RE	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-19	7.1.5	7-6	Entire section	According to PEER 2015/04 the Frankel model accounts for rupture directivity. Does including this feature create a significant bias compared to the models that don't include directivity? The TI should address this feature of the model	RE	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-20	7.1.7	7-7	second paragraph	The text says that the model is based on two-stage regression. This is a fitting technique, not a basis for the model. Please revise	NR	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-21	7.1.10	7-8	second paragraph in section	The site conditions should be obvious, because these are the reference conditions specified by the project (this is another example of inconsistency between the model descriptions). Also, meaning of "the large CENA region" is not clear. Is this term defined in chapter 4?	NR	GMM descriptions have been updated into a consistent format. This text has been removed for clarity. Reference to GMM report for details of specific model development.
Rev.0	7	7-22	7.2	7-9	Last par	Reading this, the reader assumes that developer Somerville did not want his 2001 model to be incorporated . Please be more specific on this model.	NR	Yes, this is correct. We had a discussion with Somerville.
Rev.0	7	7-23	7.3	7-10	1st sentence	"reproducible" data or reproducible methodology or process? Please provide additional explanation.	ED	Changed to "data and methodologies"
Rev.0	7	7-24	7.3.1	7-10	4th sentence	Please provide some objective criteria for "unjustifiable behavior"	RE	Text added to clarify; i.e., appears unphysical or is inconsistent with the applicable data.
Rev.1	*7*	*Rev.1 follow-up*				*A definition of what is inconsistent would be useful. Many of the residuals in Section 7.6 could be considered inconsistent.*		*The TI-Team's criterion for what is viewed as consistent with available data is that ensure most residual points lie within +/- 0.5 ln units of zero bias over the 1 – 10 Hz frequency range. We have added some text to help emphasize this point.*
Rev.0	7	7-25	7.3.1	7-10	last two paragraphs	The statement in the text about the gray curves having no special significance is not accurate. Please indicate that they represent the geometric average over all GMMs (a rather significant quantity). Also, the statement that more importance was given to spectral shape than to absolute level is somewhat odd and requires justification.	RE	Removed the phrase "no special significance". Added clarifying text that deviations in spectral shape are more likely indicator of behavior that is inconsistent with data.
Rev.0	7	7-26	7.3.2.3	7-12	1st para	For YA Sa(50 Hz) was set equal to PGA, but the TI team still wants to use it with other GMM at 50 Hz. Is this reasonable, given that the developers focused on frequencies of 20 Hz and less? Perhaps a better option would have been to use this model over a narrower frequency range. Also figure 7-11 shows a slight slope between 50 and 100 Hz, which is inconsistent to the statement that the 50 Hz spectral acceleration was made equal to PGA	RE	We confirmed that the highest frequency of Sa for this model is 50 Hz. To extrapolate to f=100 Hz, we assumed the PGA value was appropriate for a slightly higher frueqncy and perfermed a linear interpolation (in log-log space) to obtain the f=100 Hz value. This process was checked with the developers. Text added in section 7.5.2.3 for clarification.
Rev.0	7	7-27	7.3.2.5	7-12	first paragraph	Please consider adding the word predictions after "constrain the model". The model has already been defined, regardless of the number of simulations. Also, on third line from bottom of paragraph, please change fault to rupture.	NR	Text left unchanged. The simulations are used to constrain the model. Also, the radiation from a larger fault area is what causes the featues to become smoothed out.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	7-28	7.3.2.7	7-12	1st para	Typo: anomalour	ED	OK.
Rev.0	7	7-29	7.3.2.8	7-12	first paragraph	models should be singular	ED	OK.
Rev.0	7	7-30	7.3.2.8	7-12	bottom of first paragraph	Was the decision to limit the bandwidth discussed with the expert?	RE	Yes. Text has been added to clarify.
Rev.0	7	7-31	7.3.2.10	7-13	1st para	"not well constrained by the EXSIM simulation approach"	ED	Added clarifying text.
Rev.0	7	7-32	7.4.2	7-15	Above eq 7-1	"assumes that the ground motions provided by the developers are valid for the footwall." Please confirm with developers and so state.	RE	Added clarifying text.
Rev.0	7	7-33	7.4.2	7-16	1st para	No depth discussion for SP15	NR	Text added indicating how SP15 was converted
Rev.0	7	7-34	7.4.2	7-16	first paragraph, first line	use a more descriptive name for PEER report (there are many PEER reports referenced in this report)	NR	Reference is to the Median GMM report.
Rev.0	7	7-35	7.4.3.1 7.4.3.2	7-16	-	"This distance varies depending" no antecedent distance, only a distance range	ED	Fixed.
Rev.0	7	7-36	7.4.3.1		Eq. 7-4	Is there a typo in this equation? Shouldn't the term in parenthesis be the square root of the sum of the squares?	NR	Yes, square root of sum of squares, corrected
Rev.0	7	7-37	7.4.4	7-16	Last line	Please ensure that there is documentation for the developer's agreement with the final extrapolated curves.	NR	OK.
Rev.0	7	7-38	7.4.4	7-17	various	Blue and red curves are mentioned, but are not equally visible on Fig 7-25 and subsequent as printed. They are visible at 400% display. Consider explaining	ED	Figures modified to show blue curves
Rev.0	7	7-39	7.4.4.1	7-17	Last line	Typo? Should range be 140-1000 km?	ED	Fixed.
Rev.0	7	7-40	7.4.4.2	7-17	Last para	Figure 7-27 not cited & text says "for each frequency" but only 1 Hz is shown	ED	Fixed.
Rev.0	7	7-41	7.4.4.2	7-18	1st para	Add "Fig 7-22 at end of 3rd sentence	ED	Updated with correct Figure reference.
Rev.0	7	7-42	7.4.4.3	7-19	1st para	Last sentence: Did the developers approve?	NR	Developers are OK with extrapolations.
Rev.0	7	7-43	7.4.4.6	7-20	2nd para	Last sentence: state that the TI-team agreed with the developers	NR	
Rev.0	7	7-44	7.4.4.9	7-21	3rd para	"Some degree of oversaturation was allowed". Please indicate in the text how large this oversaturation is and discuss its physical justification.	RE	Revised and clarified this point about oversaturation.
Rev.0	7	7-45	7.5	7-21	Entire section	"Unphysical spectrum". Indicate the range of magnitudes and distances for which this problem occurs, and why, in the judgment of the TI team, this issue is of little practical significance. Provide additional description of "correction": was a 10-Hz corner on the spectrum always used and why?	RE	Added additional text and figure to this section to more fully describe the issue and the correction. The observed dip in the spectra does not occur for all GMMs and when it does it is a very large distance (>600 km). It can occur for all magnitudes. The trough always occurs at much higher freuqencies than the main peak of the spectra (which is usually at 1-2 Hz for these distances). As noted in the new text, a similar feature was found in the NGA-West2 GMMs at very large distance and results from developing the models indepently for different frequencies. The TI-team considers this to be an important issue, and hence applied a correction procedure to address it.
Rev.0	7	7-46	7.5	7-21	Top of second paragraph	Please remove word "essentially"	ED	OK.
Rev.0	7	7-47	Table 7-2	7-27	Second set of models	Change to "double corner point"	ED	OK.
Rev.0	7	7-48	Table 7-3	-	-	Keep GMMs same order as rest of text and figures	ED	OK.
Rev.0	7	7-49	Table 7-3	7-28	-	Suggestions: Change "What is R?" to "Distance Metric"; Add source type column (1-C, 2-c etc); Add stress parameter range/duration model column; Add site correction model	ED	For space considerations, table left unchanged. Details are provided in text and/or PEER Median GMM Report.
Rev.0	7	7-50	Table 7-4 through 7-13			Consider adding a descriptive line on site corrections/adjustments	ED	Site treatment has been added to descriptive summaries in text.
Rev.0		*Rev.2 follow-up*	Table 7-4 through 7-13			*Suggestion: do one table per page in landscape mode to improve readability.*	*ED*	*This was considered, but the landscape orientation made the information more difficult to process (a lot of long single lines of information to read). We kept the portrait format.*
Rev.0	7	7-51	Table 7-8			Update two "submitted" references if they have been accepted or published	ED	OK.
Rev.0	7	7-52	Table 7-14		PEER-EX	Bias is chiefly at large distance?	ED	Figure 7-35 shows bias is seen at near and far distance

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	7	7-53	Fig 7-25 and onwards			Please label distance in km Please add tick marks on Y-axis for each decade Please add intermediate tick marks within each decade Please label and annotate axes consistently (in particular, figure 7-34 uses very different tick marks for the x-axis)	ED	Figures updated.
Rev.0	7	7-54	Fig 7-28 and onwards	-	caption	"lower-bound limit" ’"lower-bound distance limit"	ED	OK.
Rev.0	7	7-55	Fig 7-34	-	-	Surprising bend downwards at ~600 km - wouldn't it have been safer to have extrapolated the 100-500 km values? Was the developer made aware of this behavior? "Surprising" behavior may also be a consequence of using a different scale for this graph.	NR	As indicated in the text and figure caption, this model was not extrapolated. The plot shows the model as obtained from the developer.
Rev.0	7	7-56	7.6	7-22	Last sentence in first paragraph	Please consider removing the last sentence, or changing "to avoid É Team" to "because they were developed by the GMM Working Group and not by the TI team."	RE	Sentence removed
Rev.0	7	7-57	7.6	7-22	entire section	Please indicate explicitly that the 19 GMMs documented in this Chapter and used in Chapter 8 predict ground motion amplitudes for reference site conditions. This can be done in this section or in one of the earliest sections (i.e., 7. or 7.1). If the TI team had to perform any adjustments to the proponent models in order to obtain reference site conditions, these adjustments should be documented in Section 7.4.	RE	Clarifying text added.
Rev.1	*7*	*7-58 (new)*	*7.6*	*7-19 through 7-20*	*entire section*	*Section 7.6 contains an interesting analysis of residuals for all the seed models in the 1-10 Hz frequency range. The analysis is noteworthy in that it takes account of sample size (reflected in the size of each individual error bar) and of uncertainty in the adjustments to hard rock. The associated range of magnitude, distance, and Vs30 are not easy to discern, although they are central to the discussion of these residuals and the decision not to give them any weight in the evaluation process. A table of median values of these parameters for each frequency would help support this discussion.* *As it is now, the data residuals comparison appear to be an afterthought. Perhaps it should be made part of Section 7.3.*	*RE*	*Section 7.3 lays out the 6 steps used to evaluate the candidate models, and the final Step 6 involves a check with available data. Thus putting this at the end (i.e. Sec 7.6) is consistent with the process of evaluation as described in the report. To further emphasize this organizational structure, we have added references to Sections 7.4, 7.5 and 7.6 at relavant spots in the text of Section 7.3. To further emphasize that the residual analyses were conducted as an on-going part of the evaluation process (as opposed to an afterthought), we have added added a reference to Workshop 3C (June 2015) in which these results were presented. We have also added Figures that show histograms of the magnitude, distance and Vs30 sampling, for the subset of data used to computed the residuals.*
Rev.1	*7*	*7-59 (new)*	*7.6*	*7-19 through 7-20*	*entire section*	*Section 7.6 says "Nonetheless, we have performed checks of the candidate GMMs to ensure that they are at a minimum consistent with the available data," but we observe a number of significant deviations in the residual plots. These deviations need explanation. Here are some observations:* *•There are two models that either over- or under predict the data at all frequencies (model B_sgd02 under-predicts (Figures 7-44), and SP-15 over-predicts (Figure 7-53)). How large should the deviations be to merit exclusion?* *•The report says “Additionally, most of the models do not exhibit strong trends over this frequency band.” (page. 7-20), but some e.g. Fig 7-41, 7-43, and especially 7-55 do show trends. There is no discussion on the text as to the cause of the trends for some GMMs, and why such trends should not lead to the exclusion of those models.* *•Focusing on the comparisons at 1 Hz, 10 models are roughly unbisaed (defined as at least one of the error bars bracketing the zero-bias value), 7 over-predict, and 2 over-predict. Could this be associated with the increased predictions at 1 Hz relative to EPRI (2013) (see Figure 14-70)? At 10 Hz, there is much better agreement.* *The TI Team described in some detail the frequency constraints assigned to some models to account for over-prediction at long periods in comparison to the average seed model (1-corner models in particular), so it seems appropriate that the TI Team provide at least a few sentences at the end of Section 7.6 (or 7.3 if the text is moved) on their judgement of inclusion and equal weighting of the seed models in comparison to data.*	*RE*	*We consider models with residuals that lie within +/- 0.5 ln units of zero bias to be acceptable, and the 2 models noted in bullet 1 satisfy this criterion. We have deleted the reference to "strong trends", which was a preliminary criteria that we did not use in the end. The comments in bullet 3 point out some interesting features of the models (over-prediction, under-prediction, trends, etc.). We acknowledge there are differences, and this reflects the evolution of the model development process, as well as the epistemic uncertainty. As for the comparison with EPRI (2013) shown in Chapter 14, there we state that the difference appears to be related to differences in the median NGA-East GMM and that of EPRI (2013). It is possible that this feature could be traced back to the seed models; however, given the uncertainties in site-response adjustments, along with additional potentially complicating effects that might may have impacted the ground motion levels for hazard, all of which had not yet been addressed at the time of the screening evaluation. We feel it would be inappropriate to comment on these in Chapter 7. Finally, and more importantly, plots in Figure 9-14 show that the suite of final NGA-East GMMs do not exhibit a systematic bias at 1 Hz relative to the data. Regarding the bandwidth issue, we note that models were evaluated for apropriate behavior as a function of frequency for the range (1-10 Hz) where sufficient data exist. Exclusion of particular bandwidth (e.g. 1 corner models) was discussed with developers and agreement was reached. Again, Chapter 7 is documents a screening process, so the issue of weights is not relevant here as it is addressed in Chapter 8 (following the TI team approach, which is also summarized in Chapter 6).*
Rev.1		*Rev.2 follow-up*				*IMPORTANT. While some models are well behaved, for others the residuals at 1 Hz approach/exceed -0.5, and some of these models have a frequency trend that would imply that the exceedences would be even larger for T< 1 s (e.g. 1CVSD) where admittedly the data is sparse. Fig 9-14a is reassuring. Perhaps some words in the discussion of Fig 7-47 might allay concerns*		*There are ~5 models that approach/exceed -0.5 near 1 Hz with the most severe cases being 1CCSD and 1CVSD. However, we don’t use these 2 models for f < 1 Hz as noted in Table 7-14 so this isn’t an issue. Note also that we computed the average model bias and plotted that as a line on top of the symbols on Figures 7-40 to 7-59. We amended the text to reflect this.*
Rev.1	*7*	*7-60 (new)*	*7.2.1*	*bottom of 7-3*		*The sentence “The attenuation-model-dependent stress parameters used in the stochastic-method simulations were derived from inversion of PSA data from eight earthquakes in eastern North America (ENA).” It seems that either a reference or additional discussion is needed here. Was this done independently by Boore or is this the Boatright and Seekins work or something else?*	*ED*	*We do not understand the confusion - all the sections under 7.2 are summaries of the candidate models development. This one was done by Boore.*
Rev.1	*7*	*7-61 (new)*	*7.7.4.5*	*7-26*	*first line*	*typo—“...discrete magnitudes (4-5, 5.5, 6.5,…”, 4-5, should be 4.5.*	*ED*	*OK.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*7*	*7-62 (new)*			*Figures 7-60 and figures that follow*	*Please indicate magnitudes plotted in each figure*	*ED*	*Done in the text.*
Rev.1	*7*	*7-63 (new)*			*Fig. 7-67*	*Figure caption refers to Equations 2-6 through 2-9, this appears to be from the PEER report, either correct to equation numbers from this report or refer to PEER report in caption.*	*ED*	*Fixed*
Rev.1	*7*	*7-64 (new)*						*Empty comment.*
Rev.1	*7*	*7-65 (new)*		*7-2*	*middle of page*	*Add PGV to list*	*ED*	*OK.*
Rev.1	*7*	*7-66 (new)*	*7.2.x*		*Headings*	*unfortunately the change from discussion one model to the next is not very evident from the font used for the headings. Consider making them stand out by increasing font or boldness or leaving triple space before them*	*ED*	*We are using the NRC report template for the whole report. This is the ehading definition it requires.*
Rev.1	*7*	*7-67 (new)*	*7.2.1*	*7-3 - 7-4*		*keep the model names consistent in Case (B_a04 and not A04) and use the full names in this section*	*ED*	*OK.*
Rev.1	*7*	*7-68 (new)*	*7.2.1*	*7-3*	*middle of last paragraph*	*Reference to Table 1.2 appears to be incorrect*	*ED*	*Fixed*
Rev.1	*7*	*7-69 (new)*	*7.2.1*	*7-4*	*in Model Constraints*	*"Large Magnitude Extrapolation" should be in italics*	*ED*	*OK.*
Rev.1	*7*	*7-70 (new)*	*7.5.1*	*7-15*	*5th bullet*	*Choice of Fig 7-9 to illustrate Grazier low-frequency divergence is puzzling - better to use as the example Fig 7-15*	*ED*	*Fixed*
Rev.1	*7*	*7-71 (new)*		*Table 7-14*		*Add a column for accepted, rejected, or partially accepted - otherwise this info is buried in the comments; it should be clearly evident*	*ED*	*OK.*
Rev.1	*7*	*7-72 (new)*	*7.7.1*	*7-21*	*last sentence in section*	*The references to the subsections are wrong. They should be 7.7.X.*	*ED*	*Fixed*
Rev.1	*7*	*7-73 (new)*	*7.8*	*7-28*	*line 7 of first paragraph*	*The current wording is "that a the spectrum". Either "a" or "the" should be deleted.*	*ED*	*OK.*
Rev.2	*7*	*N/A (new after Rev.2 release)*		*7-3*	*7.2*	*Consider replacing "noted" with "denoted".*	*ED*	*Fixed.*
Rev.2	*7*	*N/A (new after Rev.2 release)*		*7-8*		*anealstic?*	*ED*	*Fixed.*
Rev.2	*7*	*N/A (new after Rev.2 release)*		*7-11*		*BSSA14: use conventional reference and be consistent*	*ED*	*We introduced this notation earlier in the section after providing the full reference.*
Rev.2	*7*	*N/A (new after Rev.2 release)*		*7-16*		*"as indicated previously" - Not! See later section 7.5.2.7.*	*ED*	*Fixed to refer to Section 7.6 and Table 7–14.*
						CHAPTER 8		
Rev.0	8	G8-1 intro				Although the chapter goes a long way in explaining the approach for the characterization of epistemic uncertainty in median ground motions to the non-expert, it is still unclear in many places, thereby failing to meet the SSHAC documentation requirements. Also, the presentation seems to lack precision in other places and sometimes uses inconsistent mathematical notation. There are a number of places where additional graphs, tables, or descriptions are necessary for the sake of transparency, as indicated in the detailed comments below. In many instances, results are presented for one frequency and no information is provided to demonstrate that these results are applicable to all frequencies. The size, quality, and low readability of figures is a major problem. Important figures are not large enough to provide useful information. The following are the most important areas where the presentation of the material needs to be revised for the sake of clarity and where the PPRP identified possible problems in the methodology.		Agreed. Specific comments addressed below.
Rev.0	8	G8-1 1.				1. The explanations in sections 8.1 (page 8-1) through 8.1.4 (page 8-9) are hard to follow and confusing in many places. The section is not organized in any coherent way but rather seems to present a stream of rather disjointed ideas about the mathematics behind what was done to sample the model space. For example, we are told in one sentence on page 8-1 that Y is a set of median ground motions for different M and Rrup scenarios and in another sentence on that same page that Y describes the epistemic uncertainty in ground motions. It is not clear how the latter comes from the former.		We clarified the description of Y (corrected the sond sentence).
Rev.0	8	G8-1 2.				2. The discussion of a Gaussian process (Section 8.1.1) is another example of an explanation that is hard to follow. The term "Gaussian process" is never formally defined or succinctly explained. We are given some references about Gaussian processes and are told about properties of a particular Gaussian process. Later in section 8.1.1 equation 8-6 is discussed and how the likelihood function can be maximized to obtain the parameters in the vector theta. The Gaussian process concept seems to be dropped from this part of the discussion (except for one vague parenthetical reference). Is it important for the reader to know about Gaussian processes in order to appreciate the analyses that were carried out? If so, this needs to be explained to us. Another source of confusion in this section is the noise term beta. It is not clear why the term should be there, considering that one is observing the realizations (i.e., the 19 seed GMMs) without any noise. It is also worth noting that the likelihood function could have been constructed from the multi-normal distribution, without using the concept of Gaussian processes. The only place where this concept appears to play any role is in motivating the parametric correlation structure.		We have removed the detailed discussion on Gaussian process and reorganized the text accordingly. We briefly refer to the Gaussian process directly in the corelation discussion. That whole section was distracting is we deemed it was not necessary to go into that much detail in the report.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	G8-1 3.				3. The need for additional graphs, tables, or descriptions is particularly serious in the case for the variance as a function of magnitude and distance. Calculated values are shown for only two frequencies and for Western GMPEs (the latter on a different scale, and PGA is not the ideal ground-motion measure for these comparisons), values are picked for a few magnitude-distance combinations with somewhat limited discussion or justification, and then these values are interpolated. The rationale given for applying the same values for all frequencies is not strong. Given the effect of these variances on the mean hazard, it is very important to provide sufficient justification for the values adopted and for the decision to use the same values for all frequencies (after all, the frequency range of interest spans three orders of magnitude). This variance is modified in later steps (namely, when the sampling is done with respect to a seed GMM rather than with respect to the overall median, when the physicality constraints are introduced, and when the space is discretized into 29 GMMs). The effect of these steps on the variance should be investigated and displayed, to ensure that the TI team is satisfied with the results. Also, it is recommended that these results be presented in terms of standard deviations rather than variances. Please also see the "RE" detailed comments relating to section 8.1.2 for important questions, comments, and concerns of the PPRP.		We have systematically revised that section. We believe the concerns have all been addressed in the new version of the chapter and in the accompanying sensitivity studies provided in Appendix E.
Rev.1	*8*	*Rev.1 follow-up*				*Not all of these issues have been completely addressed, but many have. Variance of 0.15 at short distances (all magnitudes) is an unusual choice and should receive more discussion. One would expect this uncertainty to increase with magnitude, but it does not. Also, there is not enough justification for the assumption of frequency independence of the variance, in light of the frequency dependence observed in the seed GMMs and especially in SWUS. Overall, the sensitivity results in Appendix E are very helpful*		*This was practical choice that we made as the differences between frequencies was difficult to quantify. The frequency-dependence is introduced by the spread of the different sets of seeds at each frequency.*
Rev.1		*Rev.2 follow-up*				IMPORTANT. But why 0.15? And why 0.1 for M4-5 &R150-400 - doesn't this deserve a reference/justification. The effects of this choice may be partially responsible for the issues pointed out in comment 9-42 below.		*We have tested several configurations and the results are not sensitive to small differences. As explained in section 8.1.1, the final results represent a nonlinear combination of the minimum imposed variance and of the variance introduced when using each seed as a mean for the generation of other models.*
Rev.0	8	G8-1 4.				4. The development of the correlation model in section 8.1.3 is particularly difficult to follow. There seem to be errors in Eq. 8-9 (those may be simply typos, but there may be flaws in the formulation) and the presentation seems to be out of sequence in places, jumping from one topic to another and back. No values are presented for the coefficients (thetas) of Eq. 8-9, and the text does not indicate whether those coefficients depend on frequency or on the reference scenario x'. Perhaps most importantly, no figures are presented comparing the observed and fit correlations in order to demonstrate that the parametric correlation model provides an adequate fit to the observed correlation structure. These figures should be presented for a broad range of frequencies, not only for one frequency. Please also see the "RE" detailed comments relating to section 8.1.3 for important questions, comments, and concerns of the PPRP.		There was indeed an error in the equation. We have reworked this section; it is addressed in a specific comment below. We are not trying to fit the sample (seeds) correlation, we actually the mean model Gaussian Process, so the two types of correlations can't be compared. However we provide plots of this modeled corelation. We added a table of the parameter values (thetas).
Rev.1	*8*	*Rev.1 follow-up*				*Partially addresses. Equations may still have typo (confirmed) and coefficient do not seem to make sense. See comment 8-31 for more details. Overall, the sensitivity results in Appendix E are very helpful*		*We corrected the equation. We added a discussion on the values for the coeficients.*
Rev.0	8	G8-1 5.				5. Section 8.1.4 is also difficult to follow. No clear rationale is provided for abandoning the pure multi-normal model (where one randomizes around the overall mean GMM) and going to a mixture model. This material, and the motivation for this step, were presented more clearly at the workshops. In fact, some of the arguments provided in the text appear to be incorrect. Also, the apparent inconsistency in the variance that is created by this step (which would imply doubling the variance if the models had received the equal weights) is not considered at all.		This is correct: we effectively use a mixture model. We have revised our approach and clarified the explanation. We also show the final achieved variance (in Chapter 9 because it requires weights) to confirm that we didn't double-count the variance, but reached a defensible target.
Rev.1	*8*	*Rev.1 follow-up*				*Achieved variance plots are very useful in this regard.*		
Rev.0	8	G8-1 6.				6. Regarding the weights of the seed models, Figure 8-13 and equation 8-14 are critical. Not all of the models were given equal weight in selecting the 10,000 random model realizations, but this is not described clearly in the text. The justification for these weights is questionable, as it is based entirely on proximity between models on the Sammon's plane (and, by the way, Sammon's maps are not introduces until later) and not on the consideration of the underlying assumptions and data. These weights also depend on the cell size chosen, but the cell size is not justified or discussed. These weights are further modified by the physicality constraints, in a manner that may not be entirely defensible. These steps must be justified and documented in greater detail. In addition, it is important to know how much weight each model gets at each frequency. Please also see the "RE" detailed comments on section 8.1.4 for related questions, comments, and concerns of the PPRP.		We have completed sensitivity studies documented in Appendix E to address this issue. The weighting scheme selected by the TI team is behaving as intended. This is discussed in the appendix.
Rev.1	*8*	*Rev.1 follow-up*				*The sensitivity results in Appendix E.4 strongly suggest that the mean hazard is insensitive to these weights, which supports the TI Team's approach.*		
Rev.0	8	G8-1 7.				7. The screening for physicality (Section 8.1.5) is almost by necessity somewhat ad hoc. One area of concern to the PPRP is that the screening is effectively down-weighting some of the seed GMMs. The desirability and implications of this down-weighting are not discussed in the report. Another area of concern is that some unphysical GMMs may be passing the screening tests, as shown by some of the figures shown at the end of this document and discussed near the end of the general section of this review.		We have addressed these comments below where they are repeated.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*8*	*Rev.1 follow-up*				*Implicit weights resulting from physicality criteria and proximity weights are still highly variable (and frequency-dependent).* *The figure to the right of this cell illustrates the apparent contradictions introduced by these weights: The number of samples in Fig 8-33 for Frankel GMM are shown as a function of frequency. From this it appears that the Frankel model is three times better at 2 Hz than it is at 1.33 or 2.5 Hz, and it is also three times better at 25 Hz than it is at 20 or 33 Hz. These differences must be explained or discussed. Also, do other seed GMMs show similar behavior or is this a consequence of the Frankel GMM's noise?* *Can one invoque the sensitivity results in Appendix E.4 as indicating that the mean hazard is also insensitive to the implicit weights introduced by the physicality constraints? Not clear*		*The sampling doesn't reflect on how good the model is. It only reflects 1) how close the models are to other models for the initial Sammon's maps weighting and 2) how close the model is to the physical criteria. Sensitivities presented in Appendix E showed that various weighting schemes do not have a large impact on the final results.* 
Rev.0	8	G8-1 8.				8. The material after page 8-9 gets clearer. Figures 8-26 through 8-28 provide a good justification for how they handled correlations among the models. Perhaps the biggest complaint about the last half of this chapter is that it is not completely clear how the smoothing of the spectra (Figures 8-37 to 8-40) was performed. Equation 8-20 seems to have 6 free parameters in it. How were those parameters constrained?		We have revised our smoothing procedure and improve the description in the text.
Rev.1	*8*	*Rev.1 follow-up*				*The spectral shapes seem to be better behaved now.* ***The question remains whether the spectral shapes are well behaved after the frequency-dependent GMM weights are introduced in Chapter 9. Were the results in Figure 8-50 calculated using the weights in Table 9-2? If so, please indicate so. If not, this issue must be investigated. (Note: this issue is also raised in Chapter 9 comments)*** *The PPRP suggests that the coefficients of Equations 8-23 and 8-24 be released, thereby giving PSHA analysts and other users the option of using these equations or the tabulated values (although the frequency-dependent weights make these smooth spectra less useful).*		*We did use weights from Chapter 9. In response to comments on this topic in Chapter 9, we now provide mean weighted spectra for all the scenarios in appendix E.9.2.*
Rev.1		*Rev.2 follow-up*				Please indicate in Chapter 8 that the weights from Chapter 9 were used to calculate the spectra. (SUGGESTION) We see no response to the suggestion: "The PPRP suggests that the coefficients of Equations 8-23 and 8-24 be released, thereby giving PSHA analysts and other users the option of using these equations or the tabulated values (although the frequency-dependent weights make these smooth spectra less useful)." Is it possible to release these coefficients?		*We added a note in the text and in the captions for Figure 8-49 and 8-50.*
Rev.0	8	G8-1 9.				9. Figures generated by the PPRP using the tabulations of the 29 discretized GMMs that are provided in Appendix E1 indicate unphysical "sawtooth" behavior of some GMMs in both magnitude and distance scaling, as well as multiple peaks in some spectra. Three of the worst examples of this behavior found by the PPRP are provided following the table of detailed comments. Unless this behavior is due to plotting errors by the PPRP or errors in the Appendix, it should be corrected. This behavior may also be diagnostic of problems in the formulation and its cause should be investigated; brute-force smoothing of the tabulated values may not be an appropriate solution. Although the effect of this behavior on the hazard results may be negligible, this behavior may detract from the credibility of the methodology and of the resulting GMMs.		Agreed. We have refined various steps involved in the model generation. The extensive work paid off and led to smooth models in magnitude and distance scaling that only required some smoothing in the spectral shape domain The spectra smoothing had only minor effct on the final magnitude and distance scaling. Note that many of the seeds were not smooth to start with (see appedix D related to Chapter 7).
Rev.1	*8*	*Rev.1 follow-up*				*Examination of CDF plots suggests that these problems have been removed*		
Rev.0	8	G8-1 Closure				The PPRP recognizes that the material in this chapter is new to most readers and it is difficult to document and explain. For that reason, it is important for the TI team to devote a significant effort to make the material clear to a reader who is not necessarily an expert in Gaussian Processes and Sammon's maps. In addition, it is important for the TI team to develop and document "sanity checks" to demonstrate that this complicated machinery is producing sensible results. A few results of this kind are presented, but more are highly desirable.		Agreed. This chapter was reworked extensively to better document the process.
Rev.1	*8*	*Rev.1 follow-up*				*Chapter has improved substantially, but it lacks consistency in notation. For instance, fifferent notation between eqs 8-1, 8-2, and 8-15. 8-2 (using ~) is the more conventional notation. We recommend that you make them consistent.*		*We changed Equation 8-15 from = to ~. For Equation, we retain the equation symbol because the symbol ~ relates a random variable to its distribution (like Y ~ P(Y)), whereas in Equation 8-1 we say that the distribution of Y is a normal distribution (not Y is sampled from a normal distribution).*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-1	8.1	8-1	1st sentence	The continuous nature of the epistemic uncertainty in ground motions is not an assumption, it is an incontrovertible fact. It may appear discrete when one is selecting from existing GMPEs or when one creates a discrete set of GMPEs from a continuous conceptual model for computational purposes, but there is no physical reason for ground motion amplitudes not being continuous. This false dichotomy seems to create unnecessary complications in the early portions of chapter 6 and in section 8.1. Please revise accordingly.	NR	We added a sentence to that effect at the beginning of Section 6.2 and reworded the first sentence of section 8.1.
Rev.0	8	8-2	8.1	8-1	1st paragraph	Going to a multivariate normal distribution is an assumption (and a reasonable one), not an automatic extension of the 1-D result, and it requires some discussion. Not only it implies that each marginal distribution is normal (i.e., a distribution-shape assumption), but it also implies that each conditional distribution must be normal and that the conditional moments satisfy certain properties. This should be indicated in the text.	NR	Modified the text accordingly.
Rev.0	8	8-3	8.1	8-2	2nd paragraph	Consider changing "The evaluation of a more traditional equation" to "The predictions of a more traditional GMM"	ED	Modified the text.
Rev.0	8	8-4	8.1	8-2	3nd paragraph	Estimation of the mean should also be a key task (remember center, body, and range). Estimation of the mean is easier, but is also very important. Please modify text and the bulleted list accordingly.	RE	Modified the text.
Rev.0	8	8-5	8.1	8-2	5th par	Incorrect reference to "Figure 6-5".	ED	This is the correct reference.
Rev.0	8	8-6	8.1	8-2	First bullet	extraneous word "they" should be removed	ED	Modified the text.
Rev.0	8	8-7	8.1	8-2	Bulleted list	(M.Rrup) pairs are described as scenarios - correct usage?	ED	We refer to those (M, Rrup) pairs as scenarios throughout the report. In that specific instance, we changed "scenarios" to "combinations" since the lists are meant to be combined into scenarios.
Rev.0	8	8-8	8.1	8-2	Bulleted list	Should justify that half unit magnitude steps are sufficiently fine for the analysis (particularly in contrast to the step size in distance).	RE	We provided a justification
Rev.0	8	8-9	8.1	8-2	Last two paragraphs	It would seem desirable to exclude or down-weight unimportant M-R scenarios (for example, magnitude 4 at 1500 km) from this calculation and from the Sammon's formulation. Please discuss the reasons for not doing so and its implications.	RE	This range covers the scope of the NGA-East project. We have explored hazard relevant scenarios and weighted scenarios and describe the sensitivity results and decisions based on those. In the end, the TI team selected the initial list as explained in the text. Sensitivity analyses and evaluation of results are presented in Appendix E.
Rev.1	*8*	*Rev.1 follow-up*				*Sensitivity analysis in E.4 very instructive.*		
Rev.0	8	8-10	8.1.1	8-2, 8-3	Entire section	The introduction of a Gaussian process of the type given in Eq. 8 – 4 in this section appears to be largely unnecessary and may be confusing to the reader. The likelihood function could have been derived on the basis of the multi-normal distribution alone, without having to introduce a Gaussian process (especially this particular kind of Gaussian process). This section generated a large number of questions for the PPRP, including the following: What is the interpretation of the noise variance beta^2 in the context of this project? Considering that you are "observing" the 19 GMMs without any noise, shouldn't beta be zero? Does beta represent epistemic uncertainty or something else? Is beta^2 used in this study? If so, how? Is it used in the simulations to generate the 10,000 models? What is the value of beta obtained in section 8.1.3? Does this value depend on frequency? Is K-sub-f the same as the matrix "SIGMA"on page 8-1? If so, a consistent notation should be used. In the PPRP's view, the only place where the concept of random process is useful is in defining the (x - x')-dependent correlation model (e.g., Eq. 8 – 9), where the isotropic term is reminiscent of the correlation structure of a stationary random process and where concepts such as continuity, differentiability, isotropic correlation, and correlation distance are useful. It is suggested that this section be greatly streamlined, if possible, avoiding the introduction of the particular Gaussian process in Eq. 8–4.	RE	We have removed the detailed discussion on Gaussian process and reorganized the text accordingly. We briefly refer to the Gaussian process directly in the corelation discussion. That whole section was distracting.
Rev.0	8	8-11	8.1.1	8-3	Middle of page	Mis-use of "data" - should be "predictions". Also explain what "target data " is. This statement is confusing because text says "in the context of the NGAEast" as opposed to the context of this chapter. Remember that "true" data are actually used in Chapters 7 and 9.	NR	Good point. We replaced with "estimates" as we tried to avoid "predictions" in this report.
Rev.0	8	8-12	8.1.2	8-3	Figure 8-1	The contour plots end at 1000 km, while NGA-East intends to predict out to 1500 km. Please also explain why the variances rise steeply towards 1000 km. To what extent is the high variance at short distances and small magnitudes driven by the Boore models? Would it decreased substantially if some of those models where removed or downweighted?	RE	All the computations and plots have been redone. We do not see this issue anymore.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-13	8.1.2	8-3 through 8-5	Entire section	Please consider presenting the figures and tables referenced in this section in terms of standard deviations, not of variances. The rationale for this suggestion is that the standard deviations are more intuitive quantities (they have units of ln-amplitude and they provide a close approximation to the epistemic coefficient of variation). Another possible benefit is that the surfaces in Figures 8-1 and 8-2 may become smoother and may be easier to interpret if standard deviations are presented. In fact, the first four paragraphs in page 8-5 speak of variances having natural log units. If they are variances, they should have units of (natural log units)^2. This prompts the question: are the quantities in Figures 8-1, 8-2, 8-5, 8-6 variances or standard deviations? Note: the marginal ground-motion variances developed in this section (and presented in Figure 8–5) are perhaps the most important TI team decision in this chapter, because the effect of these variances on the amplitude for a given mean hazard can be significant. This effect may be approximated by a factor exp[-0.5*k*variance(M*,R*)], where k is the slope of the hazard curve (for which a value of 2-3 is often quoted and M* and R* are the dominant magnitude and distance from the deaggregation (this calculation ignores the Ch.9 tweaks to the weights, which are not too large anyway). Therefore, the thought process leading to values in Figure 8-5 deserve extensive discussion. The correlation model, on the other hand, affects the fractiles but not the mean hazard.	RE	We considered this, however, as we now explain in the text, we prefer to work in variance because of the additivity capability; it's easier to understand the process of "adding" variances where it was deemed too low. As we re-worked the text, the mention of variance units went away. We agree with the PPRP, but did not make an effort to add back those units in the text.. Agreed. We have worked extensively on the text to provide the justifcation to our variance model.
Rev.0	8	8-14	8.1.2	8-3	Eq. 8-7	Please indicate that the bars denote average values	NR	Done.
Rev.0	8	8-15	8.1.2	8-3 through 8-5	Figure 8-2	Do the variances presented in this figure include the within-model epistemic uncertainty derived by Al-Atik and Youngs (2014) for NGA West2? If not, would inclusion of this uncertainty make a difference in the values selected for Figure 8-5? One possible concern is magnitude 7.5 and greater, for which within-model uncertainty is sometimes greater than model-to-model uncertainty.	RE	We have looked into this and the added variance from Al Atik and Youngs is minimal and deemed not sufficient. Plots are provided in Appendix E along with the final achieved variance.
Rev.0	8	8-16	8.1.2	8-3 through 8-5	Figure 8-2	Please explain the high variance near (M5.25, 200 km) in the WNA dataset, as this should be a very data-rich part	RE	This comes out of the models – the values differ in the NGA-West2 models as well. We can't comment on the NGA-West2 project development. However, we added a discussion on how we used the WNA models to constraint the minimum acceptable varianec fro NGA-East. There are more plots and discussions of the NGA-West2 results.
Rev.0	8	8-17	8.1.2	8-4	Middle page, #3, last sentence	Please explain how a range of acceptable seed models could overestimate the overall epistemic uncertainty. Does this imply that something went wrong in Chapter 7?	NR	Will revised this statement. This comment was made in part due to the behavior of HA15 around M5.5. This is still a viable model that borrowed its scaling from the BSSA14 NGA-West2 model (Figure 8-3), but it leads to a large variance which should be seen as unilateral (not above and below the median).
Rev.0	8	8-18	8.1.2	8-5	2nd par	Please provide additional justification for the maximum variance of 0.4 (sigma=0.63), especially for high magnitudes and distances less than 800 km. Figure 8.1 suggests much lower variance at most distance and magnitude ranges.	NR	We have reworked the text to provide our justification.
Rev.0	8	8-19	8.1.2	8-5	3rd par	In discussing the "information', remember there is no data, only GMM predictions. The GMM predictions are based partly on observations, but also on adopted rules (for example the low frequency predictions may be influenced by the modelling assumptions adopted from data-rich regions or by simple physical models, not necessarily on observed ENA GM's)	NR	That text was removed when we re-wrote the section.
Rev.0	8	8-20	8.1.2	8-5	3rd par	"recommended" ' say "TI Team chose to adopt"	ED	That text was removed when we re-wrote the section.
Rev.0	8	8-21	8.1.2	8-5	4th par	The adopted variance model in Figure 8-5 does not reflect the variance values in Figure 8-1 for PGA and 10-Hz for M, R ranges (e.g. M6, 200km). Were other frequencies used for the linear interpolation? Please provide additional clarification or additional figures.	NR	We provide plots for additional frequencies and a discussion.
Rev.0	8	8-22	8.1.2	8-5	4th par	The adopted variance model in Figure 8-5 needs additional justification. The text indicates maximum adopted variance for M>7.5 while the Figure 8-5 shows constant variance for M>7. With the limited data for M6-7 range, might the adopted maximum variance apply to M 6 _? Please provide additional detail on the basis and development of Figure 8-5.	RE	We clarified the role of WNA GMMs in those constraints.
Rev.0	8	8-23	8.1.2	8-5	Last paragraph, 3rd sentence	Meaning of "regional distances" for WNA not clear. Please be more specific.	NR	That text was removed when we re-wrote the section.
Rev.0	8	8-24	8.1.2	8-5	first paragraph on page	"The extent to which the epistemic uncertainty is larger at regional distances, depends, at least partly, on how uncertainty is partitioned between its epistemic and aleatory components." This statement isn't clear and require substantially more explanation. No additional explanation on partitioning of epistemic and aleatory is provided in this chapter.	RE	That text was removed when we re-wrote the section.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-25	8.1.2	8-5	Last two paragraphs	Please provide additional justification for the decision to make the variance function (Figure 8-5) frequency-independent. One can think of many physical and statistical arguments that would suggest a frequency-dependent epistemic uncertainty (after all, the frequency range being considered covers 3 orders of magnitude). Also, lack of data makes this uncertainty greater. As a minimum, Figure 8-1 (and also 8-2) should show a broad range of frequencies (at the very least, please add 1 Hz and 0.1 Hz) to demonstrate that there are no significant differences with the frequencies already shown.	RE	We have reworked the text to provide our justification and include plots for more frequencies.
Rev.1	*8*	*Rev.1 follow-up*				Figures were provided for more frequencies, which is very useful. One serious problem (which makes assessments and comparisons difficult) is that the plots of variance vs. M and R make it difficult to see the behavior in the first 25 km (most important region). Why not use logarithmic distance (in Chapters 8 and 9 and in Appendix E)? Also, there is very little discussion of whether the various panels in Figure 8-1 justify the adoption of a frequency-independent model for the variance. JA: In this regard doesn't Fig 8-10 support frequency dependent variance? Wouldn't that make more sense?		We have added log-R figures.
Rev.0	8	8-26	8.1.2	8-22	Figures 8-1 and 8-2	Ideally, Figure 8-1 (and other similar figures) should show R in logarithmic scale (instead of showing logR), and Figure 8-2 should use the same scale as Figure 8-1.	NR	This was changed.
Rev.1	*8*	*Rev.1 follow-up*				*Problem persists (see above)*		*We have added log-R figures.*
Rev.1		*Rev.2 follow-up*				Where are the revised figures using logarithmic R? Current version of Chapter 8 seems to have the same figures in arithmetic-R scale. At a minimum, please reference Figure 9-20, where log-R is used.		*We added log figures in Chapter 9 that compare the NGA-East seeds and final models variances. Decided against it in 8 as the big picture issues were more visible in log space and having the extra set of figures became very clunky for the readers.*
Rev.0	8	8-27	8.1.2	8-22	Figure 8-1	The distance scaling in figure 8-19 suggest that the maximum variance should occur around 70 to 80 km distance, as a result of differences between the GMMs with different short-distance slopes. This behavior (which is quite intuitive and appears to be real) is not reflected in Figure 8-1 or in Figure 8-5. Is there an explanation for this? Was this considered an overestimate by the TI team (as per 3rd bullet in page 8-4)? Please discuss.	RE	We revised in light of the additional frequency plots discussed above. Figure 8-19 is for M5 and a frequency of 1 Hz. If we let a few cases control the variance, we would sample a lot of unphysical models in the low range. That was the original motivation for going to the smooth variance and corelation model.
Rev.0	8	8-28	8.1.3	8-6	1st paragraph,	This paragraph is confusing. "highly correlated" and "loosely correlated" should indicate correlated with what. Also, the correlation is not between the scenarios; it is between the log-amplitudes (or Y values) associated with those scenarios. Please revise text.	RE	That text was removed when we re-wrote the section.
Rev.0	8	8-29	8.1.3	8-6	Paragraph 1, line 3	Please change "as it was the case" to "as was the case"	ED	That text was removed when we re-wrote the section.
Rev.0	8	8-30	8.1.3		Figure 8-7	Figures similar to this should be presented for multiple frequencies (not just for 1 Hz). Also, the correlation contours seem to have a diagonally oriented principal direction, which would suggest nonzero off-diagonal terms in the matrices of Eq. 8-9. Please discuss.	RE	The figure was only presented to show a point and comes directly from the correlation of the seed GMMs. This is not modeled. We feel it would distract the reader to include suites of similar figures.
Rev.1	*8*	*Rev.1 follow-up*				*It would have been useful to see if all frequencies show the same correlation structure. This would provide a justification for using the 1 Hz coefficients for all frequencies*		*We will add them to the appendix. They do vary a bit with frequency, but we chose to pick a single frequency as the guide for the reasons stated above.*
Rev.1		*Rev.2 follow-up*				This is marked as TODO in comments file received from TI Team on 9/2/18. There is another TODO related to Chapter 9. Please address.		*Unfortunately, we ran out of time and resources and didn't add the plots. Adding plots in the last revision creates a potential for unlinking figure numbers with discussions in the text.*
Rev.0	8	8-31	8.1.3	8-6	Eq. 8-9 and related text	There are a number of questions regarding the correlation model defined by Equation 8-9 that need clarification (some, but not all, may be consequences of typos in the equation). (1) Are the thetas calculated for each frequency or are they frequency-independent? (2) Do some or all of the thetas depend on the value of x'? (3) It is not clear how one can go from the isotropic term in equation 8-9 to Eq. 8-10 for the one-dimensional case (and the relationship between alpha and L and the thetas is only provided much later in the section, adding to the confusion). (4) Is k(x,x) forced to be unity for all x values (as it should be)? If so, how is this achieved? Many of the above questions may be the result of a misplaced right bracket, in addition to the following: (a) The first term in brackets in the RHS of Eq. 8-9 appears to contain the addition of a scalar and a vector, which is not a valid operation (unless 1 represents a unit vector). (b) The way the equation is written, it appears that the exponent -theta_4 applies only to (2 theta_4), which does not appear consistent with Eq. 8-10. Although much of the confusion may have been generated by a typo in Eq. 8-9, the meaning of the theta parameters and their relationship to parameters L and alpha needs to be explained much more clearly than it is right now. For the sake of clarity, and to confirm the adequacy of the fitted model, figures similar to 8-7 for multiple frequencies should be presented for the parametric correlation model to confirm that the parametric fit resembles the empirical correlation. Unless the theta's are x'-dependent, their values should be tabulated. If they are x'-dependent, values for a few representative values of x' and frequency should be presented. Also, given that the number of predictor variables is only 2 (i.e., M and lnR) and that the off-diagonal terms in 8-9 are all 0 (and assuming that the value of 1 mentioned above does not represent a unit vector), the equation can be written in a much more intuitive manner, without using matrices and working directly in terms of M and lnR.	RE	The comments from the PPRP are well taken. This is a complex discussion and we tried to streamline it to make it more accessible and, more importantly, more clear. This section was reworked. There was indeed a typo in Eq. 8-9 which was fixed. We also changed this equation so it has a stronger parallel to the following equation, which described the effect of the correlaiton in one dimension for x. The matrix containing theta2 and theta3 is now the squared inverse matrix (it's still a diagonal matrix), whic makes a parallel to parameter L in the following equation. This should simplify the explanations (theta2 corresponds to L and theta4 corresponds to alpha). **(Note from PPRP: PPRP Updated Comment to the right exceeds maximum row height and is not entirely visible)**

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	8	Rev.1 follow-up				The presentation is more clear and better organized than before, but there are still a number of apparent problems in the description and development of the covariance model. The equation for the covariance model still appears to be wrong. For consistency with Eq. 8-10, the exponent - theta_4 should be outside the square bracket. Confirmed with TI Team member (N. Kuehn): equation in report is wrong but implementation of model is OK. Also, it is not clear if you are using this equation as a covariance function or a correlation function (k or rho). In other words, is k(x,x) consistent with Figure 8-12 or is it unity? If the former, how is that consistency ensured?. How are the seed-GMM residuals (GMM-median GMM) normalized prior to these calculations? Suppose we want to calculate k(x,x') for x=x'=[0,0] (i.e., value of the covariance for the "mean" scenario if we understand the standardization of x properly). Plugging in these values and the coefficients from Table 8-1, we get k=theta_1+beta^2=~4.76. Does this make sense? What does it mean? One would expect this value to be 1 because the GMM residuals for each M-R scenario appear to have been normalized. Are we mis-interpeting something? How was it possible to obtain these values? What was the process? Given that the above value of 4.76 (>>1) , how can one explain the values contoured in Figure 8-18 (which peak at 1.0)? Please explain. Also, why is Fig. 8-18 so different from Fig. 8-13, with the model showing much stronger correlation than the data? Compare the area enclosed by the 0.8 contours in both figures. These differences are not discussed at all in the text. What are the implications of this over-estimation of correlation (coming closer to a backbone model than the seeds suggest)? Also, Figures 8-13 and 8-18 should consider the same three scenarios and use a consistent contouring scale, to facilitate comparisons.		We fixed the Equation. We added a paragraph on page 8-8 (before Equation 8-9) to describe how the covariance model is used together with the correlations to calculate the final covariances. We also added a sentence on page 8-10 to say how the correlation coefficients are calculated and that they are used together with the NGA-East covariance model. We added a final sentence explaining that the theta_1 value is not equal to one due to the linear part of the correlation function, and added the value if only the rational-quadratic part is used, which is close to one.
						The one saving grace is that Appendix E.3 show that the mean hazard is insensitive to differences in the correlation model. One can interpret that lack of sensitivity as meaning that the implementation of the correlation model does not have to be perfect. It appears that the physicality constraints (and possibly some additional normalization of the synthetic GMM residuals) act as a self-correction mechanisms. Additional sensitivity results received from a TI Team member on January 9 seem to confirm that the final models are still viable, but these results are not sufficient. The project still needs to demonstrate that the resulting model is adequate despite this apparent error. In particular, the January 9 sensitivity analyses should be performed for multiple frequencies (at least five additional frequencies), and should include GMPE fractiles in addition to plots of the individual GMMs. Ideally, these sensitivities should be taken all the way to hazard. These sensitivity analyses must be documented in the final report.		
Rev.1		Rev.2 follow-up				REQUIRED Last part of question was not answered: "Also, why is Fig. 8-18 so different from Fig. 8-13, with the model showing much stronger correlation than the data? Compare the area enclosed by the 0.8 contours in both figures. These differences are not discussed at all in the text. What are the implications of this over-estimation of correlation (coming closer to a backbone model than the seeds suggest)? Also, Figures 8-13 and 8-18 should consider the same three scenarios and use a consistent contouring scale, to facilitate comparisons".		The correlation models are used as starting points and get superseded by the sampling process (see bullet points in Section 8.3.2 and the end of Section 8.3). The sampling is performed using each seed as the generator of new models, so part of the correlation from the seeds transpire through the process.
Rev.0	8	8-32	8.1.3	8-6	Paragraphs 3 and 4	The behavior of the second "linear" term in Eq. 8-9 is especially unintuitive and these paragraphs do not add any clarity. For the linear behavior shown in Figure 8-11, one would think that the covariance between Y(x) and Y(x') would indeed be proportional to xx', but their correlation coefficient would be 1 (or -1 if x and x' have different signs). This would translate into a constant second term (i.e., a floor) in Eq. 8-9, not on a term that depends on xx'. Also, the presence of this term proportional to xx' makes it difficult to satisfy the condition of k(x,x)=1 for all values of x (as mentioned earlier), unless the thetas depend on x'. Is the presence of this term important in the overall correlation model (i.e. is theta_1 significantly different from 1)? Please clarify by providing additional details or graphical examples, or correct if appropriate.	RE	We have revised the text to make this clearer. It is beyond the scope of this project to flesh out the concept of corvariance functions. We are explaining the basic reasons behind our choices and the final results show that the mechanics worked as intended. However, these concepts become clearer when one has the opportunity to apply them. For a dot product covariance function, it is helpful to program a covariance matrix based on such a function and sample from it. The samples form a straight line when plotted (we added that in the text). The book of Rasmussen and Williams (2006) is a good resource on this topic, and provides a connection between a Bayesian linear regression and a linear covariance matrix in chapter 2. Regarding a constant term in the covariance matrix, such a term would lead to a constant sampled function - for an example, it helps to think of the between-event variability tau^2, which is a constant term applied to all records from the same event and leads to a constant term added to the prediction. The correlation coefficients used in the sampling are calculated according to Equation 8-3. This is also now mentioned in the text.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*8*	*Rev.1 follow-up*				It looks like problem with xx' terms has not been resolved. See comments above. Editorial issue: Argument for linear effect (i.e., "First, the model should accommodate the generally linear trend of ground-motion with magnitude and distance (larger magnitudes generally lead to larger ground motions, larger distances generally lead to smaller ground motions)") does not appear to be valid, because the linear magnitude and distance scaling of the GMMs are already captured by the median GMM (this covariance structure applies to residuals w.r.t. the mean trend of the GMMs). I think the justification for this term is the presence of systematic model-to-model differences in slope.		We have revised the text as discussed above. We amended the text to include the systematic model-to-model differences in slope. The linear term actually is there to model both aspects.
Rev.0	8	8-33	8.1.3	8-7	5th para	"ground motion values" do you mean "spread in ground motion values"?	ED	No. This is correct.
Rev.0	8	8-34	8.1.3	8-7	first paragraph, lines 5 and 6	text refers to "longer distances, r", what does "r" mean in this context? Not clear. Also, meaning of "dropped overall variance" not clear. Also, in the paragraph following Eq. 8-11, the number of dimensions of the multi-normal distribution should be 101, not 101x101.	ED	"r" is defined at the beginning of this paragraph. We rephrased the reference to variance.
Rev.0	8	8-35	8.1.3	8-7	6th para	And subsequently seems like this theory should have come earlier? This is one of several instances in this section where the presentation seems to be out of sequence.	NR	We considered a reorganization, but it caused other sequence problems. We prefer to introduce the theory as it is needed. That was one of the issues with the Gaussian process; it seemed out of place when it was introduced in its own section.
Rev.0	8	8-36	8.1.3	8-7	Last line on page	Suggested wording change, "At the scenarios for NGA-East" to "At the specified (M Rrup) scenarios for NGA-East ."	ED	OK.
Rev.0	8	8-37	8.1.3	8-8	Bulleted list	Once more, the role of beta is not clear. What is its value and how much of the variance in Figure 8-5 is going into beta? More importantly, as asked earlier, what is the meaning of beta in this chapter, given that the GMMs are observed without noise?	RE	We have revised the text to address beta.
Rev.0	8	8-38	8.1.3	8-8	Last paragraph	The statement "Thus, the diagonal entries of the calculated covariance matrix reflect the spread of the estimates across the (M, R_rup) scenarios but not across models" is believed to be incorrect. Each diagonal term represents the spread across models for one scenario (recall Eq. 8-7). This paragraph, and the first paragraph in section 8.1.4, seem to be introducing the rationale for using the mixed distribution approach of Eq. 8 - 13. Unfortunately, both paragraphs are far from clear and the last paragraph in section 8.1.3 contains redundant and incorrect statements. Please revise.	RE	Correct. The statement was revised.
Rev.0	8	8-39	8.1.3	8-8	Last paragraph	We think that a more likely explanation for the fact that realizations from the multi-normal distribution cannot (or are very unlikely to) reproduce some or all of the seed models exactly, is that the multi-normal distribution with fairly simple parametric models for the diagonal and off-diagonal elements of the covariance matrix represents a simplification of a rather complex behavior. In particular, the presence of hinge points in the distance scaling for some models and not for others, and the fact that these hinge points occur over a relatively narrow range of distances, is difficult to capture with an (x - x')-dependent parametric correlation model. This may be the price you pay for abandoning the parametric GMPE functional forms used in SWUS, but it's probably a price worth paying.	NR	Agreed, although we have not verified that this is true. This is a consequence of choosing tabulated models vs. equations.
Rev.0	8	8-40	8.1.4	8-8	item 2 in bulleted list	Why do you need to standardize the magnitudes and distances? After all, they are the predictor variables. Please explain. Also, when you standardize the GM estimates, do you divide by the empirical sigma (i.e., from Figure 8-1 or similar figure) or by the adopted sigma (i.e., from Figure 8-5)? The two approaches may yield very different results. Please explain	RE	This was to improve numerical stability. We added a statement.
Rev.0	8	8-41	8.1.4	8-8	Line 1	"relatively strong, closer to full correlation than to zero" According to p 8-6 full correlation is essentially scaled backbone and zero represents fully independent GMMs. Also, the statement is inconsistent with Figure 8-7, where correlation coefficients as low as 0 (and even negative values) are seen. Please be quantitative as to what "closer" means. This comment also reinforces the need for figures that show the observed and parametric correlation coefficients for multiple frequencies.	RE	Agreed. We revised the text. The figures have been addressed in another comment.
Rev.1	*8*	*Rev.1 follow-up*				*See notes regarding comment 8-31*		*Addressed with reply to comment 8-31.*
Rev.0	8	8-42	8.1.4	8-8	1st para	Please use SSHAC language and say "the TI team selected XX... because" and delete 'easily retain'	NR	Revised the text.
Rev.0	8	8-43	8.1.4	8-8	Eq. 8-12 and paragraph that follows	Meaning of mu_S is not clear from the text. Is it the same Y_bar vector that appears in Eq.'s 8-7 and 8-8? If not, there appears to be an inconsistency with initial formulation. The rationale for moving from the multi-normal model to the mixture model of Eq. 8-13 is not clearly provided in the text.	RE	The quantities are defined right after equation. Mu_S is the estimate (prediction) for a particular seed model and Y_bar is the mean of all the seeds. We will clarify the change to mixture model.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-44	8.1.4	8-8	Eq. 8-13	Going from the multi-normal model in Eq. 8-1 to the mixed model in Eq. 8-13 (while using the same covariance matrix for both) introduces additional variance in ground motion, because the variances in Figure 8-5 already contain all the model to model variability that is seen across the 19 seed models (unless a significant portion of the variance goes into beta^2). Checks should be performed to confirm that the TI team is satisfied with, and can justify, the resulting variance. Similar checks should be performed to confirm that the physicality constraints and the discretization that occurs later (both of which reduce the variance) yield an acceptable value for the total variance (and do not bias the mean).	RE	This is a good point. We have added a section on the achieved variance in Chapter 9 (because we need the weights to compute the final variance), and the combination of imposed variance to our misture model and the physicality criteria lead to the desired variance. This was not a straight forward process, but the TI team is satistifed with the results.
Rev.1	*8*	*Rev.1 follow-up*				*Achieved variance plots are very useful in this regard. The bottom line is that the TI Team is satisfied with these variances.It may be worth emphasizing how these achieved variances are calculated.*		
Rev.0	8	8-45	8.1.4	8-8	2 lines after eq. 8-13	Change "Each of the individual distribution" to "Each individual distribution	ED	Revised the text.
Rev.0	8	8-46	8.1.4	8-8	Last 3 lines on page	It is not clear what the word "which" corresponds to in this clause. There are multiple possibilities in the preceding part of the sentence. Perhaps the text ", which is composed of the estimates of the ith seed model" should be removed altogether.	ED	Revised the text.
Rev.0	8	8-47	8.1.4	8-8	third line from bottom of page	"distribution" should be plural.	ED	Revised the text.
Rev.0	8	8-48	8.1.4	8-9	Top of page to end of section 8.1.4	This discussion of weights relies on the concept of Sammon's maps, which are not introduced until the next section. This material should be presented later in the chapter.	RE	The order of topics was a difficult decision we carefully considered to avoid break the flow of ideas. We have reorganized the sections to introduce the Sammon's maps before the weight on seeds.
Rev.0	8	8-49	8.1.4	8-9	1st paragraph	(1) The second sentence says "Such a bias could be introduced if two models are developed using very similar methods and subsets of data." What if two models happen to fall in the same cell, even though they use different methods and data subsets? Would they be mechanically downweighted as the text seems to suggest? (2) Going back to the one-dimensional examples in Figure 8-18a, this procedure might turn a normal distribution shape into a uniform shape. Is that appropriate? (3) In addition, the choice of 0.25 ln-units to discretize the Sammon's space may have a significant influence on the weights applied to the models. If a cell size of 0.125-ln units were chosen would results be significantly different? What is the justification for the cell size? (4) The approach for the calculation of these weights needs substantially more justification. (5)Also, please tabulate seed GMM weights resulting from this operation. We realize that they vary with frequency, so an exhaustive list might be exhausting, but a table of GMMs with the weights at PGA 10 , 1, 0.1 Hz might be revealing.	RE	(1) Yes, this is correct and as intended as we can't verify that models are confirmatory (this could have only been been possible if all the modelers provided uncertainty estimates on their coefficients/models). This was not the case. (2) Agreed. We have made this decision so as to better sample the full range without a-priori weights (as mentioned above). We have performed sensitivity analyses with each seed getting the same weights and the difeerences are not large, yet, they show that the behavoir is as intended (see appendix D for more details). (3) We performed those sensitivity analyses and showed them in a workshop. We added the sensitivity results in Appendix E. (4) and (5) The sensitivity studies showed that our process performed as intended. The hazard results are not very sensitive to the specifics of how the grid is generated. That will be discussed in light of Appendix E.
Rev.1	*8*	*Rev.1 follow-up*				*The logic in the Rev. 1 text is flawed because it does not recognize that one could get similar predictions from two or more models that do not share the same methods and data subsets. Perhaps the text should acknowledge this issue up front on page 8-15 (and not wait until the next page when you speak about whether similar results should or should not be viewed as confirmatory).* *The approach taken here of down-weighting models that fall in the same cell is also in contradiction to the approach taken in Chapter 9. In Section 9.2.1.2, when the final model weights are developed, a high weight is assigned to cells that have a large number of models contained within. In general terms, this is the opposite line of reasoning to that in Ch.8. This is somewhat confusing and should be discussed.* *Sensitivities in Appendix E.4 suggest that this decision on model weights does not have a large effect on the results. One concern about the sensitivities (E.4 and other hazard comparisons in the main text and appendices) is that the scale of the figures makes it difficult to see how "minimal" the differences are.* ***The PPRP requests that the TI Team plot the corresponding ratios (of hazard), at least for the mean hazard curves.***		*We do not see a contradiction.* *If we believed that the seed models as-is were representative samples from a distribution and were totally independent, we would not change their initial weights. However, because we can't prove or disprove their independence (or confirmatory propriety), we apply initial weights based on their proximity in Sammon's space.* *The 10,000 samples obtained in Chapter 9 represent the distribution (indended to be iid) so we can use them as they are. We then select representative models that have weight related to their preponderance in the distribution.* *We added hazard ratio plots to all the hazard senstivity results presented in Appendix E.*
Rev.0	8	8-50	8.1.4	8-9	Last paragraph of 8.1.4 and Figure 8-14	The figure caption does not correspond to the text in the last paragraph of section 8.1.4. Assuming that the text on page 8-9 is right and the caption is wrong, one could argue that the bottom-row figures (randomizing about the overall mean) are preferable to the top row (randomizing about the seed GMMs), even though a little bit more crossovers would have been desirable in the former. In other words, it seems that randomizing from the seed GMMs seems to create a number of physicality problems which could have been avoided by randomizing about the overall mean. Please revise text or caption and discuss. Also, top and bottom figures should use the same scale to facilitate comparison.	RE	OK, we will clarify - the text is correct. We did choose to randomize around each model shape so as to retain more of the model-specific features. That is also the motivation for the physicality screening.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-51			Figure 8-15	What are the values shown at 200 Hz? Please indicate in text or caption.	NR	Thise were a placeholder for PGA; so as to plots it together with the rest of the frequencies. We clarified in the caption.
Rev.0	8	8-52	8.1.5		Entire section	The physicality constraints remove a greater fraction of realizations from the GMMs that come close to these constraints, as indicated in the text and shown in Figure 8-17. Does this create a problem? Isn't this an implicit downweighting of certain GMMs? Please discuss the implications of this effect.	RE	Yes, this is intentional. We added text to this effect.
Rev.0	8	8-53	8.1.5	8-9	Line 8	Use SSHAC language to replace "such unphysical models must be screened out" and also include why	RE	The text was revised.
Rev.0	8	8-54	8.1.5	8-9	last line of page	change "Rrup> 10" to Rrup> 10 km". Also make same change on top of next page.	ED	The text was revised.
Rev.0	8	8-55	8.1.5	8-10	Second bulleted section	The screening criterion sl(10,40>0.4: does this apply for all distances between 10 and 40? Does this criterion mean monotonically decreasing ground motion between 10 and 40 km as one would expect for a direct ray path distance range? Please provide additional description.	NR	It is meant to make sure the slope is 0.4 at a minimum.
Rev.0	8	8-56	8.1.5	8-10	Line 9	Explain "min(GMM)"	ED	We clairified the text.
Rev.0	8	8-57	8.1.5	8-10	Para 2	"some of the models do not adhere to these constraints" Please use SSHAC language to explain what you did and why you did it. It appears that you did not believe some parts of some of the seed models. Which ones? Did you discuss with the developers why their GMMs behaved "unphysically"?	RE	OK. We did bring those issues up with the modelers and they were offered an opportunity to discuss the TI conclusions. There was no objection to our procedure.
Rev.0	8	8-58	8.1.5	8-10	Fig 8-15	Caption refers to left and right parts; X axes should be labelled "f (Hz)", not "F"	ED	We updated the figure.
Rev.0	8	8-59	8.1.5	8-10	Fig 8-15	Suggest adding third plot for min[lnY(6)-lnY(5)]	NR	OK.
Rev.0	8	8-60	8.1.5	8-10	3rd para	"very small" From Fig 8-15 I read off a factor of 1.8 for R>100 and a factor of 1.2 for R=10; only the latter is "small"	NR	The text was revised.
Rev.0	8	8-61	8.1.5	8-11	First sentence	Please provide the basis for the 10,000 samples. Would 1,000 be sufficient?	NR	We added a short discussion and figures to address this issue. We performed a lot of sensitivity studies at the beginning of the project and those were presented in the workshops. We distilled things down for the report.
Rev.0	8	8-62	8.1.5	8-11	Para 2	Refer to fig 8-15 (bottom)	ED	OK.
Rev.0	8	8-63	8.1.5	8-11	Last par and Figure 8-17	The number of samples used as a function of seed model is an important figure. Does this mean that for 1-Hz for all M, R that some models are effectively weighted five times others? In fact, over half the weight appears to come from 2 Darragh, 2 Boore and HA15 models, and each supplies >10% of the total, whereas about 8 models supply less than 3% each. Note that of the highly-weighted Boore models, Boore's preferred BS11 gets 11% weight, but his "unpreferred" AB14 gets higher (11.5%) weight. Note that 1-corner Darragh models get 4 times the weight of 2-corner models. Note that Frankel's model gets just ~2% weight, one tenth of the sum of Boore's models despite it having a very different approach. Please illustrate with additional frequencies (0.1, 1, 5, 10 Hz) and additional description highlighting to what extent weighting or screening led to the result.	RE	Yes, this is intentional. The issue of the Boore models will be addressed in Chapter 7. We will added plots for all the frequencies.
Rev.0	8	8-64	8.1.5	8-11	Last par	Please indicate the effect on the CBR of giving all seeds equal weight	RE	We documented sensitivity studies in the chapter, which are presented in Appendix E.
Rev.0	8	8-65	8.1.5	8-11	Figure 8-17	Increase figure size or lettering size or both	ED	Done.
Rev.0	8	8-66	8.1.6	8-11	1st paragraph	Consider changing "distinctly different" to something else; "different" may be sufficient and sounds less repetitious. Also consider changing "classed" to something else.	ED	The text was revised.
Rev.0	8	8-67	8.1.6	8-11	1st paragraph	"Distinctly different" might be quantified by consideration of the covariance matrix (see comment # 8-40)	NR	
Rev.0	8	8-68	8.1.6	8-11	1st paragraph	This paragraph is rather confusing. It seems to be trying to say that the NGA-East approach is better than the backbone approach because the use of partial correlation allows some crossing of GMPEs, even for GMPEs associated with the same seed model. This is a valid argument. Unfortunately, the paragraph is difficult to read as it stands right now.	RE	The text was revised.
Rev.0	8	8-69	8.1.6	8-11	Section heading	Consider adding "to Develop continuous distributions of GMMs" to the section heading	ED	Done.
Rev.0	8	8-70	8.1.6	8-11	Last line	Please provide the forward reference to where the TI team "considered" this	RE	We modified the text to reflect that the NGA-East approach effectively considers different scaling by using an ellipse in the Sammon's map space (as opposed to a line).
Rev.0	8	8-71	8.2.1	8-11	First paragraph, last sentence	Please modify the last sentence. Ideally, the assessment of the CBR should be made in the multidimensional space formed by all the magnitude-distance combinations. The assessment in the Sammon's map is a good practical substitute, but is not the "ultimate" space where this assessment should be made.	RE	The text was revised.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-72	8.2.1	8-12	4th full paragraph	The statement "that the GMMs occupy a lower dimensional manifold in the larger model space" is confusing, and perhaps inaccurate. Consider using a concept such as a thin cloud that becomes a 2-D manifold if its "thickness" is ignored. Also, is the manifold required to have low curvature, as suggested later?	NR	The text was revised.
Rev.0	8	8-73	8.2.2	8-13	First full paragraph below equation	PCA is not described and many readers may not be familiar with this method. Please add a footnote describing the essence of the method and providing a reference. Suggestion: consider mentioning the similarity between PCA and the eigenvalue-decomposition-based modal analysis used in structural dynamics (which is very familiar to earthquake engineers).	RE	We will add a reference.
Rev.0	8	8-74	8.2.2	8-13	Paragraph below Eq. 8-15	Is any effort made to look for global, rather than local, minima when constructing the Sammons map (e.g., multiple starting points, use of global optimization algorithms such as simulated annealing [slow])?	RE	No. It is computationally too demanding and it would not change the relationship between points on the map (it would just make the convergence slower).
Rev.0	8	8-75	8.2.2	8-13	Last paragraph	Except for 1st sentence, paragraph is confusing. Please clarify.	NR	We revised the text.
Rev.0	8	8-76	8.2.2.1	8-13 and 8-14	1st paragraph	This first example is not very useful because it only illustrates the rotational invariance of Sammon's maps. Consider removing this example and expanding the 2nd example to illustrate rotational and mirroring invariance.	NR	We felt that different people may understand different examples better and wanted to have the first take-away be this invariability of distance between points on the map. The second example may be more complex to grasp with the addition of a large number of dimensions. We re-iterated the invariability of Sammon's maps distance in the second example.
Rev.0	8	8-77	8.2.2.1	8-14	2nd full paragraph on page	Please change "as a distribution" to "as distributions" or "as two distributions."	ED	That sentence was removed during editing.
Rev.0	8	8-78	8.2.2.1	8-14	2nd full paragraph on page	Most readers will not know what symmetric KL divergences are. Please add a footnote describing the essence of the method and providing a reference. You may want to add something similar to ", which looks at the distance between GMPEs taking their aleatory distributions into account."	RE	That sentence was removed during editing.
Rev.0	8	8-79	8.2.2.1	8-14	2nd full paragraph on page	Sentence "On the other hand, the median estimates and variability of a GMM are often separated in a PSHA" is not clear. Are you saying that they may be estimated separately? This is not always the case (e.g., NGA West). Please revise.	NR	That sentence was removed during editing.
Rev.0	8	8-80	8.2.2.1	8-15	Bullet #1	Confusing words; is the average an average of the GMMs (if so, how?), or of their predictions?	ED	The text was revised.
Rev.0	8	8-81	8.2.2.1	8-15	Bullet #1	Please specify what sort of average (arithmetic average of the ground motions, arithmetic average of the log of the ground motions, or something else)	RE	The text was revised.
Rev.0	8	8-82	8.2.2.1	8-15	Fig 8-23	a) increase figure size or lettering size or both. b) please add "S" to the "++" etc legend in left figure	ED	Done.
Rev.0	8	8-83	8.2.2.1	8-15	Fig 8-24	a) increase figure size to allow more clarity on labels b) please add "S" to the "++" labels	ED	Done.
Rev.0	8	8-84	8.2.2.1	8-14	paragraph following eq. 8-16	Consider using a consistent terminology in this paragraph and in entire chapter for what each "dimension" represents, namely one (M-R_rup) scenario. In this paragraph you use "dimension" (1st line) and "predictor variable combination" (3rd line). In the previous paragraph, you use "values of the predictor variables." Earlier portions use "(M, R_rup) scenarios," which is probably the clearest term. All these terms are correct, but it is strongly recommended to use a consistent terminology.	ED	Agreed. This can be quite confusing. We tried to make the text more uniform. We added (M, Rrup) scenarios when predcitor variables were mentioned to clarify that point.
Rev.0	8	8-85	8.2.2.1	8-15	Next to last paragraph, next to last line	Is mirrored the right word? Mirroring seems to imply L-R switching, not up-down. Flipped?	ED	We clarified which axis the map is mirrored about.
Rev.0	8	8-86	8.2.2.1	8-15	last paragraph, second to last line	"distance scaling: ' "near-source distance scaling". Aside: it is interesting to note that the "S" scaling affects all distances, while the Boore 1.3 models only have steep scaling to 50 or 70 km. Therefore his models don't align along the R axis.	NR	The text was revised.
Rev.0	8	8-87	8.3	8-15	1st paragraph	Please indicate how the 10,000 models were generated (i.e. approach = Monte Carlo; model = mixed model in Eq. 8 - 13)	NR	The text was revised.
Rev.0	8	8-88			Figure 8-24	Note that Frankel's model in Figure 8-24 indicates a Sammons mapping quite different from the other 18 models (for 1-Hz) yet the number of sample models derived from that model is quite small as seen in Figure 8-17. If not a plotting error please provide additional discussion/explanation in the text or figure caption.	NR	The Frankel model is close to the limit of physicality. We have added text to explain this.
Rev.1	*8*	*Rev.1 follow-up*				*It is good that smoothing was applied to this model in Chapter 7. Therefore, the "noise" resulting from a small number of rupture simulations does not cause excessive physicality violations.*		
Rev.0	8	8-89			Figure 8-26 caption	The word plane implies zero thickness. Consider using "slab," "thin cloud"?	ED	The text was revised.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-90	8.3		Figures 8-26 through 8-28	Figures are too small. Also, it is difficult to visualize the plane in 8-26 and 8-28. What about showing 8-26 in its current orientation and then rotated so that the cloud appears thin (i.e., make the least principal direction of the point cloud parallel to the plane of the paper)? Perhaps the same should be done for 8-27 and 8-28.	NR	OK.
Rev.0	8	8-91	8.3	8-16	1st paragraph	"plotted as red dots" ’"plotted as 54 red dots"	ED	There are only 18 red dots, one for each GMMs.
Rev.0	8	8-92	8.3	8-16	2nd paragraph	Line1: delete “18” or revise number (19?) Line 7 add a reference to where to find the correlation matrix used for Figure 8-26 Line 7: after “zero” add (pjk=0, j≠k) Line 9: “form 18 straight lines” (BTW are these actually lines or just very narrow trends of points?)	ED	All changes were made as proposed.
Rev.0	8	8-93	8.3	8-16	Last paragraph	Why are the M-, M--, etc. reference points not added as part of the strategy, and to fig 8-29? They were very informative in the previous example.	RE	We have added the reference models and changed the symbols to make then clearer for chapters 8 and 9.
Rev.1	*8*	*Rev.1 follow-up*				***Much appreciated. They make the maps more intuitive.***		*Thank you.*
Rev.0	8	8-94	8.3	8-15 through 8-17	Entire section	Is there a way to quantify how much information is lost in going from 374 dimensions to two? At one of the workshops, it was suggested to use the fraction of the total variance that is explained by the first two eigenvalues in the PCA. There may be better ways to do this by working directly with Eq. 8-15. This is crucial for justifying the Sammon's approach. The 3D ’2D example shown earlier in graphical form is suggestive but not conclusive.	RE	There is no known guidance on the level of information loss (or distortion) from going to multi-dimentsion to 2D. However, we compared the Sammon's stress range we obtain from our maps relative to a map of models without correlation (spheric cloud of points). This provides at least an idea that the distortion in our maps should be fairly low. We added a discussion in the text.
Rev.1	*8*	*Rev.1 follow-up*				*Is the noise in Figures such as 9-5 be used as another indication of this information loss? The explanation provided in Chapter 9 is not entirely convincing. This is a very important issue. The numerical comparisons in page 8-19 are a good starting point but more would be better. BTW, can those numbers br turned in something like an R^2 so they ae easier to interpret?*		*The noise-like feature in Figure 9-5 represent the mismatch due the limited M-R range for which we have data, relative to the full range used to compute the Sammon's maps. We added a figure in the response to the Chapter 9 response on this issue.*
Rev.0	8	8-95	8.3	8-16	2nd full par	Please provide some discussion or basis for the reduction of M,R scenarios from 374 (pg. 8-2) to 210 (pg. 8-16) on the Sammons mapping, or correct whichever value is wrong	NR	We added text to this effect in two places. When we first defined the 374 scenarios and here regarding the 210 scenarios.
Rev.0	8	8-96	8.3	8-17	Last bullet	Explain why SP15 was chosen as the reference model here and in Fig 8-29 caption (and also in Chapter 9).	NR	The original reasoning was that it had a significantly different scaling, which was easy to track. We have replaced this reference model by the M++ model.
Rev.0	8	8-97	8.3	8-17	Fig 8-29	For visibility and consistency add "S" to the + and - (this applies to other figures as well). The "not-rotated" panels should be on the right side.	ED	We have updated all the plots with clearer reference models.
Rev.1	*8*	*Rev.1 follow-up*				*This is very useful*		*Glad to hear.*
Rev.0	8	8-98	8.3	8-17	2nd paragraph line10	"because differences in scaling" ’"because differences in magnitude scaling"	ED	Actually, the vertical placement depends on both the magnitude and distance scaling, so we prefer to make a general statement.
Rev.0	8	8-99	8.3	8-17	2nd paragraph line12	sample, not samples	ED	We change it to "sampled".
Rev.0	8	8-100	8.3	8-17	3rd paragraph line12	Figs 8-24 and 8-29 rotated at 1 Hz show very different distributions of seeds; revise text or figures	NR	We mirrored Figure 8-24 about the x-axis. This figure was oriented to have M++ on top…
Rev.0	8	8-101	8.3	8-17	para #4	Use SSHAC language for the summary paragraph	NR	The text was revised.
Rev.0	8	8-102	8.4	8-17	Last sentence on page	If we agree that P(Y) is a continuous distribution in the Sammons mapping (or a good approximation of it), please provide a basis for concluding that this mapping, corresponds to the "CBR of epistemic uncertainty associated with median ground motion-estimates" for a given frequency. As it reads now, it appears to be an assumption.	RE	We addressed this issue in the following section.
Rev.1	8	Rev.1 follow-up				Not clear how this was addressed.		See (old) edits in Section 8.5.1. We also added a sentence before section 8.5, at the end of section 8.4, explaining the rationale behind the assumption. Yes, it is an assumption, but a reasonable one.
Rev.0	8	8-103	8.4.1	8-18	2 lines above 8.4.2	Please change "a lot of space" to a less informal expression.	ED	The text was revised.
Rev.1	*8*	*Rev.1 follow-up*				*"a lot" still used on page 5-9 (ED)*		*Fixed.*
Rev.0	8	8-104	8.4.2	8-18	Middle of 1st paragraph (and paragraph above)	Please change "95.45% of the probability density" to something like "95.45% of the total probability." Remember that probability density does not even have units of probability. This expression appears at least three times in the text.	RE	The text was revised.

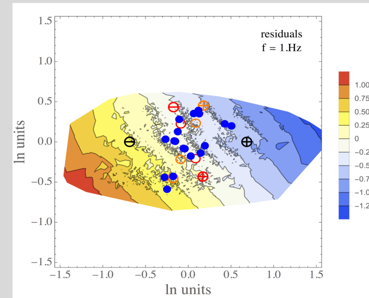
Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	8	8-105	8.4.2	8-18	Second paragraph	Were configurations with fewer cells investigated? Most of the cells are in the outer ring, where probability density is much lower, and may provide too fine a discretization.	RE	Yes, multiple configurations were considered and presented at workshops. For the report revision we considered 29, 17 and 13 cells. We concluded that 17 cells provided enough discretization and was yet more practical to use. We added a discussion and sensitivity studies in Appendix E to address this issue.
Rev.1		*Rev.2 follow-up*				This is done well		NR
Rev.0	8	8-106	8.4.3	8-18	1st paragraph	Please change "expectation of P(Y)" to "expectation of Y." One calculates the expectation of the random variable (random vector in this case) or of a function thereof, not of its probability distribution. Also, consider adding "conditional" before "expectation" and changing "over each cell" to "within each cell".	ED	The text was revised.
Rev.0	8	8-107	8.4.3	8-19	Para 3	Consider swapping order of Fig 8-36 and 8-35	ED	Done.
Rev.0	8	8-108			Figures 8-36 through 8-38	Consider using more interesting magnitude-distance scenarios for these figures. We recognize that these larger distances may be the most challenging ones for spectral shape, in which case you may want to include both interesting ones and challenging ones. Also, these and many other figures in this section are too small. Consider increasing sizes to 150% or more of current sizes.	NR	The problems only show at large distances (600 km and above) and are more pronounced for smaller magnitudes. We made the figures bigger.
Rev.0	8	8-109	8.4.3	8-19	third paragraph	Current text says-"All the samples passed the criteria of physicality established by the TI Team, ensuring that the selected models also pass the physicality criteria." Were the final derived models actually tested against the physicality constraints?	RE	Yes.
Rev.0	8	8-110	8.4.3	8-19	Last paragraph	Please provide additional discussion on how "the structure is preserved across frequencies by the rotation and reflection of the Sammon's maps in a consistent way." This process is not obvious from reading the paragraph.	NR	We revised the text.
Rev.1	*8*	*8-111 (NEW)*	*8.5.1*	*8-63*	*Figure 8-38*	*No explanation for the missing part of the elliptical cloud (upper left corner is bitten out) Why?? It seems unlikely to be due to unphysicality, as there are a few data points there, just not very many.*	*NR*	*The samples tend to gather around each mean seed GMM. They do fill the space in between, as intended, but less densely.*
Rev.1		*Rev.2 follow-up*				The questions was not about space in between models; it was about the NW corner for 40 and 50 Hz. We suggest that this be discussed in the text (ED)		*Same answer applies. The process fills around existing models and expands on them to a certain extent.*
Rev.1	*8*	*8-112 (NEW)*	*Figure 8-42*			*Fig 8-42 The fraction of area numbers surely can't be right – each of the segments looks as large or larger than the central oval yet are plotted with areas 60% and 50% of it*	*NR*	*The numbers were based on 1/area. We fixed the figure.*
Rev.1	*8*	*8-113 (NEW)*	*8.11, etc.*	*8-4 etc.*	*paragraph following itemized list.*	*General—the term "mixture model" is used in both Ch. 8 and Ch.11, but to refer to different things (although they are both mixture models in a mathematical sense). It would make sense to add a sentence to CH11 to indicate that the context for the use of the term is different in each case. In Ch.8 it is used to refer to the mixture (addition) of the simulated residuals having different means (with each mean given by a seed GMM). In Ch.11 it is used to refer to the mixture (addition) of two weighted normal distributions to develop a "heavy tail".*	*NR*	
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1*	*8-2*	*1st full paragraph*	*change "sample" to "realization" or "sample function" (3 times in paragraph and many other times throughout chapter). A sample would include multiple realizations. Right? In some cases, sample is used in the usual way, as when you speak of "sample size".*	*ED*	*A sample of one is still a sample. We opted not to change the terminology this late in the review process in case it affects other sections unintentionally.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.1*	*8-3*	*1st paragraph in section*	*Current text "Figure 8-1 shows two…", while Figure 8-1 shows eight frequencies. Suggest modifying text.*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.1*	*8-3*	*1st paragraph in section*	*Current text: "The variance numbers vary greatly …". To make thread more obvious suggested re-wording--"The variance numbers in Figure 8-1 …".*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.1*	*8-3*	*1st paragraph in section*	*Current text suggests results in Figure 8-3 are for 10 Hz and refers to Figure 8-1e which is for 10 Hz. However, Figure 8-3 is for 1 Hz. Revise text to say 1 Hz and reference Figure 8-1b.*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.1*	*8-3*	*last paragraph on page*	*Current text says "constrain", is "develop" a better word?*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.1*	*8-4*	*Mid-way in first paragraph following three principles*	*Current text: "The selected target variance we developed allowed us to achieve the final variance desired by the TI team, in order to reflect our collective understanding of the epistemic uncertainty expressed by the models and developers." Consider changing text to make more "SSHAC-like", possible suggestion "The selected target variance allowed the TI Team to achieve a final variance model that reflected our collective understanding of the epistemic uncertainty expressed by the models and developers."*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.1.2*	*8-7*		*Equation 8-7 is duplicated*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-9*	*following eqn. 8-12*	*The term Kf is duplicated in the text following eqn 8-12.*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-10*	*following the five steps*	*Current text: "Together with the **covariance** model (Figures 8–11 and 8–12), the correlation coefficients estimated in this section provide the full covariance matrix." Figs illustrate the **variance** .*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*	*8.3.2*	*8-17*	*second bullet on slope term*	*inconsistency in font*	*ED*	*Fixed.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.2	8	N/A (new after Rev.2 release)	8.3.2	8-18	in second paragraph after the 4 steps of sampling	In the paragraph that begins with "Figure 8-32 shows ..." Should the last sentence in the paragraph refer to Figure 8-30 instead of 8-32?	ED	Reference to Figure 8-32 is correct.
Rev.2	8	N/A (new after Rev.2 release)	8.3.2	8-18	in third paragraph after the 4 steps of sampling	In the third sentence of the paragraph that begins with "Figure 8-33 shows ..." the word "spawns" should be "spawn".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.3.3	8-18	Fourth sentence in first paragraph of section	Current text-"...where people use only a subset of model for their analyses..". Should model be plural or should it be a subset of <u>the</u> model?	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.4	8-19	first paragraph of section	Typo--7400 should be 7, 400	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.4	8-20	third paragraph on page	Text suggests eight reference models are added to the plots (refers to Fig 8-25). Actually it seems like there are either three (mix with amplitude scaling, mix with magnitude scaling, and mix with distance scaling perturbations) or 13. Consider revising, possible suggestion-"several reference models are added ..."	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.4	8-21	First sentence of third paragraph	Seems like the "right column of" words in reference to Figure 8-38 should be deleted.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.4	8-21	Third sentence of third paragraph	reference to black dots for seeds in Figure 8-38. In the figure- the seed models are blue dots.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.4	8-21	Third sentence of third paragraph	The text refers to the 1 Hz results shown in Figure 8-38, but there isn't a panel of 1 Hz results in that figure.	ED	We modified this section.
Rev.2	8	N/A (new after Rev.2 release)	8.5.1	8-22	Second sentence in last paragraph before section 8.5.2	Text refers to Figure 8-39 when it should be 8-40.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.5.3	8-23	First sentence of section	Typo--"17cells" should be 17 cells.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	8.5.3	8-24	Second sentence of first paragraph on page	Current text "Figure 8-43 shows the scaling of ....". Consider replacing "shows" with "illustrates".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-25	In first and second paragraphs following eqn 8-24	In the text for consistency with the equation, the a* and c* should be subscripted.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)	Figure caption-- 8-7	8-35		Figure caption refers to magnitude scaling but figure illustrates distance scaling. Either change figure or caption.	ED	Figure shows magnitude scaling, but label was wrong, so is changed. Caption is changed from 1Hz to 10Hz. Christine to change Figure in word document
Rev.2	8	N/A (new after Rev.2 release)	Figure 8-1			Currently the label "8-1(a) is confusing with sub-figure labeled a through h. Consider Figure 8-1 and 8-1 (continued for subsequent pages). Also same for Figs 8-4, 8-8 and 8-9. Please ignore this comment if this change would affect many cross references to the figures that follow.	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-3	para3	Consider replacing "Fig 8-1 shows two " with "Fig 8-1 shows eight".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-3	para3	Consider replacing "variance numbers vary" with "variance numbers (Fig 8-1) vary".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-3	para3	Consider replacing "10 Hz" with "1 Hz".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-3	para4	Consider replacing "constrain" with "= develop?".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-4	para6	Consider replacing "obliterated" with "obliterate (or use some better word)".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-3	para4	"variance desired" use SSHAC language, not "desired".	ED	Fixed.
Rev.2	8	N/A (new after Rev.2 release)		8-7	Eqn8-7	remove duplicate	ED	Duplicate comment. Fixed.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-18*	*para~3*	*Consider replacing "Figure 8-32" with "8-30??". Check - may change meaning.*	*ED*	*Removed the second reference to Fiure 8-32 which was confusing.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-18*	*para4*	*Consider replacing "spawns" with "spawn".*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-18*	*para5*	*Consider replacing "subset of model for their analysis" with "?? subset of the final models for their analysis". Check - may change meaning.*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-19*	*para1*	*Consider replacing "model is among" with "seed generated". Check - may change meaning.*	*ED*	*We rephrased that sentence.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-19*	*para2*	*Consider replacing "Consider replacing "7400" with "7, 400".*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-20*	*para5*	*Consider replacing "Eight reference" with "Five reference". Check - may change meaning.*	*ED*	*We fixed that paragraph.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-21*	*para4*	*Delete "right column of"*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-21*	*para4*	*Consider replacing "Consider replacing "black" with "blue".*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-21*	*para4*	*Consider replacing "Consider replacing "1Hz" with "0.1, 0.0133, 40, 50 Hz". Check - may change meaning.*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-22*	*para4*	*Consider replacing "8-39" with "8-40".*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-23*	*para4*	*Consider replacing "17cells" with "17 cells".*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-24*	*para1*	*Consider replacing "shows the scaling" with "shows a sample of the scaling". See above.*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-25*	*para 1&2*	*a* and c*; the * should be subscripted*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-29*	*figure 8-1*	*label "8-1(a)" is confusing with sub-figure labled a thru h*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-35*	*fig caption*	*Consider replacing "1 Hz,8-1 left and 200" with "10 Hz, 8-4e and 25".*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-2*	*3rd par, last line*	*"right side of Figure 6-5". Do you mean to say "Figure 6-5"?*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-3*	*11th line from bottom*	*Figure 8-3 is 1-Hz, text says 10-Hz. Should Figure 8-3 caption read "10-Hz" ?*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-19*	*2nd par, 2nd line from bottom*	*should read M,R = (7,400)*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-21*	*4th par, 4th line*	*Figure 8-38 does not show 1-Hz map. Suggest adding 1-Hz to Figure 8-38*	*ED*	*Duplicate comment. Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-22*	*4th par, 2nd line*	*change "Figure 8-39" to "Figure 8-40"*	*ED*	*Fixed.*
Rev.2	*8*	*N/A (new after Rev.2 release)*		*8-23*	*3rd par, first line*	*suggest changing "...for all frequencies." to "for two frequencies".*	*ED*	*Could not find that instance - may have been fixed with previous edit.*
CHAPTER 9								
Rev.0	9					PPRP additional comment: With only a few exceptions, the proposed comment resolution for the Chapter 9 PPRP comments appear to be adequate to meet SSHAC report documentation requirements and the needs of the PPRP to review the document. There are a few exceptions and the PPRP requests that the TI modify a number of the proposed resolutions as outlined below:		
Rev.0	9	G9-1				Chapter 9 (or 8 and 9) may be the logical place to consider and evaluate possible sensitivities to an alternate Sammons map cell discretization model and its potential hazard sensitivity. Development and comparison of alternate and coarser discretization models (for example evaluation of 5, 9, 16 cells in addition to the 29 cells) would provide additional basis for the fine discretization reported in Chapter 9 and may also affect how the final models can be used (i.e. avoid excessive run-time for a single site, applicability to development of national hazard maps; applicability to higher exceedance vs lower exceedance design applications). This evaluation may partially address how the CBR of simulated ground motion models is captured. Note that a related question of possible alternate cell configurations was raised by the PPRP in Chapter 8. PPRP additional comment: To understand the hazard sensitivity of the Sammons map discretization's the PPRP requested an end-to-end analysis using a few suggested alternate discretizations. Currently, the Appendix C sensitivity studies referenced in the TI response do not contain sensitivity on Sammons map discretization nor sensitivity to the median weighting models. We strongly recommend that these studies be completed and documented for review as soon as possible in order that any possible follow-on evaluations won't seriously impact the project schedule.	General	We have performed such sensitivity studies for 13, 17 and 29 cells and have documented them in Appendix E.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	9	G9-2				Given the complexity and novelty of the approach used by this project, it is imperative to include some more traditional "sanity checks" on the final model, as part of this chapter or in a separate chapter. One approach that comes to mind is to generate plots of the epistemic fractiles (as calculated from the 29 GMMs and their weights) as a function of distance for one or two magnitude intervals that contain data (and for several representative frequencies). Then, the data can be overlaid on those graphs to demonstrate that there are no significant deviations between models and data and that the epistemic uncertainty implied by those fractiles is not inconsistent with the data (taking into account the sample size and scatter of the data). One of the questions that these comparisons would answer is whether the epistemic uncertainty for small and moderate magnitudes and distances within 50 to 100 km are being overestimated (as some of the results presented seem to suggest). Similar graphs showing scaling with magnitude for a few moderate distances will show the anticipated increase in the epistemic uncertainty as a function of magnitude. One advantage of using fractiles for these comparisons is that it is easy to visualize the epistemic uncertainty that way, rather than by viewing a large number of curves with different weights. PPRP additional comment: Not only are these fractiles plots imperative for the PPRP evaluation but we also suggest that they be incorporated in the final report.	General	Addressed. We added a new section with plots of the 17 models against data (chapter 9). We also show plots of the range int erm of fractiles for a subset of scenarios (plots for all scenarios are provided in Appendix E). We also mention that the epistemic uncertainty indeed increases with mangitude, as it was intended to.
Rev.1	*9*	*Rev.1 follow-up*				*The PPRP request for the "sanity check" of comparing fractiles of ground motion prediction to site corrected data (comment G9-2) was only partially met. The request was for small magnitude-distance scaling of the GMMs in the distance range 50-100 km to be compared to site-corrected observations. The TI provided magnitude-scaling comparisons to observations between 100-200 km. The PPRP request that additional comparisons be provided in the report, including the 50-100 km range. The fractile model comparison to observations provided in Figure 9-14 show that the 10% fractile model predictions appear low compared to the observations for some magnitude ranges (e.g., M4-5 for 2, 2.5 hz). Please explain. Also please specify the distance value used for the GMM prediction.*		*We have added plots for the 50-100km distance and specified the values used in the GMM to producte the predictions for both sets of plots. We were satisfied with the data comparisons overall considering the results from the various frequencies and taking into account that 1) the models are first developed frequency by frequency and then smoothed over all the frequencies and also smoothed with magnitude and distance scaling and 2) at low magnitudes, at least some of the recordings at >100 km are expected to drop below the noise threshold and only the largest ground motions are retained.*
Rev.0	9	9-1	9.1	9-1/2	-	Section 9.1 needs to be expanded slightly and speak more directly to the process of identifying, evaluating and integrating (or incorporating) the various alternatives for weighting and the bases for those weights. In its current form the section does not give sufficient introduction to the process that was followed and it isn't clear to the reader that the process was consistent with the SSHAC framework. Specifically Section 9.1 should state that the TI Team identified several alternatives for developing weights for the 29 "cells" or GMMs, those alternatives were evaluated and a preferred methodology for developing weights was defined. Subsequent sections describe the various methods and then a preferred model is developed and the basis for that choice is documented.	RE	The section was expanded with a few sentences according to the suggestion.
Rev.0	9	9-2	9.1	9-1	Line 5	Two periods rather than one to end a sentence	ED	OK.
Rev.0	9	9-3	9.1	9-1	middle of paragraph	First sentence says that the 29 GMMs at different frequencies are selected independently. If this were true (in the sense of probabilistic independence), it would have led to very jagged spectral shapes. Please revise text, describing how this was actually done in order to achieve less jagged spectra (ideally without using the word "independently").	RE	We expanded on that concept, basically summarizing what was done in Chapter 8, and use "one at-a-time" instead of "independently".
Rev.0	9	9-4	9.2	9-1	Entire section	Section is confusing and needs significant rewriting. The writer is trying to motivate the need for combining the results of chapter 8 with weights based on the data. This is very important but tricky to write and the message is not coming through clearly. One problem with this section is that the first paragraph speaks of "median ground motion estimates," without indicating where those estimates come from. We're not told until the last paragraph that these estimates are a smooth representation of the predictions by the 19 seed GMMs. Also, the last sentence in this section says "Therefore, the weight of a GMM representing an individual cell integrates over that cell." The meaning of the sentence is not clear, except for those who have followed the process over many meetings. Please clarify. This may also be a place to discuss the likely criticism that, because the data were already used in constructing the models in Chapter 7, using the data again to modify the weights is the same as using the data twice.	RE	We have revised the text for this section extensively. The part about weights based on data is expanded to explain that one would not expect all of the models to be unbiased with respect to the observable data. Additional consideration are provided in Section 9.3 Using data at a low weight is also motivated by the concerns of using the data twice.
Rev.0	9	9-5	9.2	9-1	1st line after bulleted list and last line of page	"that the distribution P(Y), is estimated from the.." Missing word? "is representative of an area on the Sammon's map, as.." Missing word	ED	The text was revised.
Rev.0	9	9-6	9.2	9-1	4th line from bottom and everywhere in the report	"fitting the data" - it is confusing what "data" means at this point (is it the input seeds or the observed ground motions?) Recommend being explicit at each use of "data"	ED	We corrected to refer to recorded ground motions.
Rev.0	9	9-7	9.2	9-2	First line	"representing an individual cell integrates over that cell" is unclear. Perhaps "for an individual cell represents the contributions of that cell"	ED	This was rephrased.
Rev.0	9	9-8	9.2.1	9-2	Second line	"by an ellipse in Sammon's map space that contains" Wording suggestion	ED	The text was revised.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	9	9-9	9.2.1	9-2	Fig 9-1(c)	Please explain why samples on the PGV plot have a different distribution from all of the other GMIMs (Also applies to subsequent figures).	RE	In the the first draft of the report, we had used a seed GMM to re-orient the Sammon's map and that GMM's prediction for PGV didn't follow the same trend as for the other GMIM. We are now using the distance scaling reference model to orient the maps, and all the maps have the same orientation. PGV shows a cloud very similar to those at 3 to 4 Hz.
Rev.2		*Rev.2 follow-up*				*Only 1-10 Hz plots are now shown in this section. Perhaps the others are elsewhere?*		*Data are only used between 1 and 10 Hz.*
Rev.0	9	9-10	9.2.1.2	9-2	2nd Last line	translate into the" ' 'translate into asymmetry in the"	ED	The text was revised.
Rev.0	9	9-11	9.2.1.2	9-2	Last sentence and Figure 9-2	Weights of fitted PDF vs samples/cell in Figure 9-2 appear to be generally consistent and presumably hazard assessments using either of the weighting schemes would result in nearly the same hazard. Judging from the quality of ellipse fit at other frequencies in Figure 9-1, the hazard at other frequencies should also compare well. The text in this section could be expanded to discuss how consistent these two approaches are.	NR	We have added a discussion to this section which address this issue.
Rev.0	9	9-12	9.2.2	9-3	Second paragraph	Is this 468-record dataset presented somewhere (as an electronic table?) Does the table indicate the both the original observed value, and the corrected value that was used for computing the weights?	RE	We added a table of the data used for these analyses.
Rev.1	*9*	*Rev.1 follow-up*				*A request for a table of the corrected and uncorrected spectral values (comment 9-12) used for the residuals evaluation was provided without the uncorrected values. Please provide the uncorrected values for Table 9-1 and move the table to an electronic supplement.*		*The uncorrected data exist in the NGA-East Database, making both datasets easily accessible. If time permits after we've responded to the technical comments, we will add the second table and move them to the appendices.*
Rev.2		*Rev.2 follow-up*				*STRONG RECOMMENDATION. The PPRP strongly suggests that the corrected values be included as an electronic supplement. This would be very useful to future research and should not take much effort.*		*Added a note in section 9.2.2 and two electronic appendices (E8.1.1 and E8.1.2).*
Rev.0	9	9-13	9.2.2	9-3	1st paragraph after bulleted list	The second line of the paragraph refers to "between-event residuals and within-event residuals" without referring to tau and phi, later in the paragraph tau and phi are referred to explicitly. Tau and phi are not defined until Chapter 11.	ED	The text was revised.
Rev.0	9	9-14	9.2.2	9-3	bottom of last paragraph	Please add more details on the chosen parameter Delta. What is the basis for this value of delta, sensitivity? Were any quantitative criteria used? Also, please consider making Eq. 9-4 more explicit, by using summation or max{} signs as appropriate (in a manner more consistent with Eq 9-5). In addition, please consider changing "inside" to "within" in the text following Eq. 9-5.	RE	We have revised the text and provided a figure to show the sensitivity of results to delta; it is minimal.
Rev.0	9	9-15	9.2.2 and figures 9-4 through 9-6	9-3/4	Entire section	There needs to be much more interpretation of what the comparisons with data in these figures are telling us. In this regard, the M+, R+, etc. points shown in Figure 8 – 24 would be very useful (are those directions still valid, at least in an approximate way?). Is it possible to add these points to the Sammon's maps in this chapter (and also to similar figures in Chapter 8 that do not contain these points)? These reference points (or something similar) are necessary because it will show the reader which directions correspond to higher magnitude scaling and which directions to higher distance scaling. The figures in the data comparison section (figures 9-4 through 9-6) generate many questions that need to be discussed, for instance: (1) What is the meaning of the "WNW-ESE" orientation of the mean-residual contours and of the likelihood contours (except for PGV, which has a WSW-ENE orientation)? By the way, the dot clouds in Figure 9-1 show similar orientation. (2) Why is it that the likelihood contours do not seem to close? (3) Why don't the zero residual and maximum-likelihood contours go through the origin for 0.1 Hz? Does it indicate a bias of the models at low frequencies? Is that bias statistically significant? (4) What is the meaning of the noise in the mean residual and likelihood contour plots? Is it the loss of information in going from many dimensions to only two dimensions?	RE	In response to Chapter 8 and 9 comments, we added reference models for M and R scaling on all the Sammon's maps. These do help with the interpretation. We expanded the section to add to the interpretation of contour plots and the "noise" that is observed. This noise is due to the data coming from a limited range, whereas the Sammon's maps are a representation of a wider range of scenarios. We added contour plots from Sammons maps based on the data range scenarios, which are less noisy. We argue that for the purpose of the section, assigning weights, the exact orientation and trends do not matter. As we revsied the selection of a systematic subset of data for all the analyses (Chapters 7, 9, 10), we have chosen to use only data from the 1-10 Hz band where the data is present in significant quantities. This is discussed in Section 7.6

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*9*	*Rev.1 follow-up*				*The explanation for the noise in the contours in Figs. 9-5 and 9-6 is not very convincing. If two models are close in the 1-1500 km space, they will also be close in the 10-400 km space as well. A more likely reason for the lower noise in Figure 9-9 is that the 10-400 km space is easier to approximate with the Sammon's maps (i.e., lower Sammon's stress) because it has less non-linearity in M-lnR space. Along the same lines, the sentence "These models, although close together in a distance range where there are ground-motion observations, they diverge at very large and small distances" does not explain the noise because the weights depend only on what the models do in the region covered by the data. This discussion should be revised.*		*We attached a sample figure below that shows the effect of generating Sammon's maps only for scenarios covered by the data range. The figure is indeed less noisy and the countours are better defined. Ragged edges are due to imcomplete datasets, but the color bands are now well defined. Plots for all other frequencies show the same trend. Our explanation stands.*  .
Rev.2		*Rev.2 follow-up*				*PPRP still disagrees with explanation, but this is not a crucial issue.*		*NR*
Rev.0	9	9-16	9.2.2 and 9.2.3	9-3/4	Entire sections	Please discuss whether these approaches (in particular the likelihood approach) take into account that there is significant uncertainty in the conversion of recordings from much softer material to reference site conditions, especially when the site conditions at many recording sites are poorly known, and the implications of considering this uncertainty. Also, this uncertainty is likely to be different for different sites depending on how soft they are and how well their Vs30 is known. Also, if a particular site has recorded multiple earthquakes, is the correlation introduced by the same site term taken into account in the likelihood? If not, what are the implications? You can calculate the uncertainty in Sa due to uncertainty in Vs30 because you know the uncertainty in Vs30. That could be used to quantify the associated uncertainty in Sa (using the same model used to adjust the data), i.e., using sigma[ln(Vs30)]*|d(ln AF)/d(ln Vs30)|, where AF is the adjustment-factor function (Boore+BSSA) being used to convert the data from arbitrary Vs30 to 3000 m/s. On the other hand, this uncertainty may already be factored in the high value of phi_s2s obtained in Ch. 11. What about sites that have recorded multiple earthquakes? Is this taken into account in the likelihood? (this is done in EPRI, 2013).	RE	We have reworked this section. We added a section in Chapter 7 regarding the site effects models for data correction from as-recorded to reference rock condition. We refer to that in the current chapter to justify our choice of correction method. The residuals and likelyhood are computed using a mixed-effects regression, but it is true that he correlation of records from sites that record multiple events is not taken into account. It is difficult in the random effects framework of Abrahamson & Youngs, since the covariance matrix needs to be block diagonal. Note that we changed the calculation of residuals, as a constant functions fitted to the residuals. The effect is likely small, since most of the stations in the test data set only record 1or 2 events. One could take the uncertainty associated with correcting the data into account by using multiple correction methods, but this raises the question of how to give weights to these different approaches. This is briefly addressed in section 9.4, where the rationale behind giving low weights to the data approaches is given. that takes into account the number of point from events and stations, but we have not performed further segregation of the data. We feel we don't have the data to significantly quantify the true uncertainty and bias in site effects. We have an estimate of uncertainty on Vs30 based on the technique used to obtain it, but we do not know the uncertainty of site response given Vs30; given the large impedence contrasts often present in CENA, this is a major issue. In addition, the dataset is limited compared to the range of scenarios included in the Sammon's maps. We felt that our use of residuals and likelyhood as a guide for weights in the 1-10Hz, with low weights, was appropriate.
Rev.0	9	9-17	9.3.1	9-4	Middle of paragraph	(1) Regarding the sentence "Figure 9–1 shows that the upper left and lower right cells contain fewer sampled GMMs than the lower left and upper right cells." Figure 9-1 does not appear to support this statement (in fact, the figure shows the opposite for all GMIMS except PGV). (2) Sentence beginning with "This correlation" is not clear and appears to be incorrect (and the word correlation is used two or three more times in the paragraph). This effect is not a correlation, and "skewness" may not be an entirely appropriate description in this 2D situation. Please provide appropriate terminology for describing the patterns observed in the Sammons mapping of the GMMs.	NR	The text was revised completely in this section. These comments don't apply anymore.
Rev.0	9	9-18	9.3.2	9-4	Last sentence	Please provide additional explanation of how the "variability of the data" are captured. What this statement may be trying to say is that the likelihood-based weights take into account the aleatory variability in ground motions, in the sense that residuals (i.e. differences between the observed ground motion in the median model under consideration) that are smaller than one standard deviation are tolerated without a significant reduction in weight, while residuals that are considerably larger than one standard deviation cause a strong reduction in weight. The issue is slightly more complicated because residuals are correlated because of the common event term, but this is taken into account in the Abrahamson-Youngs formulation. As mentioned in an earlier comment, the correlation introduced by common site terms appears to be neglected.	RE	We added an explanation how the likelihood is calculated, and how a constant phi/tau will penalize models that can have low residuals, but a wrong scaling.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	9	9-19	9.3.2 and 9.3.3	9-4/5	Entire section	The evaluation of the data-based weighting schemes needs substantially more justification and discussion. There is a very large difference between the weights based on mean residual and the weights based on the likelihood and this difference must be understood and discussed. Another result that needs to be discussed is that the likelihood-based and posterior-based weights seem to suggest that the data strongly favor a significantly narrower region within the Sammon's map and are biased to the lower left (at 1 Hz see Figs 9-7 and 9-8) than the seed models, and that the seed models also appear to be biased. Whereas the final weights are much more symmetric (Fig 9-10). On the other hand (as indicated nicely in section 9.4), one needs to keep in mind that most of these data come from relatively small magnitudes and large distances. One way to compensate for this problem would have been to use a weighted likelihood, with weights that increase with magnitude and decrease with distance. This weighted likelihood function would then appropriately give additional weight to the observations in the more interesting M and R ranges. Please provide additional justification and discussion on why this weighting scheme was or was not considered.	RE	We expanded the text on that section. The TI team did consider the PPRP request. Sensitivity analyses presented in Appendix E show that considering the likelihood did not affect the results to start with, so we did not further discretize the likelihood.
Rev.0	9	9-20	9.3.2	9-5	First line of page 9-5	The statement "the two sets of weights provide similar insight into the data" does not appear to be correct. How can the two sets provide similar insights when the weights are so different, as shown in figure 9-7? Please revise section to clarify this issue.	RE	We have corrected the text and provided justification for keeping both approaches with low weights, based on their respective merits.
Rev.0	9	9-21	9.3.3	9-5	1st par, last sentence	Suggest changing to "leads to a concentration of models at large magnitudes,"	ED	We revised the text.
Rev.0	9	9-22	9.3.3	9-5	1st par, Figure 9-8	One might anticipate that the weights distribution for the posterior probability (Figure 9-8) to somewhat mirror the seed distribution for 1-Hz in Figure 9-1(a) since most the seed models agree with the observed data. Since the heavier weighted cells don't approximately mirror the seed cell locations, is it a result of the Sammons mapping incorporated a larger magnitude range, beyond the observed range? Please provide additional discussion on what if any comparisons could be made between the location of seeds and the higher posterior probability weights in Figure 9-8.	NR	We believe this is likely due to the limited data range relative to the Sammon's maps range.
Rev.0	9	9-23	9.3.3	9-5	1st par, next to last sentence	Suggest changing to ""hazard relevant but are not constrained by the available data."	ED	We revised the text.
Rev.0	9	9-24	9.4	9-5/6	Entire section	(1) Although this section provides considerably more justification and insight than other sections in this chapter, these are still not sufficient, given the importance of the decisions made here. For example, why are the weights 80 -10-10 and not 60-20-20? What are the implications of alternative weight choices? (2) One element that may be worth bringing into the discussion and to justify the low weights given to data is that the data were already used to define the models in Chapter 7 (although to what degree is not very clear unless one delves deeply into the details of every developer's work). (3) The sensitivity to the selection of weights would be better understood if mean and fractile hazard can be computed for each of the weighting schemes for a couple of demonstration sites for 1 and 10 Hz. Hazard sensitivity assessments to the different logic tree weighting schemes would be useful to understand the significance of the different weighting schemes.	RE	(1) We provided better justifcation for the weights. We performed sensitivity studies on this (Appendix E), within the range we were confident with (see text for details). We added a discussion on uncertain site condition. (2) We expanded on that concept. It is also part of the justificaiton for the low data-based weights. (3) Agreed. We provide sensitivity analyses in appendix and the justification for the choice of weights.
Rev.0	9	9-25	9.4	9-5	1st paragraph	delete "enough", as it is redundant	ED	We rewrote this section.
Rev.0	9	9-26	9.4	9-5	1st paragraph	"this limited range of magnitude, distance, and frequency" the limits for frequency are given, but the magnitude and distance ranges are not.	ED	Everything is provided earlier in the chapter now.
Rev.0	9	9-27	9.4	9-5	1st paragraph	"the data is not discriminative" given the muddied use of "data" earlier in the report please be specific: "the available observations(Fig 9-3)"	NR	We rewrote this section.
Rev.0	9	9-28	9.4	9-5, 9-20	Figure 9-9	This example is not very convincing because the likelihood based weights for models 20 and 28 are several orders of magnitude lower than those for model 1. One could conclude from this example that the absolute-residual based weights are not very useful and that the likelihood-based weights are preferable.	RE	We removed that example as it was not helpful.
Rev.0	9	9-29	9.4	9-6	final sentence	It would be helpful to illustrate the final weights from Table 9-1 as a 2D figure, plotting weight against frequency for each Model number. Alternatively a 3D representation may be possible. The goal would be to show the smoothness (or otherwise) of how the weights vary with frequency.	RE	We have created a new figure type to illustrate the weights.
Rev.0	9	9-30		9-9 through 9-11	Figure 9-1	The cloud of points shows a larger proportion of points outside the outer ellipse in the upper left and lower right corners (except for PGV, where the pattern is reversed). Because all dots falling outside the outer ellipse are removed, GMMs with certain scaling characteristics are preferentially removed, and it may be that more points are removed than predicted analytically. Do these two issues create a problem? Please comment on these issues and their implications. In this regard, it may be useful to calculate and report the actual fraction of dots that fall outside the outer ellipse for all frequencies or at least several representative frequencies (recall that the 95.45% value quoted in the report is only an analytical result for a bivariate distribution).	RE	We added a couple of sentences in section 9.3.1 that explain how an uneven distribution of points on the Sammons map can occur. The TI team decided to use number-based weights to correct for that issue, i.e. correct the assumption that there s a perfect 2D distribution.
Rev.0	9	9-31		9-9	Figure 9-1	Virtually impossible to discern the "blue dot" in these figures.	ED	We changed all the figures. They sould be easier to read now.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	9	9-32		9-12	figure 9-2	Please explore more informative ways to display the weight assignments to the various sectors in figures such as these. For instance, use the height of vertical bars, or use different colors (the current grayscale, which is not described in the report or captions, provides very low resolution). It is very difficult to obtain an overall view of the difference between the left and right figures.	NR	We have created new plots that provide the information. They are clearer to interpret.
Rev.0	9	9-33		9-12	Figure 9-2	Red lettering is difficult to read.	ED	We changed all the figures. They sould be easier to read now.
Rev.0	9	9-34	9	9-12	Fig 9-3	Correct labels on axes (they are reversed). Reproduce with a larger figure.	ED	We regenerated the figure and corrected an error in the data shown.
Rev.0	9	9-35	Figure 9-4	9-13		Please indicate the units of the between-event residuals. Do they have units of log amplitude or are they already normalized? Also, what is the meaning of the contour interval for the likelihood? Is the current contour interval exp(20) (i.e., 4.85e8)? Consider displaying the log likelihood in a more intuitive manner. The following is one possible way of making these figures more intuitive: set the maximum value to zero, and convert from natural log to decimal log in order to make it more intuitive (so one can see how far one needs to go from the maximum value to get a factor of 10 reduction in likelihood). All this must be explained in the captions or in the text.	RE	We added an explanation in the text how the residuals are calculated, based on natural log median estimates. Wedo not think that it is helpful to change the likelihood, even to log 10. The value of the likelihood depends on the observed data, it s not even comparable between different frequencies. There is nothing special about a difference in log10-units of a likelihood. The contour plots each have a legend, displaying the range of the reisduals
Rev.0	9	9-36	Figure 9-5	9-14		Axis annotations are very difficult to read. Please use larger and darker fonts for this figure and similar figures.	ED	We made those figures bigger.
Rev.0	9	9-37	9	9-17	Fig 9-6	Revise color legend to make the pale yellow more visible (adding a surrounding box may be sufficient) and assign limiting values (i.e. what is the largest number the pale yellow represents, & equivalent for deep blue)	ED	We tried various color schemes and returned to the original. We now include a color bar as a legend.
Rev.0	9	9-38	figures 9-7 and 9-8	9-19 and 9-20		Figures similar to these should be provided for more frequencies (recommended frequencies, 0.1, 0.333, 1.0, 2.5, 5.0, 10, 20, PGA, PGV). These figures are extremely important and it is not enough to show the weights for 1 Hz only.	RE	We provide figures for all the data-based weights (1-10 Hz) and all the figures for the final weights. We have changed the figure format to be easier to read following the PPRP comments.
Rev.2		*Rev.2 follow-up*				*Please add an insert with the ellipse and cell numbers (as in fig 8-42). Do the same for all figures that use only cell numbers (e.g., 9-2, 9-4, etc.).*		*Done for several figures in Chapter 9.*
Rev.0	9	9-39		9-21	Figure 9-10	Very difficult to read the red lettering.	ED	We changed the way we diplay the weights based on the PPRP comments.
Rev.1	*9*	*9-40*	*9.2.1.1*	*9-2*	*sentences following eq 9-1*	*Not only weights are forced to be symmetric, but they are forced to follow a normal shape (i.e., normal kurtosis, etc.). This is not obvious from the text and should be described more clearly.*	*RE*	*We added a statement to this effect. This type of weighting scheme is described for completeness, but it was not selected by the TI team (we used instead the number of models in the cells). We also added a sentence on this decision in the 9.2.3 discussion paragraph.*
Rev.1	*9*	*9-41*	*9.2.2*	*9-4*	*Eq's 9-5, 9-6 and following text*	*The weight is calculated using the mean absolute offset. It seems more intuitive to use the absolute value of the mean offset instead (i.e., reversing the order of the summation and || operators when calculating mu_k(C_0)). Consider, for example, the central cell and assume that the mean offset for GMMs within that cell is 0. Why should this cell be penalized? Please discuss the choice used.*	*RE*	*We indeed computer the mean aboslute offset. In hindsight, it would have been better to compute the absolute mean offset, as the PPRP suggests. This was caught too late (Juuly 2018) for us to change the weights and rerun all the analyses.*
Rev.1	*9*	*9-42*	*9.5*	*9-8*	*2nd paragraph, also Figure 9-13, Appendix E.9*	*It is very concerning to the PPRP that in Figure 9-13 and other figures in Appendix E.9 there are cases where the seed model CDF spread is about the same or greater than the NGA-East spread. This behavior is also observed in fractile plots of Sa vs M, for example Figures 5196, 5211 and 5221 illustrate seed and GMM fractiles for a source distance of 10-km for f= 6.7, 20 and 33.3 Hz respectively. The PPRP does not understand how or under what circumstances, at this close distance where data are extremely limited, can median GMM epistemic appear be less than seed model epistemic. Please provide in Section 9.5 a rational explanation for these instances.*	*RE*	*Overall in the number of scenarios considered, this occurs relatively rarely, yet we were not surprised to see those trends, especially those at close distance. We have added a discussion on this in Section 9.5. The large range in the seeds at close distance is due to the conversion from Rjb to Rrup and to the extrapolations that had to be performed to reach Rrup=0 km. In addition, we are forcing the models to be smooth with M, R and f, which effectively narrows the range. The choice was made to develop smooth models.*
Rev.1	*9*	*9-43*	*Table 9-2*	*9-19*		*In Chapter 8, the TI Team went to considerable effort to make sure that the 17 models led to reasonable spectral shapes. Because the weights are frequency dependent, is there a guarantee that the resulting UHS is well behaved? What about the mean, and fractile deterministic spectra for any given M-R scenario? Was Figure 8-50 calculated using the weights from Table 9-2? If so, this should be indicated in Chapter 8. If not, have the resulting spectral shapes been checked elsewhere?*	*RE*	*Figure 8-50 was generated using the final weights developed in Chapter 9 (Table 9-2).* *We added example plots of weighted mean spectra based on the final NGA-East GMMs and their weights. We also illustrate the issue of large distance predictions and provide a statement on how to address the spectral shape in those cases; the recommendation is consistent with the ones developed for the NGA-West1 and NGA-West2 GMMs.*
Rev.1	*9*	*9-44*	*Figure 9-1*	*9-21*		*The seed models shown on the new SM's have a very different configuration than shown on the previous draft (17 vs 29 cells). Compare Figure 9-1 vs the 1-Hz plot of Figure 9-1(a) of Rev 0. It seems that the pattern should be similar regardless of the cell discretization. Why do the patterns differ?*	*RE*	*The change comes from the different covariance models used in the two versions.*
Rev.1	*9*	*9-45*	*Figures 9-11-12*	*9-30 to 9-37*		*Figures 9-11 and 9-12 provide a good comparison of SM weights by sector number and weights vs frequency. These were produced in lieu of the shaded SM cells of Rev. 0 (polar plots). We request that both types of illustrations be included in this chapter and similar figures in Chapter 8.*	*RE*	*We replaced the shaded plots based on comments from the PPRP (comment 9-32). We will add back those plots if there is time at the end of the project, once all the technical comments have been addressed.* *There is no weight or other quantity presented in Sammon's maps in Chapter 8.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*9*	*9-46*	*Figure 9-10*	*9-29*		*The PPRP recognizes that the TI did not give much weight to the data residuals and likelihood, but we are surprised that while both of these show a top-right (NE) to bottom-left (SW) gradient, the cells in the NW and SE quadrants don't get more weight. For example, models 4 and 8 should thus have higher weight than 2 and 6. At 1 Hz that does not seem to be the case for Fig 9-10 or its equivalent in Fig 9-11b.*	*RE*	*The weights are computed based on the residuals and likelihood of each model and then combined for a given cell. It is impossible to visualize the number of models and their specific residuals and likelihood values. We agree with the comment that the trends don't appear consistent, but these trends can't be assessed visually, unfortunately.*
Rev.1	*9*	*9-47*	*9.2.2*	*9-4*	*Following eqn. 9-4*	*Reference is made to "average values of tau and phi in Ch.11". Consider adding reference to specific Tables in Ch. 11 containing those values.*	*NR*	*OK.*
Rev.2		*Rev.2 follow-up*				*There is still no reference to a specific figure, table, or equation in Chapter 9 here.*		*Added the reference to the two relevant sections.*
Rev.1	*9*	*9-48*	*9.1*	*9-1*	*second line*	*Typo: should be Figure 6-9, not 6.9*	*Ed*	*OK.*
Rev.1	*9*	*9-49*	*9.2*	*9-2*	*last paragraph before Section 9.2.1, fifth line*	*Incorrect figure cited in 5th line. Currently refers to Figure 8-32, should be Figure 8-41 or 8-42.*	*Ed*	*OK.*
Rev.1	*9*	*9-50*	*9.2.1*	*9-2*	*3rd line*	*Typo: Missing space between maps and (1960).*	*Ed*	*OK.*
Rev.1	*9*	*9-50*	*9.2.1*	*9-3*	*last paragraph before Section 9.2.1.3*	*Incorrect Figure number, refers to Figure 8-17, not the correct figure.*	*Ed*	*OK.*
Rev.1	*9*	*9-51*		*9-3 and 9-4*		*Problems with fonts for symbols contained in text. Numerous spots.*	*Ed*	*They appeared ok in the document. Will check in the final PDF again when it's generated for the final report.*
Rev.1	*9*	*9-52*	*Figure 9-7*	*9-27 and 9-28*		*Likelihood misspelled in figure caption.*	*Ed*	*OK.*
Rev.1	*9*	*9-53*	*Figure 9-11e*	*9-34*		*Typo on figure legend: PGV.*	*Ed*	*That comes out of the code so it runs to generate figures in batches. Same for PGA and on several figures. The captions are ok. Will change if extra time.*
Rev.1	*9*	*9-54*	*9.5*	*9-8*	*2nd paragraph, also Figure 9-13, Appendix E.9*	*Figure caption for Figure 9-14 refers to .."NGA-East GMM predictions are plotted at the mean of the data range." Consider adding a sentence to the text on pg. 9-8 that explains what "the mean of the data range is" or better yet how it is calculated.*	*NR*	*Done*
Rev.2		*Rev.2 follow-up*				*In 9-15(c) through 9-17(c), some black lines appear to be missing. If they are over-printed, please indicate so.*		*The legend was not correct and misleading - it has been fixed for all the c plots.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-4*		*REQUIRED* *Two problems with equations on this page:* *(1) Eq. 9-4 is missing plus sign after c_0 (was correct in Rev. 1 report; are equations being corrupted? e.g., in Mac<-->PC copying>)* *(2) There is an equation from Chapter 10 or 11 that got moved here (Ho=....., just below Eq. 9-6). Please also check whether the equation is missing in Chapters 10 or 11.*	*NR*	*Added the plus sing and removed the extra Equation. The Extra Equation was Eq 10-15, which is still there.*
Rev.2	*9*	*N/A (new after Rev.2 release)*	*9.5.4*			*May want to indicate that these inconsistencies in high-frequency spectral shape at long distances have no hazard significance.*	*NR*	*Added a sentence.*
Rev.2	*9*	*N/A (new after Rev.2 release)*	*Fig 9-5 and 9-6*	*9-25*		*Figure captions in Figs 9-5 and 9-6 are identical, one plot is based on residuals the other on log-likelihood. Caption in Figure 9-6 should be modified.*	*NR*	*Changed caption for Figure 9-6.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-1*	*sec 9.2*	*Consider replacing "each a cell" with "each cell".*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-3*	*towards bottom*	*Consider replacing "The samples have" with "The data now have".*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-6*	*para1*	*Consider replacing "may not be" with "need not be".*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-6*	*para1*	*Consider replacing "studies we completed" with "studies.".*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-8*	*9.5.1*	*Consider replacing "the one of the seed" with "that of the seed". Check - may change meaning.*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-8*	*9.5.1*	*Consider replacing "for a few scenarios" with "for two scenarios".*	*ED*	*Fixed.*
Rev.2	*9*	*N/A (new after Rev.2 release)*		*9-27,28*	*Fig 9-6 caption*	*Consider replacing "offset residual" with "log-likelihood". Check - may change meaning.*	*ED*	*Fixed.*
						CHAPTER 10		
Rev.0	10	G10-1				This section needs a better road map to keep the reader on track. Table 1 summarizing the notation is a big help, but it's easy to get lost in what is being expounded, and what the conclusions are. A set of summary figures of the candidate models for each parameter would be a good place to end up. The detailed comments below contain a number of requests for additional figures; those figures would help substantially in enhancing the clarity of the presentation. The authors should consider more forward referencing to Chapter 11, make it clearer how the model will be used.	General	The text has been revised in Chapter 10 to provide a better and clearer presentation of the contents and goals of this chapter with additional figures and forward referencing to Chapter 11.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	G10-2				The assumption that is the foundation for the approach employed in this study is that the development of the median models and the aleatory (sigma) model can be de-coupled. So, in effect, it doesn't matter what median model(s) is/are used to compute residuals and then tau and phi. Hence the resulting aleatory model can be applied to all the derived median models in the hazard calculations. This is the approach that was used in the EPRI 2013 model (based on the EPRI 2004/06 work) and numerous other studies. This assumption is probably sound for cases where the GMM used to compute the residuals is something like the "average" of the median models (near the center of Sammon's space) and similar models will used in the hazard calculations. How sound is this assumption when applied to models that are exploring the range of median models and when this range is broad (i.e., those near the periphery of the sampled Sammon's space)? There is no substantive discussion of the fundamental assumption noted above and the potential implications when applied to the full range of median models. Some discussion is justified. The approach currently used probably produces the lowest possible estimate of sigma. Consider Figures 10-6 and 10-15. Different values of tau and phi_ss are noted for the different NGA-West 2 models (due in part to different data selection, use of alternative functional forms etc.). These differences are factored into the Global model by increasing the epistemic uncertainty in tau and phi_ss (figs 10-10a, 10-19, and 10-20). In principle, something similar should probably be done with the CENA data. In order to provide additional insights regarding this issue, the PPRP has created plots that compare the GMM used in this Chapter to the seed GMMs and to the fractiles derived from the GMMs and weights obtained in Chapters 8 and 9 (please see figures attached at the end of this document). These figures illustrate the broad ranges spanned by the seed GMMs and by the final set of GMMs, and that the GMM used in this chapter is not always near the center of these ranges for magnitude-distance combinations for which data are available.	General	A discussion of the decoupling the median GMMs and the aleatory variability models and the applicability of the sigma models to the broad range of median models was added to Section 10.1.3.
Rev.0	10	G10-3				In Chapter 4, the CNA, APL, and ACP regions were combined to give a "mid-continent" region that was distinct from the Gulf Coast region. The PPRP has been critical of the documentation supporting this decision, and has requested additional justification. In response, the fourth paragraph in 10.3.4 [and the Appendix C.6 (sic) it is pointing to] attempts to assess from site and event terms whether the ground motions in APL (termed region 3 in the document) are different from CNA (region 2). It concludes that no difference can be resolved from the limited dataset used (6 rejection criteria applied on top of those applied in Chapter 5 (Database)). However, the "no difference" conclusion seems to be contradicted by the statistically-significant difference in average site terms (Figure C.5-1) for 1 to 2 Hz and higher and the difference in average event terms between 10 and 30 Hz (Figure C.5-2) for CAN versus APL. Some additional comparisons of residuals for the largest appropriate subset of the NGA-East database should be considered that compares CAN and APL results to bolster the conclusion of 'no difference". The comparisons of total residuals vs. site and event terms could be helpful.	General	The discussion in AppendixF addresses this question. While Figure F.1-1 shows a bias in the average site terms for Region 3, the average event terms for Region 3 does not generally show a bias between 1-10 Hz (Figure F.1-2). This indicates no clear trade-offs between event and site terms for Region 3. Note that trends observed outside of the 1-10 Hz frequency range are not considered reliable due to the discussed data limitations. Further discussion in Appendix F.1 looks into the potential causes of the bias in the average site terms for region 3. There is not enough data to provide definitive conclusions. The TI team does not state that there is no difference between the regions. The conclusion is rather that "regional differences cannot be reliably resolved using the available data" due to the limited dataset. As a result, the TI team decided not to build a region-dependent model for CENA.
Rev.0	10	G10-4				In the calculation of tau and phi_ss for CENA data, somewhat anomalous results are obtained for frequencies outside the 1-10 Hz frequency range, and the results are dismissed without sufficient discussion. For frequencies below 1 Hz, the constant model turns out to be conservative, so it is not difficult to justify its adoption (although it would be nice to understand what the cause(s) of the low values is/are). The problem comes at frequencies between 10 and 35 Hz, for which the tau values are significantly higher and the error bars are not outrageously large. It is important to understand the cause of those high tau values before they are dismissed. What are the typical distances in that part of the data set? What are the typical magnitudes of the earthquakes and how many earthquakes are there? Figures similar to 10-2 and 10-4 for 25 Hz may help in this regard. Note, this concern is echoed in several detailed comments below.	General	Additional discussion was added to Section 10.3.1.1 to address this question. A figure and table were added to show the number of recordings, earthquakes, stations and the magnitude-distance distribution for the data at f = 25 Hz, as requested.
Rev.0	10	10-1	10.1.1	10-1	Entire Section	The text should reference a figure such as Figure 1 from Al Atik et al. (2010) illustrating between-event and within-event residuals. This figure would be a helpful addition to accompany this summary section.	NR	A reference to Figure 1 from Al Atik et al. (2010) was added in section 10.1.1 along with a brief description of the between-event and within-event residuals.
Rev.0	10	10-2	10.1	10-1	Entire section	There is no discussion of how, or if, any aleatory models provided by the seed-model developers informed the TI in their development of an aleatory model of variability. See General comment 2 above. At least some discussion would be desirable.	RE	As part of the general approach of decoupling the sigma from the median models, the seed-model developers were not tasked with providing sigma models. We added Section 10.2.3 to discuss the aleatory variability from the seed GMMs.
Rev.0	10	10-3	10.1	10-1	entire section	It may be a good idea to relate this chapter to Chapter 11 in this section, indicating that this chapter introduces alternative models, but Chapter 11 selects models and assigns weights.	NR	Text was edited as proposed.
Rev.0	10	10-4	10.1	10-1	entire section	Text on line 3 should refer to chapter 9 or to chapters 8 and 9 (not to 8 alone). Third sentence should probably include the word aleatory somewhere.	ED	Text was edited as proposed.
Rev.0	10	10-5	10.1	10-1	Line 4	CENA is used frequently and explicitly in this chapter. The definition of CENA should be provided/illustrated in Chapter 4 and referenced here. Please double-check as CEUS is used in this Chapter in a few places, is this intentional? Ensure that CENA and CEUS are being correctly and consistently used throughout the report.	ED	The definition of CENA was provided in the list of acronyms, at the beginning of Chapter 4, and at the beginning of this Chapter. The acronyms CENA and CEUS are used correctly in Chapter 10. CEUS is only used in reference to the EPRI (2013) study.
Rev.0	10	10-6	10.1.1	10-1	1st paragraph	In table 10-1, consider using indentation (or inserting eqs. 10-1 and 10-3) to indicate the relationship between the various terms appearing on this table. Discrepancy in font size in table. Consider using consistent font size.	NR/ED	Table 10-1 was edited as suggested.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-7	10.1.2	10-2	1st sentence	Suggest deleting “from a relatively small source region” As this is not always the case (consider the hazard from New Madrid for instance).	NR	The expression “from a relatively small source region” was deleted as suggested.
Rev.0	10	10-8	10.1.2	10-2	Middle of paragraph	May also want to indicate that the ergodic assumption does not introduce errors in the PSHA because the PSHA concerns itself with rare events, so that repeated occurrences (with the associated correlation effects) are highly unlikely	NR	Text was edited as suggested.
Rev.0	10	10-9	10.1.2	10-2	1st paragraph, last sentence	This sentence is difficult to understand. It should be rewritten and perhaps expanded to clarify what the authors want the readers to understand here. Please indicate that, instead of adjusting the median GMM, this may be done as part of the site response. In fact, this is the way it is usually done in the CEUS.	RE	The sentence was modified and expanded to clarify the intent.
Rev.0	10	10-10	10.1.2	10-2	Last sentence of 2nd paragraph	This sentence is hard to understand. Consider rewriting and perhaps expanding to clarify what the authors want the readers to understand here.	RE	The sentence was modified and expanded to clarify the intent.
Rev.0	10	10-11	10.1.2	10-2	3rd par, 4th line from bottom	Please change "is estimated" to "be estimated"	ED	Text was edited as proposed.
Rev.0	10	10-12	10.1.3	10-3	first line	“are”, please watch the tenses in the entire report. The science report was completed and the SSHAC report is citing it, so it should be past tense. Generally, watch the tenses where the parallel science work is cited	ED	The use of the present tense was replaced with the past tense when the science report is cited.
Rev.0	10	10-13	10.1.3	10-3	Line 4	100 Hz – inconsistent with other parts of the report	ED	Table 1-1 lists the minimum set of frequencies for the NGA-East project (0.1 to 50 Hz). For the sigma work, the develped models are applicable to a frequency range of 0.1 to 100 Hz. This is a result of either using non-CENA models which were defined at 100 Hz or extrapolating the models developed using the CENA data based on the frequency range of 1 to 10 Hz. No change to the report was done here.
Rev.0	10	10-14	10.1.3	10-3	Sentence 3	Suggest starting a new paragraph?	ED	A new paragraph was started here.
Rev.0	10	10-15	10.2.1	10-3	title	As the notation is difficult, consider adding the symbol (σ) etc to the section titles	ED	Notations were added to section titles as suggested. This was also done for Chapter 11.
Rev.0	10	10-16	10.2.1	10-3	Paragraph 2	“Similar to the judgement by EPRI (2006), EPRI (2013) increased s by 0.03 natural log units”	ED	Text was edited as proposed.
Rev.0	10	10-17	10.2.1	10-3	Paragraph 2, 4th line	Missing word—[not including the Idriss (2014) GMM]	ED	Text was edited as proposed.
Rev.0	10	10-18	10.2.1	10-3	Middle of second paragraph	Is "between 10 Hz and PGA" correct? Figure 7.10-2-2 of EPRI 2013 suggests that it should be "between 10 Hz and 40 Hz." Also, consider including that figure in the report and perhaps in some of the comparisons.	NR	This was changed to "between 10 and 40 Hz" in accordance with Figure 7.10.2- 2 and Table 7.10.2-2 of the EPRI 2013 report. Though the report on page 7-49 states the following "In addition, the values of Tau and Phi at high frequency (between PGA and 10 Hz) are set equal to the value at 10 Hz to account for the increased high frequency content of CEUS ground motions", which is misleading.
Rev.0	10	10-19	10.2.1	10-3	Para 2 sentence 5	We don’t understand the “Why” here, seems like a non seq. Please explain.	RE	This sentence is simply describing the EPRI 2013 aleatory variability model. No justification is necessary. Additional explanation was provided.
Rev.0	10	10-20	10.2.1	10-4	Line 1	“with an ….” "while its alternative model included an”	ED	Text was edited as proposed.
Rev.0	10	10-21	10.2.1	10-4	Para 1 Line 2	“aleatory variability “ à “aleatory variability (σ)” We presume this is what was meant?	ED	The expression “aleatory variability” refers to σ and is used consistently throughout the chapter without adding the symbol to it.
Rev.0	10	10-22	10.2.2	10-4	Section heading	Section title should indicate that these are models for other regions.	NR	Section titles for 10.2.1 and 10.2.2 were modified to indicate that these are existing models.
Rev.0	10					Also, please consider adding a figure with graphical comparisons of all of the models described in this section.		Such comparison figures are presented in Chapter 11 as part of the model evaluations and comparisons.
Rev.0	10	10-23	10.2.2	10-4	First paragraph line 5	Please also provide values in natural log units	NR	Values were provided in natural log units.
Rev.0	10	10-24	10.2.2	10-4	Para 3	Start new paragraph with “The Hanford..	ED	A new paragraph was started with “The Hanford…"
Rev.0	10	10-25	10.3	10-5	Line 3	Should “analyses” be “analyzed”?	ED	Text was edited as proposed.
Rev.0	10	10-26	10.3.1.1	10-5	1st par	No justification for the 5 criteria is offered.	NR	Additional explanation/justification was added to each bullet point.
Rev.0	10	10-27	10.3.1.1	10-5	4th bullet	“Gulf region” à “Gulf region as defined/mapped in Section 4.YY”	NR	Text was edited as proposed.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-28	10.3.1.1	10-5	3rd bullet	"CENA-defined regions" is a new term, which does not appear in Chapter 4. Please clarify and maintain consistency in terminology regarding the regions. Regarding the Gulf region (next bullet), was the selection based on the site location alone or on epicentral location, and/or the entire path?	NR	"CENA-defined regions" was replaced with "CENA regions defined in Chapter 4". The Gulf region bullet refers to excluded recordings that have the station, earthquake, or both located in the Gulf region. This was clarified in the text.
Rev.0	10	10-29	10.3.1.1		Last paragraph	Unless one goes to Al Atik (2015; PEER report), it is not clear how site effects are handled. To answer this and other these questions, it may be good to include a few more details about this GMM here. We suggest that, at a minimum, you include the following details about the GMM: distance metric used, whether depth is considered, whether Vs30 is a predictor variable.	RE	More details were added including the functional form of the GMM developed for the purpose of analyzing ground-motion variability.
Rev.0	10	10-30	10.3.1.1	10-5	Last paragraph	Regarding the GMPE in Al Atik (2015), the slopes terms (c4h) are purely model-driven (because SMSIM requires distance slopes as input). Is this appropriate and or necessary? Aren't there enough data to constrain the second slope? Please indicate the distance-scaling approach assumptions that were made in the SMSIM input and discuss whether this is appropriate and/or necessary	RE	The reason we adopted the approach in question was the difficulty we found in simultaneously resolving the far distance geometrical spreading coefficient (c4h) and the "gamma" coefficient (c7). There were trade-offs between these two coefficients when both were determined from the regression. We regionalized the c7 term (PIE/Tectonic) which made simultaneously resolving them even more difficult. In SMSIM, we assumed that, for FAS, the far distance geometrical spreading coefficient was equal to -0.5 and frequency independent (both common assumption found in literature). We ran various SMSIM scenarios in M and R with the assumption of -0.5 far distance geometrical spreading slope on FAS to get simulated response spectra and derive c4h. Then, using the c4h slope implied by the SMSIM results, we solved for the regionalized c7 term for the GMM.
Rev.1		*Rev.1 follow-up*				*The response seems satisfactory, but should it be described in the report?*		
Rev.0	10	10-31	10.3.1.1	10-5, 10-6	1st sentence after bullets into next page	The derivation of a median GMM to support the evaluation of ground motion variability requires additional discussion and justification. This GMM was not part of the developer seed models and has not been compared to these models or the resulting set of 29 GMMs for Vs > 2,000 m/s site conditions; why is this model appropriate for use in assessing ground motion variability? The PEER report which describes this model does not include a table of the model coefficients, preventing independent model comparisons to be made. Where does this model plot in Sammon's space relative to the other models (both seed and derived models)? Please see figures attached at the end of this document. The PPRP recommends that figures similar to these be included in the report and their implications discussed.	RE	The table of the model coefficients and the model functional form were added to this section. Aleatory variability of ground motion is best evaluated using residuals of a ground motion model that fits available empirical data. This is the purpose for developing the ground-motion model presented here. Note that this model is not meant to be used for prediction purposes which is in contrast with the seed GMMs. Therefore, this model cannot really be compared to the seed GMMs for this reason. A disuccsion on the applicability of the aleatory variability model developed independently from the median models for CENA was added to section 10.1.3. Additional discussion was also added to this section.
Rev.0	10	10-32	10.3.1.1	10-6	1st paragraph	Figure 10-3 shows the total number of recordings versus frequency and indicates that the evaluation of ground motion variability using CENA data will only be reliable between spectral frequencies of 0.5 to 13.33 Hz. However, subsequent figures in this Chapter and in Chapter 11 show comparisons outside this spectral frequency range. Both Chapters 10 and 11 should present a consistent discussion of the spectral frequency range or limitations used to assess ground motion variability and all figures should plot data consistent with this range.	RE	A discussion of the reliable frequency range was added. The figures in Chapter 10 and Chapter 11 showing the results of the ground motion residuals analysis using the CENA data are consistently shown for the entire frequency range. The reliable results (between 1 and 10 Hz) are indicated by the solid vertical lines at 1 and 10 Hz.
Rev.0	10	10-33	10.3.1.1	10-6	Entire paragraph	Consider adding a figure (similar to Figs 10-1 and 2) that displays the distribution of Vs30 for the data used in the analyses.	RE	A histrogram was added to show the distribution of Vs30 for the data used in the between-event and within-event residuals analysis.
Rev.0	10	10-34	10.3.1.1	10-6	Last paragraph	Is there a disadvantage (in terms of statistical efficiency) in performing two nested mixed effect analyses to fit the GMM and decompose the residuals, rather than doing it in one step (in which the covariance matrix captures both the common-event and common-site correlations)?	RE	Solving for both the event terms and site terms simultaneously was attempted using a Baysian regression method developed in the STAN modeling language. The main drawback was that these runs were taking a long time. Comparisons of PhiSS, PhiS2S, and Tau were made using three different approaches: two-regression approach that was adopted in the study, an iterative approach for solving for the event terms and site terms, and the Bayesian regression for one spectral period. The differences in PhiSS, PhiS2S, and Tau resulting from the 3 approaches were small. An additional consideration for using the two-regression approach was that we didn't have to apply the minimum number of recordings per station criterion in the within-event and between-event residuals analysis. Solving for the event terms and site terms simultaneously would have required the use of the minimum number of recordings per event and per station criteria at once which would have limited the dataset for the Phi/Tau analysis.
Rev.0	10	10-35	10.3.1.1	10-6	Last paragraph	It might be useful to include the equations for the site terms and single-station within-event residuals, as those equations constitute an alternative use of the corresponding equations of Abrahamson and Youngs (1992), which work with intra- and inter-event only.	NR	The equation for the site terms obtained by maximmizing the likelihood solution was added.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-36	10.3.1.1	10-6	Last paragraph	What is the minimum number of records required in order to obtain a reliable estimate phi_ss and phi_s2s with the Abrahamson-Youngs formulation? How is this value determined? How reliable are the estimates obtained using 200 to 800 recordings? The figures seem to show values with large (but not huge) error bars outside the 1 to 10 Hz range. Although data outside this range seem to follow a different pattern, it is not clear that small sample size is a reason for excluding them. Are there any other reasons for excluding them?	RE	The impact of the number of recordings per earthquake and per station used in the regression on the estimates of Tau, PhiSS, and PhiS2S was discussed in Sections 4.2, 4.4, and 4.5 of the Al Atik (2015) report. A minimum of 3 recordings is considered common practice for obtaining reliable estimates of event terms and site terms. A minimum of less than 3 recordings leads to potentially unreliable estimates while a minimum of more than 3 recordings could result in an undesirable reduction of the dataset. A minimum of 3 recordings was adopted to ensure reliable estimates of event terms and site terms without causing a significant reduction in the size of the dataset. A justification to the number of recordings used was added to the report. A discussion on the reliable frequency range of 1 to 10 Hz has been included in Chapter 7 and added to the sections on the CENA dataset (10.3.1.1). A reduction of more than 60% of the number of recordings occurred outside of 0.5 to 13.33 Hz. The TI Team considered that the results of the CENA analysis between 1 and 10 Hz where the reduction in the number of recordings is within 20% as reliable for evaluating ground-motion varaibility. The further the frequencies are from the borders of the 1 to 10 Hz range, the more erratic the trends of Tau and PhiSS with frequencies tend to become and the larger are the error bars. This is likely a result of the limted dataset at those frequencies and cannot be interpreted as real trends.
Rev.0	10	10-37	10.3.1.1	10-5	4th bullet	Was there consideration of processing Gulf recordings as a separate analysis? Please discuss in the revised text. The approach for the Gulf Coast is not clearly explained.	RE	Yes, the Gulf recordings were processed in a separate analysis that is discussed in Section 11.9. This is now clarifed in the 4th bullet.
Rev.0	10	10-38	10.3.1.1	10-5 and 10-6	Second full paragraph	There appears to be an additional criterion buried in this paragraph. Why can't it be listed (and explained with the other 5?	NR	A sixth bullet was added to list the additional criterion of the minimum number of recordings per earthquake.
Rev.0	10	10-39	10.3.1.1	10-5 and 10-6	2nd paragraph line 1	Clarify: was the 5th exclusion criteria applied before the derivation of the new median relation, or just to the running of it to extract the residuals desired?	RE	All the criteria were applied before the derivation of the median model. A clarification was added.
Rev.0	10	10-40	10.3.1.1	10-5 and 10-6	2nd paragraph line 1	"used to derive a median GMM" à "used to derive a new median GMM just "	ED	Text was edited as proposed.
Rev.0	10	10-41	10.3.1.1	10-6	Top of page Line 3	F à f "f" for frequency in other places in report	ED	"F" was replaced by "f" for frequency consistent with the rest of the report.
Rev.0	10	10-42	10.3.1.1	10-6	Line 3	"CENA earthquakes " à "CENA earthquakes in the dataset" because there are lots of other CENA earthquakes bigger and smaller	ED	Text was edited as proposed.
Rev.0	10	10-43	10.3.1.1	10-6	Line 5	PIEs à PIE	ED	Text was edited as proposed.
Rev.0	10	10-44	10.3.1.1	10-6	Line 8	have Vs30 à have assigned Vs30	ED	Text was edited as proposed.
Rev.0	10	10-45	10.3.1.1	10-6	1st para line 8	For NGA-West 2 sigma evaluation, the recording stations have Vs30 ranging from "200 to 600 m/sec". For those stations closer to the source, those recording sites very likely experienced a nonlinear response which might have the effect of reducing sigma (and its components). Could such an effect introduce a bias relative to the application of WUS sigma to reference CENA sites (Vs30 of 3000m/sec)? Recall Al Atik and Abrahamson (2010, BSSA). If this is a concern, it should be kept in mind in Chapter 11 when assigning weights to magnitude-dependent and magnitude–independent models.	RE	The NGA-W2 data were used to develop Tau and PhiSS models for CENA. For the global Tau model, which is based on the NGA-W2 tau models, the proposed Tau models by the NGA-W2 developers for linear site conditions were used. Therefore, soil nonlinearity is not expected to affect the global tau model. The data distribution of the NGA-W2 datasets used in the single-station sigma analysis was discussed in Al Atik (2015) - Figures 2.11 to 2.14. For the single-station sigma analysis using the NGA-W2 data, the effects of soil nonlinearity are taken out with removing the site terms from the within-event residuals. Therefore, the global PhiSS model developed using the NGA-W2 data is not expected to be affected with soil nonlinearity. Figure 4.37 of Al Atik (2015) shows PhiSS estimated using the NGA-W2 data as a function of Vs30. For the Vs30 bins with large number of recordings, PhiSS does not seem to be dependent on Vs30.
Rev.0	10	10-46	10.3.1.1	10-6	Para 1, last line	"(due to limitations on the useable frequency bandwidth of the recordings)" Point to which section discusses this (?Section 5.XX?) or explain why the limitations arose	RE	A reference was added to Section 5.2.2.4.
Rev.0	10	10-47	10.3.1.1	10-6	2nd para	The first 3 sentences appear to repeat material of the preceding paragraph. Please confirm that is indeed intended.	NR	This is intentional as this is specific to the single-station sigma analysis.
Rev.0	10	10-48	10.3.1.2	10-6	First word	What does "This' refer to? ?--> "The present report…"?	ED	"This study" was replaced with "The NGA-East study".
Rev.0	10	10-49	10.3.1.2	10-6	Paragraph 2 line 1	"performed" – by whom?	ED	"performed" was replaced by "performed by the TI Team".
Rev.0	10	10-50	10.3.2	10-7	1st paragraph	The text states that CENA τ values outside of 1 to 10 Hz range are not reliable. Why is this different than the range of 0.5 to 13.33 Hz previously described? If this difference is justified it should be explained. Additionally in section 10.3.2.2 and as shown on Figure 10-11, the τ model is displayed well outside this frequency range.	RE	A discussion on the reliable frequency range of 1 to 10 Hz was added and explanation of the figures showing the results of the analysis for the entire frequency range. Refer to the response to Comment 10-32.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-51	10.3.2.1	10-7	section title	Is the term "Global" accurate? What fraction of the data come from California? If changing it, please make sure changes are made throughout this and the next chapter.	NR	The NGA-W2 dataset was discussed in detail in Ancheta et al. (2014) "NGA- West2 Dataset" paper. Figure 3 of that paper shows the data distribution by region. Note that different subsets of the data were used by the NGA-West2 developers. Most of the NGA-W2 data come from California. We believe that the term "Global" is adequate in acknowledging that some of the data come from regions other than California. We added a sentence on the origins of the NGA-West2 data in Section 10.3.1.2.
Rev.0	10	10-52	10.3.2.1	10-7	Figures 10-8 and 10-9	Consider plotting Figures 10-8 and 10-9 as a function of frequency to facilitate comparison with 10-7.	NR	These plots were borrowed from another report and we do not have the actual data to replot them as a function of frequency.
Rev.1		*Rev1 follo-u*				*Appears satisfactory*		
Rev.0	10	10-53	10.3.2.1	10-7	Equation 10-6	The magnitude ranges should be explicit, not implicit, i.e. 5.0<M≤5.5 instead of just M≤5.5.	NR	Equation was edited as suggested.
Rev.0	10	10-54	10.3.2.1	10-7	Last line	Give units for stress drop	ED	The unit was added for the stress drop.
Rev.0	10	10-55	10.3.2.1	10-8	Figure 10-8; 10-9	It is confusing to have these figures given in period mixed with others in frequency. Suggest relabeling the axes in frequency and/or flipping the figure	NR	These plots were borrowed from another report and we do not have the actual data to replot them as a function of frequency.
Rev.1		*Rev1 follo-u*				*Appears satisfactory*		
Rev.0	10	10-56	10.3.2.1	10-8	Line 5 on page	"in tau but not in phi" Casual interpretation of Fig 10-8 suggests this is reversed. Consider additional discussion to clarify.	RE	Yes, there is a typo here and it was corrected (reversed).
Rev.0	10	10-57	10.3.2.1	10-8	Para 2 Line 9	"an artifact of kappa" à "an artifact of kappa in the NGA-West2 dataset" Just to keep in the reader's mind that this is western and not eastern data	ED	Text was edited as proposed.
Rev.0	10	10-58	10.3.2.1	10-8	Para 3 Fig 10-10	On the "within model" figure the M4.5 curve appears identical to the M5.0 curve. Is this so? Even in this dataset there is no information for M>6.5?	NR	For the within-model figure, the M4.5 and M5.0 curves are identical because these are based on the CY14 Tau model which has the first breakpoint at M5.0. These plots show the values at the magnitude breakpoints of M = 4.5, 5.0, 5.5, and 6.5. There is information for M > 6.5. We edited the title to clarify that these curves show the results at the magnitude breakpoints.
Rev.0	10	10-59	10.3.2.1	10-8	last paragraph	In Figure 10-10c, the uncertainty is higher for frequencies below 10-20 Hz than for frequencies above. Is it reasonable to expect that this drop in uncertainty will occur at a higher frequency in the East where the ground motions contain more energy at high frequencies? If so, this may affect the proposed (average) model. Please discuss.	RE	Figure 10-10c (now Figure 10-11c) does show a drop in the SD(tau^2) for frequencies greater than 10-20 Hz based on the global Tau^2 model. While median ground motions in the East certainly contain more high-frequency energy than in WUS, the same observation does not necessarily extend to the aleatory variability models or to the standard deviations of the aleatory variability. For CENA, we lack data above 10-20 Hz to be able to comfirm that the ground-motion varaibility is larger at high frequencies compared to lower frequencies.
Rev.0	10	10-60	10.3.2.2	10-8	2nd par, 2nd sentence	Fig 10-11 arguably shows that the constant tau model fails for f>20 Hz and f<0.4 Hz. Why were these apparently-significant values ignored?	RE	Outside of 1 to 10 Hz, the observed trend is affected by the limited datasets and is not necessarily significant. Please see responses to comments 10-32 and 10-36. We added an explanation on this point in Section 10.3.2.2.
Rev.0	10	10-61	10.3.2.2	10-8	second paragraph, second line	which regression? Please clarify.	ED	A clarification was added.
Rev.0	10	10-62	10.3.2.2	10-8	2nd par, bottom	- Lower statistical variability than Global model is difficult to justify, given that the data are much less abundant than in the global data set (it should be even higher for the CENA data). Could it be that some sources of statistical uncertainty are not being captured or that these uncertainties be calculated incorrectly? Please provide additional explanation/justification. - Also, please discuss the values below 1 Hz and above 10 Hz. Although the error bars are somewhat broader than for 1-10 Hz, the differences from the results between one and 10 Hz appear to be statistically significant. Justification for ignoring data outside 10-10 Hz is needed. By the way, are these one sigma error bars? Please indicate as appropriate. - The peak and 25 Hz maybe the same bump of Figures 10-8 and 10-9, but shifted to higher frequencies because kappa is lower.	RE	Additional explanation/justification was added to this section. The statistical uncertainty in the Tau^2 for CENA was calculated according to Searle (1971), page 474, part d. The statistical uncertainty in the global tau^2 model is based on the CY14 estimates. We do not believe that the numbers were calculated incorrectly. But we agree that a lower statistical uncertainty using the CENA data compared to the NGA-W2 data is difficult to justify. As a result, we did not use the statistical uncertainty computed using the CENA data and replaced that with the uncertainty obatined for the global model. - The error bars are +/- one standard error. This was added to the captions of the figures where applicable. Additional discussion was added on the justification for ignoring the values outside of 1 to 10 Hz. - This is possibly true but the data limitations at 25 hz and above limit the ability to make definitive conclusions.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-63	10.3.2.3	10-9	entire section	- How does this model compare to the magnitude- independent model in terms of goodness of fit? Were likelihood ratios or AIC values calculated? This may be something worth doing anytime alternative models are used to fit the same data set in this chapter. - Also, please justify the assumption of maintaining the global tau2/tau1 and tau3/tau1, given the issues raised in comment 10-45.	RE	- Likelihood ratios or AIC values were not calculated. The M-independent and M-dependent models are almost identical for M less than 5.0. The main difference between both models is how they extrapolate to large M where there are no CENA data. For the constant model, all the CENA data (which is mostly with M less than 5) were used. For the M-dependent model, the CENA data were used to determine tau for M less than 5.0 and then the trend with M for M greater than 5.0 is borrowed from NGA-W2. - As discussed in the response to Comment 10-45, the NGA-W2 models proposed by the developers for linear site conditions were used in this study.
Rev.0	10	10-64	10.3.2.2 and 10.3.2.3	10-8 and 10-9	Entire sections	Why is the between-model uncertainty in tau considered for the global models (recall Figure 10-10) and not for CENA? At least in principle, this could have been done with the GMMs obtained in Chapter 8. Please discuss.	RE	A discussion was added to Section 10.1.3 on the approach used to develop the aleatory variability models for CENA. The seed model developers were not tasked with providing aleatory variability models. Although a few of them did provide aleatory variability, these values were not explicitly used for the development of the CENA aleatory variability models. Instead, comparisons will be provided in Chapter 11 between the final CENA aleatory variability models and those provided by the seed model developers. Note that the between-model variability for the global model was generally smaller than within-model variability for M less than 6.5.
Rev.0	10	10-65	10.3.3.1	10-10	Para 1	Please don’t mix frequency and period; use one or the other	ED	Text was modified to use frequency consistent with the rest of the chapter.
Rev.0	10	10-66	10.3.3.1	10-10	Para 3	Consider: “The station-to-station variability in phi-SS was analyzed using the ASK14 dataset with M larger than or equal to 4.0 as part of the South Western U.S. utilities SWUS project (GeoPentech 2015),” to make the following “Their” reference clearer.	ED	OK.
Rev.0	10	10-67	10.3.3.1	10-10	entire section	It would be easier for the reader to visualize the results if the x-axis always shows frequency in log scale, and the magnitude dependence is shown either by alternative lines or alternative panels. This chapter switches between using magnitude and using frequency as the X axis, making it difficult to create a mental picture of the results.	NR	There are two features for the global PhiSS model: magnitude dependence and frequency dependence. It is important to show the PhiSS trend with magnitude such as in Figure 10-22. The frequency dependence is shown in Figure 10-23 at the magnitude breakpoints of the proposed model.
Rev.0	10	10-68	10.3.3.1	10-11	2nd full paragraph, line 2	The "variation of the variability" is mentioned here. This is a confusing phrase. What is the variation with respect to?	RE	The "variability of the variance" was replaced by "the total standard deviation of the variance, SD(PhiSS^2)" for clarification.
Rev.0	10	10-69	10.3.3.2	10-11	Para 1 line 1	Does the tectonic data also result from the 5 (or 6) criteria of 10.3.3.1 plus the additional (7th) criterion of “not PIE”?	NR	Yes. This was clarified at the beginning of Section 10.3.3.2.
Rev.0	10	10-70	10.3.3.2	10-11	2nd par, 2nd sentence	Bandwidth limitations issue for phiSS (see comment above)	NR	This was addressed in the responses to the previous comments above on the bandwidth limitations issues (ex. Comment 10-32, 10-36, 10-60).
Rev.0	10	10-71	10.3.3.2	10-11	2nd par, line 6	Consider using COV instead of CV. This is the more common usage.	NR	COV is commonly used as an acronym for covariance and CV is commonly used as an acronym for coefficient of variation. No change was made.
Rev.0	10	10-72	10.3.3.2	10-11	Bottom of second paragraph	Regarding the statement “It can be easily shown that for normally distributed residuals, the CV of the variance (phi_SS^22) is twice the CV of the standard deviation (phi_SS)." Is the statement true in general or is it true only for small values of the variance? Recall that the equality between CV and logarithmic standard deviation of a lognormal is only an approximation, and is valid only for small values. Please confirm and revise if necessary.	NR	This statement is true for small values of CV(PhiSS). A clarification will be added. Also, note that Eq. (10-10) was wrong and it is now corrected.
Rev.0	10	10-73	10.3.3.2	10-11	2nd para	Consider inverting paragraph to explain what/why, then illustrate the consequence	ED	We don't see a need for inverting the paragraphs here. Instead, we added a sentence at the end of the first paragraph to set the intent of this section.
Rev.0	10	10-74	10.3.3.2	10-11	second paragraph	The decision to use uncertainties from WUS (aka Global) is difficult to justify. If data are more limited, one would expect higher epistemic uncertainty. Also, CENA sites may have more diverse site conditions, which may contribute to more variable phi_ss. Perhaps you can take advantage of the fact that you have assumed that phi_ss is constant (not a bad assumption given Figure 10-21) to pool the data from more frequencies, thereby obtaining a lower statistical uncertainty.	RE	The station-to-station variability on PhiSS for CENA was adopted from WUS and measures the variability in PhiSS from one site to another. This can only be estimated using a large number of recordings per site. Otherwise, the results would be affected by sampling error. Since it is not possible to quantify this uncertainty using the CENA data, we used the estimate from WUS. Discussion was added to this section to explain and justify the decisions made by the TI Team.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-75	10.3.3.3	10-12	second paragraph	Is there a rationale for constraining the ratios rather than the differences? Comment applies to other places in chapter with the same assumption is made. Also, consider the issues raised in comment 10-63.	RE	We chose to constrain the reduction in PhiSS from M 5.0 to M 6.5 to be equal to that of WUS model. A consistent assumption was used for Tau to extrapolate to large magnitudes. Figure 11-6 shows a comparison of the PhiSS versus magnitude for the CENA M-dependent model and the global PhiSS model. Figure 11-6 shows that the slopes of the CENA M-dependent model and those of the global models are not very different. Our approach of constraining the reduction in PhiSS versus the differences results in slightly more conservative estimates of PhiSS for CENA at large magnitudes (CENA slopes are slightly less steep than those of the global model). Similarly, Figure 11-2 compares the candidate Tau models and shows that the slopes of the CENA M-dependent model and the global Tau models are comparable.
Rev.0	10	10-76	10.3.4	10-12	2nd paragraph	The discussion of the F-test and the conclusion reached from this test requires additional information. Figure 4.43 from the PEER Report and the text from that report note that $\phi S2S$ for PIE events is significantly smaller than that for tectonic events and Table 10-5 shows that 2 out of 9 spectral frequencies fail the F-test criteria. If PIE events have a lower $\phi S2S$ value this could suggest that site response may not be the parameter of importance (source versus site). Given the follow-on statement in the text which notes that for CENA VS30 may not be a good parameter for capturing site response; however VS30 is the parameter modeled with the GMPE which forms the foundation for the variability evaluation completed in this Chapter. The value assessed for $\phi S2S$ is critical in terms of moving forward with using the single station sigma model.	RE	This section was re-written to clarify this point and present other sensitivity analyses that were part of the sigma report. As discussed in this section, the difference in PhiS2S between tectonic events and PIE is likely due to the clustering of the stations that recorded PIE in a relatively small geographic region with similar geologic conditions.
Rev.0	10	10-77	10.3.4	10-12	Entire paragraph	- Illustrations could be added to this section of phiS2S vs f where there were systematic and significant differences between tectonic and PIE events (higher phiS2S for tectonic). Those observations were suggestive of regional PIE site differences that may not be as great as for the range of sites recording tectonic events. Based on the phiS2S comparisons, one might object to mixing tectonic and PIE data for phiS2S evaluation. The F-test in this section may not fully capture this significance. Additional detail should be provided by the TI on how this issue was resolved. - Illustrations could also be added illustrating the dependency of phiS2S on Vs30. - Did TI-Team consider using only rock data from CENA to reduce the effects of the assigned Vs30? - In addition to the statistical sampling modeling, did the TI-Team model the uncertainty in Vs30 assignation and track its effects into phiS2S?	RE	This section was re-written and additional information and justification was presented. We agree that the differences in PhiS2S between tectonic events and PIEs are likely due regional site differences that do not seem to be as great in the PIE region compared to the rest of CENA. We ended up using both tectonic events and PIEs for the development of the CENA PhiS2S model in order to maximize the dataset. Using only tectonic events would have reduced the number of stations in the dataset by about 50%. - Figures showing the dependence pf PhiS2S on Vs30 were added and discussed. - This was explored and additional discussion on this point was added in this section. We note that sites with Vs30 >= 1500 m/sec are primarily located in Canada and 39 out of the 42 stations with VS30 >= 1500 m/sec have inferred Vs30 values. - The errors in the Vs30 values were not tracked into the PhiS2S calculations. The TI Team did however compare PhiS2S results from stations with measured/inferred VS30 values and the results were comparable. Additional discussion on this point was added.
Rev.0	10	10-78	10.3.4	10-12	entire section	Is this F test applicable when one dataset is a subset of the other? If not, please revise accordingly.	RE	The F-test was not applied here to the PhiS2S results obatined from the same regression to test the equality of variances for tectonic versus tectonic + PIE data. Two separate regressions were performed using the tectonic + PIE data and the tectonic data alone. The F test was applied to the results of the two regressions and not to the results from one regression using different subsets of the data. A clarification was added in Section 10.3.4.
Rev.0	10	10-79	10.3.4	10-13	1st full par, last sentence	The Japanese and CENA data in fig 10-26 track each other, and differ from NGA-West2 except around 2 Hz. Others have commented on the “shallow soil cover over hard rock,” issue and it may be helpful to provide some references to other work and perhaps explain the reversal in variability relative to NGA West2 at 2 Hz.	RE	We are not aware of such references. Note that further analyses were performed and documented in this section that help explain these issues.
Rev.0	10	10-80	10.3.4	10-13	2nd par, line 1	Should be Appendix C.5?	ED	Yes, it was. It is now Appendix F.1.
Rev.0	10					In that appendix, regions are given as number codes, but this should be changed to reflect usage in the rest of the report.		In this appendix, regions are given number codes as defined in Figure 4-6 and consistent with the rest of the report. The second line of the first paragraph in Appendix C.5 states "see Figure 4–6 for the regions map". No change is made.
Rev.0	10	10-81	10.3.4	10-13	2nd par, next to last sentence	Suggest changing the end of the sentence to “…for capturing the site response	ED	This section was written and expanded. This comment was addressed.
Rev.0	10	10-82	10.3.4	10-13	last 2 paras	Consider swapping them to keep clear Japanese-results discussion together. The (current) last paragraph is a bit too condensed and feels like it is rushed	ED	This section was re-written based on the feedback given by the PPRP. The paragraphs referred to here were swapped accordingly.
Rev.0	10	10-83	10.3.4	10-13	bottom	Some discussion/comparison of the recommended sigma models to the seed ergodic sigma models (where available). This comparison should include a discussion of the basis of differences and merits of the recommended models over the seed models.	NR	A discussion on this point was added to section 10.1.3 and section 10.2.3 and addressed in responses to some of the previous comments.
Rev.0	10	10-84	10.4	10-13	New section	Chapter just trails off in the middle of a detailed choice. Needs a summary paragraph and foreshadowing how the conclusions/relations from this chapter are going to be used in Chapter 11.	RE	A new section was added as requested.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	10	10-85			Fig 10-21 and 10-23	Delete undue precision in legend	ED	Figures 10-21 and 10-23 show the values of the coefficients in the legend with the same number of significant digits as reported in the Sigma report and Chapter 11. The precision is kept in the legend for consistency.
Rev.0	10	10-86			Fig 10-27 and 10-28	Improve wording in legend for "CENA-Mod"	ED	The legend was improved for Fig 10-27 and 10-28.
Rev.0	10	10-87	Table 5	10.17	Following the table	It would be nice of the null and alternate hypotheses were mentioned somewhere, such as after the table. Then the table could be understood fully by the reader without forcing the reader to scan the text to find out what the hypotheses are.	ED	The null and alternate hypotheses were added after the table as suggested.
Rev.1	*10*	*Rev.1 G-10-1*				*In section 10.3.3.1 (Global PhiSS Model), Section 10.3.3.2 (CENA Constant PhiSS Model) and Section 10.3.3.3 (CENA Magnitude-Dependent Model) the discussion of how the uncertainty in phi was computed for each model is not clear. Please add additional clarifying text for each of the sections.*	*RE*	*Additional text was added to Section 10.3.3 to better describe the derivation of the uncertainty for each of the three PhiSS models.*
Rev.1	*10*	*Rev.1 10-1*	*Section 3.4.2*	*pg. 10-23, 3rd paragraph*		*Section 10.3.4.2 (pg. 10-23), third paragraph: "The standard deviation of the CENA phiS2S model consists of the standard deviation of the CENA phiS2S values and those of the Japanese borehole phiS2S values….". Examination of Figure 10-54 suggests that these are simply combined with SRSS. Consider adding a sentence that states how and what assumption was used to combine the two elements of the SD.*	*NR*	*The text in Section 10.3.4.2 was edited to clarify the derivation of the standard deviation of the CENA PhiS2S model.*
Rev.1	*10*	*Rev.1 10-2*	*Section 10.1.3*	*pg. 10-3, second line*		*… "(refer to Chapter 6)", should make reference to a specific section in Chapter 6.*	*NR*	*We added the proper reference.*
Rev.1	*10*	*Rev.1 10-3*	*Section 10.1.3*	*pg. 10-3, 10th line*		*Delete "the" in "the Bayesian". Also, Kuehn and Abrahamson (2017) has already been published. Please update the reference.*	*ED*	*Text and reference were edited as proposed.*
Rev.1	*10*	*Rev.1 10-4*	*Section 10.2.3*	*top of pg. 10-7*		*"A brief overview of the aleatory variability provided by some of the seed GMM developers is summarized here for completion purposes." Suggested wording change—"for the sake of completeness".*	*ED*	*Text was edited as proposed.*
Rev.1	*10*	*Rev.1 10-5*	*Section 10.3.1.1.2*	*pg. 10-10, 6th line*		*"was applied to ensure a reliable estimate of site terms…". Would it be better to replace "reliable" with "stable"? Not sure we can speak to reliability, perhaps just stability of the estimate.*	*ED*	*Text was edited to use "stable" instead of "reliable" as proposed.*
Rev.1	*10*	*Rev.1 10-6*	*Section 10.3.1.2*	*pg. 10-11, 1st paragraph, line 8*		*"NGA-west2", West should be capitalized.*	*ED*	*Text was edited as proposed.*
Rev.1	*10*	*Rev. 1 10-7*	*Section 10.3.1.3*	*pg. 10-12, line 5-6*		*"(three at the surface and three at the borehole)", suggested wording change—"at the base of the borehole or within the borehole").*	*ED*	*"three at the ground surface level and three deep within the borehole" was used instead.*
Rev.1	*10*	*Rev.1 10-8*	*Section 10.3.1.3*	*pg. 10-12, last line before Section 10.3.2*		*typo: 500 km should be 500 m.*	*ED*	*Typo was fixed.*
						CHAPTER 11		
Rev.0	11	G11-1				The "mixture model" is referenced but not described. No evaluation is performed. The section seems to suggest "SWUS did it this way so we should as well". The mixture model was briefly presented in the June 2015 Workshop (WS3C). It would make sense to describe the model in Chapter 10 and provide evaluation/justification in Chapter 11. At the very least, a few paragraphs and illustrations should be included. Additional references (not just SWUS Report) should be provided as well.	General	Extensive discussion was added on the mixture model in Section 11.10.
Rev.0	11	G11-2				Chapters 10 and 11 make frequent use of statistical tests based on a 5% significance level. In this project, this practice helps keep the model simple. This practice is routinely used in many scientific disciplines, but it has its critics (see https://www.sciencebasedmedicine.org/psychology-journal-bans- significance-testing/). The question for this project is whether rejecting alternative hypotheses at the 5% level is consistent with the SSHAC goal of representing the CBR of the TDI. Please discuss this issue, including whether critical values greater than 5% might be more appropriate in a SSHAC situation.	General	The use of the statistical tests and the 5% significance levels is simply to get an insight on the overall similarities and differences between the variances of different datasets. The 5% significance level is common practice and is used here.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	11	G11-3				Additional discussion is needed for the results presented in this chapter. Some of the main issues that need additional discussion are the following: (1) In EPRI (2013) and in Atkinson and Adams, the aleatory standard deviation is higher for low frequencies than for high frequencies. The results obtained here, both for single-station and ergodic sigma, show a different trend (especially for low magnitudes). Please discuss this difference, for both the single-station and ergodic sigmas. In this regard, it might be useful to show figures similar to 11-28, but using the single-station sigma's obtained in this study (it is not a comparison of identical quantities, but it is a comparison where one would expect one quantity to be larger than the other). (2) The Atkinson and Adams, NGA-West 2 and EPRI sigmas are significantly lower than both the single-station and ergodic sigmas obtained here. The report states that "This largely reflects greater variability in the range of site conditions and path effects…and is influenced by the inadequacy of Vs30 as a site response variable…" One might argue that the "Global" model likely reflects greater variability than the "CENA".model. These differences (and the potential reasons for them) need to be discussed in much greater detail, including a description of the data used by Atkinson and Adams. (3) It is important to at least make mention of why the ergodic sigmas obtained here may not be appropriate for application to a typical nuclear site for which there is significant geotechnical information and for which a site-response analysis (including the characterization of uncertainty) is performed and combined with the rock hazard using approach 3 or 4. Some elements for this discussion are given near the bottom of page 11-9, but more is needed.	General	Extensive discussion was provided on these issues.
Rev.0	11	G11-4				EDITORIAL CONSIDERATIONS: - Notation: the same item (phiSS, etc) is written out differently in the text, tables and figures: the document should strive for consistency - Use of Non-SSHAC language: e.g. "recommends", "can", etc. Need to use SSHAC language. - Ch. 10 uses frequency; Ch. 11 uses period (mainly in Tables). Please make consistent.	General	We addressed these comments in the revised version of the report.
Rev.0	11	11-1	11.1	11-1	Second paragraph	- Give additional thought to the use of "global" and "WUS" when referring to data-sets and models. The WUS data set was called the Global data set in Chapter 10. WUS may actually be a more accurate name, as we commented on in Chapter 10. The two Chapters should be made consistent. - Given that there are a number of references to the "global" data set, then subsequently reference and/or comparisons to SWUS model results, NGA-West 2 results, Hanford, Pegasos refinement project, etc., consider adding a paragraph supported by a table that summarizes the similarities and/or differences in these data sets and which projects utilized each one.	RE	- The NGA-West2 dataset is referred to as "global dataset" consistent with Chapter 10. This paragraph was edited accordingly. - A summary table was added to this chapter.
Rev.0	11	11-2	11.1	11-1	Third paragraph, first line	After "independent", please add "standard"	ED	OK.
Rev.0	11	11-3	11.1	11-1	Para 3 and rest of report	Use of the word "can". We can do many things, but in the TI Teams judgement it chose to do XXX. In other words, attempt to use SSHAC language	ED	The use of the word "can" was revised when referring to actions by the TI Team.
Rev.0	11	11-4	11.2.1	11-1	First paragraph, second line	Since the evaluation of the tau models is contained in Section 11.2.2 a suggested wording change: "Three candidate tau models were developed (Section 10.3.2) for CENA: ".- The same comment applies to the second sentence of Section 11.3.1. -	ED	The suggested wording change was accepted.
Rev.0	11	11-5	11.2.1	11-1	First paragraph, last line	Give the section or sections in Chapter 10 and/or in PEER 2015/07 where these arguments are presented.	NR	References were added as suggested.
Rev.0	11	11-6	11.1	11-1	Para 3 and rest of report	"are". better to use past tense for science reports and keep present tense for TI-Team's actions	ED	OK.
Rev.0	11	11-7	11.2.1	11-1	First paragraph, second line	The 3 candidate models and their three statistical uncertainty branches (9 branches in total, though note that the example in Fig 11-1 has only three effective branches (as the rest are zero-weighted)).	ED	The 3 candidate models and their 3 statistical branches yield to 9 branches as shown in Figure 11-2. All the models that were evaluated (3 candidate models and 9 branches) are shown in Fig. 11-1 and 11-2 and referred to in Section 11.2.1. The evalualtion of the 3 candidate models is later discussed in Section 11.2.2. As a result of the evaluation, only one model was adopted. No changes were considered necessary here.
Rev.0	11	11-8	11.2.2	11.2	Line 1	"Favored" ?--> "chose" i.e. more SSHAC-like language, be more definitive.	ED	The language was changed as requested.
Rev.0	11	11-9	11.2.2	11-2	Entire Section	The text explaining the evaluation for τ requires additional information. Figure 11-2 shows that the central model of τ for the global model is larger than either of the CENA τ models (in fact the lower model of τ for the global model appears close to the central model of τ for either of the CENA τ models). Given that much of the seismic hazard contribution at annual frequencies of importance to nuclear facilities may be from M of 5 to 5.5 it is important that values for τ not be overestimated.	RE	Additional justification was added to this section on the evaluation of Tau and the assigned weights to the candidate models. Although Figure 11-2 shows the CENA Tau to be smaller than that of the global model for M< 5, the equality of Tau^2 between NGA-West2 and CENA cannot be rejected in this magnitude range due to the limited number of events in the CENA dataset compared to the NGA-West2 dataset. Figure 11-2 indicates that the difference between the CENA models and the global model decreases for M > 5.
Rev.0	11	11-10	11.2.2	11-2	Entire section	Conclusions in this section rely on the argument that the high CENA tau for f > 10 Hz can be explained as un-representative in Ch. 10. Otherwise, alternative assumptions are necessary.	RE	Additional discussion was provided in Chapter 10 (Section 10.3.1.1) on the frequency range limitations for the CENA dataset and the conclusion that the CENA Tau for f > 10 Hz is not considered reliable.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	11	11-11	11.2.2	11-2	Third bullet	What is the frequency range of the global dataset? The global dataset is mentioned in each of the first two bullets. “the model is simply extrapolated with a constant” Is this a choice or an assumption? Refer back to where it is justified.	ED	The third bullet has been edited to answer these comments.
Rev.0	11	11-12	11.2.2	11-2	First line	Consider adding a sentence to be clear that the test of statistical significance was made for M<5.0 as this is where the CENA data is most abundant.	ED	The sentence was modified as suggested.
Rev.0	11	11-13	11.2.2	11-2	3rd para	Consider using bullets for Options 1 and 2	ED	Bullets were used for Options 1 and 2
Rev.0	11	11-14	11.2.2	11-2& 11-3	Last paragraph of section	What is the logic of adopting the global model for tau because the null hypothesis cannot be rejected for CENA versus NGA-West2? There seems to be a jump in logic here.	RE	Additional justification was provided in this section.
Rev.0	11	11-15	11.2.2	11-2	Equation 11-3	Numerator in equation should be tau^2subCENA	ED	Typo was corrected.
Rev.0	11	11-16	11.2.2	11-3	3rd line	“Equation (10-3)” should be “Equation (10-6)”	ED	Typo was corrected.
Rev.0	11	11-17	11.2.2	11-3	last line	100 Hz” Be clear everywhere if you mean Sa at 100 Hz or are just using this as a convenient representation for PGA. If not including PGA, where is the model for PGA?	ED	OK. Values for PGA will be explicitly added.
Rev.0	11	11-18	11.2.2	11-3	Entire section	Figure 11-1 and Table 11-3 indicate central, high, and low values for tau. There is no discussion or reference for where SD(tau) used in figure and table came from. Should at least reference back to Section 10.3.2.1 for development in global tau model.	RE	This is described in Section 11.2.1 (first paragraph, last sentence).
Rev.0	11	11-19	11.2.3	11-3	Entire section	- What is the reader to learn from this section? Provide some motivation for the comparisons. Discuss similarities/differences in data sets (see comment above r.e. comparison of data sets used for different studies). - Also consider forward referencing if some sensitivity of hazard to the differences will be discussed subsequently.	ED	- An introduction paragraph is added to this section to explain the purpose of the comparisons. Similarities and differences are discussed. - Sentence was edited as recommended.
Rev.0	11	11-20	11.2.3	11-3	First paragraph, line 7	“uncertainty” à uncertainty (spread between 5th and 95th percentiles)”	ED	
Rev.0	11	11-21	11.2.3	11-3	2nd para last line	Hanford is generally higher at low frequencies and higher at high frequencies. Perhaps some discussion of how/why this arises is warranted.	NR	A discussion was added on the difference between the Hanford model and the global Tau model.
Rev.0	11	11-22	11.3.1	11-3	First paragraph, line 7	Give the section or sections in Chapter 10 where these arguments are presented. Explicitly explain (or cite references for) why it is reasonable to assume a scaled chi-squared distribution (turns up many times in this chapter, needs to be addressed once). See General Comment 11-1.	ED	Reference to Section 10.3.3 was added. The use of the scaled chi-square distribution to represent the uncertainty in Tau, PhiSS and PhiS2S is explained in Section 11.1 with the appropriate references (Ang and Tsang 2007, Keefer and Bodily 1983, and Al Atik 2015 report).
Rev.0	11	11-23	11.3.1	11-3	First paragraph, line 9	“period-independent” à “period-independent and magnitude-independent”	NR	Text was edited as proposed.
Rev.0	11	11-24	11.3.2	11-4	Entire section	- If there is the possibility that the magnitude-dependence of phi_ss for high frequencies in the Global model is due to non-linearity in site response (as suggested in one of the Ch. 10 comments), then it would seem that the constant CENA model should receive more weight than 0.1 (recall also that CENA M-dependent model also uses WUS relative information regarding magnitude dependence). Non- linearity will be much weaker or non-existent on 3000 m/s reference rock. The same comment applies to the Global tau model, which also shows lower values for higher magnitudes. - Note to the TI team: apparently Peter Stafford has an alternative explanation for the dependence of phi_ss on magnitudes.	RE	- This point was addressed in an added discussion at the beginning of Section 11.3.2. In summary, the analysis of PhiSS using Japanese borehole data (rock sites) show magnitude-dependence of PhiSS similar to that observed on softer sites. We do not believe that the M-dependence of PhiSS is the resullts of soil- nonlinearity. It is likeley the result of path effects being more variable for small magnitudes. - We reviewed the paper by Stafford et al. on the scenario dependence of site effects at high frequencies. While we concur with their argument on the dependence of the site effects on magnitude and distance of the scenario earthquake, we do not believe that this phenomenon necessaily explains the M-dependence of PhiSS. Additional research is needed before making such a conclusion (e.g., looking at PhiSS results from FAS-based models, etc).
Rev.0	11	11-25	11.3.2	11-4	Paragraph 2, line 5	What is meant by "overwhelming evidence"? Decisions like this are usually based on the results of a statistical test.	RE	The sentence was edited to remove "overwhelming evidence".
Rev.0	11	11-26	11.3.2	11-4	Paragraph 2, line 6&7	The non-global models were heavily downweighted. Arguably the global model was “heavily-favored”. It would be nice to get away from language like “favor” which seems emotive using instead words like choose, judge, etc	ED	The language was changed as requested.
Rev.0	11	11-27	11.3.2	11-4	Paragraph 2, line 7	The text talks about "for reasons discussed previously". It is unclear what discussion is meant here. The discussion for tau above? Suggest adding specific reference to Section 11.2.2.	ED	A reference was added to Sectiom 11.2.2.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	11	11-28	11.3.2	11-4	Paragraph 2, line 8	Non-zero weights are given here for the CENA models. However in the section on tau, the CENA models were not given any weight. Even so, the text tells the reader that the same logic is used in both cases. It appears that the same logic leads to different conclusions in the two sections. Some clarification warranted.	NR	The same approach was adopted for the evaluation of Tau and PhiSS models. However, the results of the evaulation (particularly the F test) were different for Tau and PhiSS. Therefore, different weighting scheme was adopted. The section was edited to clarify this point.
Rev.0	11	11-29	11.3.3	11-4	First paragraph, last sentence	The Hanford model used a COV of 0.10 for the calculation of site-to-site variability. Should indicate that the present study used a COV of 0.12. Perhaps reference PEER report.	NR	Text was edited as proposed.
Rev.0	11	11-30	11.4	11-5	Line 6	Typo: "Table 8 presents" not present.	ED	Typo was corrected.
Rev.0	11	11-31	11.5	11-5	First paragraph	Please indicate on which data set this result of week negative correlation is based on.	NR	Descitpiton was added to the text. This is based on the mixed effects regression performed on the CENA data.
Rev.0	11	11-32	11.5	11-5	First paragraph Line 4	"are assumed to be uncorrelated" à "TI team chose to assume that they were not correlated"	ED	Text was edited as proposed.
Rev.0	11	11-33	11.5	11-5	Line 6	Reference to Figure 11-12. Consider adding a footnote to Figure 11-12 that clarifies that all three branches of j model utilize the same CENA/Japanese jS2S model.	NR	A footnote was added to Figure 11-12 as suggested.
Rev.0	11	11-34	11.5	11-5	Eq. 11-9	Please provide some details on how a and b are derived for each branch.	NR	Explanation on the derivation of coefficients a and b was added.
Rev.0	11	11-35	11-6	11-6	Last paragraph	Writer may want to remind reader that tau model is based entirely on global tau. Also, may want to present the SD last, in keeping with the sequence in the logic-tree figures.	NR	Text was edited as proposed.
Rev.0	11	11-36	11.6	11-6	Second paragraph and Fig 11-15	This figure is the first comparison in this chapter to the NGA-West2 models. 1. Why isn't there a comparison for the Tau or phisSS models? 2. Given that the global model is (we presume) heavily based on NGA-West2 data, why is the overall difference so large? Is this a case where the "global" name for the model is misleading, as the values are strongly influenced by the CENA-only phiS2S? 3. Specifically for M6 and M7 the "global" model is much less than the West2 models for T>1 s and much greater for T<0.3 s. This is attributed to the difference in phiS2S here, which points back to section 11.4, which points to section 10.3.4 and figure 10-26. 4. As with a subsequent suggestion, consider adding a footnote to Figure 11-12 specifying the constituent elements of the Phi model.	NR	This figure is not the first comparison to the NGA-W2 models. The Phi models were also compared to NGA-W2. Tau was not compared to NGA-W2 as this is redundant since the Tau model for CENA is based on the NGA-W2 tau models. 1. The CENA Tau model and the global PhiSS model are based on NGA-W2. Therefore, comparison figures of these models to the NGA-W2 models is considered redundant. 2. The SigmaSS models do have PhiS2S in them. This plot was updated in light of the updated PhiS2S model. 3. This plot was updated in light of the updated PhiS2S model. 4.. OK.
Rev.0	11	11-37	11.6	11-7	Eq. 11-12	Can the model be simplified so it has only two break points and one ramp? How much of an error is introduced? Same comment applies to sections 11.6.1 and 11.7. Looking at Figure 11-2, it appears to be easy to fit the 4-point curve with 2 points and one ramp. However, should that result in an increase in the standard-deviation (reflecting increased uncertainty in the fit)? Figure 11-17 (which shows the individual models, not the composite) suggests that the effect will be small, but some discussion is warranted.	NR	The TI team chose to keep all the breakpoints since the model is a simple linear model and is easy to implement despite the multiple breakpoints.
Rev.0	11	11-38	11.6	11-7	Eq. 11-12	There are some subscripting problems in the last two terms on the right hand side of the equation.	ED	Subscripting problems were fixed.
Rev.0	11	11-39	11.6.1	11-7	First paragraph	The use of the word "continuous" is not clear in the sentence, because it could also refer to the continuous dependence on frequency or on magnitude. You may want to use "continuous distribution" to remove this ambiguity. Additional suggestions at the end of paragraph: consider changing "discretized by three alternative values" to "discretized into a three point distribution."	ED	First paragraph was edited as proposed.
Rev.0	11	11-40	11.6.	11-7	Last paragraph	Last sentence notes that CENA model 1 is much greater than CENA model 2 or the global model (illustrated in Figure 11-19). Should there be some comment or explanation?	NR	A comment was added.
Rev.0	11	11-41	11.6.1	11-8	First paragraph	Please consider also showing the comparison to the single station model from the SWUS study.	NR	A comparison plot of CENA sigmaSS to the model from the SWUS study was added.
Rev.0	11	11-42	11.7	11-8	Second paragraph	Reference to Figure 11-22. Consider adding a footnote to the figure that lists the specifics of each model, i.e., Global = global phi-SS plus global tau plus CENA phiS2S, CENA-M1 = CENA const. phiSS plus global tau plus CENA phiS2S, etc.	NR	A footnote was added to Figures 11-16 and 11-22.
Rev.0	11	11-43	11.7.1	11-9	Last line on page	It is highly likely that the population of NGA-East site conditions is more variable that the rock set used as the basis for the Atkinson-Adams total sigma. It would be nice to have this demonstrated/discussed. In addition, the paths may be more variable.	NR	A sentence was added to this effect.
Rev.0	11	11-44	11.7.1	11-10	First line on page	If you believe that the Vs30 site response variable was often inadequate, why not use just station recordings where you think the database Vs30 is adequate? This was clearly discussed by the TI Team, consider adding some discussion reflecting the rationale for the choice of data in the sigma study.	NR	This was addressed in the updated section 10.3.4.
Rev.0	11	11-45	11.7.2	11-10	Section	Consider naming this Section as 11.8 instead; i.e. raising its significance. Seems out of order.	ED	This section was named 11.8 instead of 11.7.2.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	11	11-46	11.7.2	11-10	Para 1 lines 1 &2	It is distracting that the reason for including PIEs referred to here is given at the beginning of 10.3.4, and is followed there by the same sort of applicability test that is done for tau and phis in 11.7.2. Why the separate treatment in 2 chapters? Perhaps it would be wise to summarise the tests and outcomes from 10.3.4 in 11.7.2	NR	This was addressed in edits to the sections on the dataset, tau, PhiSS, and PhiS2S in Chapter 10. The first 2 sentences summarizes the use of PIEs in the different models developed for CENA. Additional discussion and reference to the appropriate sections are added here.
Rev.0	11	11-47	11.7.2	11-10	Para 2, last sentence	Consider "As a result, the TI team concluded that with the current small dataset the tau model developed for tectonic events in CENA (global tau model) should be applied to PIEs in CENA"	ED	Text was edited as proposed.
Rev.0	11	11-48	11.7.2	11-10	Paragraph 3	Why is it justified to use so many more events for phiSS than for tau? Why was Rrup limited at 300 km? Consider adding a few lines of explanatory text.	NR	The bigger dataset of PhiSS compared to tau is a result of the larger number of recordings avaialble compared to the number of earthquakes. The Rrup=300 km limit was discussed in Section 10.3.3.2. A reference to that section was added here.
Rev.0	11	11-49	11.8	11-10	Third full paragraph, line 8	The sentence starts "We recommend". However, in other places in the text, the report discusses decisions of the TI team. The wording should be consistent throughout the report. Consider editorial suggestion for preceding paragraph here also. This is a global issue for the chapter	ED	"We recommend" was replaced in this section to refer to TI Team decisions.
Rev.0	11	11-50	11.8	11-10	Section	The entire report should be consistent in how it refers to the "Gulf Region"	ED	We replaced "Gulf region" with "Gulf Coast region" to be consistent with the rest of the report.
Rev.0	11	11-51	11.8	11-10	Section	This section of the report will need to be revisited after the PPRP has reviewed the Gulf Coast adjustment Chapter. Discussion needs to make clear that the PEER 2015-08 adjustment factors are not necessarily the ones used in Chapter 13, and should examine the consequences of that. Entire section needs to be recast in SSHAC language.	NR	We decoupled sigma from the median models for this project. So, the Gulf Coast adjustment factors on Ch. 13 should have no bearing on this section.
Rev.0	11	11-52	11.8	11-10	Sentence 1	Sentence is contradicted by line 1 of 10.3.4	RE	There is no conradiction here. Gulf Coast data were not used for the development of PhiS2S. We clarified this point in Section 10.3.4 (first sentence).
Rev.0	11	11-53	11.8	11-11	Para 1, line 1	Clarify for the reader that the median GMM's referred to here are not the ones in chapter 9.	RE	This was clarified in the last sentence of the preceding paragraph.
Rev.0	11	11-54	11.8	11-11	Para 2, line 6	400 km here but 300 km in 11.7.2. Please justify choices	RE	The choice of M and R ranges here were justified as stated by: "(comparable M and Rrup ranges for the Gulf Coast region and the rest of CENA)".
Rev.0	11	11-55	11.8	11-11	Para 2, line 3	"132" GC recordings. For comparison, using the same criteria how many recordings went into the CENA model?	NR	The "132 recordings" for the GC region was mentioned here to emphasize the small dataset available for the GC region. The following sentence was added regarding the recordings for the CENA constant and global models: "The datasets used to derive the global and CENA constant PhiSS models were discussed in Chapter 10."
Rev.0	11	11-56	11.8	11-11	Para 2, line 7	"Table 11-27 indicates that the equality of phiSS2 cannot be rejected at a 5% significance level when tested period by period" Considering the suggested change in italics, is there not additional information in the consistent lower bias in Gulf values? Is the period-by-period test appropriate? An eye-fitted curve would suggest GC-CNA = -0.03	RE	"when tested period by period" was added to the sentence as suggested. Conclusions regarding the observed bias in PhiSS for the GC region cannot be reliably made given the very limited number of recordings available for the GC region (123 recordings). We believe that the period-by-period test is appropriate as PhiSS for GC is not constant as shown in Figure 11-32. Figure 11-32 shows that PhiSS for GC appears to be slightly smaller than the CENA median models. However, given the very small dataset for GC, we cannot build a reliable GC-specific model. Instead, Figure 11-32 indicates that the PhiSS results for GC do not contradict the PhiSS models for the rest of CENA and the conclusion was that the CENA PhiSS models can be applied to the GC.
Rev.0	11	11-57	11.8	11-11	Para 3, line 5	The point of statistical tests is to quantify/qualify subjective judgements. Here the team rejects the "advice" of the test (the team accepts it in many other places). The test indeed suggests a GCR phiS2S model is needed for frequencies above ~ 6 Hz (it is possible that the CNA model could be applied at f<6 Hz). The language needs to express the TI team's decision more clearly (that the CENA phiS2S model should be applied at all periods).	RE	The statistical test is used here as a tool to quantify/qualify subjective judgments. However, it is not the cony consideration for the conclusion on the applicability of the CENA PhiS2S model to the GC. Given that the equality of variance was not rejected at most of the frequencies tested, the fact that a reliable GC-specific PhiS2S model cannot be developed using the very small GC dataset (20 stations available at f = 4 Hz), and the large error bars for the GC PhiS2S in Figure 11-33, the TI Team decided that the CENA PhiS2S model can be applied to the GC. Additional justification was added to this paragraph as requested.
Rev.0	11	11-58	11.8	11-11	Para 3, last sentence	Start a new paragraph. It's too important to bury at the end of the existing paragraph. Also it is a logical outcome from the preceding 3 paragraphs, and should be expressed as such, and in SSHAC language	ED	A new paragraph was started and the text in question was edited as suggested by this comment.
Rev.0	11	11-59	11.9	11-11	First paragraph, fourth line	Change "such as the NGA-West 2 data" to "such as the NGA-West 2 project".	ED	"NGA-West2 data" was kept because this was not part of the NGA-West2 project but another project using the NGA-West2 data.
Rev.0	11	11-60	11.9	11-11	Line 5	"at large deviations from the mean, ground motions …" "at large deviations from the mean (i.e. the tails of the distribution), the ground motions…" (too easy to miss the comma)	ED	Text was edited as proposed.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.0	11	11-61	11.9	11-12	1st full para, first 2 sentences	Explain (be explicit on the reasoning) why you think that the CENA ground motion distribution might follow the SWUS pattern even though you consider that the data can't choose one way or the other.	RE	This section was re-written and the justification for the use of the mixture model is now better explained.
Rev.0	11	11-62	11.9	11-12	First full paragraph, line 4	Change "fit" to "fits"	ED	Typo was corrected.
Rev.0	11	11-63	11.9	11-12	2nd par	There does not appear to be any explanation of the two normal models of the "mixture" model. These normal models are factored by 0.8 for one and 1.2 for the other. Please describe the basis for the normal models and the difference between these two normal models? Graphical representation will provide clarity. See comment G11-1.	NR	This section was re-written and the mixture model is better explained.
Rev.0	11	11-64	11.9	11-65	Figure 11-34	Should the distribution "tree" have "log-normal" for the upper branch and "Mixture Model (2 normal)" for the lower branch?	ED	"Normal" was replaced with "Log-Normal"
Rev.0	11	11-65	11.10	11-12	New paragraph	Needs a concluding paragraph linking to rest of report. For a practitioner, it's hard to see just how the coefficients in the tables are to be implemented	ED	The equations for each of the models discussed in Chapter 11 were originally referenced to Chapter 10. For clairifcation and ease of implementation, we wrote the equations in Chapter 11 for each of the models and referenced the appropriate tables of coefficients.
Rev.0	11	11-66	Tables	11-15	Table 11-1 and others	Give the null and alternate hypotheses after the table	ED	The null and lternate hypotheses were added after the relevant tables.
Rev.0	11	11-67	11.9	11-12	3rd para last 2 sentences	"The hazard plots in Appendix D.5 show small to negligible difference in the hazard due to the distribution of the single-station sigma model (traditional lognormal versus mixture model)." 1. Please justify why, given the uncertainties in the rest of the analysis, the complexity of the mixture model is needed when. 2. Regarding the "small difference for < 2 Hz", please quantify the "small" in percentage terms.	RE	This section was re-written to better explains the justification for the use of the mixture model. The sentence from item 2 was removed.
Rev.0	11	11-68	11.9	11-65	Figure 11-34	Should the distribution "tree" have "log-normal" for the upper branch and "Mixture Model (2 log-normals)" for the lower branch?	ED	"Normal" was replaced with "Log-Normal"
Rev.0	11	11-69	Tables	11-15	Table 11-1 and others	Give the null and alternate hypotheses after the table	ED	The null and lternate hypotheses were added after the relevant tables.
Rev.0	11	11-70	Tables	11-15	Table 11-1 and others	Use rows labels "Period (s)" and "Frequency (Hz)" instead of capital T and capital F in each column	ED	Labels were edited as suggested.
Rev.0	11	11-71	Tables	11-15	Table 11-1 and others	Ensure that nomenclature in tables matches that in text (if the text uses Greek symbol for tau, so should tables. etc). The subject is complex enough without having to cope with different representations of the same thing	ED	We ensured that nomenclature in tables and text is consistent (we used greek symbols everywhere).
Rev.0	11	11-72	Table 11-3	11-15	All tables	What are the values for PGA?	ED	Values for PGA were added to the tables
Rev.0	11	11-73	Figure 11-1		And other figures likewise	All abbreviations such as "cte"(meaning ???) should be replaced by full words (or, at worst, unambiguous abbreviations).	ED	Abbreviations were explained in the figure captions.
Rev.0	11	11-74	Figure 11-2		And other figures likewise	Captions should explain figures, explicitly: what are the numbers in red? What are the numbers in green? Why are some in red and some in green?	ED	All logic tree weights were changed to black.
Rev.0	11	11-75	Figure 11-1		And other figures likewise	Captions should explain figures, explicitly: what are dashed lines? Is Tau in natural log units as shown (or base 10) isn't the standard abbreviation for natural log ln, not LN? see https://betterexplained.com/articles/demystifying-the-natural-logarithm-ln/	ED	LN is the standard abbreviation for natural logarithm. Captions were modified to explain the dashed/solid lines where applicable.
Rev.0	11	11-76	Figure 11-8, 11-9			Are these two figures enough, or should you illustrate 10 s and 0.1 s? Do they differ?	ED	These figures are considered sufficient for illustration purposes.
Rev.0	11	11-77	All figures			Increase figure size to aid reader (fill page if practicable)	ED	Figure size seems appropriate.
Rev.0	11	11-78	Fig 11-19, 11-20			Are these two figures enough, or should you illustrate 10 s and 0.1 s? Do they differ?	ED	These figures are considered sufficient and the behavior is similar at other periods.
Rev.0	11	11-79	Fig 11-29, 11-30			Consider moving the legend into the plot frame (like other figures) so it doesn't get lost	ED	A border was added around each of the two figures to enclose the caption.
Rev.1	*11*	*Rev.1 Ch11 G1*				*The Dawood and Rodriguez-Marek (2015) reference is significant in both Ch. 10 and 11. The reference list still notes it has been "submitted for publication". If it has been published, please update the reference list.*	*RE*	*We checked with Dr. Rodriguez-Marek and the Dawood and Rodriguez-Marek (2015) reference is no longer valid (they did not end up publishing the paper). The reference was replaced instead with Dawood (2014) which is a PhD dissertation.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	11	Rev.1 Ch11-1	Section 11.7.1	pg. 11-12, last paragraph		There is a discussion of the comparison of the NGA-East total sigma results to those from NGA-West2 and EPRI 2013 and Atkinson and Adams 2013 models. In discussing Figure 11-29, the report states that the NGA-East composite model is "generally lower than the NGA-Wast2 model, especially at lower frequencies." However, examination of the subject figure does not confirm that observation. The NGA-East composite model **is** lower than the NGA-West models at low frequencies, however it is HIGHER at frequencies above ~3 Hz. The same comment applies to the discussion of Figure 11-30 on pg. 11-13.	RE	Figures 11-29 and 11-30 in the report are wrong and referring to an older version of the CENA model. These figures were updated to refer to the correct version of the CENA model and the observation that CENA model is "generally lower than NGA-West2 model, especially at lower frequencies" is now valid.
Rev.1		Rev.1 Ch.11-2	Section 11.7.1	pg. 11-13		The comparison of the NGA-East ergodic sigma to sigma of Atkinson and Adams (2013) deserves more than just a sentence. The differences are very significant and should be discussed more fully. The related Figure 11-30 shows that the NGA-East sigma trends are somewhat opposite to Atkinson and Adams and EPRI 2013 (sigma decreasing with increasing frequency between 1-10 Hz while NGA-East is increasing).	NR	Additional discussion was added at the end of Section 11.7.1 to address the difference between NGA-East sigma and Atkinson and Adams (2013) sigma values.
Rev.1						For PPRP edification only: only, we would like to see the available seed sigma models plotted in Figure 11-30. The TI has decoupled sigma and median models but it is a comparison that will likely be made.	NR	The TI Team does not include a comparison of the final CENA sigma model to the available sigma models from the seed GMPEs for three main reasons: 1) The seed sigma models were not intended to be used in ground motion applications and including them in Figure 11-30 would give the wrong illusion that they are viable models, 2) the seed sigma models are the direct result of the seed GMPE model development and are affected by the limited CENA dataset while the CENA sigma model resorted to other datasets and models in order to overcome the dataset limitations (limited magnitude and frequency ranges), 3) the CENA sigma model was corrected to hard rock conditions in CENA.
Rev.1	11	Rev.1 Ch11-3		pg. 11-6, fourth paragraph, second sentence		Typo-"..as discussed in Section 11.2.2, The TI team …". "The" should not be capitalized.	ED	Fixed.
Rev.1	11	Rev.1 Ch11-4	Section 11-4	Pg. 11-7, first paragraph		"Moreover, the phis2s model was corrected….". Consider adding a reference where this correction is described (either in this report or in Al Atik, 2015 PEER report).	NR	A reference was added as proposed.
Rev.1	11	Rev.1 Ch11-5		Pg. 11-16, first full paragraph, first sentence		"The mixture model was highly weighted because of …..". The prior paragraph was discussing the SWUS project, the following paragraph is discussing the Hanford project. Consider adding a phrase in the first sentence to confirm to the reader that this paragraph is still discussing the SWUS project.	NR	Text was edited as proposed.
Rev.1	11	Rev.1 Ch 11-6	Figure 11-30	Pg. 11-71		Missing "C" in figure title.	ED	Fixed.
Rev.2	11	N/A (new after Rev.2 release)		12-11	Fig 12-6	wrong ellipse index figure used (13, not 17)	ED	Fixed.
Rev.2	11	N/A (new after Rev.2 release)		11-11	2nd line	Please cite reference or section for "...which is justified based on the regression results".	ED	Fixed.
CHAPTER 12								
Rev.1	12	G12-0				Provided below are PPRP comments on Chapter 12 of the Draft Report Rev. 1. A general set of comments are provided first, followed by a set of more detailed comments. The PPRP recommends that the general set of comments be addressed first as these may result in significant changes to Chapter 12 sections. After this step is accomplished the PPRP recommends that the detailed comments be reviewed and addressed given the revised text developed to address the general comments.		
Rev.1	12	G12-1				The results in this chapter are interesting because they may provide a starting point for understanding the causes for the differences observed in Chapter 14. Three sets of hazard results are presented, as follows: 1. using the NGA East GMPEs and weights 2. applying the Sammons map procedure of chapters 8 and 9 to the EPRI (2013) equivalent of the "seed" GMPEs 3. Using the EPRI GMPEs and weights (pink) In all cases, the TI Team used the central branch of the NGA East single-station sigma model, which makes the comparisons "apples-to-apples" (unlike Ch. 14).		
Rev.1	12	G12-2				As the PPRP has indicated previously, it is difficult to quantify the extent of differences, given the scale of the figures and the lack of tabular results. This comment applies to this and several other chapters and appendices.		We added hazard ratio plots to facilitate the interpretation.
Rev.1	12	12-1	12.1	12-1	Last paragraph in section	Possible typo--"Section 12.2 summarizes key results from the third bullet item above …". Seems like Section 12.2 discusses the second bullet.	ED	Fixed.
Rev.1	12	12-2	12.2	-	Figure 12-1	Some explanation should be provided for the much higher M rejection rate of NGA-East than EPRI	RE	We have added an explanation and figures to address this issue. It is mainly due to the lower M-scaling slopes at close distance (see section 9.5) for the NGA-East seeds.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*12*	*12-3*	*12.2*	*-*	*Figure 12-2*	*Need to discuss this figure in greater detail: - Why are all red dots together for EPRI? - What is the explanation for the behavior seen for EPRI-seed results at 1 Hz and 100 Hz (i.e., clustering of gray dots, which do not cover entire region)? Was the same correlation model used as in Chapter 8? (i.e., same variance(M,R)?) - Why is EPRI 100 Hz Sammon's map so different from the one in rev. 0 of report? Seeds have not changed.*		*Answers for each bullet: - We added a paragraph of discussion and figures to explain the clustering at certain frequencies. In the process of reviewing that section, we also found that the reference models for M and R in Figure 12-3 where all based on the 1Hz case - we updated the figures. - We used the same covariance as for NGA-East and not re-tuned it to achieve the desired variance given The EPRI seeds have low covariance with M and large covariance with R. We added a paragraph on this in the text. - In Rev0, we had only used scenarios up to 500 km, based on the EPRI 2013 range of distance used to define the weights (specified in Table 7.2.6-2 of the EPRI 2013 report). However, when re-running the comparisons, we preferred to use the same range as for NGA-East (1,000 km) for consistency. The clustering reflects 1) the lower number of seeds in EPRI and 2) the trends in M and R slopes spanned discussed above. This is addressed in new paragraphs in the text.*
Rev.1	*12*	*12-4*	*12.2*		*Figure 12-2*	*For 100 Hz, for cells 11, 12, and 16 how were models defined and the weights calculated, given that there are no samples (i.e., gray dots) in these cells. Figure 12-5 shows that there are models for all 17 cells. Recall also that Section 9.2.1.3 indicates that weights were based on the number of models within the cell. Same comment for cell 16 at 1 Hz. (see fig 8-42 for cell naming convention).*	*RE*	*Then the weight is zero. Figure 12-5 is consistent with that. Cell nomenclature defined in Chapter 8 was added for convenience.*
Rev.2		*Rev.2 follow-up*				*Fig 12-3 why were scales changed between left and right columns? Does this obscure something fundamental? (or doesn't it really matter with the Sammons approach?)*		*The EPRI models span a larger range.*
Rev.1	*12*	*12-5*	*12.3*	*12.2*	*First paragraph on page*	*Please provide more discussion related to the following sentences: "The scaling of the ellipse following the assumption of a bivariate normal distribution does not seem appropriate for the EPRI case, especially for the 100 Hz PSA. This shows that the NGA-East approach described in this report is applicable under certain conditions, notably that the range of GMMs is already well populated". Please provide further explanation on how the SM approach is not appropriate or ideal for the EPRI seed models. This is confusing considering that the Chapter 8 machinery was to overcome the problems that arise when the range of GMMs are not MECE. Wasn't it? Were the same variance and correlation model from Chapter 8 used for this exercise, or was a new model fitted to the EPRI GMM's.*	*RE*	*We understand the concern and confusion - this statement was made in hasted and did not provide any explanation. We have rephrased now that we have added the supporting documentation (few comments above). The process is applicable in theory to the EPRI models, but we tuned our covariance model to achieve MECE with with a target covariance based on the NGA-East seeds. We did not fit or re-optimize the covariance matrix for the EPRI seeds. The EPRI seed covariance is lower than that from the NGA-East seeds and the sampling process uses both that covariance and the imposed covariance (Chapter 8) to achieve the target (desired) covariance. We also highlight that the choice of covariance is an important step in the NGA-East procedure and refer to Figure 6-18 where it is highlighted.*
Rev.1	*12*	*12-6*	*12.3*	*12.3*	*Last sentence in 1st paragraph*	*typo (CENA), not (CENA0*	*ED*	*OK.*
Rev.1	*12*	*12-7*						*Empty comment.*
Rev.1	*12*	*12-8*	*12.10*	*-*	*Figure 12-5*	*Please add 100-Hz and polar-plot presentation of the weights for the three frequencies.*	*ED*	*Same answer as in Chapter 8: will do if we have time.*
Rev.1	*12*	*12-9*	*12.9*		*Figures 12-3 and 12-4*	*Please show these figures for the 3 frequencies*	*ED*	*These figures are used to illustrate the fit to data, which is only used in the 1-10 Hz cases as described in Chapter 9.*
Rev.1	*12*	*12-10*	*12.10*		*Figures 12-6 through 12-12*	*Please provide tabular values or ratios to facilitate comparisons. Also, consider plotting only from 1E-1 to 1E-6 on y-axis. Might allow a little better visualization of results.*	*RE*	*We added hazard ratio plots to facilitate the interpretation.*
Rev.2		*Rev.2 follow-up*				*The ratio plots are very informative.*		*Glad to read!*
Rev.2	*12*	*N/A (new after Rev.2 release)*		*12-8*	*1 caption*	*add "for EPRI seeds"*	*ED*	*Fixed.*
CHAPTER 13								
Rev.1	*13*	*G13-2*	*13.3.2*	*13-7 onwards*		*The formulation of depth-scaling effects is difficult to understand, even despite our having sat through hours of the workshops. The explanation assumes deep familiarity with NGA-West discussions and outputs, and the notation adopted does not help. The label on Figure 13.9 implies that the depth scaling effect is per kilometre, but the equations (e.g. 13-4) do not appear to include multiplying by Z (several pages and equations later we find out that, indeed, the last term in Eq. 13-4 has units of depth). One might presume from Figure 13-9 (forgetting about centering for a moment) that for an earthquake at Z=20 and M~6 and f=5 Hz the factor is 0.05*20 = 1, but is this a multiplicative factor (i.e. no amplification) or a natural log factor (2.7 times stronger)? There is no clarity whether such a positive DSF represents stronger ground motions than the standard result (or not) - I think the answer is yes, but the text should be unambiguous in informing the reader.*	*General*	*The section on depth effect adjustments (Section 13.3) has been revised to provide a more clear and consistent description of the depth scaling and depth centering models and their application. This includes some reorganization and renumbering of the sub-sections to be more consistent with the steps involved with the derivation and applications of these adjustments. Additionally, the terminology has been cleaned-up so as to be self-consistent throughout this section.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*13*	*G13-4*				*A chapter summary at the end is needed. What factors were determined? What are their effects on the hazard? How should they be used? Or can they be ignored?*	*General*	*This is addressed in Chapter 14.*
Rev.1	*13*	*13-1*	*13.0*	*13-1*	*first sentence*	*This sentence regarding PEER (2013) and Geopentech is out of place. This information should be integrated into the following section and into Sections 13.2-13.4*	*ED*	*Fixed.*
Rev.1	*13*	*13-2*	*13.2.1*	*13-1*	*entire section*	*Please refer to map of regions (in ch 4 or later in this chapter)*	*ED*	*Fixed.*
Rev.1	*13*	*13-3*	*13.2.1*	*13-1*	*line 6*	*Move "new" to previous sentence*	*ED*	*Fixed.*
Rev.1	*13*	*13-4*	*13.2.2*	*13-2*	*line 3 & 4*	*Implications of zero ray paths in Florida? Implications of many ray paths from Missisippi embayment earthquakes that may not be in GCR (depending on the definition)? "may slightly bias" is this the TI-team's judgement? How is it justified?*	*RE*	*We revised the text.*
Rev.1	*13*	*13-5*	*13.2.2*	*13-2*	*Eqs. 13-1 through 13-3*	*It is not clear why the ratios in Eq. 13-1 are independent of magnitude. Was this tested? The same question applies to the independence on frequency in Eq. 13-2. Some discussions on these issues should be added, without forcing the reader to go to PEER 2015/08 for these basic results.*	*RE*	*We added a short summary on this issue.*
Rev.1	*13*	*13-6*	*13.2.2*	*13-2*	*5th line from bottom*	*Suggest changing to "...conditions Tasks could include..." Missing period?*	*ED*	*Fixed.*
Rev.1	*13*	*13-7*	*13.2.3*	*13-5*	*line 7*	*"the coastal plain" perhaps be more specific like "Gulf coastal plain" a) to distinguish from Atlantic coastal plain, and b) is this really all "coastal"?*	*ED*	*Changed for Gulf.*
Rev.2		*Rev.2 follow-up*				*IMPORTANT. Wrongly done & needs to be corrected. At the moment it says "places much of the Gulf in MCR. Perhaps "northen part of the Gulf states"? Or "much of the onshore GCR in MCR"??*		*The text was modified.*
Rev.1	*13*	*13-8*	*13.2.4*	*13-5*	*text block 3, line 14*	*"accreted to North America" - the accretion happened much earlier (Appalachian orogeny); it got left on the west side of the Atlantic when the Atlantic opened.*	*NR*	*We revised the text.*
Rev.1	*13*	*13-9*	*13.2.4*	*13-6*	*11th line from the top*	*wording is confusing. In particular, the words "in which uses the" makes no sense and appears to be missing something.*	*ED*	*Fixed.*
Rev.1	*13*	*13-10*	*13.2.4*	*13-6*	*final paragraph line 8*	*"used" and "their". I presume "their" refers to Cramer and Al Norman. TI team needs to use SSHAC language "TI team chose to adopt.....xxxx"*	*NR*	*Fixed.*
Rev.1	*13*	*13-11*	*Table 13-2*			*The GCR zone boundary coordinates are too detailed for their likely accuracy, or their impact on the hazard. Consider simplifying!*	*RE*	*It is agreed that the locations of the GCR boundaries are not precisely known. However, the boundaries of the GCR zones were defined to be consistent with boundaries of CEUS SSC source zones, as was done in EPRI (2013). This simplifies its application in PSHA.*
Rev.1	*13*	*13-12*	*13.2.4*	*13-6*	*final paragraph*	*How many hazard codes can use the proposed GCR model? Will the hazard codes cope with New Madrid earthquakes propagating to Miami, which (depending on the model) start in MCR, propagate through GCR, and then pass through MCR again?*	*??*	*Hazard codes will have to be updated to address all aspects of the model and verified accordingly. The decision on what to be addressed is left to the judgement of the hazard analysts and we provide guidance in Chapter 14 on the importance of various issues.*
Rev.1	*13*	*13-13*	*13.3.1*	*13-6*	*line 10*	*"primarily of importance mostly for PIEs" But (although not strongly represented in the NGA-East dataset), the seismicity near some sites (e.g. southern Ontario) is dominated by shallow earthquakes, and the shaking from these is important. Also perhaps try wording: "of primary importance chiefly for PIEs"*	*NR*	*Reworded.*
Rev.1	*13*	*13-14*	*13.3.1*	*13-6*	*line 11*	*"this assumption" has no anteceedent. What was intended? There may be a problem with the entire sentence.*	*ED*	*Reworded.*
Rev.1	*13*	*13-15*	*13.3.1*	*13-6*	*Figure 13-6*	*Please confirm a PIE at depth of 14 kms*	*ED*	*Yes, Slaughterville 2010-10-13.*
Rev.1	*13*	*13-16*	*13.3.1*	*13-7*	*lines 3&4*	*"with the intent to be used with any of the seed or final median GMMs" perhaps better as "with the intent it be used with the final median GMM suite or any of the seed GMMs" to avoid implication that individual NGA-East GMMs can be used separately.*	*ED*	*Models can indeed be used "separately" for certain (non-nuclear) applications.*
Rev.1	*13*	*13-17*	*13.3.1*	*13-7*	*last line*	*Refers to Appendix G.1. Explicit discussion (a few lines) needed (see general comment)*	*RE*	*Added Section 13.3.6 summarizing the TI team's findings.*
Rev.1	*13*	*13-18*	*13.3.2*	*13-7*	*line 11*	*"implied" - it's only implied? - it isn't explicitly quantified?*	*ED*	*Reworded.*
Rev.1	*13*	*13-19*	*13.3.2*	*13-8*	*line 3 & 4*	*"following the PEER model at high frequencies" demonstratably false from the lower part of Fig 13-7*	*RE*	*Fixed the figure.*
Rev.1	*13*	*13-20*	*13.3.3*	*13-8*	*last line in section*	*The statement "ZTOR is the actual depth-to-top-of-rupture of the earthquake source, as provided in a SSC model" appears to be incorrect. The SSC model does not provide ZTOR, it provides the model for the PSHA code to randomize ZTOR. Please revise.*	*RE*	*Reworded.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*13*	*13-21*	*13.3.2*	*13-8*	*Figures 13-7 and 13-8*	*Please provide an example of how the depth scaling factor is used. Is it additive or multiplicative? Equation 13-4 and the text following it are very confusing in this regard.Some frequencies/magnitudes show a DSF of 0.* *One possibility is to introduce DZTOR beginning in Eq. 13-4 (and indicate that it is related to the difference between the actual ZTOR and the centering ZTOR). That way, it is clear that second term in the RHS has units of depth. Also, you need to say that the quantity in Eq. 13-4 is added to the natural log of the median* *ground motion calculated from the tables. Any changes in this notation should also be reflected in the HID.* *Also, Shouldn't the values for M=5 in Figure 13-8 agree with the red values (proposed) on Figure 13-7? They do not agree at low frequencies.*	*RE*	*The reworking of that section should have cleared things up. We added a sentence to the effect that the model is added to the natural log of the ground motions.* *We have reworked the section based on comments above.* *We fixed the figure.*
Rev.1	*13*	*13-22*			*Figure 13-8*	*Caption is confusing. What is the meaning of "PEER Hybrid"?*	*ED*	*We added a definition while addressing comment G13-2.*
Rev.1	*13*	*13-23*	*13.3.4.1*	*13-10*	*Figure 13-10*	*Where is the Saguenay earthquake on this figure? Why does it not show?*	*RE*	*We incresed the vertical axis to 25 km. Saguenay is now shown at Ztor=21.5 km).*
Rev.1	*13*	*13-24*	*13.3.4.1*	*13-10*	*Figure 13-10*	*Why does Figure 13-10 seem inconsistent with the depth distribution in Figure 13-6. Please note in caption*	*ED*	*Figure 13-6 shows focal depth and Figure 13-10 shows Ztor. The captions appears clear.*
Rev.1	*13*	*13-25*	*13.3.4.1*	*13-10*	*Figure 13-11*	*Update the references to table numbers given in legend and caption*	*ED*	*Fixed.*
Rev.1	*13*	*13-26*	*13.3.5*	*13-10*	*all*	*The names used in the section don't reflect those in the prior sections, so it is more complex than necessary to understand what is being recommended. Try to keep the naming consistent: e.g. not "GMM-based" (unless you go back and insert that term in section 13.3.4.1) but "Model Based on Implied Depths from Seed GMMs". Also add Section 13.2.2 and Fig 13-8 references into paragraph 1.*	*NR*	
Rev.1	*13*	*13-27*	*13.3.8.1*	*13-12*	*Eqn 13-8 & 13-9*	*either replace the comma with much more space (comma separator gets lost) or put the sigma on a second line*	*ED*	*Looks good in word - limited editing with MathType/Equation editor.*
Rev.1	*13*	*13-28*	*13.3.8.1*	*13-13*	*Fig 13-16*	*might have better been shown as CDFs*	*NR*	
Rev.1	*13*	*13-29*	*13.3.8.2*	*13-13*	*last line*	*"always" not true for M8 on Fig 13-17 (bottom)*	*ED*	*Figure 13-17 (bottom) shows that M8 always ruptures to the surface (ZTOR=0).*
Rev.1	*13*	*13-30*	*13.3.8.2*	*13-13*	*Fig 13-17 &13-18*	*The chance of surface ruptures is lower than one would have expected. Please discuss. 1886 Charleston (~M7) likely ruptured to top of rock as evidenced by rail shortening on the coastal plain. This event was also likely to be strike-slip. Based on the very limited data, M7 should perhaps have a 50-50 chance of rupturing the surface.*	*??*	
Rev.1	*13*	*13-31*	*13.4.1*	*13-13*	*line 4*	*"evidenced" - perhaps you mean "championed", or "promoted" or "exemplared"??*	*ED*	*Reworded.*
Rev.1	*13*	*13-32*	*13.4.1*	*13-13*	*line 6*	*2 different uses of "above". Suggest changing the second by "compared to"*	*ED*	*Reworded.*
Rev.1	*13*	*13-33*	*13.4.1*	*13-13*	*line 12*	*Most people will not be able to access the GeoPentech report, so please indicate what you/they mean by moderately dipping, and comment on more steeply dipping and more gently dipping ruptures. In addition, may want to provide NRC accession number for report, if available.*	*NR*	*The report is publicly accessible on the PG&E website.*
Rev.2		*Rev.2 follow-up*				*It still may be a good idea to indicate what is mean by moderately and steeply dipping.* *Also, do we know for how long that report be available at PGE web site? An NRC ADAMS reference (if possible) would have more longevity*		*Description of moderate dipping added.*
Rev.1	*13*	*13-34*	*13.4.1*	*13-14*	*last 2 sentences*	*Statement is only true with respect to identified faults. However what about "random" spinning faults used to model large earthquakes in distributed seismicity sources? Some fraction of these would include hanging wall effects, so you should show that this is important (or not) for the total hazard. Effects would be strongest for shallow-epicenter, reverse-faulting environments at low probabilities (where earthquakes almost under the site contribute a large fraction of the hazard), such as New England.*	*RE*	*Application of HW model to distributed seismicity sources is investigated in Section 14*
Rev.1	*13*	*13-35*	*13.4.2*	*13-14*	*last clause*	*Perhaps neater to express this as the first line of equation 13-11*	*ED*	*This has been removed during editing.*
Rev.2	*13*	*N/A (new after Rev.2 release)*	*13.3*	*13-8, 13-11*	*Eqs. 13-5 and 13-7*	*There are some problems with the equations in this section:* *(1)The horizontal alignment of Eq. 13-5 is off (1st and 3rd rows should be offset to the right. Once more, this was OK in previous version of report)* *(2) Same problem on Eq. 13-7.* *(3) somewhere in or near Eq. 13-7, we suggest that you indicate that Delta_ZTOR=f_ZTOR,Z in order to establish the connection to Eq. 13-4.*	*Strongly recommended*	*Equations were fixed. We removed the fZtor,z notation and only use DeltaZtor. It simplifies the explanations.*

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.2	13	N/A (new after Rev.2 release)	13.4.1	13-15	last paragraph	This paragraph seems to suggests that HW effects should only be used for known faults (and, by implication, not used for the pseudofaults and virtual faults used in PSHA for the calculation of Rjb and Rrupt in areal sources). On the other hand, the next to last paragraph in 14.4 indicates that the effect is quite important at low AFEs. Please clarify here and in HID.	Strongly recommended	Revised text to provide consistent message.
Rev.2	13	N/A (new after Rev.2 release)	13.3.5.3	13-13	Eqs. 13-9	Equation 13-9 also has formatting problems (alignment) and a typo- it is for ln(AR) not ln(RA).	Strongly recommended	Equation fixed.
Rev.2	13	N/A (new after Rev.2 release)		13-2	line 1	Consider replacing ", but not paths sampling" with "; no paths sample".		Fixed.
Rev.2	13	N/A (new after Rev.2 release)		13-4	0.67 compare	0.67 compared		Fixed.
Rev.2	13	N/A (new after Rev.2 release)		13-40	Fig 13-11	Smootehd		Fixed.
Rev.2	13	N/A (new after Rev.2 release)		13-40	Fig 13-11	Consider replacing "E[ZTOR].km" with "E[ZTOR] (km)".		Fixed.
Rev.2	13 and H, All, especially 13 and H	N/A (new after Rev.2 release)				(An additional concern is that many equation errors [in this and other chapters] were introduced in this version of the report [i.e., equations that were OK in the previous version of the report now have problems]. We recommend re-checking all equations .)	Strong recommendation	Equations were fixed.
						CHAPTER 14		
Rev.1	14	G14-0				Provided below are PPRP comments on Chapter 14 of the Draft Report Rev. 1 (provided by email via Y. Bozorgnia to the PPRP on June 29, 2018). A general set of comments are provided first, followed by a set of more detailed comments. The PPRP recommends that the general set of comments be addressed first as these may result in significant changes to Chapter 14 sections. After this step is accomplished the PPRP recommends that the detailed comments be reviewed and addressed given the revised text developed to address the general comments.		
Rev.1	14	G14-1				The purpose of Chapter 14 is not clear to the PPRP. In the table of contents this chapter is listed as "Hazard Demonstration", in section 1.4 the text states that "Chapter 14 provides implementation guidance for practitioners, and the draft reviewed by the PPRP is titled "Full Model Implementation". The Chapter contains numerous hazard curve figures that are at such a scale (7 orders of magnitude in annual frequency and 5 orders of magnitude in ground motion) to render any meaningful hazard comparisons as opaque. If this Chapter does not contain the hazard demonstration results for the seven test sites, please indicate where in the report those will be provided. From a broad perspective Chapter 14 should contain the following: 1. A clear introduction which explains what information is being presented and why it is being presented. 2. A discussion, up front, regarding hazard comparison perspective to inform the reader what aspects of the hazard curve comparisons they should focus on. Many of the current figures show fractiles out to the 5th and 95th percentile. In contrast past hazard demonstrations focused on fractiles out to the 16th and 84th percentile. The PPRP believes that (any) changes to the mean (or median) hazard deserve attention. This is not to say that understanding how the range of epistemic uncertainty has changed is not important, but perspective is needed. Perhaps the context of this discussion should link back to the SSHAC concept of center, body and range of technically defensible interpretations. 3. Sufficient quantitative information to support observations and conclusions. 4. Figures (possibly additional figures) that are able to clearly distinguish differences between results being compared; perhaps these are figures of AFE ratios at several ground motions with accompanying text that puts perspective on what ratios should be considered as important (tolerance factor). 5. If this chapter includes the hazard demonstration calculations, sufficient tables of hazard results at each of the seven test sites, so that hazard analysts can properly determine if they are implementing the NGA-East model. 6. A clear summary to explain the information presented, and as appropriate how the hazard changes, depending on the GMM input used. If this chapter includes the hazard demonstration calculations the summary should include any overall hazard trends associated with implementing the NGA-East model. The TI Team should explain the basis for hazard differences – to the extent possible what data, models, or		We reworked this chapter extensively based on the constructive PPRP comments. A few examples and answers provided here. We revised the descriptions and titles in chapters 1 and 14. We added hazard ratio plots. Throughout the project, we showed on 5-95% percentile. This is consistent with the TI team's definition of the range. We explored adding 16-84th but found that it made the plots even more difficult to read. The hazard input document is in Appendix H with tables provided in Appendix I for the seven demonstration sites; these provide the 16-84 percentile ground motions.
Rev.1	14	G14-2				Relative to the hazard demonstrations for the seven test sites, an important issue is to provide perspective and explain the differences between the NGA-East GMM and the EPRI (2013) GMM. The PPRP believes that the TI Team is in the best position to explain what are of the causes for any hazard differences between GMMs including an understanding of whether changes are a result of new data, new methodology used to develop the NGA-East GMM, or other factors such as change in the aleatory variability values. The hazard demonstrations should make it clear what the hazard impacts of moving from a "fully ergodic" to "partially ergodic" aleatory variability are.		Fixed.
Rev.1	14	14-1	14.1.2	14-3	End of section	It would be useful for the TI Team to include a summary recommendation at the end of this section – is the inclusion of the depth effect necessary and if so for what places or cases?	RE	We added a recommendation.
Rev.1	14	14-2	14.2	14-3	1st paragraph	It is understood that the choice of sigma models for these comparison represents the change from current practice to post-NGA-East practice. Still, it would be useful to show the effect of the median models and of the sigma models separately. There is more on this issue in the next comment.	RE	Hazard sensitivities to sigma added.

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	14	14-3	14.2	14-4	Last paragraph	The report states that the differences in hazard are attributed primarily to differences in the median models. The basis for this statement appears to be the argument that the differences in hazard seen in Figures 14-21 through 14-69 are approximately the same as those seen in Chapter 12 (Figures 12-6 through 12-12), which used a common sigma model. Although this statement is difficult to verify given the scale of the figures (especially those in Chapter 12) and that Chapter 12 shows results for only two sites, a visual comparison of the amplitudes for mean 1E-4 probability suggests that the NGA-East/EPRI ratios are significantly greater in Chapter 12 than in Chapter 14. This suggests that both the changes in the median and in sigma are important and that they are working in opposite directions, so that the net effect is smaller. This underscores the need for a discussion of the results. In addition, separate sensitivity analyses to show the effects of the median model and of sigma would be highly desirable.	RE	Discussion expanded and hazard sensitivies to sigma added.
Rev.1	14	14-4	14.2	Entire section		The report is missing a closing section or chapter containing a detailed explanation and/or discussion of the changes in models and in hazard from EPRI (2013) to the new model. Is it a result of the new data? Not likely, as the two datasets have the same cutoff date (but different record processing). Is it the "seed" models vs. the models considered by EPRI? Is it the new methodology from Chapters 8 and 9? Is it the new sigma model from Chapters 10 and 11? Why is this model more credible and should supersede EPRI (2013), other than the procedural argument that it went through a lengthy SSHAC 3 process? Much of the information needed is already in the various chapters and sensitivity analyses, but it needs to be put together in one place (in Chapter 14 or in a new summary and discussion Chapter).	RE	Discussion added.
Rev.1	14	14-5	-	Figures	-	Chapter 12 shows hazard results starting with the lowest frequencies; Chapter 14 follows the opposite convention. It would be preferable for all chapters to follow the same convention.	ED	Fixed.
Rev.1	14	14-6	14.1.1	4-1	1st paragraph	The text should be revised to state: "The larger region boundary is weighted 0.6 and the smaller region boundary is weighted 0.4."	ED	Fixed.
Rev.1	14	14-7	14.1.1	14-2	3rd and 4th paragraph	"GRC" should be "GCR"	ED	Fixed.
Rev.1	14	14-8	14.1.2	14-2	1st paragraph	"alteratives" should be "alternatives"	ED	Fixed.
Rev.1	14	14-9	14.1.2	14-3	2nd paragraph	"Manchester were inclusion" should be changed to "Manchester **where** inclusion"	ED	Fixed.
Rev.1	14	14-10	14.1.2	14-3	3rd paragraph	PGA results are not shown on Figure 14-20; revise text to match the figure.	ED	Fixed.
Rev.1	14	14-11	14.2	14-4	Last paragraph	"produces" should be "produced"	ED	Fixed.
Rev.1	14	14-12	14.2	14-4	5th paragraph	"reverence" should be "reference"	ED	Fixed.
Rev.2	14	N/A (new after Rev.2 release)		14-14	caption	change "deed" to "seed"		Fixed.
Rev.2	14	N/A (new after Rev.2 release)		14-4	Section 14.1.3	Figures 14-30 and 14-31 are not cited in text	ED	Missing paragraph added.
Rev.2	14	N/A (new after Rev.2 release)		14-9	4th par	For specification of reference user site conditions, the TI specifies an acceptable range of site-specific amplication factors based on the range of seed model site specific amp factors and kappa (shown in Figure 14-99). At 10-Hz, the recommended site amp range is 25-30% but considerably less at other frequencies. Suggest that the TI provide range of reference velocity and kappa recommended by the geotechnical group and also range from seed models to supplement the the site amps recommentdation.	Recommended	Reference velocity and kappa values already in report in Table 14-1. Plot added along with Hashash et al values, which were referenced.
Rev.2	14	N/A (new after Rev.2 release)		14-12	last par	There may be other lessons learned, e.g., limiting number of participants; early identification of SSHAC and non-SSHAC components of investigation; early detailed work plan that defines scope and budget for each element of program.	Recommended	From the TI team perspective, the most important was the seperation of the science and SSHAC parts of the project. This is reflected in the final paragraph.
Rev.2	14	N/A (new after Rev.2 release)		14-43	Figure 14-29	Please provide the range of depth effects adjustments in addition to the mean on this figure.	Recommended	Range added to Figure.
APPENDIX E								
Rev.0	E	N/A (new after Rev.2 release)		E-10, E-11	Figure caption	caption reads 1-Hz and 10-Hz shown in figures		Fixed.
Rev.0	E	N/A (new after Rev.2 release)		E-15	Figure caption	caption reads 1-Hz and 10-Hz shown in figures		Fixed.
Rev.0	E	N/A (new after Rev.2 release)		E-16	Figure caption	caption reads 10-Hz and 1-Hz shown in figures		Fixed.
Rev.0	E	N/A (new after Rev.2 release)		E-25	Section E.3.4, 5th line	change "E.3-9 to E.3-10" to "E.3-10 to E.3-12"		Fixed.
APPENDIX H								
Rev.1	Appendix H	GH-0				Provided below are PPRP comments on Appendix H of the Draft Report Rev. 1 (provided by email from Y. Bozorgnia to the PPRP on June 29, 2018). A general set of comments are provided first, followed by a set of more detailed comments. The PPRP recommends that the general set of comments be addressed first as these may result in significant changes to Chapter 14 sections. After this step is accomplished the PPRP recommends that the detailed comments be reviewed and addressed given the revised text developed to address the general comments.		

Version	Chapter	Number	Section	Page	Location	Comment	Type	TI Response
Rev.1	*Appendix H*	*GH-1*				*As indicated in the Chapter 13 comments, the PPRP found the notation and description of the depth adjustments very confusing. Most notably:* *1. fZtoR is called an adjustment factor. The word factor denotes multiplication, but this is not how it works, because the actual factor that multiplies the median amplitudes is exp[fZtoR]. Right?* *2. It is not completely clear from the equations and tables that fZtor,Z and fZtor,M have certain units. The Figures in Chapter 13 indicate that fZtor,M has units of 1/km, but the tables here do not.* *The PPRP strongly suggest that the notation and description in Chapter 13 and in the HID be revised to make them more clear and intuitive.* *Also, the reader is left with the impression that these adjustments for depth may not be needed in some cases. A clarification would be very useful.*		*(1) As indicated in the first line of Section H.3, the factor is added to the natural log for the median ground motions.* *(2) Text modified to indicate units are km.* *Chapter 13 revised.* *Chapter 14 addresses need to include adjustments for depth.*
Rev.1	*Appendix H*	*GH-2*				*Readers and implementers may be confounded by the rock velocity profile in Table H-7. The profile appears out of the blue, and contradicts section 1.2.3. The precision of the values in the table is remarkable! The crustal layering is probably more complicated than need be.* *More importantly, this profile raises the following question "If my site is on Vs3000, but doesn't have the layering of Table H-7, what do I do?" In the PPRP's view, this profile and the answer to the above question do not belong in the HID. They should be somewhere else in the report.*		*Removed, discussion of reference profile is now in Chapter 14.*
Rev.1	*Appendix H*	*GH-3*				*Hazard results for all test sites and all frequencies must be provided in electronic (not just graphical) form so that developers can test and validate their implementation of the HID.*		*Provided now in Appendix I, matching what has been provided in previous projects (mean, median, 16th and 84th for PGA, 10 Hz, and 1 Hz).*
Rev.1	*Appendix H*	*H-1*	*H*	*H-1*	*2nd paragraph*	*Drop the decimal 0's*	*ED*	*Fixed.*
Rev.1	*Appendix H*	*H-2*	*H*	*-*	*Table H-2*	*Set out as 3 columns, and not 6-column format; bolding is inconsistent*	*ED*	*Fixed.*
Rev.1	*Appendix H*	*H-3*	*H*	*H-7*	*Paragraph below Eq. H-5*	*Text says "ZTOR is the actual depth-to-top-of-rupture of the earthquake source, as provided in a SSC model." The SSC model does not provide ZtoR; it provides the elements to calculate its distribution for a given source and magnitude. Please revise.*	*ED*	*SSC is used in a generic sense. Changed to seismic source model.*
Rev.1	*Appendix H*	*H-4*	*H*	*H-7*	*Last paragraph*	*Text references Section 13.6, which does not exist*	*ED*	*Corrected to 13.5.*
Rev.2	*H*	*N/A (new after Rev.2 release)*	*H.3*	*H-7*	*entire page*	*The model for the depth adjustment is not described properly. Here are the problems:* *(1) The wording "The adjustment factor" in line 2 is unclear because it does not link with the sentence above (which speaks of addition) and because the word factor implies multiplication. We strongly suggest that it be modified to "The adjustment term," so it links with the first sentence (a similar change will be needed in Ch. 13). Alternatively, you may refer explicitly to fZTOR in the first sentence (e.g., insert fZTOR between "term" and "that" in the first sentence).* *(2) Eq. H-3 introduces fZTOR,M and fZTOR,Z, but fZTOR,Z is never defined. Is there a typo in Eq. H-5, so that perhaps fZTOR,M should actually be fZTOR,Z?* *(3) Eq. H-5 uses DeltaZTOR, but that quantity is never defined. Is there an equal sign missing between DeltaZTOR and the square bracket?* *The HID should be abundantly clear and unambiguous regarding the models. The text and equations in Section H.3* ***must*** *be revised and corrected to achieve this requirement.* *In addition to the changes identified above, we strongly recommend that an example of the depth adjustment be provided. This example would go through the steps to adjust the prediction of one GMM (for a particular magnitude-distance combination) to account for a particular value of ZTOR.*	*Strong recommendation*	*Wording changed and equations corrected. Example depth effect application added to Section 13.*
Rev.2	*H*	*N/A (new after Rev.2 release)*	*H.3*	*H-7*	*last paragraph on page, 2nd line*	*reference to Section 13.5 should be to Section 13.3.5.*	*Strong recommendation*	*Corrected.*
Rev.2	*H*	*N/A (new after Rev.2 release)*	*H.4*	*H-9*	*entire section*	*It is not entirely clear from the HID whether the hanging-wall effects terms should be used for areal sources or only for RLMEs. On the one hand, the second paragraph in Section 13.4.1 seems to suggests that these effects should only be used for known faults (and, by implication, not used for the pseudofaults and virtual faults used in PSHA for the calculation of Rjb and Rrupt in areal sources). On the other hand, the next to last paragraph in 14.4 indicates that the effect is quite important at low AFEs. This issue* ***must*** *be clarified in the HID and the related text in 13.4.1 may require modification.*	*Strong recommendation*	*Guidance provided in Section 14.4.*
Rev.2	*H*	*N/A (new after Rev.2 release)*		*H-1*	*para 1*	*periods....Hz*		*Both periods and frequencies are given in text*

A.3 NGA-East Original Project Plan

The original NGA-East project plan was developed following the first NGA-East SSHAC Workshop in 2010. The Workshop was a great opportunity for the project team to publicly discuss the critical issues and to refine the original “NGA-East Roadmap” document developed by Bozorgnia et al. (2008). Revision zero was submitted for review by the PPRP in April 2011; the revised project plan was published on July 7, 2011. The project plan and the PPRP correspondence are included in the following sections.

This material is included in the following pages.

NGA-East Final Project Plan

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July 2011

NGA-East Final Project Plan

VERSION CONTROL INFORMATION

This project plan is a living document that will be used to communicate the project goals and activities to project participants and to the public. The following information is provided for tracking released versions.

Version	Forwarding date	Changes	Submitted by	Comments
None	July 7, 2011	None, original document.	C. Goulet	Final Project Plan approved by the PPRP after the revision of draft documents.

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LIST OF ACRONYMS AND ABBREVIATIONS

CENA	Central and Eastern North America
CEUS	Central and Eastern United States
CEUS SSC	Central and Eastern U.S. Seismic Source Characterization for Nuclear Facilities Project
DNFSB	Defense Nuclear Facilities Safety Board
DOE	United States Department of Energy
EPRI	Electric Power Research Institute
GM	Ground Motion
GMC	Ground Motion Characterization
GMPE	Ground motion prediction equation (AKA attenuation relationship)
HFA	Hazard Feedback Analysis or Hazard Feedback Analyst
JMC	Joint Management Committee
MIA	NGA-East/CEUS SSC Model Interface Advisor
NGA	Next Generation Attenuation Relationship
NGA-East	Next Generation Attenuation Relationship for the Central and Eastern North American Region
NGA-West	Next Generation Attenuation Relationship for shallow crustal earthquakes in active tectonic regions (original project)
NGA-West2	Next Generation Attenuation Relationship for shallow crustal earthquakes in active tectonic regions (phase 2 of NGA-West project)
NRC	United States Nuclear Regulatory Commission
NUREG	Regulatory guides, reports and brochures from the U.S. Nuclear Regulatory Commission
NUREG/CR	Regulatory guides, reports and brochures from the U.S. Nuclear Regulatory Commission prepared by NRC Contractors
PEER	Pacific Earthquake Engineering Research Center
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
PM	Project Manager
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
Q	Quality factor
RFP	Request For Proposal
Sa	Spectral acceleration
SCR	Stable Continental Region
SGPM	SSHAC Guidelines Process Manager
SSC	Seismic Source Characterization
SSHAC	Senior Seismic Hazard Assessment Committee
T	Spectral period (in seconds)
TI	Technical Integrator
U.S.	United States
USGS	United States Geological Survey
V/H	Vertical to horizontal ground motion ratio
WG	Working Group
WUS	Western United States

1. INTRODUCTION

This document outlines the Next Generation Attenuation for Central and Eastern North-America project (NGA-East). The objective of NGA-East is to develop a new ground motion characterization (GMC) model for the Central and Eastern North-American (CENA) region. The GMC model consists in a set of new ground motion prediction equations (GMPEs) for median and standard deviation of ground motions (GMs) and their associated weights in the logic-trees for use in probabilistic seismic hazard analyses (PSHA).

NGA-East is a multi-disciplinary research project coordinated by the Pacific Earthquake Engineering Research center (PEER), with headquarters at the University of California, Berkeley. The project involves a large number of participating researchers from various organizations in academia, industry and government. The project is jointly sponsored by the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI) and the U.S. Geological Survey (USGS).

A major component of NGA-East is treated as a SSHAC Level 3 project (SSHAC, 1997). The current project plan sent to the Participatory Peer Review Panel (PPRP) for review was developed for the SSHAC Level 3 tasks only. Additional “non-SSHAC” tasks are managed by the Project Manager (PM) and the Joint Management Committee (JMC) outside of the SSHAC framework. This document presents the SSHAC project objectives and the technical work plan devised to meet these objectives, along with intermediate deliverables with their associated schedule. The technical work plan was developed over a period of time with input from the NGA-East project teams and the JMC. The NGA-East Technical Integration team (TI team) and Project Manager then refined the plan to its current form. The project plan is consistent with the budget and scope revisions approved by the JMC in a conference call on March 9, 2011.

The project is funded by U.S. agencies, and their interest is to develop the ground motion model for the Central and Eastern U.S. (CEUS). Nonetheless, because the tectonic region of interest reaches across into Canada, the ground motion model developed in NGA-East will be applicable to the larger CENA region. A large number of earthquake records used in this project were provided with support from the Geological Survey of Canada.

2. OBJECTIVES

The goals of the NGA-East project, listed below, are based on input from the sponsors and other stakeholders. This section focuses on principal objectives; task-specific objectives are presented in Section 5.

The general objective of NGA-East is to develop a new ground motion model for the CENA region. The products of the project are a set of new candidate GMPEs, commonly known as attenuation relationships, and a set of associated logic-trees for use in PSHA. Additional products include earthquake ground motion databases as well as models for site response and for vertical component ground motion.

A large portion of the NGA-East project is treated as a SSHAC Level 3 project (SSHAC, 1997). More details on the SSHAC level specification are presented in Section 3. The project objectives associated with the SSHAC Level 3 portion of the project are referred to as "SSHAC objectives". There are additional project objectives that are not covered by the SSHAC Level 3 umbrella and those are referred to as "non-SSHAC objectives". The non-SSHAC objectives are not discussed further in this project plan, but are listed below for completeness.

Principal SSHAC Objective

To provide the best estimate of the distribution (median and standard deviation) of average horizontal ground motions (PGA, PGV and 5%-damped Sa for T=0.01-10s) on hard-rock sites located up to 1,000 km from future earthquakes in CENA with moment magnitudes in the 4.0 to 8.0 range, and to provide the epistemic uncertainty associated with this estimate.

This objective must be achieved in the context of a SSHAC Level 3 study. More specifically, the SSHAC objectives are associated with the development of new databases, the full assessment and incorporation of variability and uncertainty, the inclusion of the center, body and range of technically defensible interpretations of the available data, models and methods, the development of exhaustive documentation, and a thorough peer review.

Interaction with the CEUS SSC Project

Input to PSHA computations require both seismic source and ground motion characterization. The NGA-East project is a ground motion characterization project. The complementary Central and Eastern United States Seismic Source Characterization for Nuclear Facilities project (CEUS SSC) is nearing completion. The CEUS SSC is also conducted as a SSHAC Level 3 study (Coppersmith and Salomone, 2008). Because the NGA-East and CEUS SSC products will be used together in PSHA assessments, there needs to be a strong interaction between the two projects. A timely dialogue between key participants of both projects is necessary to ensure compatibility of the source characterization and ground motion characterization and to make sure that the final PSHA estimates reflect the intent of the CEUS SSC and NGA-East products. Therefore, the GMPEs developed in this project and the implementation guidance developed by the NGA-East TI team, should be compatible with the logic tree-based model that will result from the CEUS SSC Project.

Principal Non-SSHAC Objectives

To develop site amplification models to account for site response effects on geo-materials not defined as hard rock.

To develop models to quantify the ground motions in the vertical direction of shaking.

In addition, other non-SSHAC objectives include the collaboration and integration with other projects:

Collaboration with NGA-West2

The NGA-West2 project is currently updating the NGA-West models within PEER. There are issues that are addressed in NGA-West2 that are of interest to NGA-East and some results from the NGA-West2 effort will be transferable to NGA-East. This applies mainly to the tasks from the Sigma and Vertical Ground Motion Working Groups. These working groups have the same teams of researchers.

Integration with the USGS National Hazard Mapping Program

The project plan was designed to have at least some products, including draft GMPEs if possible, completed in a timeline that allows the USGS to incorporate them in the development of the next iteration of the U.S. National Seismic Hazard Maps.

3. PROJECT EVOLUTION AND SSHAC STUDY LEVEL

NGA-East was originally developed as a science-based research project (Bozorgnia, 2008). The project was to be a follow-up to the previous NGA project (referred to as NGA-West for clarity) that focused on the development of GMPEs for shallow crustal earthquakes in active tectonic regions (Power et al., 2008). NGA-East evolved to a SSHAC Level 3 in early 2010 so that it would be consistent with the CEUS SSC project and to allow the products of these projects to be combined for use in Level 3 site-specific studies. As a result, the scope of work and the level of complexity of the project have increased considerably.

SSHAC stands for the "Senior Seismic Hazard Analysis Committee", which is the entity that developed the SSHAC Guidelines detailed in the NUREG/CR-6372 document (SSHAC, 1997). The SSHAC assessment process can be used in the development of PSHA input models or in PSHA studies. The fundamental goal of a SSHAC assessment process is to carry-out properly and document completely the activities of evaluation and integration, defined as:

- **Evaluation:** The consideration of all the data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis.
- **Integration:** Representing the center, body, and range of technically defensible interpretations in light of the evaluation process.

The SSHAC guidelines define four study levels, each higher level corresponding to an increase in complexity. Higher study levels are associated with a higher confidence that the center, body and range of technically defensible interpretations of the available data, models and methods have been captured in the final products. The SSHAC Level 3 was selected as appropriate to ensure the stability and transparency of the NGA-East products given the complexity, importance and regulatory concerns associated with the study. More details on the level of study and the SSHAC process are presented in SSHAC (1997), Hanks et al. (2009) and in U.S. NRC (2011, in prep.), which is currently under preparation.

The SSHAC Level 3 assessment process requires a level of documentation and review that is much more demanding than what was carried out in other comparable research projects, such as NGA-West for example. This implies larger resources in both time and capital investment. In an effort to optimize the needs of the different agencies with the available resources, the SSHAC Level 3 study was assigned to tasks associated to NRC and DOE objectives only. The remaining “non-SSHAC” tasks and objectives will be addressed as typical research tasks coordinated by PEER.

4. ORGANIZATION

As a result of the project evolution, the NGA-East organization features all the components of a SSHAC Level 3 project, but it also features groups from the original project model (Figure 1). An important feature of NGA-East is the inclusion of Working Groups (WGs) that support the TI Team and focus on specific technical areas. Some NGA-East WGs and technical tasks are not formally part of the SSHAC Level 3 process, but they are nonetheless important to the overall project. These are the Geotechnical and Vertical WGs shown in Figure 1. The role of the different groups and participants in Figure 1 are briefly summarized below and more details on roles in SSHAC studies are available in SSHAC (1997) and U.S. NRC (2011, in prep.). Note in Figure 1 that the Geotechnical WG and sub-award researchers and contractors provide support to SSHAC and non-SSHAC tasks. In the context of the SSHAC process, the WGs essentially play the role of Resource Experts and the sub-award researchers and contractors play the role of Specialty Contractors. Some individuals from these two groups will also play a Proponent Expert role at specific times during the project. Refer to SSHAC (1997) and U.S. NRC (2011, in prep.) for the key attributes and requirements associated to the SSHAC roles.

4.1 General Organization

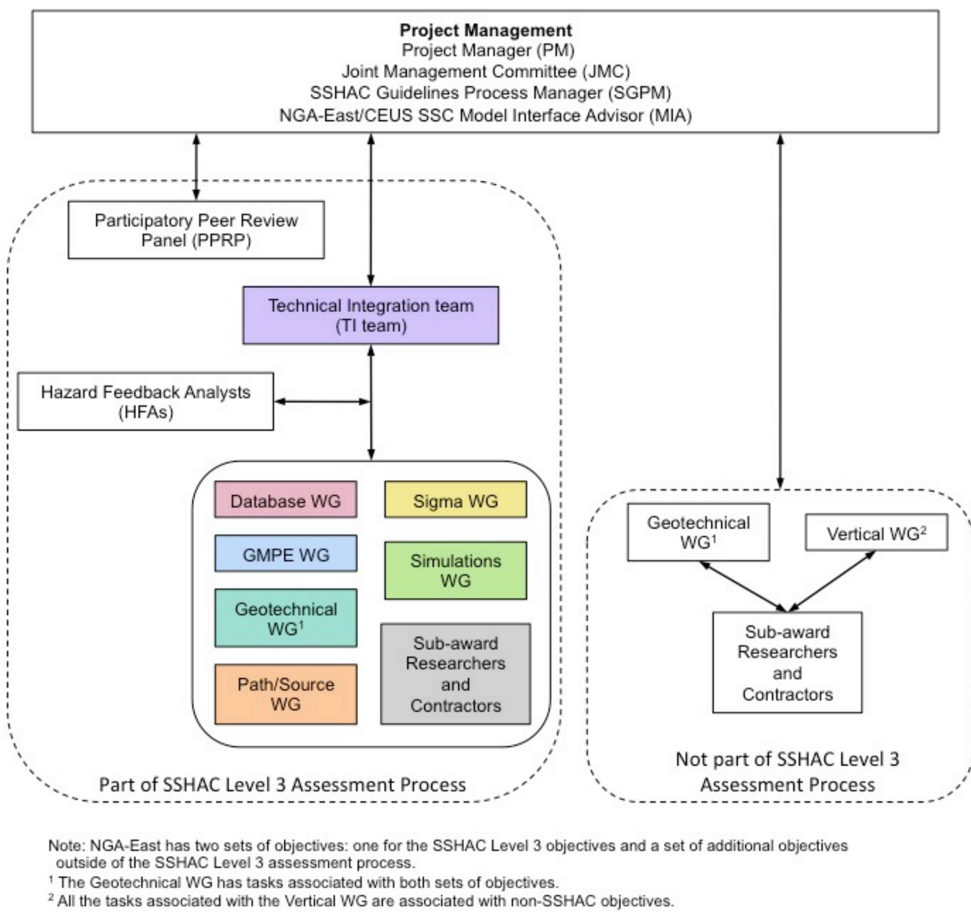

Figure 1. NGA-East organization flowchart and lines of communications.

Project Management: Project Manager, Joint Management Committee and SSHAC Guidelines Process Manager

The project is managed by the PM and the JMC which is composed of representatives of the key sponsoring organizations. These organizations are the NRC, EPRI, DOE and USGS. The PM and JMC authorize the use of project resources on various tasks and are responsible for the overall direction of the project. The PM and JMC oversee that there is adequate funding and cash flow for the project.

The SSHAC Guidelines Process Manager (SGPM) provides further guidance on the implementation of the SSHAC Level 3 assessment process. The SGPM is also responsible to maintain discussion and communication with the NRC and Defense Nuclear Facilities Safety Board (DNFSB) staff to assure the ongoing regulatory acceptability of the NGA-East SSHAC Level 3 approach.

Participatory Peer Review Panel (PPRP)

The PPRP provides the overall process and technical review as required by the SSHAC Level 3 process. The PPRP reports directly to the Project Manager, as shown in Figure 1. The role of the PPRP is by definition participatory and continual from project inception to project completion. The PPRP will be responsible for assuring that the overall process is consistent with the objectives of the SSHAC guidelines. The PPRP is not responsible for the review of NGA-East tasks that are not defined in the SSHAC Level 3 process.

Technical Integration Team (TI team)

The TI team takes ownership of the results from the SSHAC Level 3 assessment process. The TI team is ultimately responsible for all GMC technical products, technical assessments and for defending their bases, as well as for the associated documentation. The TI team also oversees and coordinates the technical work performed by the WGs, sub-award researchers, and contractors and supports the PM when ensuring that the project scope and schedule are maintained. The TI team will participate regularly in WG meetings to monitor the progress on technical tasks. The TI team, in collaboration with the PM, is responsible for the development of the project plan and for the organization of the workshops. Note: the two TI co-chairs (Section 4.2) are also referred to as TI Leads in the current document.

Epistemic Uncertainty Consultant (EUC)

The Epistemic Uncertainty Consultant (EUC) works directly with the TI team. The EUC will provide the TI team with a new tool to support their assessment and quantification of the epistemic uncertainty captured by the logic trees.

Hazard Feedback Analysts

The Hazard Feedback Analysts (HFAs) provide hazard feedback estimates. The goal of these analyses is to facilitate the systematic quantification of impact related to decisions made on parameters, models or specific logic tree weights. Two teams will contribute to hazard analyses results. A team composed of a USGS researcher, and a member of the TI team will be selected by the TI team to run the analyses and develop analysis tools for use by the TI team. The USGS will help with this task and provide the necessary software to conduct the analyses. Because it is anticipated that the USGS software may only include a simplified implementation of the CEUS SSC model, another team of external HFAs was selected to conduct additional analyses (Table 1) with the complete source model. This dual process will allow the TI team the flexibility to easily run regular analyses while the second set of analyses will ensure that the TI team conclusions are also consistent with the complete source model implementation.

Working Groups (WGs)

The NGA-East project includes seven WGs, each of which is focused on a specific technical area. The WGs were originally created to address the key technical issues identified in Bozorgnia (2008). The WGs are an essential part of NGA-East. They support the TI team by providing guidance on research needs and/or research products. Some research tasks are performed directly by the WG members while other tasks are performed by other researchers outside the WG. The WGs work closely with the TI team. Below is a short overview of the main tasks associated with each WG.

Database WG: develop an exhaustive database of recorded motions in CENA and other Stable Continental Regions (SCRs), with the associated metadata. The database will be used by most WGs and by the TI team.

Path/Source WG: develop regionalized models for correlated sets of source (stress-drop) and path parameters (attenuation and quality factor, Q).

Simulations WG: coordinate the validation and forward modeling of ground motion simulation, considering different methods for finite fault and point source simulations. Because simulations are important to achieving the project goals, the TI team assumes a very active role in the tasks related to the Simulations WG. The Simulations WG relies on input from the Database, Path/Source, and Geotechnical WGs.

Geotechnical WG: develop a simplified model to remove site effects at the recording stations, define the reference rock shear wave velocity and kappa values, and the range of conditions to which they apply. The Geotechnical WG is also tasked to develop a site effects model for NGA-East, but this task is not formally part of the SSHAC Level 3 process and is not discussed further.

Sigma WG: develop a suite of candidate standard deviation models for the project. This WG uses both recorded data and numerical simulations from CENA and Western U.S. (WUS) to develop the models. The Sigma WG tasks are integrated through both the NGA-East and the NGA-West2 projects.

Vertical Motions WG: develop models for V/H ratios to be applied to the horizontal ground motion models. This task is not part of the SSHAC Level 3 process, and is coordinated by PEER in conjunction with the NGA-West2 project.

GMPE Developers WG: develop candidate GMPEs for CENA. The members for this WG will be selected by an open request for proposals (RFP). This WG will work in close collaboration with the TI team who will evaluate the candidate GMPEs developed by the group and incorporate the selected models into the ground motion logic tree.

Sub-award Researchers and Contractors

This category represents researchers that will contribute data, models or methods outside of the working groups. Some of the contractors will be coordinated by WGs while others will be directly coordinated by the TI team. In the context of Figure 1, this category also represents the different Resource Experts that provide data, models or methods and the Proponent Experts as defined in the SSHAC assessment process documentation (SSHAC, 1997).

The NGA-East/CEUS SSC Model Interface Advisor (MIA)

The NGA-East/CEUS SSC MIA will ensure compatibility and consistency between the SSC and GMC models in terms of parameter definitions and ranges that link the seismic sources to the GMPEs.

4.2 Project Team, Lines of Communications and Points of Contacts

Efficient communication and timely transfer of information is critical to the success of NGA-East. The flow of information in the project is shown on Figure 1, and the list of core participants is provided in Table 1. The points of contact for the different groups and entities are highlighted in yellow in Table 1. The PM is to be copied on all correspondence and work products. The PM is the point of contact for the JMC and the main point of contact between the PPRP, the TI team and the JMC. To streamline the flow of information between groups, communications should be done primarily through the points of contact highlighted in Table 1. In instances where two chairpersons or points of contact are listed for a group, both should be included in the correspondence.

The PM, with the assistance of the TI team, is to inform the JMC and the PPRP of process and technical developments. The TI Team Leads (e.g., co-chairs) are responsible to make sure that all the technical participants (TI team, HFAs, MIA, WGs, sub-award researchers and contractors) have the required information to support the project. The TI team, with input from the whole project team, is responsible for identifying and providing invitations to the resource and proponent experts proposed for the workshops Project-wide e-mail distributions are to be coordinated by the PM and the TI Leads to be channeled through the PEER staff.

Table 1. NGA-East project team and points of contact (group chairs are the points of contact for each group and are highlighted in yellow).

Committee or Group	Members			
	Name	Last Name	Organization	e-mail
Project Manager (PM)	Yousef	Bozorgnia	PEER, UC Berkeley	yousef@berkeley.edu
Joint Management Committee (JMC)	Annie	Kammerer	NRC	annie.kammerer@nrc.gov
	Mark	Petersen	USGS, Denver	mpetersen@usgs.gov
	Lawrence	Salomone	EPRI	lawrence.salomone@srs.gov
	Steve	McDuffie	DOE	Stephen.McDuffie@RL.Doe.Gov
SSHAC Guidelines Process Manager (SGPM)	Annie	Kammerer	NRC	annie.kammerer@nrc.gov
NGA-East/CEU SSC Model Interface Advisor (MIA)	Kevin	Coppersmith	Coppersmith Consulting, Inc.	kcoppersmith@earthlink.net
Technical Integrator Team (TI)	Norman	Abrahamson	UC Berkeley	abrahamson@berkeley.edu
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	Gail	Atkinson	Univ. of Western Ontario	Gmatkinson@aol.com
	Robert	Graves	USGS, Pasadena	rwgraves@usgs.gov
	Eric	Thompson	Tufts Univ.	eric.thompson@tufts.edu
Epistemic Uncertainty Consultant (EUC)	Frank	Scherbaum	Univ. of Potsdam	fs@geo.uni-potsdam.de
Hazard Feedback Analysts (HFAs)	Gabriel	Toro	Risk Engineering, Inc.	toro@riskeng.com
	Robin	McGuire	Risk Engineering, Inc.	mcguire@riskeng.com
Participatory Peer Review Panel (PPRP)	Julian	Bommer	Imperial College	j.bommer@imperial.ac.uk
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	Jeff	Kimball	National Nuc. Security Admin.	JeffreyK@DNFSB.GOV
	Rich	Lee	Los Alamos National Lab	rclee@lanl.gov
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	Gabriel	Toro	Risk Engineering, Inc.	toro@riskeng.com
	David	Boore	USGS, Menlo Park	boore@usgs.gov
	Kenneth	Campbell	EQECAT, Inc.	KCampbell@eqecat.com
	Chris	Cramer	Univ. of Memphis	ccramer@memphis.edu
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	Walt	Silva	Pacific Engineering, Inc.	pacificengineering@juno.com
	Jonathan	Stewart	Univ. of California - Los Angeles	jstewart@seas.ucla.edu
GMPE Working Group	Members to be defined by RFP			
Path/Source Working Group	Martin	Chapman	Virginia Tech.	mcc@vt.edu
	Gail	Atkinson	Univ. of Western Ontario	Gmatkinson@aol.com
	Dave	Boore	USGS, Menlo Park	boore@usgs.gov
	Kenneth	Campbell	EQECAT, Inc.	KCampbell@eqecat.com
	Robert	Herrmann	Saint Louis Univ.	rbh@eas.slu.edu
	Shahram	Pezeshk	Univ. of Memphis	spezeshk@memphis.edu
	Walt	Silva	Pacific Engineering, Inc.	pacificengineering@juno.com
Sigma Working Group	Linda	Al Atik	PEER, UC Berkeley	l_atik@berkeley.edu
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	Brian	Chiou	Caltrans	Brian_Chiou@dot.ca.gov
	Ellen	Rathje	Univ. of Texas - Austin	e.rathje@mail.utexas.edu
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	Melanie	Walling	USGS, Golden	mwalling@usgs.gov
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	Norman	Abrahamson	UC Berkeley	abrahamson@berkeley.edu
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	Yousef	Bozorgnia	PEER, UC Berkeley	yousef@berkeley.edu
	Walt	Silva	Pacific Engineering, Inc.	pacificengineering@juno.com

5. TECHNICAL WORK PLAN

NGA-East is focused on development of the next generation GMPEs, as opposed to producing the next incremental GMC model update. The project plan was designed to allow a reassessment of all key issues that form the technical basis for GMPE development, without being tied to past decisions.

The SSHAC Level 3 objectives are addressed by 12 groups of tasks, labeled from A to M (Figures 2 and 3). The groups of tasks are divided into main numbered tasks as shown on Figure 3. Section 5.1 focuses on a global presentation of the groups of tasks (Figure 2) while Section 5.2 goes into more details on the key numbered tasks and their relationships (Figure 3). Many of the numbered tasks are composed of intermediate subtasks that the WG chairs and/or the TI team use to monitor the progress of the main tasks and to manage the project. For brevity, these detailed subtasks are not presented here.

The workflow converges to the final products being developed by the TI team: the GMPE logic trees for the median and standard deviation (sigma) models. The planned approach is described below. The proposed approach may need to be revised based on the results or budget constraints.

5.1 Summary of General TI Team Approach

The TI team plans to use point-source stochastic simulations (Figure 2, box G) as the primary tool for developing median rock GMPEs (H). This will require the development of new general point-source models (F) for this task (the source spectrum is expected to be a double-corner model). Recorded data (A) will be corrected to rock conditions (B) for their use in most tasks shown on Figures 2 and 3. Recorded data from CENA (A) will be used to evaluate the regional characteristics of ground motion attenuation (C) and to define source and path parameters (D). Results from these two tasks will allow the definition of CENA-specific input parameters for the point-source models (G). The plan is to constrain the lower and higher frequency range ordinates of the point-source spectra using finite-fault simulation results (E) and recorded data (A) in conjunction with source information (D) respectively. Because finite-fault simulations are resource intensive, the plan is to use them for low frequencies only (less than 1 Hz), for which they are the most reliable. The suite of GMPEs developed by the TI team will be complemented by a second set developed by the GMPE WG (H).

The plan is to develop the standard deviation (sigma) models (J) independently from the median models. The primary approach consists in using well-constrained sigma models for WUS and adjusting them as needed to be applicable to CENA. Standard deviations from both recorded data and numerical simulations will be used to evaluate the applicability of WUS standard deviation models to CENA.

The TI team will assemble the median GMPEs and standard deviation models into logic trees (L), which constitute the final products of the project. The ground motion models (logic tree branches) will also be tested (I) against available intensity and paleoliquefaction data from large earthquakes in CENA and by a set of key records from CENA and other SCRs to check that the candidate GMPE models are not inconsistent with the range of ground motions implied by these data sets. Epistemic uncertainty of the GMPEs will also be formally evaluated (K). A useful tool in this evaluation is the new methodology being developed by Prof. Frank Scherbaum, which is based on a visualization technique involving Self-Organizing Maps (SOMs).

The Hazard Feedback Analysis (task M) is performed throughout the project, at points when critical decisions need to be made, and is coordinated by the TI team. Task M helps in defining what parameter or model is important to the ground motion hazard and where resources should be spent in model refinement. A separate box is shown in Figures 2 and 3, but for readability reasons, no arrows are shown pointing to this box. Hazard feedback analyses are to be presented at each SSHAC workshop (Section 6) to keep the discussion focused on hazard-relevant issues.

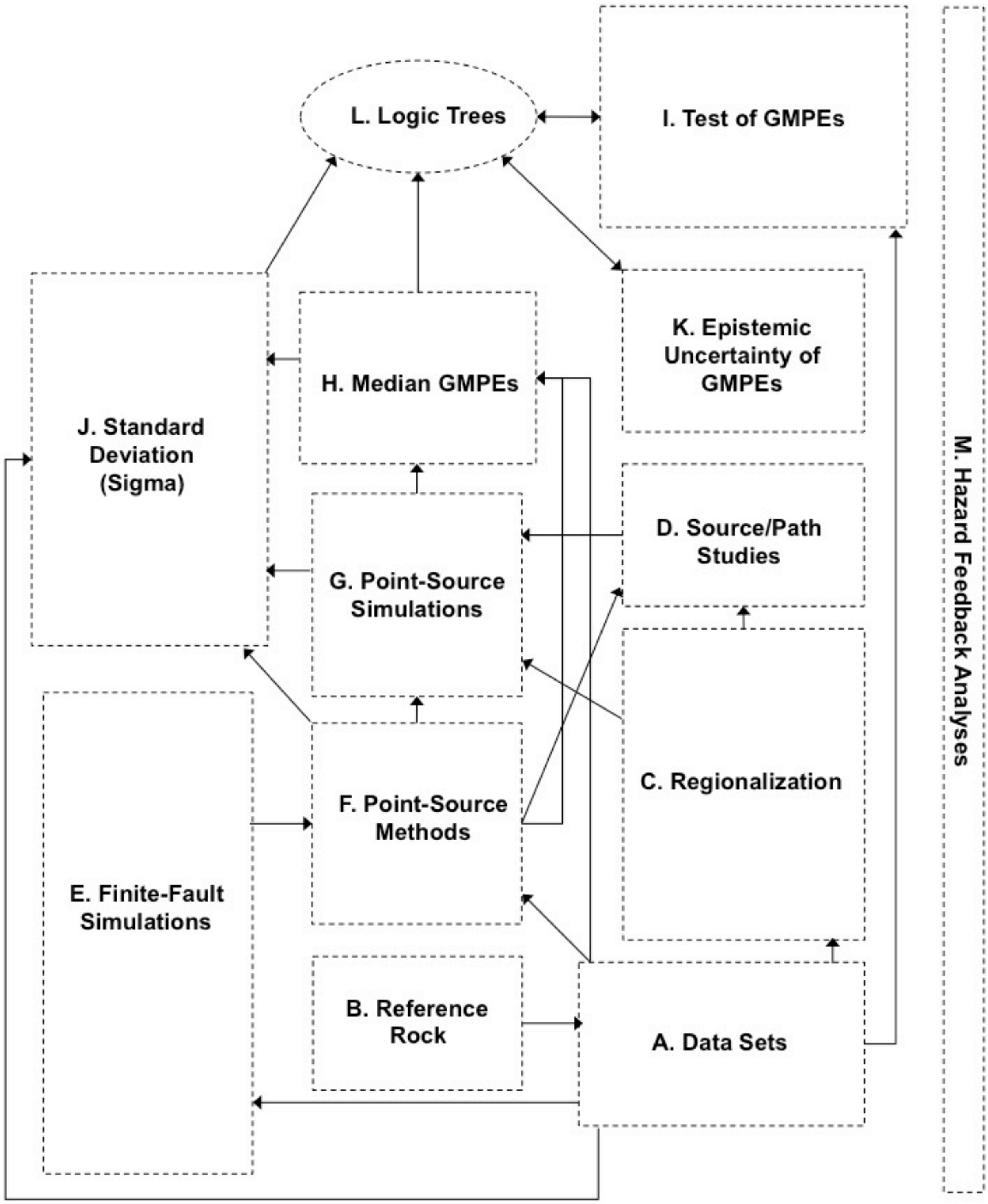

Figure 2. NGA-East tasks, simplified flowchart showing task groups.

5.2 Description of Tasks

The main tasks shown in Figure 3 are described below and the appropriate task identifier is shown in parenthesis in the text (e.g. A.1 refers to the CENA Database). The key objectives related to each group of tasks are also listed below. The tasks use a combination of open RFPs and directed work by the WGs or to sub-awards researchers and contractors.

Tasks in groups C through H are essentially part of the median GMPE development while task J is the only group for the development of standard deviation models. This representation should not impress on the reader that the standard deviation models are less important in the NGA-East scope. The tasks in group J are more self-contained and were combined to allow the global project representation shown in Figure 3.

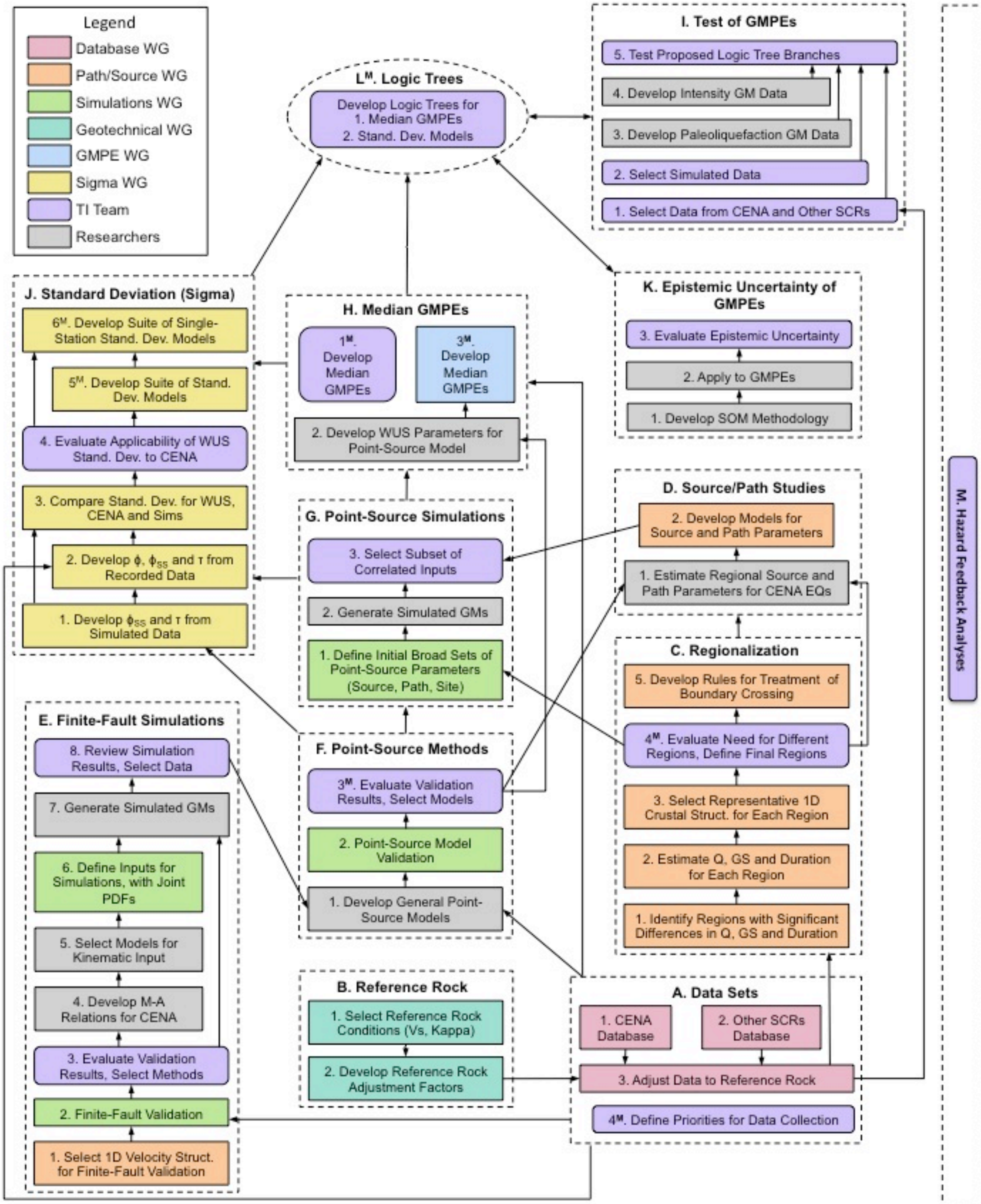

Figure 3. NGA-East tasks flowchart. "M" superscripts refer to tasks associated with HFAs.

A. Data Sets

Objective:

- *To develop earthquake databases (with metadata) for CENA and other SCRs.*

As part of NGA-East, two new earthquake record databases will be developed (for CENA and other SCRs). Data collection includes the reviewing and processing of earthquake recordings from stations on various site conditions (rock and soil) and also includes the compilation of available metadata into a flatfile (magnitude, distance, site conditions, etc.). The Database WG is responsible for developing the CENA ground motion database (Task A.1). The ground motions will be adjusted to the reference rock conditions using the scale factors provided by the Geotechnical WG (B.2 and A.3). The site-corrected data are provided to the Path/Source WG for evaluation of the need for regionalizing the ground motion attenuation (C.1).

An interface issue between the CEUS SSC and NGA-East project is the earthquake magnitudes. The GMPEs will be based on moment magnitude. If magnitude conversions to moment magnitude are required for the older earthquakes, then the conversions need to be consistent between the CEUS SSC and NGA-East data sets.

The Database WG will also compile additional key ground motion data from other SCRs (A.2) to the extent that there are sufficient metadata available to make these data useful. A subset of the other SCRs' data will be used as checks on the GMPEs in task I.1. Database development for active tectonic regions (also referred to as the WUS database) is outside the scope of NGA-East.

The Simulations WG will select subsets of recorded data to be used for the simulation method validations (E.2 for finite-fault and F.2 for point-source models). The recorded data sets will be used by the GMPE developers in Task H and by the Sigma WG for Task J.2.

The TI team is responsible for defining priorities for further collection of data (A.4), based on the project needs.

B. Reference Rock

Objectives:

- *To select the reference rock conditions to be used for simulations and GMPE development.*
- *To develop amplification factors or models to be used to remove site effects at recording stations.*

The Geotechnical WG is responsible for selecting the center, body and range of the shear-wave velocity and kappa of the reference rock to be used for the GMPEs and simulations (B.1). This task involves the analysis of recorded data for CENA, coming both from the A task and from additional gathering of data. The Geotechnical WG will also develop a simple method for adjusting the recordings in the CENA database to the reference rock conditions (B.2). Task B.2 involves a preliminary and a final model. The site-corrected data are provided to the Path/Source WG for evaluation of the need for regionalizing the ground motion attenuation (C.1). Given the tight schedule, task C.1 will use the preliminary version of the site correction factors developed in collaboration with the TI team. Task I.1 will use the site-corrected records (final site correction for CENA records and using a simplified correction for other SCRs).

C. Regionalization

Objectives:

- *To define a small number of discrete crustal regions (with associated attenuation parameter values) to capture essential differences in distance attenuation that affect ground motions.*
- *To develop rules for computing ground motions when paths cross regions.*

The Path/Source WG will evaluate the CENA data to identify regions that have significant differences in the ground motion attenuation (e.g., regions that require different GMPEs) in task C.1. As mentioned above, task C.1 will use site-corrected records from tasks A.3 and B.2. Tasks C.2, C.3 and C.5 will also be completed by the Path/Source WG. Task C.2 will focus on defining the appropriate values of Q, geometrical spreading and duration for each of the regions defined in C.1. Task C.3 involves the selection of representative 1D crustal velocity structure for each of the regions defined in C.1

The TI team will make the final decision on the number of separate regions considering the trade-off between simplicity (fewer regions) and the accuracy of GMPEs that most affect the hazard at CENA sites (task C.4, which requires HFA).

Task C.5 involves the development of a set of rules for the treatment of region boundary crossings (source in one region and ground motion estimates in another).

D. Path/Source Studies

Objective:

- *To develop regional models for source and path parameters that include the correlation between parameters.*

Source/Path Studies tasks (D.1 and D.2) are needed to define the subset of point-source simulations that will be used in the GMPE development (G.3). Task D.1 draws from task C.4 and from the Point Source Model Validation results (F.2) to estimate the regional source and path parameters for CENA earthquakes. This task will be performed by targeted researchers and involves the estimation of parameter values and their distribution, but also the evaluation of the correlation between the parameters. The researchers developing the double-corner models will participate actively in the development of parameter correlation models so that they are consistent with the software/code they use in task F.1. The Path/Source WG will then develop models for the source and path parameters developed in D.1.

E. Finite-Fault Simulations

Objective:

- *To develop a database of low frequency simulated ground motions to supplement the recorded data for CENA using finite-fault models.*

The main use of the finite-fault simulations is to guide the development of the general double-corner model and to constrain the scaling of the low frequency behavior for earthquake events not represented in the database (e.g. large magnitudes). The Simulations WG is responsible for selecting the methods for validation (task E.2, selection through RFP) and for developing the validation requirements, in collaboration with the TI team. Additional selected methods developed by USGS researchers will be validated as well and considered for use in forward simulations. As part of E.2, the WG will also evaluate the finite-fault methods based on the validations (pass/fail). The TI team will review the WG recommendations and make the final decision as to which model(s) will be applied in the forward simulations (E.3).

The Simulations WG will coordinate the definition of the inputs for the selected finite-fault simulations. This includes the development of area-magnitude scaling relations for CENA (task E.4 to be completed by a researcher selected through RFP) and the selection of models for kinematic input (E.5 to be completed by a pre-identified researcher).

As part of task E.6, the Simulations WG will also define the cases for forward simulations (earthquake scenarios and station locations). The simulations will be completed in task E.7 by the researchers selected in task E.3. The Simulations WG will conduct initial reviews of the simulation results to compare the results from the different finite-fault modelers, identify areas with significant differences in the ground motions, and identify the causes of the differences in the ground motions. The results of that initial review phase will be presented for discussion at a workshop. The final review of the simulations results including recommendations on which results to use will be presented following the workshop. Although not formally shown in the figure, the TI team will work closely with the Simulations WG on tasks E.6 and E.8.

The suites of finite-fault simulations will be provided to the Point-Source Simulation Method tasks (F) for use in constraining the low frequency end of the source spectrum.

The finite-fault simulation results will also be compared to the GMPEs as a consistency check that the finite-fault effects were captured in the implemented general point-source model and carried through the GMPE development (I.2).

F. Point-Source Simulation Methods

Objective:

- *To develop new alternative generalized (double-corner) point-source simulation models using CENA data and the finite-fault simulation results to constrain the source spectrum.*

A pair of general (most likely double-corner) suites of models will be developed, one via a targeted proposal to pre-identified researchers and a second via RFP (task F.1). It will be important to ensure consistency in implementation of the models with derivation of various input parameters that feed them. For example, the specification of the source/path parameters is closely linked with how those parameters were determined in the Path/source WG studies. The models should be consistent with large magnitude data (from finite-fault simulations and WUS data). Single-corner point source models will be a special case of the general models. The Simulations WG will lead the effort for the validation (tasks F.2) in collaboration with the TI team. The TI team will review the simulation results and select the model to be used in the forward computations (F.3). This important task will use HFA results, as shown by the M superscript in Figure 3. Results from F.3 will be used in tasks D.1, H.1 and H. 3.

G. Point-Source Simulations

Objectives:

- *To develop a database of simulated ground motions to be used in GMPE development.*

The point-source simulations will be the main method for generating ground motion data for GMPE development. The first task (G.1) consists in the Simulations WG selecting broad sets of point source parameters. The goal of this task is to cast a net wide enough that it will include all the plausible combinations of input parameters in the generation of simulated ground motions (task G.2). This will create a large database of simulated ground motions and will prevent the need to go back and conduct additional simulations following the TI team evaluations. Task G.2 represents the actual simulations, to be completed by a contracted researcher. In task G.3, the TI team will select the subsets of input parameters that correspond to realistic combinations properly representing the correlation between the parameters. Only the ground motions from simulations using these combinations of parameters will be used in the GMPE development (H.1 and H.3). Task G.3 is dependent on the completion of task D.2.

H. Median GMPEs

Objectives:

- *To develop a set of median GMPEs using the simulated data set.*
- *To develop additional median candidate GMPEs using all the data available (recorded and simulated data).*

In task H.1, the TI team will develop a set of median GMPEs using the point source simulation results and conduct HFAs. To help capture the epistemic uncertainty associated with GMPE development, additional models will be developed outside of the TI team. An open RFP will be issued for the development of up to three alternative GMPEs based on different approaches (simulation-based and at least one hybrid model). The hybrid model consists of the revision of an existing GMPE developed for another region (WUS) that will be adjusted for CENA. For the hybrid model, the funded team(s) will need to identify the point source model parameters for WUS (task H.2) and CENA, to run the required simulations and to develop adjustment factors that account for source and path differences in the two tectonic regions. The selected researchers (also referred to as GMPE developers) will form the GMPE WG and will have access to all of the recorded data and numerical simulations and they will have the flexibility to select subsets of the available data. The GMPE development itself is done in task H.3. The median GMPEs from tasks H.1 and H.3 will be incorporated in the median logic tree (L.1) and tested in task I.

I. Test of GMPEs

Objectives:

- *To develop simple relationships to relate paleoliquefaction and intensity data to ground motion intensity measures.*
- *To evaluate the GMPEs developed in tasks H.1 and H.3 and J.5-6 against finite-fault simulations results, CENA and other SCRs data and the intensity measures associated with paleoliquefaction and intensity data.*

Four main sets of data will be used to evaluate the GMPEs developed in tasks H.1 and H.3 and J.5-6 against: 1) ground motion data from CENA and other SCRs (for large magnitudes not represented in the CENA database), 2) finite-fault simulation results and 3) liquefaction and 4) intensity data from past large CENA earthquakes. Given that some of the data has large inherent uncertainty, and that some data come from simulations and not observations, the goal of these tests is not to calibrate the GMPEs, but rather to check if the different data sets are consistent with the GMPEs. The ground motion data from CENA and other SCRs come directly from Data Sets tasks A.1 and A.2 (task I.1); the other SCRs data will mostly be used for large magnitude events not represented in the CENA database. The TI team will also use finite-fault simulation ground motions (I.2) to ensure that their properties have been carried through the GMPE development process. The paleoliquefaction data are expected to come directly from the CEUS SSC project, but will need to be associated with ground motion intensity measures (task I.3). A simple database of earthquake intensity will be developed by a contracted researcher, possibly from the USGS, who will also need to associate the intensity with ground motion intensity measures (task I.4). Finally, a member of the TI team will conduct the test of the GMPEs against these data to identify any inconsistency (I.5). The tests will be conducted at the logic tree level, but on single branches that combine the median and standard deviation models. The TI team will adjust the weights for the GMPEs as needed based on the test results (task L).

J. Sigma

Objective:

- *To develop suites of standard deviation models applicable to CENA for:*
    - *ergodic within-event standard deviation (Phi, ϕ)*
    - *single-station within-event standard deviation (Phi_{SS}, ϕ_{SS})*
    - *between-event standard deviation (Tau, τ)*

The standard deviation (sigma) of GMPEs has a strong influence on the results of PSHA. The present state-of-the-practice of seismic hazard studies applies the standard deviations from ground-motion models developed using a broad range of earthquakes, sites, and regions to analyze the hazard at a single site from a single small source region. This is referred to as the ergodic assumption. The most promising approach to reducing the aleatory sigma is identifying the components of ground motion variability at a single site that are repeatable and removing them from the aleatory variability. These repeatable components are then transferred to the quantification of the epistemic uncertainty. A standard deviation term for which the site effects are systematically removed from the variability is referred to as single-station sigma.

The main objectives of the Sigma WG are to evaluate the ergodic within-event standard deviation (Phi), the single-station within-event standard deviation (Phi_{SS}) and the between-event standard deviation (Tau) for CENA. These values will be compared to Phi, Phi_{SS} and Tau evaluated for WUS and other regions around the world (Mexico, Japan, Turkey, Taiwan, Switzerland, China and Australia). The final product of the Sigma WG is a suite of parametric ergodic and single-station sigma models. These variability models will be adopted by the NGA-East TI team and assigned weights in the standard deviation logic tree (task L).

The sigma models will be developed using simulated data and the WUS data, which are much more complete than for CENA (tasks J.1 and J.2 respectively). The WG will compare the ergodic sigma and single-station sigma from small magnitude earthquakes from CENA and WUS to determine the applicability of the models to CENA (J.3). The TI team will then formally evaluate the applicability of the models to CENA (J.4). If needed, adjustments will be made to the within-event and between-event standard deviation terms. Final models for ergodic (J.5) and single-station (J.6) standard deviations will be developed and incorporated in the sigma logic tree (task L.2).

K. Epistemic Uncertainty of GMPEs

Objective:

- *To evaluate the body of the distribution and making sure that the individual GMPEs collectively sample the epistemic uncertainty space.*

The TI team will systematically assess and quantify the epistemic uncertainty captured by the logic trees. The definition of the range of epistemic uncertainty to capture in the logic tree models will be defined by expert judgment of the TI team, with insight from the larger project team. A useful tool in the epistemic uncertainty evaluation is to use the new methodology introduced in Scherbaum et al. (2010). This tool will be further developed by the EUC for the project. The methodology is based on a visualization technique involving Self-Organizing Maps (SOMs). The SOM figures show the distribution and separation of the models in ground-motion space, and will aid the TI team in assessing the similarities or differences between models. This new method, as one possible tool, will be used applied to all the GMPEs developed in the project. The TI team will use these results to evaluate if the suite of GMPEs and weights in the logic tree are adequate. If needed, the logic tree will be modified and/or additional GMPEs will be proposed to better capture the epistemic uncertainty. If modifications are made, the evaluation of the epistemic uncertainty will be repeated.

L. Logic Trees

Objective:

- *To develop weights that capture the center, body and range of the technically defensible interpretations, as informed by the various tasks and by the hazard feedback analyses.*

The TI team is responsible for developing the GMPE logic trees. This final task combines all the products from the other NGA-East tasks and addresses the principal project objective. As mentioned above (task I), the branches of the logic trees will be tested against recorded and simulated data.

M. Hazard Feedback Analyses

Objective:

- *To conduct hazard sensitivity studies to assess the importance of factors, models and parameters that affect the ground motion hazard.*

HFAs represent a critical task that will ensure that the project team stays focused on issues that affect the ground motion hazard. The analyses essentially consist of a series of sensitivity studies on models and/or parameters used to develop the models. HFAs will be conducted throughout the project and key results will be presented at each workshop to help the project keep the focus on the key factors that control the hazard. As mentioned earlier, the TI team plans to use a dual approach for the HFAs. The TI team will coordinate with the USGS to use their implementation of the CEUS SSC model and run their own analyses. However, it is anticipated that the USGS software may only include a simplified implementation of the CEUS SSC model, and a second team of external HFAs was selected to conduct additional analyses (Table 1) with the complete source model. This dual process will allow the TI team the flexibility to easily run regular analyses while the second set of analyses will ensure that the TI team conclusions are also consistent with the complete source model implementation.

The hazard feedback for GMPEs needs to consider the magnitude and distance contributions from the different tectonic environments in CENA. The plan is to coordinate with the CEUS SSC project and possibly include the seven test sites that were used for the CEUS SSC hazard feedback. The seven sites were previously selected by the CEUS SSC to capture the range of tectonic environments and are appropriate for use in the ground motion hazard feedback. The goal is to use the sites to illustrate the relative importance of various components of the GMC model to seismic hazard. The final site selection will also depend on the regionalization models selected.

As mentioned above, the HFAs will be conducted regularly and presented at the workshops. An "M" superscript is shown next to the key tasks where HFAs are anticipated (Figure 3). This list of tasks is not exhaustive and the need for HFAs will be regularly re-assessed by the TI team throughout the project.

5.3 Documentation

A critical task is the project documentation, which is vital to the successful completion of any project. The need for comprehensive documentation is especially important for studies conducted within the regulatory arena. The SSHAC guidelines document devotes a full chapter on the type and required level of documentation (SSHAC, 1997).

In a SSHAC Level 3 assessment project, the TI team is responsible for the documentation of the technical bases for accepting, rejecting and assigning weights to models. Because of the project complexity and breadth of topics, the WG Chairs will support the TI team by developing the documentation of intermediate products and by performing the integration in the project timeframe. Therefore, each WG Chair will ensure the documentation related to their group's specific activities is complete. A researcher assigned by the TI team will help the WG Chairs and individual sub-award researchers and contractors for the documentation tasks. As stated earlier, the TI team is responsible to ensure that the documentation is complete and will work closely with the WG Chairs and the SGPM to ensure that the level and type of documentation is consistent with that of a SSHAC Level 3 assessment project. It is anticipated that the documentation of the CEUS SSC project (also a SSHAC Level 3 assessment project) will serve as an example and template for the NGA-East documentation. The PPRP, through their review of intermediate documents produced by the project team, will also play an instrumental role in achieving the proper level of documentation. The approval of the final report by the PPRP will signify that the documentation goal was achieved.

The project documentation is expected to include the following items (also shown is the entity supporting the TI Team in the documentation development):

- Project plan - TI team and PM
- Summary table (as appropriate) for NGA-East data for CENA and other SCRs - Database WG
- Evaluation table (as appropriate) for NGA-East data for CENA and other SCRs - All users of data
- Project parameter and acronym glossary, including definitions of terminology used for the various components of uncertainty - SGPM
- Project final report that includes full project information from the final version of the project plan and (all by TI team unless stated otherwise)
    - SSHAC Workshop summaries, including slides and videos
    - Other workshops and working meeting summaries (including WG meetings)
    - Description of the complete technical bases for the GMPEs developed - GMPE WG and TI team
    - PPRP letters and final report - PPRP
    - Hazard Input Document providing the final logic tree and application recommendations for critical facilities
    - NGA-East database of earthquake recordings, including waveforms, flat file and metadata, and report on how the database was developed.

The documentation should achieve the following:

- Allow the reader to fully understand the project objectives, technical approaches and activities, data sets, participants, and results.
- Provide a clear and complete description of the technical basis for all GMPEs, their associated uncertainties, and their ultimate weights provided in the final project model and guidance.
- Document that all relevant data/information/models that were reviewed and incorporated or not into the assessment and the reasons for inclusion or exclusion.
- Lead to transparency, openness, and communication with the public and other stakeholders.

6. WORKSHOPS

6.1 SSHAC Workshops

This section focuses on the "SSHAC workshops", which are different from other working meetings or public workshops already held during the project (Section 6.2). Workshops play a vital role in the SSHAC Level 3 assessment process. The SSHAC workshops provide opportunities for key interactions to occur; for models and interpretations to be presented, debated, and defended; and for sponsors and reviewers to observe and comment on the progress being made on the study. For a SSHAC Level 3 assessment process, there are three mandatory SSHAC workshops or workshop themes, each serving a specific purpose. The objectives and goals of each SSHAC workshop are briefly described below for convenience. Refer to the SSHAC (1997) original document and to U.S. NRC (2011, in prep.) for more details.

The TI Leads with input from the PM and PPRP are responsible for preparing the workshop agendas, for inviting the relevant resource and proponent experts and for leading the workshops. Each workshop should begin with a clear definition of the goals of the workshop, an explanation for the process that will be followed, and a definition of the roles of those who attend.

The text below refers to the project key technical issues. As mentioned above, these key technical issues were first highlighted in the “Roadmap” document (Bozorgnia, 2008) that was prepared in the development of the NGA-East project (before the SSHAC Level 3 designation). These issues were organized into the seven categories that led to the formation of the WGs. The key remaining issues are identified by the WGs and the TI team in the course of the project and summarized at the SSHAC Workshops by the TI team. The list of technical issues is to be circulated in the form of a draft agenda three months before each workshop along with the list of identified participants (Resource and Proponent Experts) for each topic.

First and foremost, the workshops are held to provide information to assist the TI team and the project team in their technical assessments. Workshop attendees presenting and/or involved in discussions with the TI team include members of the WGs and additional invited Resource Experts or Proponent Experts, as per SSHAC (1997). Other technical attendees, such as the PM or members of the PPRP and JMC may pose questions if doing so will clarify the discussions. The PPRP will provide preliminary observations to the TI Team, PM and JMC after each day of each workshop. All other workshop attendees are “observers”. The workshops will be open to the public and videos of the presentations and discussions will be posted on the PEER website following each workshop.

SSHAC Workshop Themes

The required SSHAC workshops are organized into three themes that are summarized here for convenience. The term "theme" is used because the NGA-East SSHAC workshops may cover more than a single SSHAC workshop element.

Workshop Theme 1 - Significant Issues and Data Needs

The goals of this workshop are: 1) to identify the technical issues of highest significance to the hazard analysis, and 2) to identify the available data and information that will be needed to address those issues. The discussions of the available data should be made by a series of presentations by resource experts who have developed specific data sets.

From the standpoint of the SSHAC assessment process, the evaluation of the data for use in the hazard analyses is led by the TI team. In the case of the NGA-East project, a significant amount of technical development work is required and is being lead by the WGs. As a result, the WGs will support the TI team by performing a number of critical evaluations and proposing a variety of technical choices.

Workshop Theme 2 - Proponent Discussions of Alternative Interpretations

The goals of Workshop 2 are: 1) to present, discuss, and debate alternative viewpoints regarding key technical issues; 2) to identify the technical bases for the alternative hypotheses and to discuss the associated uncertainties; and 3) to provide a basis for the subsequent development of preliminary hazard models that consider these alternative viewpoints. The workshop also provides an opportunity to review the progress being made on the database development and to elicit additional input, as needed, regarding this activity.

A key attribute of this workshop is the discussion and debate of the merits of alternative viewpoints regarding key technical issues. Proponents and Resource Experts (see role definitions in SSHAC, 1997) will present their interpretations and the data supporting them. Alternative viewpoints will be juxtaposed and facilitated discussions will be focused on implications to the inputs to the hazard analysis (not just on scientific viability) and on uncertainties (e.g., what conceptual models would capture the range of interpretations and what weights should be applied). The Proponent Experts need to be prepared to discuss the uncertainties in their interpretations, the strengths and weaknesses in their arguments, and their view of where their interpretations lie with regard to the larger technical community. When organizing the proponent workshops, the TI Leads will circulate the proposed list of participants to ensure that the agenda incorporates all viable views and hypotheses. Individuals who may not be present at the workshops will be identified so that their interpretations are presented and considered.

Workshop Theme 3 – Presentation and Feedback on Proposed Models

Typically following the workshop (or workshops) focused on proponent discussions of alternative interpretations, the TI team members develop their preliminary models, and preliminary calculations and sensitivity analyses are conducted. The goal of Workshop 3 is to present and discuss the preliminary models and calculations in a forum that provides the opportunity for feedback to the TI team. Feedback can be given in the form of input by technical specialists or in the form of hazard results and sensitivity analyses to shed light on the most important technical issues. The feedback gained at this workshop will ensure that no significant issues have been overlooked and will allow the TI team to understand the relative importance of their models, uncertainties, and assessments of weights. At this time, the PPRP will be invited to interrogate the TI team on the models and weights they are proposing. This information will provide a basis for the finalization of the models following the workshop.

The workshop typically consists principally of the TI team presenting their preliminary models, with particular emphasis on the manner in which alternative viewpoints and uncertainties have been captured. The technical bases for the assessments and weights will be described to allow for a reasoned discussion of the constraints provided by the available data. The invited experts will be responsible to question and probe aspects of the preliminary model to understand the manner in which the range of technically defensible interpretations has been captured.

Planned SSHAC Workshops

A total of five workshops are planned. A preliminary list of topics for each workshop is presented below (the associate task identifiers are shown in parentheses when applicable). Additionally, at each workshop, the TI team plans to:

- Review the scope of the workshop, clearly explain the participants' roles and workshop rules and include a warning regarding the dangers of cognitive biases
- Present and overview of the project objectives and tasks (e.g. Figure 3) and give an update on progress
- Address relevant remaining critical issues and data needs
- Present relevant hazard feedback analyses results

<u>*Workshop 1 – Critical Issues and Data Needs (November 15-18 2010)*</u>

SSHAC Workshop theme 1

Presentation of known critical issues and data needs and working group proposals to address needs:

- Overview of critical issues and interface issues identified by the TI team
- Review of the preliminary recorded ground motion databases for CENA and other SCRs, discussion of additional available data and discussion on prioritizing further data needs (A.1-2)
- Presentation of available site profile data for CENA (B.1-2)
- Presentation of reference rock definition (shear wave velocity and kappa) and available data sources (B.1)
- Presentation of issues with point-source models (single Vs double corner(s), large magnitude, frequency related issues) and past validation results (F)
- Presentation of available and considered models for finite fault simulations (E)
- Presentation of current knowledge on regionalization of 1D crustal structures and Q and discussion of critical issues for use as input in finite fault simulations (C, E.1)
- Presentation on alternative regionalization of geometrical spreading and Q for point source simulations (C)
- Discussion of range of input stress drops and correlation of input parameters for point source simulation (C, E)
- Overview of alternative methods of generating finite source inputs (E)
- Presentation of the Sigma WG plan (J)
- Identification of other critical issues and data needs

Workshop 2 – Proponent Discussions (October 11-13 2011)

SSHAC Workshop themes 1 and 2, with focus on theme 2

- Review of action items and progress from Workshop 1
- Overview of remaining critical issues and interface issues identified by the TI team
- Presentation of selection and discussion of proposed sites for hazard feedback analyses (M)
- Presentation of hazard feedback analyses results using existing GMPEs with the CEUS SSC model
- Review of the final recorded ground motion databases for CENA and other SCRs, discussion of additional available data and discussion on prioritizing further data needs (A.1-2)
- Presentation of final reference rock definition (shear wave velocity and kappa) (B.1)
- Presentation of simplified (prelim.) and final site amplification factor models applied to CENA and other SCRs records (B.2)
- Presentation of final simulation validation results for finite fault simulations (E.2), including validation protocol
- Presentation of plan for development of alternative point-source simulation methods and review of critical issues (F.1)
- Overview and proponent discussions on regionalization issues (C and E.1):
  - regionalization model for Q, geometrical spreading and duration (C.1)
  - estimation of Q, geometrical spreading and duration for identified regions (C.2)
  - 1D velocity structure for finite fault simulations (E.1)
  - preliminary selection of 1D velocity structure for each region (C.3)
- Overview and proponent discussions on finite fault simulations (E):
  - magnitude-area relationships for CENA (E.4)
  - models for kinematic input (E.5)
  - community distribution (center, body and range) for input to finite fault simulations (E.6)
  - finite fault models to generate simulated data (E.7)
- Proponent discussions on community distribution (center, body and range) for point source model parameters based on technical basis and input developed by working groups (G.1)
- Proponent discussions on range of GMPE approaches to appropriately capture uncertainty (H)
- Proponent discussions on GMPE approaches (hybrid and empirical) and their development (H.2-3)
- Presentation of Sigma WG plan and proponent discussion on alternative approaches (J)

- Presentation of TI team plan to select final regionalization model (C.4)
- Presentation and proponent discussion for regional source and path parameters (D.1)
- Presentation of preliminary results for cross-boundary rules (D.2)
- Presentation of preliminary plan for point source simulation validations (F.2)
- Review of plan and critical issues for testing of GMPEs (I.1-5)

Workshop 3 – Proponent Discussions and Feedback Analyses (October 2012, exact dates to be determined later)

SSHAC Workshop themes 1, 2 and 3, with focus on theme 2

- Review of action items and progress from Workshop 2
- Overview of remaining critical issues and interface issues identified by the TI team
- Presentation of hazard feedback analyses results using existing GMPEs with the CEUS SSC model for issues and parameters identified by the TI team and the WGs
- Presentation of preliminary hazard feedback analyses for GMPEs under development by TI team (H.1)
- Presentation and proponent discussions of final finite fault simulations results (E.8)
- Presentation of plan and approach for developing cross-boundary rules (D.2)
- Presentation and proponent discussion of
    - point source simulation methods (F.1, F.3)
    - point source validation protocol (F.2)
- Proponent discussions on GMPE approaches (H.1 and H.3)
- Presentation and proponent discussion on the testing of GMPEs (I.1-5), focusing on the development of ground motion intensity parameters for paleoliquefaction and intensity data
- Presentation on the development (K.1) and planned use (K.2-3) of the SOM tool
- Presentation of draft of initial logic tree structure (L) by the TI team

Workshop 4 – Presentation of Median and Standard Deviation GMPE Models, Preliminary Logic Trees and Feedback Analyses (September 2013, exact dates to be determined later)

SSHAC Workshop themes 2 and 3

- Review of action items and progress from Workshop 3
- Presentation of hazard feedback analyses results using existing GMPEs with the CEUS SSC model for issues and parameters identified by the TI team and the WGs
- Presentation and proponent discussion of final point source simulation results and final finite source simulation results (E.7, G.2-3), with focus on G.3 (appropriate subset of correlated input parameters)
- Comparison and discussion of point source and finite fault source results, including development of technical approach to explain differences, if necessary

- Proponent discussion of modeling uncertainties and sensitivity to parametric uncertainties in point source simulations (G)
- Proponent discussion
    - of technical basis for alternate GMPEs (medians) by the GMPE development teams (H)
    - alternate sigma models by Sigma WG (J)
- Presentation of draft weighted logic tree structure (L) by the TI team, discussion of logic tree branches
- Presentation of Hazard feedback using CEUS SSC source characterization model at selected sites

Workshop 5 – Presentation and Discussion of Weighted Logic Tree Models (April 2014, exact dates to be determined)

SSHAC Workshop theme 3

- Presentation and discussion of revised weighted model by TI team
- Presentation of updated hazard feedback results

6.2 Other Workshops and Working Meetings

In the NGA-East project, several working meetings will be held by the different WGs. The objective of these meetings is to assure that the project has sufficient opportunities to capture the full range of viewpoints in the technical community. Unlike the SSHAC Workshops, the purpose and scope of these working meetings is not described in the SSHAC guidelines. In these less formal meetings, a wider group of researchers and experts will openly discuss data and technical issues. It is expected that these meetings will significantly contribute to the technical advancement of the project. The WG members will summarize and present the key points from these meetings and discussions at the SSHAC workshops.

7. SCHEDULE

The deadlines for the main tasks are shown graphically on Figure 4, which completely parallels Figure 3 for quick reference. Figure 5 presents the same information in a different format with the addition of the SSHAC Workshop dates (e.g. WS 1 refers to the November 2010 workshop, as identified in Section 6.1).

The deadlines represent the time at which the products are handed off to the TI team for review and/or to be distributed to other groups. Ideally, most tasks should be performed sequentially, but the tight schedule requires that in some instances, a preliminary version of the work be used as the hand-off to another task (e.g. for task B.2, the preliminary version of the site factors are used in tasks A.3 and C.1). Some tasks require a review from either the WG or the TI team (e.g. task E.8). For these tasks, two deadlines are shown on Figure 5: one for the preliminary version and one for the final version of the product (identified by P and F). The shown deliverable dates correspond to the end of month (for example, the preliminary model from task B.1 was delivered as planned by the end of January 2011). The planned schedule is directly linked to, and influenced by, available long-term and short-term funding from sponsoring agencies.

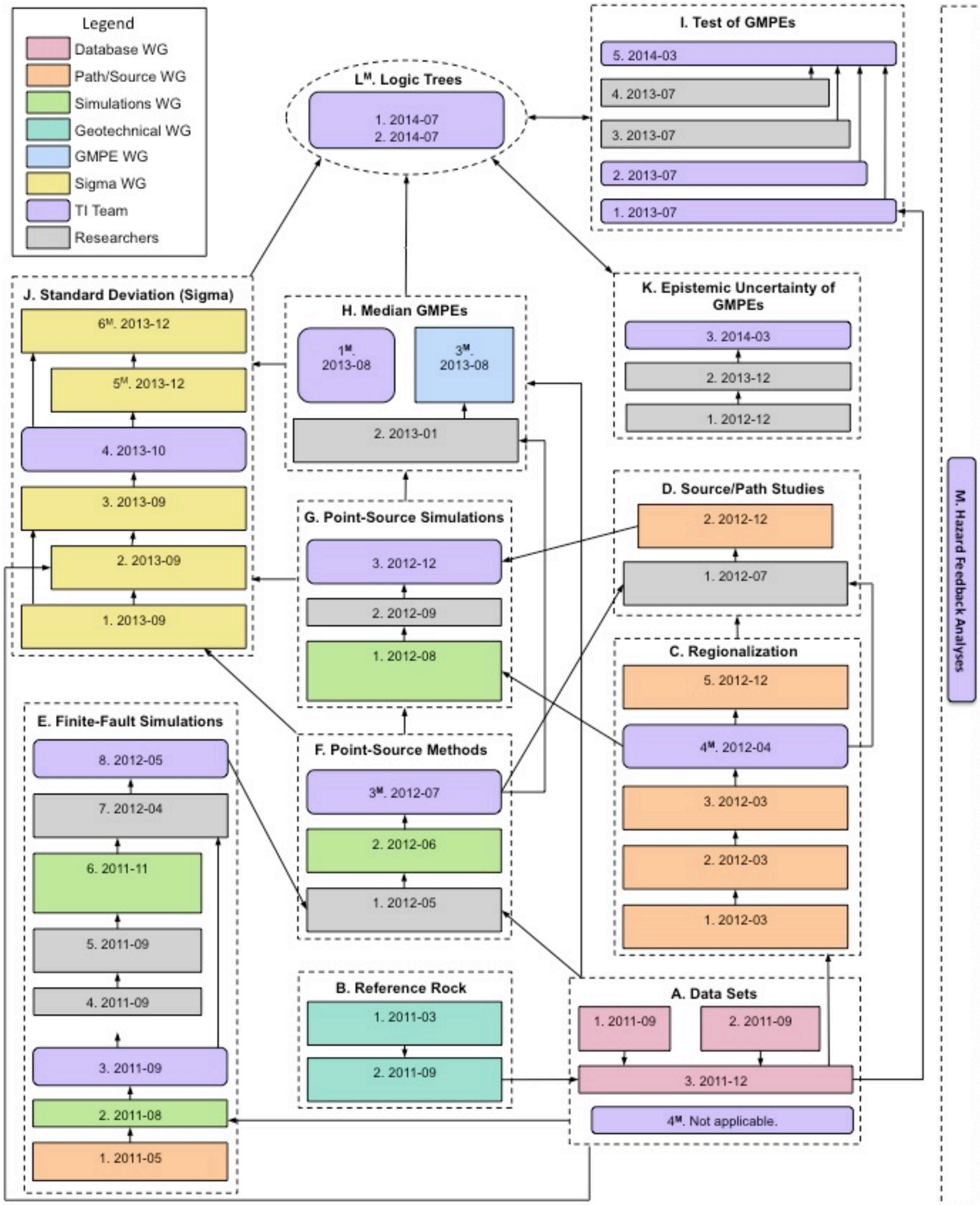

Figure 4. NGA-East schematic schedule (see Figure 3 for task definitions). Dates shown correspond to final product deliverables.

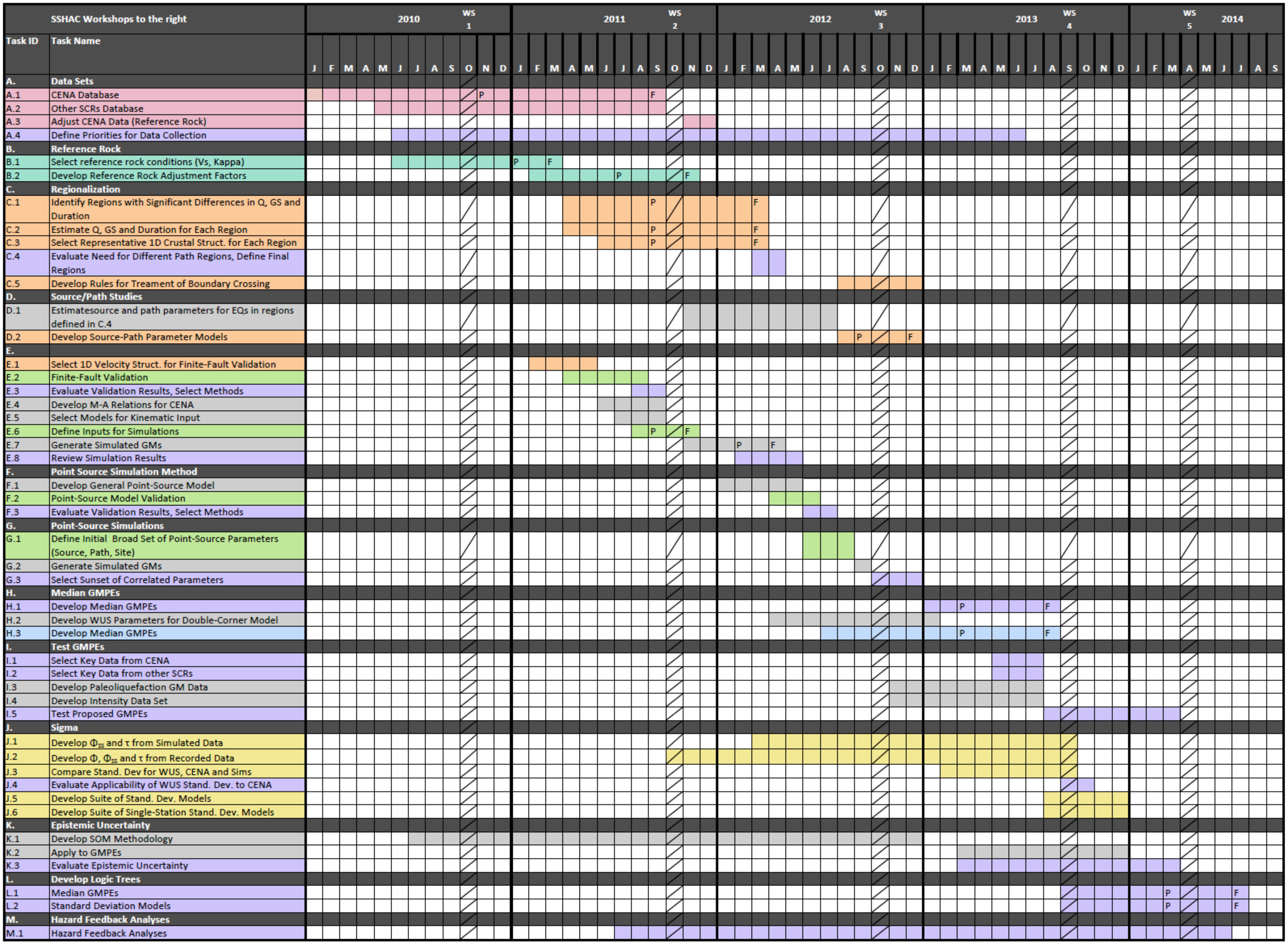

Figure 5. NGA-East tasks schedule. P and F refer to Preliminary and Final results respectively.

8. REFERENCES

Bozorgnia, Y. (2008), "A Roadmap for the Next Generation Attenuation Models for Central & Eastern North America (NGA-East)," PEER letter report to the U.S. NRC.

Coppersmith, K.J. and Salomone, L.A. (2008), "Project Plan: Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," EPRI Report 1016756. [Publically available at www.epri.com]

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Power, M., Chiou, B., Abrahamson, N., Bozorgnia, Y., Shantz, T., and Roblee, C. (2008), "An Overview of the NGA Project," Earthquake Spectra, Vol. 24, No. 1, pp. 3-21.

Scherbaum, F., Kuehn, N. , Ohrnberger, M. and A. Koehler (2010), "Exploring the Proximity of Ground-Motion Models Using High-Dimensional Visualization Techniques," Earthquake Spectra, Vol. 26, No. 4, pp. 1117-1138.

Senior Seismic Hazard Analysis Committee (SSHAC). (1997). "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," U.S. Nuclear Regulatory Commission Report, NUREG/CR-6372.

U.S. NRC (2011, in prep.) "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies," U.S. Nuclear Regulatory Commission Report, Draft NUREG in preparation (draft dated May 2011).

A.4 NGA-East PPRP Correspondence on Project Plan

A.4.1 PPRP Letter Following the Review Rev.0 of the NGA-East Project Plan

This material is included in the following pages.

A.4.2 Project team Response to PPRP Letter

This material is included in the following pages.

NGA-East Project

PPRP Comments on Draft Project Plan (April 2011)

General Comments

The PPRP welcomes the responses provided by the PM and the TI Leads to our comments on the high-level project plan that was issued on January 12, 2011. The issues raised by the PPRP regarding that document are now fully resolved, and herein we focus our attention exclusively on the DRAFT Project Plan issued in April 2011.

Overall, the new Project Plan represents a great improvement on previous documents and provides a clear overview of the objectives, participants, organization, technical tasks and schedule. We are pleased to see that such a clear plan has now been produced and trust that it can be finalized very soon and used to guide the work of all participants in the NGA-East Project.

In the section below, we provide a number of specific comments and observations that may be useful to the TI Leads and to the PM in producing the final version of the Project Plan. We close with a brief section with suggestions for the TI Leads and Project Manager, which are somewhat beyond the remit of the PPRP but which reflect some lingering concerns about the coordination and integration of such a complex and multi-faceted project.

Specific Comments on the Draft Project Plan

The comments in this section all refer specifically to the actual Project Plan document, and the PPRP asks that these be considered in the preparation of the final version of the plan. The first few comments are general in that they refer to the entire report.

To be pedantic, the word “data” is plural. Thus, at several places in the document, the correct subject and verb should be “data are”. Americans often use “data is” with no embarrassment, and so the current wording in the document could be left as. However, purists would prefer that the word “data” always use the plural form of the verb.

The project plan comprises many buzz terms and acronyms that many unfamiliar with the SSHAC process may find difficult to follow (although the PPRP members acknowledge the onus on us to become conversant with the SSHAC process since we are charged with judging if the project conforms to the specified requirements). The plan would benefit from a glossary of terms included either at the beginning or end of the document. In the current version of the Project Plan many of the acronyms are defined in multiple places (CENA, GMPEs, PSHA, and GMC on p. 1, again on p. 2. and again later in the document).

The reference to Coppersmith *et al*. (2011) appears several times in the document and in the reference list: this should be changed to U.S. NRC (2011, in prep.).

In several places (p. 6 and p. 18) the discussion on Hazard Feedback suggests the TI Team will coordinate with the USGS who will have responsibility for developing software and conducting sensitivity analyses. However, Table 1 identifies staff from Risk Engineering as members of the project team with this task. Some clarification on this point would be helpful in the final Project Plan.

Page	Location	Comment
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1	1st paragraph	How does a "ground motion characterization (GMC) model" differ from a "ground motion prediction equation (GMPE)"? To some, these might appear to be the same thing. It may be prudent to explain the conceptual difference between the two.
2	4th paragraph, 1st line	Suggest inserting "(median and sigma)" after "distribution"
2	6th paragraph, lines 9-10	Change "…the final PSHA estimates reflect the intent of the individual project's products. Therefore, the GMPEs developed in this project…" to "…the final PSHA estimates reflect the intent of the CEUS SSC and NGA-East products. Therefore, the GMPEs developed in the NGA-East project…"
4	2nd line	Change "e.g." to "now"
4	Lines 4-5	It could be useful to explain here why the project "evolved to a SSHAC Level 3 study", which is to make is consistent with the CEUS SSC project and to allow the output from these two projects to be combined in Level 2 site-specific updates for PSHA. It might be nice to insert the date (like "mid-2010") the decision to be SSHAC-3 was made.
4	2nd paragraph, 3rd line	Insert "input" between "PSHA" and "models"
4	1st bullet, 1st line	Insert "all" before "the data"
5	1st paragraph	It might be helpful, in terms of relating the Project Plan to the SSHAC Guidelines and the Implementation Guidelines referred to under the General Comments heading, to clarify that the Working Groups and sub-award Researchers and Contractors essentially fulfill the roles of Resource Experts and Specialty Contractors

Page	Location	Comment
5	Legend on Figure 1	"Lvel" needs to be corrected
6	Whole page	In addition to outlining the roles and the associated responsibilities, it might be useful to also add some of the attributes required for the essential SSHAC roles, including (where appropriate) knowledge of GMPEs/PSHA, understanding of epistemic uncertainty, willingness to be impartial and forfeit proponent positions and to follow the SSHAC guidelines and principles, etc. This would help map the personnel in Table 1 onto the roles, and also give the project leverage should any individual not behave according to the stipulations for the role they have been assigned.
6	1st paragraph, 4th line	Change "agencies" to "organizations" since EPRI is not an agency.
6	1st paragraph, 7th line	Change "insure" to "ensure" (unless the PM is ready to underwrite the project!)
6	5th paragraph	Hazard Feedback Analysts. The words here seem to conflict with the entries in Table 1 which still show involvement by Risk Engineering as the appointed organization that will conduct hazard calculations. Does the table need to be changed?
7	7th paragraph, 1st line	Presuming that the CBR is required on ground motions, it is acceptable for the V/H ratios to be outside the SSHAC Level 3 process since they are applied to horizontal ground motions that already capture the range of epistemic uncertainty. However, if models for the vertical component of motion are going to be used directly in PSHA (which is not advised) then these should capture the CBR of the TDI, and should be developed inside the SSHAC Level 3 process
8	1st paragraph, 4th line	Insert "to" between "is" and "be."
8	1st paragraph, last line	Does this mean that all communications with the TI Leads should be sent simultaneously to both Norm and Christine? It might be helpful to state if this is the case.
8	2nd paragraph, 4th line	For completeness, insert "Team" after "TI"
9	Table 1, 5th line	Would it be sufficient to say "DOE" or is this to distinguish that Steve McDuffie is not a formal representative of this sponsor?
9	Table 1, PPRP	Since membership looks set to be reduced, the final membership should be clarified in the final Project Plan, with an acknowledgement to those who have stepped down but who contributed at earlier meetings and in review of documents, etc.
9	Table 1	Affiliation for Adams should be "Geological Survey of Canada"; for Allen it should be "Geoscience Australia"
9	Table 1	Delete Adams from the DB working group, or indicate him as a former member
9	Table 1	Make affiliations for USGS staff consistent
10	4th paragraph, first two lines	Re-word the sentence to "The workflow converges to the final products being developed by the TI team: the GMPE logic trees for the median and the standard deviation (sigma)."

Page	Location	Comment
10	5th paragraph, lines 7-8	This does not necessarily need to be recorded in the Project Plan, but obviously with one set of GMPEs developed by the TI Team and other(s) developed externally, there will clearly need to be vigilance to avoid cognitive bias in evaluating and integrating the complete set of models
10	5th paragraph, end	Will the project also look for systematic differences among SCR ground motions? This might not be important for the NGA-East project but it could have significant implications for how the results are used around the world. At the moment, the comparisons planned seem to assume that SCR ground motions are all comparable or equivalent. Perhaps the project could crudely test whether significant differences exist as a basis for deciding how much weight to give to the other SCR records in Task I.1. Also it might be then nice for NGA-East to be able to say, for example "ENA is different from Australia and India but not from South Africa" – helpful for global applications and also useful for any subsequent ENA work
10	Last sentence	This statement may not be true: the SOMs convey the degree to which models are clustered or not in ground-motion space, but the borders of the 'map' are defined by the included models – the actual range of epistemic uncertainty could be much broader and the SOM figures alone do not provide insight to this issue
12	Figure 2	This is an excellent figure! Would be nice to add a caption note about the use of the M superscript. Also some abbreviations/acronyms needed for brevity tripped some readers up – perhaps a consolidated list at the end of the document. Recommend expanding the color boxes in the legend to facilitate distinguishing the colors. Should there be an arrow from G into H2? (see comment below regarding p.16)
13	2nd paragraph, lines 2-4	Given that CEUS-SSC is complete, should this not just say that their conversions have been adopted?
13	3rd paragraph, lines 2-3	As noted previously, this assumes equivalence among SCR ground motions, which is unproven
14	Task C.1	Will Task C.1 consider differences in geological/tectonic environment (*e.g.*, archean craton, failed rift, etc)? And to what extent will it follow recommendations from the CEUS SSC project? Should the MIA be involved in this step?
14	2nd paragraph	A key point needing consideration here is that some of the magnitudes (perhaps most of the smaller ones) might be biased by the regionalization. Therefore the impact of the regionalization used for the GMs on the CEUS-SSC catalog magnitude needs to be considered in the hazard feedback analysis
14	Section D, line 5	"estimation of parameter values and their uncertainty/range"
15	Last paragraph, line 1	Are two models sufficient to capture the uncertainty? Given

Page	Location	Comment
		that there are two sources (pre-identified researchers and an RFP), two models may be sufficient. We assume that each of these models will have associated uncertainty estimates and that the 2-corner class of models may differ on how they capture the longer period finite-fault constraints. If so, the question remains as to whether are two enough?
16	Task G	The text suggests that Task G feeds into Task H2, which confirms the comment above that there may be an arrow missing on Figure 2?
16	Last bullet (I)	It is debatable as to whether comparing GMPEs with simulations and observations constitutes ‘validation’ – consider an alternative wording. Alternatively, the Project Plan should clarify what validation means in the context of NGA-East.
17	1st paragraph, lines 7-8	Will any use be made of SCR data from smaller magnitude earthquakes? Will the differences or similarities among SCR ground motions be explored?
17	1st sub-bullet	Change “ergotic” to “ergodic”
18	2nd paragraph (K)	The Scherbaum et al. (2010) visualizations indicate to what extent models cluster or occupy different parts of ground-motion space, which is useful to identify models that might be adding branches to the logic-tree without adding more epistemic uncertainty. The range of epistemic uncertainty requires expert judgment
18	Task M	See comment on p.6, paragraph 5
18	Last par, 1st sentence	This sentence seems at odds with the remainder of the paragraph. Use of seven test sites for GMPE evaluation or comparison does not seem particularly useful.
20	2nd paragraph, end	Another very important factor in ensuring the required documentation in a SSHAC Level 3 project is the review of final draft report by the PPRP! This is a very important step and where the final stamp of approval for the project comes from the PPRP. This needs to be clearly visible in the Project Plan.
20	4th bullet	Change “pieces” to “components”?
20	6th bullet	“SSHAC Workshop summaries…”?
20	7th bullet	“Working Group meeting…”?
20	Final reporting	We recommend an additional section acknowledging all contributions to the Project. In particular the many seismic networks and data owners from which data are sourced.
22	2nd paragraph, middle	Resource and proponent experts should not have ‘observer’ status when they attend the Workshops (except in the case that they were also invited to feedback workshop). Value could be added from engaging them in the discussions, and in particular from technical challenge and defense between Proponent Experts.
22	2nd line from the bottom	How are the “key technical issues” identified, when is the list circulated, and will the PPRP have a chance to comment on the list and whether the participants are

Page	Location	Comment
		appropriate/sufficient? (see also comment on p.23, 2nd paragraph, 10th line)
23	2nd paragraph, 10th line	List of invited/proposed Proponent Experts should be circulated to PPRP sufficiently early to identify and invite additional participants. This is key to the PPRP being able to concur that the TI Team consider the views of the full technical community
23	4th paragraph, bottom	At SSHAC Workshop #3, the forthcoming NUREG will propose that sessions should be include that allow the PPRP to interrogate the TI Team on the models, which can preempt and prevent difficult issues arising in the review of the final report (a lesson learnt from CEUS SSC). We recommend considering this option in NGA-East.
23	Bullets at bottom	Add warning about cognitive bias in making evaluations and the importance of impartiality to capture the CBR of the TDI http://en.wikipedia.org/wiki/Cognitive_bias
30	Figure 4	P and F presumably mean Preliminary and Final, but this should be stated somewhere. Other than that, this is a very effective summary of the Project Schedule. One suggestion is that instead of using blue color for all the activities the color scheme from Figure 2 could be used. That would quickly identify the components the TI team is performing, for example.
31	Hanks et al. (2009)	Spell out full author list
31	Power et al. (2008)	Spell out full author list
31	Scherbaum et al. (2010)	Published in vol. 26, no. 4, November 2010, pp.1117-1138

One additional comment in passing concerns Section 6.2 (p.27): The PPRP asked to be informed about Working Group meetings, but we have not seen any such notifications to date. Having said this, given the new budget constraints it probably needs to be made clear to us whether or not attendance by PPRP representatives at Working Group meetings would still be welcomed, and if so how such participation would be funded.

Suggestions

In this closing section, we offer some suggestions that we acknowledge may go slightly beyond our remit. At the moment, as noted in the table above, the Project Plan does not include a clearly identified task for the PPRP to review the final report and associated documentation, which is a vital component of the SSHAC Level 3 process. Although how the TI Team brings together that final documentation is entirely for them to decide, the PPRP will clearly review it for completeness in terms of having considered the full range of data, methods and models, and provide detailed justification and the technical bases for all decisions.

While the PPRP recognize it is not their role or desire to be involved with the management of the program, the complexity and interdependency of the WGs and their support to the TI Team suggests that the quality and timing of product delivery from the WGs is absolutely essential to program success.

The program plan could be modified to require a short plan from each WG that would include an outline of deliverables, delivery date of draft and final products (including documentation) to be provided to the TI Team, and commitments from the WGs to provide short monthly or quarterly progress reports to the TI Team. The Project Plan could address these issues in the 2nd paragraph of Section 5.3 (p.20).

Response to PPRP comments on the draft project plan

(NGA_East_Draft_ProjectPlan_20110411_AsSubmittedToPPRP.doc)

Introduction

On April 11, 2011, the draft NGA-East Project Plan (Rev.0) was submitted to the PPRP. That version of the Project Plan already addressed the JMC comments collected prior to the distribution to the PPRP. The PPRP provided their written comments on May 2, 2011. Working Group (WG) chairpersons also provided written comments by May 13, 2011. The various tasks included in the project plan originated from the project management and the WG chairpersons. The project scope evolved over time and was further modified to accommodate the issues raised in the first SSHAC Workshop in November 2010. Budget limitations required a further prioritization of the previously proposed tasks. It was therefore crucial to return the project plan to the WG chairpersons for final feedback. In order to keep the documentation streamlined, this document addresses the PPRP comments as well as the modifications completed following the WG chairpersons.

The updated project plan (Rev.1) is being submitted to the PPRP for final review. The TI team and PM gratefully acknowledge the PPRP, JMC, and all WG members for providing constructive comments.

The following sections provide: (1) a short summary of the key changes made to the project plan in response to all the comments received, and (2) responses to the specific comments by the PPRP. The PPRP comments are repeated in *italic*, followed by the collective reply of the TI Leads and PM.

Summary of key changes to the Project Plan

Many comments were gathered from the project team and the PPRP. In response to these collective comments, we have made the following improvements to the project plan:

1. Addition of a simplified flow chart (new Figure 2). We had prepared a similar figure for a tele-conference meeting between the TI team and the WG chairs. The consensus was that this really helped in understanding the process globally and set the stage for the detailed flowchart. This figure is now introduced in Section 5.1 (Summary of General TI team approach), which was reworked.

2. Modifications to Figures 3 and 4 (were originally Figures 2 and 3)

- Removed original tasks E.2 and F.2 (Define validation data sets) as they are really sub-tasks of the validation and only cluttered the space. The E and F tasks were re-numbered accordingly.
- Renamed task H as "Median GMPEs" and moved task G.4 (GMPE from TI team) to this box, effectively grouping all the median GMPE development

tasks together. We have also added links from all the pertinent data sources to this box.

- Reorganized the tasks spatially:
  - Moved task L (Logic Trees) to the top center of the figure since it is the final product.
  - Moved tasks K (Epistemic Uncertainty of GMPEs) and H (Median GMPEs) to optimize the flow and arrows placement.

3. Amended the color codes for the different entities to allow the use of the same colors in Figure 5 (original color for “researchers” category was white and would not have been visible in Figure 5). Used the new color scheme for all the figures.

Response to PPRP Comments

General Comments

The PPRP welcomes the responses provided by the PM and the TI Leads to our comments on the high-level project plan that was issued on January 12, 2011. The issues raised by the PPRP regarding that document are now fully resolved, and herein we focus our attention exclusively on the DRAFT Project Plan issued in April 2011.

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We have made the change. We also opted for the consistent use of “data set”, and removed “dataset” instances.

The project plan comprises many buzz terms and acronyms that many unfamiliar with the SSHAC process may find difficult to follow (although the PPRP members acknowledge the onus on us to become conversant with the SSHAC process since we are charged with judging if the project conforms to the specified requirements). The plan would benefit from a glossary of terms included either at the beginning or end of the document. In the current version of the Project Plan many of the acronyms are defined in multiple places (CENA, GMPEs, PSHA, and GMC on p. 1, again on p. 2. and again later in the document).

We added a list of acronyms at the beginning of the document and defined the terms on their first instance only.

The reference to Coppersmith et al. (2011) appears several times in the document and in the reference list: this should be changed to U.S. NRC (2011, in prep.).

We have made the change.

In several places (p. 6 and p. 18) the discussion on Hazard Feedback suggests the TI Team will coordinate with the USGS who will have responsibility for developing software and conducting sensitivity analyses. However, Table 1 identifies staff from Risk Engineering as members of the project team with this task. Some clarification on this point would be helpful in the final Project Plan.

We clarified the plan for hazard feedback analyses and the role of the two hazard feedback analysts (HFAs) listed in Table 1 (Sections 4 and 5.2). The TI team plans to use a dual approach for the hazard feedback analyses. The TI team will coordinate with the USGS to use their implementation of the CEUS SSC model and run their own analyses. However, it is anticipated that the USGS software may only include a simplified implementation of the CEUS SSC model, and a second team of external HFAs was selected to conduct additional analyses (Table 1) with the complete source model. This dual process will allow the TI team the flexibility to easily run regular analyses while the second set of analyses will ensure that the TI team conclusions are also consistent with the complete source model implementation.

The following table lists the specific comments provided by the PPRP and the NGA-East responses.

Page	***Location***	***PPRP Comment***	**NGA-East Response**
1		*There are currently 3 page 1s – please fix document section breaks*	Done.
1	*1st paragraph*	*How does a "ground motion characterization (GMC) model" differ from a "ground motion prediction equation (GMPE)"? To some, these might appear to be the same thing. It may be prudent to explain the conceptual difference between the two.*	We rephrased a sentence in the first paragraph to address this issue. A GMC model is the ground motion logic tree composed of a suite of GMPEs and their weights.
2	*4th paragraph, 1st line*	*Suggest inserting "(median and sigma)" after "distribution"*	Done.
2	*6th paragraph, lines 9-10*	*Change "…the final PSHA estimates reflect the intent of the individual project's products. Therefore, the GMPEs developed in this project…" to "…the final PSHA estimates reflect the intent of the CEUS SSC and NGA-East products. Therefore, the GMPEs developed in the NGA-East project…"*	Done.
4	*2nd line*	*Change "e.g." to "now"*	Removed "e.g.".
4	*Lines 4-5*	*It could be useful to explain here why the project "evolved to a SSHAC Level 3 study", which is to make is consistent with the CEUS SSC project and to allow the output from these two projects to be combined in Level 2 site-specific updates for PSHA. It might be nice to insert the date (like "mid-2010") the decision to be SSHAC-3 was made*	Done.
4	*2nd paragraph, 3rd line*	*Insert "input" between "PSHA" and "models"*	Done.
4	*1st bullet, 1st line*	*Insert "all" before "the data"*	Done.
5	*1st paragraph*	*It might be helpful, in terms of relating the Project Plan to the SSHAC Guidelines and the Implementation Guidelines referred to under the General Comments heading, to clarify that the Working Groups and sub-award Researchers and Contractors essentially fulfill the roles of Resource Experts and Specialty Contractors*	Added a short description.
5	*Legend on Figure 1*	*"Lvel" needs to be corrected*	Done.

Page	Location	PPRP Comment	NGA-East Response
6	Whole page	*In addition to outlining the roles and the associated responsibilities, it might be useful to also add some of the attributes required for the essential SSHAC roles, including (where appropriate) knowledge of GMPEs/PSHA, understanding of epistemic uncertainty, willingness to be impartial and forfeit proponent positions and to follow the SSHAC guidelines and principles, etc. This would help map the personnel in Table 1 onto the roles, and also give the project leverage should any individual not behave according to the stipulations for the role they have been assigned.*	The NGA-East project internally debated this issue during the development of the Project Plan. We decided to not re-interpret the SSHAC Guidelines and refer to them instead. We added a reference for key attributes of SSHAC roles.
6	1st paragraph, 4th line	*Change “agencies” to “organizations” since EPRI is not an agency.*	Done.
6	1st paragraph, 7th line	*Change “insure” to “ensure” (unless the PM is ready to underwrite the project!)*	Done.
6	5th paragraph	*Hazard Feedback Analysts. The words here seem to conflict with the entries in Table 1 which still show involvement by Risk Engineering as the appointed organization that will conduct hazard calculations. Does the table need to be changed?*	This was corrected as mentioned above (general comments from P.6 and 18).
7	7th paragraph, 1st line	*Presuming that the CBR is required on ground motions, it is acceptable for the V/H ratios to be outside the SSHAC Level 3 process since they are applied to horizontal ground motions that already capture the range of epistemic uncertainty. However, if models for the vertical component of motion are going to be used directly in PSHA (which is not advised) then these should capture the CBR of the TDI, and should be developed inside the SSHAC Level 3 process*	The CBR will be captured on the horizontal ground motions, and the V/H ratios will be applied to these horizontal ground motions, as obtained in relation to the project’s main SSHAC objective. We do not deem necessary to add further information in the project plan.
8	1st paragraph, 4th line	*Insert “to” between “is” and “be.”*	Done.
8	1st paragraph, last line	*Does this mean that all communications with the TI Leads should be sent simultaneously to both Norm and Christine? It might be helpful to state if this is the case.*	Yes. We added a general statement to this effect; this also applies to the Database and Sigma WGs.
8	2nd paragraph, 4th line	*For completeness, insert “Team” after “TI”*	Done.
9	Table 1, 5th line	*Would it be sufficient to say “DOE” or is this to distinguish that Steve McDuffie is not a formal representative of this sponsor?*	The extra words were removed; this was an oversight on our part.

Page	**Location**	**PPRP Comment**	**NGA-East Response**
9	*Table 1, PPRP*	*Since membership looks set to be reduced, the final membership should be clarified in the final Project Plan, with an acknowledgement to those who have stepped down but who contributed at earlier meetings and in review of documents, etc.*	Table 1 was updated and an acknowledgement to those who contributed was added in a new "Acknowledgements" section at the beginning of the document.
9	*Table 1*	*Affiliation for Adams should be "Geological Survey of Canada"; for Allen it should be "Geoscience Australia"*	Done.
9	*Table 1*	*Delete Adams from the DB working group, or indicate him as a former member*	Done.
9	*Table 1*	*Make affiliations for USGS staff consistent*	Done.
10	*4th paragraph, first two lines*	*Re-word the sentence to "The workflow converges to the final products being developed by the TI team: the GMPE logic trees for the median and the standard deviation (sigma)."*	Done.
10	*5th paragraph, lines 7-8*	*This does not necessarily need to be recorded in the Project Plan, but obviously with one set of GMPEs developed by the TI Team and other(s) developed externally, there will clearly need to be vigilance to avoid cognitive bias in evaluating and integrating the complete set of models*	Agreed. This is a primary concern for the TI team that will be treated as such.
10	*5th paragraph, end*	*Will the project also look for systematic differences among SCR ground motions? This might not be important for the NGA-East project but it could have significant implications for how the results are used around the world. At the moment, the comparisons planned seem to assume that SCR ground motions are all comparable or equivalent. Perhaps the project could crudely test whether significant differences exist as a basis for deciding how much weight to give to the other SCR records in Task I.1. Also it might be then nice for NGA- East to be able to say, for example "ENA is different from Australia and India but not from South Africa" – helpful for global applications and also useful for any subsequent ENA work*	The differentiation of ground motion data per region is not part of the project scope. The project team will work with the assumption that data for all SCRs outside of CENA is equivalent for ground motion estimation purposes. In Task I, mean event terms from different regions will be compared to the mean event terms from CENA data to determine if there is significant bias that is attributable to a specific region.
10	*Last sentence*	*This statement may not be true: the SOMs convey the degree to which models are clustered or not in ground-motion space, but the borders of the „map" are defined by the included models – the actual range of epistemic uncertainty could be much broader and the SOM figures alone do not provide insight to this issue*	We removed that last sentence in the text and reworked the text on the use of SOMs in the description of task K.

Page	Location	PPRP Comment	NGA-East Response
12	Figure 2	*This is an excellent figure! Would be nice to add a caption note about the use of the M superscript. Also some abbreviations/acronyms needed for brevity tripped some readers up – perhaps a consolidated list at the end of the document. Recommend expanding the color boxes in the legend to facilitate distinguishing the colors. Should there be an arrow from G into H2? (see comment below regarding p.16)*	A list of acronyms and abbreviations is now provided at the beginning of the document. The boxes in the legend were enlarged. Task G.4 was merged into task H.: this is more intuitive and keeps the tasks grouped by topics. Our initial intent was to avoid too many arrows pointing to task H, and we had the "All Simulations and Recorded GMs" box, but we removed it and added arrows instead.
13	2nd paragraph, lines 2-4	*Given that CEUS-SSC is complete, should this not just say that their conversions have been adopted?*	The CEUS-SSC tasks may be complete, but the products and documentation are not available yet and won't be for many more months. It is very likely that the conversions will be adopted, but we have not officially seen them yet.
13	3rd paragraph, lines 2-3	*As noted previously, this assumes equivalence among SCR ground motions, which is unproven*	The main use the other SCRs data will be for Task I, and we responded to the comment regarding that task above. The other potential use for the data is to better constrain the magnitude vs. stress-drop relationship, provided there is enough close-in data to allow good stress drop estimates to be made. In this case, once again, by looking at the event terms plotted separately for each region, we will be able to assess whether the source scaling from other SCRs is applicable to CENA or not. We may find that the attenuation at large distances is different. If this is the case, then the event terms will need to be developed for short distances to avoid mapping attenuation differences into source differences.

Page	Location	PPRP Comment	NGA-East Response
14	*Task C.1*	*Will Task C.1 consider differences in geological/tectonic environment (e.g., archean craton, failed rift, etc)? And to what extent will it follow recommendations from the CEUS SSC project? Should the MIA be involved in this step?*	The focus of the regionalization is on differences in attenuation (distance scaling). These attenuation regions will not be based on the source zones from the SSC study. The number of regions is expected to be 2 or 3 only as compared to a much larger number of source zones.
14	*2nd paragraph*	*A key point needing consideration here is that some of the magnitudes (perhaps most of the smaller ones) might be biased by the regionalization. Therefore the impact of the regionalization used for the GMs on the CEUS-SSC catalog magnitude needs to be considered in the hazard feedback analysis*	This is an important SSC/GMC interface issue that will need to be addressed. We agree that regional differences in the attenuation could lead to biases in the earthquake magnitudes. Once the ground motion attenuation regions have been identified, we will coordinate with the MIA to evaluate potential magnitude bias by region. If needed, we will develop simple correction factors for the GMPEs that can be easily implemented in the hazard analyses.
14	*Section D, line 5*	*"estimation of parameter values and their uncertainty/range"*	Changed to "estimation of parameter values and their distribution"
15	*Last paragraph, line 1*	*Are two models sufficient to capture the uncertainty? Given that there are two sources (pre-identified researchers and an RFP), two models may be sufficient. We assume that each of these models will have associated uncertainty estimates and that the 2-corner class of models may differ on how they capture the longer period finite-fault constraints. If so, the question remains as to whether are two enough?*	There are two independent groups developing models, but each group will provide suites of models to represent the CENA sources. The words "suite of [models]" were added to allude to this.
16	*Task G*	*The text suggests that Task G feeds into Task H2, which confirms the comment above that there may be an arrow missing on Figure 2?*	This was taken care of in our flowchart reorganization.

Page	Location	PPRP Comment	NGA-East Response
16	Last bullet (I)	*It is debatable as to whether comparing GMPEs with simulations and observations constitutes "validation" – consider an alternative wording. Alternatively, the Project Plan should clarify what validation means in the context of NGA-East.*	"To test the validity of the GMPEs…" was changed to "To evaluate the appropriateness of the GMPEs…". The italicized text was also added in the sentence below: "Given that some of the data has large inherent uncertainty, *and that some data come from simulations and not observations*, the goal of these tests is not to calibrate the GMPEs, but rather to check if the different data sets are consistent with the specific GMPEs."
17	1st paragraph, lines 7-8	*Will any use be made of SCR data from smaller magnitude earthquakes? Will the differences or similarities among SCR ground motions be explored?*	The smaller magnitude data from other SCRs will only be used for sigma task J.3. For CENA, the small magnitude data are used for attenuation as well as for sigma. Again, we are not considering regionalization across different SCRs, except for CENA which is treated separately as the focus of the research.
17	1st sub-bullet	*Change "ergotic" to "ergodic"*	Done.
18	2nd paragraph (K)	*The Scherbaum et al. (2010) visualizations indicate to what extent models cluster or occupy different parts of ground- motion space, which is useful to identify models that might be adding branches to the logic-tree without adding more epistemic uncertainty. The range of epistemic uncertainty requires expert judgment.*	Agreed, this was clarified and reworded.
18	Task M	*See comment on p.6, paragraph 5*	This was addressed as stated above.
18	Last par, 1st sentence	*This sentence seems at odds with the remainder of the paragraph. Use of seven test sites for GMPE evaluation or comparison does not seem particularly useful.*	The two first sentences were interchanged to provide a better flow. The hazard feedback for GMPEs needs to consider the magnitude and distance contributions from the different tectonic environments from the CEUS. The seven sites were previously selected by the CEUS SSC to capture the range of tectonic environments and are appropriate for use in the ground motion hazard feedback. This explanation has been added in the project plan.

Page	***Location***	***PPRP Comment***	**NGA-East Response**
20	*2nd paragraph, end*	*Another very important factor in ensuring the required documentation in a SSHAC Level 3 project is the review of final draft report by the PPRP! This is a very important step and where the final stamp of approval for the project comes from the PPRP. This needs to be clearly visible in the Project Plan.*	The PPRP review of the final report was implicitly included in the "PPRP letters and final report – PPRP" item. We have added a clear statement at the end of the second paragraph to reinforce this point. We have also added a note regarding the role of the PPRP throughout the project: input from the PPRP will be instrumental from beginning to end.
20	*4th bullet*	*Change "pieces" to "components"?*	Done.
20	*6th bullet*	*"SSHAC Workshop summaries…"?*	Done.
20	*7th bullet*	*"Working Group meeting…"?*	Used "Other workshops and working meetings" to be consistent with Section 6.2
20	*Final reporting*	*We recommend an additional section acknowledging all contributions to the Project. In particular the many seismic networks and data owners from which data are sourced.*	An acknowledgment section was added to the project plan document. We will include an exhaustive list of acknowledgements in the final report.
22	*2nd paragraph, middle*	*Resource and proponent experts should not have "observer" status when they attend the Workshops (except in the case that they were also invited to feedback workshop). Value could be added from engaging them in the discussions, and in particular from technical challenge and defense between Proponent Experts.*	This was reworked.
22	*2nd line from the bottom*	*How are the "key technical issues" identified, when is the list circulated, and will the PPRP have a chance to comment on the list and whether the participants are appropriate/sufficient? (see also comment on p.23, 2nd paragraph, 10th line)*	The key technical issues were first highlighted in the "Roadmap" document that was prepared in the development of the NGA-East project as a science-based project (before the SSHAC Level 3 designation). These issues were organized into the seven categories that led to the formation of the Working Groups. We added this information in Section 4 at the beginning of the Working Groups sub-section. The key remaining issues are also summarized at the SSHAC Workshops by the TI team, and circulated in the form of a draft agenda three months before each workshop. The list of identified participants is to be circulated at the same time. This information was added in Section 6.1.

Page	***Location***	***PPRP Comment***	**NGA-East Response**
23	*2nd paragraph, 10th line*	*List of invited/proposed Proponent Experts should be circulated to PPRP sufficiently early to identify and invite additional participants. This is key to the PPRP being able to concur that the TI Team consider the views of the full technical community*	See comment above.
23	*4th paragraph, bottom*	*At SSHAC Workshop #3, the forthcoming NUREG will propose that sessions should be include that allow the PPRP to interrogate the TI Team on the models, which can preempt and prevent difficult issues arising in the review of the final report (a lesson learnt from CEUS SSC). We recommend considering this option in NGA-East.*	Agreed. A note to this effect was added in the project plan.
23	*Bullets at bottom*	*Add warning about cognitive bias in making evaluations and the importance of impartiality to capture the CBR of the TDI http://en.wikipedia.org/wiki/Cognitive_bias*	This is a central feature of the SSHAC process and does not need to be repeated in the project plan.
30	*Figure 4*	*P and F presumably mean Preliminary and Final, but this should be stated somewhere. Other than that, this is a very effective summary of the Project Schedule. One suggestion is that instead of using blue color for all the activities the color scheme from Figure 2 could be used. That would quickly identify the components the TI team is performing, for example.*	Agreed. Both suggestions were implemented.
31	*Hanks et al. (2009)*	*Spell out full author list*	Done.
31	*Power et al. (2008)*	*Spell out full author list*	Done.
31	*Scherbaum et al. (2010)*	*Published in vol. 26, no. 4, November 2010, pp.1117-1138*	Done.

One additional comment in passing concerns Section 6.2 (p.27): The PPRP asked to be informed about Working Group meetings, but we have not seen any such notifications to date. Having said this, given the new budget constraints it probably needs to be made clear to us whether or not attendance by PPRP representatives at Working Group meetings would still be welcomed, and if so how such participation would be funded.

> We apologize for not keeping you informed. We still plan to inform the PPRP on the various public workshops and meetings, but as the PPRP acknowledges, budget limitations will not allow the project to provide travel costs reimbursement. Those meetings will be accessible via internet. The WGs are treated as contractors and will produce technical reports and documentation for the TI team and PPRP to review. The TI team review of these documents will be observable by the PPRP in the TI team working meetings. We will also inform the PPRP of all TI team working meetings, which will be accessible via web.

Suggestions

In this closing section, we offer some suggestions that we acknowledge may go slightly beyond our remit. At the moment, as noted in the table above, the Project Plan does not include a clearly identified task for the PPRP to review the final report and associated documentation, which is a vital component of the SSHAC Level 3 process. Although how the TI Team brings together that final documentation is entirely for them to decide, the PPRP will clearly review it for completeness in terms of having considered the full range of data, methods and models, and provide detailed justification and the technical bases for all decisions.

> This was corrected.

While the PPRP recognize it is not their role or desire to be involved with the management of the program, the complexity and interdependency of the WGs and their support to the TI Team suggests that the quality and timing of product delivery from the WGs is absolutely essential to program success.

The program plan could be modified to require a short plan from each WG that would include an outline of deliverables, delivery date of draft and final products (including documentation) to be provided to the TI Team, and commitments from the WGs to provide short monthly or quarterly progress reports to the TI Team. The Project Plan could address these issues in the 2nd paragraph of Section 5.3 (p.20).

> We did consider including more detail on the WG activities in the project plan. However, the key goal was to keep the project plan document to a manageable size so it would actually be used as a tool for the project team. We have decided not to include further details. The TI team plans to have bi-monthly conference calls with all the WG chairpersons in addition to topic-specific calls with

certain WGs. The meetings will be used to review the WGs progress and to solve interface issues between the groups; the TI team will update the schedule based on that information.

Appendix C Databases

C.1 NGA-East Database

C.1.1 Source Table: Selection of Metadata for Individual Earthquakes

This appendix presents the basis for selection of the metadata for the individual earthquakes.

EQID 01 – Charlevoix, QC, 1925

The primary source of the location and focal mechanism data is Bent (1992). Johnston (1996) develops an average estimate of log(M_o), and this value is selected to compute **M**. The standard deviation of **M** is computed as two-thirds of the log of the multiplicative error factor given by Johnston (1996).

EQID 02 – Grand Banks, NL, 1929

The primary source of the location and focal mechanism data is Bent (1995). Johnston (1996) develops an average estimate of log(M_o), and this value is selected to compute **M**. The standard deviation of **M** is computed as two-thirds of the log of the multiplicative error factor given by Johnston (1996). Most catalogs give the earthquake latitude as 44.69˚N, but Engdahl and Villaseñor (2002) relocate the earthquake to latitude 44.539˚N, and their location is selected as the preferred location. The Engdahl and Villaseñor (2002) hypocentral depth of 15 km is used, but the CMT depth is kept at the 20 km value found by Bent (1995) from her waver form modelling.

EQID 03 – Timiskaming, QC, 1935

The primary source of the location and focal mechanism data is Bent (1996a). Johnston (1996) develops an average estimate of log(M_o), and this value is selected to compute **M**. The standard deviation of **M** is computed as two-thirds of the log of the multiplicative error factor given by Johnston (1996). Most Canadian catalogs list the latitude as 46.78˚N [e.g., Lamontagne et al., (2008)], but several U.S. catalogs list the latitude as 46.87˚N. The Canadian location is selected as the preferred location.

EQID 04 – Cornwall-Massena, ON, 1944

The primary source of the location and focal mechanism data is Bent (1996b). Johnston (1996) develops an average estimate of log(M_o), and this value is selected to compute **M**. The standard deviation of **M** is computed as two-thirds of the log of the multiplicative error factor given by Johnston (1996).

EQID 05 – Saguenay, QC, 1988

The selected source parameters are those selected for the finite-fault ground motion validation exercise for the NGA-East project. It should be noted that Johnston (1996) developed an average estimate of log(M_o) that produces **M**5.85. The standard deviation of **M** is computed as two-thirds of the log of the multiplicative error factor given by Johnston (1996). Haddon (1992) obtains a much smaller seismic moment, but he indicated that his value may be an

Appendix B Workshops Summaries and Participatory Peer Review Panel (PPRP) Correspondence

This appendix includes the documentation relative to the Senior Seismic Hazard Analysis Committee (SSHAC) Workshops.

As is described in Chapter 1, the NGA-East project was first initiated as a research project (Bozorgnia 2008). Several science meetings were held in the development phase of the project, which are not described here. Rather, the current appendix includes a short summary for each of the SSHAC Workshops held after the project was assigned as SSHAC Level 3. Because of the project evolution and the large number of research tasks initiated as part of NGA-East, the SSHAC Workshops were also an opportunity to present research results and discuss various issues that were deemed important and relevant to the development of ground-motion models (GMMs). This strategy allowed the project to increase the level of transparency throughout the process and to keep everyone (SSHAC participants and researchers alike) informed and involved in the discussions. This is evidenced by the range of topics covered in the Workshops' presentations linked below, which is broader than expected for a typical SSHAC Workshop.

All the sections below follow a similar organization:

- Short introduction and context
- Letter from the Participatory Peer Review Panel (PPRP)
- The Technical Integrator (TI) team's response to the PPRP letter

In addition, the workshops are all documented at the following link: https://peer.berkeley.edu/research/nga-east/events

Each workshop page consists in the agenda with links to all the presentations. Videos of the workshop are also available on each page.

B.1 Workshop 1, November 15–18, 2010

B.1.1 Workshop Summary

This Workshop followed the SSHAC Theme 1: Critical Issues and Data Needs.

The workshop was also the opportunity to further discuss the project organization and to initiate the development of the official project plan (Appendix A).

The workshop started with an overview of the project, as well as an introduction to the SSHAC process. The morning session of the first day highlighted critical issues identified for the project, such as geometrical spreading in Central and Eastern North America (CENA), variability and magnitude dependence of the stress parameter, regionalization, and the inclusion of simulations. The afternoon session of the first day was about the NGA East database, with presentations about the current state of the database—highlighting different aspects such as number of data, processing of recordings, metadata uncertainty—and the consideration of possibly adding of new data, both from CENA and from other stable continental regions (SCRs). Discussions revolved around the input parameters to simulations, in particular for large magnitudes, and geometrical spreading at short distances. Other discussion points involved the tails of the ground-motion distribution and the verification of GMMS.

The morning session of the second day focused on site effects issues, with presentations on reference rock conditions and issues regarding the inclusion of kappa as a parameter in NGA-East. Discussion points were the range of both reference-rock shear-wave velocity and kappa conditions, and the estimation of site conditions for sites with observed ground motion.

The day continued with sessions on simulations, with one part highlighting issues for point-source models [mainly informed by experience from Western North America (WNA)]. This was followed by an overview of finite-fault simulations, which presented different methods and their evaluation based on observed data. Main discussion points were about the stress parameter in point-source simulations, its range, magnitude, and depth dependence.

The third day started with an investigation of CENA regionalization based on crustal structure, and the inclusion of point-source models using different attenuation models. The afternoon session focused on the range of the stress parameter as input for point source models. Discussions revolved around the inclusion of the path and source parameters (and their correlation) in point-source simulations.

The fourth day's morning session was about inputs to finite-fault models and featured presentations on different modeling approaches. Main discussion points were the range and correlation of different input parameters, as well as validating simulation methods against observed data.

The focus moved to aleatory variability, with an overview of available data/data needs regarding the estimation of single-station sigma. The effect of aftershocks/swarms on sigma were discussed, as well as the possible inclusion of variability from simulations. The Workshop concluded with an overview of the approach/status of work to modeling vertical ground motions. Finally, the morning session was revisited with a presentation of evaluation methods/metrics for finite-fault simulations.

B.1.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

November 19, 2010

Dr Yousef Bozorgnia
Project Manager NGA-East
Pacific Earthquake Engineering Research Center
325 Davis Hall
University of California Berkeley
Berkeley, CA 94720-1792, USA

Dear Dr Bozorgnia,

Next Generation Attenuation for Central and Eastern North America (NGA-East):
Participatory Peer Review Report on Workshop No. 1.

This letter constitutes the report of the PPRP[1] on Workshop No. 1 ("WS-1") for the referenced project. The *Critical Issues and Data Needs* workshop was held November 15-18, 2010, at the University of California Berkeley. Following guidance described in the Technical Approach and Work Plan for the Next Generation Attenuation Relationship Development Project for Central and Eastern North America[2] for the PPRP, and consistent with the expectations of the SSHAC process[3], the PPRP participated in WS-1 in order to be informed and to review both procedural and technical aspects of the workshop.

Since this was also the first opportunity for the PPRP to review and comment on the current (draft) version of the Technical Approach and Work Plan, our observations and comments provided below also address that document. Additionally, the occasion of the Workshop provided the PPRP with an opportunity to discuss its own organization and operation, and also the interaction of the Panel with the NGA-East project.

Nine members of the PPRP (John Adams, Jon P. Ake, Trevor Allen, Julian J. Bommer, John Ebel, Jeffrey K. Kimball, Richard C. Lee, Leon Reiter, and Frank Scherbaum) attended WS-1 and were able to fully observe all aspects of the workshop. The Panel's other two members (Aybars Gurpinar, and James R. Martin) were unable to attend the workshop because of unavoidable conflicts.

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[1] Acronyms are explained in the Appendix.

[2] At the time of Workshop 1, Draft of Version 5 for Comments (dated November 2, 2010) of the Technical Approach and Work Plans was available to the PPRP. This will be referred to as the Technical Approach and Work Plan

[3] Budnitz, R. J., 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.* NUREG/CR-6372, Washington, DC, U.S. Nuclear Regulatory Commission.

PPRP Operation and Interaction with the Project

The PPRP currently has 11 members, which means that there is a considerable breadth of technical expertise and experience within the Panel, but also that it could become slightly cumbersome in terms of operation. In order to facilitate the operation of the PPRP, the following decisions were taken:

- Jon Ake will serve as vice-chairman of the PPRP, to assume the chair role at any Workshop or other meeting that Julian Bommer (PPRP chairman) cannot attend
- The PPRP currently has 11 members, so it is considered that at very least 6 need to be present at any workshop; if circumstances should lead to fewer being present, the PPRP would declare itself below quorum
- Any PPRP member who does not manage to attend a WS in person but can follow the proceedings via web link will be encouraged to contribute to the consensus report provided this can be done while the PPRP is still assembled to write the WS report; absent PPRP members will be asked to submit concerns in writing to go into the report, which they will then receive for information (each report clearly identifying those PPRP members who were present or contributed)
- The PPRP chairman will communicate directly with absentee members to ensure that they are informed and that their concerns, if any, have been raised with the TI Leads and Project Manager
- Any PPRP member who misses two consecutive Workshops will be considered to have left the PPRP
- PPRP members may attend Working Group meetings, as possible and according to their areas of expertise, but this should not be considered a requirement; if PPRP members are present at a WG meeting they will be required to produce a summary report for circulation to the full Panel

We view the primary responsibilities of the PPRP as being to provide process and technical review so that at the end of the project we can vouch that: (1) the SSHAC Level 3 process was adhered to throughout, (2) the TI Team duly considered all available data, methods, and models relevant to CENA ground motions, and (3) the TI Team provided adequate documentation to justify the technical bases for all their decisions regarding models and their weights.

The PPRP will strive to remain assembled for at least one day following each WS in order to produce a consensus letter report. These reports will be submitted in each case to the Project Manager, Dr Yousef Bozorgnia, who will communicate the observations, suggestions, requests and concerns of the PPRP to the TI Leads, Drs Norm Abrahamson and Christine Goulet, and the SSHAC Guidelines Process Manager, Dr Annie Kammerer. The major concerns of the PPRP will be underlined in our letter reports. <u>The PPRP will expect a written response from the TI Leads, communicated via the Project Manager, within two weeks of the date of</u>

<u>the letter report, explaining the actions that will be taken to address these concerns</u>.

General Observations

The PPRP would like to thank the project organizers for their hospitality and for the arrangements of this Workshop with so many participants. We appreciate that the scope of the NGA-East project is very ambitious and that its successful execution requires the effective coordination of large numbers of participants, and we feel it is important to note that the project organizers have done a great deal of work to bring so many people together for this Workshop.

We would also like to express our gratitude and appreciation for the constructive and receptive attitude of the Project Manager, the TI Leads and the SSHAC Guidelines Process Manager during the informal feedback sessions at the end of each day of the Workshop. These discussions were very useful and the PPRP saw marked improvements in a number of key aspects – particularly in terms of the degree of participation of all of the members of the TI Team – as the week progressed.

The purpose of WS-1 was to identify the technical issues of highest significant to the hazard analysis and to review the available data and identify the data, information and/or additional work that will be needed to address those issues. The PPRP felt, however, that the explicit hazard significance of the key issues was not actually shown. The Project Manager and TI Team Leaders worked together very effectively, executing their respective roles, and were well prepared and effective in their respective contributions, all of which resulted in a successful workshop. The PPRP were impressed by the very significant and valuable database that is being compiled for this project, and also by the clarity and technical quality of most of the presentations that were made at the Workshop. At the end of each day the TI Team Leaders usefully summarized the key technical issues and data needs, although prioritization of these needs is still required. We observed that the workshop accomplished the stated goals established for this important milestone of the NGA-East project.

Given that the NGA-East project has been underway for some time it is urgent that the Technical Approach and Work Plan be finalized. As discussed below, there are several organizational aspects of that plan that need immediate attention to ensure that the structure and organization of the project effectively accomplishes the project goals. At the present time, the lines of communication and inter-relationships of the different project participants groups are unclear. Of particular importance is the linkage between the TI Team and the Working Groups, which are effectively specialty contractors and resource experts working to provide input to the evaluation and integration that will eventually be performed by the TI Team. The PPRP appreciates that the project has been evolving from the NGA-West model to a SSHAC Level 3 framework, but we feel that it is now urgent to impose the SSHAC Level 3 process on those aspects and participants for which this is relevant.

Specific Comments and Recommendations

Provided below are comments and recommendations for consideration and follow-up action by the TI Team. The comments are not ranked in order of priority. Because the PPRP will not have another scheduled opportunity to comment on the NGA-East Project for a number of months, some of our comments extend beyond the content of WS-1, specifically our comments on the draft Technical Approach and Work Plan.

1. *The Structure and Organization of the Project:* We appreciate that the NGA-East project has several contributing organizations and a large number of participating researchers from various organizations. To accomplish the project goals seven WGs have been formed. The use of WGs from a SSHAC Level 3 context presents certain organizational challenges that must be addressed early in the project to ensure that lines of communication and project deliverables are appropriately defined. The linkage between the TI Team and the WGs needs to be strengthened. <u>We recommend that at least one member of the TI Team be represented on each of the WGs.</u> Although the WGs may execute some elements of the evaluation and integration, this should be directed, or ultimately approved, by the TI Team. Ultimate ownership of the ground-motion models (and logic-tree for PSHA) to emerge from the NGA-East Project will reside with the TI Team.

2. *Identification of Project Deliverables*: We think that it is very important to clearly identify the deliverables in terms of ground-motion models that are required with complete characterization of uncertainty. This is needed in order to focus the elements of the work plan where the SSHAC process needs to be fully adhered to throughout to ensure that center, body and range (CBR) of technically-defensible interpretations are captured. The Panel would suggest that the TI Team consider if other elements of the project need to be subject to the SSHAC Level 3 requirements, in order to enable the TI Team to focus its efforts on the topics of primary importance. Similarly, the handover points between the different components of the project leading to these final products should be clearly and unambiguously defined. <u>We recommend that project deliverables be clearly identified in the Technical Approach and Work Plan.</u>

3. *Revised Project Plan*: The focus and objectives of the project seem to have been clarified during WS-1, and the Panel believes that a new Project Plan that reflects the objectives and structural changes should be produced as soon as possible. The PPRP will not provide detailed comments and feedback on the current draft (version 5) because we believe that the changes will be far-

reaching and extensive, effectively constituting the drafting of a new Project Plan rather than an editing of the current document. The Panel believes that the Project Plan could probably be a shorter document, since the current version contains a great deal of repetition, and would benefit from very clear diagrams illustrating both the organizational structures (including relationships between different groups) and technical work plans (including flow of information and results). The PPRP would like to review the new Project Plan when it is drafted, and strongly encourages the TI Team to produce this at the earliest possible date so that it can serve to provide direction and guidance to everyone in the project. <u>The Panel requests a draft of the revised Project Plan for review by December 17, 2010</u>.

4. *Determination of source, path and site parameters for the simulation of ground motion for the NGA-East project, and the propagation of uncertainties.* For the earthquakes that generally drive seismic hazard estimates, the ground-motion prediction models from the NGA-East project will be mainly obtained from seismological simulations, which will therefore play a very major role in the project. It is therefore crucial to develop a clear concept to address the trade-offs between the stochastic model parameters and to deal with parameter correlations for kinematic rupture models. The PPRP recognizes that it is still not clear how these issues will be dealt with, but during the course of the workshop the PPRP became convinced that it now receives the attention it deserves. <u>We recommend that these issues be clearly addressed, even if not conclusively, in the revised Project Plan.</u> The PPRP is also encouraged by the decision to expand the scope of the Path WG to explicitly include the joint determination of both Source and Path parameters.

5. *Hybrid Empirical Method.* Given that the hybrid empirical is intended to be used as one of the methods to predict ground motions for CENA, <u>the PPRP requests information to what degree critical issues and/or data needs regarding the host region characterization are assumed not to exist or if they have been overlooked</u>. Related to that might be the issue that the characterization of the host and target region are done on records from events of different magnitudes.

6. *Validations of models and results*: We are concerned about the lack of specifics that were presented at the workshop concerning how validations of models and results are going to be carried out. Validation can be carried out on two levels. In validating computer codes, there must be assurance that the codes are working properly, i.e., are making the proper computations. In this case, validation refers to carrying out tests that confirm that the codes give the results expected for given inputs. In some cases, this can be done by comparing computer code outputs to the results of analytic computations. In other cases, this is done by comparing the outputs of a code being validated with those from other computer codes that are designed to carry out similar computations. The second level of validation entails taking the results of a

computer code and comparing those results to observations. During the workshop, the technical presenters and the TI team were not always clear about which kind of validation they were referring to. Furthermore, for the second type of validation, the TI team did not present a detailed explanation or criteria for how such validations will be carried out. The PPRP appreciates that the TI team may not yet have determined all of its validation procedures. The PPRP recommends that the details concerning validation need to be worked out as early as possible in the project.

7. *Use of Macroseismic Intensity Data:* Given the paucity of instrumental ground-motion recordings from large intraplate earthquakes, the use of macroseismic intensity data from historical earthquakes may play an important role for calibrating GMPEs developed through the NGA-East program. These data can provide important information on both the upper and lower bounds of ground-shaking predictions (from the use of appropriate conversion equations), having particular utility in constraining near-source ground-motions. Given the limited instrumental data for large-magnitude intraplate earthquakes compared to the relative abundance of macroseismic data collected in many global regions, the Panel recommends that the TI Team consider the use of macroseismic intensity data for NGA-East to test ground motions produced from numerical simulations for large-magnitude earthquakes.

8. *Adjusting Ground-motion Values in the Earthquake Database to the Reference Rock:* Recorded eastern ground motion values are the primary check on the simulation results, so they need to be carefully adjusted from the recording site condition to the reference rock. Determining the best adjustments requires integrating information from the installer/operators of the seismic stations with geotechnical information. The PPRP recommends that the value of the adjusted data should be weighted by the quality of the adjustment when it is considered in any validation.

9. *Geotechnical WG (#1)*: The PPRP is not clear regarding the specific contribution of the Geotechnical WG to the core objectives of the project, in terms of horizontal and vertical ground motions on hard rock. The TI Team and JMC may therefore reconsider the tasks assigned to this WG and where they might usefully feed into the development of deliverables (such as in addressing the issue of site response factors for vertical ground motions). The PPRP recommends that the role of the Geotechnical WG be reviewed and that its relationship to the SSHAC Level 3 objectives be clearly defined.

10. *Geotechnical WG (#2)*: Presentations on statistical correlations on reference rock velocities suggest that there is either inadequate input to the WG or appreciation of geology and geophysics to properly accommodate already available geologic conditions and stratigraphic information. In addition there is apparently no input or appreciation of geophysical methodologies,

interpretations and uncertainties. Thus, the statistical evaluations appear to be divorced from available geological and stratigraphic data and fundamental strengths and weaknesses of the various geophysical methods and results applied in the analysis. In addition the Geotechnical WG evaluations appear to miss available and already scrutinized bodies of geophysical data available from the DOE. The PPRP recommends that the TI Team ensure that the Geotechnical WG products related both to definition of reference rock and to site response incorporate geological and geophysical evidence appropriately.

11. *Vertical-to-Horizontal WG*: The PPRP supports the approach of developing V/H ratios to apply to horizontal response spectral ordinates as the preferred way to obtain vertical response spectra that are consistent with the horizontal motions. Caution needs to be applied regarding the degree of epistemic uncertainty captured in the model for V/H ratios since these will be applied to the full range of estimates of the horizontal spectral ordinates, which will already have captured considerable epistemic uncertainty. The convolution of epistemic uncertainty in the horizontal motion and in the V/H ratios should not exceed that associated with the direct estimation of vertical response spectra. Since the CBR of V/H ratios is therefore not required, the PPRP recommends that the necessity of the V/H WG operating within the SSHAC Level 3 framework be reconsidered.

12. *Single-station Sigma WG*: The TI team has indicated that it will focus on developing a model for single-station sigma (σ_{ss}). This multi-component representation of the aleatory variability (σ_{ss}) and single overall sigma (σ) is fundamentally different than previous studies. The PPRP suggests that the project confirm with the sponsoring agencies that this approach is acceptable. If this approach is used in the NGA-East project, the PPRP recommends that very explicit guidance be provided in Project documentation regarding the utilization/application of the σ_{ss} model, including the requirements for site-specific geotechnical and geophysical data.

13. *Preparations for WS-2*: The PPRP suggests that clear instructions and guidelines, possibly in the form of questions to be addressed, should be prepared by the TI Team and issued to invited proponent experts to assist the preparation of their presentations. Since representation of the full range of proponent views is critical to the SSHAC process, the PPRP expects that a draft agenda and list of invitees for WS-2 be drafted and sent to the PPRP for comment by mid-January 2011. The PPRP may suggest additional names of proponents to be invited. If any proponent expert cannot, or will not, attend in person then it is important that the TI Team arranges for someone else to present the views (data, method or model) of that proponent.

14. *Technical Issues of High Significance to the Hazard Analysis.* As stated in the WS-1 agenda, one purpose of the workshop was to identify the technical issues of high significance to PSHA. There were no formal presentations in

WS-1 that addressed this purpose. At several times during the workshop this issue came up and it was clear that a concise presentation on hazard significance relative to GMPEs would have been useful. The PPRP recommends that a concise presentation of technical issues of high significance to PSHA be planned for WS-2.

The PPRP would like to have the option to send one or two suitably-qualified observers to some of the key meetings of the WGs. In order for us to coordinate and plan these attendances, the PPRP requests notification of the date and location of WG meetings with sufficient notice to make travel arrangements. We would also like to request that a document repository be established from which the PPRP may access the reports and other supporting products emerging from the WGs.

Do not hesitate to contact me if you wish to clarify any of our observations, comments, or recommendations. We look forward to receive the written response to this letter, and specifically to those items underlined, by Monday, December 6, 2010.

Yours sincerely,

Julian J Bommer
for and on behalf of the PPRP
Tel: +44-20-7594-5984, Cell: +44-7787-351-004, j.bommer@imperial.ac.uk

Copy: TI Leads
Sponsor Representatives
PPRP Members

APPENDIX

Acronyms

CBR	Center, Body and Range
CENA	Central and Eastern North America
GMPEs	Ground-Motion Prediction Equations
JMC	Joint Management Committee
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
SSHAC	Senior Seismic Hazard Analysis Committee
TI	Technical Integrator
V/H	Vertical-to-horizontal ratio

December 9, 2010

Dr. Julian Bommer
NGA-East PPRP Chair
Department of Civil & Environmental Engineering
Imperial College London
London SW7 2AZ, U.K.

Subject: Next Generation Attenuation for Central and Eastern North America (NGA-East): Reply to Participatory Peer Review Report on Workshop No. 1.

Dear Dr. Bommer:

This letter is the NGA-East response to the PPRP letter-report dated November 19, 2010. The PPRP letter constituted the report on the NGA-East SSHAC Workshop 1 on "Critical Issues and Data Needs", held on November 15-18, 2010, at the University of California, Berkeley.

The following sections provide responses to the general as well as specific comments stated in the PPRP letter-report. In these sections, we first quote the PPRP letter-report in *italic*, followed by our replies.

Reply to General Comments

> *"The PPRP will expect a written response from the TI Leads, communicated via the Project Manager,…"*

The NGA-East responses to the PPRP, including this letter, represent the collective response from the Project Manager and the TI Team. In this reply process, we may also have asked input from various other individuals and working groups.

Replies to Specific Comments and Recommendations

> *1. The Structure and Organization of the Project: We appreciate that the NGA-East project has several contributing organizations and a large number of participating researchers from various organizations. To accomplish the project goals seven WGs have been formed. The use of WGs from a SSHAC Level 3 context presents certain organizational challenges that must be addressed early in the project to ensure that lines of communication and project deliverables are appropriately defined. The linkage between the TI Team and the WGs needs to be strengthened. <u>We recommend that at least one member of the TI Team be represented on each of the WGs.</u> Although the WGs may execute some elements of the evaluation and integration, this should be directed, or ultimately approved, by the TI Team. Ultimate ownership of the ground-motion models (and logic-tree for PSHA) to emerge from the NGA-East Project will reside with the TI Team.*

The current composition of the TI team includes members of the following WGs: Database (Boore), Simulation (Abrahamson & Chapman), and Path (Boore & Chapman). The other WGs are Geotech, Sigma, and Vertical. We are planning to assign Vertical and a large portion of Geotech WGs activities outside of the SSHAC process; therefore, we do not recommend adding members of these two WGs to the TI team. For the Sigma WG, we have identified two options: (a) Christine Goulet has been participating to the Sigma WG; and one option is to add Christine Goulet to become a member of that

WG; (b) the other option is to add a member from the Sigma WG to the TI team. We will let the PPRP know about the final choice.

2. Identification of Project Deliverables: We think that it is very important to clearly identify the deliverables in terms of ground-motion models that are required with complete characterization of uncertainty. This is needed in order to focus the elements of the work plan where the SSHAC process needs to be fully adhered to throughout to ensure that the center, body and range (CBR) of technically-defensible interpretations are captured. The Panel would suggest that the TI Team consider if other elements of the project need to be subject to the SSHAC Level 3 requirements, in order to enable the TI Team to focus its efforts on the topics of primary importance. Similarly, the handover points between the different components of the project leading to these final products should be clearly and unambiguously defined. <u>We recommend that project deliverables be clearly identified in the Technical Approach and Work Plan.</u>

Agreed. This should become clearer once we identify the specific objectives in the reorganized project plan. We agree that clear project deliverables, especially with regard to hand-offs between WGs and contractors are crucial for the success of the project.

3. Revised Project Plan: The focus and objectives of the project seem to have been clarified during WS-1, and the Panel believes that a new Project Plan that reflects the objectives and structural changes should be produced as soon as possible. The PPRP will not provide detailed comments and feedback on the current draft (version 5) because we believe that the changes will be far-reaching and extensive, effectively constituting the drafting of a new Project Plan rather than an editing of the current document. The Panel believes that the Project Plan could probably be a shorter document, since the current version contains a great deal of repetition, and would benefit from very clear diagrams illustrating both the organizational structures (including relationships between different groups) and technical work plans (including flow of information and results). The PPRP would like to review the new Project Plan when it is drafted, and strongly encourages the TI Team to produce this at the earliest possible date so that it can serve to provide direction and guidance to everyone in the project. <u>The Panel requests a draft of the revised Project Plan for review by December 17, 2010.</u>

The NGA-East is in process of re-drafting the project plan in light of technical issues that arose from the Workshop No. 1 and to further address comments brought up by the PPRP letter-report dated November 19, 2010. First, an overall Project Plan is being drafted and reviewed internally. This overall Project Plan will be a high level plan showing the main structure of the project. The draft of the revised overall Project Plan will be sent to the PPRP by December 24, 2010. PPRP comments on the first draft of the overall Project Plan, received by January 15, 2011, will be incorporated into a more detailed project plan that will be completed by February 8, 2011.

4. Determination of source, path and site parameters for the simulation of ground motion for the NGA-East project, and the propagation of uncertainties. For the earthquakes that generally drive seismic hazard estimates, the ground-motion prediction models from the NGA-East project will be mainly obtained from seismological simulations, which will therefore play a very major role in the project. It is therefore crucial to develop a clear concept to address the trade-offs between the stochastic model parameters and to deal with parameter correlations for kinematic rupture models. The PPRP recognizes that it is still not clear how these issues will be dealt with, but during the course of the workshop the PPRP became convinced that it now receives the attention it deserves.

> *We recommend that these issues be clearly addressed, even if not conclusively, in the revised Project Plan. The PPRP is also encouraged by the decision to expand the scope of the Path WG to explicitly include the joint determination of both Source and Path parameters.*

Agreed. We believe this is a critical aspect of the project, as it was reflected in the Workshop No. 1 discussions. This will be addressed in the detailed revised project plan.

> *5. Hybrid Empirical Method. Given that the hybrid empirical is intended to be used as one of the methods to predict ground motions for CENA, the PPRP requests information to what degree critical issues and/or data needs regarding the host region characterization are assumed not to exist or if they have been overlooked. Related to that might be the issue that the characterization of the host and target region are done on records from events of different magnitudes.*

Acknowledged. The only host zone that we are currently considering for the hybrid method is California. We understand that the host and target models need to be consistent for the hybrid model. A task will be included that will evaluate the current stochastic models for California in terms of their applicability for use in the hybrid method.

> *6. Validations of models and results: We are concerned about the lack of specifics that were presented at the workshop concerning how validations of models and results are going to be carried out. Validation can be carried out on two levels. In validating computer codes, there must be assurance that the codes are working properly, i.e., are making the proper computations. In this case, validation refers to carrying out tests that confirm that the codes give the results expected for given inputs. In some cases, this can be done by comparing computer code outputs to the results of analytic computations. In other cases, this is done by comparing the outputs of a code being validated with those from other computer codes that are designed to carry out similar computations. The second level of validation entails taking the results of a computer code and comparing those results to observations. During the workshop, the technical presenters and the TI team were not always clear about which kind of validation they were referring to. Furthermore, for the second type of validation, the TI team did not present a detailed explanation or criteria for how such validations will be carried out. The PPRP appreciates that the TI team may not yet have determined all of its validation procedures. The PPRP recommends that the details concerning validation need to be worked out as early as possible in the project.*

For this project, validation means consistency of the model predictions with observations. We use the term "verification" for numerical checks on the codes. Verification will be performed for the point source models using different computer codes as cross-checks. Verification will not be performed for the finite-fault simulations.

The details for the validation are being prepared by the simulation WG and will be completed by January 31, 2011.

> *7. Use of Macroseismic Intensity Data: Given the paucity of instrumental ground-motion recordings from large intraplate earthquakes, the use of macroseismic intensity data from historical earthquakes may play an important role for calibrating GMPEs developed through the NGA-East program. These data can provide important information on both the upper and lower bounds of ground-shaking predictions (from the use of appropriate conversion equations), having particular*

> *utility in constraining near-source ground-motions. Given the limited instrumental data for large-magnitude intraplate earthquakes compared to the relative abundance of macroseismic data collected in many global regions, the Panel recommends that the TI Team consider the use of macroseismic intensity data for NGA-East to test ground motions produced from numerical simulations for large-magnitude earthquakes.*

A task will be added to address the use of Macroseismic intensity data for constraining the ground motion models.

> *8. Adjusting Ground-motion Values in the Earthquake Database to the Reference Rock: Recorded eastern ground motion values are the primary check on the simulation results, so they need to be carefully adjusted from the recording site condition to the reference rock. Determining the best adjustments requires integrating information from the installer/operators of the seismic stations with geotechnical information. The PPRP recommends that the value of the adjusted data should be weighted by the quality of the adjustment when it is considered in any validation.*

Acknowledged. The Geotech WG will address the issue of quality of the site adjustment factors. We expect that, for most sites, the adjustments will be based on broad site categories.

> *9. Geotechnical WG (#1): The PPRP is not clear regarding the specific contribution of the Geotechnical WG to the core objectives of the project, in terms of horizontal and vertical ground motions on hard rock. The TI Team and JMC may therefore reconsider the tasks assigned to this WG and where they might usefully feed into the development of deliverables (such as in addressing the issue of site response factors for vertical ground motions). The PPRP recommends that the role of the Geotechnical WG be reviewed and that its relationship to the SSHAC Level 3 objectives be clearly defined.*

Acknowledged. We have initiated discussions regarding this topic within the TI Team and with the Project Manager and the Geotech WG. We believe that keeping the site-response removal at recording stations should fall under the SSHAC Level 3 process, but that the final site response model should not be part of the SSHAC process. Our plan regarding the vertical ground motions is that it would not be treated as a SSHAC Level 3 task. Site response model and vertical ground motions will still be part of the NGA-East program, but treated outside of the SSHAC Level 3 process.

> *10. Geotechnical WG (#2): Presentations on statistical correlations on reference rock velocities suggest that there is either inadequate input to the WG or appreciation of geology and geophysics to properly accommodate already available geologic conditions and stratigraphic information. In addition there is apparently no input or appreciation of geophysical methodologies, interpretations and uncertainties. Thus, the statistical evaluations appear to be divorced from available geological and stratigraphic data and fundamental strengths and weaknesses of the various geophysical methods and results applied in the analysis. In addition the Geotechnical WG evaluations appear to miss available and already scrutinized bodies of geophysical data available from the DOE. The PPRP recommends that the TI Team ensure that the Geotechnical WG products related both to definition of reference rock and to site response incorporate geological and geophysical evidence appropriately.*

Acknowledged. This issue will be brought up with the Geotech WG. The Geotech WG is in touch with the DOE to obtain supplemental data.

> *11. Vertical-to-Horizontal WG: The PPRP supports the approach of developing V/H ratios to apply to horizontal response spectral ordinates as the preferred way to obtain vertical response spectra that are consistent with the horizontal motions. Caution needs to be applied regarding the degree of epistemic uncertainty captured in the model for V/H ratios since these will be applied to the full range of estimates of the horizontal spectral ordinates, which will already have captured considerable epistemic uncertainty. The convolution of epistemic uncertainty in the horizontal motion and in the V/H ratios should not exceed that associated with the direct estimation of vertical response spectra. Since the CBR of V/H ratios is therefore not required, the PPRP recommends that the necessity of the V/H WG operating within the SSHAC Level 3 framework be reconsidered.*

Agreed. The project will exclude from the SSHAC process the development of V/H and V spectra. The activities will be part of the NGA-East program, but treated outside of the SSHAC process.

> *12. Single-station Sigma WG: The TI team has indicated that it will focus on developing a model for single-station sigma (σss). This multi-component representation of the aleatory variability (σss) and single overall sigma (σ) is fundamentally different than previous studies. The PPRP suggests that the project confirm with the sponsoring agencies that this approach is acceptable. If this approach is used in the NGA-East project, the PPRP recommends that very explicit guidance be provided in Project documentation regarding the utilization/application of the σss model, including the requirements for site-specific geotechnical and geophysical data.*

Agreed. We will provide guidance on the proper use of the single-station sigma, which should be used for (single) site-specific analyses only. The project will also provide a general sigma estimate in addition to the single-station sigma.

> *13. Preparations for WS-2: The PPRP suggests that clear instructions and guidelines, possibly in the form of questions to be addressed, should be prepared by the TI Team and issued to invited proponent experts to assist the preparation of their presentations. Since representation of the full range of proponent views is critical to the SSHAC process, the PPRP expects that a draft agenda and list of invitees for WS-2 be drafted and sent to the PPRP for comment by mid-January 2011. The PPRP may suggest additional names of proponents to be invited. If any proponent expert cannot, or will not, attend in person then it is important that the TI Team arranges for someone else to present the views (data, method or model) of that proponent.*

Agreed. The lists will be drafted and sent to the PPRP by January 31, 2011.

> *14. Technical Issues of High Significance to the Hazard Analysis. As stated in the WS-1 agenda, one purpose of the workshop was to identify the technical issues of high significance to PSHA. There were no formal presentations in WS-1 that addressed this purpose. At several times during the workshop this issue came up and it was clear that a concise presentation on hazard significance relative to GMPEs would have been useful. The PPRP recommends that a concise presentation of technical issues of high significance to PSHA be planned for WS-2.*

We will start WS-2 with preliminary hazard feedback based on current source and ground motion models to focus the discussions on technical issue that matter to the hazard.

> *The PPRP would like to have the option to send one or two suitably-qualified observers to some of the key meetings of the WGs. In order for us to coordinate and plan these attendances, the PPRP requests notification of the date and location of WG meetings with sufficient notice to make travel arrangements. We would also like to request that a document repository be established from which the PPRP may access the reports and other supporting products emerging from the WGs.*

Due to the budget constraints in the project, the face-to-face attendance of the PPRP members in working groups meetings will have to be approved in advance by the project manger on a case-by-case basis. Overall, due to the budget constraints, at this point the project has to limit such expenses to attend various working group meetings, both in terms of hourly payment to the PPRP members as well as travel expenses to attend WG meetings. The project, however, welcome PPRP members to attend working groups meetings via Internet access.

On behalf of the NGA-East, we thank the PPRP for their comments, efforts and cooperation.

Sincerely,

Yousef Bozorgnia, Ph.D., P.E.
NGA-East Project Manager, and
PEER Executive Director,
University of California, Berkeley

Norman A. Abrahamson, Ph.D.
NGA-East TI Team Co-Chair,
Dept. of Civil & Envir. Engineering
University of California, Berkeley

Christine Goulet, Ph.D.
NGA-East TI Team Co-Chair, and
Assistant Researcher, PEER,
University of California, Berkeley

Copy: PPRP Members
NGA-East Joint Management Committee

B.2 Workshop 1B-2A, October 11–13, 2011

B.2.1 Workshop Summary

This Workshop followed the SSHAC Theme 1: Critical Issues and Data Needs and initiated discussions on Theme 2: Proponent Discussions.

The Workshop started with an overview of preliminary hazard feedback results using point-source stochastic models, showing the sensitivity of hazard to different input parameters, such as the median stress parameters, duration model, and geometrical spreading. The afternoon session covered the status of the NGA-East database and data from SCRs. Discussions revolved around how the data from other regions can be incorporated into NGA-East. This was followed by a presentation on the 2011 Mineral, Virginia, earthquake, and its comparison to other existing CENA data. The first day concluded with the proposed reference-rock shear-wave velocity and kappa values, and models for simple corrections of recorded motions to reference-rock conditions.

The morning session of the second day focused on regionalization, with presentations on different aspects (source, path) and the identified regions. Discussion points were empirical evaluation of ground motions from different regions, the regional differences of median stress parameter, and the inclusion of depth/style-of-faulting into GMMs. Subsequently, hazard feedback analyses with respect to path effects were shown.

The afternoon session of the second day featured proponent median GMMs, using different approaches (point-source stochastic simulations, hybrid empirical, empirical). Inputs to all methods were discussed, and the question of testing the different models was approached. This was followed by a presentation of a study regarding single-station sigma for Switzerland; it was discussed whether the available sigma models cover the range of interpretation allowed by available data.

The final day of the Workshop was devoted to finite-fault simulations. The morning session presented results of validation from different simulation methods against observed events. Discussion revolved around extending the set of events that are used for validation and the treatment of site effects. This was followed by a presentation/discussion of magnitude-area relationships, which compared CENA data against available models. Discussion points were the range of epistemic uncertainty and the treatment of aleatory variability. The afternoon session was about inputs to different finite-fault simulation methods and the question how to modify available GMMs to accommodate a different value of kappa. The workshop concluded with presentations about inputs (in particular regarding the stress parameter) to point-source stochastic models.

B.2.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

October 28, 2010

Dr Yousef Bozorgnia
Project Manager NGA-East
Pacific Earthquake Engineering Research Center
325 Davis Hall
University of California Berkeley
Berkeley, CA 94720-1792, USA

Dear Dr Bozorgnia,

Next Generation Attenuation for Central and Eastern North America (NGA-East):
Participatory Peer Review Report on Workshop #2.

This letter constitutes the report of the PPRP[1] on Workshop #2 ("WS-2") for the referenced project. The *Proponent Discussions and Remaining Critical Issues and Data Needs* workshop was held October 11-13, 2011, at the Shattuck Plaza Hotel, Berkeley. Following guidance described in the NGA-East Final Project Plan[2], and consistent with the expectations of the SSHAC process[3], the PPRP participated in WS-2 in order to be informed and to review both procedural and technical aspects of the workshop.

There are now six members of the PPRP (John Adams, Jon P. Ake, Julian J. Bommer, John Ebel, Jeffrey K. Kimball and Richard C. Lee), and the PPRP acknowledges the earlier contributions of others who served on the Panel during the preliminary phase of the project (Trevor Allen, Aybars Gurpinar, James R. Martin, Leon Reiter and Frank Scherbaum). All six current members of the PPRP attended WS-2 but Jeffrey Kimball had to leave after the morning of the second day because of an unavoidable commitment.

The PPRP met on the morning of Friday, October 13th (immediately after the Workshop) to begin the drafting of this report. This report has been subsequently completed through correspondence among all the Panel members.

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[1] Acronyms are explained in the Appendix.

[2] At the time of Workshop 2, the July 2011 version of the Project Plan was in effect and the PPRP assumes this to be the current definition of the project structure, objective and scope of work although it is recognized that the Project Plan may be revised to reflect changes

[3] Budnitz, R. J., 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.* NUREG/CR-6372, Washington, DC, U.S. Nuclear Regulatory Commission.

The PPRP would like to thank the project organizers for their hospitality and for the arrangements of this Workshop. We appreciate that this Workshop involved many participants, and we were impressed by the efficiency with which the event was coordinated and the efforts taken to make all participants comfortable. We particularly appreciate the attention to providing suitable working conditions for the PPRP to fulfill its obligations.

We would also like to express our gratitude and appreciation for the constructive and receptive attitude of the Project Manager, the TI Leads and the TI Team during the informal feedback sessions at the end of each day of the Workshop. We felt that the discussions were open and the project participants were very receptive to our feedback, issues and suggestions.

Before entering into the detail of our feedback, the PPRP would like to say that overall we have seen tremendous progress and improvements in the project, in terms of organization and operation, in the year since Workshop #1. There is now a clear and workable Project Plan, an excellent TI Team and effective TI Lead through the combined roles of Drs Goulet and Abrahamson. Although we believe that there will still be significant challenges ahead, given the ambitious scope of the project, we are also convinced that the successful completion of this important endeavor is entirely feasible.

This report is submitted to the Project Manager, Dr Yousef Bozorgnia, with our usual request to communicate the observations, suggestions, requests and concerns of the PPRP to the TI Leads, Drs Norm Abrahamson and Christine Goulet, the TI Team members, and the SSHAC Guidelines Process Manager, Dr Annie Kammerer. As before, the major concerns of the PPRP are underlined in this letter report, and <u>the PPRP will expect a written response from the TI Leads, communicated via the Project Manager in due course explaining the actions that will be taken to address these highlighted concerns</u>. The other comments in this letter report are for information although the PPRP shall keep track of the extent to which the concerns and suggestions are addressed as the project advances; however, we do not wish to create additional work for the TI Team at this stage by requesting written responses to those comments.

The PRPP would like to note with satisfaction that all of the suggestions and recommendations made in our report following WS-1 have been taken on board by the TI Team and the Project Manager. Even though not all of the recommendations of the PPRP have been implemented as suggested (for example, not all of the WGs are represented on the TI Team), we believe that the intention of our recommendations have largely been addressed and we would conclude that there are no major issues still outstanding from our first letter report at this time. Nonetheless, a few of the issues and concerns are still relevant, and these are addressed in our comments in the remainder of this letter report.

PPRP Interaction with the Project

We view the primary responsibilities of the PPRP as being to provide process and technical review so that at the end of the project we can vouch that: (1) the SSHAC Level 3 process was adhered to throughout, (2) the TI Team duly considered all available data, methods, and models relevant to CENA ground motions, and (3) the TI Team provided adequate documentation to justify the technical bases for all their decisions regarding models and their weights.

In order to improve the interactions between the PPRP and the TI Team, the PPRP proposes the following actions:

1. Each workshop, occurring over a period of only a few days and on an annual basis, has correspondingly a very large amount of technical information that is presented and discussed. Because the PPRP has not been part of the TI-WG interactions, there is really no preparation time for the PPRP and consequently, the days of presentation material can be difficult to fully absorb. To improve this situation, prior to future workshops, the TI Leads should provide or make available the presentation material to the PPRP when possible. The material could be draft or final and preferably provided a few days prior to the workshop presentation. Since these meetings are conducted on an annual basis and require substantial preparation and review, the PPRP does not believe that providing informal draft or final presentation material a few days in advance is an inordinate burden on the TI Team or workshop presenters. The purpose of the PPRP preview of the presentation material is to improve the technical understanding of the material by the PPRP. This preview will be especially important to the PPRP for WS-3. A preview of the workshop presentations does not commit or restrict the authority of the TI Team from making 'last minute' changes to the presentations or presenters. Also, the workshop preview material is not subject to PPRP review or comment; it is the workshop presentations and discussions that are material to the PPRP. Note that the TI Team could make the presentation and other material available to the PPRP very simply with a password-protected web-link.

2. In the course of the workshop proceedings, it was evident to the PPRP that members of the TI Team did not always effectively challenge technical proponents or technical experts. It is evident to the PPRP that there could be a variety of reasons: (1) the presentations were under severe time constraints because of the amount of material that must be presented over a short period; (2) the TI Team may have felt that sufficient technical challenges were provided at WG meetings; (3) the TI Team did not feel that challenge was necessary because the TI Team members are expert in the subject area; or (4) the TI Team felt that they did not have sufficient expertise to challenge the proponents. To ensure that the TI Team is adequately challenging the WG proponents and experts, the PPRP has determined that one or more members of the PPRP should observe a number of the TI-WG meetings. <u>The PPRP requests that the schedule for all WG meetings be provided well in advance to the PPRP so that, at the PPRP discretion (and with</u>

the agreement of the Project Manager), some WG meetings can be attended by one or more PPRP members to observe and document the technical interactions.

3. The PPRP feels it essential that sufficient technical and proponent experts be used in the NGA-East project. Consequently the PPRP asks to review the list of invited or scheduled technical experts and proponents prior to each of the future workshops. The PPRP commits to provide the TI Team with comments and recommendations on technical experts and proponents. For example, Art Frankel and Brad Agar are examples of key technical experts/proponents that the PPRP considers essential to the success of NGA-East, in terms of their views needing to be given full consideration to demonstrate that TI Team has evaluated the views and interpretations of the broad scientific community.

Also the TI Team may need to appoint a proponent (possibly, but not necessarily, from within the Team) to represent a body of relevant work that the author of which is either unwilling or unable to present, as required for the SSHAC process.

Adherence to the SSHAC Process

Now that the structure, scope and schedule of the project have been clearly established, and strong technical teams have been assembled, the PPRP believes that it is timely to recall the key requirements of a SSHAC Level 3 project. The ultimate charge of the PPRP will be to assess if the project has met these requirements, in order to issue a final concurrence letter that the project conformed to a SSHAC Level 3 procedure. In this regard, the PPRP makes specific reference to the draft NUREG[4] on practical implementation guidelines for SSHAC Level 3 processes, which it urges all members of the TI Team to read.

The fundamental objective of a SSHAC Level 3 process is for the TI Team to develop a logic-tree that captures the center, body and range of the technically-defensible interpretations (CBR of the TDI). In this regard, we strongly urge the NGA-East project to adopt this terminology in place of the original SSHAC formulation that aimed at the CBR of informed technical community (ITC), a term which has caused considerable confusion. The TDI concept emphasizes that we are not interested in hypothetical people, but rather in justifiable scientific interpretations. The process does not seek opinions but justifiable scientific interpretations.

A key feature of a SSHAC Level 3 process is that by the end of the project, the TI Team must achieve full and collective ownership of the model (logic-tree). This means that each member of the team would be prepared to defend the output as reflecting the CBR of the TDI, and would be able to explain the technical bases of the decisions that led to the development of the logic-tree. Since all members of

[4] USNRC (2011). *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Draft NUREG, in preparation, US Nuclear Regulatory Commission.

the TI Team must ultimately assume such ownership, it is expected that during the course of the project there will be considerable technical challenge and defense (in which lines of reasoning from evidence to claim will be given, rather than opinions) among the TI Team members.

A very important point to emphasize is that a requirement of the TI Team members is to act as impartial evaluators within the project, which means suspending any proponent positions when the Team is evaluating the available data, models and methods. This does not preclude members of the TI Team from making proponent presentations during Workshops and working meetings, provided it is made clear that they are switching roles and that they subsequently adopt the role of impartial assessor. This means that in the integration phase, when the logic-tree is being constructed, the members of the TI Team must objectively evaluate all candidate models and give due consideration to those deemed to have a defensible technical basis. The focus must shift to ensuring that the range of defensible interpretations is captured rather than identifying any preferred best estimate.

Since the logic-tree developed and owned by the TI Team is the ultimate output from a SSHAC Level 3 project, it is useful to recognize that the development of the project database and all analyses are ultimately conducted to assist and inform the TI Team in executing their task. This is an important point to emphasize because in the NGA-East project it may be helpful for the TI Team to acknowledge that the activities of the Working Groups and also the SSHAC Workshops are intended primarily for their benefit.

The PPRP recognizes that the project needs to consider factors related to sponsor and end-user requirements, as well as general perception and acceptance of the final products by the relevant technical communities, but the core focus must always be on the TI Team being fully informed regarding data, methods and models from which they will build their logic-tree.

Procedural Issues

As the TI Leads stated in the final de-briefing meeting on Thursday, October 13th, this Workshop was effectively a 're-launch' of the project, with the revised Project Plan and the newly constituted TI Team in place. As such, it is an appropriate time for the PPRP to provide feedback and comments specifically on procedural matters, since effective organization at this stage will bring major benefits as the project moves forward. The comments from the PPRP on procedural issues are presented below, grouped under headings of those related to overall conduct of the project, and those specifically related to the conduct of the workshops.

Conduct of the Project

NGA-East now has a clear and workable Project Plan to follow, and two joint TI Leads who are clearly working very well together and who constitute very effective leadership for the TI Team. The project has assembled a technically very strong TI Team, which brings considerable expertise and experience together, with clear coverage of all the major technical areas that the project will need to address. There are also very competent WGs assembled to develop key components of the project, and the challenge facing the project is now to combine and coordinate all these diverse elements into a functional structure that will produce the required output within the project schedule.

NGA-East is an ambitious SSHAC Level 3 project that is attempting to take research-intensive inputs and turn them into a practical result. NGA-East has chosen to do this by delegating much of the technical work, such as accumulating a ground-motion data set, selecting model input parameters, creating finite-source simulations, and validating results, to the WGs, which are composed of a number experts on each of these topics. The PPRP recognizes that this organizational structure for the project imposes a major challenge for the TI Team to ensure that the WGs carry out their assigned tasks thoroughly and in a cost-effective manner. It appeared from the workshop presentations that some of the WGs do not yet have a clear idea about what deliverables they need to produce for the TI Team. For example, while the Source/Path WG showed convincing evidence that the seismic attenuation in the Gulf Coast sediments is quite different from that in the area of the Midwest to the north, no information about spatial variations in wave propagation or Q structures was provided for other parts of CENA. From the discussions during the workshop, apparently this WG has not yet looked at other parts of CENA, nor have they yet developed a course of action to do so.

The PPRP notes that in a SSHAC project, it is the responsibility of the TI Team to assemble, document, and defend the final results of the project. <u>This means that the TI Team has the primary responsibility for all aspects of the project, including the work carried out by the WGs. For this reason, the PPRP urges the TI Team to take a very active role in guiding the WGs in their work and ensuring WG documentation meets the needs of the TI Team</u>. The PPRP appreciates the difficult task faced by the TI Team of trying to convince research scientists to produce results of practical use rather than to focus on research questions of scientific interest. Furthermore, the TI Team is faced with the challenge of convincing research scientists to accumulate information on a broad range of models and interpretations available from the scientific community rather than merely developing and defending their own personal model or interpretation. Although some evidence that this had been attempted by the TI Team was apparent in the workshop presentations and discussions, it appeared clear to the PPRP that more guidance of the WGs is needed from the TI Team. The TI Team (and not the WGs) must ensure that the final project captures the full center, body and range of the current models and interpretations of the scientific community.

There is still plenty of time in this project for the WGs to accomplish their assigned tasks and to provide the TI Team with the information that they need for their work. At future stages in this project the PPRP will be looking for strong evidence that the TI Team has exerted its leadership over the WGs and that the WGs have provided adequate documentation of their work.

Conduct of the Workshops

The PPRP would like to offer comment on the conduct of this meeting as well as provide suggestions for future Workshops. The PPRP feels this Workshop was in fact a combination of SSHAC *workshop-1* and *workshop-2* as well as a Working Meeting. The blended framework of the meeting was the result of the major re-scoping of the project that occurred in 2010. This attempt to fit a broad spectrum of issues and objectives into a single meeting was clearly challenging. The loss of electrical power for a portion of one afternoon provided an additional challenge to the schedule. As a result, some of the discussions were difficult to follow. At times there did not seem to be a clear understanding regarding the objectives of the meeting and hence for some presentations a lack of clarity with respect to the objectives was evident. The PPRP recommends that the TI Team and project management carefully consider how much information/scope can reasonably and effectively be incorporated in a single meeting/workshop.

The TI Leads articulated the roles and responsibilities of the TI Team and rules of conduct for attendees at the beginning of the Workshop. The PPRP feels there may be a need to reiterate the roles of participants (TI Team, WG members, resource experts) within the Workshop setting multiple times. It may be useful to include a summary of these roles and responsibilities in the Workshop Agenda or other handouts. During the Workshop the TI Team needs to remain focused on the primary responsibility of evaluation and integration. They may, during the course of the Workshop, play the role of resource expert or proponent. In such instances it is desirable and appropriate for the TI Team members to explicitly state if they are "wearing the hat" of proponent or resource expert. The emphasis of the Workshop needs to remain on the TI Team in the role of evaluator.

Some generic questions and issues were conveyed to the proponent experts prior to the meeting by the TI Team. The PPRP endorses this activity but would suggest that a stronger emphasis on developing proponent-specific questions could improve the process. The TI Team was clearly focused on drawing out alternative ideas from Workshop participants and for most sessions good interaction was evident. The presentation by Dr Norm Abrahamson on preliminary hazard feedback was excellent and the TI Team should consider providing either a brief summary or handouts for all future Workshops.

The PPRP endorses the idea of having TI Team members present summaries of the technical results of WGs. The PPRP feels this will maximize the engagement of TI Team members and will facilitate the appropriate distillation of results and result in “in-context” presentations.

Specific observations from WS-2 are noted for completeness. There were instances of "scientific" presentations and discussion at WS-2 that more properly belonged at the Working Meeting level, and it would have been better if each WG met before each workshop so as to clarify the information being brought forward for TI Team consideration. In addition it is recommended that WS presenters be given clear direction as to the questions they are being asked and must answer, and a limit on the material presented (either time or number of slides). Such measures worked well in the CEUS SSC project.

Most effort seemed to be placed on presenting "best" values, and very little on the range. The range will be important when the point-source simulations are run (as we understand they are to cover the entire range of parameters, presumably with some trimming for correlated parameters?).

The "physicality" of the models was challenged at the WS, and this is likely indicative of the wider reaction of the scientific community to the final results. The TI Team needs to decide how to address this, and how to defend against such external comments, otherwise the credibility of the results might be challenged soon after release. At the same time, the project is to be commended for having engaged some proponents expressing such views at this early stage and for persuading them to participate in this workshop. However, from a SSHAC perspective, the more formal engagement of these individuals as proponent experts would clearly be beneficial.

The PPRP encourages prior directions and clarification from the TI Leads regarding consistency in terminology (*e.g.*, stress parameter/drop, Fourier amplitude spectra versus response spectra, oscillator frequency versus signal frequency, *etc*.) so that all proponents and contributors mean the same thing when they use these technical terms in workshop presentations and discussions. The lexicon that Dr Linda Al Atik will be preparing should help considerably in this respect.

Specific Comments on Technical Issues Addressed at Workshop #2

As noted above, the purposes of WS-2 were manifold, combining themes normally associated with both *workshop-1* and *workshop-2* of a SSHAC Level 3 process. The themes related to *workshop-1* are remaining hazard-sensitive issues and data needs, whereas *workshop-2* themes are proponent discussions of candidate models. It was generally agreed in the discussions between the PPRP and the TI Teams that the *workshop-2* themes are not maturely developed at this stage, but it was nonetheless useful to begin to address these because the experience has provided insight into both procedural and technical issues.

The technical comments of the PPRP on the specific issues of WS-2 are addressed in the order of the agenda followed during the three days.

Tuesday Morning

As noted previously, the presentation of Preliminary Hazard Feedback results by Norm Abrahamson was excellent. It provides a framework for continuously refocusing the project direction to emphasize the most important issues. This discussion was presented in a way that clearly outlined the issues without promoting anchoring.

The PPRP was pleased to see that the TI Team recognized that some validation data (MMI, paleo-liquefaction) might have embedded assumptions such as magnitudes based on prior attenuation relations, and as such could involve circular reasoning that is to be avoided.

Tuesday afternoon

CENA and "other SCR" database

The PPRP is pleased that the CENA database is essentially complete and commends the addition of the important 2011 Mineral, Virginia, earthquake dataset.

The great value of the CENA database will be compromised if alias methods (*e.g.*, topographic slope or more complicated functions) are used to assign site class or V_{s30} to the seismograph and accelerometer stations. This may inflate the sigma, and possibly bias the median results. **The PPRP strongly urges a focussed program of site measurements at key sites (especially hard rock sites and those with many earthquakes records) instead of using the V_{s30} estimates.** If possible, this could be done with external funding but if no such opportunity exists then the relative priority of some other aspects of the project may need to be considered in order to enable these station characterizations to be realized.

A priority list, and needed characterization data should be developed as soon as possible. The characterization priority list should be reviewed together with the sites of the 25-30 USGS V_{s30} evaluations for the 2011 Mineral, Virginia, earthquake. Simple rock/soil classifications for sites may additionally be considered and should be collected where possible.

The database of "other SCR" earthquakes is not a core resource for NGA-East, but may be useful for single-station sigma estimation. While results from evaluation these events will contribute to the use of NGA-East results outside North America (or more specifically enhance the inevitable application of NGA-

East models to other SCRs), it appears to be of lesser value for the project's core objectives.

Reference rock

We note that this work is complete and that the TI Team now has a basis on which to make its judgement as to the appropriate reference velocity and kappa, and also how to adjust predictions to this reference profile. The TI Team is clearly considering the potential issues that might arise from changing the reference V_{s30} value from that used in previous work (2,800[5] m/s) to the new value proposed by the Geotechnical WG (3,000 m/s), especially since the difference in site amplifications is expected to be only on the order of 3%. Although the PPRP notes that this is a cleanly completed element of the work, it has doubts regarding the cost effectiveness of this work, which perhaps emphasizes the need for closer coordination of the WG activities by the TI Team. Based on our understanding, this WG should be able to prepare documentation for the TI Team in the near future (indeed, per the project plan this documentation is already behind schedule).

Proxy methods for determining V_{s30}

None of the proxy methods presented appear to translate reliably to all parts of CEUS. The estimates from different methods are poorly correlated, and estimates from the methods are far too low for the expected hard rock values at known sites. In view of these outcomes the TI Team may wish to abandon this work in favor of direct measurements where they are important (see above). Alternatively, in the course of discussion of site response evaluations, the TI Team members expressed an interest in a more simplified site response evaluation (rock/soil classification) than the V_{s30} descriptor. There may be value in conducting a parallel path in developing simpler site response models to judge the value of any more detailed characterization programs and incorporate the two or more program directions as additional epistemic uncertainty.

Wednesday morning

Geometric spreading in first 70 km is critical, given that the disaggregations, in many cases suggest the dominant hazard is from M~6 at distance <100 km. The PPRP directs the TI Team's attention to this as an important problem and cautions that judgements may have to be made on limited evidence, thus requiring the adequate capture of the associated epistemic uncertainties.

[5] A value rounded up after conversion to SI units from the approximated estimate of 9,000 ft/sec

<u>Regionalization</u>

A reasonably good case was made for treating the Gulf Coast as a distinct region from the north-western CENA.

However, at an early stage — it seems that the Transportable Array will not provide data in time for the resolution of this issue throughout CENA — the TI Team should (i) establish the criteria for recognizing regionalization (perhaps focusing on Q and geometric spreading differences), and (ii) identify proponents for other possible regions (*e.g.*, Appalachians). The regional differences and proposed regional parameters should be presented in a common format so as to simplify their relative evaluation. The TI Team could then decide whether the regionalization is necessary according to its effect on the hazard.

Any regionalization also needs to be guided by CEUS SSC results; otherwise, the disjoint may cause problems (some source zones may extend over two different regions).

The PPRP agrees with the TI Lead's comment that clear regional differences might be needed to justify inclusion in the final model, but points out that failure to include a clear regional effect where it exists will introduce a bias for hazard in that region. The TI Team is clearly considering the option of using enlarged sigma values in some cases to capture regional differences, which needs to be weighed carefully because the increased sigma will impact all regions without removing the bias that should be present if these differences are strong. The TI Team indicated that additional regionalization (beyond about two regions) would not be added unless strongly justified by observational data. The PPRP is sympathetic to this position since the enhanced granularity of more regional models must be carefully weighed against the added complexity of implementation. However, the TI Team will need to provide a robust justification for the approach that is finally chosen. As it seems very likely that there will be at least two regions, work needs to be started on Task C5 (Rules for treatment of boundary crossings). The PPRP was split on whether the extra complexity in handling a few more regions than two might be excessive for the benefit in better hazard estimates. However regionalization is done, there needs to be clear documentation and implementation guidelines to avoid erroneous implementation by users outside the project.

<u>1-D Profiles</u>

There were some decisions made at WS-2 to move box C3 (Select Representative ID Crustal Structure for each Region) to be the first item (C1). The PPRP suggests that C3 may have been correct but that it be *informed* by a non-SSHAC compilation of input crustal structures (otherwise considerable work is being done to little effect). Also there is an existing database (Bob Herrmann's) of dispersion-derived crustal models that are available on a regular grid; the PPRP recommends that these should be evaluated relative to the refraction models for accuracy and applicability.

Wednesday afternoon

Point Source Modeling

Some questions mentioned in the agenda are still open, and so our comments are brief. As noted above, the PPRP reminds the TI Team that capture of the CBR of the TDI does not necessarily mean that all available methods need to be employed.

The TI Team may need to decide: whether the stochastic approach is flexible enough to capture finite fault effects; whether finite fault effects matter in modeling CENA hazard; whether introducing finite fault effects reduces the sigma; and whether adjusting the distance metric captures both geometry and directivity effects.

Thursday morning

Finite Fault modeling

Finite fault simulation (FFS) validation and FFS forward-modeling implementation need clear and consistent guidelines. The documentation burden for selection and weighting of these models will be onerous, and consequently, clear and carefully defined requirements are desirable.

Although the PPRP was pleased to see some uniformity among these presentations, a single non-partisan presentation by the WG Chair or a member of the TI Team would have been more effective.

The PPRP is not convinced that the full range of finite fault models and interpretations is currently being considered, for example Haddon's forward-modeling isochron-integration method for finite-fault sources in the M_w 4.5-5.9 range which captures directivity effects to >3 Hz, and Haddon's generic eastern source models for average RMS spectra irrespective of fault azimuth (which is often unknown). This body of work needs to be represented by a proponent and duly considered by the TI Team.

Proponents who classified their simulations as "*pretty close*" when they referred to scatter of observed-model residuals on l*og*$_e$ (ln) plots should also state the multiplicative factors for the separation.

In addition to the chosen recordings for Riviere du Loup (all with similar azimuths) there are more close-in recordings at different azimuths – was there a reason they were not selected for modelling?

The use of poorly-determined site V_{s30} values means good models could fail the test. It was apparent that site effects are not being treated consistently between groups in the validation exercises. This needs to be consistent if the TI Team is going to make an unbiased decision regarding choice of models.

Site conditions for almost all Riviere du Loup and Saguenay recording stations are rock, and these recordings need to be treated properly.

Thought needs to be given as to how to adjust recorded motions to a standard ground condition (easier for response spectra than for time histories?).

For fixed and free parameters, it is vital to know if the parameter-tuning is systematic by all modelers for all events, or individually per event?

The Saguenay starting model is rather unlikely and involves kilobar stress drop, much higher than stress drops being considered elsewhere in the project. Also the Tottori slip model has 3 m of slip at the surface but this is contradicted by the lack of surface rupture.

The modelers do not seem to have informed themselves about previous modeling (*e.g.*, Haddon's for Saguenay) so as to be sure to capture a reasonable sampling of possible forward models.

The starting points for the FFS are suspect for causing circularity in the modelling. Why this is not the case needs to be documented.

Dr Paul Somerville's presentation on magnitude-rupture area scaling relationships in active and stable continental regions was clear and focused, and its relevance to the project abundantly clear; it stood in rather stark contrast to many of the presentations in this session.

Thursday afternoon

The presentation on parameter correlation by Prof. Ralph Archuleta was very well done; this will be very important subject for the final evaluation/integration.

Discussions on parameter correlation have begun but this attempt was premature, as noted by the TI Team during the close-out discussions.

Closure

We trust that this feedback, although rather extensive, will be useful to the TI Team and to the Project Manager. Do not hesitate to contact me if you wish to clarify any of our observations, comments, or recommendations. We look forward to receive the written response to the underlined points this letter in due course, and to the continued progress of the NGA-East Project.

Yours sincerely,

Julian J Bommer
for and on behalf of the PPRP
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Copy: TI Leads
Sponsor Representatives
PPRP Members

APPENDIX

Acronyms

CBR	Center, Body and Range
CENA	Central and Eastern North America
CEUS	Central and Eastern United States
FFS	Finite Fault Simulations
GMPEs	Ground-Motion Prediction Equations
ITC	Informed technical community
JMC	Joint Management Committee
MMI	Modified Mercalli intensities
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
SSC	Seismic Source Characterization
SSHAC	Senior Seismic Hazard Analysis Committee
TDI	Technically-defensible interpretations
TI	Technical Integrator
WG	Working Group
WS	Workshop

November 23, 2011

Dr. Julian Bommer
Chair, NGA-East Participatory Peer Review Panel

Subject: NGA-East responses to PPRP review comments on SSHAC Workshop 2

Dear Dr. Bommer:

This letter constitutes the NGA-East collective response to the PPRP letter dated October 28, "2011", on the NGA-East SSHAC Workshop 2. On behalf of the entire NGA-East project we thank you and other members of the PPRP for the constructive comments provided following the NGA-East SSHAC Workshop 2. We are also grateful for all PPRP's efforts and cooperation on the NGA-East project.

This letter provides responses to the specific comments as requested in the PPRP letter. The specific PPRP comments are repeated in italic, followed by the collective reply of the NGA-East project. Although we are not providing written responses to other PPRP comments, they will be duly considered in the NGA-East project.

Responses to specific comments

Bottom of page 3, Item 2: *To ensure that the TI Team is adequately challenging the WG proponents and experts, the PPRP has determined that one or more members of the PPRP should observe a number of the TI-WG meetings. <u>The PPRP requests that the schedule for all WG meetings be provided well in advance to the PPRP so that, at the PPRP discretion (and with the agreement of the Project Manager), some WG meetings can be attended by one or more PPRP members to observe and document the technical interactions.</u>*

> Agreed, but it is important to clarify the difference between the regular NGA-East WG meetings with the "working meetings" described in the SSHAC guidelines. This clarification is specific to the structure of NGA-East.
>
> In NGA-East, WGs are acting as contractors conducting research activities under the TI Team direction. As such, the WGs' activities should be fostering a free flow of technical activities among the participants. In keeping with this idea, the TI team members often either participate or play a lead role in these meetings, but are not always present. These meetings tend to be held frequently, with a week or two of advance notice, and often consist of web meetings, although some are attended in person.
>
> Working meetings, on the other hand, provide WGs the opportunity to share their preliminary results with the TI team. Working meetings are an important part of the SSHAC process where proponent discussions on alternative interpretations of the data or models are to take place. This is also where the TI team is expected to challenge the WGs and other proponent experts during discussions. Working meetings are generally scheduled several months in advance and we will inform the PPRP as they are scheduled. We will maintain a master list of planned working meetings on the NGA-East website. The logistics and expenses associated with PPRP member(s) attending working meetings (in person or via Internet) will have to be addressed on a case-by-case basis.

Top of page 3, Item 3: *The PPRP feels it is essential that sufficient technical and proponent experts be used in the NGA-East project. Consequently the PPRP asks to review the list of invited or scheduled technical experts and proponents prior to each of the future workshops.*

> Agreed. We did provide such a list in July for Workshop 2. We plan to provide the list again at least three months prior to future workshops.

Page 6: *The PPRP notes that in a SSHAC project, it is the responsibility of the TI Team to assemble, document, and defend the final results of the project. This means that the TI Team has the primary responsibility for all aspects of the project, including the work carried out by the WGs. For this reason, the PPRP urges the TI Team to take a very active role in guiding the WGs in their work and ensuring WG documentation meets the needs of the TI Team.*

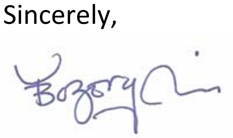
> Agreed. We recognize that the TI Team is ultimately responsible for the challenging task of documentation. The TI Team is working on this with the WGs.

Page 9: *The great value of the CENA database will be compromised if alias methods (e.g., topographic slope or more complicated functions) are used to assign site class or Vs30 to the seismograph and accelerometer stations. This may inflate the sigma, and possibly bias the median results. The PPRP strongly urges a focused program of site measurements at key sites (especially hard rock sites and those with many earthquakes records) instead of using the Vs30 estimates. If possible, this could be done with external funding but if no such opportunity exists then the relative priority of some other aspects of the project may need to be considered in order to enable these station characterizations to be realized.*

> The original schedule and budget did not allow the collection of additional Vs data, and the development of "simple correction factors" at recording stations was devised. We are now working on a possible parallel track to obtain measured Vs data at additional critical recording sites. If this attempt is not successful, we will re-evaluate the priority of the tasks to possibly allocate some funding to carry out some measurements.

We thank you and PPRP again for all the efforts and cooperation.

Sincerely,



Yousef Bozorgnia, for and on behalf of NGA-East Project
NGA-East Project Manager, and
Executive Director, Pacific Earthquake Engineering Research Center (PEER),
University of California, Berkeley

Copy: Members of PPRP
NGA-East TI Leads
NGA-East JMC

B.3 Workshop 2B, July 1416, 2014

B.3.1 Workshop Summary

This Workshop followed the SSHAC Theme 2: Proponent Discussions.

This Workshop was focused on proponent discussions of candidate models. It also summarized the conclusions of various science tasks, including the development of the ground-motion database, the regionalization of path effects, the status of finite-fault simulations and update on the modeling of standard deviation.

The morning session of the first day focused on the development of median response spectral estimates using a new approach, which is based on the combination of a Fourier spectral model and a duration model through RVT. In particular, this approach was called for a consistent, calibrated duration, and initial models for both the Fourier spectrum and the duration were shown. In addition, investigations into kappa, the parameter controlling the high-frequency spectrum, and issues relating to its estimation from CENA stations, were presented. Discussions focused on depth scaling issues for the regression and the problem of extrapolation, in particular for the duration model, to large magnitudes. The issue of consistency in the complete model building for the duration model was also raised.

The afternoon session of the first focused on database issues. The status of source, site, and regionalization tasks were presented. Discussion points were in particular the issue of sites with poorly constrained predictor values (VS30) and their inclusion in the regressions, as well as the extrapolation to hard-rock conditions. In addition, the robustness of the conclusion that there are only two main regions was discussed. Furthermore, discussion focused on the stress parameter and its depth dependence, in particular, the regional differences between the depth dependence.

The morning session of the second day started with a discussion on epistemic uncertainty with respect to median approaches, and an overview of previous approaches was presented. Then, the approach used in the Southwestern United States Ground Motion Characterization SSHAC Level 3 Project (SWUS) was presented (based on a continuous distribution of median predictions), and its application to NGA East was discussed. Discussions focused on the method (Sammon's maps), including redundant models, and the inclusion of simulation results.

Focus shifted to finite-fault simulations and their validation. Different simulation methods and their evaluation against data were presented. Discussion points were some of the events that the simulations were compared against (in particular the Saguenay event), as well as how the simulations can be incorporated into NGA-East. In addition, the input parameters for the forward simulation runs were discussed.

B.3.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

August 11, 2014

Dr. Yousef Bozorgnia
Project Manager for PEER NGA-East Project
Pacific Earthquake Engineering Research Center (PEER)
University of California, Berkeley
325 Davis Hall, MC 1792
Berkeley, CA 94720

Dear Dr. Bozorgnia:

Reference: *Next Generation Attenuation – East Project*: Participatory Peer Review Report on SSHAC Workshop No. 2.

Acronyms

ACP Atlantic Coastal Plain
CEUS Central and Eastern United States
CNA Central North America
ENA Eastern North America
EPRI Electric Power Research Institute
FAS Fourier Amplitude Spectrum
FFS Finite Fault Simulation
GCR Gulf Coast Region
GMPE Ground Motion Predication Equation
GWG Geotechnical Working Group
HEM Hybrid Empirical Model
NGA-East Next Generation Attenuation East
PEER Pacific Earthquake Engineering Research Center
PPRP Participatory Peer Review Panel
PSHA Probabilistic Seismic Hazard Analysis
RVT Random Vibration Theory
SASW Spectral Analysis of Surface Waves
SSHAC Senior Seismic Hazard Analysis Committee
SWUS Southwestern United States Ground Motion Project
TI Technical Integrator
USGS United States Geological Survey
WNA Western North America
WS-2 Workshop 2

This letter constitutes the report of the PPRP on WS-2, “Alternative Interpretations,” for the referenced project. The workshop was held July 14-16, 2014, at the University of California, Berkeley in Berkeley, California.

Following guidance described in the NGA-East Project Plan[1] for the PPRP, and consistent with the expectations of the SSHAC process[2], the PPRP participated in WS-2 in order to be informed and to review both procedural and technical aspects of the workshop. All six members of the PPRP (J. Adams, J. Ake, J. Ebel, J. Kimball, R. Lee, and G. Toro) attended WS-2 and were able to observe all aspects of the workshop[3].

The observations and comments from the PPRP focus on assuring that the overall objectives for WS-2 are achieved. The three primary WS-2 objectives are: (1) to present/discuss/debate alternative viewpoints, (2) to identify the technical basis for alternative hypotheses and associated uncertainties, and (3) to provide the basis for subsequent develop of models.

GENERAL OBSERVATIONS

The workshop was well structured and satisfied the SSHAC requirements for WS-2. In particular, the presentations were clear and focused, and the discussions provided additional clarity and depth. This allowed the PPRP to have a good understanding of the alternative interpretations of existing data, the technical basis for these interpretations, and the associated uncertainties.

The presentations during the first two days provided an overview of the data that have been collected by the project (i.e., ground-motion, crustal structure, site characterization, and finite-fault simulations) and how these data are being used as part of the process to generate new GMPEs for the CEUS. There were also interesting methodological presentations on how RVT will be employed (including the advantages and the issues that this decision creates), on the proposed approaches for the estimation of kappa, and on the approach for the characterization of uncertainty in the median amplitudes. The third day was devoted to presentations of alternative proponent models for the median amplitude and a proponent model for the aleatory uncertainty (including the decomposition of residuals and the rationale for the use of single-station sigma).

At the conclusion of each meeting day, the TI Leads prepared a summary that identified the key issues and action items arising from that day's presentations and discussions. These summaries are very thorough and well prepared, and the Project is encouraged to play close attention to them.

During the course of the meeting, the Project provided the PPRP a number of published papers, draft papers and reports, and other materials from parallel projects, which provide support for the methodologies employed by the Project. These materials facilitate the PPRP's review. The volume of this material, on the other hand, underscores the documentation task that this Project will be facing in the coming months.

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[1] Goulet, et al., 2011, *NGA-East Project* Plan, Pacific Earthquake Engineering Research Center (PEER), University of California, Berkeley

[2] Budnitz et al., 1997, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.* NUREG/CR-6372, NRC; and NRC, 2012, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Revision 1, NUREG-2117.

[3] J. Ebel, attended on July 15-16, 2014.

Also on the topic of documentation, the PPRP acknowledges receipt of the draft Table of Contents for the Project final report. Our comments on this document are contained in the Documentation section below.

SPECIFIC COMMENTS AND RECOMMENDATIONS

The comments and recommendations below are organized by topic. Items requiring a formal response are underlined.

RVT Approach for the Calculations of Spectral Acceleration

Subsequent to the last Workshop, the NGA-East TI team has revised the focus of the project to use FAS as a primary development tool. The TI team has recognized the importance and integral role that RVT will play in developing response spectra from FAS. As described in WS-2, the project has formed the RVT WG that will evaluate certain important parameters used in the RVT process. The discussion in WS-2 suggested to the PPRP that preferred values for the Peak-to-RMS factor and a calibrated duration model would be developed by the RVT WG.

It is the PPRP understanding that the outcomes of the working group activities will be evaluated and integrated into the final project workflow. It is not yet clear to the PPRP how the evaluation of alternative duration models will be accomplished. The presentation by N. Kuehn suggested that misfit to data would be used as a primary criterion (as has been done in other recent studies cited). However, the NGA-East database has poor magnitude coverage and it may be problematic to rely solely on that dataset to develop duration models for larger events. Instead, it may be necessary to use results or insights from the finite-fault simulations to constrain these durations. The PPRP again emphasizes the need for this evaluation and integration process to be fully documented as soon as practicable. <u>This documentation should be shared with the PPRP as soon as possible and included in the final project report.</u>

Ground-Motion Database

The PPRP was encouraged to see that the re-processing of the ground-motion database has been satisfactorily completed. The PPRP has two recommendations regarding the database, as follows:

- <u>It would be useful to populate the quality field (or any comments from the processing) in a more consistent manner than what was done in earlier versions of the flat file.</u> It is essential to know the relative quality of the records and which can be used without reservation. It is also important to know why certain records were considered less than adequate, so that downstream users can make a decision whether to consider these records in specific situations where those records might be of particular importance.

- As an outcome of the WS2 discussions the PPRP suggests <u>that earthquakes known to be induced should be flagged in the flat file, and that the assignments already implemented by the USGS should be used for this purpose</u>.

Site Classification

The GWG has expended significant effort developing techniques to classify recording sites based on available site geophysical information and site proxies. Based on the within-event standard deviations presented at the workshop, the magnitude of ground motion sigma appears may be larger than expected (~0.75 $\sigma_{\ln}$). As mentioned at WS-2, site geotechnical misclassification could be a possible contributor to the variability. A spot check by one PPRP member showed two of the 1988 Saguenay recording sites (CN.CHIQ and CN.SANQ) were assigned Vs30 = 500 m/s whereas documentation indicates that they are bedrock sites with Vs30 better estimated as 2000 m/s. If a significant number of sites are misclassified, a bias in the site correction (and possibly in the reference-rock motion, as well) could occur, increasing the ground motion variability and making it difficult to make inferences from the data.

We request that the TI team (with help from the GWG) identify how site classification can be improved and how the limitations introduced by this misclassification can be overcome in the analysis. One approach mentioned at the workshop is to "bin" the residuals by both region and site classification and possibly identify questionable site classifications and reclassify outliers. Another approach is to use "robust" statistics for the site terms. If reclassifications are made strictly on the basis of residual analysis, the TI team is encouraged to demonstrate that this procedure provides objective and unbiased site classification.

If there is any GWG document (however preliminary) describing the evaluation of the proxy methods and the development of the weights (one PPRP member recalls that a memo by Jon Stewart was mentioned in this regard), the PPRP requests that a copy of this memo be provided. Furthermore the PPRP notes that the flatfile released on July 8th lacks any documentation for the choices in some of the fields (explicitly column AN: on what document was each "1" based?) and trusts that this will be forthcoming.

The following are some **suggestions** for consideration by the TI team regarding the treatment of site conditions for sites without direct Vs measurements:

- Try to determine whether any available and nearby site characterizations could be used to classify a recording site. To what extent has this been done already?
- Many of the site classifications assigned by the GWG for Canadian sites method have low Vs30, even where this seems unlikely based on the GSC's long-term goal of locating the national seismograph network (CNSN) seismographs on rock (Adams checked the Saguenay earthquake recording sites and will confer with Gail Atkinson to improve Canadian site assignments).
- Many USArray stations being used are in low-topography regions (Oklahoma, etc.), where the site is expected to be thin sediment over high-velocity sedimentary rock (rather than having a low Vs30), and so such sites might have a high chance of being wrongly classified. If the number and importance of the affected records justify it, the TI should consider the development of an alternate approach for this region, rather than using a

global approach. The same may be done for other regions containing high-value sites, (e.g., certain portions of Canada), if the data are sufficient.

- The list of data sources in the presentation by Joseph Harmon indicates that one profile was used from the USGS SASW campaigns following the Mineral earthquake. It is the PPRP's understanding that more profiles are available (12 are tabulated in the EPRI, 2013, report and more may be available at present). If the GWG has not done so, it is encouraged to track down these data and incorporate them in their evaluation of the proxy methods.
- Apply the weighted proxy methods (Code 4 and 5 assignments) to the measured Vs30 sites and determine whether there appears to be a bias in the result and how much the variance is reduced by using the weighted sum. This may also guide the assignment of sigma [ln(Vs30)] for these cases.
- The PPRP understands that the weights for the various proxies is being calculated using 1/(residual bias^2 + residual variance) and that the proxy estimates are not being bias-corrected prior to calculation of the weighted sum. If this is the case, the GWG may wish to consider testing one or more of the following modifications to their approach: (1) use a weight that is inversely proportional to the residual variance, as is common practice (the difference with existing weights will not be extreme because the bias is approximately equal to ½ sigma); (2) remove the bias from each estimate, prior to combining the estimates (most biases are statistically significant according to slide 10 and it may be beneficial to remove them); (3) calculate the correlation coefficient between residuals and take this correlation into account to develop the weights (also, if these correlations are low, the weighted estimates should have lower standard deviations than the individual estimates). The benefit of these approaches may be judged by using the test described in the previous bullet.

In summary, given the limitations of the dataset (70 events) and the number of records with measured Vs30 (only 6%), it is very important for the GWG to make the best possible use of the available proxy site data and for <u>the TI Team to develop (and document) an analysis approach that takes the limitations of the site data into account, without introducing significant biases.</u>

Kappa

A number of alternative methods for developing estimates of kappa in CENA were discussed on the first day of the Workshop. At the end of that discussion the PPRP did not have a clear understanding of the proposed path forward for developing kappa in the NGA-East project. After subsequent discussions, the TI Team and Project Manager described how the approach currently being implemented in the SWUS was likely to be utilized in NGA-East. The Project Manager provided access to a recently completed PEER Report that summarizes the SWUS approach to kappa development. After a preliminary review of the SWUS report the PPRP has a better understanding of the proposed process. However, no real discussion of how results derived using the three alternative methods for estimating kappa (high-frequency, low-frequency, broad-band) would be evaluated or combined in this project has been shared with the PPRP. <u>The PPRP again emphasizes the need for this evaluation and integration process to be fully documented as soon as practicable, shared with the PPRP and included in the final project report</u>.

As part of the kappa sub-project a major effort is being focused on performing broad-band inversions of the available data to estimate kappa. Based on the discussion in the SWUS PEER Report, these calculations will be inverting for corner frequency, stress-drop, geometric spreading cross-over distance and Q in addition to kappa. It is not clear how this data will be used, and if it will be used beyond estimating kappa. For example, will this data be used to inform/constrain distributions of the parameters in the Point-Source modeling? The TI Team should describe how they will use the data from the broad-band inversions, and how they will account for possible effects of inconsistencies between the parameters used in this inversion and those used in the forward modeling.

Regionalization

The PPRP has not yet reviewed the Mooney et al. report, so the following comments are based on the slides from the presentations at WS2.

Geographic extent.

The geographic regionalization appears reasonable, though the northern end in the Gulf of St. Lawrence is a poor approximation. The offshore region in Canada might better belong with the ACP (however, no justification was provided for why the ACP stops near Cape Cod). The inclusion of the Mississippi embayment into the GCR was also questioned, as the embayment does not have very thick sediments like the GCR (and the verbal rationale for its inclusion in GCR was mantle, not crustal, structure). The TI should ensure that the inclusion is documented and defended, and that the consequences of the proposed treatment for the determination of mid-continent hazard are explained. The PPRP notes that sediment thicknesses vary greatly (from <1 km to >15 km) for GCR, so it is by no means a uniform characteristic of that region and it may need to be treated as a site property as proposed by Martin Chapman (see below).

Validity of crustal profiles.

The PPRP notes that equally weighting all velocity profiles irrespective of the method of determination may not sufficiently recognize the differences in quality of the profiles from the different methods. The PPRP suggests that an internal review be completed on the selection and weighting of crustal velocity profiles and the inferred regional median profiles to inform the consequences of the adopted approach on the final results.

Step increase in velocity at about 12 km depth.

The PPRP observed this step in the averaged data for both CNA and Appalachians. Because of its possible relevance to the discussion of depth-dependent effects on various parameters, the TI Team should consider if its spatial extent might be mapped in some way.

Q in each region.

The reasons for treating the rest of ENA as a single unit as distinct from the GCR need to be clearly articulated. The chief basis seems to be the similarity of median Q curves for each of its 3 subregions. However the basis for those curves is uncertain in the following ways:

- Rationale for choices from the literature of the Q relations to be used (are all of the relations used valid for the entire region being considered?)
- Whether the chosen relations are comparable in terms of geometric spreading used in their derivation (i.e. are apples being averaged with oranges?)
- Method of determining the median relation from the individual Q(f) curves (in what way is it the median? Does it average over 1/Q or over Q?) – to be blunt, it looks like a straight-line eye-fit through the cloud of curves – if so, it is unlikely to have the precision needed to decide if there are regional differences or not

The PPRP asks that a TI member familiar with determination of Q (and pitfalls thereof) <u>provide a written assessment of the WG's procedures, confirm that the "median" relations are really representative and assess their uncertainty, and thence verify the validity for considering some of the regions as having the same Q.</u>

Treatment of GCR in terms of Q or Kappa.

The approach proposed by Martin Chapman for the treatment of the differences between the GCR and the rest of CENA in terms of a high kappa due to thick sediments (instead of the interpretation used earlier in terms a lower crustal Q) is an interesting one. The difficulty in confirming Chapman's interpretation is compounded by the high correlation between distance to the source and thickness of the sediment column. There is also the possibility that Lg wave propagation is being impeded by changes in crustal thickness. As is the case with any significant deviations from existing practice, this approach must be thoroughly documented and defended in the final report. The PPRP will be interested in seeing how the TI team chooses to model these differences in terms of crustal Q(f) or Kappa and how this choice is documented.

There is some confusion among the PPRP on how this approach will be implemented on a site-specific basis. It is not clear what site-specific information (inferred kappa, site geophysical characterization, inferred or measured Vs30) would be used for site-specific hazard assessments at Gulf Coast sites. The PPRP suggests that in the final report the TI explain how these effects will be incorporated in a site-specific study for a GCR site and what site data the user may need.

Final check.

Analysis of residuals for the observations should be carried out for all four initially-proposed regions to confirm that there is no difference between three of them.

Q-depth-stress drop.

The PPRP were interested in the debate as to whether stress drop increases with depth, as had been suggested for part of Canada by Jack Boatwright. They were mindful that many had searched for such an effect and few had found it (Allen for SE Australia being an exception). The California and Japan data sets (Baltay) were given as examples that it does not exist, though one would need to control the datasets for geometrical spreading (which would change the Mo and consequently stress drop), and ensure that the depth range is satisfactorily represented (i.e. half the data above ~10 km and half deeper so that the picture is not swamped by shallow data).

An alternate explanation is that attenuation changes with depth (Atkinson), and that changes in Q(f) (or geometric spreading) with depth are erroneously mapping into stress drop. Speculatively, the change in crustal properties might coincide with the ~12-km-deep velocity increase from Mooney et al., with a small difference in Q or geometric spreading mapping into a large apparent change in stress drop. It is thought that Boatwright might have investigated event-specific Q models for the events he studied (as well as using a single geometric spreading and Q model for all of them). If so, that work needs to be investigated to assess the size of the change in Q that would be needed to make the depth–stress drop effect vanish.

PPRP advises this is a crucial issue for the point-source (and finite-fault) modelling and that attention needed to be paid so that it does not get lost.

Use of Sammon's Maps to Characterize Uncertainty in the Median Ground Motion.

The approach adopted by the TI team for the characterization of epistemic uncertainty in the median ground motion by constructing a multidimensional GMPE space, generating a large set of new models from this space, and then using Sammon's maps to visualize the resulting ground motions, select a smaller set of representative models, and assign weights to the representative models, is becoming a key element in the project. The PPRP recommends that TI team members pay close attention to the documentation of this technique to ensure that the final report is not only complete and scientifically sound, but also as transparent and persuasive as possible to the PPRP and to a broader technical audience. This documentation effort should also include extensive sensitivity analyses in both ground-motion space and hazard space.

A useful exercise in this regard may be the application of this approach (for demonstration purposes) to the published GMPEs and data used in the EPRI 2004-2006 GMM Review Project (EPRI, 2013). <u>The PPRP encourages the project to perform this exercise. The TI Team should examine the EPRI experience and the results from this exercise to identify pitfalls that may arise when using the smaller CEUS data set and when covering a broader distance range.</u>

Use of Finite-Fault Simulations (FFSs) in NGA-East.

The PPRP continues to be concerned about the question of how the FFSs will be used in the creation of the GMPEs in NGA-East. The original purpose for using FFSs in NGA-East was to help constrain the long-period part of the source spectrum of CENA earthquakes and to provide simulated near-source records for large magnitude events. For CENA the largest earthquake for which observed ground motions are available is the Mw 5.9 Saguenay event, and the strong-motion records from that event contain little in the way of longer period seismic energy. This may have been due to instrumental noise, low instrument dynamic range at long periods, or a lack of long-period energy excited by the earthquake. Both the Saguenay earthquake and the Mw 5.8 Mineral earthquakes are lacking in near-source strong motion records. It was planned that FFS could be used with a suite of finite fault ruptures that would span the anticipated range of ruptures that could be expected for large CENA events, and those FFSs would then provide simulated data to fill these important gaps in the available CENA strong-motion database.

The FFS validation analyses presented at the WS-2 seem to highlight the issues that the TI team must deal with. The validation analyses of the FFSs with western U.S. data showed that these simulations are capable of matching observed amplitudes across the entire period range tested (0.01 s to 10.0 s). However, the FFSs did not match the observations from eastern earthquakes, particularly the two largest events (Saguenay and Mineral), nearly as well at longer periods (above about 0.5 s). Furthermore, the uncertainties in the simulations for the CENA events are much larger than the uncertainties in the FFS for WNA events at all frequencies. Rob Graves showed some analyses that indicated that a Haddon-type rupture source for the Saguenay event provides a better match to the amplitudes at Sa0.3 s and Sa1.0 s. However, this rupture model was derived to specifically fit the Saguenay observations, and the PPRP believes its value for other possible sources in CENA is more in helping define the minimum extent of the parameter space that should be used than in giving representative values for all CENA earthquakes.

The PPRP has some suggestions for the TI team based on the WS-2 presentations. First, the PPRP would like to see comparisons of point-source stochastic model simulations to the data from Saguenay and Mineral. This would provide another context for judging the utility of the FFSs relative to the point-source simulations. A second suggestion is that the TI team ensure that Haddon-style rupture models are included as part of the family of models for which FFSs are run. As summarized by Rob Graves, some characteristics of the Haddon model that are important are a strong unilateral rupture, impulsive slip function, very short slip duration, high rupture velocity, and abrupt termination of slip at fault edges. Rob also used a somewhat high L/W ratio, though not as high as Haddon's. A third suggestion is to carefully define what measure of distance to use for the GMPEs derived from the FFSs. The sense of the PPRP is Rrup is better than RJB for events in northeastern North America, because these events usually have thrust mechanisms on dipping faults that may not rupture the ground surface even in large magnitude events. There is a similarity of these events to the blind thrust fault earthquakes observed in parts of California. On the other hand, many of the events in central North America have strike-slip mechanisms, and for these RJB may be the more appropriate distance measure used in the GMPEs. .

In summary, regarding FFSs the PPRP requests clarity on the role of FFS going forward in this project. <u>How will FFSs be used, especially relative to the point-source simulations, in the final GMPEs? At the beginning of NGA-East it was hoped that FFSs would help generate realistic ground motions for large magnitude events at close fault distances. Is this possible, given what has been learned from the FFS testing and validations?</u>

Other Developers

As discussed on the final day of WS-2 (following presentations by V. Graizer and K. Campbell) there will be serious schedule challenges for external (non-NGA-East project) researchers to develop alternative GMPEs in a time frame that will support evaluation by the TI team. The PPRP was encouraged by the Project's decision to set up a Developers Working Group. That fact notwithstanding, the PPRP feels strongly that the project needs to make the project databases and interim results available to other developers as soon as the information is reviewed, mature and stable. This will enhance the potential for updated models to be included in the evaluation process and ensure the broader community views are included in the final assessment. The PPRP also requests to be notified when meetings of this Working Group are scheduled, because we would like the opportunity to observe.

One issue that concerns the PPRP in this regards is that Ken Campbell indicated that he would not be able to update his Hybrid Empirical Model (HEM) in time for consideration by the Project. The project is encouraged to investigate ways for filling this gap, including the following: (1) have the project update the HEM in consultation with Ken, or (2) encourage other HEM developers to develop new models that incorporate the NGA-West2 host models and the Project database (possibly in consultation with Ken).

Requested Sensitivities

The TI team is making excellent progress on developing the draft GMPEs. Although it is not an issue whether the NGA-East GMPEs will result in significantly higher or lower hazard at eastern US sites relative to prior hazard assessments, the project does have an obligation to understand the nature of the changes to perceived CEUS hazard and communicate how and why the NGA-East GMPEs may have significantly increased or decreased the perceived hazard. In anticipation of more mature results for Workshop 3a (October 2014), the PPRP requests that the workshop presentations include some comparisons in both ground motion (Sa) and hazard against the CEUS SSC model (EPRI, 2013) and the EPRI (2004, 2006) CEUS GMPEs. Since hazard models have been previously prepared and run for selected "demonstration sites" (contained in the CEUS-SSC report and in EPRI, 2013), we do not envision this request to be a large effort.

The PPRP requests that the TI team prepare a comparison of the draft NGA-East GMPE median and sigma models to the EPRI (2013) and EPRI (2004, 2006) GMPEs. Median and sigma ground motions should be compared for pga, 10 Hz and 1 Hz for M 5, 6, 7, and 8 from 1 to 1000 kms and by oscillator frequency for several representative source distances.

The PPRP also requests that the TI Team calculate hazard curves at the seven CEUS-SSC demonstration sites and compare these results to those obtained with the earlier EPRI GMPEs (2004-2006 and 2013; these results are contained in the CEUS-SSC report and in EPRI, 2013, and do not need to be re-calculated). Comparisons need only be made for a hard-rock site conditions. Similar to the CEUS SSC model report, we request that total hazard and contribution to hazard from background and RLMEs be presented for PGA, 10 Hz and 1 Hz. These computations should be timed for presentation at Workshop 3B.

Documentation

During Workshop 2 it became clear to the PPRP that there will be a wide range of documentation reflecting the work completed as part of the NGA-East Project. The PPRP appreciates that the work completed does not simply fit into the SSHAC process as expressed in NUREG/CR-6372 and NUREG-2117. However, it is equally clear to the PPRP that the success of the project directly depends on the complete set of project documentation which will include more than the NGA-East Final Documentation report.

From a documentation perspective the PPRP endorses the guidance provided by NUREG-2117, specifically Section 4.10 of that document. To aid the Project and Technical Integrator Teams the PPRP restates the high level guidance from NUREG-2117 regarding documentation, tailored to the NGA-East project.

> *The project documentation is the fundamental basis for the reader to understand (1) what process was used to derive the NGA-East GMPEs; (2) what data were available and used in the evaluation process; (3) how the data, models, and methods of the larger technical community were considered; (4) the elements of the GMPE models and their technical bases; (5) how the models capture the center, body, and range of technically defensible interpretations; and (6) the sufficient hazard sensitivity result to understanding the implications of using the NGA-East GMPEs for future PSHAs.*

While the Project Team has provided the PPRP with a draft Table of Contents for the NGA-East Documentation, there remains uncertainty as to how much of that documentation will rely on supporting reports and references. Given that the schedule for completing the project is very aggressive, including the completion of Workshops 3A and 3B, the PPRP is concerned that our review of the project report and supporting documentation will not be a simple task that can be completed quickly. In recognition of this the Project Team has already provided a number of supporting references to the PPRP — the PPRP supports this so long as the references provided are considered as critical supporting documentation that either provides an understanding of the critical intellectual framework being followed, or direct data/analyses being used by the project.

Recognizing these documentation issues, <u>the PPRP requests that the Project Team initiate the development of a list of critical supporting documentation and of an expected schedule that this material can be provided to the PPRP to support our review</u>. We point out that the PPRP does not expect this to be a “reference list” or all “references” — we will leave it up to the Project and Technical Integration Teams to identify critical supporting documentation that will expedite the PPRP review of the draft report. It would be helpful if the Project team also identified in what way each report will contribute to the final report. We also recognize that the list of critical supporting documentation should be considered as a “living document” that can change and be updated as the project approaches the development of the draft NGA-East Report. The list of critical supporting documentation should also identify if the Project Team needs explicit review and feedback from the PPRP or the document is being provided as background material needing no PPRP feedback.

The Project has provided to the PPRP a draft Table of Contents for the Project final report, for preliminary review. Given the paramount importance of documentation in a SSHAC Level 3 study, the PPRP requests that the TI develop a more detailed draft Table of Contents, either by providing a one paragraph description of the contents and objective of each section of the report, and/or by providing a list of second-level headings. This additional material should include what is being discussed in each section, what external documents will support that section, who is responsible for developing the supporting documents, and when the supporting documents will be completed. This revised draft Table of Contents should be prepared as soon as practical (we suggest no later than mid-September) and then provided to the PPRP for comments.

The PPRP's initial review of the Table of Contents prompted the following questions and comments from some of the members. The project should keep these questions and comments in mind while revising and expanding the Table of Contents.

- It is not clear where in the report one would find the discussion of input parameters such as stress drop, Q, and whether geometrical spreading is R^{-1} or $R^{-1.3}$.
- The intent of Part IV may be better captured by the title "*Implications for* Hazard Results and Instructions for ~~their~~ *GMPE* Use" (italics indicated suggested additions, strikeout indicates suggested deletions). The present title may convey the idea that these hazard results are the primary product of the project and that instructions are being provided for the use of these results. Along the same lines, the PPRP suggests the following descriptions for Chapters 10 and 11. Chapter 10: Thorough documentation of hazard *implications* and sensitivity analyses that provide information on the dominant contributors to the hazard. Chapter 11: Instructions for the use of ~~the hazard results~~ *the GMPEs* and their limitations (e.g. M, R, frequency, near-fault effects captured only in a global sense, etc.).

In closing, the PPRP wishes to congratulate the Project for a successful Workshop 2 and looks forward to the success of Workshops 3A and 3B, as well as to model completion and the documentation effort to follow.

Please feel free to contact us if you would like to discuss further our comments or recommendations.

Sincerely,

Gabriel R. Toro Chair, PPRP	John Adams Member, PPRP
Jon Ake Member, PPRP	John Ebel Member, PPRP
Jeffrey Kimball Member, PPRP	Richard C. Lee Member, PPRP

September 9, 2014

Dr. Gabriel Toro
Chair, NGA-East Participatory Peer Review Panel

Subject: NGA-East responses to PPRP review comments on SSHAC Workshop 2

Dear Dr. Toro:

This letter constitutes the NGA-East collective response to the PPRP letter dated August 11, 2014, on the NGA-East SSHAC Workshop 2. On behalf of the entire NGA-East project we thank you and all members of the PPRP for the constructive comments provided during and following the workshop. We are also grateful to you and the PPRP members for all you efforts, interactions and cooperation on the NGA-East project.

This letter provides responses to the specific comments as requested in the PPRP letter. The specific PPRP comments are in *italic*. The <u>underlined sections</u> represent the questions and comments that the PPRP requested formal responses. These are followed by the NGA-East collective responses in **bold face**. Although we are not providing formal written responses to other PPRP comments, they will be considered in the NGA-East project and we appreciate your efforts in communicating those to us.

RESPONSES TO SPECIFIC COMMENTS

Documentation

The Project has provided to the PPRP a draft Table of Contents for the Project final report, for preliminary review. Given the paramount importance of documentation in a SSHAC Level 3 study, <u>the PPRP requests that the TI develop a more detailed draft Table of Contents, either by providing a one paragraph description of the contents and objective of each section of the report, and/or by providing a list of second-level headings. This additional material should include what is being discussed in each section, what external documents will support that section, who is responsible for developing the supporting documents, and when the supporting documents will be completed.</u> This revised draft Table of Contents should be prepared as soon as practical (we suggest no later than mid-September) and then provided to the PPRP for comments. Recognizing these documentation issues, <u>the PPRP requests that the Project Team initiate the development of a list of critical supporting documentation and of an expected schedule that this material can be provided to the PPRP to support our review</u>.

> **Agreed. We will let you know about the time frame of submitting the updated Table of Contents.**

RVT Approach for the Calculations of Spectral Acceleration

The PPRP again emphasizes the need for this evaluation and integration process to be fully documented *as soon as practicable. This documentation should be shared with the PPRP as soon as possible and included in the final project report.*

Agreed. Following the workshop, the RVT Working Group initiated drafting a PEER report to document their work. We will share this report once it is near completion or ready to be published.

Ground-Motion Database

The PPRP was encouraged to see that the re-processing of the ground-motion database has been satisfactorily completed. The PPRP has two recommendations regarding the database, as follows: 1) It would be useful to populate the quality field (or any comments from the processing) in a more consistent manner than what was done in earlier versions of the flat file. It is essential to know the relative quality of the records and which can be used without reservation. It is also important to know why certain records were considered less than adequate, so that downstream users can make a decision whether to consider these records in specific situations where those records might be of particular importance.

Agreed. Following the workshop, we have started a task to provide a quality flag consistent with the approach used in NGA-West2. Once fully checked, the flag will be added to the flatfile, and the updated flatfile will be shared with the PPRP.

As an outcome of the WS2 discussions the PPRP suggests that earthquakes known to be induced should be flagged in the flat file, and that the assignments already implemented by the USGS should be used for this purpose.

Yes. We have obtained the list of events flagged as "potentially induced" from the USGS. A new column in the flatfile will be added indicating "potentially induced events".

Site Classification

If there is any GWG document (however preliminary) describing the evaluation of the proxy methods and the development of the weights (one PPRP member recalls that a memo by Jon Stewart was mentioned in this regard), the PPRP requests that a copy of this memo be provided. Furthermore the PPRP notes that the flatfile released on July 8th lacks any documentation for the choices in some of the fields (explicitly column AN: on what document was each "1" based?) and trusts that this will be forthcoming.

A document has been developed by the Geotechnical Working Group (GWG). We will forward this to the PPRP. In addition, a PEER database report is being drafted and we will share that draft report with the PPRP.

In summary, given the limitations of the dataset (70 events) and the number of records with measured Vs30 (only 6%), it is very important for the GWG to make the best possible use of the available proxy site data and for the TI Team to develop (and document) an analysis approach that takes the limitations of the site data into account, without introducing significant biases.

Agreed. The TI team is working closely with the GWG in implementing the approach discussed at the workshop.

Kappa

A number of alternative methods for developing estimates of kappa in CENA were discussed on the first day of the Workshop. At the end of that discussion the PPRP did not have a clear understanding of the proposed path forward for developing kappa in the NGA-East project. After subsequent discussions, the TI Team and Project Manager described how the approach currently being implemented in the SWUS was likely to be utilized in NGA-East. The Project Manager provided access to a recently completed PEER Report that summarizes the SWUS approach to kappa development. After a preliminary review of the SWUS report the PPRP has a better understanding of the proposed process. However, no real discussion of how results derived using the three alternative methods for estimating kappa (high-frequency, low-frequency, broad-band) would be evaluated or combined in this project has been shared with the PPRP. <u>The PPRP again emphasizes the need for this evaluation and integration process to be fully documented as soon as practicable, shared with the PPRP and included in the final project report</u>.

Agreed.

As part of the kappa sub-project a major effort is being focused on performing broad-band inversions of the available data to estimate kappa. Based on the discussion in the SWUS PEER Report, these calculations will be inverting for corner frequency, stress-drop, geometric spreading cross-over distance and Q in addition to kappa. It is not clear how this data will be used, and if it will be used beyond estimating kappa. For example, will this data be used to inform/constrain distributions of the parameters in the Point-Source modeling? <u>The TI Team should describe how they will use the data from the broad-band inversions, and how they will account for possible effects of inconsistencies between the parameters used in this inversion and those used in the forward modeling.</u>

Based on recent work conducted for SWUS, it was found that kappa obtained from the two different approaches (broadband inversion and Anderson and Hough 1984 with Biasi and Smith 2001) were not very different. Therefore, our main approach to obtain kappa is through the broadband inversion method, with a comparison of the results using the Anderson and Hough approach for a subset of stations in each region. The broadband inversions are constrained by selected models of for Q and geometrical spreading. The TI is currently selecting a set of Q and geometrical spreading to be used for the broadband inversion.

We have defined three main approached for the GMPEs 1) empirical with seismological constraints for extrapolation; 2) stochastic using SMSIM; and 3) stochastic using Silva's model. The SMSIM is a hard rock model and will use the kappa value defined by the GWG (V_{s30}=3000 m/s and kappa=0.006s). For the other two types of GMPEs, we will use the kappa estimated from the broadband method as long as the assumption on Q and geometrical spreading are consistent, keeping the correct correlation of attenuation, site and kappa.

Regionalization

Geographic extent.

The geographic regionalization appears reasonable, though the northern end in the Gulf of St. Lawrence is a poor approximation. The offshore region in Canada might better belong with the ACP (however, no justification was provided for why the ACP stops near Cape Cod). The inclusion of the Mississippi embayment into the GCR was also questioned, as the embayment does not have very thick sediments like the GCR (and the verbal rationale for its inclusion in GCR was mantle, not crustal, structure). The TI should ensure that the inclusion is documented and defended, and that the consequences of the proposed treatment for the determination of mid-continent hazard are explained. The PPRP notes that sediment thicknesses vary greatly (from <1 km to >15 km) for GCR, so it is by no means a uniform characteristic of that region and it may need to be treated as a site property as proposed by Martin Chapman (see below).

Agreed. This is part of the evaluation and documentation mandate of the TI team.

Q in each region.

The PPRP asks that a TI member familiar with determination of Q (and pitfalls thereof) provide a written assessment of the WG's procedures, confirm that the "median" relations are really representative and assess their uncertainty, and thence verify the validity for considering some of the regions as having the same Q.

Agreed. This was informally done in working meetings but will be part of the evaluation documentation by the TI team.

Use of Sammon's Maps to Characterize Uncertainty in the Median Ground Motion.

A useful exercise in this regard may be the application of this approach (for demonstration purposes) to the published GMPEs and data used in the EPRI 2004-2006 GMM Review Project (EPRI, 2013). The PPRP encourages the project to perform this exercise. The TI Team should examine the EPRI experience and the results from this exercise to identify pitfalls that may arise when using the smaller CEUS data set and when covering a broader distance range.

Agreed. We have added this task to this Fall's schedule.

Use of Finite-Fault Simulations (FFSs) in NGA-East.

In summary, regarding FFSs the PPRP requests clarity on the role of FFS going forward in this project. How will FFSs be used, especially relative to the point-source simulations, in the final GMPEs? At the beginning of NGA-East it was hoped that FFSs would help generate realistic ground motions for large magnitude events at close fault distances. Is this possible, given what has been learned from the FFS testing and validations?

Following Workshop 2, the plan for using the Finite Fault simulations (FFS) is going through a re-assessment. The plan is now to use the simulation results in a relative

sense for scaling of large magnitude events, as constraints on the empirical models (FAS space). A large number of simulations have been completed since the workshop spanning a M5.5-7.5 range. The data is being processed to produce FAS with a frequency sampling similar to that of the recorded data. The first required step is to calibrate the FFS results using other available data at small M and use the difference for the extrapolation as the constraint for extrapolating to large M. As mentioned in the workshop, the GMPE development team will evaluate the best use of the data, in collaboration with the TI team. Applications to consider are listed in the workshop daily summaries.

Other Developers

That fact notwithstanding, the PPRP feels strongly that the project needs to make the project databases and interim results available to other developers as soon as the information is reviewed, mature and stable. This will enhance the potential for updated models to be included in the evaluation process and ensure the broader community views are included in the final assessment.

Agreed. The flatfile has already been shared with interested proponent experts in late June 2014 (Cramer, Grazier, Pezeshk, Campbell). A GMPE Working Group weekly call was set-up and started on August 22, 2014 to ensure everyone has access to the same data. The purpose of these calls is to make the most of PEER as a Center and to allow sharing of ideas, concepts, and alternate interpretations. This was successfully achieved in the past with the NGA-West1 and NGA-West2 projects.

The PPRP also requests to be notified when meetings of this Working Group are scheduled, because we would like the opportunity to observe.

Agreed. We have already notified the PPRP about the GMPE working group meetings.

Requested Sensitivities

The PPRP requests that the TI team prepare a comparison of the draft NGA-East GMPE median and sigma models to the EPRI (2013) and EPRI (2004, 2006) GMPEs. Median and sigma ground motions should be compared for pga, 10 Hz and 1 Hz for M 5, 6, 7, and 8 from 1 to 1000 kms and by oscillator frequency for several representative source distances.

Agreed.

The PPRP also requests that the TI Team calculate hazard curves at the seven CEUS-SSC demonstration sites and compare these results to those obtained with the earlier EPRI GMPEs (2004-2006 and 2013; these results are contained in the CEUS-SSC report and in EPRI, 2013, and do not need to be re-calculated). Comparisons need only be made for a hard-rock site conditions. Similar to the CEUS SSC model report, we request that total hazard and contribution to hazard from background and RLMEs be presented for PGA, 10 Hz and 1 Hz. These computations should be timed for presentation at Workshop 3B.

Agreed.

We thank you again for your constructive feedback. If you have any questions please do not hesitate to contact us.

Sincerely,

Yousef Bozorgnia,
NGA-East Project Manager

Norman Abrahamson,
NGA-East TI Lead

Christine Goulet,
NGA-East TI Lead

Copy: Members of PPRP
NGA-East JMC

B.4 Workshop 3A-2C, October 29–30, 2014

B.4.1 Workshop Summary

This Workshop followed the SSHAC Theme 2: Proponent Discussions and Theme 3: Feedback Analyses. The key new element for this workshop was the summary of new GMMs developed as part of the GMM Working Group. Preliminary versions of those models were presented. This Workshop focused on proponent discussions of candidate models and their impact on hazard.

The morning session of the first day presented some updates regarding the NGA-East database, in particular, advances regarding assigning metadata (VS30, kappa) to different stations. The rest of the day focused on proponent median GMMs. Different models were proposed, based on different methodologies (for example, stochastic point-source and referenced empirical). This was carried on in the morning session of the second day, which also featured an overview of the proposed hanging-wall model, borrowed from the SWUS project, and an introduction to random vibration theory (RVT), used in one of the median proponent models. The different approaches to median GMMs were discussed.

The afternoon session of the second day presented a comparison of the different proponent models, both in terms of scaling differences and in terms of their distance in ground-motion space. This then lead to a presentation of the NGA-East approach to capturing epistemic uncertainty, based on an underlying probability distribution. The initial set of results using the proponent models were presented. Discussions followed about ensuring a physical spectral shape, about scenarios underlying the projection to two dimensions, and how to measure similarities between different models.

The workshop concluded with the TI team's approach to models regarding aleatory variability. The general approach, the underlying data for NGA-East, and existing models (from shallow active tectonic regions) were presented. Discussions focused on differences between tau models relative to those from NGA-West2.

B.4.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

November 21, 2014

Dr. Yousef Bozorgnia
Project Manager for PEER NGA-East Project
Pacific Earthquake Engineering Research Center (PEER)
University of California, Berkeley
325 Davis Hall, MC 1792
Berkeley, CA 94720

Dear Dr. Bozorgnia:

Reference: *Next Generation Attenuation – East Project*: Participatory Peer Review Report on SSHAC Workshop No. 3A-2C.

Acronyms

ACP	Atlantic Coastal Plain
CEUS	Central and Eastern United States
CNA	Central North America
ENA	Eastern North America
EPRI	Electric Power Research Institute
FAS	Fourier Amplitude Spectrum
FFS	Finite Fault Simulation
GCR	Gulf Coast Region
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GWG	Geotechnical Working Group
HEM	Hybrid Empirical Model
NGA-East	Next Generation Attenuation East
PEER	Pacific Earthquake Engineering Research Center
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
RVT	Random Vibration Theory
SASW	Spectral Analysis of Surface Waves
SSHAC	Senior Seismic Hazard Analysis Committee
SWUS	Southwestern United States Ground Motion Project
TI	Technical Integrator
USGS	United States Geological Survey
WNA	Western North America
WS-2	Workshop 2
WS-3	Workshop 3
WS-3A-2C	Workshop 3A-2C

This letter constitutes the report of the PPRP on WS-3A-2C for the referenced project. The workshop was held October 29 and 30, 2014, at the University of California, Berkeley in Berkeley, California.

Following guidance described in the NGA-East Project Plan[1] for the PPRP, and consistent with the expectations of the SSHAC process[2], the PPRP participated in WS-3A-2C in order to be informed and to review both procedural and technical aspects of the workshop. All six members of the PPRP (J. Adams, J. Ake, J. Ebel, J. Kimball, R. Lee, and G. Toro) attended WS-2 and were able to observe all aspects of the workshop.

The observations and comments from the PPRP focus on assuring that the overall objectives for WS-2 and WS-3 are achieved. The three primary WS-2 objectives are: (1) to present/discuss/debate alternative viewpoints, (2) to identify the technical basis for alternative hypotheses and associated uncertainties, and (3) to provide the basis for subsequent develop of models. The primary WS-3 objectives are: (1) to present and discuss the preliminary models and sensitivity calculations, (2) present feedback in the form of sensitivity results, and (3) provide the opportunity for the PPRP and resource experts to probe the preliminary model to understand the manner in which the variety of technically defensible interpretations has been considered and incorporated in the preliminary model.

GENERAL OBSERVATIONS

The workshop was well structured and satisfied the SSHAC requirements for WS-2 with respect to the presentation and discussion of proponent models. It also satisfied the requirements for WS-3, but only with respect to the evaluation of proponent models, presentation of the approach that the TI team has developed for integrating the proponent models into a comprehensive GMM (i.e., approach based on Sammon's maps), and presentation of some exploratory results from the application of this approach. The PPRP understand that this combination of WS-2 and WS-3 elements may have been unavoidable, given the technical complexity of the project and the constraints imposed by organizational issues (such as the dual science and SSHAC-3 nature of the project, budget, and schedule). Nevertheless, the PPRP is concerned about the many remaining tasks, given the scheduled dates of January 2015 for WS-3B and April 2015 for project completion. Specifically, the PPRP is concerned that major elements [(2) and (3) described above] of the primary WS-3 objectives were not addressed in this workshop. In particular, the draft final GMM has not been presented or compared to existing GMMs (such as EPRI 2004 and EPRI 2013), and no full-hazard sensitivities have been presented.

Presentations during the Workshop were clear and focused, and the discussions provided additional clarity and depth, with good participation by the TI Team and Resource Experts. This

[1] Goulet, et al., 2013, *NGA-East Project* Plan - Version 2, Pacific Earthquake Engineering Research Center (PEER), University of California, Berkeley, April.
[2] Budnitz et al., 1997, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.* NUREG/CR-6372, NRC; and NRC, 2012, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Revision 1, NUREG-2117.

allowed the PPRP to have a good understanding of the proponent models, and the associated uncertainties.

At the conclusion of each meeting day, the TI Leads prepared a summary that identified the key issues and action items arising from that day's presentations and discussions. These summaries are very thorough and well prepared, and the Project is encouraged to pay close attention to them as a way to track critical issues and loose ends.

SPECIFIC COMMENTS AND RECOMMENDATIONS

The comments and recommendations below are organized by topic. Items requiring a formal response are underlined.

Pending Issues (from Project Response to last PPRP Letter)

The PPRP has not yet received a detailed draft table of contents for the final report, which the PPRP had requested and the Project had agreed to provide. This is of paramount importance and urgency, given the SSHAC Level 3 requirements for documentation and the schedule constraints. The PPRP encourages the Project to submit this detailed draft table of contents in the near future (no later than end of calendar year 2014).

In this regard, we want to reiterate the high standards for documentation in a SSHAC Level 3 project. We repeat our request that the Project Team initiate the development of a list of critical supporting documentation and of an expected schedule that this material can be provided to the PPRP to support our review.

The PPRP is encouraged to observe that the project has been providing supporting technical reports to the PPRP. The PPRP requests copies of key reports and other supporting literature that will be used by the Project, together with a short summary of what material within each publication will be used by the TI Team and how it will be used.

The Project previously had agreed to perform the complete Sammon's map analysis (all the way to the generation of GMPE's and weights) using the EPRI (2013) data and candidate models and present results at this Workshop. This material was not presented, although it was listed in early versions of the agenda. Instead, Nico Kuehn presented preliminary Sammon's visualization of the EPRI models and other proponent models. The PPRP believes the full application of the approach to the EPRI models and data is a valuable exercise and recommends that this analysis be performed and presented to the PPRP via webinar by early December.

Sammon's Maps

The TI Team's approach of using Sammons Maps to develop a suite of median GMPEs appears to be promising. As indicated above, we ask the TI Team to perform the full Sammons Maps exercise using exclusively the EPRI GMPEs and data, in order to generate additional support and understanding for the approach. Completion of this example will be extremely illustrative to the PPRP. Only representative periods need be completed, so as to compare the center, body and range for median ground motion predictions to the earlier study. How do these models relate to the 12 GMPEs in the EPRI 2013 GMM? The PPRP wishes to understand how the Sammons

Maps are constructed and/or constrained to capture the CBR of the median models. How does the median model (center) compare for the two approaches? For specific magnitudes, distances and periods, are there new median ground motion models that expand the range covered by the EPRI models? If so, how are these models justified? The PPRP wishes to understand the objective or subjective judgments that are employed to develop the new median models and their weights. The PPRP also wishes to understand to what extent and how the TI Team uses the data to make judgments on the acceptable models and weights. Is there any correlation between the models by period? Are the shapes of the mean spectra reasonable?

The PPRP also suggests that the above study with the EPRI models be used to demonstrate how (or not) just a few (3-5) GMPEs can give acceptable estimates of mean hazard, as this will be important for national mapping applications.

Another issue of concern is the removal of non-physical models. One criterion was mentioned for a non-physical model: Sa that decreases with magnitude. What other exclusion criteria are there? The PPRP would like to see more details on this removal process and a Sammons Map illustration of the removed models and the accepted ones. Another concern of the PPRP is whether the Sammons Map process is repeatable. Would another independent TI Team get similar results? The full Sammons Map treatment of the EPRI models and data should be completed as early as possible so that lessons learned can be applied and the approach documented.

<u>It was not clear to the PPRP why the ellipses have left-right major axes when the both residual and likelihood contours allow more variation up-down.</u>

<u>The PPRP also requests that portions of the SWUS report describing the Sammons Maps approach and its application be made available to the PPRP, with proper authorization from the SWUS project.</u> This material, together with the application to EPRI, is likely to answer many of the PPRP's questions. The application of the Sammons map approach to develop an appropriate suite of median ground motion models is novel but not necessarily conceptually intuitive. As a result the PPRP may wish to pursue additional engagement with the TI Team to ensure that the panel has a clear understanding of the process and results.

RVT Duration model

The empirical path and source duration model based on minimizing differences between the observed Sa and the RVT-based Sa appears to be more robust than the earlier procedures. However, the durations appear to be significantly longer than the path and source durations used previously by Atkinson and Boore and others in the CEUS. Is there an explanation for this change? <u>Does this new duration model introduce a (low) bias in the RVT Sa predictions or is it accommodated elsewhere in the model? Most other researchers have used the additive model, which also makes physical sense. The rationale for rejecting this model because of distribution shapes is not clear and needs additional explanation. Will there be only one duration model?</u>

Soil Database
In the database there is a clear concentration of sites at exactly 2000 m/s, due to assignment of this velocity to many hard rock sites. Will this cause a problem in the analysis? Does this (minimizing the variability in velocity) map into the sigma in an unfortunate way (or is it small enough to be neglected)?

For the work on the "potential misclassified sites", add a section in the database report (new 5.6), or alternatively a stand-alone report, to describe the method and its results. Potentially misclassified sites should be mapped. <u>TI team needs to clarify how this work (i.e. data from potentially-misclassified site) will be used in the analysis (if at all). Will this issue affect the estimates of ergodic sigma and/or site-to-site variability?</u>

There is discussion on using P-wave H/V to assign site class in PEER2014-17, but this was not discussed during this meeting. <u>Has all the potential of this work been achieved? How did it update the proxy methods, and what was learned about how good (or bad) those methods might be? Please distribute a pre-publication copy of Kim et al 2014 to the PPRP.</u>

Regionalization
The PPRP expects to see full justification for lumping CENA, Appalachian and Atlantic Plain regions together. If CENA, Appalachian and Atlantic Plain regions are lumped together for analysis, residuals for each region should be examined and either dismissed as negligible or accommodated within the GMPEs. One nagging concern is whether regional differences may have been missed as a result of shortcomings in the USGS compilation and summary of Q models.

Martin Chapman's model of a thickness-proportional kappa for the Gulf Coastal Region (GCR) was presented at WS2, but there appeared to be some doubts about this model. For instance, there were concerns about possible tradeoffs between distance and thickness of the sedimentary section. There was no follow-up on this model at WS3A-2C. In addition, Darragh and Silva presented an alternative model for the GCR (which does not consider thickness of sediments) at this workshop. <u>Please summarize the status of the model for the GCR and how the GCR differences will be incorporated in the final model.</u>

Examination and Selection of Proponent GMPEs
The PPRP would like to see a <u>brief written justification</u> for going from 20 GMPEs to the 6 to be used (from last three slides in Gail Atkinson's October 29 morning presentation).

Attributes of Final GMPEs
The PPRP thinks it is important for the GMPEs to be able to predict broadband PSA for ruptures starting in or extending into the top 4 km. Small events like this are common in the top 6 km or rock in the stable craton, and Ungava is a M6 example that ruptured the top 5 km of the crust. This has implications for surface waves at 0.3 Hz and higher. The finite-fault (FF) modeling results for ZtoR=0 are very important in this regard (if they are credible). Somerville's western Australia GMPEs should be tested for compatibility with proposed NGA-East relations (should fall within Sammons map); they are believed to include the appropriate surface wave contribution. This issue may gain importance for induced events, which tend to be shallow.

When using the FF simulations, the PPRP needs clear justification for smoothing out the curves, as some of the "bumps" are likely real surface waves resulting from shallow energy release and one could argue that they should be retained. The TI team may need to commission additional simulations with different crustal models (not just Virginia), which may mean that there might be a GMPE variant applicable to the northeast (hard rock at the surface) and another variant for the rest of the CENA where there is a softer sediment layer.

The PPRP would like clarification on how the Somerville report on M-A scaling will be used by TI team (if at all).

It is not clear how the TI Team will use FF results to quantify near-fault effects. Please summarize the proposed approach.

Will aftershocks be treated as a separate model, or by an additive correction?

Hanging wall term and related issues

The TI Team appropriately incorporates a hanging wall term in the ground motion model for the CEUS. The PPRP requests that the PEER report (SWUS report appendix) on the hanging wall model be provided for PPRP review. The PPRP is anxious to see how numerical modeling was validated and to what extent the modeling was constrained or validated by available empirical data from thrust and normal faulting earthquakes. If there are no comparisons of the modeled effects to the very limited global empirical data on hanging wall effects, we ask that the TI provide that comparison. Also, will the effect be included for M<5½?

Please also confirm our understanding on the following issues:

- That directivity is out-of-scope & so will not be explicitly modelled, but will be represented in the sigma.
- That input choices for the simplified hazard calculations will be consistent with SSC-CEUS (e.g. distribution of depths).
- That a finite fault adjustment will be used with the NGA-East GMPEs to compute the hazard consequences, and whether this adjustment will be part of the SSHAC process.

Sigma

The presentation on sigma shows significant progress, but there are a number of pending issues that need to be resolved. The "Summary of Day 2 Discussions" prepared by the TI Team Leads captures these issues accurately and there is no need to repeat them here. The TI Team should follow up on these issues, so that they can present a preliminary sigma model at WS3B. If this sigma model proves to be significantly different from existing sigma models such as EPRI (2013), additional sensitivity calculations should be performed to capture the effect of sigma.

Need for Additional Interactions between Project and PPRP
As the project approaches completion, the PPRP considers that it may be appropriate to hold a few informal conference calls or webinars for the PPRP to obtain clarifications or explanations, or for the TI Team to obtain quick feedback on key issues. These calls should be scheduled at the request of either the PPRP or the TI Team.

In closing, the PPRP wishes to congratulate the Project for a successful Workshop 3A-2C and looks forward to the success of Workshop 3B, as well as to model completion and the documentation effort to follow.

Please feel free to contact us if you would like to discuss further our comments or recommendations.

Sincerely,

Gabriel R. Toro
Chair, PPRP

John Adams
Member, PPRP

Jon Ake
Member, PPRP

John Ebel
Member, PPRP

Jeffrey Kimball
Member, PPRP

Richard C. Lee
Member, PPRP

December 18, 2014

Dr. Gabriel Toro
Chair, NGA-East Participatory Peer Review Panel

Subject: NGA-East responses to PPRP review comments on SSHAC Workshop 3A-2C

Dear Dr. Toro:

This letter constitutes the NGA-East collective response to the PPRP letter dated November 21, 2014, on the NGA-East SSHAC Workshop 3A-2C. As always, we thank you and all members of the PPRP for the constructive comments. We are also grateful to you and the PPRP members for all your efforts, interactions and cooperation on the NGA-East project.

As we are entering the evaluation and integration phases of the project, the two essential activities under the SSHAC Level 3 process, we are committed to keep the PPRP engaged and informed. We will also keep the PPRP aware of critical meetings they may want to attend remotely. The NGA-East "science" reports, documenting the technical activities of various working groups, will also be shared with the PPRP as soon as working draft of such reports become available.

This letter provides responses to the specific comments as requested in the PPRP letter. The specific PPRP comments are in *italic*. The <u>underlined sections</u> represent the questions and comments that the PPRP requested formal responses. These are followed by the NGA-East collective responses in **bold face**. Although we are not providing formal written responses to other PPRP comments, they will be considered in the NGA-East project and we appreciate your efforts in communicating those to us.

RESPONSES TO SPECIFIC COMMENTS AND RECOMMANDATIONS

Pending Issues (from Project Response to last PPRP Letter)

The PPRP has not yet received a detailed draft table of contents for the final report, which the PPRP had requested and the Project had agreed to provide. This is of paramount importance and urgency, given the SSHAC Level 3 requirements for documentation and the schedule constraints. <u>The PPRP encourages the Project to submit this detailed draft table of contents in the near future</u> <u>(no later than end of calendar year 2014).</u> In this regard, we want to reiterate the high standards for documentation in a SSHAC Level 3 project. <u>We repeat our request that the Project Team initiate the development of a list of critical supporting documentation and of an expected schedule that this material can be provided to the PPRP to support our review</u>.

> **Agreed. Please see the attached document which contains 1) the draft table of content, followed by 2) the list of key documents to be provided as attachments, with their estimated release dates. Note that the SSHAC report**

will summarize the key elements of these documents and point to specific sections of PEER "science" reports as needed for more details.

The PPRP is encouraged to observe that the project has been providing supporting technical reports to the PPRP. The PPRP requests copies of key reports and other supporting literature that will be used by the Project, together with a short summary of what material within each publication will be used by the TI Team and how it will be used.

Agreed. We will provide this information for the recently released PEER reports.

The Project previously had agreed to perform the complete Sammon's map analysis (all the way to the generation of GMPE's and weights) using the EPRI (2013) data and candidate models and present results at this Workshop. This material was not presented, although it was listed in early versions of the agenda. Instead, Nico Kuehn presented preliminary Sammon's visualization of the EPRI models and other proponent models. The PPRP believes the full application of the approach to the EPRI models and data is a valuable exercise and recommends that this analysis be performed and presented to the PPRP via webinar by early December.

The candidate models used by EPRI (2013), as well as the clusters developed by the project, were included in the Sammon's maps shown at the October SSHAC workshop. This comparison showed how the different clusters used by EPRI (2013) compared in ground motion space.

All the GMPEs considered by EPRI (2013) will be considered in the NGA-East evaluation as candidate models.

Before the March workshop, we will provide the PPRP with Sammon's maps that only include the EPRI models for comparison.

We also agree that it would be interesting to see how the EPRI (2013) evaluation would change if the Sammon's map approach was used with the information that was available at the time; however, such a comprehensive re-evaluation may be sponsored by a separate task.

Sammon's Maps

It was not clear to the PPRP why the ellipses have left-right major axes when the both residual and likelihood contours allow more variation up-down.

The ellipses presented were examples from the SWUS project. NGA-East will perform its own evaluation and definition of the area to be covered by the models.

The PPRP also requests that portions of the SWUS report describing the Sammons Maps approach and its application be made available to the PPRP, with proper authorization from *the SWUS project. This material, together with the application to EPRI, is likely to answer many of the PPRP's questions. The application of the Sammons map approach to develop an appropriate suite of median ground motion models is novel but not necessarily conceptually intuitive. As a result the PPRP may wish to pursue additional engagement with the TI Team to ensure that the panel has a clear understanding of the process and results.*

> **The SWUS report is under preparation. We will share this report with the PPRP as soon as it becomes available, provided we have the permission from SWUS to do so.**
>
> **We are currently drafting a PEER report summarizing the evaluation of epistemic uncertainty in median ground-motion space using Sammon's maps. We plan to release the draft to the PPRP in January.**

RVT Duration model

The empirical path and source duration model based on minimizing differences between the observed Sa and the RVT-based Sa appears to be more robust than the earlier procedures. However, the durations appear to be significantly longer than the path and source durations used previously by Atkinson and Boore and others in the CEUS. Is there an explanation for this change? Does this new duration model introduce a (low) bias in the RVT Sa predictions or is it accommodated elsewhere in the model? Most other researchers have used the additive model, which also makes physical sense. The rationale for rejecting this model because of distribution shapes is not clear and needs additional explanation. Will there be only one duration model?

> **This duration model, which can be referred to as a "PSA-Matched-RVT Duration (D^*_{RVT})", is different from other duration models previously developed for CENA and does not refer to a physical duration. D^*_{RVT} is a "duration" (or parameter) used along with FAS in the RVT computations to compute PSA, such that there is no bias in PSA relative to the PSA computed directly from time series. This duration is still partitioned into source and path components, but only to allow appropriate extrapolation to larger magnitudes. D^*_{RVT} is only used for the PEER FAS-based GMPE. Other RVT duration models are used for other GMPEs as part of their development, such as GMPEs from the SMSIM suite from Dr. Boore (he presented his revised duration model and adjustment factors at the July Workshop). In short, there are multiple "duration" models used for different purposes in NGA-East and different RVT durations used among the models using RVT (i.e. PEER, SMSIM and Darragh et al. suites of models), covering a range of epistemic uncertainty.**

Soil Database

For the work on the "potential misclassified sites", add a section in the database report (new 5.6), or alternatively a stand-alone report, to describe the method and its results. Potentially *misclassified sites should be mapped.* *<u>TI team needs to clarify how this work (i.e. data from potentially-misclassified site) will be used in the analysis (if at all). Will this issue affect the estimates of ergodic sigma and/or site-to-site variability?</u>*

> **The treatment of misclassified sites is the responsibility of independent GMPE developer teams. The identification process for potentially misclassified sites was summarized by Dr. J. Stewart at the October Workshop. This information, as well as the process used for the PEER model, is shared with individual developer teams. For the PEER model, the complete dataset (both reliable and questionable sites) is used to constrain the magnitude and distance scaling with site-specific site terms. The use of site-specific site terms avoids the V_{S30} errors from affecting the magnitude and distance scaling. Holding the magnitude and distance scaling fixed, the constant term in the model is then estimated using only the reliable sites. For the standard deviation, all sites are used to estimate the between-event standard deviation (tau) and the single-station within-event standard deviation (Phi_{SS}). For the traditional ergodic within-event standard deviation (Phi), only the reliable sites are used. This approach allows us to take advantage of all of the data where is it applicable, but avoids having the questionable sites introduce a bias into the median or an over-estimation of the standard deviation.**

There is discussion on using P-wave H/V to assign site class in PEER2014-17, but this was not discussed during this meeting. <u>Has all the potential of this work been achieved? How did it update the proxy methods, and what was learned about how good (or bad) those methods might be? Please distribute a pre-publication copy of Kim et al 2014 to the PPRP.</u>

> **The report refers to the P-wave method, but not to methods based on H/V. The P-wave method is essentially based on the concept of receiver function and the related P to S conversion at impedance contrast interfaces. The method is used to estimate V_S. We have requested a pre-publication copy of Kim et al. (2014) to distribute it to the PPRP to help clarify this issue. The method was used to estimate V_{S30} at 10 sites (Code 2) and in combination with other proxies (Code 4) for an additional 12 sites out of a total of 1378 stations.**

Regionalization

The PPRP expects to see full justification for lumping CENA, Appalachian and Atlantic Plain regions together. If CENA, Appalachian and Atlantic Plain regions are lumped together for analysis, residuals for each region should be examined and either dismissed as negligible or accommodated within the GMPEs. One nagging concern is whether regional differences may have been missed as a result of shortcomings in the USGS compilation and summary of Q models.

Martin Chapman's model of a thickness-proportional kappa for the Gulf Coastal Region (GCR) was presented at WS2, but there appeared to be some doubts about this model. For instance, there were concerns about possible tradeoffs between distance and thickness of the sedimentary section. There was no follow-up on this model at WS3A-2C. In addition, Darragh and Silva presented an alternative model for the GCR (which does not consider thickness of sediments) at this workshop. Please summarize the status of the model for the GCR and how the GCR differences will be incorporated in the final model.

> **This will be documented in the SSHAC report. The regionalization task conclusions were accepted as the a-priori assumption. Residual analyses of ground motions conducted so far are in agreement with the proposed regionalization. At this point, this evaluation is performed by each GMPE developer team.**
>
> **The approach for treating the GCR is similar to the one used in the original EPRI work, in which adjustment factors are computed using GMPEs from ENA (e.g. Mid-continent) and GCR. The need to incorporate additional epistemic uncertainty in GCR adjustments will be evaluated.**

Examination and Selection of Proponent GMPEs

The PPRP would like to see a brief written justification for going from 20 GMPEs to the 6 to be used (from last three slides in Gail Atkinson's October 29 morning presentation).

> **The models selected are not GMPEs, but rather a representative set of alternative attenuation rates in the literature, in terms of both shape and overall decay rates from near to regional distances. We have attached a memo by Dr. Gail Atkinson describing this characterization. In the memo, it is noted that this is a subjective grouping of alternative attenuation models, which is used for convenience for a limited purpose. Specifically, the 6 attenuation models are used as alternatives, in concert with the NGA-East database, to derive representative suites of GMPEs by inversion, notably for the SMSIM suite and the Darragh et al. suite of models. Thus, each attenuation model becomes linked with a correlated source model in the point-source model context.**

Attributes of Final GMPEs

The PPRP would like clarification on how the Somerville report on M-A scaling will be used by TI team (if at all).

> **M-A relationships were used for the NGA-East science tasks of database and finite-fault simulations, which feed into the GMPE development task. For the finite-fault simulations, M-A relations were used to define the source areas. The Somerville model was also used to generate the alternative fault geometries (Section 4.4 of the database report) from which distances provided in the flatfile were computed.**

It is not clear how the TI Team will use FF results to quantify near-fault effects. Please summarize the proposed approach.

> **Finite-fault simulation results (both for FAS and PSA) have been generated and shared with all GMPE developers. Finite faults effects are more important in the near-field, therefore the simulations were focused in the first 100 km. NGA-East developed a suite of distance-dependent magnitude scaling models for ground motions based on ground motion ratios relative to M5. These models have been shared with the GMPE developers.**

<u>Will aftershocks be treated as a separate model, or by an additive correction?</u>

> **Each GMPE developer team selects its own data and decides to include or exclude aftershocks, or adjust its model for aftershocks. The data selection is documented as part of the GMPE documentation from each team. For the PEER GMPE, we will investigate the residuals to quantify the need for and the magnitude of adjustments for aftershock ground motions.**

Hanging wall term and related issues

The TI Team appropriately incorporates a hanging wall term in the ground motion model for the CEUS. <u>The PPRP requests that the PEER report (SWUS report appendix) on the hanging wall model be provided for PPRP review.</u> The PPRP is anxious to see how numerical modeling was validated and to what extent the modeling was constrained or validated by available empirical data from thrust and normal faulting earthquakes. If there are no comparisons of the modeled effects to the very limited global empirical data on hanging wall effects, we ask that the TI provide that comparison. <u>Also, will the effect be included for M<5½?</u>

> **We will provide this report as soon as it becomes available. We are examining the need for including hanging wall corrections for small magnitudes.**

Please also <u>confirm</u> our understanding on the following issues:

- ✓ *That directivity is out-of-scope & so will not be explicitly modeled, but will be represented in the sigma.*
  Yes
- ✓ *That input choices for the simplified hazard calculations will be consistent with SSC- CEUS (e.g. distribution of depths).*
  Yes; however, a model for the distribution of depths will need to be developed under a separate task.
- ✓ *That a finite fault adjustment will be used with the NGA-East GMPEs to compute the hazard consequences, and whether this adjustment will be part of the SSHAC process.*
  Finite-fault adjustments are part of GMPE development, to be documented in a

PEER report. As such, the GMPEs themselves will be evaluated as part of the TI team evaluation.

We thank you again for your constructive feedback. If you have any questions please do not hesitate to contact us.

Sincerely,

Yousef Bozorgnia,
NGA-East Project Manager

Norman Abrahamson,
NGA-East TI Lead

Christine Goulet,
NGA-East TI Lead

Copy: Members of PPRP
NGA-East JMC

B.5 Workshop 3B, March 4–5, 2015

B.5.1 Workshop Summary

This Workshop followed the SSHAC Theme 2: Proponent Discussions and Theme 3: Feedback Analyses.

The focus of the workshop was to go through proponent models for both the median and the aleatory variability, and preliminary hazard feedback regarding those models. The first day started with a presentation of the median proponent GMMs that were considered for inclusion in NGA-East. Then, an overview of the NGA-East approach for integration of the median GMMs was given, and preliminary results using the NGA-East median GMMs were presented. Discussion revolved around various details of the NGA-East integration approach, such as the physicality of sampled models, and the selection of models on the two-dimensional projection of ground-motion space. In addition, it was suggested to apply the NGA-East process for median models to the proponent models that were used in the EPRI project to obtain a comparison of the approaches used in both projects.

The morning session of the second day wrapped up the presentation of median models, with an overview of approaches to assigning weights to the median models. Different possibilities of weighting the models based on their fit to data (e.g., residuals and likelihood), and their range of covered probability density were summarized.

Focus then moved on to models for the standard deviation. The CENA data, which can be used to evaluate the models, was presented. The resulting models for the different components of aleatory variability (based on CENA) were compared to standard deviation model for shallow active tectonic regions (NGA-West2, Japan). The dependence of the components on magnitude and distance was investigated, and challenges of building a model based on limited CENA data were discussed. The preliminary logic tree for the various components of standard deviation was presented, together with an investigation into their uncertainties, which is important for assigning weights.

B.5.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

March 29, 2015

Dr. Yousef Bozorgnia
Project Manager for PEER NGA-East Project
Pacific Earthquake Engineering Research Center (PEER)
University of California, Berkeley
325 Davis Hall, MC 1792
Berkeley, CA 94720

Dear Dr. Bozorgnia:

Reference: *Next Generation Attenuation – East Project*: Participatory Peer Review Report on SSHAC Workshop No. 3B (March 4 and 5, 2015).

Acronyms

ACP	Atlantic Coastal Plain
CEUS	Central and Eastern United States
CNA	Central North America
ENA	Eastern North America
EPRI	Electric Power Research Institute
FAS	Fourier Amplitude Spectrum
FFS	Finite Fault Simulation
GCR	Gulf Coast Region
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GWG	Geotechnical Working Group
HEM	Hybrid Empirical Model
NGA-East	Next Generation Attenuation East
PEER	Pacific Earthquake Engineering Research Center
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
RVT	Random Vibration Theory
SASW	Spectral Analysis of Surface Waves
SSHAC	Senior Seismic Hazard Analysis Committee
SWUS	Southwestern United States Ground Motion Project
TI	Technical Integrator
USGS	United States Geological Survey
WNA	Western North America
WS-2	Workshop 2
WS-3	Workshop 3
WS-3A-2C	Workshop 3A-2C

This letter constitutes the report of the PPRP on WS-3B for the referenced project. The workshop was held March 4 and 5, 2015, at the University of California, Berkeley in Berkeley, California.

Following guidance described in the NGA-East Project Plan[1] for the PPRP, and consistent with the expectations of the SSHAC process[2], the PPRP participated in WS-3B in order to be informed and to review both procedural and technical aspects of the workshop. All six members of the PPRP (J. Adams, J. Ake, J. Ebel, J. Kimball, R. Lee, and G. Toro) attended WS-2 and were able to observe all aspects of the workshop.

The observations and comments from the PPRP focus on assuring that the overall objectives for WS-3 are achieved. The primary WS-3 objectives are: (1) to present and discuss the preliminary models and sensitivity calculations, (2) present feedback in the form of sensitivity results, and (3) provide the opportunity for the PPRP and resource experts to probe the preliminary model to understand the manner in which the variety of technically defensible interpretations has been considered and incorporated in the preliminary model.

GENERAL OBSERVATIONS

The workshop was well structured and satisfied the SSHAC requirements for WS-3 with respect to the presentation of the approach that the TI team has developed for evaluating the proponent models, integrating the proponent models into a comprehensive GMM (i.e., approach based on Sammon's maps), presentation of very preliminary results from the application of this approach (still with no weights), development of a model for sigma, and presentation of preliminary sensitivity results. PPRP is concerned about the many remaining tasks, given the scheduled dates of April 13, 2015 for the next Working Meeting and June 17 and 18, 2015 for the final Workshop (WS3C). In particular, the draft final GMM has not been presented or compared to existing GMMs (such as EPRI 2004 and EPRI 2013), and no full-hazard sensitivities have been presented.

Presentations during the Workshop were clear and focused, and the discussions provided additional clarity and depth, with good participation by the TI Team and Resource Experts. This allowed the PPRP to have a good understanding of the proponent models and their associated uncertainties.

At the conclusion of the first meeting day, the TI Leads prepared a summary that identified the key issues and action items arising from that day's presentations and discussions. These summaries are very thorough and well prepared, and the Project is encouraged to pay close attention to them as a way to track critical issues and loose ends.

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[1] Goulet, et al., 2013, *NGA-East Project* Plan - Version 2, Pacific Earthquake Engineering Research Center (PEER), University of California, Berkeley, April.
[2] Budnitz et al., 1997, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.* NUREG/CR-6372, NRC; and NRC, 2012, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Revision 1, NUREG-2117.

SPECIFIC COMMENTS AND RECOMMENDATIONS

The comments and recommendations below are organized by topic. Items requiring a formal response are underlined. When these items were drawn or abstracted from earlier PPRP written requests to the TI and the project, the project meeting is so noted.

Documentation

The PPRP was pleased to have received a revised TOC, a list of attachment reports and their delivery schedule, a partial early draft of the PEER Median Ground-Motion Epistemic Uncertainty Report (2015-XX), and the draft report documenting the seed GMPEs (titled "Median Ground Motion Models for the Central and Eastern North America Region"). Some of the promised documentation is still pending as indicated below.

The PPRP has requested copies of key reports and other supporting literature that will be used by the project, together with a short summary of what material within each publication will be used by the TI Team and how it will be used. Some of these documents have been received, but without the short summaries and indications of how the material will be used (ref PPRP letters 11/21/14; 8/11/14; 2/28/14). Please provide the reports still missing and the summaries at the TI Team's earliest convenience.

The PPRP has requested copies of the portions of the SWUS report that describe 1) the Sammons map approach and its application to the project and 2) the hanging wall model (ref PPRP letter 11/21/14). By the way, the PEER Hanging-Wall Report is not listed in Section 1.3 of the January 23 TOC; should it? Please provide this information as soon as the Project can secure permission or the material becomes publically available.

The PPRP requested and the Project agreed to provide a pre-publication copy of the Kim et al. 2014 paper on the reflectivity method (ref PPRP letter 11/21/14).

Interface with the GMPE Developers

The PPRP is interested in understanding what if any feedback the TI has received from the ground motion developers on the TI products using the Sammons map approach (also the range extension where extrapolated by the TI). Have there been discussions between the TI and the developers regarding these topics and is the feedback documented? If so, can the project provide the documentation for PPRP review? If no feedback has been requested, are there plans to query the developers on this subject and document their responses? How did the developers of the excluded models react to their exclusion?

The PPRP expects to see very careful documentation on the exclusion of the seven candidate GMMs. Also, the exclusions were based on "inappropriate magnitude and distance scaling". No exclusion criteria (or weighting) were used based on model methodology. Is this justified? It is our understanding that residuals were not used in this process. Please confirm.

Given the difficulties with the Vs30 assignments to a majority of the sites, and the limitations of Vs30 as a predictor of site amplifications in CENA, is the TI Team concerned about any inconsistencies introduced by the developers in applying their own adjustment to convert the data to reference conditions? Please provide a short discussion. This issue and its possible implications should also be discussed in the final report.

Sammons Maps

Given that the Sammons map approach is new, the PPRP reiterates that it is important for the TI Team to demonstrate by means of sensitivity analyses that the technique is performing properly and is producing and adequate characterization of the CBR of the median ground-motion amplitudes. To this effect, we strongly encourage that the TI Team perform and document the following tests (some of which we had proposed in the past).

1. The magnitude (Mw 4-7.5) and distance (0-400 km) range used to collapse the GMMs to a point on the Sammons map approach seems appropriate, but the question remains of whether selection of other magnitude and distance ranges would yield similar results, i.e., are the mapping results repeatable and stable from a ground motion and hazard perspective. The validation of a stable process would entail mapping seed ground motion models using the Sammons map approach for alternate magnitude and distance ranges and then evaluate and compare corresponding hazard results. For this evaluation, we suggest a simple source model be tested for a site in close proximity to a RLME such as the Savannah site to test for hazard bias. The general ground motion model case hazard for that site (already run for PGA, 10 and 1 Hz?) can be compared to the Sammons map approach developed using a narrower site-specific magnitude and distance composition (e.g., Mw: 4-6; 6-8; R: 0-100, 100-200, 200-1200; this will generate a space with lower dimension than the original space). If the TI has already verified that this process is stable for other sites, we wish to see the comparisons for other sites, magnitudes and distances.
2. For the CEUS SSC model (EPRI, DOE, NRC, 2012) complete a full Sammons map analysis including generation of GMPE and weights using exclusively the EPRI (2004, 2006) seed GMPEs and data in order to generate additional support and understanding for the approach. Only representative periods need be completed (PGA, 1 and 10 Hz) for Mw 4, 5, 6, 7.5 from 1-1000 km, so as to compare the CBR for median ground motion predictions to the earlier study. Hazard then should be computed using the EPRI Sammons-based maps and compared to the NGA-East results. The PPRP wishes to understand the objective or subjective judgments that are employed to develop the new median models and their weights (ref PPRP

letter 11/21/14; 8/11/14). Based on discussions at the Workshop, the TI Team may want to follow equivalent ways to achieve the same goals of the exercise proposed above, namely:

   a. Plot EPRI seed and final models on the NGA-East Sammon's maps.
   b. Calculate weights for EPRI final models using the Sammon's map cells and run example hazards using these weights.
   c. Re-introduce the EPRI seed and final models in the plotting tools (see item 4 below).

3. Calculate NGA-East hazard curves at the seven CEUS-SSC demonstration sites and compare these results to those obtained with the earlier EPRI GMPEs (2004-2006 and 2013; these result are contained in the CEUS-SSC report and in EPRI 2013 and do not need to be recalculated). Comparisons need only be made for a hard-rock site condition. Similar to the CEUS SSC model report, we request that the total hazard contribution from background and RLMEs be presented separately for PGA, 1 and 10 Hz (ref PPRP letter 11/21/14; 8/11/14).

The PPRP's motivation for repeatedly requesting some of these sensitivity tests is that it is imperative to understand to what extent any changes to the overall model (what EPRI, 2013, calls the GMM) and its associated hazard are due to (a) changes in the data, (b) changes in the seed models, (c) methodological changes (i.e., use of Sammons maps), or (d) changes in sigma model.

Regarding the Sammons map process, we also want to note the following issues that still require attention:

4. Based on discussions during the Workshop, the visualization tool should be updated as follows: (a) include all seed models at all frequencies, and provide some kind of identification of which were included or excluded at each frequency; (b) the EPRI (2013) seed models and cluster median, high, and low models; and (c) <u>Please provide the updated version of this very useful tool to the PPRP as soon as it is available.</u>
5. The process for the exclusion of "non-physical" models from the set of 2,000 generated models needs to be implemented and documented. The criteria must be defined, and the results must be documented. <u>Please provide the PPRP with a description of the criteria and documentation of the results.</u> The documentation may include the following: percent of models removed, graphs of the retained and excluded models in amplitude vs. magnitude space, amplitude vs. distance space, and Sammons space.
6. Because the Sammons maps are generated separately for each frequency, it is likely that the resulting spectra be jagged (for both M-R scenarios and for uniform-hazard spectra). The final report should address this question and contain guidance on how to smooth the results. <u>Please discuss the TI Team's approach for alleviating the jaggedness of spectra.</u>
7. The PPRP is comfortable with using circles with segments to divide the Sammons space, although it may be necessary to adjust circle radii as a function of frequency depending on the spread of the seed models and the simulated models.
8. In one example the residual contours clearly divided a segment; should consider if in some cases there would be a benefit from halving such segments

9. The choice of the one representative sample relation needs thought. PPRP agrees it should not be one of the candidate GMM, even if it were close to the center of the segment. TI need to decide on and defend a way of capturing the "center of mass" or "center of gyration" (based on rms distance to center) of the samples in the segment.
10. The choice on weighting "nearby" GMM (on the Sammons plane) needs to be resolved. Two nearby GMM could be redundant or could be confirmatory, depending on their underlying assumptions and data. Also, the process may be strongly dependent on grid size. This redundant/confirmatory decision can only be made by understanding the seed models and involves judgment. The handling of this issue will affect the pdf (or prior-based weights). Please summarize the TI Team's current thinking on this issue.
11. It is not clear why the weights based on likelihood reach a plateau instead of decreasing as a function of distance from the center of the Sammons map. Please verify this calculation.

Regionalization

The PPRP has requested the examination of station residuals by region as a way to confirm the appropriateness of combining all regions except the Gulf (ref PPRP letter 11/21/14). A map of station residuals at a few frequencies (with or without smoothing) may be a useful way to present this information. Please provide the mean station regional residuals by region at a few frequencies, either as maps or in other form.

Following the October Workshop, there was some lack of clarity about how the alternative models for Q and kappa for the Gulf Coastal Region (GCR) was going to be treated. Please summarize the status of the model for the GCR and how the differences between the two GCR models will be incorporated in the final GCR GMPEs (ref PPRP letter 11/21/14).

Treatment of Depth

It is the PPRP's understanding that the final model will include depth as an explanatory variable. Please confirm. Also, the treatment of depth should (in principle) include the following three effects: (a) the need to introduce a pseudo-depth (just to introduce saturation), (b) effects of parameters that may change with depth (like stress parameter), and (c) physical wave-generation that is a function of depth (such as enhanced surface waves). Please clarify which of these effects will be captured in the final model.

PIE Events

It was not clear whether the PIE events were included in the analysis of residuals for the sigma calculations, and whether the final model will be applicable to both natural and PIE events. Please clarify and discuss.

Sigma

There will be significant interest in using single station sigma for the evaluation of critical facility hazard. <u>The PPRP requests that the final report include guidance on the proper use of single-station sigma.</u>

Based on the discussions of application of single station sigma and limitations of Vs30 for characterization of seismic instrumentation sites, the recommendations section of the final report should identify new research and data collection efforts: (1) development of guidance for existing and future critical facility sites to install passive seismic instrumentation to collect seismic data that may support use of single station sigma; and (2) new site characterization and/or site response correction techniques for existing CENA instrumentation sites.

Upcoming Working Meeting and Workshop 3C

The PPRP agrees with the decision to use the April 13, 2015 meeting as a joint Working Meeting (to be conducted via web-conferencing) and to hold the final Workshop (3C) on June 17 and 18, 2015.

In closing, the PPRP wishes to congratulate the Project for a successful Workshop 3B and for the progress made in model development and documentation since the January Working meeting. The PPRP looks forward to the success of the upcoming Working Meeting and Workshop 3C, as well as to model completion and the documentation effort to follow.

Please feel free to contact us if you would like to discuss further our comments or recommendations.

Sincerely,

Gabriel R. Toro
Chair, PPRP

John Adams
Member, PPRP

Jon Ake
Member, PPRP

John Ebel
Member, PPRP

Jeffrey Kimball
Member, PPRP

Richard C. Lee
Member, PPRP

April 21, 2015

Dr. Gabriel Toro

Chair, NGA-East Participatory Peer Review Panel

Subject: NGA-East responses to PPRP review comments on SSHAC Workshop 3B

Dear Dr. Toro:

This letter constitutes the NGA-East collective response to the PPRP letter dated March 29, 2015, on the NGA-East SSHAC Workshop 3B. As always, we thank you and all members of the PPRP for the constructive comments, efforts and cooperation on the NGA-East project.

This letter provides responses to the specific comments as requested in the PPRP letter. The specific PPRP comments are in *italic*. The <u>underlined sections</u> represent the questions and comments that the PPRP requested formal responses. These are followed by the NGA-East collective responses in **bold face**. Although we are not providing formal written responses to other PPRP comments, they will be considered in the NGA-East project and we appreciate your efforts in communicating those to us.

RESPONSES TO SPECIFIC COMMENTS AND RECOMMANDATIONS

Documentation

The PPRP was pleased to have received a revised TOC, a list of attachment reports and their delivery schedule, a partial early draft of the PEER Median Ground-Motion Epistemic Uncertainty Report (2015-XX), and the draft report documenting the seed GMPEs (titled "Median Ground Motion Models for the Central and Eastern North America Region"). Some of the promised documentation is still pending as indicated below.

The PPRP has requested copies of key reports and other supporting literature that will be used by the project, together with a short summary of what material within each publication will be used by the TI Team and how it will be used. Some of these documents have been received, but without the short summaries and indications of how the material will be used (ref PPRP letters 11/21/14; 8/11/14; 2/28/14). <u>Please provide the reports still missing and the summaries at the TI Team's earliest convenience</u>.

We will provide an updated outline of the SSHAC report, including references to specific sections and/or chapters of the documents that were used by the TI team.

The PPRP has requested copies of the portions of the SWUS report that describe 1) the Sammons map approach and its application to the project and 2) the hanging wall model (ref PPRP letter 11/21/14). By the way, the PEER Hanging-Wall Report is not listed in Section 1.3 of the January 23

TOC; should it? Please provide this information as soon as the Project can secure permission or the material becomes publically available.

The SWUS report can be found at the Dropbox PPRP shared folder, and the link has already been provided to the PPRP.

The PPRP requested and the Project agreed to provide a pre-publication copy of the Kim et al. 2014 paper on the reflectivity method (ref PPRP letter 11/21/14).

The paper can be found at the Dropbox PPRP shared folder, and the link has already been provided to the PPRP.

Interface with the GMPE Developers

The PPRP is interested in understanding what if any feedback the TI has received from the ground motion developers on the TI products using the Sammons map approach (also the range extension where extrapolated by the TI). Have there been discussions between the TI and the developers regarding these topics and is the feedback documented? If so, can the project provide the documentation for PPRP review? If no feedback has been requested, are there plans to query the developers on this subject and document their responses? How did the developers of the excluded models react to their exclusion?

Yes, we had discussions with the GMM developers. They participated to a few conference calls with the NGA-East team. The technical scope of the project has been clarified both in writing and in the conference calls. Occasionally the GMM developers asked questions via emails that were promptly answered. For models that were not selected or only partially selected, we contacted the GMM developers and the discussions and interactions were done verbally before the SSHAC Workshop 3B. Further discussions also occurred during the Workshop 3B. We did not intent to document these interactions in writing.

Given the difficulties with the Vs30 assignments to a majority of the sites, and the limitations of Vs30 as a predictor of site amplifications in CENA, is the TI Team concerned about any inconsistencies introduced by the developers in applying their own adjustment to convert the data to reference conditions? Please provide a short discussion. This issue and its possible implications should also be discussed in the final report.

Since the site conditions are uncertain and because there are multiple defendable approaches to compute site effects correction, the various approaches allow us to capture a wider range of epistemic uncertainty that reflects these limitations. We have compared the site correction factors from the various approaches and they all looked reasonable in the range for which the GMMs are used. We can document this in the final report.

Sammons Maps

Given that the Sammons map approach is new, the PPRP reiterates that it is important for the TI Team to demonstrate by means of sensitivity analyses that the technique is performing properly and is producing and adequate characterization of the CBR of the median ground-motion amplitudes. To this effect, we strongly encourage that the TI Team perform and document the following tests (some of which we had proposed in the past). The PPRP wishes to understand the objective or subjective judgments that are employed to develop the new median models and their weights (ref PPRP's *letter 11/21/14; 8/11/14). Based on discussions at the Workshop, the TI Team may want to follow equivalent ways to achieve the same goals of the exercise proposed above, namely:*

a. Plot EPRI seed and final models on the NGA-East Sammon's maps.

b. Calculate weights for EPRI final models using the Sammon's map cells and run example hazards using these weights.

c. Re-introduce the EPRI seed and final models in the plotting tools (see item 4 below).

Agreed. Items *a* and *b* will be covered at the SSHAC Workshop 3C; item *c* has already been completed was shared with the PPRP on April 13th working meeting. We have further developed the tools to include the individual GMMs used in the EPRI project. The latest tools are available at the Dropbox PPRP shared folder.

Based on discussions during the Workshop, the visualization tool should be updated as follows: (a) include all seed models at all frequencies, and provide some kind of identification of which were included or excluded at each frequency; (b) the EPRI (2013) seed models and cluster median, high, and low models; and (c) Please provide the updated version of this very useful tool to the PPRP as soon as it is available.

The tools reflect all the information available from the modelers. We prepared a summary table explaining which models were used in the Sammon's maps. The table can be found at the Dropbox PPRP shared folder, and the link has already been provided to the PPRP. The statistics computations are based on pre-defined M, R but done independently at each frequency. Limitations in model usage is restricted to specific frequency ranges only.

The process for the exclusion of "non-physical" models from the set of 2,000 generated models needs to be implemented and documented. The criteria must be defined, and the results must be documented. Please provide the PPRP with a description of the criteria and documentation of the results. The documentation may include the following: percent of models removed, graphs of the retained and excluded models in amplitude vs. magnitude space, amplitude vs. distance space, and Sammons space.

The criteria currently established by the TI team are summarized on page 12 of Dr. Kuehn's presentation file presented at the working meeting held on April 13, 2015. The presentation file is at the Dropbox PPRP shared folder.

Because the Sammons maps are generated separately for each frequency, it is likely that the resulting spectra be jagged (for both M-R scenarios and for uniform-hazard spectra). The final *report should address this question and contain guidance on how to smooth the results. Please discuss the TI Team's approach for alleviating the jaggedness of spectra.*

Preliminary results show that this is currently not a concern; however, we will show the final results, and address this issue, at Workshop 3C as needed.

The choice on weighting "nearby" GMM (on the Sammons plane) needs to be resolved. Two nearby GMM could be redundant or could be confirmatory, depending on their underlying assumptions and data. Also, the process may be strongly dependent on grid size. This redundant/confirmatory decision can only be made by understanding the seed models and involves judgment. The handling of this issue will affect the pdf (or prior-based weights). Please summarize the TI Team's current thinking on this issue.

The Sammon's map approach is a way to evaluate models in terms of the ground motions they produce (aggregated over a wide M, R range). In this context, models in close proximity in the Sammon's maps are effectively treated as redundant and share the unit weight of the cell they lie in. The grid size selection was based on the TI team's judgment and we completed a suite of sensitivity studies on this issue, which were presented at Workshop 3B. Given that the empirical data is limited to M<6 and the Sammon's maps go to M7.5, there is no data to discern whether GMMs providing similar ground motions are effectively reflects *redundant or confirmatory* information, and this decision is largely a matter of expert judgment.

Regionalization

The PPRP has requested the examination of station residuals by region as a way to confirm the appropriateness of combining all regions except the Gulf (ref PPRP letter 11/21/14). A map of station residuals at a few frequencies (with or without smoothing) may be a useful way to present this information. Please provide the mean station regional residuals by region at a few frequencies, either as maps or in other form.

Agreed.

Following the October Workshop, there was some lack of clarity about how the alternative models for Q and kappa for the Gulf Coastal Region (GCR) was going to be treated. Please summarize the status of the model for the GCR and how the differences between the two GCR models will be incorporated in the final GCR GMPEs (ref PPRP letter 11/21/14). -

Two independent models for the GCR (Region1) were developed. One based on the PEER (Graves and Pitarka) model and one developed from the four DASG models. The plan is to provide one or two models that will be defined in terms of adjustments (ratios of PSA models from Region 1 to those in Region2). The TI Team is currently evaluating these two models.

Treatment of Depth

It is the PPRP's understanding that the final model will include depth as an explanatory variable.

Please confirm. *Also, the treatment of depth should (in principle) include the following three effects: (a) the need to introduce a pseudo-depth (just to introduce saturation), (b) effects of parameters that may change with depth (like stress parameter), and (c) physical wave-generation that is a function of depth (such as enhanced surface waves). Please clarify which of these effects will be captured in the final model.*

Yes, we are developing models to account for depth. These are to address point (b) above, i.e., source depth effects on ground motions. Item (a) is considered in models using a point-source approach as a saturation term, even though it is parameterized as a "depth". Item (c) is not considered directly, but is indirectly included through consideration of data containing these effects.

PIE Events

It was not clear whether the PIE events were included in the analysis of residuals for the sigma calculations, and whether the final model will be applicable to both natural and PIE events. Please clarify and discuss.

They were included to quantify phiS2S terms only. The inclusion of additional recordings increased the reliability of the repeatable site effects.

Sigma

There will be significant interest in using single station sigma for the evaluation of critical facility hazard. The PPRP requests that the final report include guidance on the proper use of single-station sigma.

Agreed.

We thank you again for your constructive feedback. If you have any questions please do not hesitate to contact us.

Sincerely,

Yousef Bozorgnia, NGA-East Project Manager	Norman Abrahamson, NGA-East TI Lead	Christine Goulet, NGA-East TI Lead

Copy: Members of PPRP
NGA-East JMC

B.6 Workshop 3C, June 17–18, 2015

B.6.1 Workshop Summary

This Workshop followed the SSHAC Theme 3: Feedback Analyses.

The Workshop's focused on the proposed NGA-East models for the median predictions and the standard deviations. The workshop started with the median models—first, the evaluation of available median models used in the integration of NGA-East was presented. Then, the extrapolation to large distances for these models in a reliable, consistent fashion was presented. The integration of the models via the NGA-East process was presented next, with a focus on the reasoning behind the process. This involved an overview of the complete approach, where the first part reiterated the idea of a continuous distribution of median predictions that is essential to the NGA-East characterization of median models. The focus on median models concluded with a presentation on the process applied to the NGA-East seed models, which covered the visualization of the ground-motion space covered by the NGA-East distribution and the discretization into a manageable subset of models. This part also covered the weight assignment approach, based on the probability density covered by each model and the respective fit to CENA records. Discussion focused on the selection of underlying magnitude and distance scenarios for the visualization, and on improved method for displaying the weights.

The rest of the first day was devoted to the proposed models for the standard deviations. The underlying CENA data was presented, and approaches to model building for the different components of aleatory variability were laid out. The uncertainty of the different component models, important for building the logic tree, was discussed.

The second day dealt with adjustments to the NGA-East median models, in particular regional adjustments for the Gulf Coast, adjustments for varying source depth and hanging-wall adjustments. The presentation on source-depth effects showed differences between the CENA median models that include scaling with hypocentral depth and the NGA-West2 models. The hanging wall model from SWUS was presented as a proponent model for NGA-East. The day wrapped up with a feedback on hazard calculations using the median and standard deviation models.

B.5.2 PPRP and TI Team Correspondence

The correspondence is included in the following pages.

June 26, 2015

Dr. Yousef Bozorgnia
Project Manager for PEER NGA-East Project
Pacific Earthquake Engineering Research Center (PEER)
University of California, Berkeley
325 Davis Hall, MC 1792
Berkeley, CA 94720

Dear Dr. Bozorgnia:

Reference: *Next Generation Attenuation – East Project*: Participatory Peer Review Report on SSHAC Workshop No. 3C (June 17 and 18, 2015).

Acronyms

ACP	Atlantic Coastal Plain
CEUS	Central and Eastern United States
CNA	Central North America
ENA	Eastern North America
EPRI	Electric Power Research Institute
FAS	Fourier Amplitude Spectrum
FFS	Finite Fault Simulation
GCR	Gulf Coast Region
GMM	Ground Motion Model
GMPE	Ground Motion Prediction Equation
GWG	Geotechnical Working Group
HEM	Hybrid Empirical Model
NGA-East	Next Generation Attenuation East
PEER	Pacific Earthquake Engineering Research Center
PPRP	Participatory Peer Review Panel
PSHA	Probabilistic Seismic Hazard Analysis
RVT	Random Vibration Theory
SASW	Spectral Analysis of Surface Waves
SSHAC	Senior Seismic Hazard Analysis Committee
SWUS	Southwestern United States Ground Motion Project
TI	Technical Integrator
TOC	Table of Contents
USGS	United States Geological Survey
WNA	Western North America
WS-2	Workshop 2
WS-3	Workshop 3

This letter constitutes the report of the PPRP on WS-3C for the referenced project. The workshop was held June 17 and 18, 2015, at the University of California, Berkeley in Berkeley, California.

Following guidance described in the NGA-East Project Plan[1] for the PPRP, and consistent with the expectations of the SSHAC process[2], the PPRP participated in WS-3C in order to be informed about the Project's progress and to review both procedural and technical aspects of the workshop. All six members of the PPRP (J. Adams, J. Ake, J. Ebel, J. Kimball, R. Lee, and G. Toro) attended WS-3C and were able to observe all aspects of the workshop.

The observations and comments from the PPRP focus on assuring that the overall objectives for WS-3C are achieved. According to SSHAC guidance cited above, the primary WS-3 objectives are: (1) to present and discuss the preliminary models and sensitivity calculations, (2) present feedback in the form of sensitivity results, and (3) provide the opportunity for the PPRP and resource experts to probe the preliminary model to understand the manner in which the variety of technically defensible interpretations has been considered and incorporated in the preliminary model.

GENERAL OBSERVATIONS

The workshop was well structured and satisfied the SSHAC requirements for WS-3 with respect to the presentation of the approach that the TI team has developed for evaluating the proponent models, integrating the proponent models into a comprehensive GMM (i.e., approach based on Sammon's maps), presentation of preliminary results from the application of this approach, development of a model for sigma, and presentation of preliminary sensitivity results for a few sites. The Project has made significant progress since WS-3B in March 2015. Nonetheless, the PPRP is concerned about some remaining tasks, given the planned delivery of the draft final report in July 2015. In particular, the models for depth effects and for the Gulf Coastal Region (GCR) have not been finalized and the PPRP considers that some additional sensitivity analyses are required.

Presentations during the Workshop were clear and focused, and the discussions provided additional clarity and depth, with good participation by the TI Team and Resource Experts. This allowed the PPRP to have a good understanding of the proponent models and their associated uncertainties.

At the conclusion of the first meeting day, the TI Co-Lead prepared a summary that identified the key issues and action items arising from that day's presentations and discussions. These

[1] Goulet, et al., 2013, *NGA-East Project* Plan - Version 2, Pacific Earthquake Engineering Research Center (PEER), University of California, Berkeley, April.
[2] Budnitz et al., 1997, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.* NUREG/CR-6372, NRC; and NRC, 2012, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Revision 1, NUREG-2117.

summaries are very thorough and well prepared, and the Project is encouraged to pay close attention to them as a way to track critical issues and loose ends.

SPECIFIC COMMENTS AND RECOMMENDATIONS

The comments and recommendations below are organized by topic. Items requiring a formal response are underlined. A number of comments and requests were made during the June 18 de-briefing but are repeated here for the sake of completeness

Documentation

The PPRP was pleased to receive a revised Table of Contents (TOC) on June 2, together with a list of supporting documents, including delivery dates and notes regarding their intended use by the Project. In addition, the draft reports on GMM adjustments and on aleatory uncertainty were received a few days later.

In the June 2 version of the TOC, it is not clear whether Section 13 covers the selection of sigma (ergodic vs. single-station), or the treatment of GCR sites (including both the issue of sources and sites situated in different regions and of thick sedimentary columns beneath the site). More generally, this portion of the TOC provides little detail. <u>Please provide an updated TOC with additional details on Section 13.</u> Given the hazard implications of the sigma selection, and the requirements introduced if single-station sigma is used, this guidance is extremely important. Guidance on the treatment of boundary crossings is also important, as this treatment can affect the hazard at low-seismicity sites where RLMEs are large contributors.

The PPRP is concerned about how the many supporting reports will be treated in the final SSHAC report. Although it would be impractical to duplicate all the material from the supporting documents in the SSHAC report, the SSHAC report must provide sufficient context as to how the material from the key supporting documents is used. Where choices are made as to the data or conclusions that are adopted into the SSHAC report, the reasons for these choices should be clear. Also, because many of these supporting documents cannot be revised, the SSHAC report must fill any gaps that the PPRP or TI Team identify in these supporting documents.

Regarding the final SSHAC report, the PPRP considers that its review process can only commence after the complete draft report is received. As agreed earlier, the PPRP will provide a schedule for its review of the draft SSHAC report and for the review meeting two weeks after receiving the complete draft report.

Treatment of Epistemic Uncertainty in the Medians (correlation model, Sammons maps, discretization, weights)

The PPRP is pleased to see considerable progress in these tasks, both in terms of refining and streamlining the approach and in the results obtained and presented at WS3C. Given that the approach is new, the PPRP requests that the following sensitivities and additional tests be performed. Whenever possible, the sensitivity analyses should be taken all the way to hazard for a minimum of two sites (e.g., Savannah and Manchester) and presented separately for background seismicity and nearby RLMEs for PGA (or for 10 Hz) and for 1 Hz.

1. Please calculate sensitivity to alternative covariance models (both for the diagonal terms and for the correlation coefficients).
2. The tests on the effect of using smaller magnitude-distance ranges for the Sammons maps was very instructive. Please carry those tests all the way to hazard.
3. Some steps in the approach developed by the Project have a tendency to increase the variance in the median, and some to decrease it (i.e., sampling the GMPE shape from a random seed model instead of the overall median increases the variance, removing un-physical model decreases the variance, ignoring points outside the outer ellipse in the Sammons maps decreases the variance, the 2-D discretization in the Sammons maps may either increase or decrease the variance depending on how it is implemented and on the details of the cloud of points). Please examine the individual and combined effects of these and other steps on the total epistemic uncertainty in the median amplitude and discuss their implications (including hazard sensitivity).
4. Please calculate sensitivity to alternative choices of weights. For instance, consider the effect of giving 1/3 weight each to GMMs, likelihood, and residuals. Also, please discuss the rationale for combining the weights additively rather than multiplicatively (as in Bayes' Theorem).
5. Please indicate whether the rejection rates for unphysical models were similar for the NGA-East and EPRI seed models.

The PPRP requests that the Project provide the results requested above prior to submitting the draft report. It may be appropriate for the Project to present these results to the PPRP in a webinar with a duration of one-half day or less.

Adjustments for Depth and for GCR Paths and Sites

Although significant progress has been made in these two areas, they lag behind other elements of the model. The PPRP requests to be informed of progress in these areas. The PPRP would like to be able to provide technical feedback on these areas, prior to their crystallization in the draft SSHAC report.

The PPRP also reminds the Project that the effect of Rg waves needs to be investigated further and included in the final model (perhaps in a simplified manner) if it is found to be hazard significant.

Regionalization and Residuals at Appalachian Stations

Some concern remains about possible negative residuals for stations in the Appalachian region. The PPRP is encouraged by the recent direct communications between TI Team member Dr. Linda Al Atik and PPRP member John Adams about how to resolve this issue. These communications should always cc. Project Manager and other PPRP members.

Insights from Sensitivity Analyses

The sensitivity results presented so far suggest that the most important difference with respect to the EPRI 2013 results is an increase in hazard for annual exceedance frequencies lower than 10^{-4}, which seems to be a consequence of increased epistemic uncertainty at shorter distances. The PPRP suggest that the TI Team explore and document which seed models, regions of the Sammons maps, or steps in the analysis control this effect.

In closing, the PPRP wishes to congratulate the Project for a successful WS-3C and for the progress made in model development and documentation since the March WS-3B and the April Working Meeting. The PPRP looks forward to the success in the model completion, the documentation effort to follow, and the PPRP review.

Please feel free to contact us if you would like to discuss further our comments or recommendations.

Sincerely,

Gabriel R. Toro
Chair, PPRP

John E Adams
John Adams
Member, PPRP

Jon Ake
Member, PPRP

John E. Ebel
John Ebel
Member, PPRP

Jeffrey K Kimball
Jeffrey Kimball
Member, PPRP

Richard C. Lee
Richard C. Lee
Member, PPRP

July 20, 2015

Dr. Gabriel Toro
Chair, NGA-East Participatory Peer Review Panel

Subject: NGA-East responses to PPRP review comments on SSHAC Workshop 3B

Dear Dr. Toro:

This letter constitutes the NGA-East collective response to the PPRP letter dated June 26, 2015, on the NGA-East SSHAC Workshop 3C. As always, we thank you and all the PPRP members for the constructive comments, efforts and cooperation on the NGA-East project.

This letter provides responses to the specific comments as requested in the PPRP letter. The specific PPRP comments are in *italic*. The <u>underlined sections</u> represent the questions and comments for which the PPRP requested formal responses. These are followed by the NGA-East collective responses in **bold face**. Although we are not providing formal written responses to other PPRP comments, they will be considered in the NGA-East project and we appreciate your efforts in communicating those to us.

RESPONSES TO SPECIFIC COMMENTS AND RECOMMANDATIONS

Documentation

In the June 2 version of the TOC, it is not clear whether Section 13 covers the selection of sigma (ergodic vs. single-station), or the treatment of GCR sites (including both the issue of sources and sites situated in different regions and of thick sedimentary columns beneath the site). More generally, this portion of the TOC provides little detail. <u>Please provide an updated TOC with additional details on Section 13.</u>

We will provide an updated TOC with additional details.

Treatment of Epistemic Uncertainty in the Medians (correlation model, Sammons maps, discretization, weights)

The PPRP is pleased to see considerable progress in these tasks, both in terms of refining and streamlining the approach and in the results obtained and presented at WS3C. Given that the approach is new, the PPRP requests that the following sensitivities and additional tests be performed. Whenever possible, the sensitivity analyses should be taken all the way to hazard for a minimum of two sites (e.g., Savannah and Manchester) and presented separately for background seismicity and nearby RLMEs for PGA (or for 10 Hz) and for 1 Hz.

1. Please calculate sensitivity to alternative covariance models (both for the diagonal terms and for the correlation coefficients).
2. The tests on the effect of using smaller magnitude-distance ranges for the Sammons maps was very instructive. Please carry those tests all the way to hazard.
3. Some steps in the approach developed by the Project have a tendency to increase the variance in the median, and some to decrease it (i.e., sampling the GMPE shape from a random seed model instead of the overall median increases the variance, removing un- physical model decreases the variance, ignoring points outside the outer ellipse in the Sammons maps decreases the variance, the 2-D discretization in the Sammons maps may either increase or decrease the variance depending on how it is implemented and on the details of the cloud of points). Please examine the individual and combined effects of these and other steps on the total epistemic uncertainty in the median amplitude and discuss their implications (including hazard sensitivity).
4. Please calculate sensitivity to alternative choices of weights. For instance, consider the effect of giving 1/3 weight each to GMMs, likelihood, and residuals. Also, please discuss the rationale for combining the weights additively rather than multiplicatively (as in Bayes' Theorem).
5. Please indicate whether the rejection rates for unphysical models were similar for the NGA-East and EPRI seed models.

> **We have added a new appendix to the Final Report table of contents dedicated to sensitivity studies and additional analyses. The plan is to document the final results in the core of the report and to provide the reference to the specific sections of the appendix for the details on sensitivity or additional analyses. The five sensitivity studies requested above will be included as sections in the appendix of the final report.**

The PPRP requests that the Project provide the results requested above prior to submitting the draft report. It may be appropriate for the Project to present these results to the PPRP in a webinar with a duration of one-half day or less.

> **Agreed. We are working on these topics and we will provide the results to the PPRP before the submittal of the final report.**

Adjustments for Depth and for GCR Paths and Sites

Although significant progress has been made in these two areas, they lag behind other elements of the model. The PPRP requests to be informed of progress in these areas. The PPRP would like to be able to provide technical feedback on these areas, prior to their crystallization in the draft SSHAC report.

> **Agreed. We are working on these issues and will provide the results to the PPRP before the submittal of the final report.**

The PPRP also reminds the Project that the effect of Rg waves needs to be investigated further and included in the final model (perhaps in a simplified manner) if it is found to be hazard significant.

We are investigating these effects and will provide PPRP with the results before the submittal of the final report.

Insights from Sensitivity Analyses

The sensitivity results presented so far suggest that the most important difference with respect to the EPRI 2013 results is an increase in hazard for annual exceedance frequencies lower than 10-4, which seems to be a consequence of increased epistemic uncertainty at shorter distances. <u>The PPRP suggest that the TI Team explore and document which seed models, regions of the Sammons maps, or steps in the analysis control this effect.</u>

We have started such an evaluation. The source of such trends will be documented in the report.

We thank you again for your constructive feedback and interactions. If you have any questions please do not hesitate to contact us.

Sincerely,

Yousef Bozorgnia, NGA-East Project Manager	Norman Abrahamson, NGA-East TI Lead	Christine Goulet, NGA-East TI Lead

Copy: Members of PPRP
NGA-East JMC
TI Team

B.7 List of Selected Working Meetings

Selected TI Team Working Meetings

2012-10-16 Working Meeting Path-Source Issues
2012-12-11 Working Meeting Simulations Validations
2014-01-27 Working Meeting Regionalization
2014-04-07 Working Meeting Simulations Validation
2015-01-20-22 TI Meeting
2015-04-13 TI Meeting
2010-12-13 TI Meeting
2011-01-14 TI Meeting
2012-05-25 TI Meeting
2015-02-20 TI Meeting
2015-02-27 TI Meeting
2015-03-13 TI Meeting
2015-03-20 TI Meeting
2015-03-27 TI Meeting
2015-04-03 TI Meeting
2015-04-08 TI Meeting
2015-04-30 TI Meeting
2015-05-15 TI Meeting
2015-05-29 TI Meeting
2015-06-05 TI Meeting
2015-06-12 TI Meeting
2015-06-15 TI Meeting
2015-06-26 TI Meeting
2015-07-02 TI Meeting
2015-07-08 TI Meeting
2015-07-15 TI Meeting
2015-07-20 TI Meeting
2015-07-27 TI Meeting
2015-08-12 TI Meeting
2015-08-18 TI Meeting
2015-08-26 TI Meeting
2015-09-01 TI Meeting
2016-02-19 TI Meeting
2016-03-08 TI Meeting
2017-03-21 TI Call
2017-03-29 TI Call
2017-04-25 TI Call
2017-05-04 TI Call
2017-05-10 TI Call
2017-05-11 TI Call
2017-05-24 TI Call
2017-05-30 TI Call
2017-06-12 TI Call
2017-06-15 Call PPRP call prep
2016-04-04 TI Meeting with PPRP
2017-06-16_Call with PPRP
2011-05-03 TI and WG chairs conference call
2012-05-22 NGA-East Working Group Chairs conference call

GMM Large Group Calls with TI (PPRP was welcome)

2014-08-22
2014-08-29
2014-09-05
2014-09-12
2014-09-19
2014-09-26
2014-10-03
2014-10-10
2014-10-17
2014-10-24
2014-11-07
2014-11-14
2014-11-21
2014-12-05
2015-01-09

Selected Database Meetings

2009-09-29 Meeting
2011-01-03 Albert_Vs30Info
2011-06-01 Database Update and QA CC
2011-08-24 QA
2012-01-20 NGA-East Database
2012-01-30 NGA-East Database
2013-01-10 Database Meeting at PEER
2014-01-28 Working Meeting Database

Selected Geotechnical WG Meetings

2009-10-01 Meetings
2010-10-07 Meeting
2011-10-05 NGA-East Site Effects
2012-01-03 NGA-East Sims WG Ref Rock conference Call
2013-09 Site Profiles
2014-01 Final Rock Reports Vs and Kappa
2014-01-28 Kayen Mineral Virginia Sites
2014-01-28 Kayen Mineral Virginia Sites.zip
2014-10-13 Meeting

Sigma WG Meetings and Conference Calls

2010-02-12 Sigma Workshop
2010-10-20 Conference Call
2013-05-22 Conference call
2011-12-08 NGA-East Sigma WG

Simulations WG Meetings and Conference Calls

2011-10-03 NGA-East Simulations WG
2012-01-03 Conference call
2012-01-04 Simulations WG Conference Call
2014-04-07 TI Team FFS evaluation meeting at PEER
2014-08 Forward Runs Set 1
2014-09-18 Prelim Sims Review Meeting
2014-10-06 Forward Runs Set 2
Plus numerous SCEC Broadband Platform Calls for Validation of Simulation

Regionalization/Path and Source Meetings and Conference Calls

2011-07-01 Path/Source WG conference call
2012-06-12 Regionalization Meeting
2012-10-01 Path Source Issues at USGS
2012-06-12 NGA-East Regionalization meeting
2013-08-22 Regionalization
2013-11-08 NGA-East Path/Source WG Meeting
2011-09-29 NGA-East Path/Source WG Meeting
2015-11-10 Working Meeting on Regionalization (large public meeting)
Plus numerous other conference calls on regionalization

RVT Group Meetings

2014-03-19 Meeting
2014-07-02 Meeting
2014-07-30 Meeting
2014-09-05 Meeting
2016-09-11 Meeting

underestimate because of exclusion of significant low-frequency signal due to poor signal to noise ratio for periods longer than 2.5 sec.

The finite-fault model used in the NGA-East validation exercise is given in Table C.1. Note that the moment magnitude is slightly lower than the average value taken from Johnston (1996). The finite-fault model was used to compute the distances to the recording stations.

Table C.1 NGA-East finite-fault model for Saguenay, 1988.

Latitude*	Longitude*	Depth*	Strike	Dip	Rake	RL	RW	Mo	M
48.098	-71.208	21.47	320	65	78	6.48	6.48	5.85E+24	5.81

*Location of center point of the top of the rupture plane.

EQID 06 – La Malbaie, QC, August 1997

The parameters for this earthquake are taken from NUREG-2115. The value of **M** is estimated from M_N. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 07 – La Malbaie, QC, October 1997

The parameters for this earthquake are taken from Du et al. (2003) except for the more precise location given in the NRCAN catalog. Boatwright (2014) also reports **M**4.29 based on regional spectral analysis (RSA). A nominal uncertainty of 0.1 is assigned to **M** based on typical values.

EQID 08 – Cap-Rouge, QC, November 1997

The parameters for this earthquake are taken from four sources. Three sources report very similar seismic moments and focal mechanisms, and the fourth (Boatwright 2014) reports a very similar value of **M**. A fifth source (Bent 2014) reports a significantly larger seismic moment (~0.5 units larger **M**) and a significantly different focal mechanism. Given the large difference between the values from Bent (2014) and the other sources, and the consistency of the other estimates, the values from Bent (2014) were not used to derive the average values of **M** and depth. The preferred focal mechanism was taken from Ma and Adams (2002) as it is intermediate between the solutions of SLU and Du et al. (2003). The more precise epicentral location given in the NRCAN catalog is used.

EQID 09 – Cote-Nord, QC, March 1999

The parameters for this earthquake are taken from a number of sources. Four reported values of M_o and Boatwright's (2014) RSA **M** are used to compute an average value of **M**. It should be noted that the value of M_o provided by Bent (2014) are consistent with the other estimates as is the focal mechanism. The reported focal mechanisms are all similar, and the one from Lamont was used as the preferred value for simulating ruptures. The selected depth is an average of the reported depths.

EQID 10 – Kipawa, QC, January 2000

The parameters for this earthquake are taken from a number of sources that report similar results. The focal mechanism is taken from the Bent et al. (2002) study of this event. It is similar to other estimates.

EQID 11 – La Malbaie, QC, June 2000

The location is taken from the NRCAN catalog and the estimate of **M** from Atkinson (2004a; 2004b). A nominal uncertainty in **M** of 0.1 is assigned. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 12 – Laurentide, QC, July 2000

The location is taken from the NRCAN catalog and the estimate of **M** from Atkinson (2004a; 2004b). A nominal uncertainty in **M** of 0.1 is assigned. The focal mechanism is taken from Bent et al. (2003).

EQID 13 – Laurentide, QC, July 2000 (second event)

The location is taken from the NRCAN catalog and the estimate of **M** from Atkinson (2004a; 2004b). A nominal uncertainty in **M** of 0.1 is assigned. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 14 – Ashtabula, OH, January 2001

The location and depth are taken from the Seeber et al. (2004) study of this event. The value of **M** is averaged from the available assessments and the focal mechanism is taken from Du et al. (2003).

EQID 15 – Enolal, AR, July 2001

The location is taken from the more precise value in NUREG-2115. The depth, value of **M** and focal mechanism are taken from the SLU website. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 16 – Au Sable Forks, NY, April 2002

The location and focal mechanism are taken from the Kim and Seeber (2003) study of this event. The value of **M** and the depth are averages of the reported values.

EQID 17 – Lac Laratelle, QC, June 2002

The more precise location is taken from the NRCAN catalog. The focal mechanism and depth are taken from the SLU website. Bent (2014) reports a depth of 23 km, but indicates that it is poorly constrained. The reported values of **M** are averaged.

EQID 18 – Carbon, IN, June 2002

The more precise location is taken from the SLU website along with the focal mechanism. The depth and value of **M** are averages of the two reported values.

EQID 19 – Boyd, NE, November 2002

The more precise location is taken from NUREG-2115. The depth, **M**, and focal mechanism are taken from the SLU website. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 20 – Charleston, SC, November 2002

The more precise location is taken from NUREG-2115. The depth, **M**, and focal mechanism are taken from the SLU website. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 21 – Ft Payne, AL, April 2003

The more precise location is taken from ANSS. The depth, **M**, and focal mechanism are taken from the SLU website. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 22 – Blytheville, AR, April 2003

The location and values of **M** and $\sigma_{\mathbf{M}}$ estimated from other magnitude measures are taken from NUREG-2115.

EQID 23 – Bardwell, KY, June 2003

The location and focal mechanism are taken from the SLU web site. The values of **M** and source depth are averages of the SLU and LNSN assessments.

EQID 24 – La Malbaie, QC, June 2003

The location is taken from the NRCAN catalog. The focal mechanism is taken from the SLU website. The depth is taken as the average of the source depths from SLU and Atkinson (2004a). The depth from Bent (2014) is not used as she indicates that it is poorly constrained. The reported values of **M** are averaged to produce the selected value.

EQID 25 – Bark Lake, QC, October 2003

The location is taken from the NRCAN catalog. The values of **M** and $\sigma_{\mathbf{M}}$ estimated from other magnitude measures are taken from NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 26 – Jefferson, VA, December 2003

The parameters for this earthquake are taken from Kim and Chapman (2003).

EQID 27 – St. Teresa, Mexico, April 2004

This earthquake is not investigated in this report.

EQID 28 – La Baie, QC, May 2004

The location is taken from the NRCAN catalog. The values of **M** and $\sigma_{\mathbf{M}}$ estimated from other magnitude measures are taken from NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 29 – Prairie Center, IL, June 2004

The location and focal mechanism are taken from the SLU web site. The values of **M** and source depth are averages of the SLU and LNSN assessments.

EQID 30 – Port Hope, ON, August 2004

The location and focal mechanism are taken from Kim et al. (2006), a study if this event. The values of **M** and source depth are averages of the available assessments.

EQID 31 – Milligan Ridge, AR, February 2005

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 32 – Rivière du Loup, QC, March 2005

The selected source parameters are those selected for the finite-fault ground-motion validation exercise for the NGA-East project. Note that the average of the reported values of **M** is 4.67, instead of the value of **M** of 4.60 used in the validation exercise.

The finite-fault model used in the NGA-East validation exercise is given in Table C.2. The finite-fault model was used to compute the distances to the recording stations.

Table C.2 NGA-East finite-fault model for Rivière du Loup, March 2005.

Latitude*	Longitude*	Depth*	Strike	Dip	Rake	RL	RW	Mo	M
47.751	-69.724	12.3	170	60	80	1.6	1.6	9.02E+22	4.60

*Location of center point of the top of the rupture plane.

EQID 33 – Shady Grove, AR, May 2005

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 34 – Miston, TN, June 2005

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 35 – Thurso, ON, February 2006

The location and focal mechanism are taken from the SLU web site. The location matched the NRCAN location. The value of **M** is averaged from the reported values and the source depth is an average, excluding the estimate of Bent (2014) as she indicated hers is poorly constrained.

EQID 36 – Hawkesbury ON, February 2006

The location is taken from NRCAN, and the value of **M** is estimated from other size measures in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 37 – Baie Saint Paul QC, April 2006

The location and focal mechanism are taken from the SLU website. The value of **M** is an average of the available estimates.

EQID 38 – Ridgley, TN, September 2006

The location and estimate of **M** (based on other size measures) are taken from NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 39 – Gulf of Mexico, September 2006

This earthquake is not investigated in this report.

EQID 40 – Acadia, ME, October 2006

The more precise location is taken from the Weston Observatory catalog. The depth, value of **M,** and focal mechanism are taken from the SLU website. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 41 – Marston, MO, October 2006

The location and estimate of **M** (based on other size measures) are taken from NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 42 – Marvin, VA, November 2006

This event is a mine collapse (Chapman, Personal communication).

EQID 43 – Skeggs, VA, November 2006

This event is a mine collapse (Chapman, Personal communication).

EQID 44 – Cobourg ON, July 2007

The location is taken from NRCAN, and the value of **M** is estimated from other size measures in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 45 – Baie Saint Paul, QC, January 2008

The location is taken from NRCAN, and the value of **M** is estimated from other size measures in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 46 – Mt Carmel, IL, April 2008

The location and focal mechanism are taken from the SLU web site. The values of **M** and source depth are averages of the SLU and USGS assessments.

EQID 47 – Mt Carmel, IL, April 2008, aftershock

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 48 – Mt Carmel, IL, April 2008, aftershock

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 49 – Mt Carmel, IL, April 2008, aftershock

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 50 – Buckingham, QC, June 2008

The location is taken from NRCAN and the value of **M** is estimated from other size measures in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 51 – Rivière du Loup, QC, November 2008, aftershock

The location is taken from NRCAN and the value of **M** is the average reported values. The source depth and focal mechanism are taken from the SLU website.

EQID 52 – Pine Forest, SC, December 2008

The location and estimate of **M** (based on other size measures) are taken from NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 53 – Rosehill, SC, January 2009

The location is taken from ANSS, and the value of **M** is estimated from m_D using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 54 – Palmetto, SC, May 2009

The location is taken from ANSS, and the value of **M** is estimated from m_{bLg} using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 55 – Constance Bay, ON, May 2009

The location is taken from NRCAN, and the value of **M** is estimated from M_N using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 56 – Jones, OK, January 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 57 – Lincoln, OK, February 2010

The more precise location is taken from ANSS, the focal mechanism, source depth, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 58 – Whiting, MO, March 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 59 – Lebanon, IL, May 2010

The location is taken from ANSS, and the value of **M** is estimated from m_D using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be strike–slip based on the predominant focal mechanisms in the area.

EQID 60 – Val-des-Bois QC, June 2010

The location and focal mechanism are taken from the SLU web site. The value of **M** and source depth are averages of the reported values.

EQID 61 – St Flavien QC, July 2010

The more precise location is taken from NRCAN; the source depth, value of **M**, and focal mechanism are taken from Lamontagne et al. (2013). As discussed in that paper, a depth of 19–20 km (average of 19.5 used) based on waveform modelling is preferred over the 13-km depth obtained from the moment tensor solution.

EQID 62 – Bhuj, India, January, 2011

This earthquake is not investigated in this report.

EQID 63 – Mt. Laurier QC, October 1990

The more precise location is taken from NRCAN; the source depth, value of **M**, and focal mechanism are taken from Lamontagne et al. (1994), which show two focal planes; but the steep dip is consistent with the aftershock distribution they show. Therefore, it is recommend to only use the steeply dipping plane.

EQID 64 – Montgomery, MD, July 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 65 – Gazli, USSR, May 1976

Information for this event was taken from the NGA-West2 database.

EQID 66 – Slaughterville, OK, October 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 67 – Guy, AR, October 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 68 – Concord, NH, September 2010

The location is taken from ANSS, and the value of **M** is estimated from m_{bLg} and m_C using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 69 – Nahani, NWT, November 1985 Foreshock

Information for this event was taken from the initial NGA-East Event File (Cramer et al. 2013).

EQID 70 – Nahani, NWT, December 1985 Second Mainshock

Information for this event was taken from the NGA-West2 database.

EQID 71 – Nahani, NWT, December 1985 Aftershock

Information for this event was taken from the initial NGA East Event File (Cramer et al. 2013).

EQID 72 – Nahani, NWT, December 1985 Aftershock

Location and **M** are taken from Boore and Atkinson (1989) and the focal mechanism from Horner et al. (1990).

EQID 73 – Arcadia, OK, November 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 74 – Bethel Acres, OK, December 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 75 – Greenstown, IN, December 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 76 – Guy, AR, November 2010

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 77 – Greenbrier, AR, February 2011

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 78 – Greenbrier, AR, February 2011

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 79 – Greenbrier, AR, February 2011

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 80 – Greenbrier, AR, February 2011

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 81 – Sullivan, MO, June 2011

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 82 – Eagle Lake, ME, July 2006

The more precise location is taken from the Weston catalog. The source depth and focal mechanism are taken from the SLU website. The value of **M** is an average of the SLU and Boatwight (2014) values.

EQID 83 – Val-des-Bois, QC, June 2010, Aftershock

The location is taken from NRCAN and the value of **M** is estimated from M_N using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 84 – Val-des-Bois, QC, July 2010, Aftershock

The location is taken from NRCAN, and the value of **M** is estimated from M_N using the relationships in NUREG-2115. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 85 – Hawkesbury ON, March 2011

The location is taken from NRCAN. The focal mechanism is taken from the SLU website. The values of **M** and source depth are averaged from the reported values.

EQID 86 – Charlevoix, QC, May 2001

The location is taken from NRCAN, and the value of **M** is taken from Atkinson (2004a; 2004b). A nominal uncertainty in **M** of 0.1 is assigned. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 87 – Baie Saint Paul, QC, August 2002

The location is taken from NRCAN and the value of **M** is taken from Atkinson (2004a; 2004b). A nominal uncertainty in **M** of 0.1 is assigned. No focal mechanism is available. The earthquake is assumed to be reverse based on the predominant focal mechanisms in the area.

EQID 88 – Mineral, VA, August 2011

The selected source parameters are based primarily on Chapman (2013). The average of the reported values of **M** is 5.74, which is larger than the value used in the validation exercise. The preferred SLU solution is the strike of 175˚ while Chapman (2013) and Motazedian and Ma (2014) prefer a strike of 29˚.

The finite-fault model used in the NGA-East validation exercise is given in Table C.3. The finite-fault model was used to compute the distances to the recording stations.

Table C.3 NGA-East finite-fault model for Mineral, Virginia, August 2011.

Latitude*	Longitude*	Depth*	Strike	Dip	Rake	RL	RW	Mo	M
37.929	-77.981	5.84	29	51	113	5.56	5.56	3.72E+24	5.68

*Location of center point of the top of the rupture plane.

EQID 89 – Mineral, VA, August 2011, Aftershock

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 90 – Sparks, OK, November 2011, Foreshock

The location, focal mechanism, and value of **M** are taken from the SLU web site. A nominal uncertainty in **M** of 0.1 is assigned.

EQID 91 – Sparks, OK, November 2011, Mainshock

The location and focal mechanism are taken from the SLU web site. The values of **M** and source depth are averages of the reported values.

EQID 92 – Cormel, TX, October 2011

The location and focal mechanism are taken from the SLU web site. The values of **M** and source depth are averages of the reported values.

EQID 93 – Miramichi, NB, March 1982, Aftershock

The location and focal mechanism are taken from Wetmiller et al. (1984). The value of **M** is an average of the Atkinson (2004a; 2004b) and Shin and Herrmann (1989) values.

EQID 94 – Miramichi, NB, May 1982, Aftershock

The location and focal mechanism are taken from Wetmiller et al. (1984). The value of **M** is an average of the Atkinson (2004a; 2004b) and Shin and Herrmann (1989) values.

EQID 116 – Saguenay, QB, November 1988, Foreshock

The location and value of **M** are taken from Boore and Atkinson (1992). The focal mechanism is taken from North et al. (1990). A nominal uncertainty in **M** of 0.1 is assigned.

EQID 117 – Saguenay, QB, November 1988, Aftershock

The location and value of **M** are taken from Boore and Atkinson (1992). The focal mechanism is taken from North et al. (1990). A nominal uncertainty in **M** of 0.1 is assigned.

C.1.2 Earthquake Source Table (Electronic Appendix)

File: C.1.2_NGA-East_EarthquakeSourceTable_Public_20141118.xlsx

C.1.3 Station Database (Electronic Appendix)

File: C.1.3_NGA-East_StationDatabase_Public_20141118.xlsx

C.1.4 Database Flatfile (Electronic Appendix)

File: C.1.4_NGA-East_RotD50_5pct_Flatfile_Public_20141118.xlsx

C.2 Finite Fault Simulations (Electronic Appendix)

Broadband Platform User guide (single file)

C.2.1 BBP User Guide. File: Appendix C.2.1 BBP User Guide.pdf

Simulation Results from Three Methods (folders)

C.2.2 Results from EXSIM. Folder: C.2.2_ResultsEX

C.2.3 Results from GP. Folder: C.2.3_ResultsGP

C.2.4 Results from SDSU. Folder: C.2.4_ResultsSD

C.3 References

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Shin, T.-C., and R.B. Herrmann. 1987. "Lg Attenuation and Source Studies using 1982 Miramichi Data." Bull Seismol. Soc. Am., 77: 384–397.

Wetmiller, R.J., J. Adams, F.M. Anglin, H.S. Hasegawa, and A.E. Stevens. 1984. "Aftershock Sequences of the 1982 Miramichi, New Brunswick Earthquakes." Bull Seismol. Soc. Am., 74: 621–653.

Appendix D Selection of Representative Correlated Models for Geometrical Spreading and Anelastic Attenuation and Seed Models Plotting Tools

D.1 Selection of Representative Correlated Models for Geometrical Spreading and Anelastic Attenuation

D.1.1 Motivation

This section summarizes the selection of representative attenuation models for Central and Eastern North America (CENA). The Technical Integrator (TI) team performed the evaluation of existing models and selected six models as a representative subset for attenuation conditions (geometric spreading and anelastic attenuation Q) in CENA. The selection was aiming to get a range of attenuation shapes that capture the center, body, and range of technically defensible attenuation models. The TI team specifically asked David Boore to generate a suite of ground motion-models (GMMs) based on the subset of representative attenuation models, so as to have GMMs developed using a consistent process. The GMMs developed through that process are described in Chapter 7 as the Boore (SMSIM) GMMs.

D.1.2 Candidate Geometrical Spreading and Q Models

The starting point for the exercise was a list of 56 attenuation models from a literature study (Figure D.1–1). From this list, a subset of complete models was selected. A model was considered “complete” if it allowed both amplitude and shape to be specified. There were 20 such models that could be plotted over the entire project distance range. We sought representative models that would describe the shapes included in the 20 models. The 20 selected complete models have their short name included in the last column of Figure D.1–1. We focused on shape rather than absolute amplitude level, as the overall level of each curve type will be set by the source parameters in the inversion and/or in the simulations. The initial 20 models are shown at frequencies of 1, 5, and 10 Hz in Figures D.1–1 to D–3.

To find representative models that cover the range of attenuation effects, we focused on how much the amplitude of the motion decays in three representative distance ranges: 1 to 50 km; 50 to 150 km, and 150 to 500 km. These represent near-distance direct-wave spreading, the transition zone from direct waves to Lg (including Moho bounce), and the Lg spreading (surface wave spreading), respectively. Figures D.1–4 to D.1–6 summarize these decay attributes, in log10 units of amplitude decay, across the 20 models. For each model, the amplitude decay is shown for each distance range; the plotted value is the difference in log units between the amplitude at the beginning and end of the distance range. For example, the red points give log(A at 50 km) – log(A at 10 km). A solid line shows the average taken across all models. The brown points and lines at the top of each figure show the sum of the amplitude decay (red+blue+green colors) from 10 to 500 km (dotted brown lines indicate +/- standard deviation of the average). The figures below show these model statistics for frequencies from 0.5 Hz to 20 Hz.

A few key features should be noted: (i) the high amplitude decay from 10 to 50 km is associated with models that feature $R^{-1.3}$ geometric spreading at < 50 km; (ii) a particular model may not be consistently high or low in its amplitude decay over all frequencies or all distances, making it tricky to pick representative models; (iii) a number of the models are quite similar as they were derived from the same information base; (iv) two models (19 and 20) give notably higher amplitude decay at higher frequencies beyond 150 km, and tend to skew the statistics; these two models are for the Gulf Coast and feature lower Q (steeper attenuation); (v) initially, we focus on Models 1–18, and leave aside the Gulf Coast models (19 and 20). We need to return to this point later. Arrows mark the recommended representative models for CENA, discussed below.

D.1.3 Selection of Representative Geometrical Spreading and Q Models

We aimed to select models that would: (i) include the range of model shapes in the literature, including linear, bilinear, and trilinear; (ii) include the range of geometric spreading slope, b_1, at <5 0 km ($b_1 = 1$, $b_1 = 1.3$); and (iii) sample points across the amplitude decay space indicated in the preceding figures (excluding the Gulf Coast models 19 and 20), covering points above and below the average decay in each distance range and at each frequency. For similar models, we preferred the more recent and frequently referenced variants, presuming they are based on more data in general.

Through inspection of the preceding figures and considering the points stated above, the objectives listed above could be met by using of the following six models: AB14 (bilinear, $b_1 = 1.3$); BCA10a (trilinear, $b_1 = 1.3$, features the A04 model and referred-to as such in the main report); BCA10d (linear, $b_1 = 1$); BS11 (bilinear, $b_1 = 1$); J97 (trilinear, $b_1 = 1$, features the AB95 attenuation form and is referred to as such in the main report); S02sc (bilinear, also referred to as SGD02 in main report). These are models 5, 8, 11, 14, 16, and 17 in the plots.

Figures D.1–7 to D–9 illustrate the recommended models in comparison to the 20-curve suite (as plotted in Figures D.1–1 to D–3). Note that the shape, not overall amplitude level, was the key factor in the selection. These models are all representative of the mid-continent CENA region (exclude the Gulf Coast and Mississippi Embayment region). The representative models are summarized in Figure D.1–2.

Table D.1–1 List of collected attenuation models relevant to CENA.

Full reference	Region studied	Model # and short name used in figures
Atkinson G.M. (2004). Empircal attenuation of ground motion spectral amplitudes in southeastern Canada and the northeastern United States, Bull. Seismol. Soc. Am., 94:3: 1079–1095	Southeastern Canada and northeastern U.S.	1. A04, BCA10a
Atkinson G.M. (1989). Attenuation of the Lg phase and site Response for the Eastern Canada telemetered network. Seismological Research Letters, 60:2, 59–69.	Southeastern Canada and northeastern U.S.	2. A89a 3. A89b
Atkinson G.M. (1993) Earthquake source spectra in eastern North America, Bull. Seismol. Soc. Am., 83(6): 1778–1798.	Eastern North America	4. A93
Atkinson G.M., Boore, D. M., (2014) The attenuation of fourier amplitudes for rock sites in eastern North America, Bull. Seismol. Soc. Am., 104(1): 513–528.	Northeast Area of ENA Lat 54 to 34 Lon -50 to -90	5. AB14
Atkinson G.M., Boore D.M. (1995) New ground motion relations for eastern North America. Bull. Seismol. Soc. Am., 85(1): 17–30.	Also referenced by Joyner (1997) and Atkinson and Boore (1998)	6. AB95, J97
Boatwright J., Choy G. (1992). Acceleration source spectra anticipated for larger earthquakes in northeastern North America. Bull. Seismol. Soc. Am., 82(2): 660–682.	-	7. BC92
Boore D.M., Campbell K.W., Atkinson G.M. (2010). Determination of stress parameters for eight well-recorded earthquake in eastern North America, Bull. Seismol. Soc. Am., 100(4): 1632–1645.	Northeastern U.S. and southeastern Canada	8. BCA10a 9. BCA10b 10. BCA10c 11. BCA10d
Campbell K.W. (2003). Prediction of strong ground motion using the hybrid empirical method and its use in the development of ground-motion (attenuation) relations in eastern North America, Bull. Seismol. Soc. Am., 93(3): 1012–1033.	Eastern North America	12. C03
Frankel A., Mueller C., Barnhard T., Perkins D., Leyendecker E.V., Dickman N., Hanson S., Hoppe, M. (1996). National Seismic-Hazard Maps: Documentation June 1996, U.S. Geological Survey Open-File Report 96–532.	-	13. Fea96
Boatwright J., Seekins L., (2011). Regional spectral analysis of three moderate earthquakes in northeastern North America, Bull. Seismol. Soc. Am., 101(4): 1769–1782.	Northeasters U.S./ southeastern Canada	14. BS11
Atkinson G.M., Boore D.M. (1998). Evaluation of models for earthquake source spectra in eastern North America, Bull. Seismol. Soc. Am., 88(4): 917–934. Refers to Haddon R. (1996). Earthquake source spectra in eastern North America, Bull. Seismol. Soc. Am., 86(5): 1778-1798; and Joyner W. (1997). reference from Senior Seismic Hazard Analysis Committee (SSHAC). (1997). "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," U.S. Nuclear Regulatory Commission Report, NUREG/CR-6372.		15. H96 for Haddon 16. J97 for Joyner

Full reference	Region studied	Model # and short name used in figures
Silva W.J., Gregor N., Darragh R.B. (2002). Development of regional hard rock attenuation relations for Central and Eastern North America, Pacific Engineering and Analysis, El Cerrito, Calif., 6/25/2014; available at www.pacificengineering.org/CEUS/Development%20of%20Regional%20Hard_ABC.pdf	Mid-continent and Gulf Coast	17. S02sc, SGC02: single corner, mid-continent 18. S02sc_mds: single corner, M-dependent stress parameter, mid-continent 19. S02scGC: single corner, Gulf Coast 20. S02scGC_mds: single corner, M-dependent stress parameter, Gulf Coast
Abrahamson N.A., Silva W.J. (2002). Hybrid model – Empirical attenuation relations for central and eastern U.S. hard and soft rock and deep soil site conditions: Presentation Slides, CEUS Ground Motion Project Workshop, September 24-25, 2002, Las Vegas, NV.	-	-
Al-Shukri H.J., Mitchell B.J. (1990). Three-dimensional attenuation structure in and around the New Madrid seismic zone, Bull. Seismol. Soc. Am., 80(3): 615–632.	-	-
Atkinson G.M. (2012). Evaluation of attenuation Models for the northeastern United States/southeastern Canada, Seismol. Res. Lett., 83(1): 166–178.	Ran simulations for the mid-continent, Appalachian Region, Atlantic Coastal Plain, and Mississippi Embayment	-
Atkinson G.M., Assatourians K., Lamontagne M., (2014). Characteristics of the 17 May 2013 M 4.5 Ladysmith, Quebec, earthquake. Seismol. Res. Lett., 85(3): 755–762.	-	-
Atkinson G.M., Mereu R.F. (1992). The shape of ground motion attenuation curves in southeastern Canada, Bull. Seismol. Soc. Am., 82(5): 2014–2031.	Southeastern Canada and northeastern U.S.	-
Atkinson G.M. (2001). An alternative to stochastic ground-motion relations for use in seismic hazard analysis in Eastern North America Seismol. Res. Lett., 72(2): 299–306.	-	-

Full reference	Region studied	Model # and short name used in figures
Atkinson G.M. (2008) Ground motion prediction for eastern North America from a referenced empirical approach: Implications for epistemic uncertainty, Bull. Seismol. Soc. Am., 98(3): 1304–1318.	-	-
Atkinson G.M., Boore D.M. (2006). Earthquake ground-motion prediction equations for eastern North America, Bull. Seismol. Soc. Am., 96:6, 2181–2205.	-	-
Baqer S. Mitchell B.J. (1998). Regional variation of Lg Coda Q in the continental United States and its relation to crustal structure and evolution. Pure Appl. Geophys., 153: 613–638.	Continental U.S.	-
Benz H.M., Frankel A., Boore D.M (1997). Regional Lg attenuation for the continental United States. Bull. Seismol. Soc. Am., 87(3): 606–619.	California (southern California and central coast ranges), Basin and Range (Mostly the state of Nevada), central U.S. (New Madrid Seismic Zone), northeastern U.S.southeastern Canada (New England, New York, and southern Quebec)	-
Boatwright J. (1994). Regional propagation characteristics and source parameters of earthquakes in northeastern North America, Bull. Seismol. Soc. Am., 84(1): 1–15.	-*	-
Boore D.M., Atkinson G.M. (1987). Stochastic prediction of ground motion and spectral response parameters at hard-rock sites in eastern North America, Bull. Seismol. Soc. Am., 77(2): 440–467.	-	-
Boore D.M., Atkinson G.M. (1992). Source spectra for the 1988 Saguenay Quebec, earthquakes, Bull. Seismol. Soc. Am., 82(2): 683–719.	-	-
Burger R.W., Somerville P.G., Barker J.S., Herrmann R.B., Helmberger D. V. (1987). The effect of crustal structure on strong ground motion attenuation relations in eastern North America, Bull. Seismol. Soc. Am., 77(2): 420–439.	Eastern Canada	-
Chapman M.C., Beale J.N., Catchings R.D. (2008). Q for P- waves in the sediments of the Virginia Coastal Plain, Bull. Seismol. Soc. Am., 98(4): 2022–2032.	Atlantic Coastal Plain (Virgina Coast)	-
Chapman M.C., Godbee R.W. (2012). Modeling geometrical spreading and the relative amplitudes of vertical and horizontal high-frequency ground motions in eastern North America, Bull. Seismol. Soc. Am., 102(5): 1957–1975.	Northeastern U.S./ southeastern Canada	-
Chun K., West G.F., Kokoski R.J., Samson C. (1987). A novel technique for measuring Lg attenuation results from eastern Canada between 1 to 10 Hz, Bull. Seismol. Soc. Am., 77(2): 398–419.	Southeastern Canada	-

Full reference	Region studied	Model # and short name used in figures
Dwyer J.J., Herrmann, R.B., Nuttli O.W. (1983). Spatial attenuation of the Lg Wave in the central United States, Bull. Seismol. Soc. Am.,. 73(3): 781–796.	New Madrid seismic zone	-
Erickson D., McNamara D.E., Benz H.M. (2004). Frequency-dependent I Q within the continental United States, Bull. Seismol. Soc. Am., 94(5): 1630–1643.	Continental U.S.	-
Frankel A. (1991). Mechanisms of seismic attenuation in the crust: Scattering and anelasticity in New York State, South Africa and Southern California. J. Geophys. Res., 96(B4): 6269–6289.	-	-
Frankel A., McGarr A., Bicknell J., Mori J., Seeber L., Cranswick E., (1990). Attenuation of high frequency shear waves in the crust: measurements from New York State, South Africa, and Southern California. J. Geophys. Res., 95(B11): 17441–17457.	-	-
Ge J., Pujol J., Pezeshk S., Stovall S. (2009). Determination of shallow shear-wave attenuation in the Mississippi Embayment using vertical seismic profiling data, Bull. Seismol. Soc. Am., 99(3): 1636–1649.	Mississippi Embayment and southwestern Tennessee	-
Gupta I.N., McLaughlin K.L. (1987). Attenuation of bround motion in the eastern United States, Bull. Seismol. Soc. Am.,:2, 366–383	Eastern U.S.	-
Hanks T.C., Johnston A.C. (1992). Common features of the excitation and propagation of strong ground motion for North American earthquakes, Bull. Seismol. Soc. Am., 82:1, 1–23	Continental U.S.	-
Hasegawa H.S. (1985). Attenuation of Lg waves in the Canadian Shield, Bull. Seismol. Soc. Am., 75(6): 1569–1582.	Canadian Shield (eastern Canada)	-
Hwang H., Huo J.R. (1997). Attenuation relations of ground motion for rock and soil sites in eastern United States, Soil Dyn. Earthq. Eng., 16, 363–372.	-	-
Langston C.A., Bodin P., Powell C., Withers S., Horton S., Mooney M. (2005). Bulk sediment Q_p and Q_s in the Mississippi Embayment, central United States, Bull. Seismol. Soc. Am., 95(6): 2162–2179	Mississippi Embayment	-
Liu Z., Wuenscher M.E., Herrmann R. B. (1994). attenuation of body waves in the central New Madrid seismic zone, Bull. Seismol. Soc. Am., 84(4): 1112–1122.	New Madrid Seismic Zone (lat 36.85 to 35.75 lon -89.2 to -90.2 Mississippi Embayment)	-
Mereu R.F., Dineva S., Atkinson G.M. (2013). The application of velocity spectral stacking to extract information on source and path effects for small-to-moderate earthquakes in southern Ontario with evidence for constant-width faulting, Seismol. Res. Lett., 84(50): 899–916	Southeastern Canada and northeastern U.S.	
Ou G-B., Herrmann R.B. (1990). A statistical model for ground motion produced by earthquakes at local and regional	Canada	-

Full reference	Region studied	Model # and short name used in figures
distances, Bull. Seismol. Soc. Am., 80(6): 1397–1417.		
Ou G-B., Herrmann, R.B. (1990). Estimation theory for peak ground motion, Seismol. Res. Lett., 61:2, 99–107	-	-
Pezeshk S., Zandieh A., Tavakoli B. (2011). Hybrid empirical ground-motion prediction equations for Eastern North America using NGA models and updated seismological parameters, Bull. Seismol. Soc. Am., 101(4): 1859–1870.	-	-
Phillips W.S., Stead R.J. (2008). Attenuation of Lg in the western US using the USArray, J. Geophys. Res., 35(L07307): 1–5.	Western U.S.	-
Pulli J.J., (1984). Attenuation of Coda waves in New England, Bull. Seismol. Soc. Am., 74(4): 1149–1166.	New England	-
Saiki C K. (1990). Shear velocity and intrinsic Q structure of the shallow crust in Southeastern New England and from Rg wave dispersion, J. Geophys. Res., 95(B6): 8257–8541.	New England	-
Shi J., Kim W., Richards P.G. (1996). Variability of crustal attenuation in the Northeastern United States from Lg waves, J. Geophys. Res., 101:B11 25231–25242.	Northeastern U.S. Regionalization into 5 sub regions: Adirondack Mt., Erie-Ontario Lowlands, Appalachian Plateau, Coastal Zone, Northern New England.	-
Shin T.-C., Herrmann R. B. (1987). Lg attenuation and source studies using 1982 Miramichi data, Bull. Seismol. Soc. Am., 77(2): 384–397.	Southeastern Canada	
Silva W.J., Gregor N., Darragh R.B. (2003). Development of regional hard rock attenuation relations for central and eastern North America, mid-continent and Gulf Coast Areas. Pacific Engineering and Analysis, El Cerrito, CA, 6/25/2014; available at http://www.pacificengineering.org/gulf/Development%20ENA%20Midcontinent%20Gulf.pdf.	Mid-continent and Gulf Coast	-
Singh,S., Herrmann R.B. (1983). Regionalization of crustal Coda Q in the continental United States, J. Geophys. Res., 88:B1: 527–538.	-	-
Somerville P., Collins N., Abrahamson N.A., Graves R.W., Saikia C. (2001). Ground motion attenuation relations for the Central and Eastern United States, Final report to U.S. Geological Survey, prepared by URS Group, Inc., Pasadena, CA, 36 pgs.	-	-
Toro G.R. (2002). Modification of the Toro et al. 1997 attenuation equations for large magnitudes and short distances; unpublished manuscript available at http://www.riskeng.com/ downloads/attenuation_equations.	-	-
Toro G.R., Abrahamson N.A., Schneider J.F. (1997). Model of strong ground motions from earthquakes in Central and Eastern North America: Best estimates and uncertainties, Seismol. Res. Lett., 68: 41–57.	-	-

Full reference	Region studied	Model # and short name used in figures
Woodgold C.R.D. (1990) Estimation of Q in Eastern Canada using Coda waves, Bull. Seismol. Soc. Am., 80:2: 411–429	Southeastern Canada and northeastern U.S.	-
Zandieh A., Pezesh S. (2010) investigation of geometrical spreading and quality factor functions in the New Madrid Seismic Zone, Bull. Seismol. Soc. Am., 100:5A: 2185–2195.	New Madrid Seismic Zone (Mississippi Embayment)	-

Figure D.1–2 Representative geometric spreading and Q models selected for the Boore GMMs development.

Model and Reference	Geometric Spreading G(R)	What is "R"?[1]	Attenuation $\exp(-\pi fR/Q\beta)$	Applicable Range[2]
B_ab95 Atkinson and Boore (1995)	$G(R) = \begin{cases} R^{-1}, & R \le 70 \text{ km} \\ C_0 R^{0}, & 70 \text{ km} < R \le 130 \text{ km} \\ C_1 R^{-0.5}, & R > 130 \text{ km} \end{cases}$ $C_0 = (1/70)$, $C_1 = (130^{0.5}/70)$	$R = R_{hyp}$	$Q(f) = 680f^{0.36}$ β = 3.8 km/sec	$4.0 \le \mathbf{M} \le 7.25$ $10 \le R \le 500$ km $0.5 \le f \le 20$ Hz
B_sgd02 Silva et al. (2002)	$G(R) = \begin{cases} R^{-(a+b(\mathbf{M}-6.5))}, & R \le 80 \text{ km} \\ C_0 R^{-0.5(a+b(\mathbf{M}-6.5))}, & R > 80 \text{ km} \end{cases}$ $a = 1.0296$, $b = -0.0422$, $C_0 = 80^{-0.5(a+b(\mathbf{M}-6.5))}$	$R = R_{hyp}$	$Q(f) = 351f^{0.84}$ β = 3.52 km/sec	$4.5 \le \mathbf{M} \le 8.5$ $1 \le R \le 400$ km $0.1 \le f \le 100$ Hz
B_a04 Atkinson (2004)	$G(R) = \begin{cases} R^{-1.3}, & R \le 70 \text{ km} \\ C_0 R^{0.2}, & 70 \text{ km} < R \le 140 \text{ km} \\ C_1 R^{-0.5}, & R > 140 \text{ km} \end{cases}$ $C_0 = (70^{-0.2}/70^{1.3})$, $C_1 = C_0(140^{0.5}/140^{-0.2})$	$R = R_{hyp}$	$Q(f) = \max(1000, 893f^{0.32})$ β= 3.7 km/sec	$4.4 \le \mathbf{M} \le 6.8$ $10 \le R \le 800$ km $0.05 \le f \le 20$ Hz
B_bca10d Boore et al. (2010)	$G(R) = R^{-1}$ all R	$R = R_{PS}$	$Q(f) = 2850$ β= 3.7 km/sec	$4.4 \le \mathbf{M} \le 6.8$ $10 \le R \le 800$ km $0.05 \le f \le 20$ Hz
B_bs11 Boatwright and Seekins (2011)	$G(R) = \begin{cases} R^{-1}, & R \le 50 \text{ km} \\ C_0 R^{-0.5}, & R > 50 \text{ km} \end{cases}$ $C_0 = (50^{0.5}/50)$	$R = R_{hyp}$	$Q(f) = 410f^{0.5}$ β= 3.5 km/sec	$4.4 \le \mathbf{M} \le 5.0$ $23 \le R \le 602$ km $0.2 \le f \le 20$ Hz
B_ab14 Atkinson and Boore (2014)	$G(R) = \begin{cases} 10^{T_c C_{LF}} R^{-1.3}, & R \le 50 \text{ km} \\ C_0 R^{-0.5}, & R > 50 \text{ km} \end{cases}$ $T_c = \begin{cases} 1, & f \le 1 \text{ Hz} \\ 1 - 1.429 \log_{10}(f), & 1 \text{ Hz} < f < 5 \text{ Hz} \\ 0, & f \ge 5 \text{ Hz} \end{cases}$ $C_{LF} = \begin{cases} 0.2 \cos\left[\frac{\pi}{2}\left(\frac{R-h}{1-h}\right)\right], & R \le h \\ 0.2 \cos\left[\frac{\pi}{2}\left(\frac{R-h}{50-h}\right)\right], & h < R < 50 \text{ km} \end{cases}$ h = focal depth (km), $C_0 = (50^{0.5}/50^{1.3})$	$R = R_{PS}$	$Q(f) = 525f^{0.45}$ β= 3.7 km/sec	$3.5 \le \mathbf{M} \le 6$ $10 \le R \le 500$ km $0.2 \le f \le 20$ Hz

[1]R_{hyp} = hypocentral distance; R_{PS} = effective point source distance; $R_{PS} = (R_{hyp}^2 + h_{FF}^2)^{1/2}$, $\log_{10}(h_{FF}) = -0.405 + 0.235\mathbf{M}$ (Yenier and Atkinson 2015)
[2]When applicable range not explicitly stated in paper it was inferred from data comparisons.

Figure D.1–1 Attenuation of 1 Hz FAS amplitudes with distance, as computed using 22 complete models.

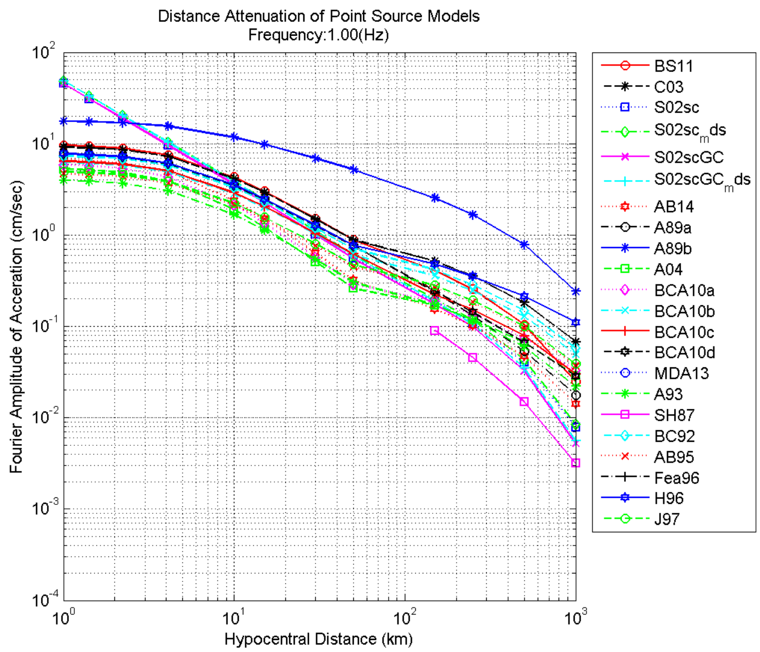


Figure D.1–2 Attenuation of 5 Hz FAS amplitudes with distance, as computed using 22 complete models.

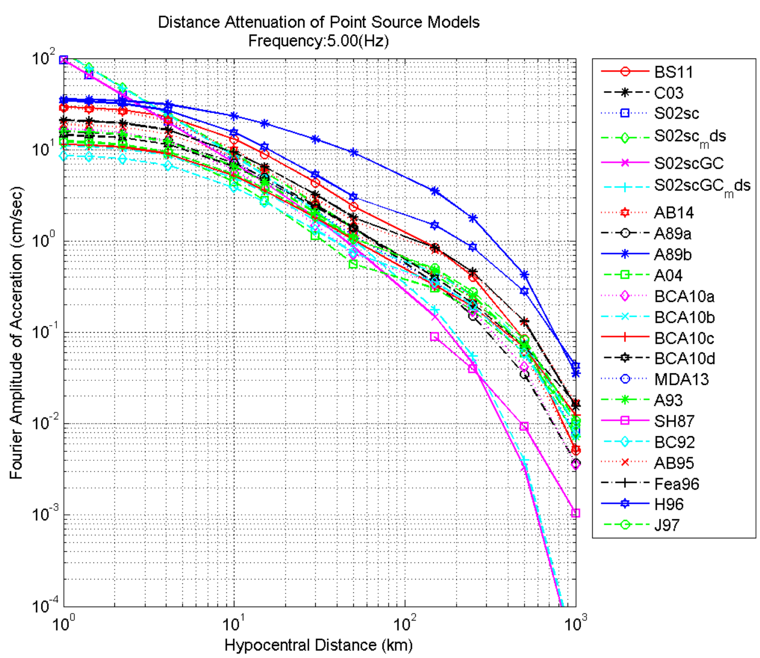


Figure D.1–3 Attenuation of 10 Hz FAS amplitudes with distance, as computed using 22 complete models.

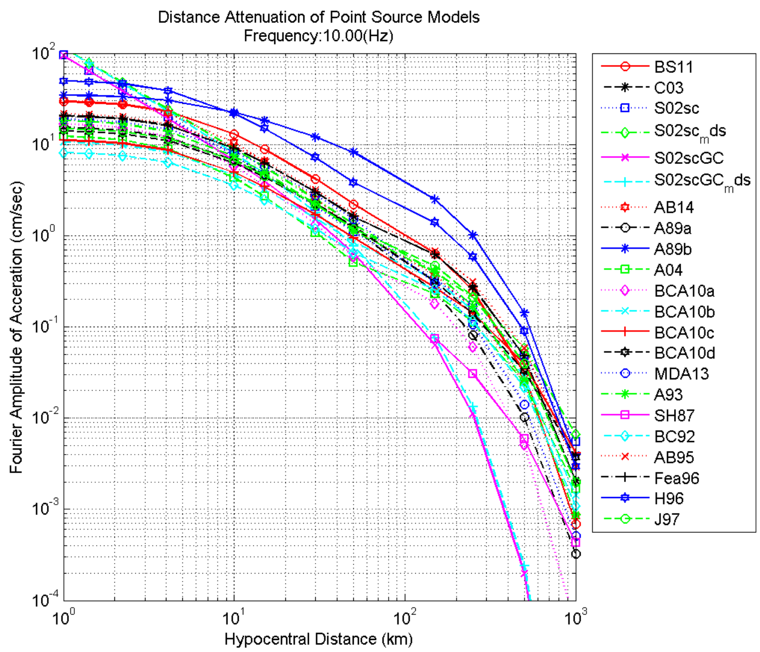
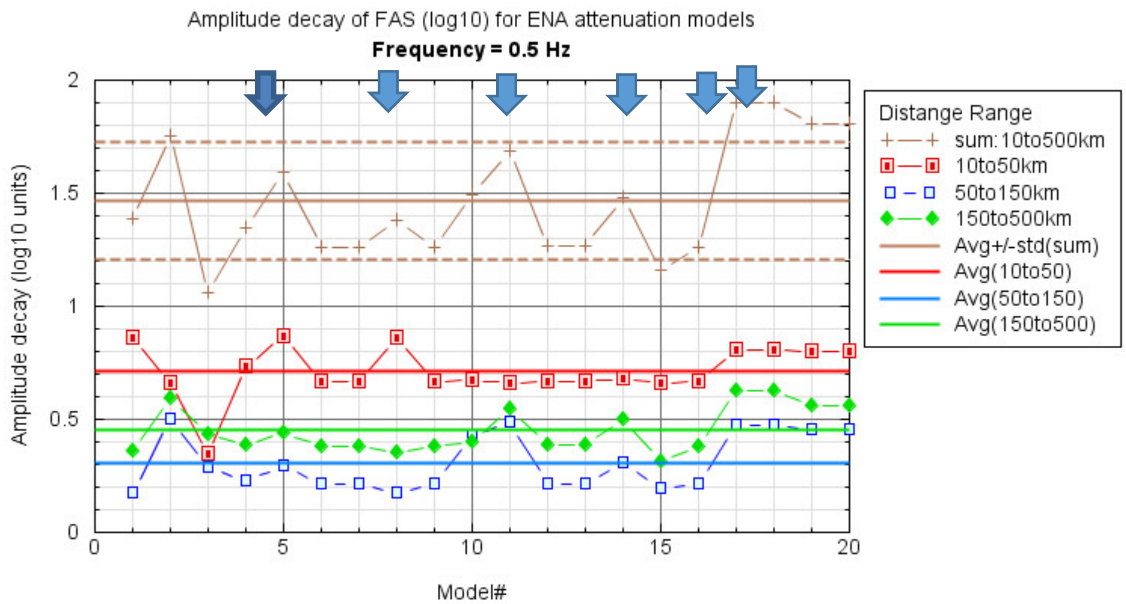
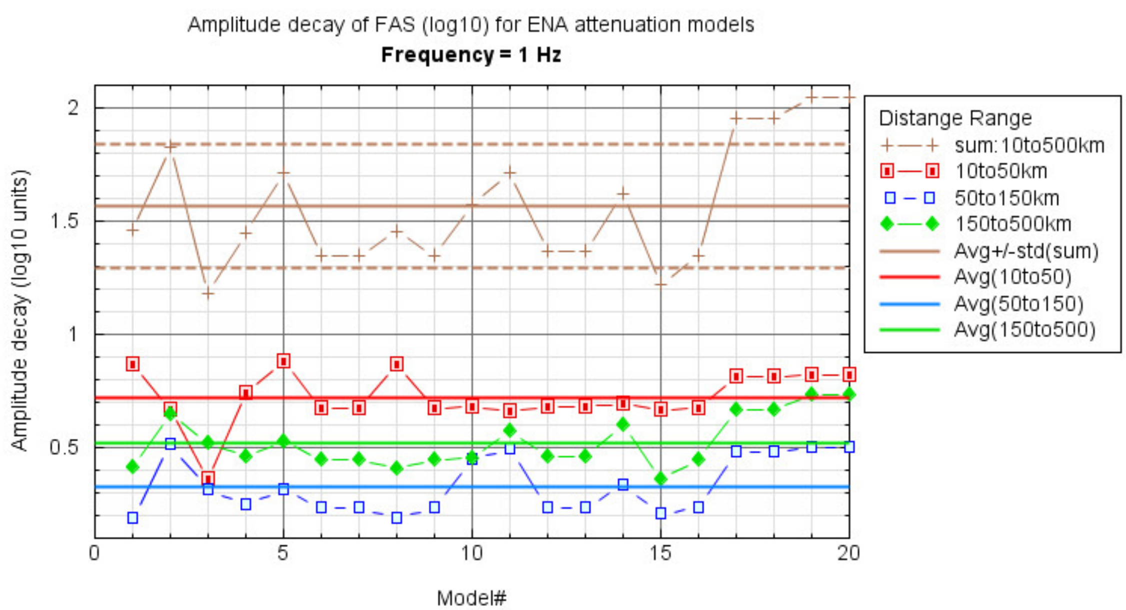


Figure D.1–4 Summary of FAS amplitude attenuation characteristics per distance bin, for 0.5 Hz (top frame) and 1 Hz (bottom frame). See text in Section A.2 for explanation.

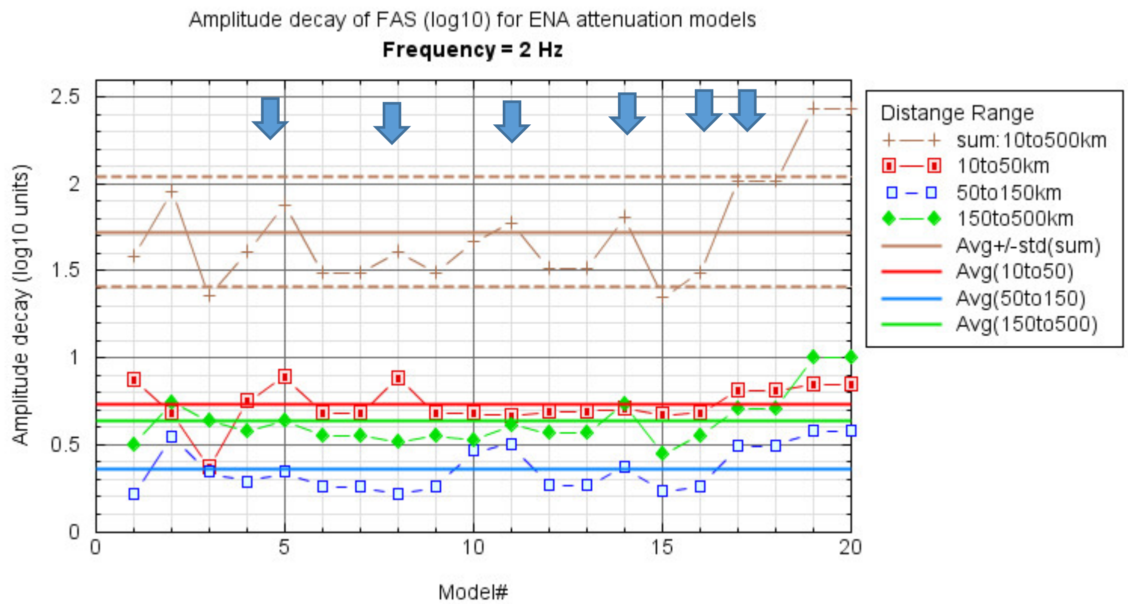


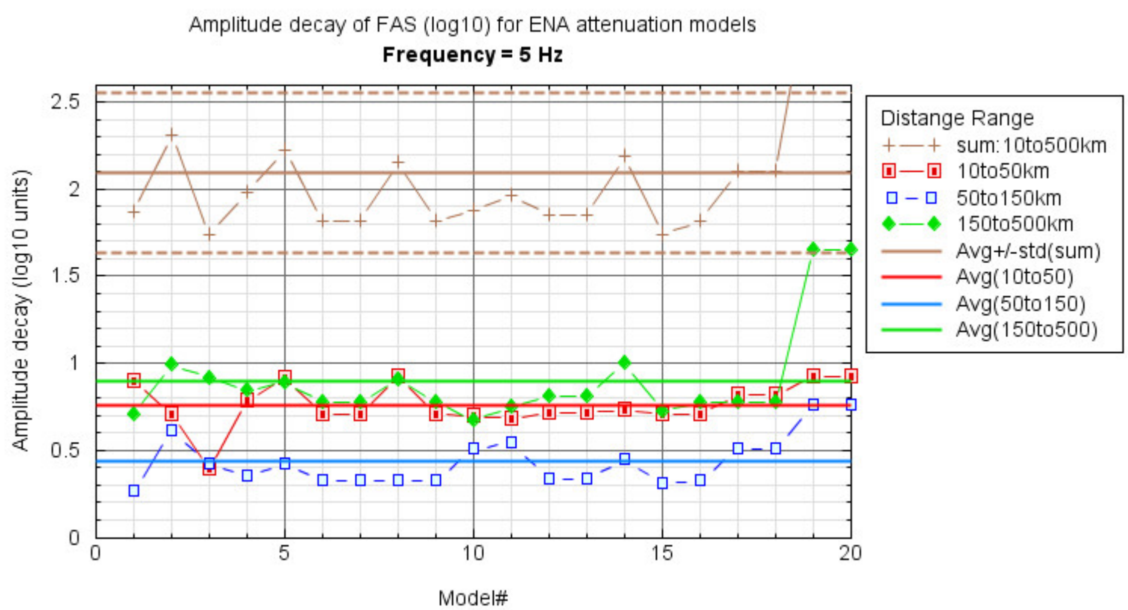


1-11: A04 A89a A89b A93 AB14 AB95 BC92 BCA10a BCA10b BCA10c BCA10d

12-20: C03 Fea96 BS11 H96 J97 S02sc S02sc_mds S02scGC S02scGC_mds

Figure D.1–5 Summary of FAS amplitude attenuation characteristics per distance bin, for 2 Hz (top frame) and 5 Hz (bottom frame). See text in Section A.2 for explanation.

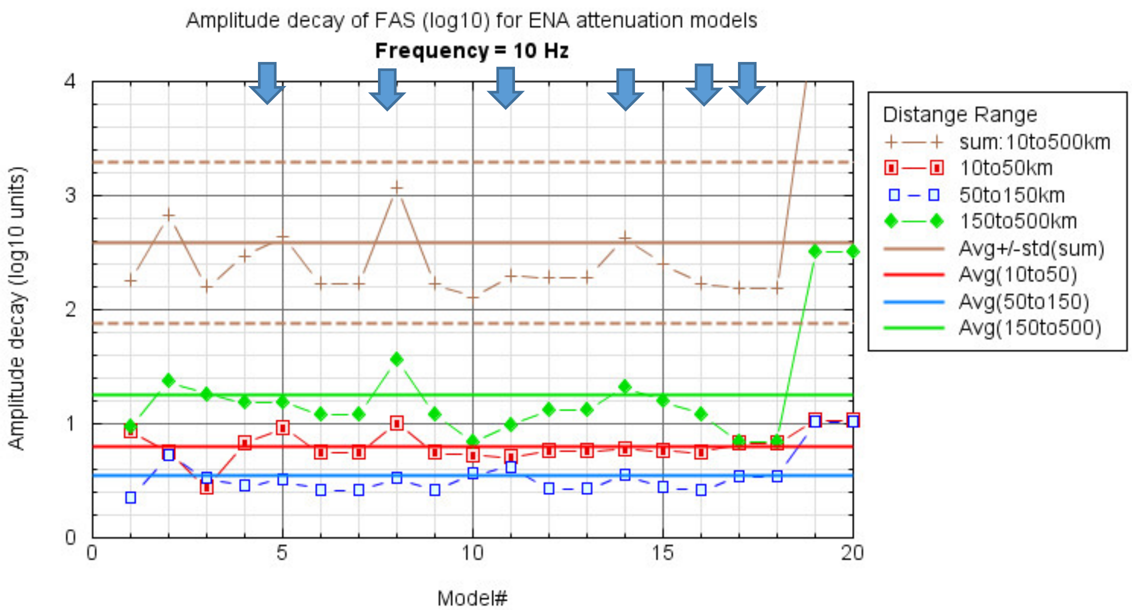


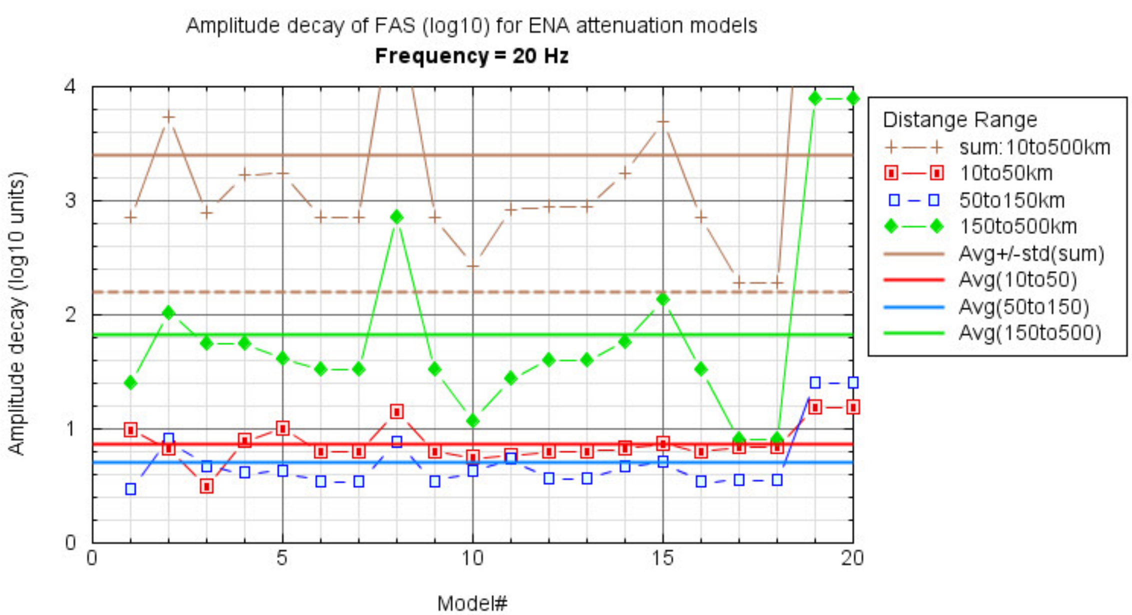


1-11: A04 A89a A89b A93 AB14 AB95 BC92 BCA10a BCA10b BCA10c BCA10d

12-20: C03 Fea96 BS11 H96 J97 S02sc S02sc_mds S02scGC S02scGC_mds

Figure D.1–6 Summary of FAS amplitude attenuation characteristics per distance bin, for 10 Hz (top frame) and 20 Hz (bottom frame). See text in Section A.2 for explanation.





1-11: A04 A89a A89b A93 AB14 AB95 BC92 BCA10a BCA10b BCA10c BCA10d

12-20: C03 Fea96 BS11 H96 J97 S02sc S02sc_mds S02scGC S02scGC_mds

Figure D.1–7 Attenuation of 1 Hz FAS amplitudes with distance, as computed using 20 complete models. Selected models are highlighted.

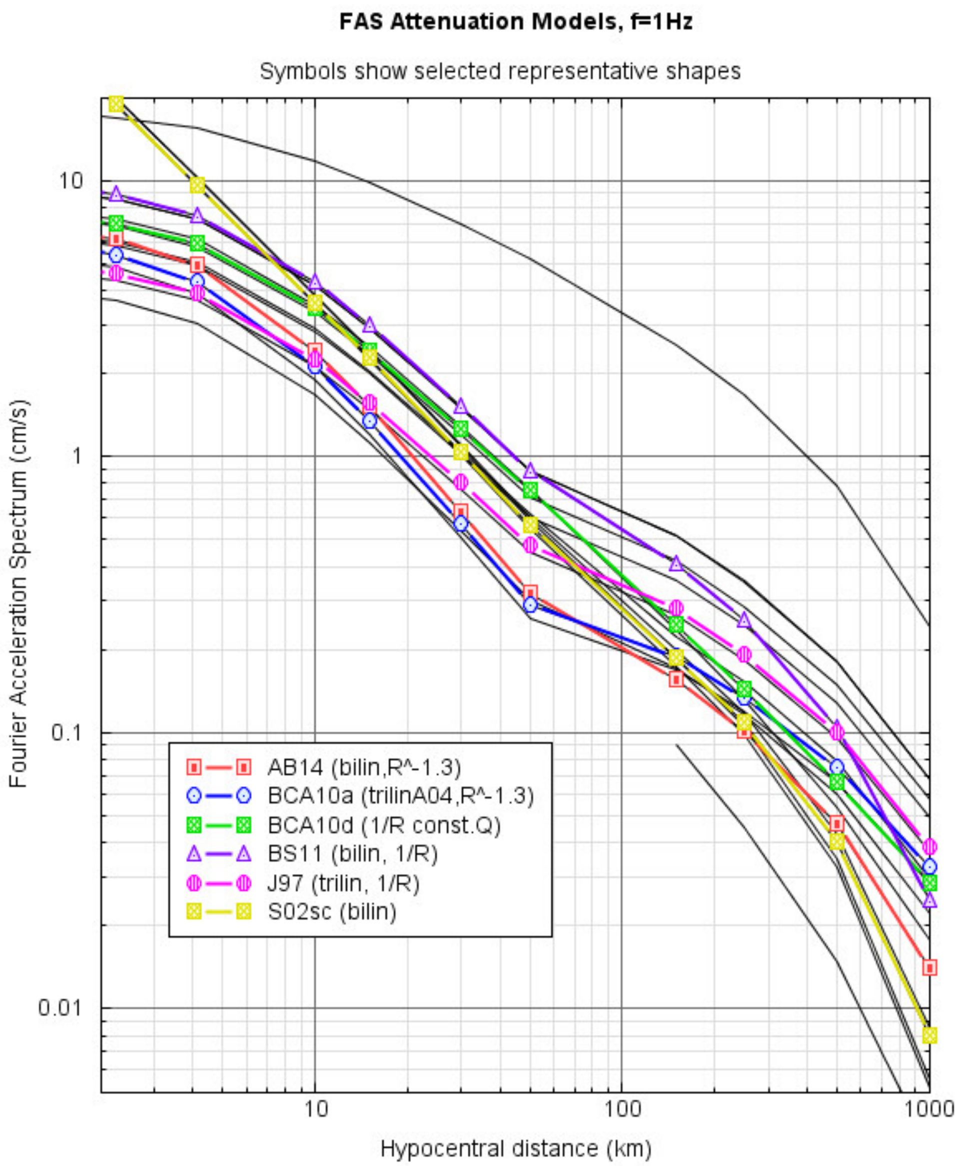


Figure D.1–8 Attenuation of 5 Hz FAS amplitudes with distance, as computed using 20 complete models. Selected models are highlighted.

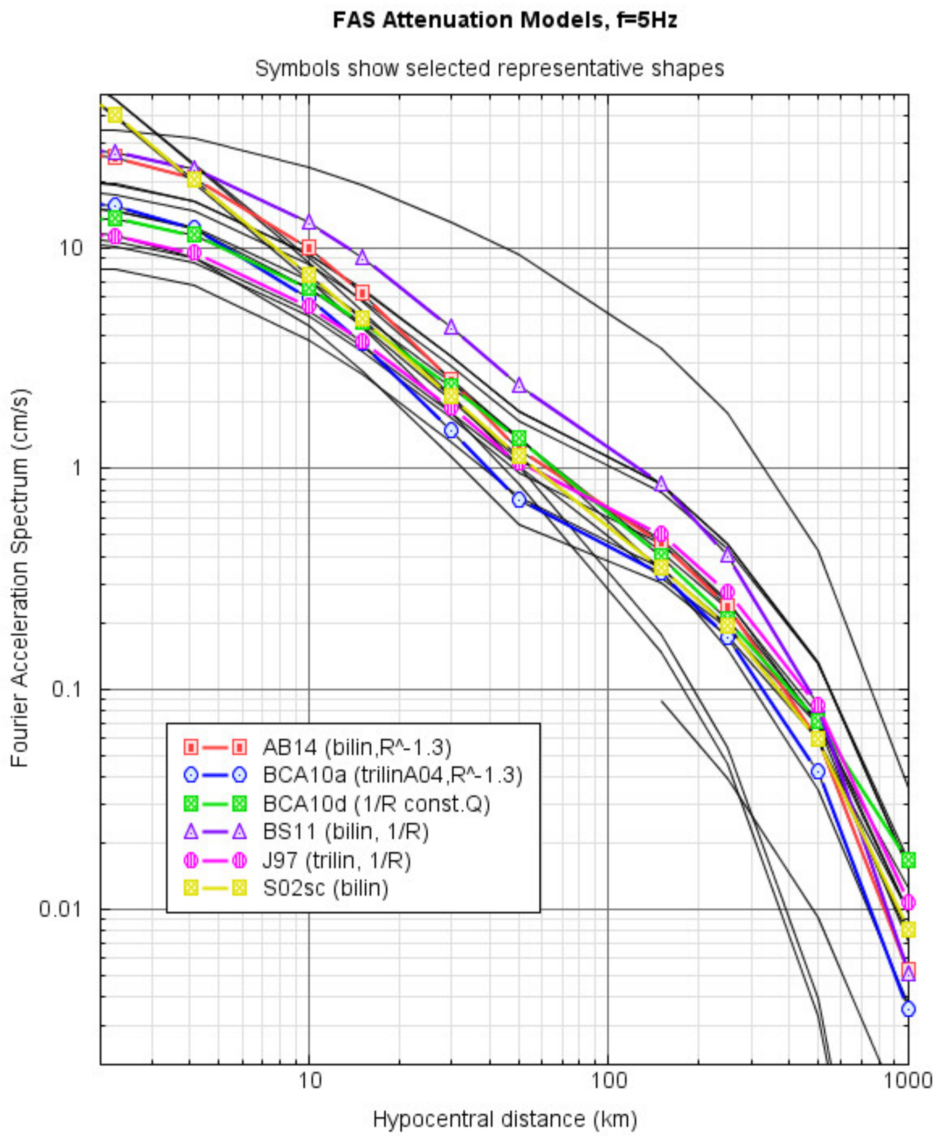
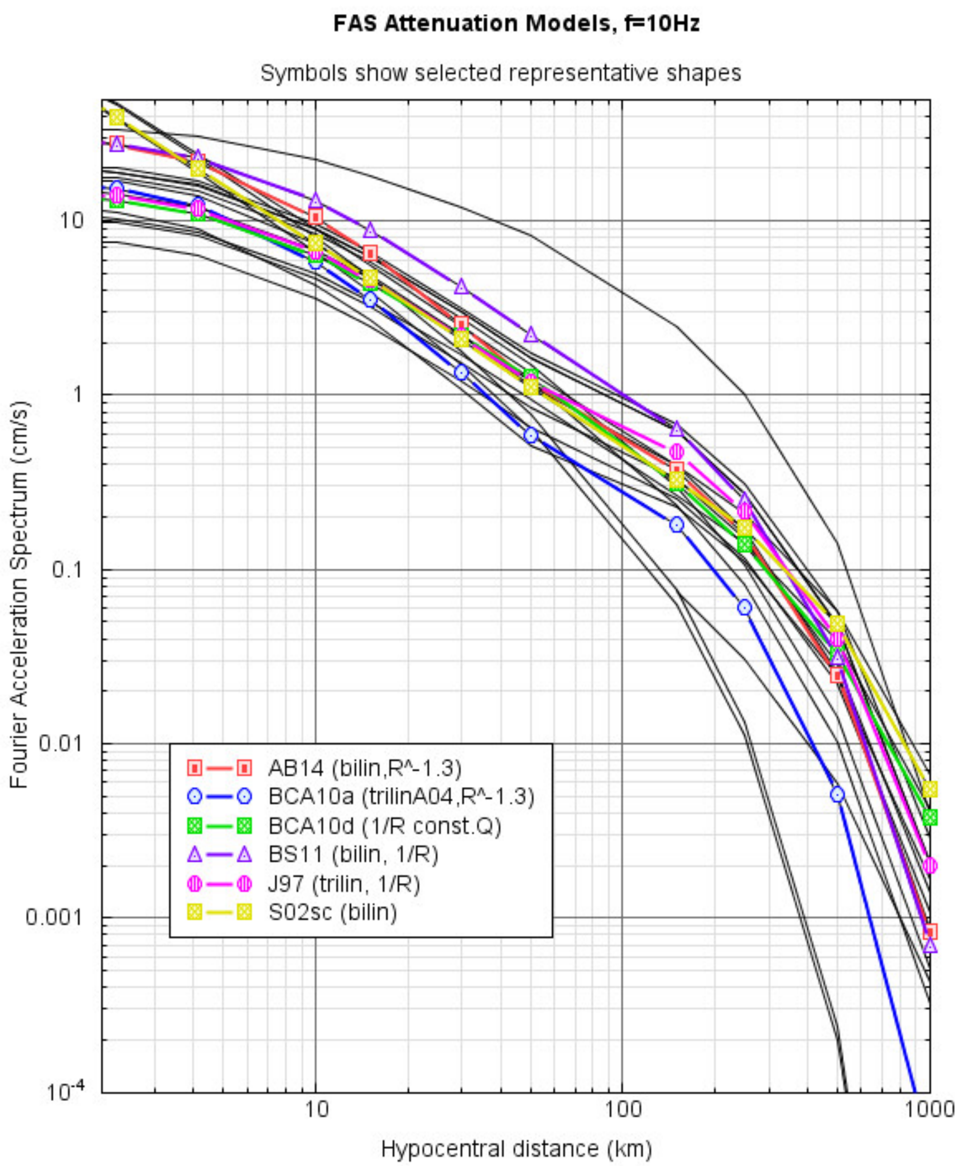


Figure D.1–9 Attenuation of 10 Hz FAS amplitudes with distance, as computed using 20 complete models. Selected models are highlighted.



D.2 Median Seed GMM Plots and Plotting Tools (Electronic Appendices)

Plots and plotting tools are provided as an electronic appendix.

D.2.1 Plots of Seed Median GMMs

The D.2.1_Plots_Seed_GMMs.pdf file contains plots organized in the following sections:

1 Magnitude Scaling of Final GMMs

2 Distance Scaling of Final GMMs

Three plotting tools are provided as electronic appendices. They all require a free Wolfram app which is available online at: https://www.wolfram.com/cdf-player/.

All frequencies are included, even though some seed GMMs are used for a subset of frequencies.

D.2.2 Plotting Tool for Median Seed GMMs, with M

File: D.2.2_PlottingTool_Seed_GMMs_M.cdf

D.2.3 Plotting Tool for Median Seed GMMs, with R_{Rup}

File: D.2.3_PlottingTool_Seed_GMMs_RRup.cdf

D.2.4 Plotting Tool for Median Seed GMMs, with F

File: D.2.4_PlottingTool_Seed_GMMs_F.cdf

D.3 References

Table D.1–1 provides all the references for this appendix.

Appendix E Sensitivity Analyses for Median Model Development

This appendix provides additional documentation on various sensitivity, demonstration, and analysis computations carried-out to support the NGA-East TI team on topics discussed in Chapters 8 and 9.

Hazard sensitivity analyses are presented for three of the EPRI/DOE/NRC (2012) demonstration sites, covering different types of sources and seismicity: Manchester, Central Illinois, and Savannah. Manchester is representative of a moderate-seismicity site with contributions from a distant (~500 km) repeated large-magnitude earthquake (RLME) source with a moderate rate of activity, Central Illinois is in an area of moderate-to-low seismicity with a very active RLME (New Madrid) at a distance of ~ 400 km), and Savannah is close to the Charleston RLME source. Demonstration calculations are presented for each site showing the hazard separately from the distributed seismicity and RLME sources as well as the combined total hazard. All calculations are performed considering only the epistemic uncertainty in ground-motion characterization using the mean predicted seismicity rates from the CEUS SSC model. Calculations showing sensitivity to alternative approaches to the median models were performed using the central estimate of the partially non-ergodic (single-station) aleatory variability model. Hazard sensitivities are performed for 1 and 10 Hz ground motions at the three sites listed above.

E.1 Sensitivity to Seeds with and without Al Atik and Youngs (2014) Epistemic Uncertainty Model

Sensitivity analyses are present in this and the following section as complements to Section 8.1.1, which described the selection of variance model by the TI team. That section also explains why TI team did not think that the Al Atik and Youngs (2014) uncertainty model was adequate to fully capture epistemic uncertainty in median ground motions in CENA. In the current section, we illustrate the differences in hazard from considering the seed GMMs as-is as well as the seed ground-motion models (GMMs) with the Al Atik and Youngs (2014) uncertainty model in contrast to the approach selected by the TI team, which involved sampling a larger distribution informed by the seed GMMs. Figure E.1–1 shows for two frequencies the variance obtained from the distributions of the seed GMMs for the suite of (**M**, R_{RUP}) covering the NGA-East scope (top), the variance achieved when the uncertainty model is applied to the seed GMMs (middle), and the variance achieved with the TI team approach (bottom). The variance values for the seed GMMS with and without the uncertainty model are only marginally different, as described in Section 8.1.1 in the context of the WNA GMMs and shown on Figure E1–1. The variance for larger magnitudes produced by the TI team approach is larger than that of the seed models because it has been constrained to be larger for **M**6.5 and above. As a result, the hazard computed using models developed using the seed variances with or without the Al Atik and Youngs (2014) uncertainty model is expected to lead to narrower hazard distributions than those based on the TI-team approach. This is presented in Figures E.1–2 to E.1–4 for the three demonstration sites and two frequencies, with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz and part (c) showing the hazard ratio for both frequencies. The largest differences are between the seed GMMs variances and the final model variances for larger magnitudes, which translates into a wider difference in the range of hazard for the RLME sources, as shown on Figures E.1–2 to E.1–4. For the distributed sources and for high annual frequency of exceedance (AFE), the hazard results are not significant between the three alternatives, an observation that mirrors the similarities in variances in smaller magnitudes and at shorter distances shown in Figure E.1–1.

Figure E.1–1 Original weighted seed GMMs variance (top), seed GMMs variance with the Al Atik and Youngs (2014) uncertainty model (middle), and achieved weighted variance of the NGA-East final GMMs (bottom) for 1 Hz (left) and 10 Hz (right).

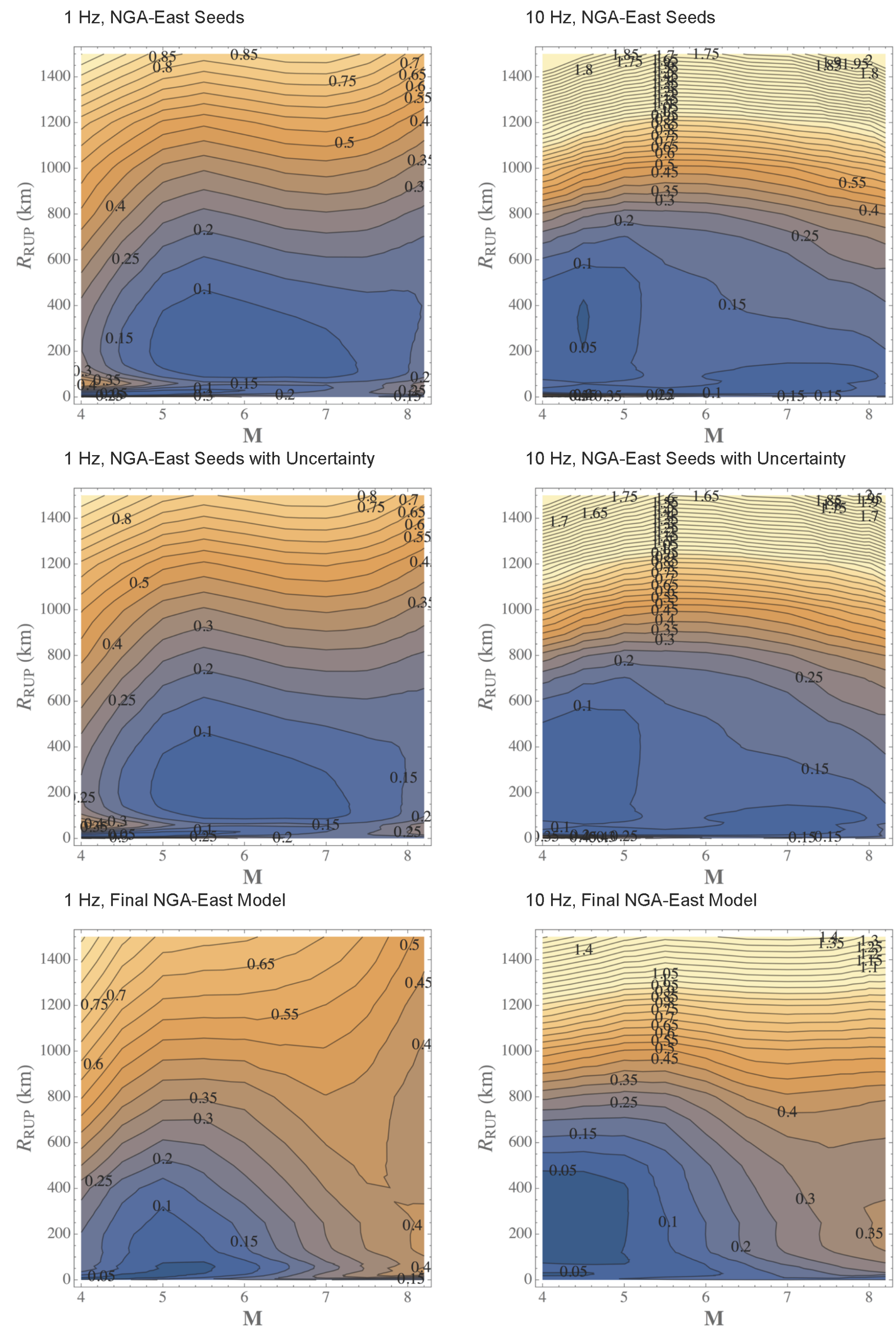


Figure E.1–2(a) Hazard results for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz at Manchester.

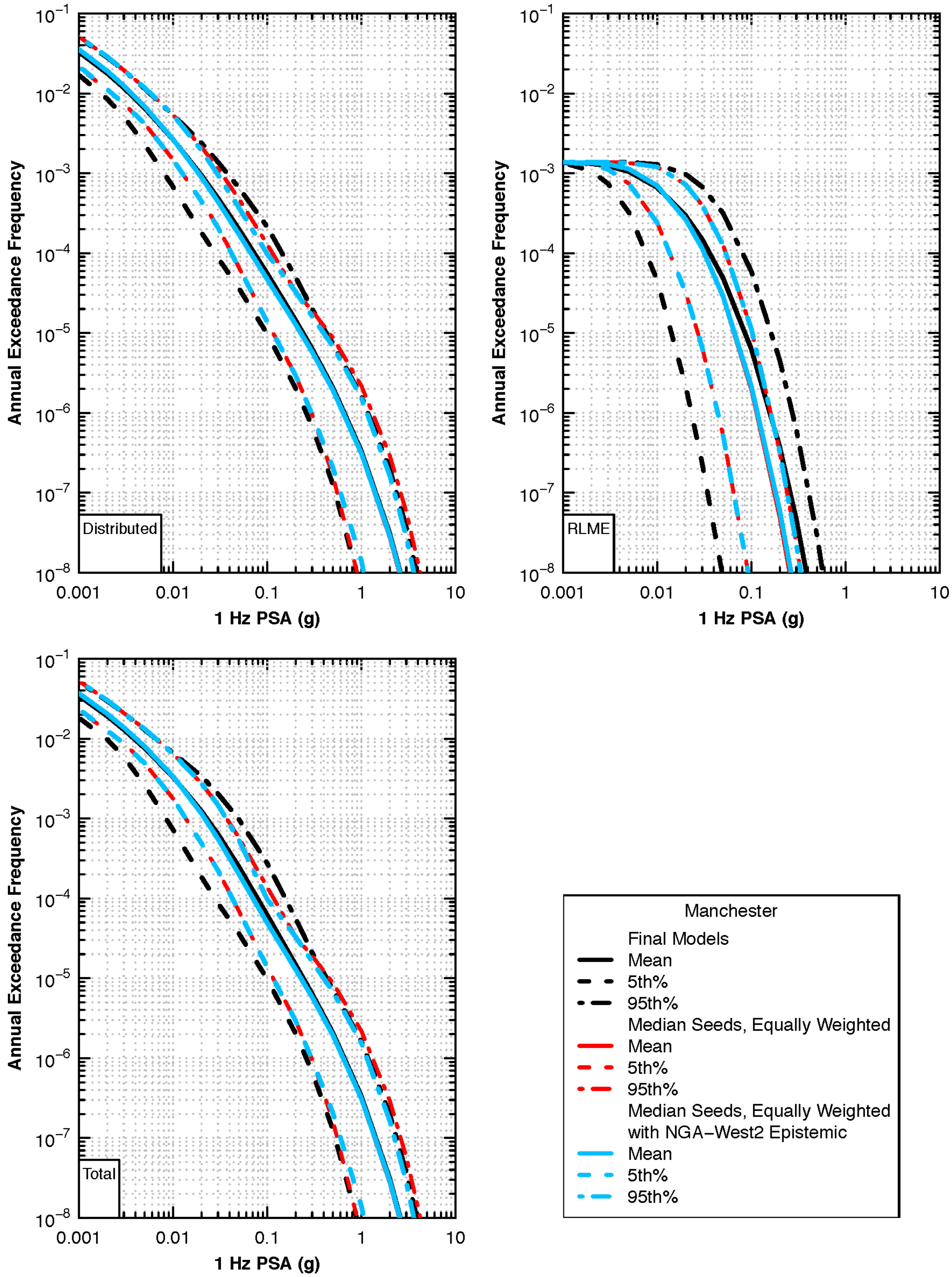


Figure E.1–2(b) Hazard results for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 10 Hz at Manchester.

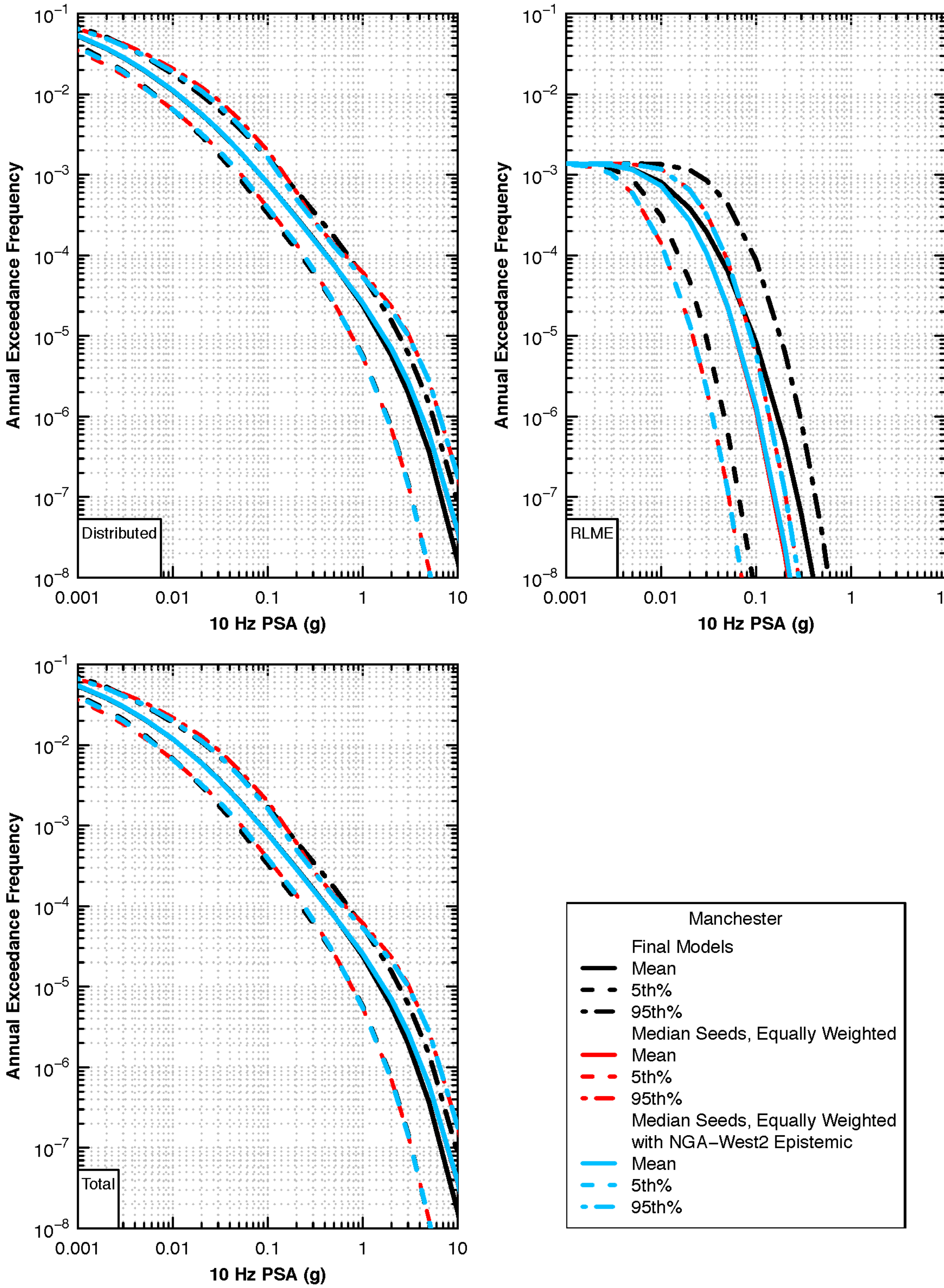
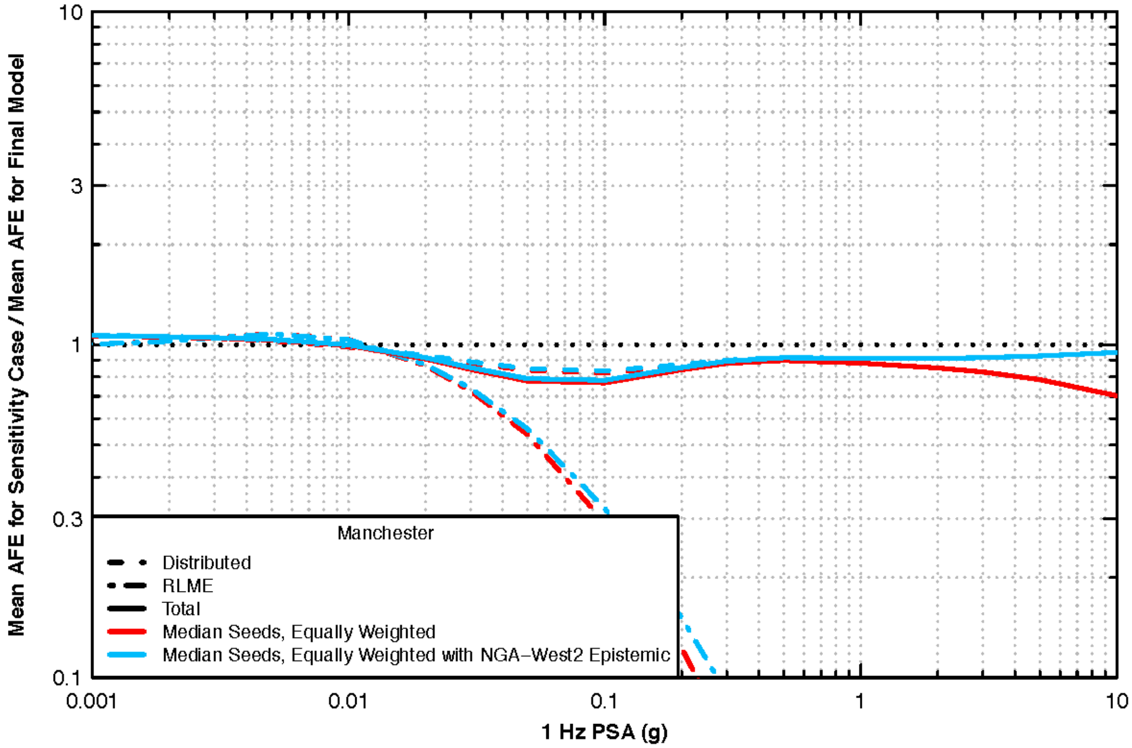


Figure E.1–2(c) Hazard ratio for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz and 10 Hz at Manchester.



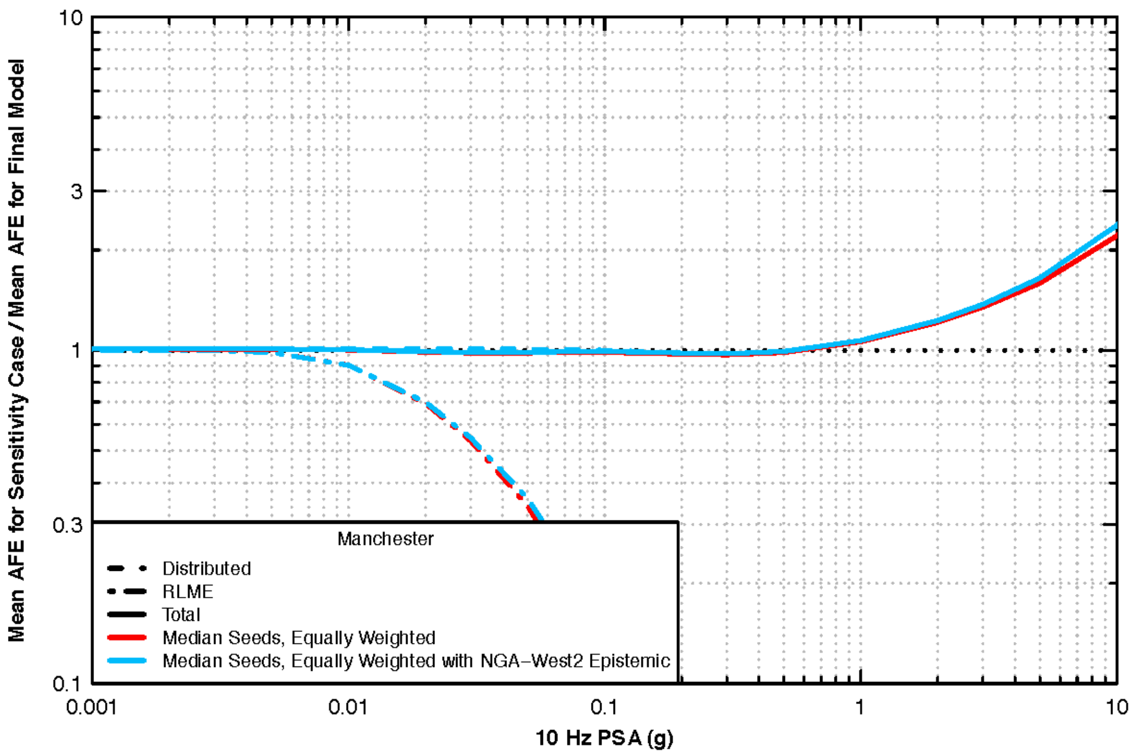


Figure E.1–3(a) Hazard results for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz at Central illinois.

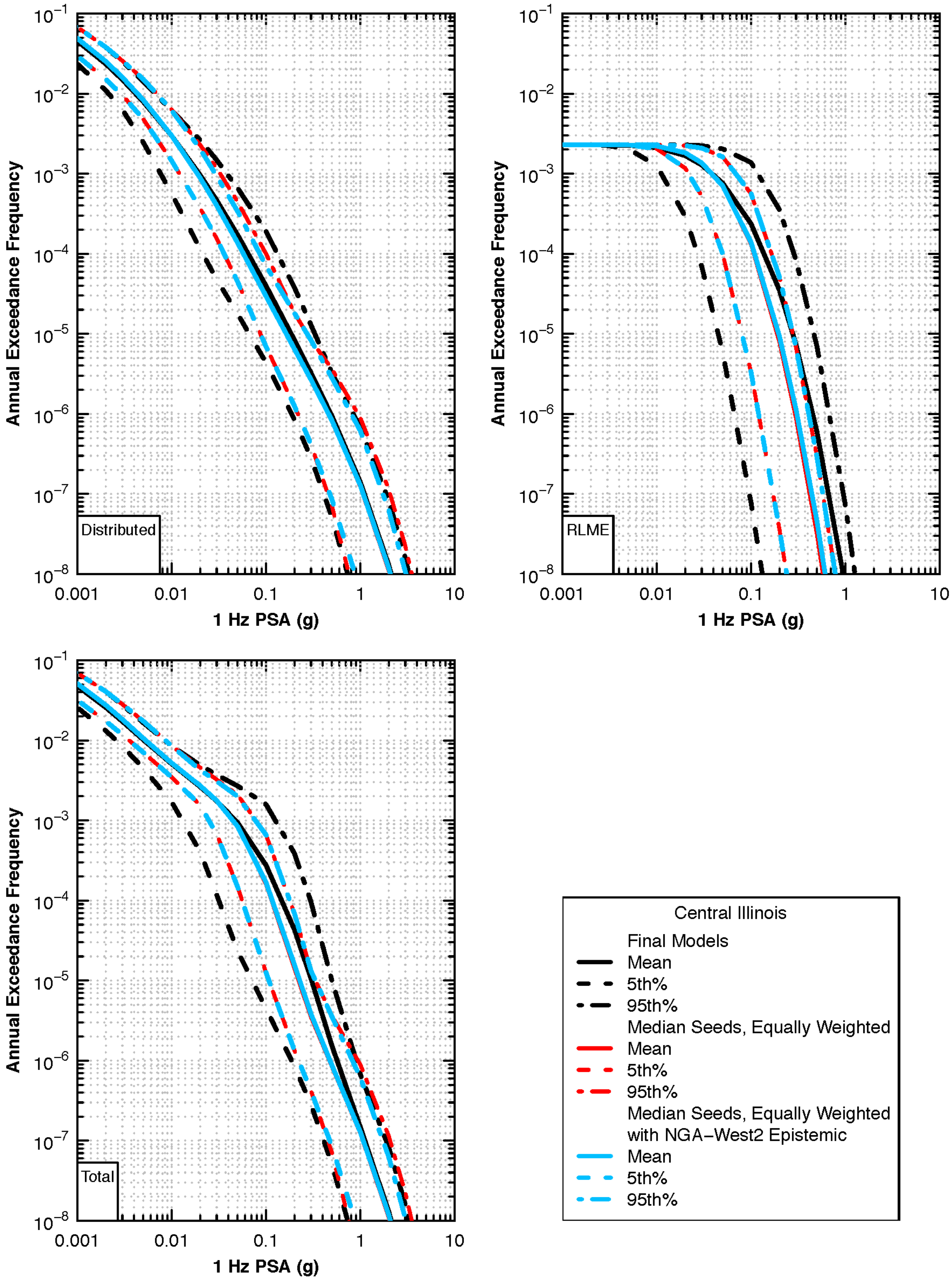


Figure E.1–3(b) Hazard results for seed GMMs , seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 10 Hz at Central illinois.

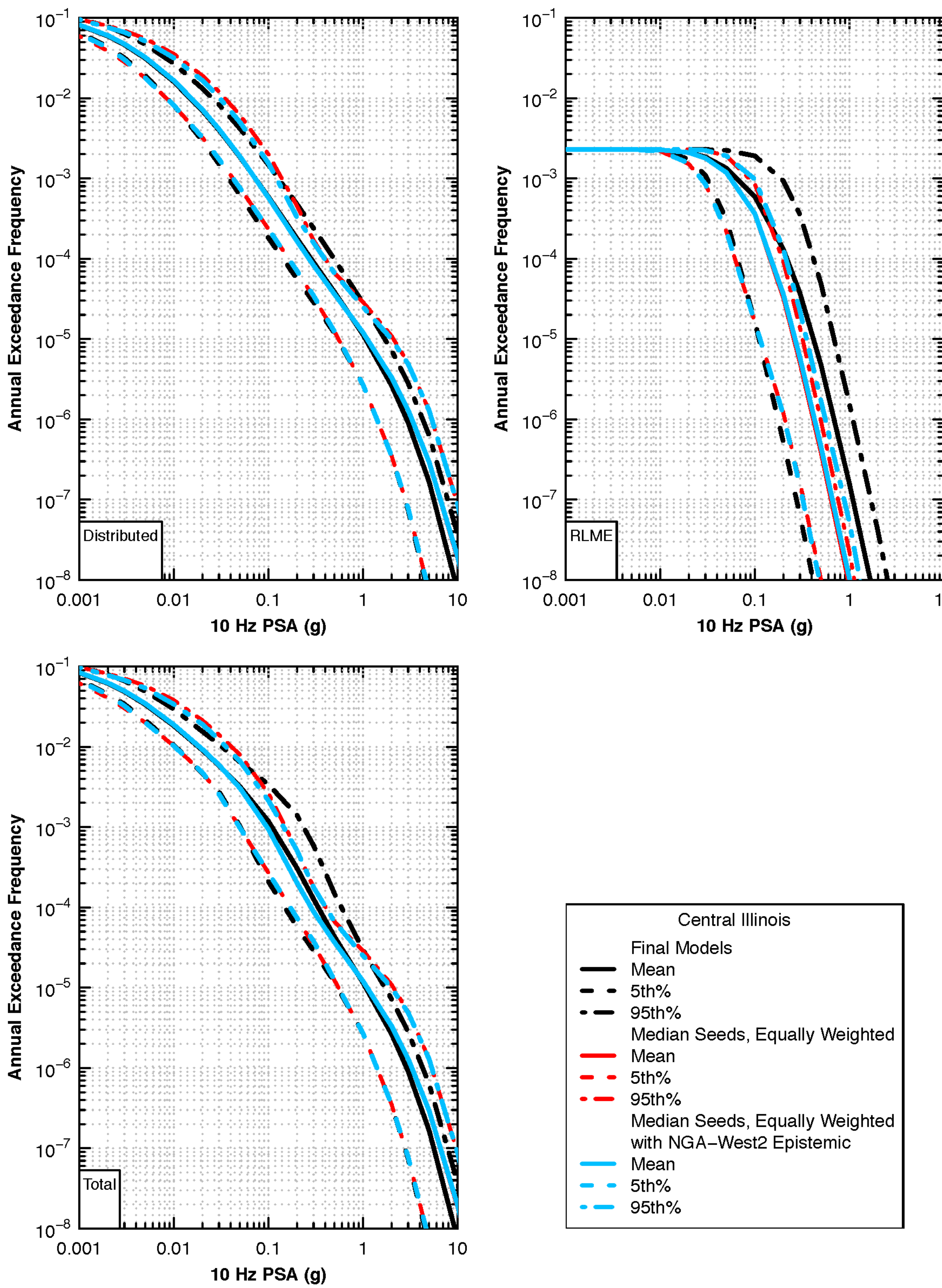
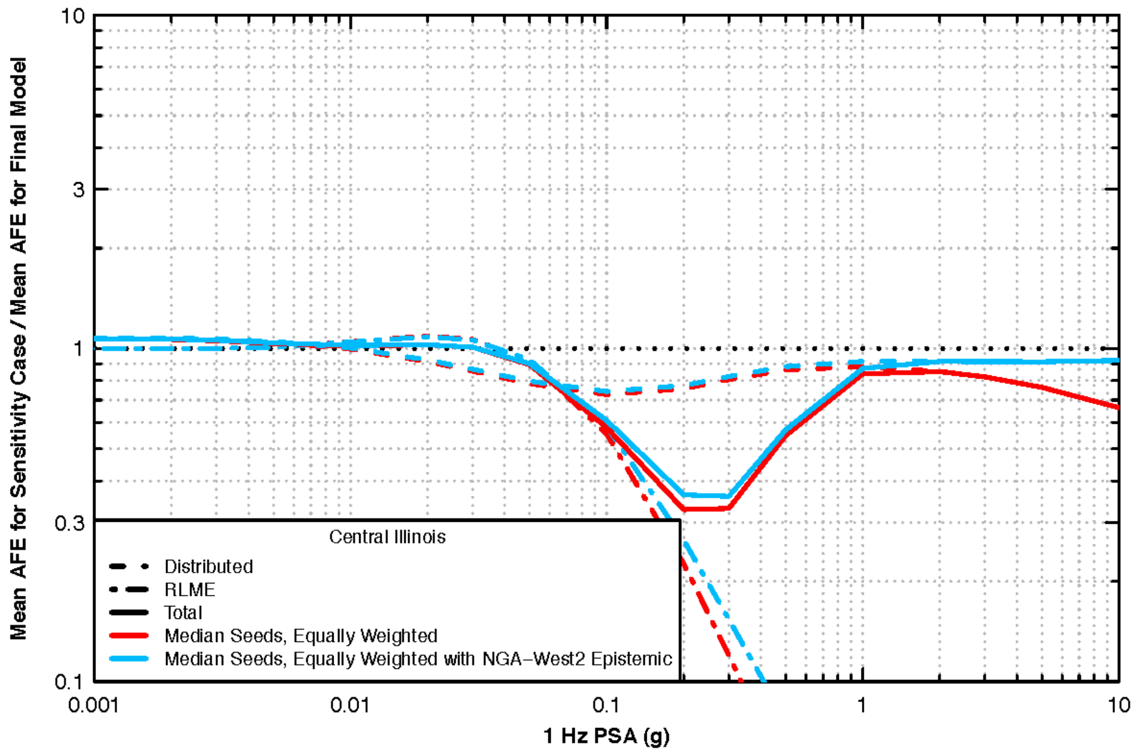


Figure E.1–3(c) Hazard ratio for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz and 10 Hz at Central Illinois.



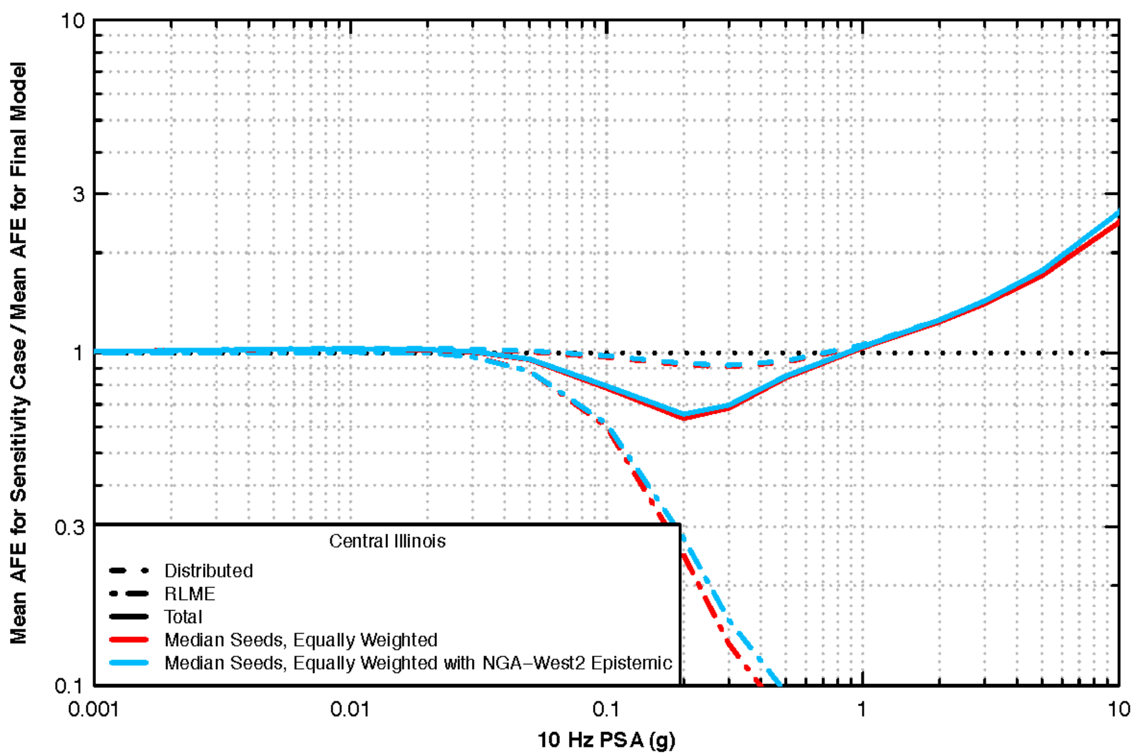


Figure E.1–4(a) Hazard results for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz at Savannah.

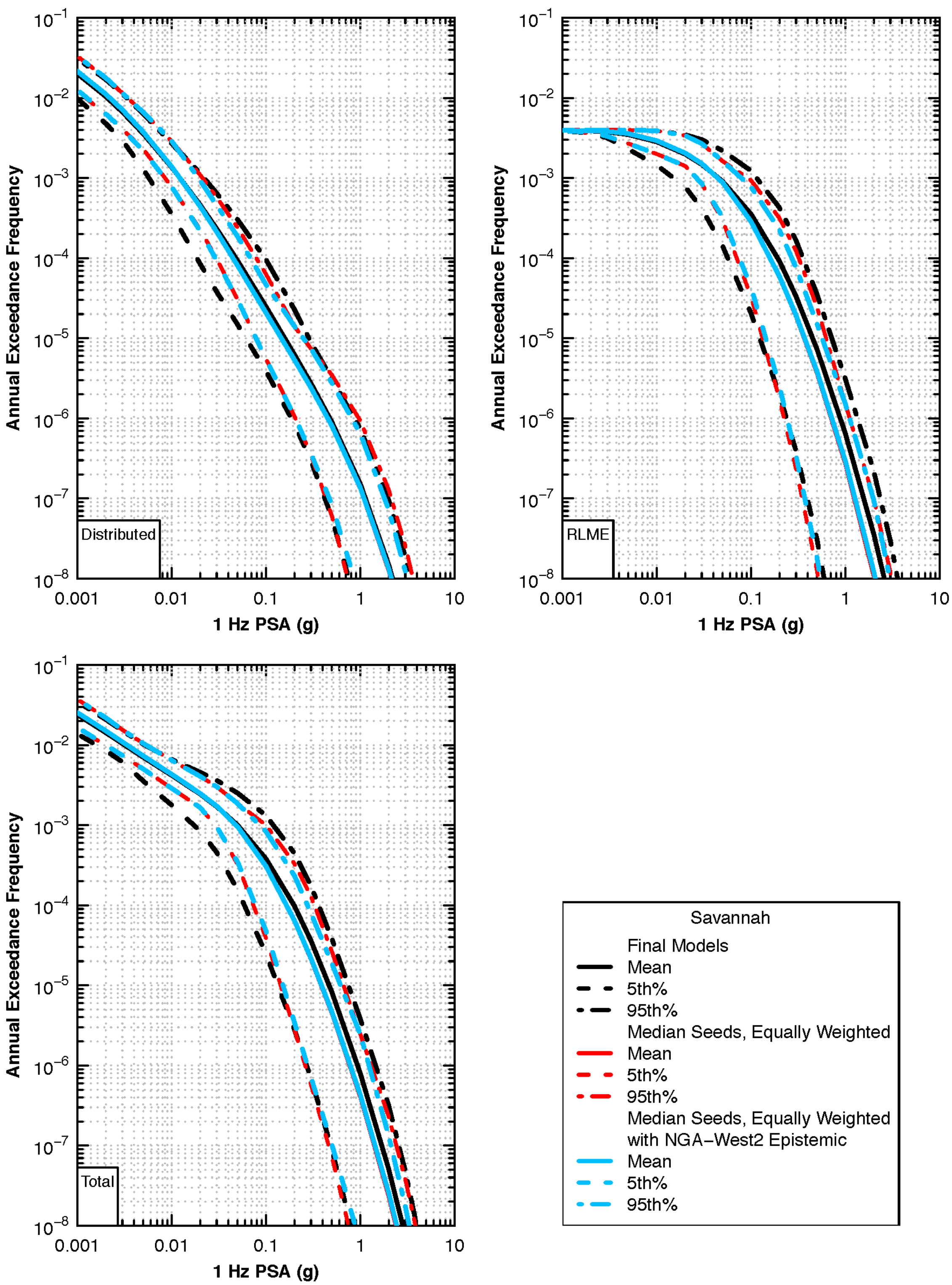


Figure E.1–4(b) Hazard results for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 10 Hz at Savannah.

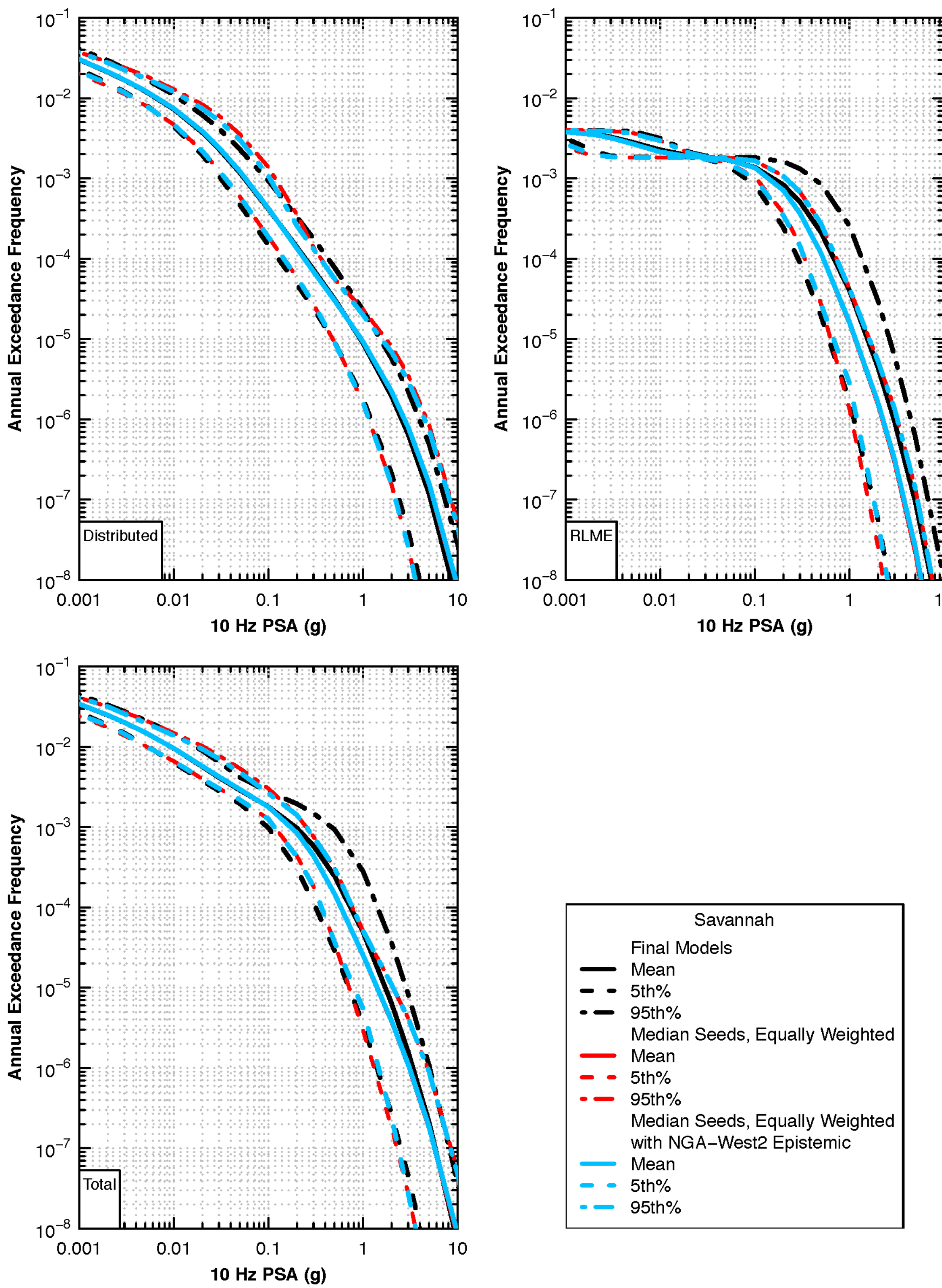
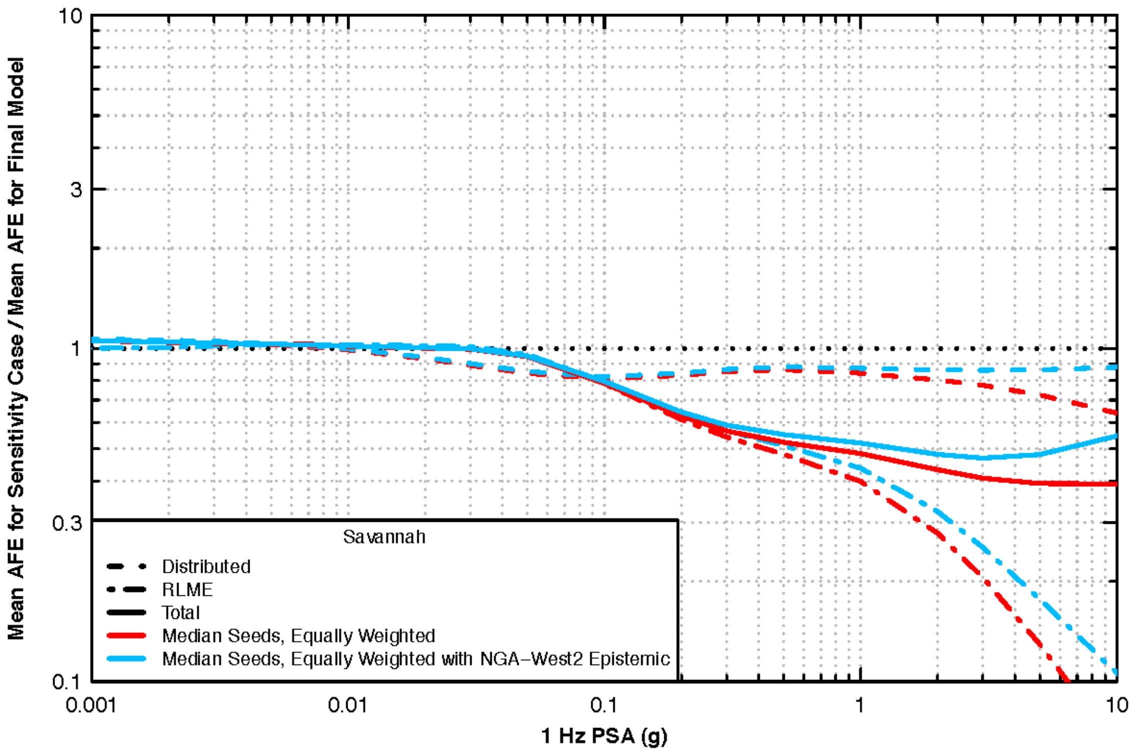
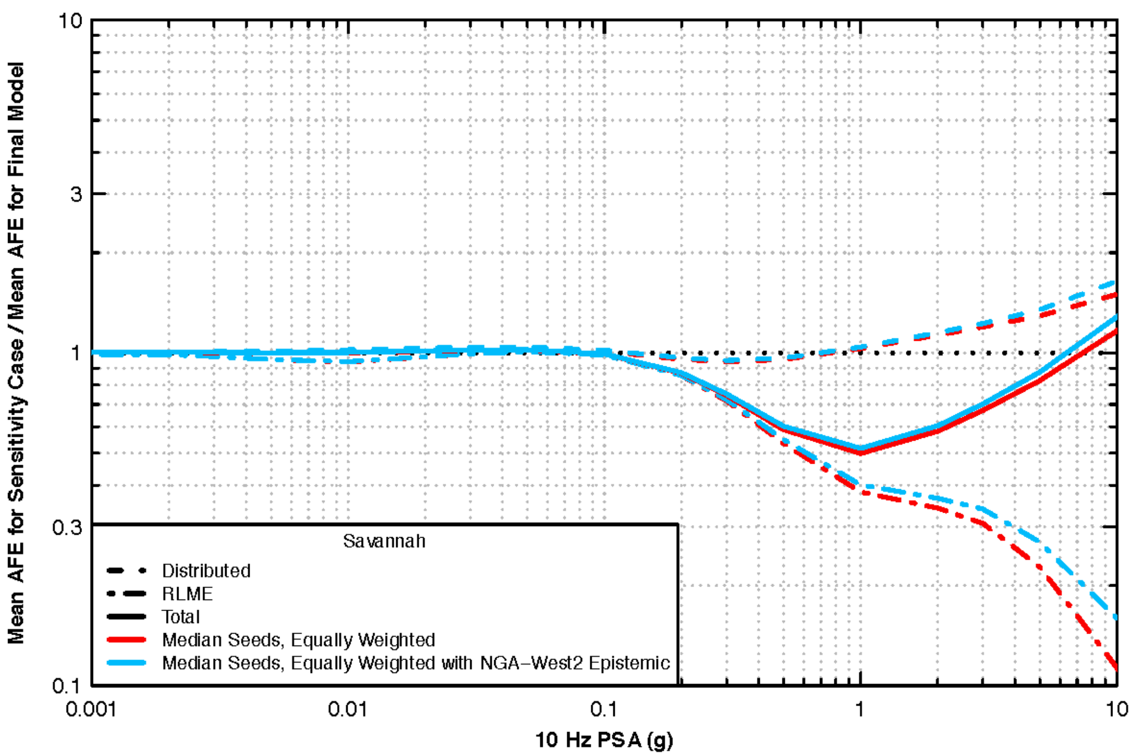


Figure E.1–4(c) Hazard ratio plots for seed GMMs, seed GMMS with the Al Atik and Youngs (2014) uncertainty model, and achieved weighted variance of the NGA-East final GMMs for 1 Hz and 10 Hz at Savannah.





E.2 Sensitivity to Maximum Variance Constraint

The development of imposed variance constraints is described in Section 8.1.1. The largest value of imposed variance selected by the TI team was 0.4, which was prescribed at the largest magnitude (**M**8.2) of the magnitude range for the developed models (shaded area in Figure 8–11). The justification for imposing this value of the desired minimum variance was also provided in the text. The TI team felt that 0.3 and 0.5 were respectively lower- and upper-bounds of what could be technically defensible based on their evaluation of WNA epistemic uncertainties. The TI team therefore developed suites of 17 GMMs using alternate maximum variance values of 0.3 and 0.5 with everything else in the sampling and selection process remaining the same as for the final GMMs. The achieved variance in the three suites of 17 GMMs is shown in Figure E.2–1. Sensitivity analyses to those sets of GMMs are presented in Figures E.2–2 to E.2–4, with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz and part (c) showing the hazard ratio for both frequencies. Those figures show that overall the hazard results are not very sensitive to that range of imposed variance. Exceptions are for the 95th percentile of the 1-Hz RLME hazard below 10^{-5} AFE at Manchester and Central Illinois, which are significantly lower for the 0.3 maximum variance case. These results are as expected, since the differences in variance are mostly for larger magnitude events such as RLMEs.

Figure E.2–1 Achieved GMM variance for three different cases of imposed maximum variance values: 0.3 (top), 0.5 (middle) and 0.4 (bottom), for 1 Hz (left) and 10 Hz (right).

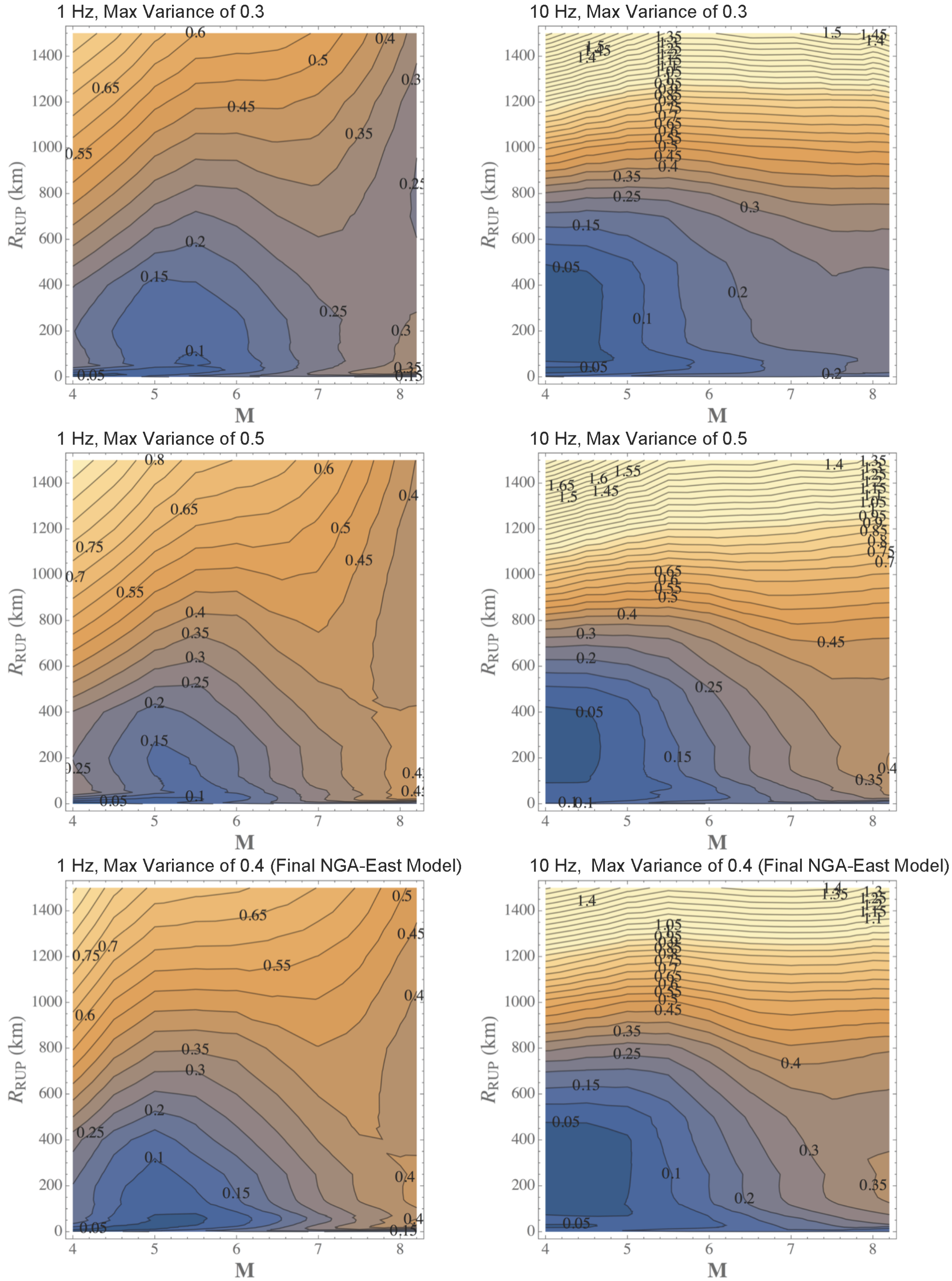


Figure E.2–2(a) Hazard results for three levels of maximum imposed variance in the GMM sampling for 1 Hz at Manchester.

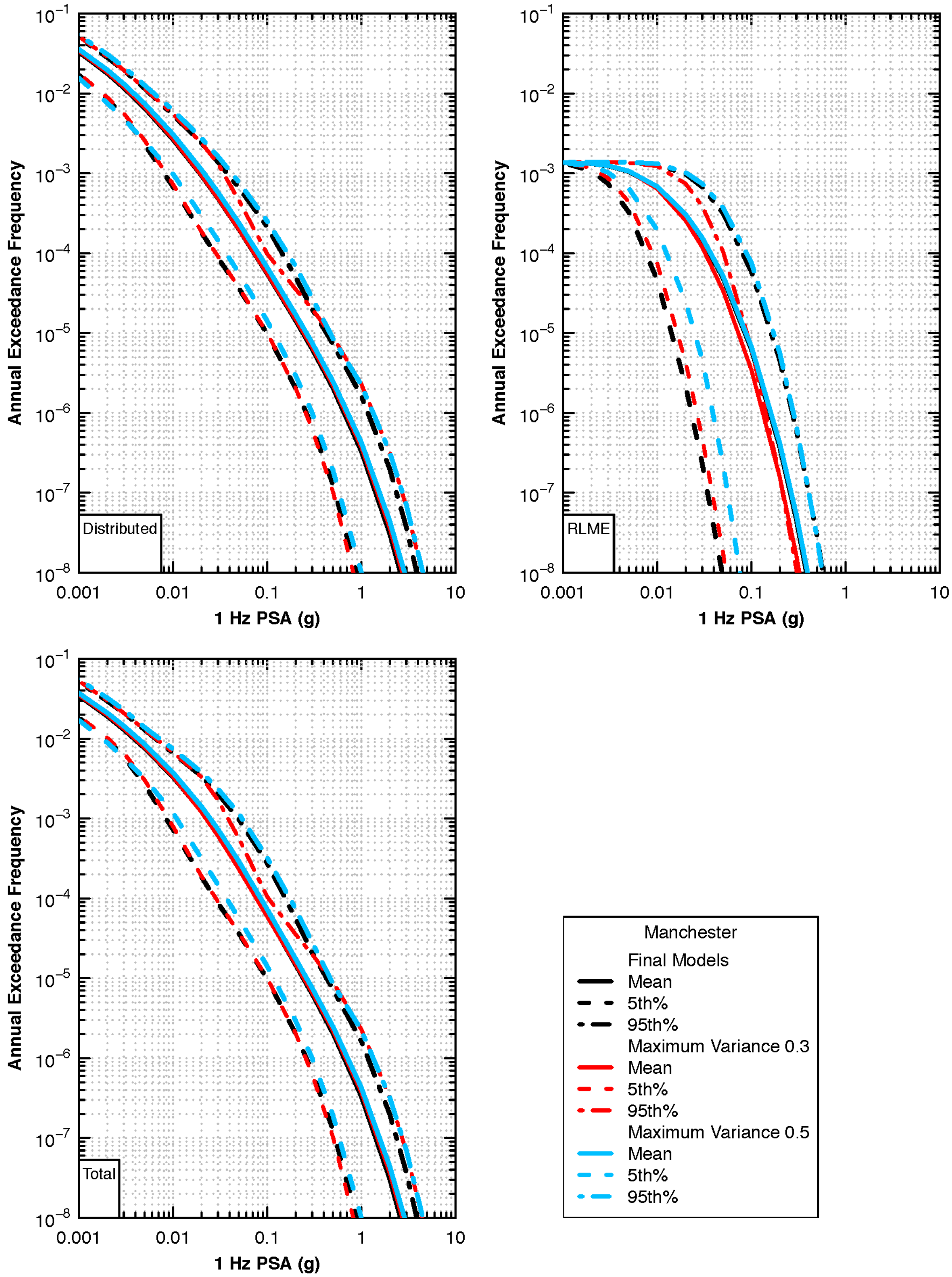


Figure E.2–2(b) Hazard results for three levels of maximum imposed variance in the GMM sampling for 10 Hz at Manchester.

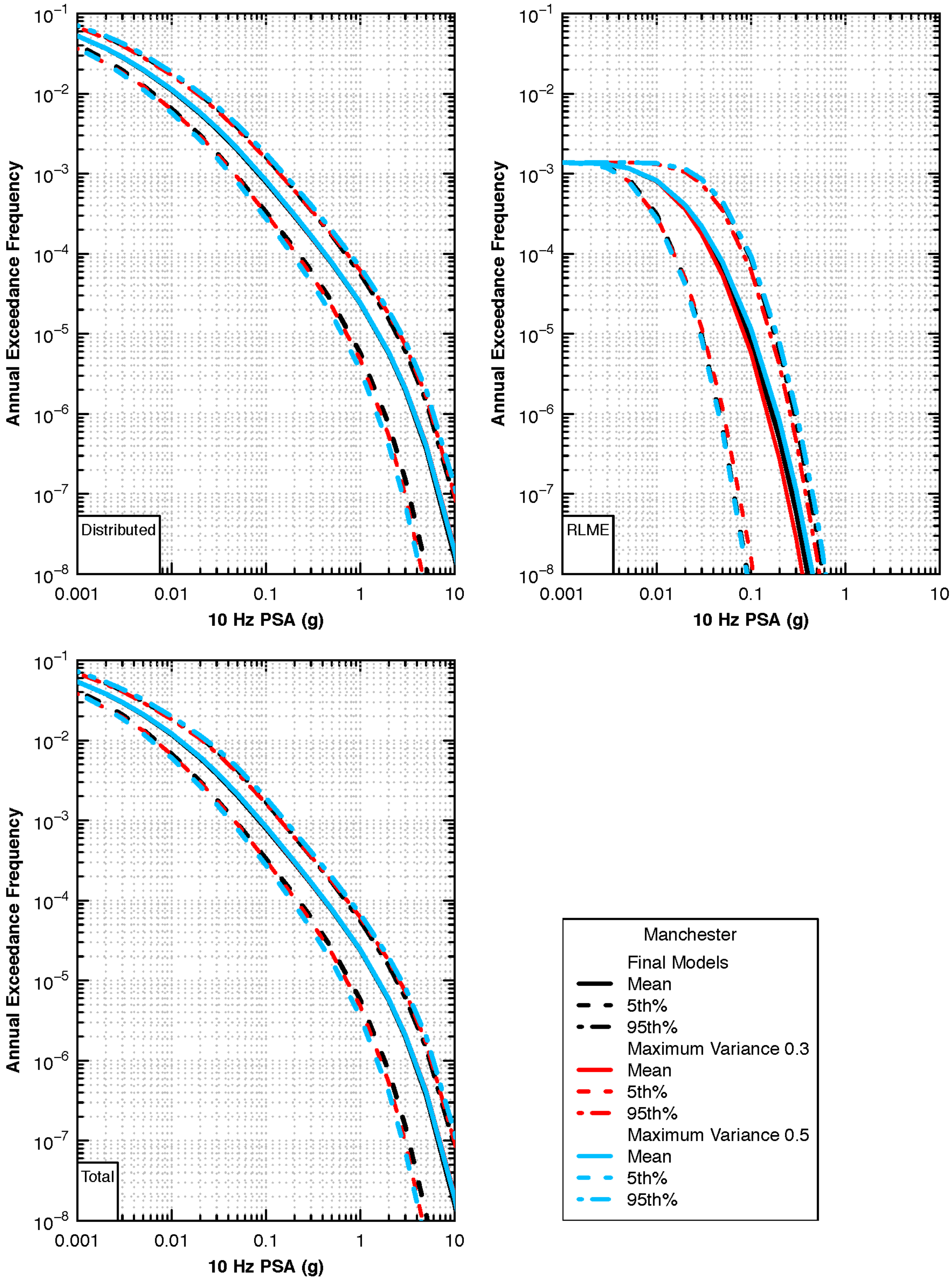


Figure E.2–2(c) Hazard ratio plots for three levels of maximum imposed variance in the GMM sampling for 1 and 10 Hz at Manchester.

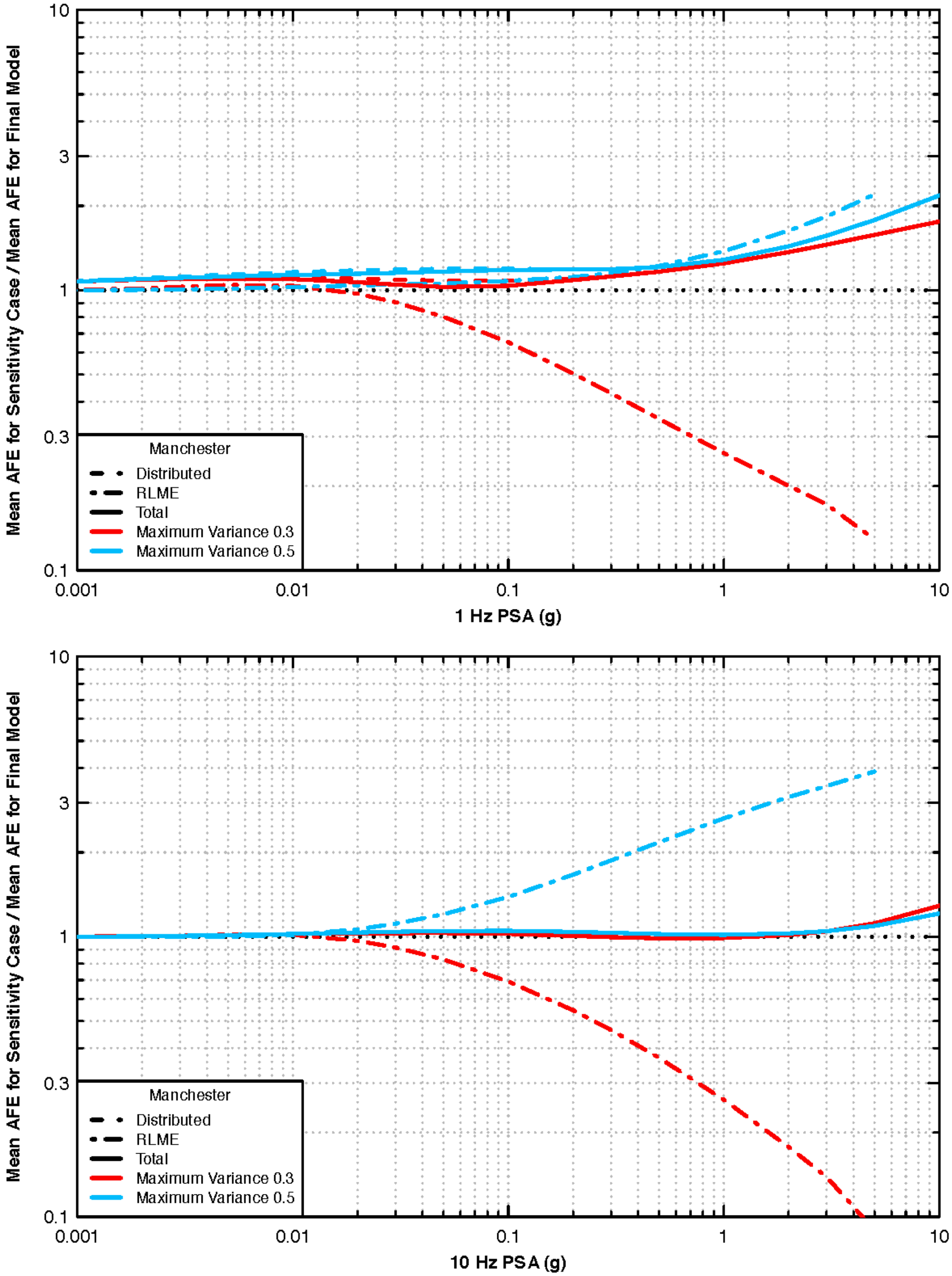


Figure E.2–3(a) Hazard results for three levels of maximum imposed variance in the GMM sampling for 1 Hz at Central illinois.

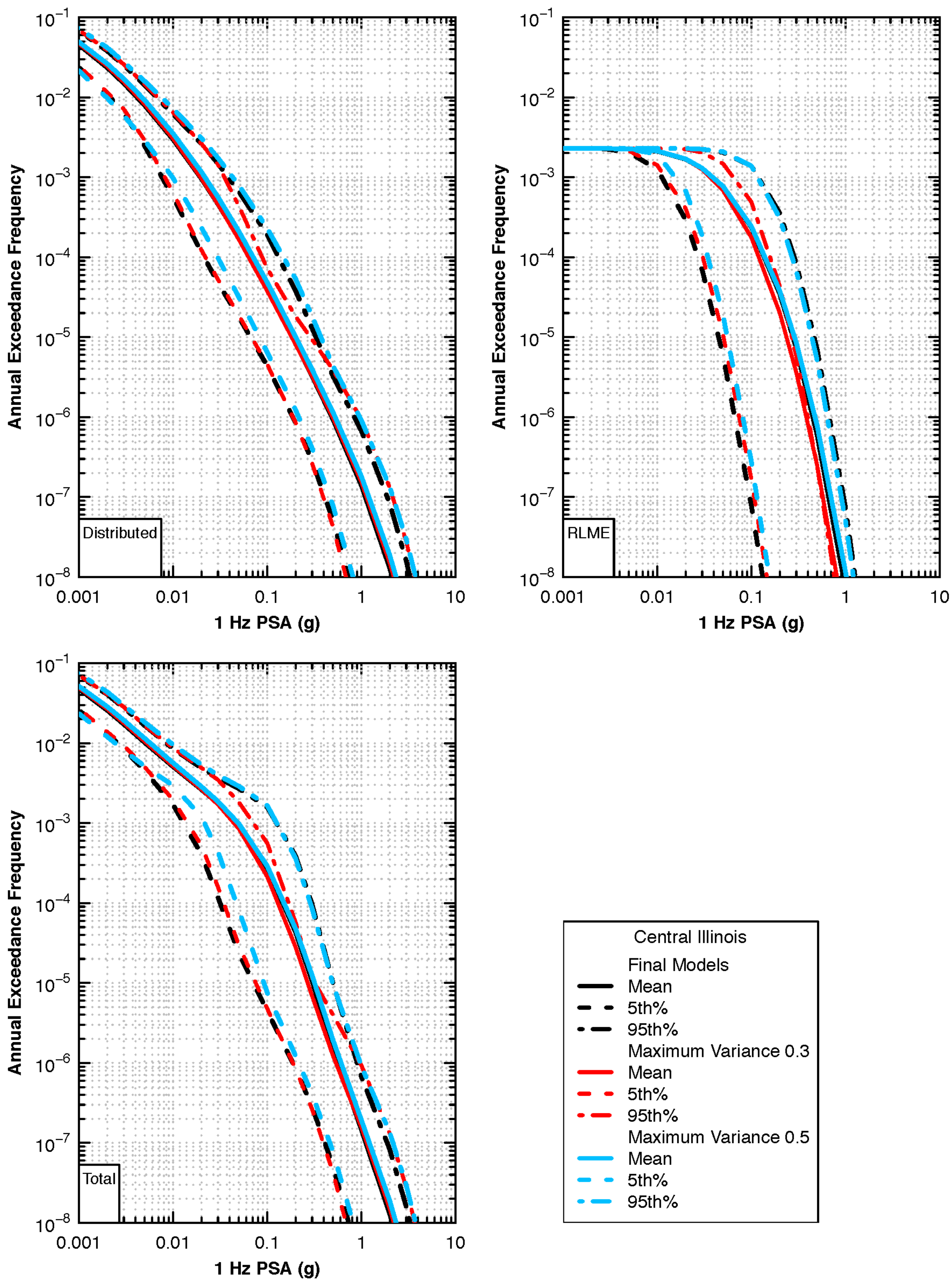


Figure E.2–3(b) Hazard results for three levels of maximum imposed variance in the GMM sampling for 10 Hz at Central illinois.

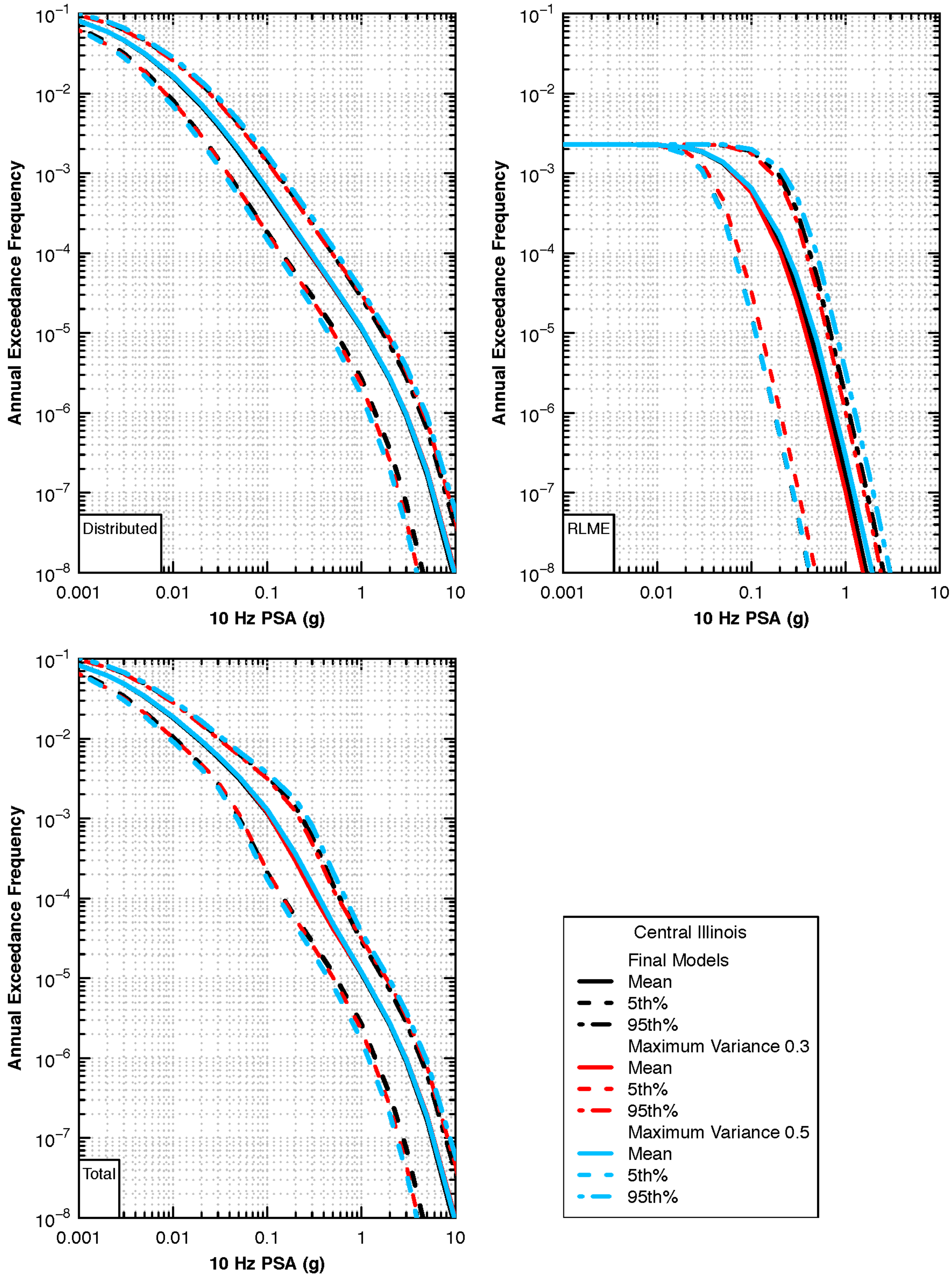


Figure E.2–3(c) Hazard ratio plots for three levels of maximum imposed variance in the GMM sampling for 1 and 10 Hz at Central Illinois.

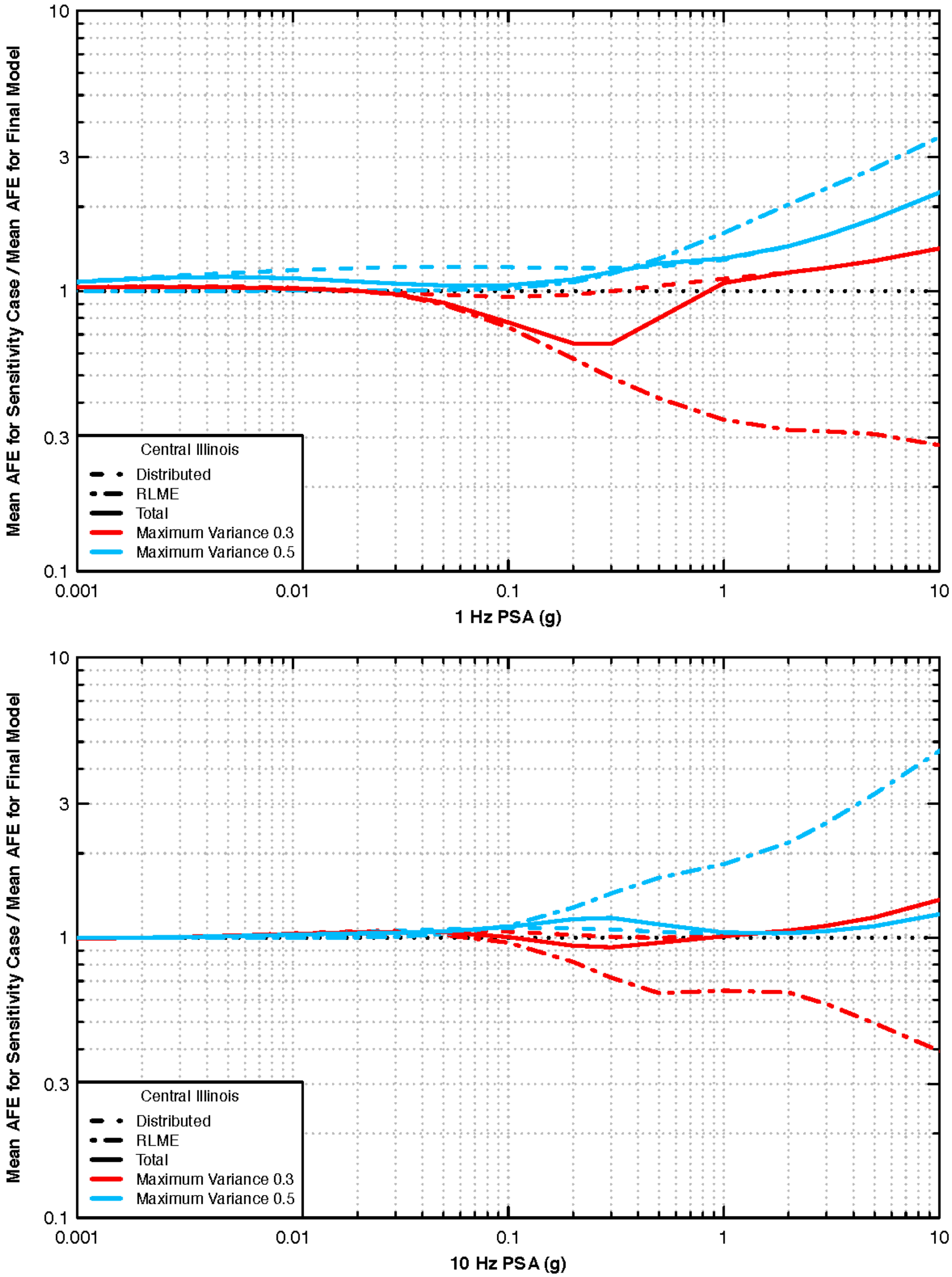


Figure E.2–4(a) Hazard results for three levels of maximum imposed variance in the GMM sampling for 1 Hz at Savannah.

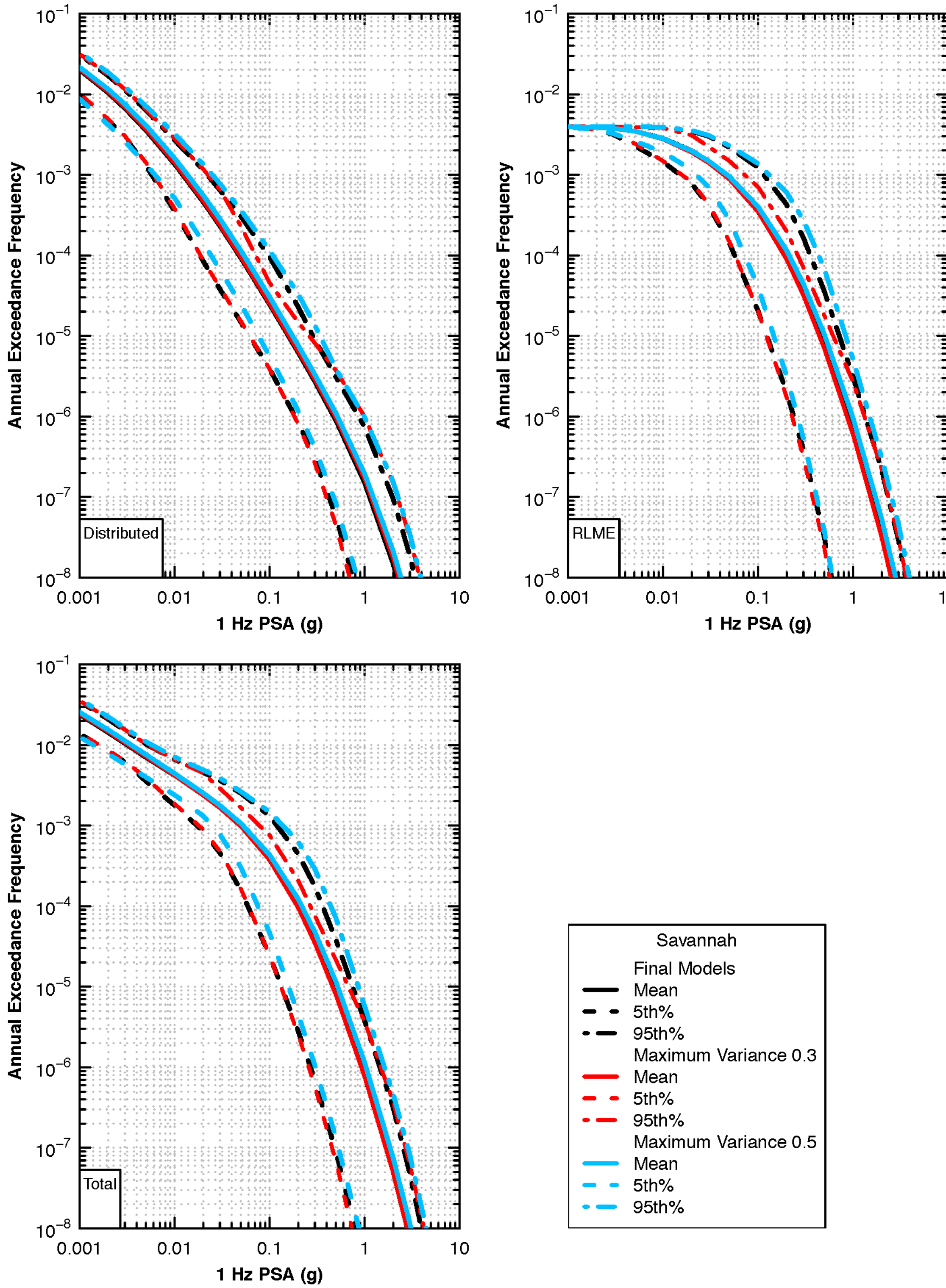


Figure E.2–4(b) Hazard results for three levels of maximum imposed variance in the GMM sampling for 10 Hz at Savannah.

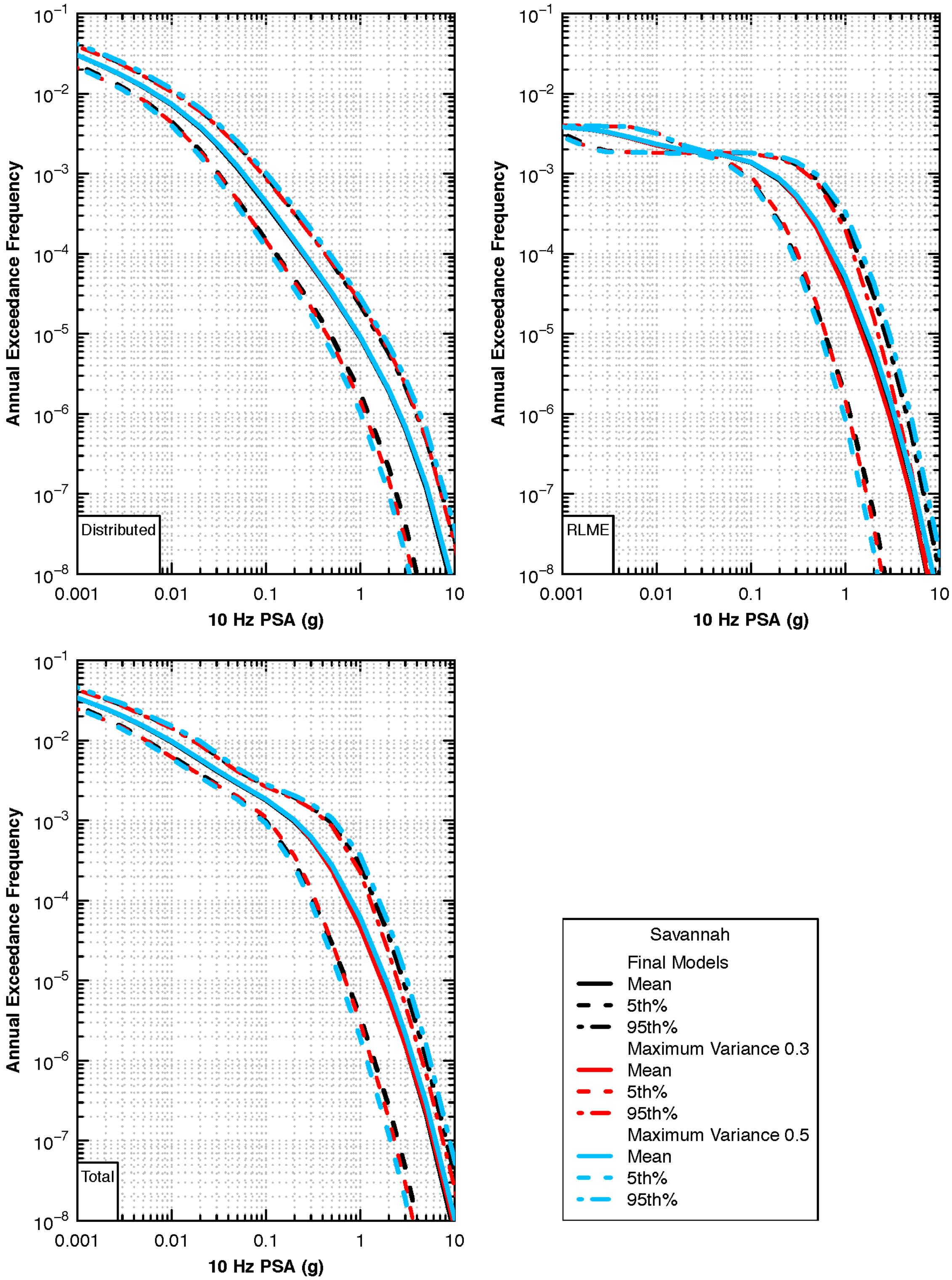
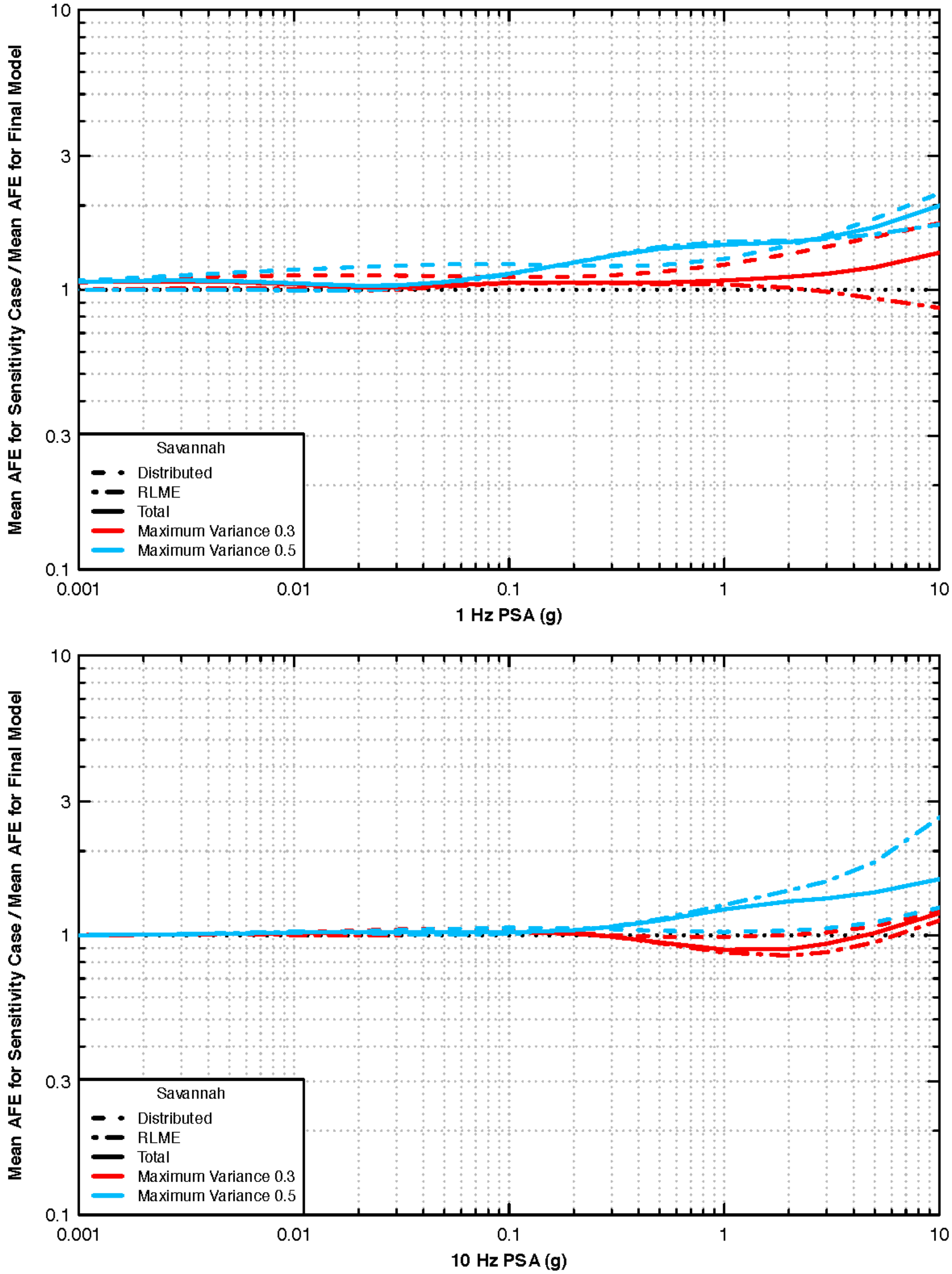


Figure E.2–4(c) Hazard ratio plots for three levels of maximum imposed variance in the GMM sampling for 1 and 10 Hz at Savannah.



E.3 Sensitivity to Correlation Model

In this section, sensitivities to the correlation model used in the development of the NGA-East GMM distribution are investigated. As described in Section 8.1.2, for NGA-East a rational quadratic covariance function combined with a linear function was used to model the correlation between median predictions at different (**M**, R) scenarios. Section 8.1.2 contrasted this correlation model with a ground-motion distribution without correlation (ρ_{ij} = 0) and with full correlation (ρ_{ij} = 1), which corresponds to a linearly-scaled backbone approach. In addition, the NGA-East models are compared to models that are derived based on the same process, but using a different covariance function (the squared exponential covariance function). The following subsections show the impact of these three modeling alternatives on the 1-Hz and 10-Hz hazard curves for the three selected demonstration sites.

E.3.1. No Correlation

The TI team generated random samples from a multi-normal distribution with no correlation between the different (**M**, R_{RUP}) scenarios (i.e., the correlation coefficient is zero, ρ_{ij} = 0). In other words, the covariance is a diagonal matrix whose entries are determined by the NGA-East variance model, with the non-diagonal entries being zero. The mean of the distribution is the weighted mean of the seed models, so no actual seed is used.

Figure E.3–1 shows 10 models sampled from that distribution. The (point-wise) variance at each (**M**, R) scenario is the same as when using the NGA-East covariance model, but the sampled "functions" lose all physicality (large variations are observed over small differences in magnitude and distance). These models do not tend to be physical and were not used in hazard sensitivity analysis.

E.3.2 Full Correlation (Scaled-Backbone Approach)

In this section, hazard curves are compared for 17 models calculated from a scaled-backbone approach. This corresponds to a correlation model with a correlation coefficient of one, ρ_{ij} = 1. The weighted mean of the seed models is taken as the reference, which is then scaled up and down to cover the range $\pm 2\sigma$, where σ is calculated for each (**M**, R_{RUP}) scenario from the NGA-East variance model. As in the previous section, the (point-wise) variance at each (**M**, R_{RUP}) scenario is the same as when using the NGA-East variance model. The resulting ground motion values shown on Figure E.3–2 now show very smooth variations with magnitude and distance, and are essentially parallel to each other as expected in the scaled-backbone approach.

Figures E.3–3, E.3–4 and E.3–5 compare the hazard curves for the full truncation model to those for the Final NGA-East models for the three demonstration sites for oscillator frequencies of 1 and 10 Hz. The weights for the scaled-backbone models are calculated from the probability density function, giving each model a weight that corresponds to the density it covers. The hazard curve distributions are very similar for all sites. This is expected, as the Final NGA-East GMM has high correlation; see Chapter 8.

E.3.3 Squared Exponential, Non-Adjusted, Weighted Seeds

The models in this section are based on a different covariance function, the squared exponential (SE) covariance function together with a linear function:

$$k(x,x') = \theta_1 \exp\left[(x,x')^T \cdot \begin{pmatrix} \theta_2 & 0 \\ 0 & \theta_3 \end{pmatrix} (x,x')\right] + x^T \cdot \begin{pmatrix} \theta_4 & 0 \\ 0 & \theta_5 \end{pmatrix} x' \qquad \text{(E.1)}$$

The SE function is a standard covariance function widely used in applications of Gaussian processes (Rasmussen and Williams 2006). The parameters for this function are estimated in the same fashion as for the NGA-East correlation model, by maximizing the marginal likelihood with respect to the parameters (see Chapter 8). The value of the log marginal likelihood is $\ln p\left(\mathbf{y} \middle| \mathbf{X}, \theta\right) = 867.23$ for the squared exponential function, compared with $\ln p\left(\mathbf{y} \middle| \mathbf{X}, \theta\right) = 1394.96$ for the rational quadratic function used for the NGA-East GMMs. The lower value for the SE covariance function indicates that the correlation in ground-motion values between the different ($\mathbf{M}$, R_{RUP}) scenarios is better captured by the rational quadratic function. The achieved variance from this correlation model was also too low, as shown in Figure E.3–6.

Figures E.3–7 to E.3–9 show the hazard curve distributions for the three sites, for oscillator frequencies of 1 and 10 Hz, respectively. The narrow width of 5^{th} and 95^{th} fractile band is another expression of the low marginal likelihood and of the low achieved variance.

E.3.4 Frequency-Dependent Correlation

The models in this section are based on the covariance function selected by the TI team [Chapter 8, Equation (8–8)]; however, parameters are estimated for all frequencies. They are calculated from the mean of the seed models at the different frequencies by maximizing the marginal likelihood [Equation (8–11)]. Since there is only a small difference in hazard (Figures E.3–10 to E.3–12), it was decided to use the parameters at 1 Hz for all frequencies and let the frequency dependence be handled by using the mixture model of the seed models. This approach selected by the TI team also makes the different Sammon's maps more comparable across frequencies.

E.3.5 Discussion

Hazard ratio plots for all the sensitivities discussed above are presented for 1 Hz and 10 Hz for the three demonstration sites (Figure E.3–13). The comparison of the hazard curves and ratios in this section was based on median models that are all derived from a full ground-motion distribution P(**Y**) but used in different correlation models to account for the correlation between median ground-motion estimates at different ($\mathbf{M}$, R_{RUP}) scenarios. In general, the mean hazard estimates are very similar between all approaches, which is expected since the mean of the distribution is approximately the same in all cases. Differences can ensue because both the NGA-East and the SE models are based on sampling from a mixture model, whereas the no-correlation and scaled-backbone models are directly sampled/calculated from a distribution with the weighted mean of the seeds.

The main differences between the four cases for which we provide hazard results occur in the fractiles of the hazard curve distribution. One case is the scaled-backbone model, which leads to a hazard curve distribution that is similar to the one obtained from the NGA-East model.

Similar to the NGA-East correlation model, the SE covariance function can be thought of as a compromise between the no-correlation ($\rho_{ij} = 0$) and scaled-backbone case ($\rho_{ij} = 1$); however, compared to NGA-East, it leads to less correlation between the ($\mathbf{M}$, R_{RUP}) scenarios. Therefore, its resulting hazard curve distribution is narrower than for the Final NGA-East GMM.

Figure E.3–1 Scaling of 10 sampled models with mean of the seed GMMs and no correlation. The mean of the seed GMMs is plotted as a solid black line.

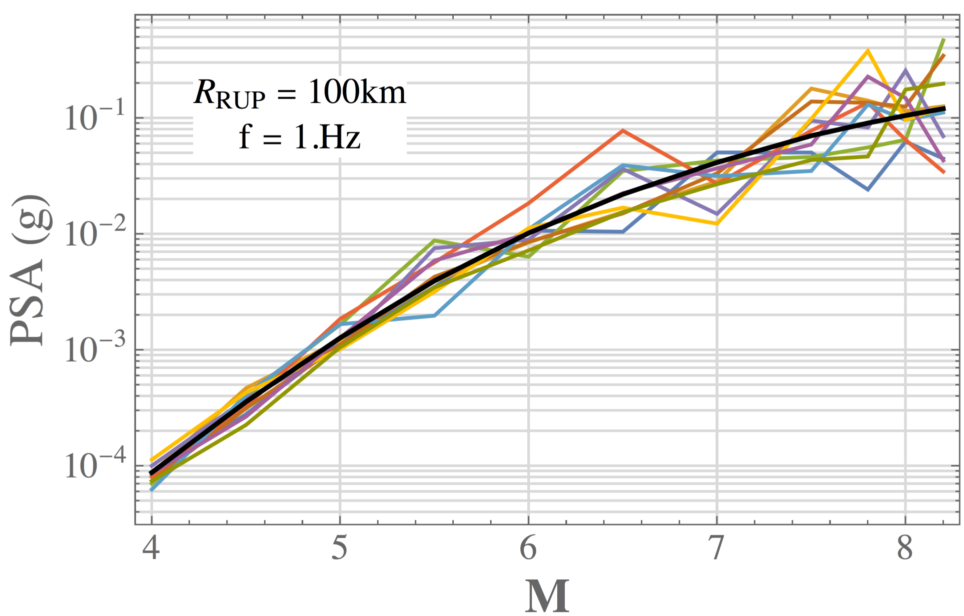


Figure E.3–2 Scaling of 17 sampled models with mean of the seed GMMs and full correlation (scaled backbone) for 1 and 10 Hz

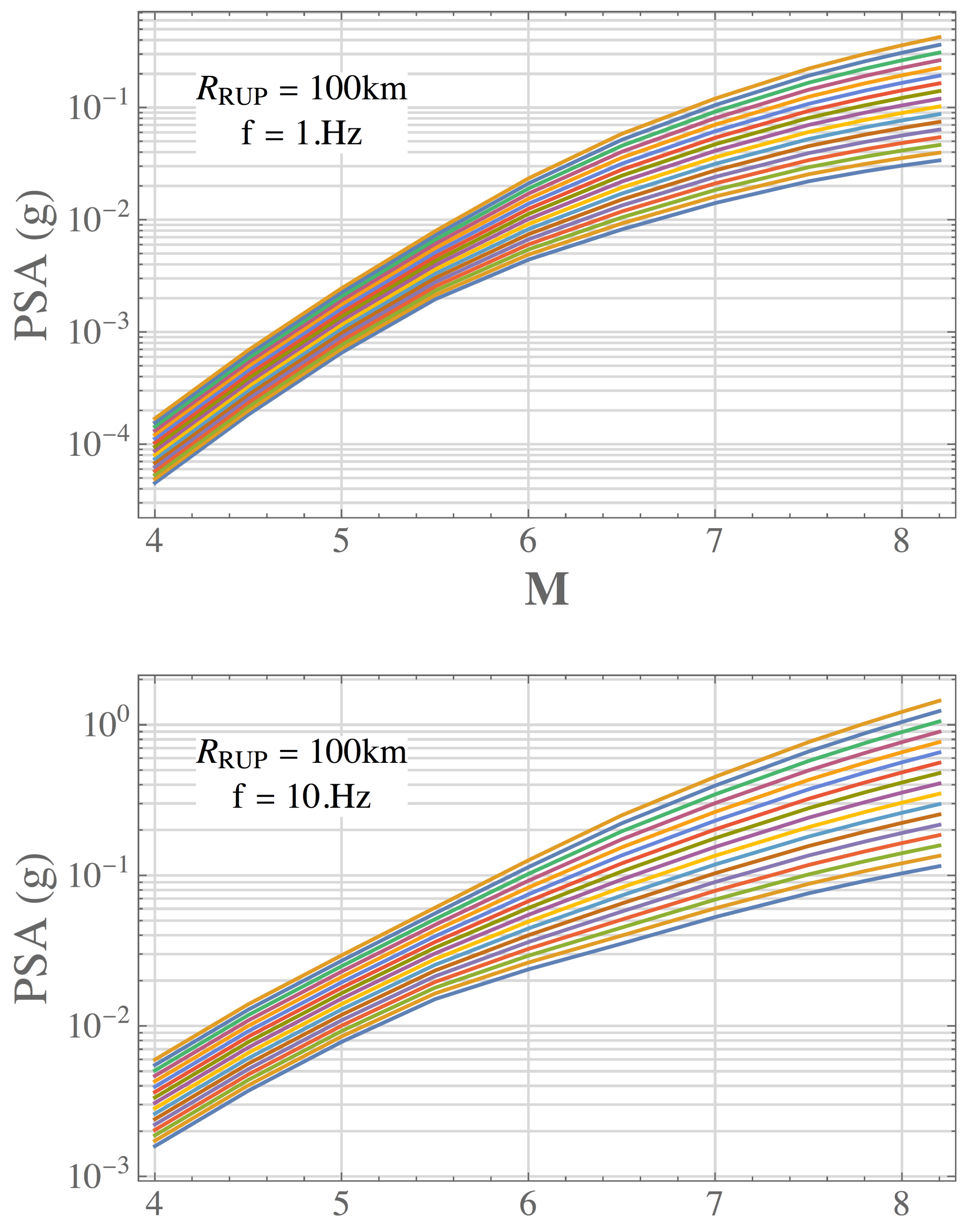


Figure E.3–3(a) Hazard results for an imposed correlation of 1 in the GMM sampling for 1 Hz at Manchester.

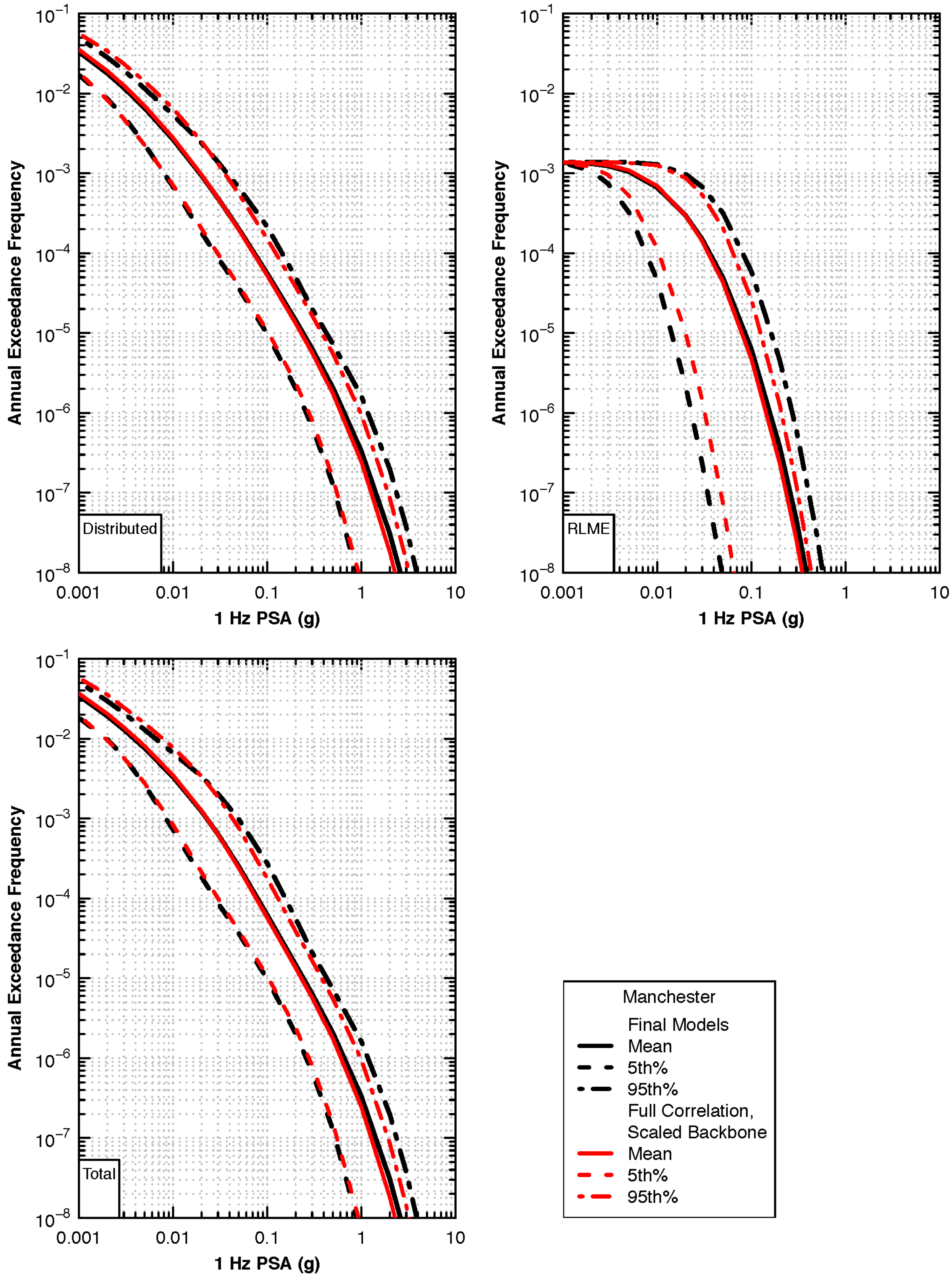


Figure E.3–3(b) Hazard results for an imposed correlation of 1 in the GMM sampling for 10 Hz at Manchester.

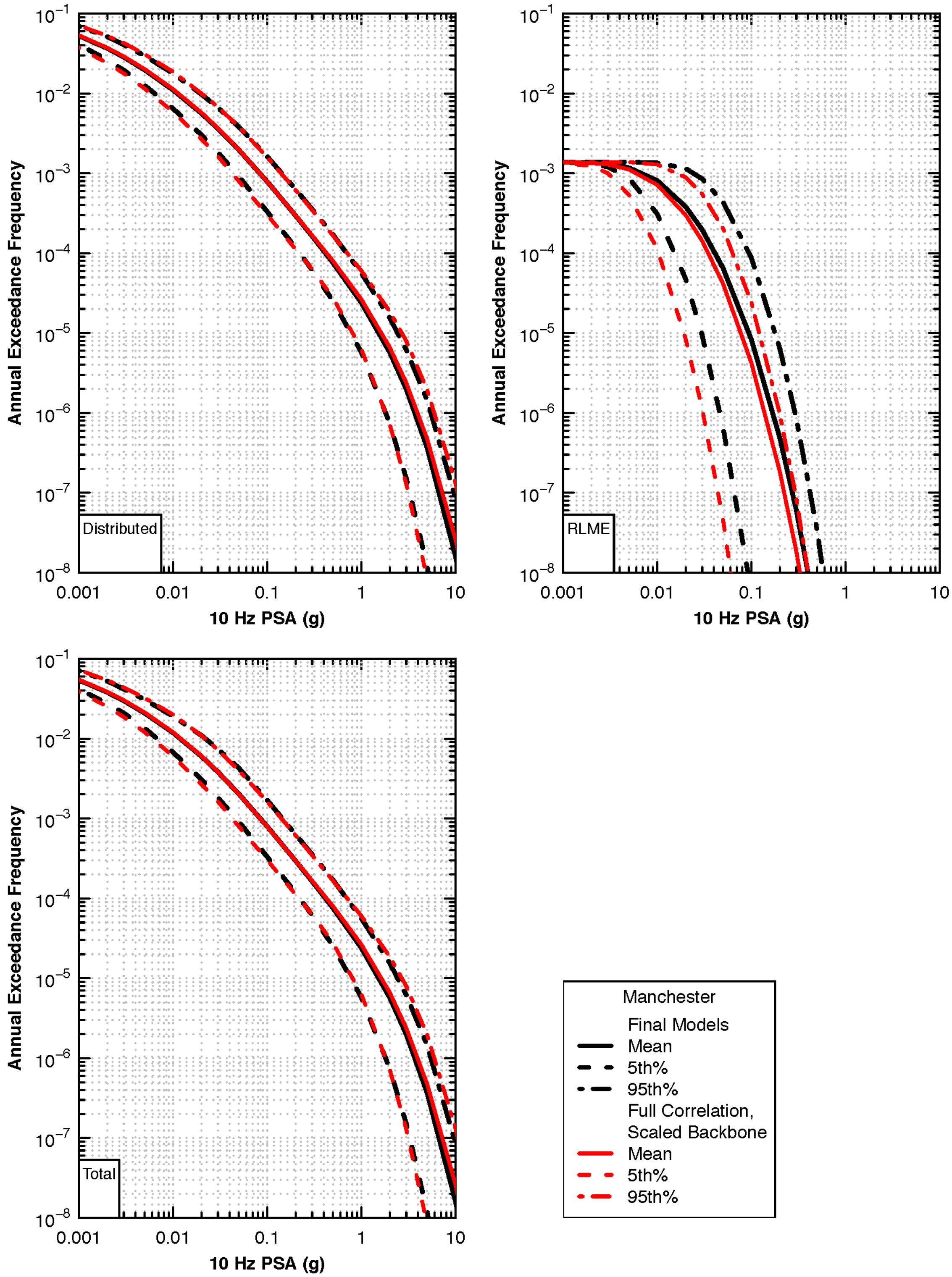


Figure E.3–4(a) Hazard results for an imposed correlation of 1 in the GMM sampling for 1 Hz at Central illinois.

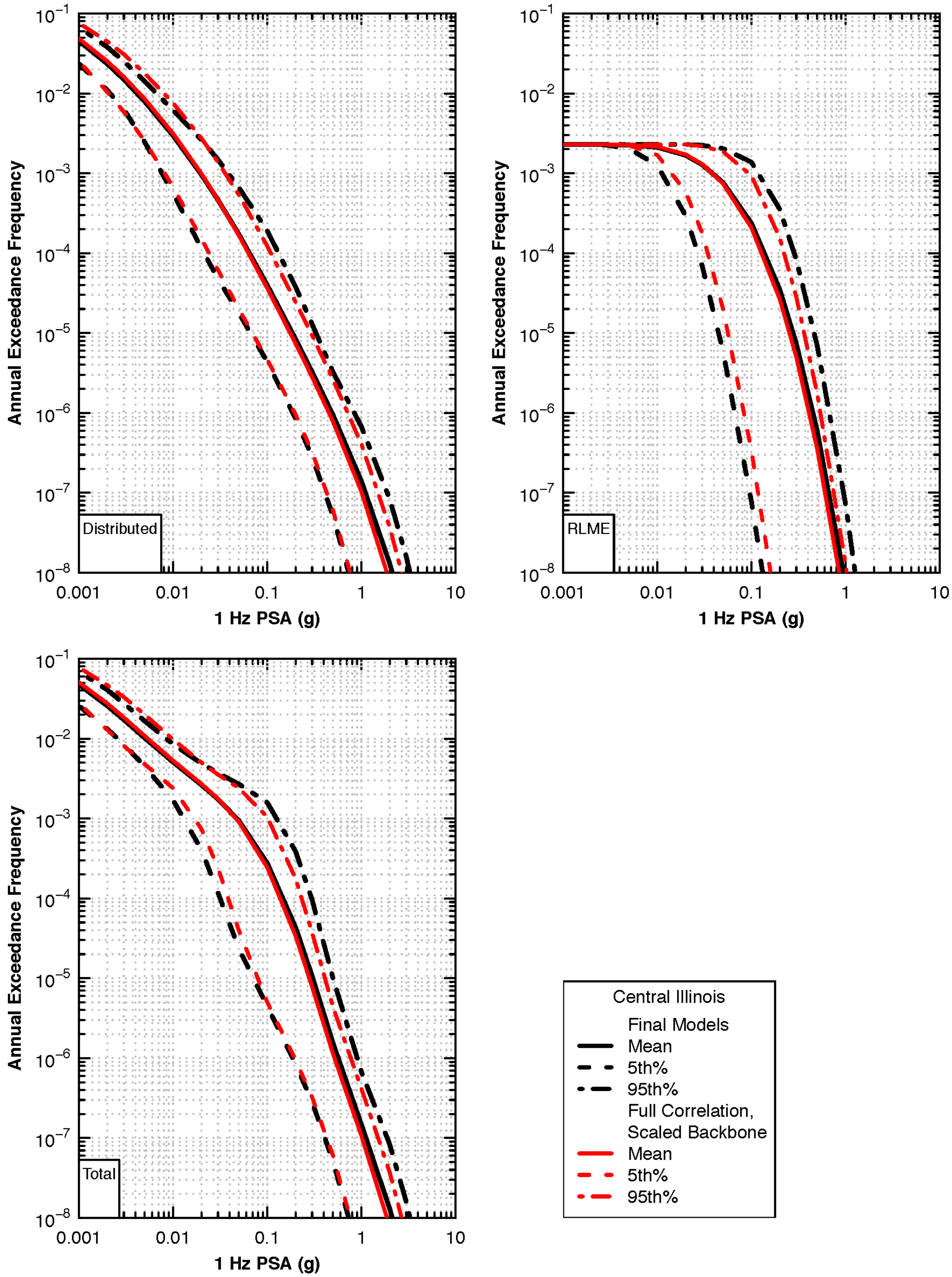


Figure E.3–4(b) Hazard results for an imposed correlation of 1 in the GMM sampling for 10 Hz at Central illinois.

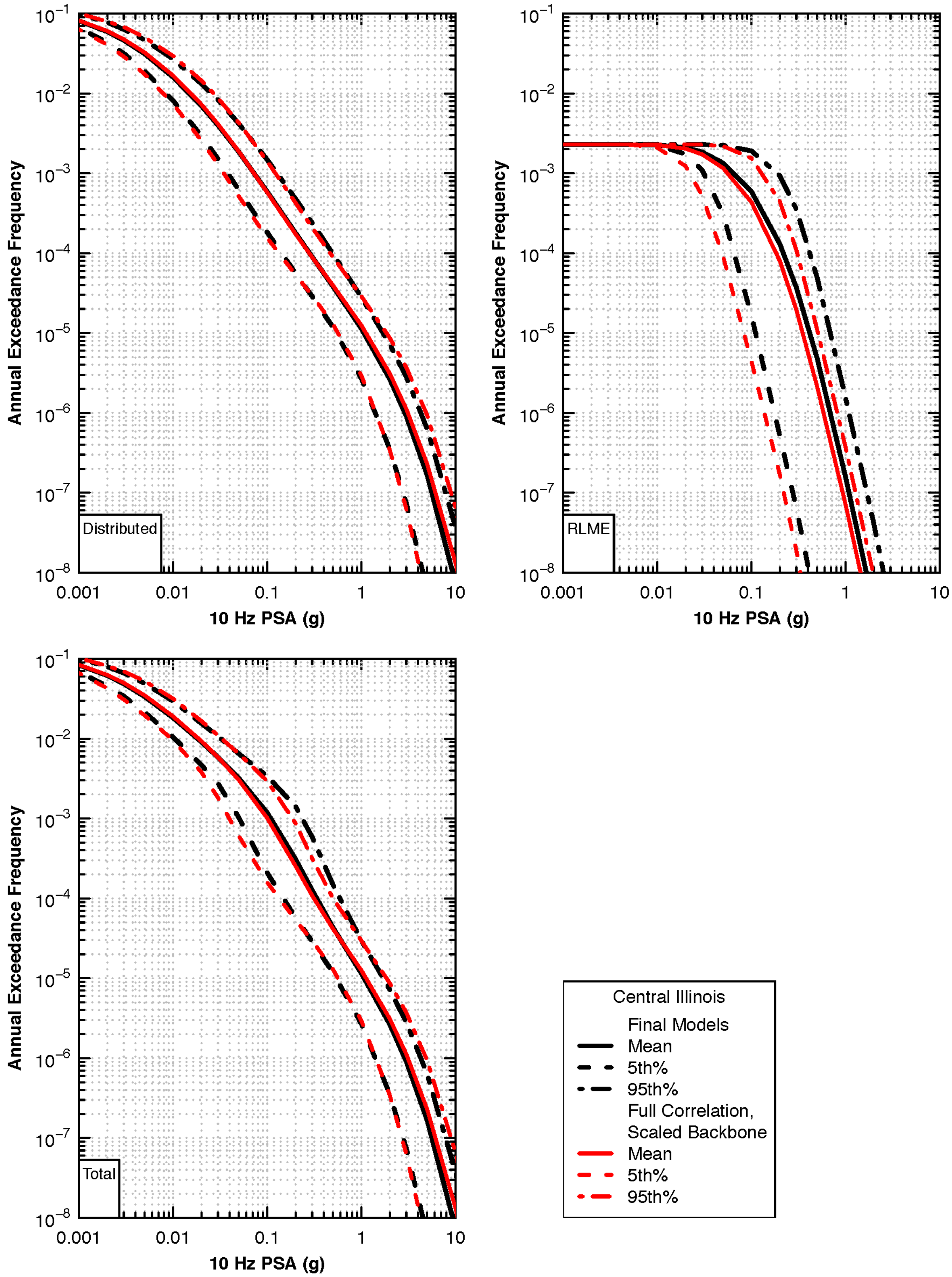


Figure E.3–5(a) Hazard results for an imposed correlation of 1 in the GMM sampling for 1 Hz at Savannah.

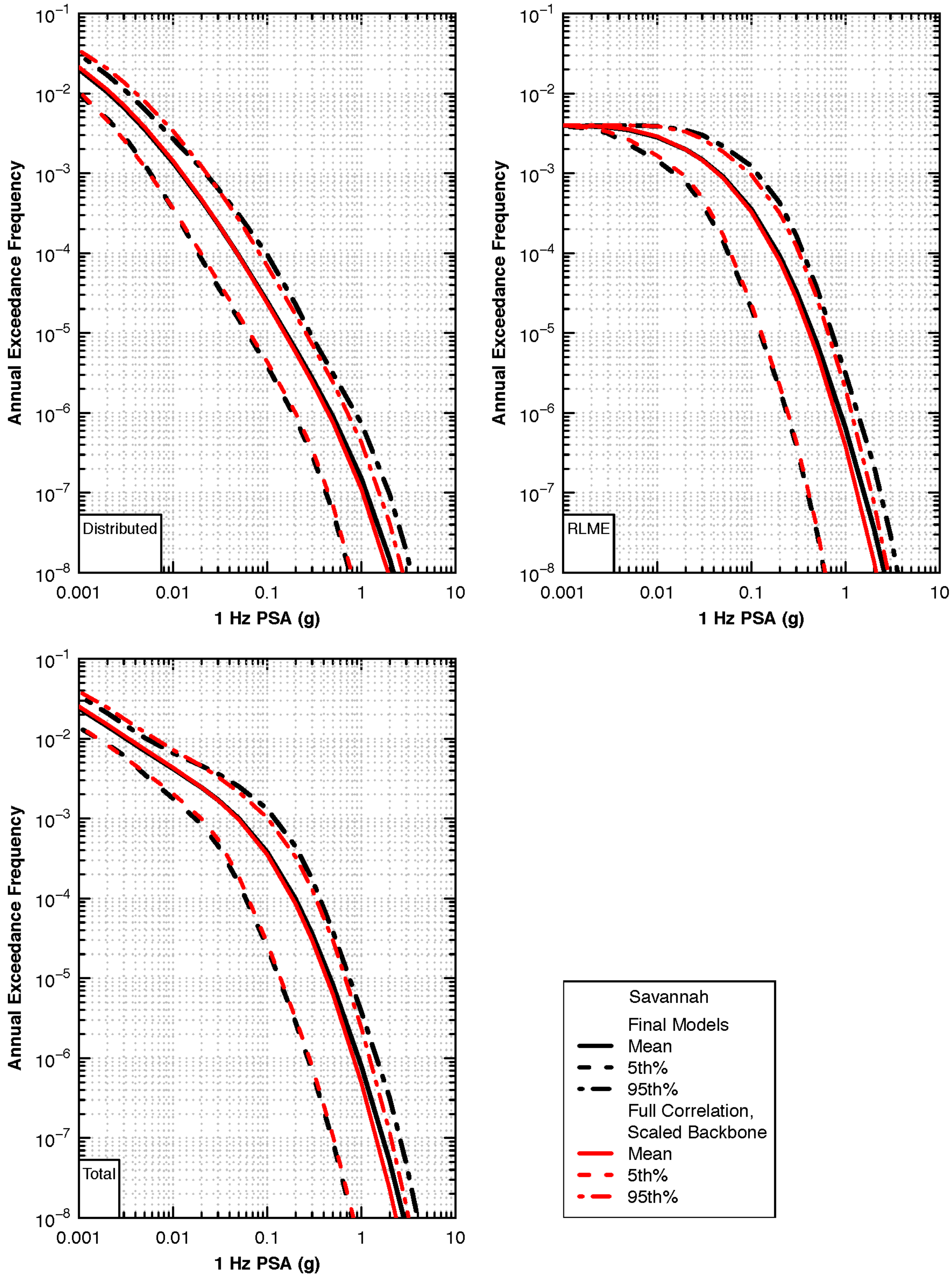


Figure E.3–5(b) Hazard results for an imposed correlation of 1 in the GMM sampling for 10 Hz at Savannah.

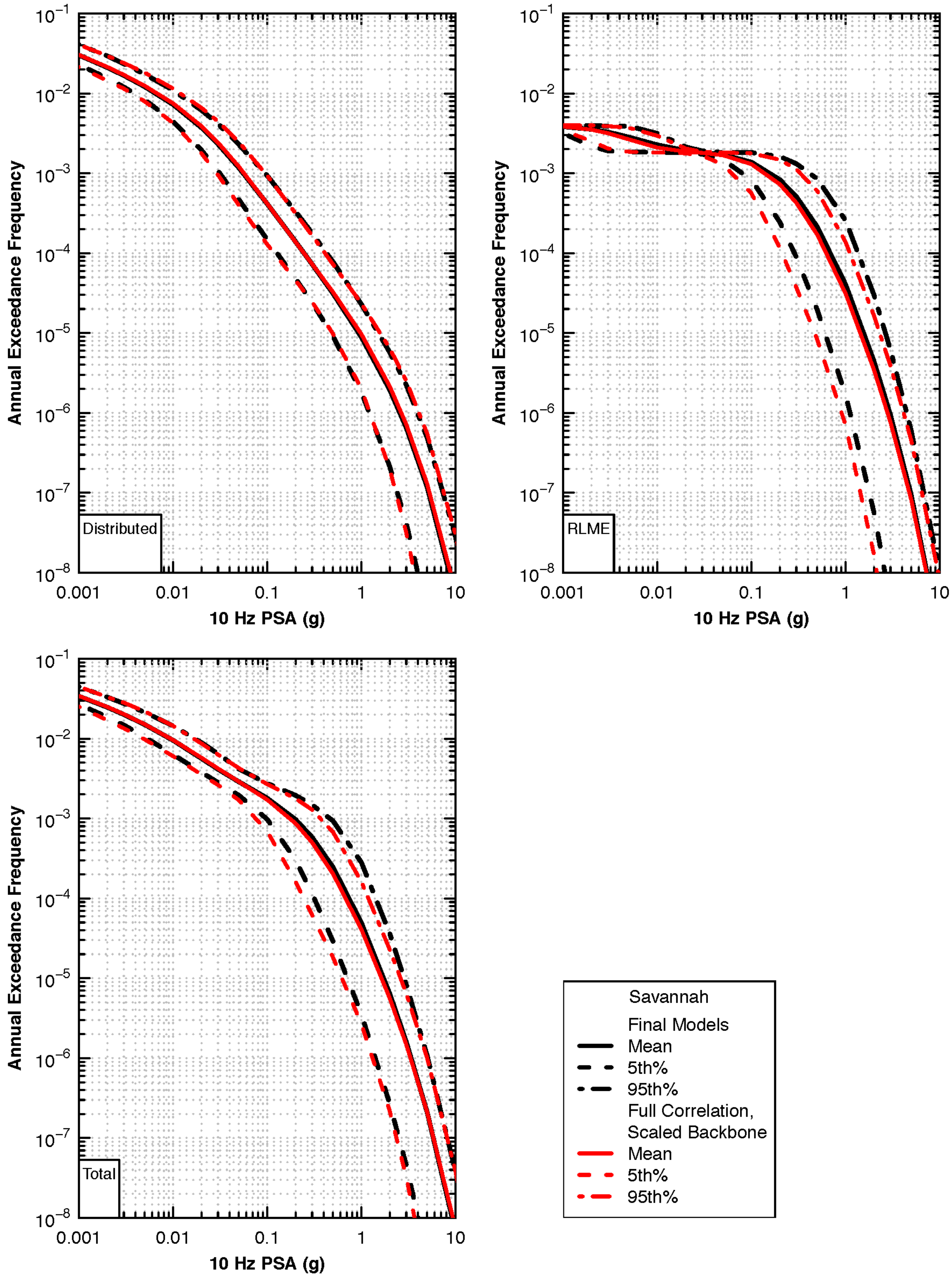


Figure E.3–6 Achieved variance for 17 GMMs sampled from a square exponential correlation model, for 1 (left) and 10 Hz (right).

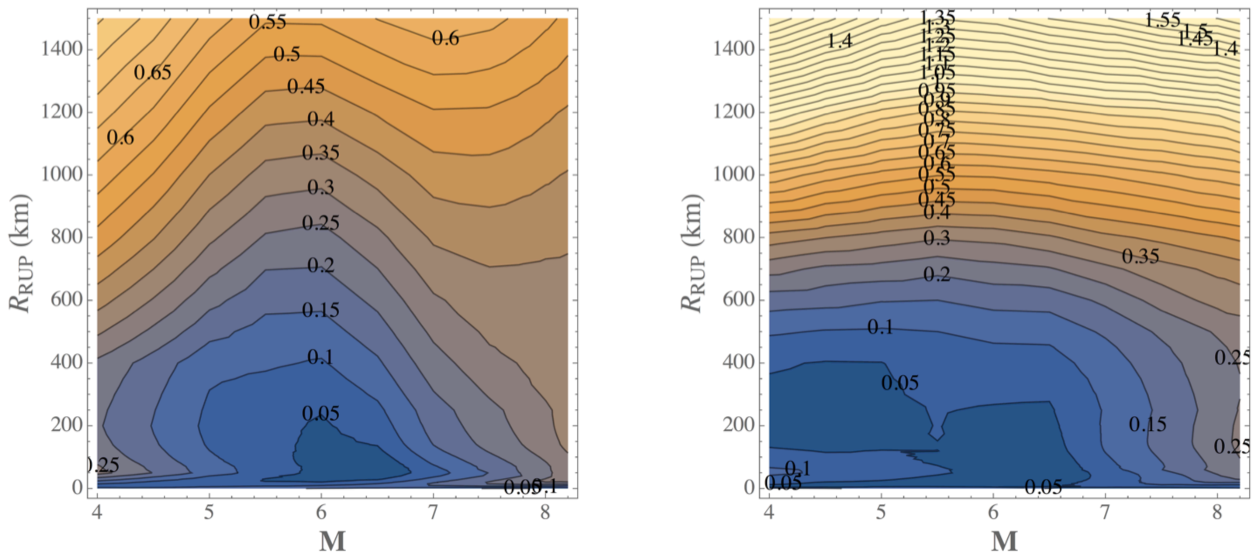


Figure E.3–7(a) Hazard results using the square exponential correlation model in the GMM sampling for 1 Hz at Manchester.

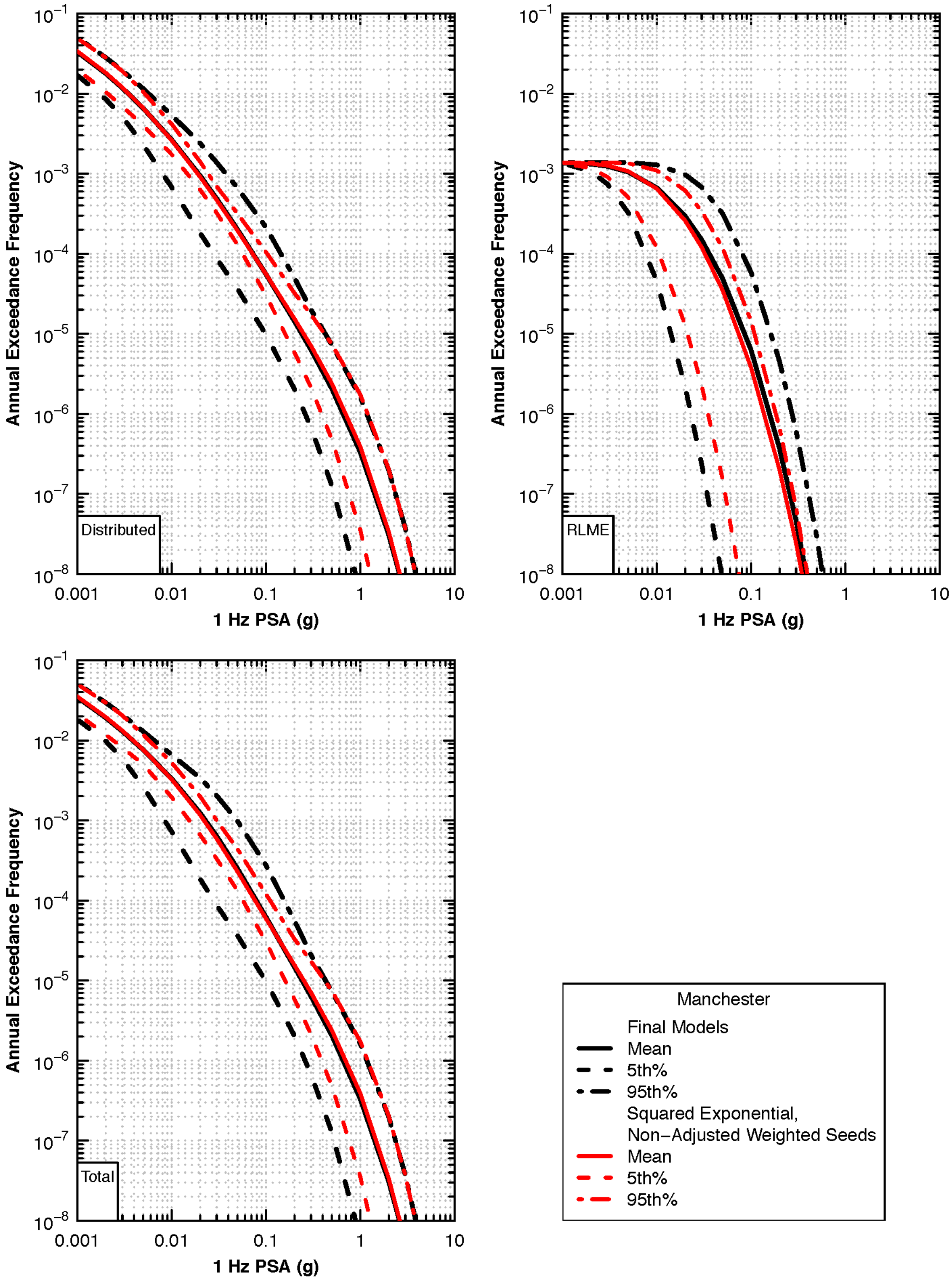


Figure E.3–7(b) Hazard results using the square exponential correlation model in the GMM sampling for 10 Hz at Manchester.

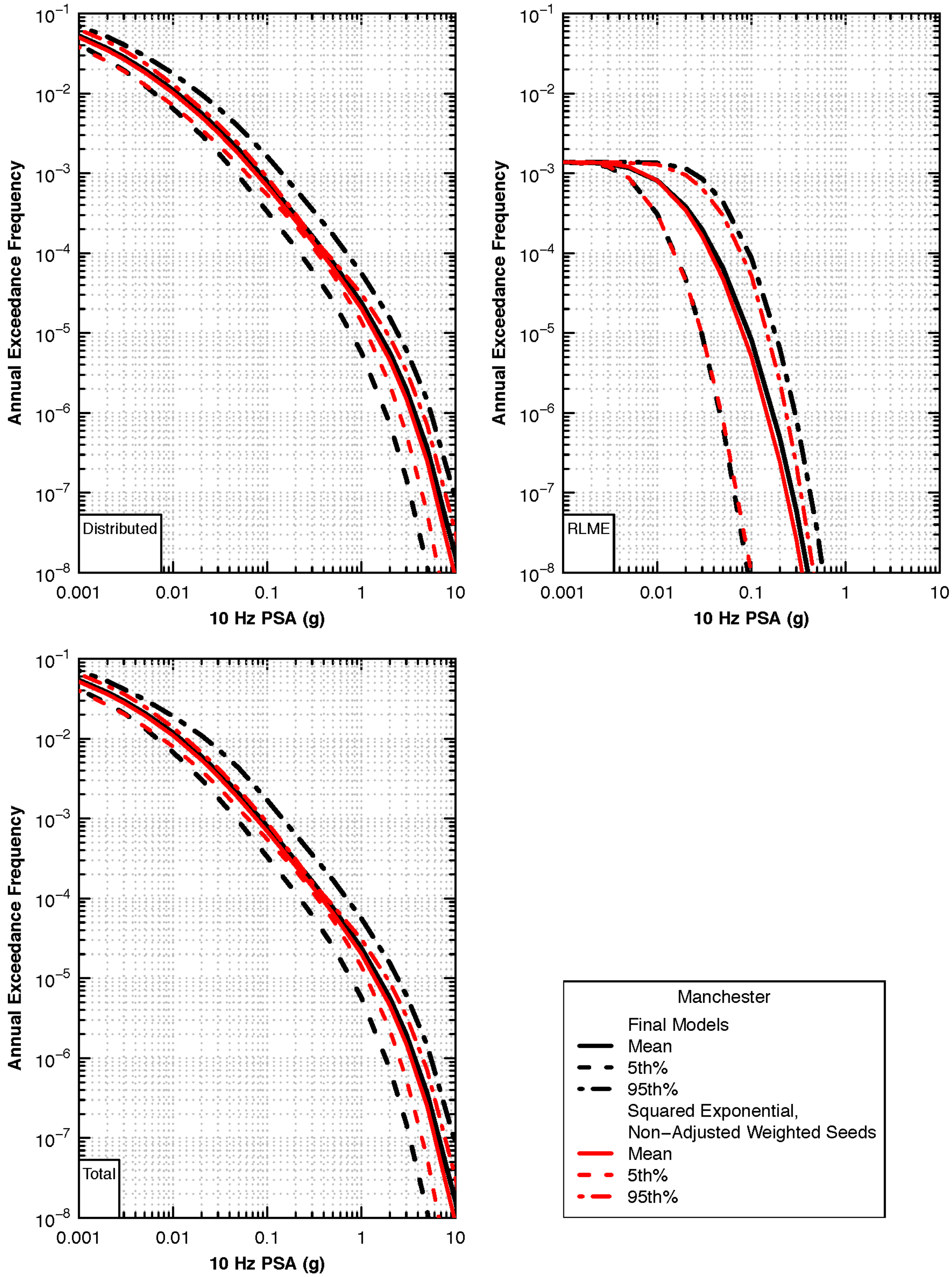


Figure E.3–8(a) Hazard results using the square exponential correlation model in the GMM sampling for 1 Hz at Central Illinois.

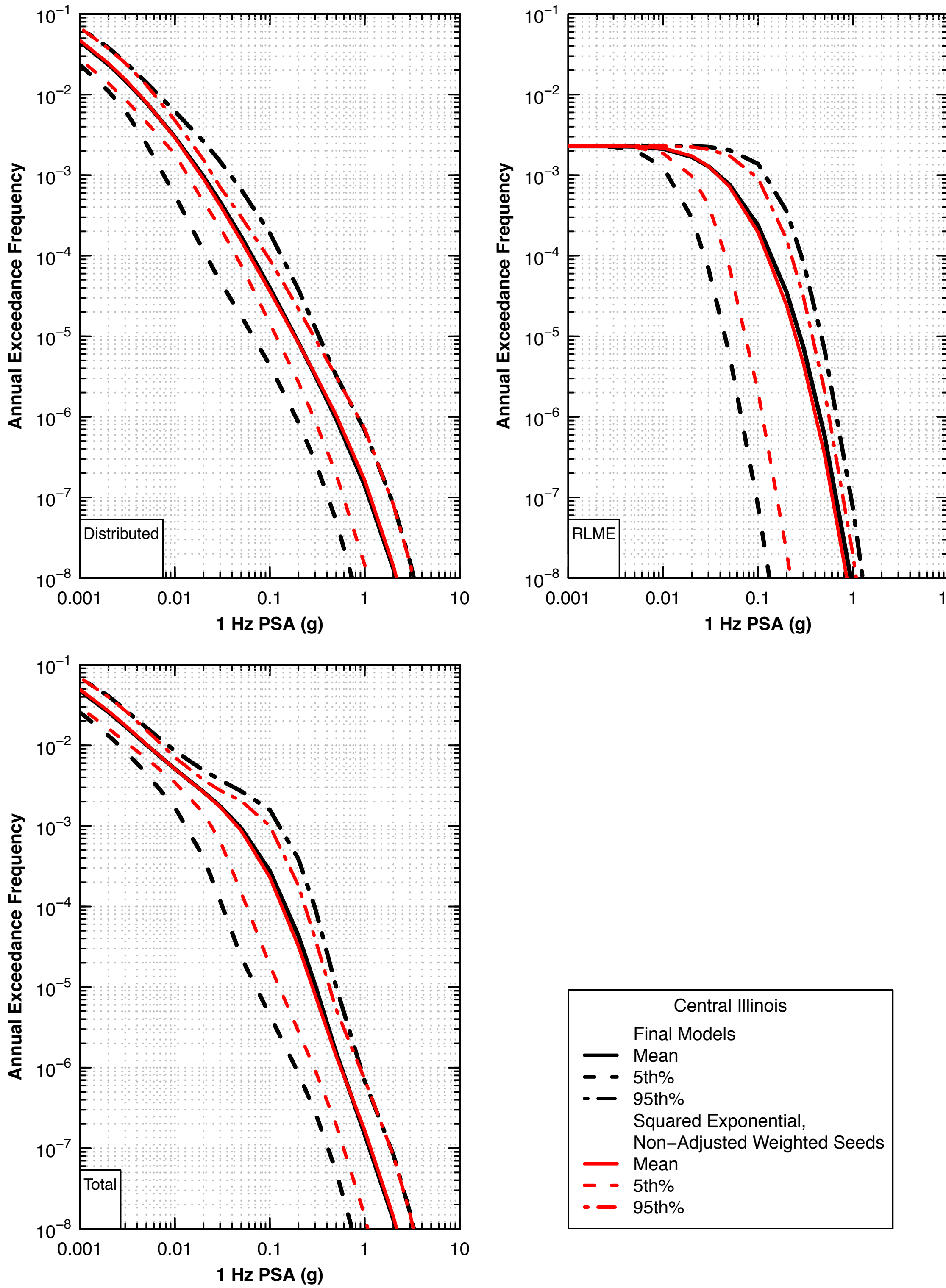


Figure E.3–8(b) Hazard results using the square exponential correlation model in the GMM sampling for 10 Hz at Central Illinois.

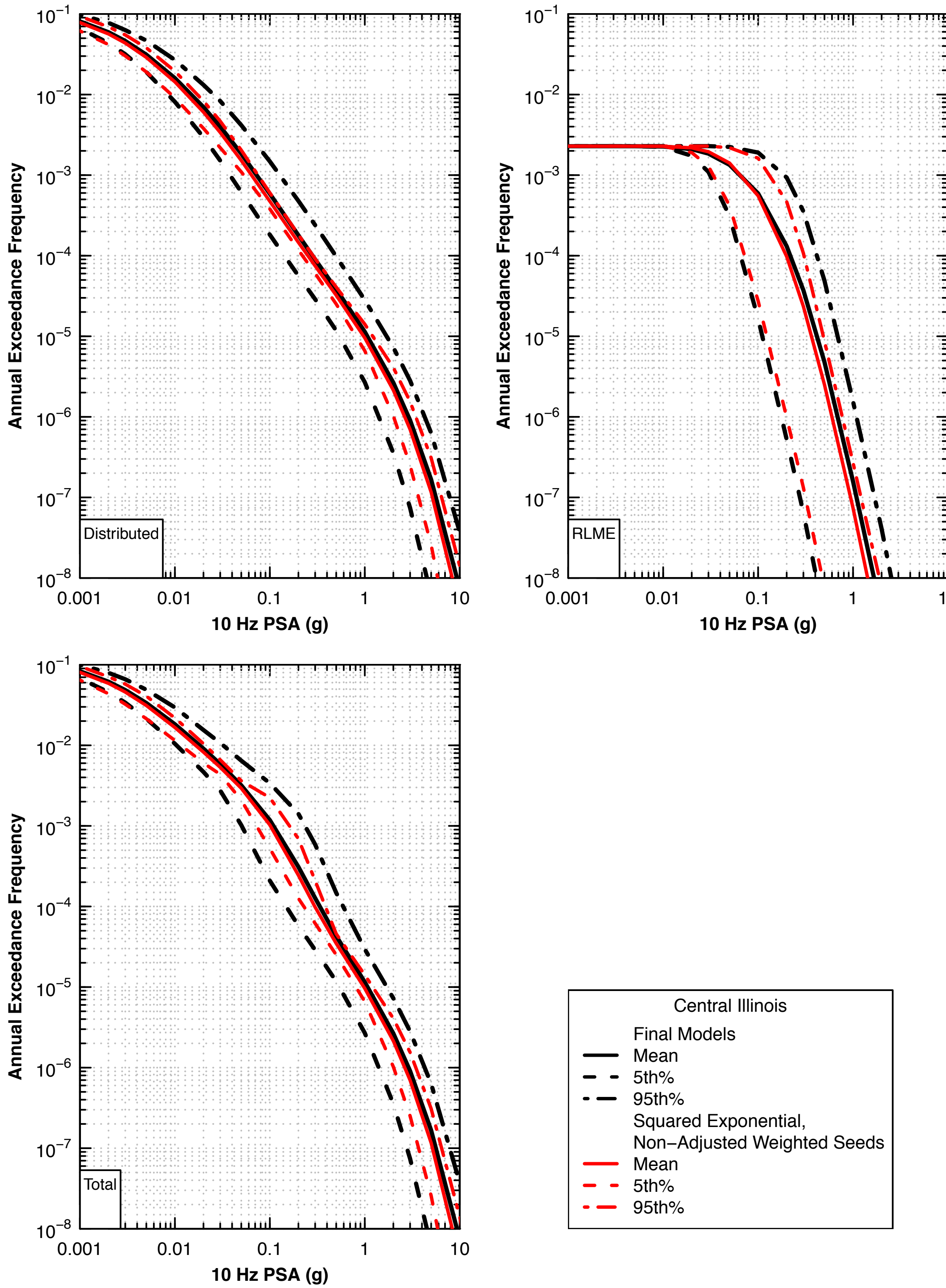


Figure E.3–9(a) Hazard results using the square exponential correlation model in the GMM sampling for 1 Hz at Savannah.

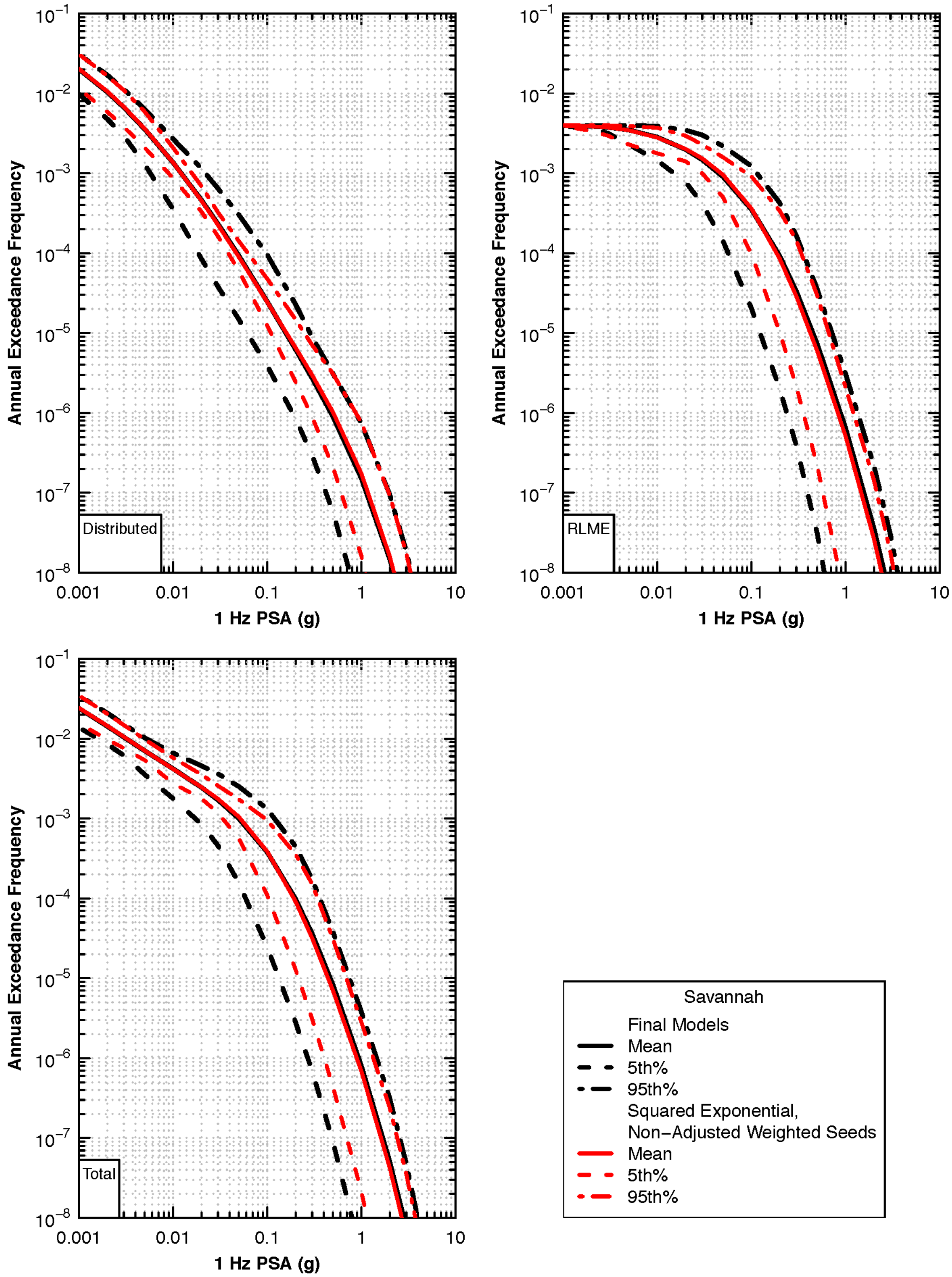


Figure E.3–9(b) Hazard results using the square exponential correlation model in the GMM sampling for 10 Hz at Savannah.

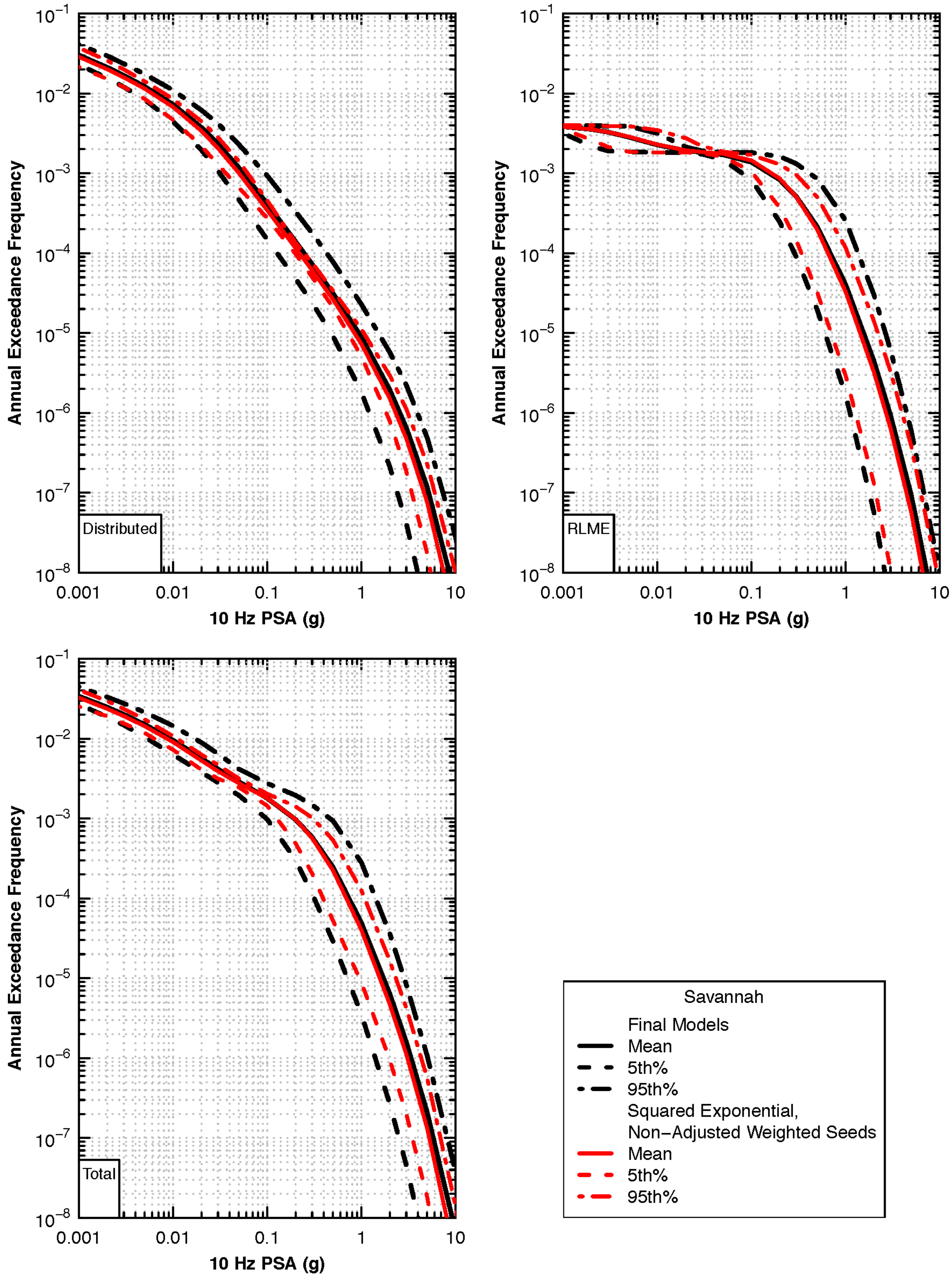


Figure E.3–10(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Manchester.

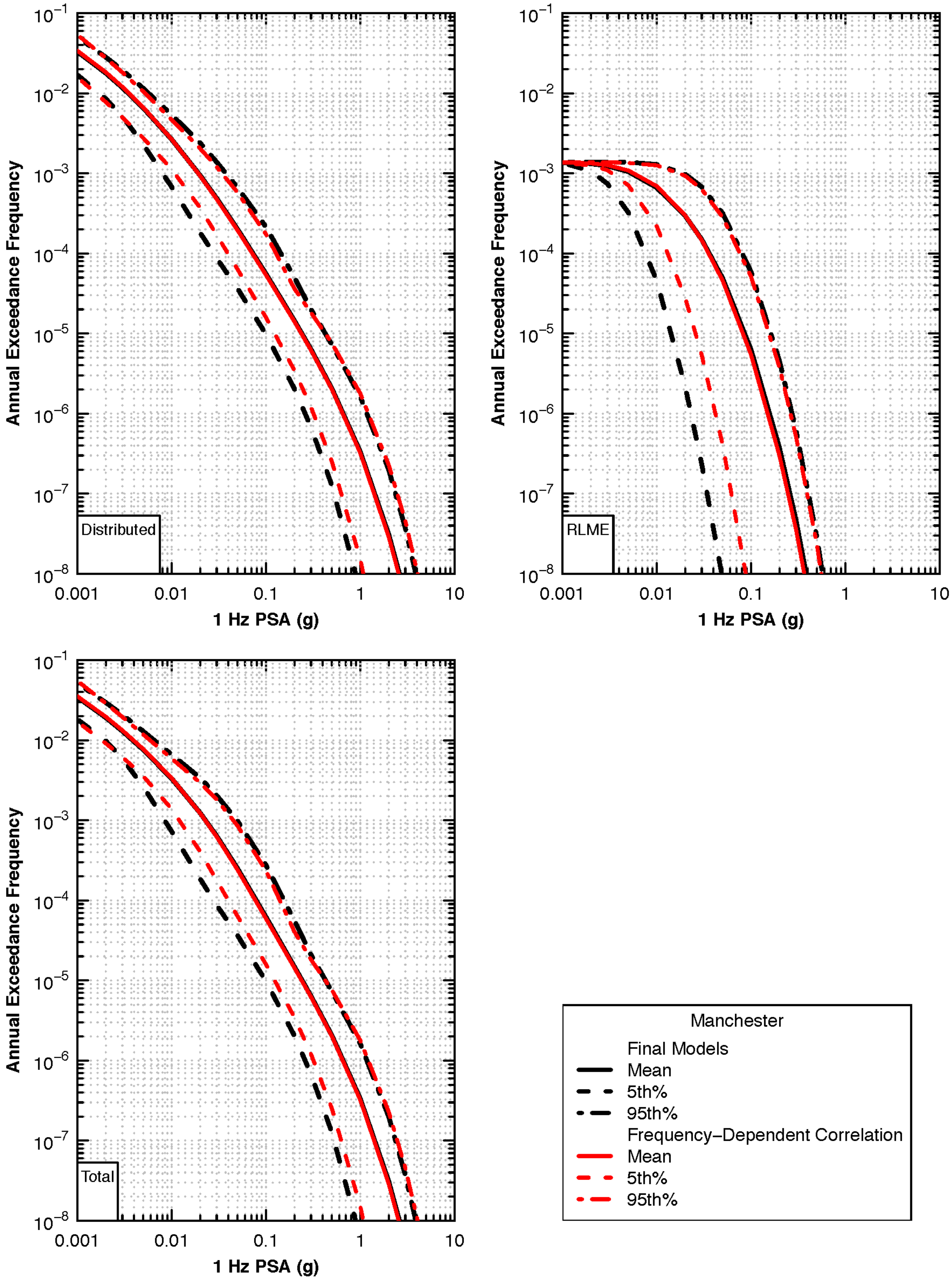


Figure E.3–10(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Manchester.

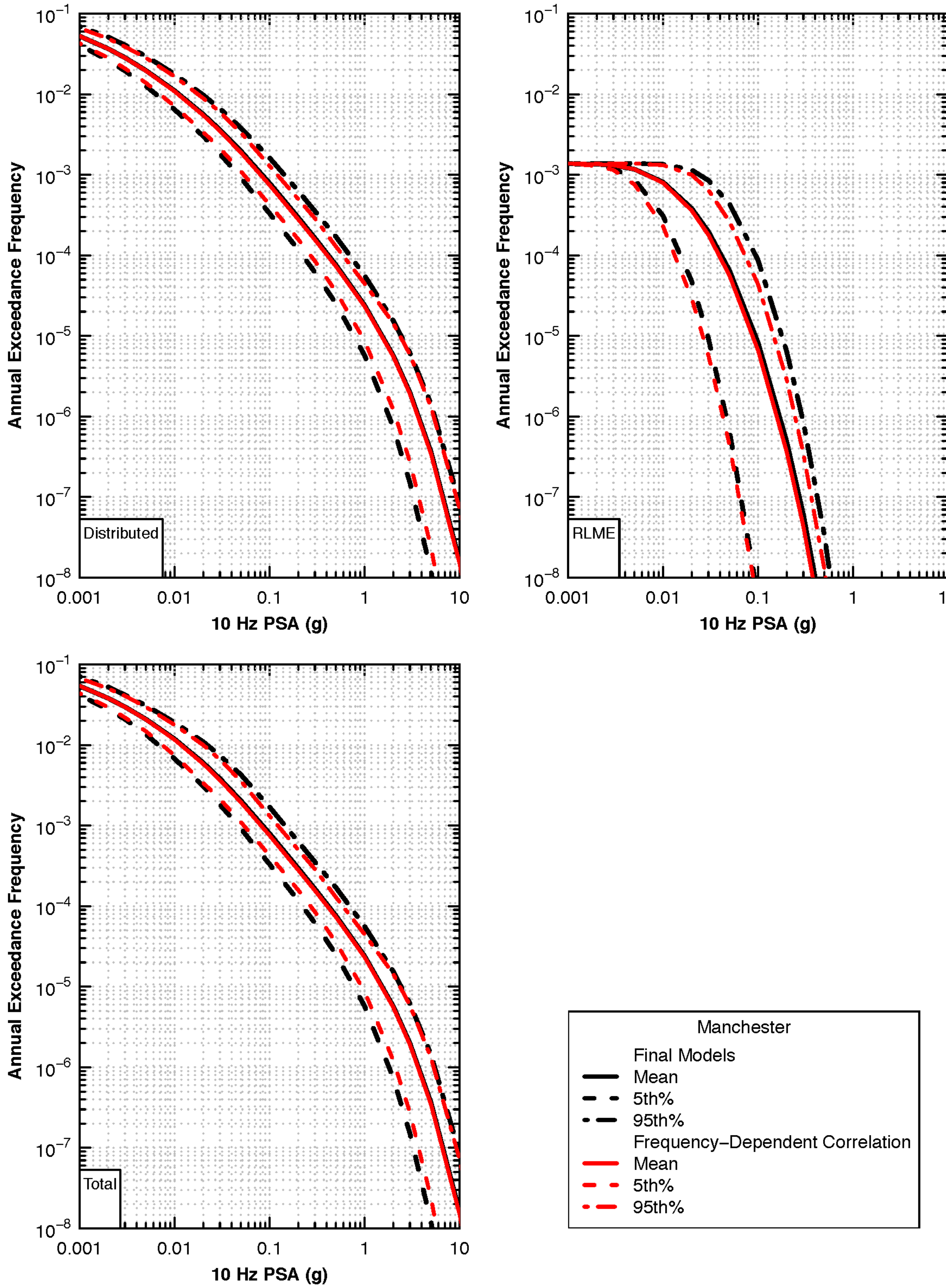


Figure E.3–11(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Central Illinois.

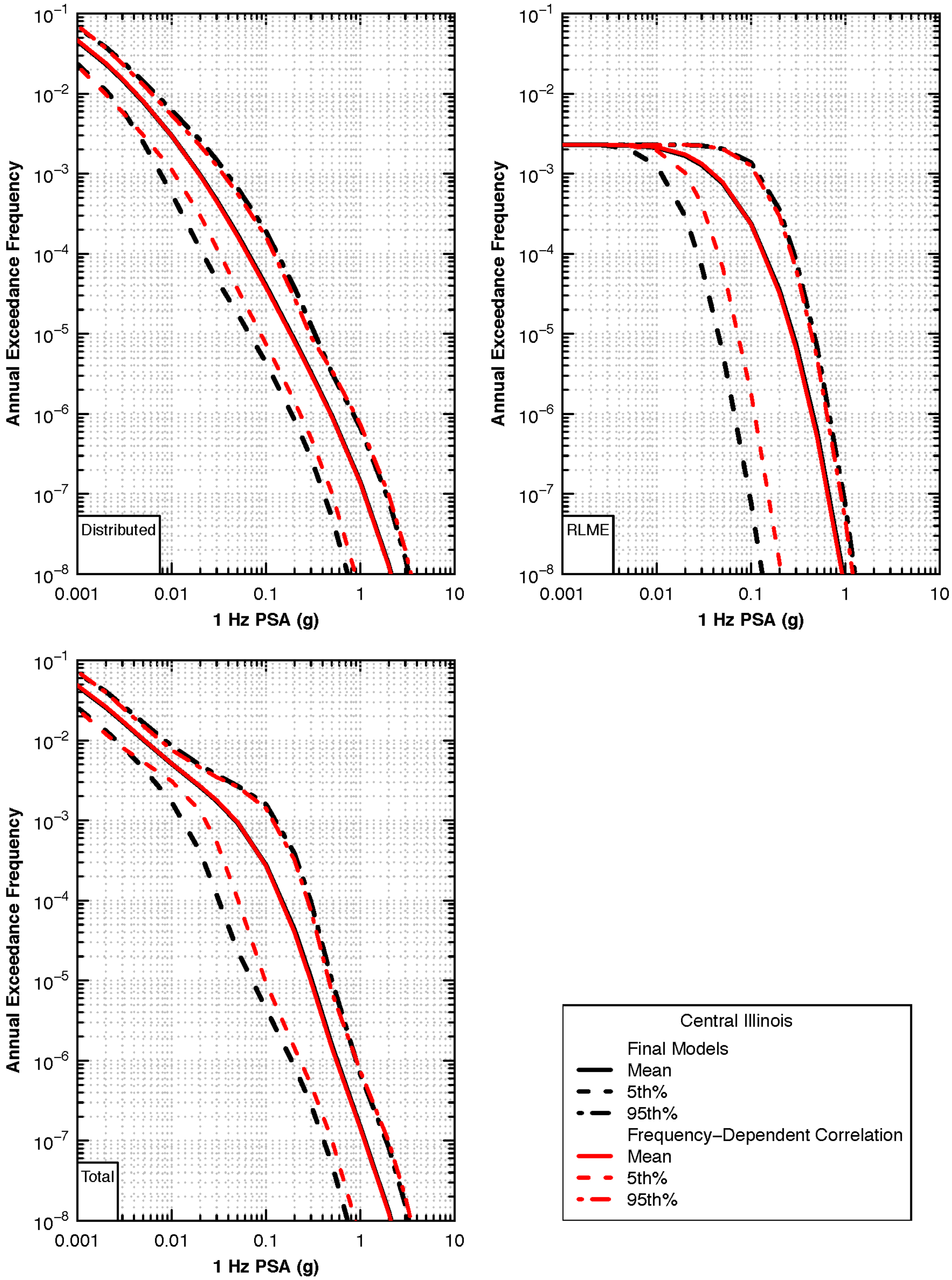


Figure E.3–11(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Central Illinois.

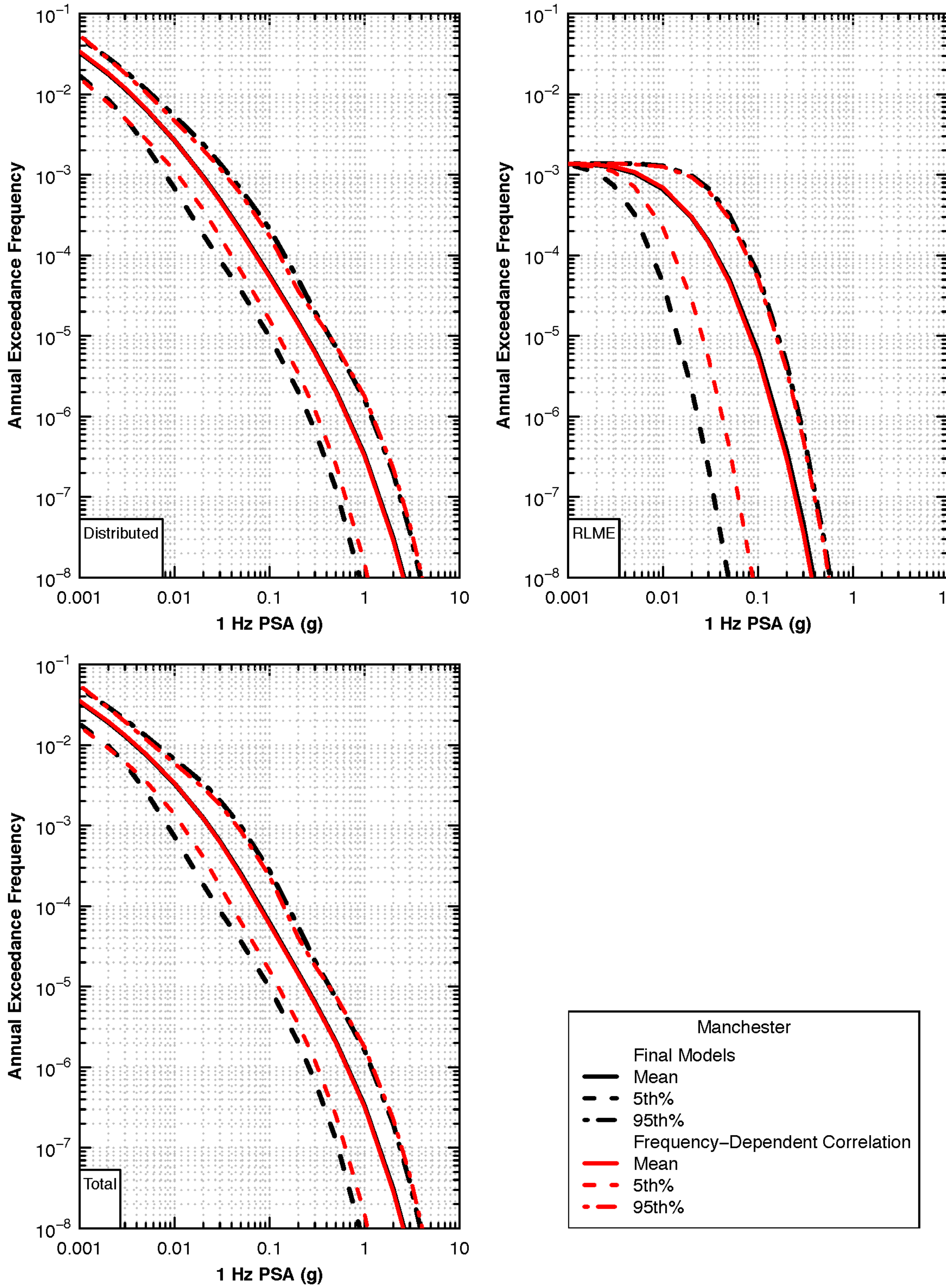


Figure E.3–12(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Savannah.

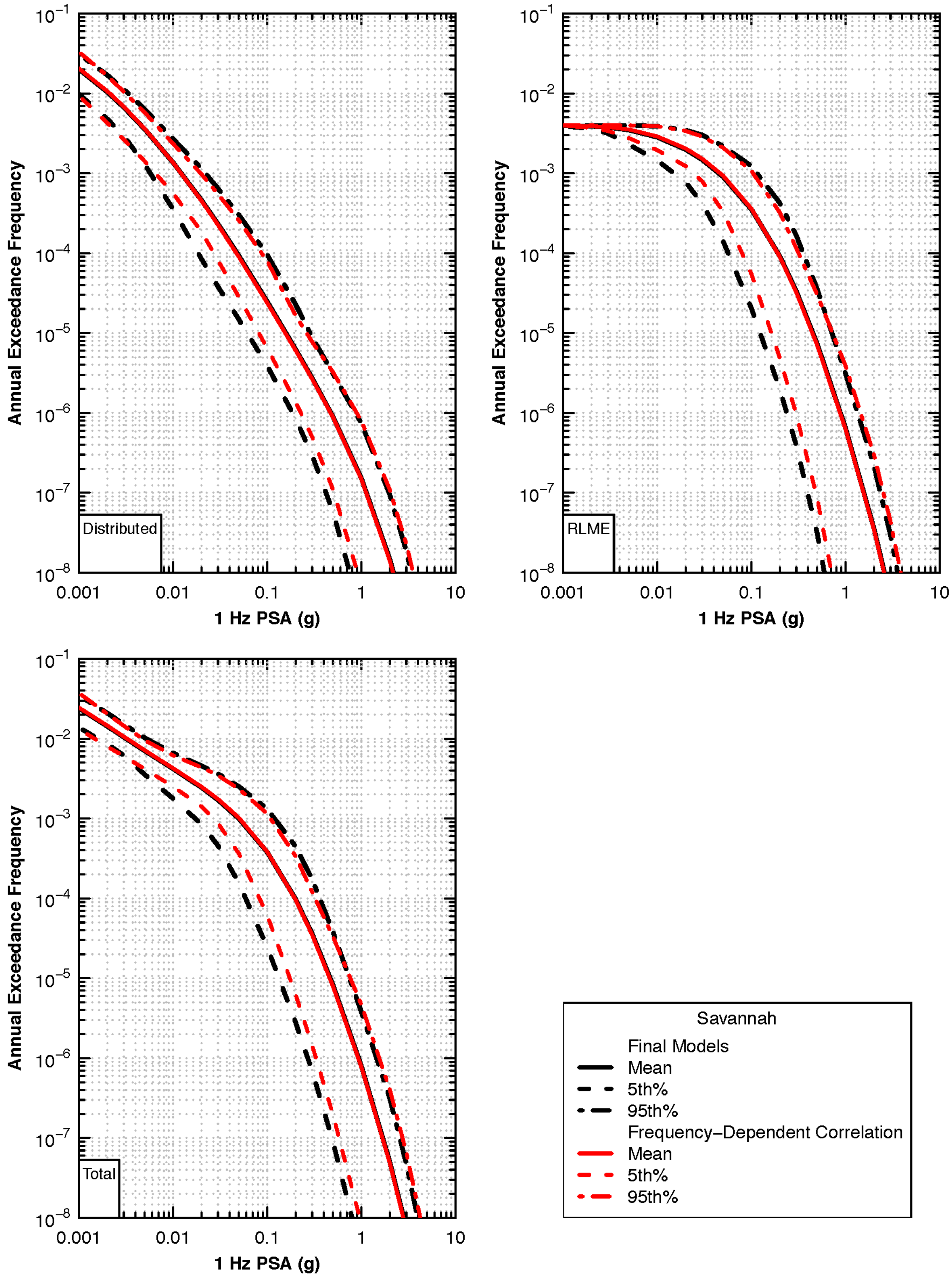


Figure E.3–12(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Savannah.

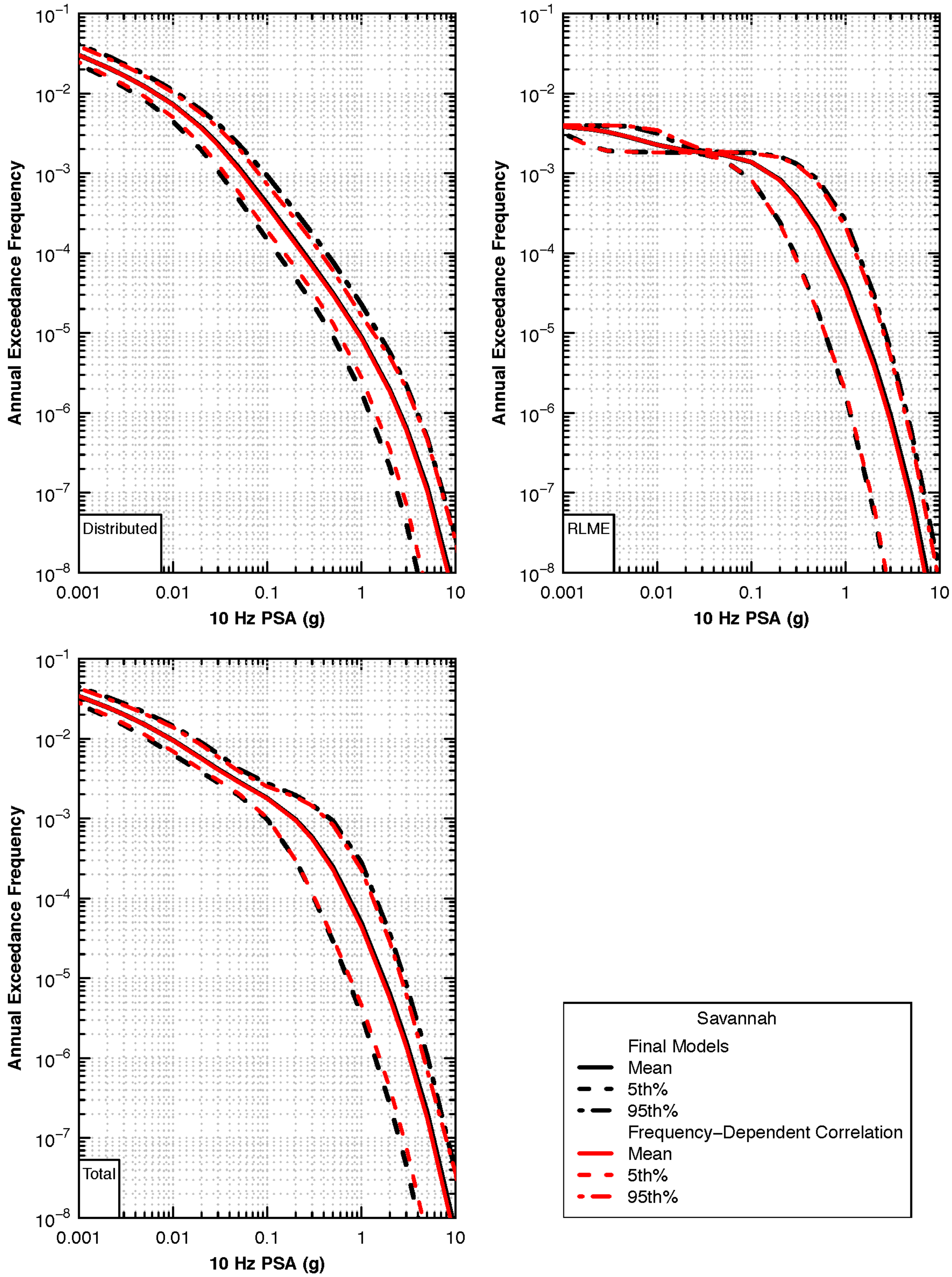
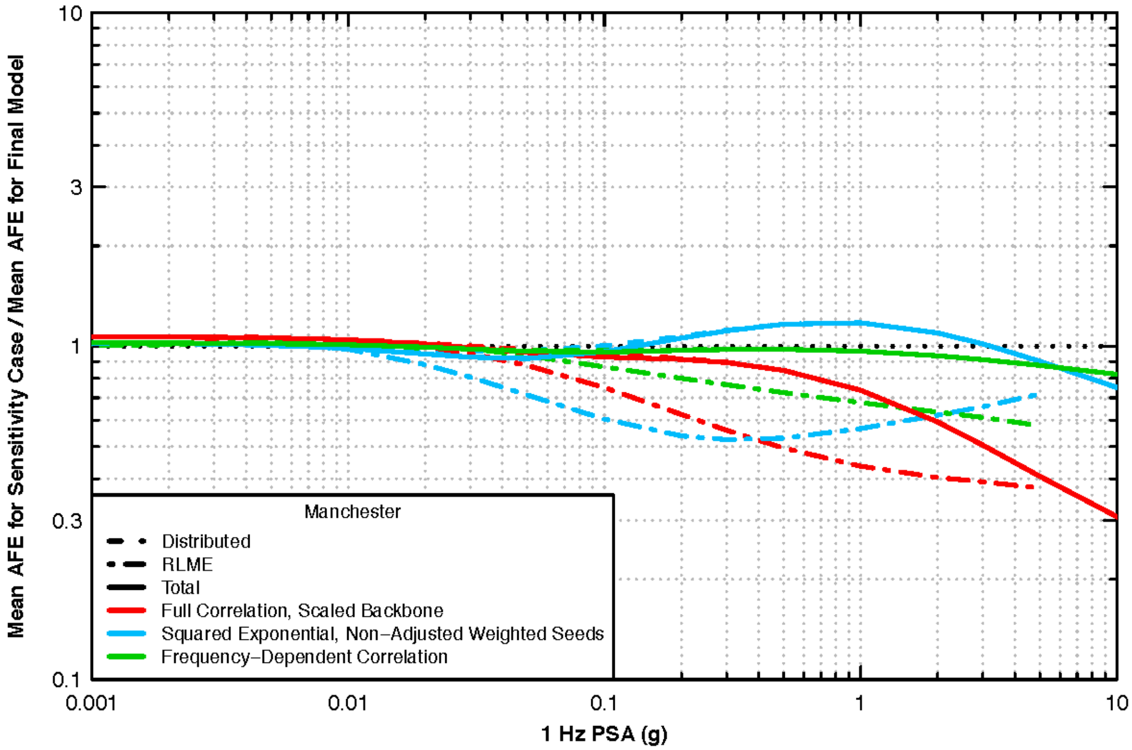


Figure E.3–13(a) Hazard ratio plots for correlation models in the GMM sampling for 1 and 10 Hz at Manchester.



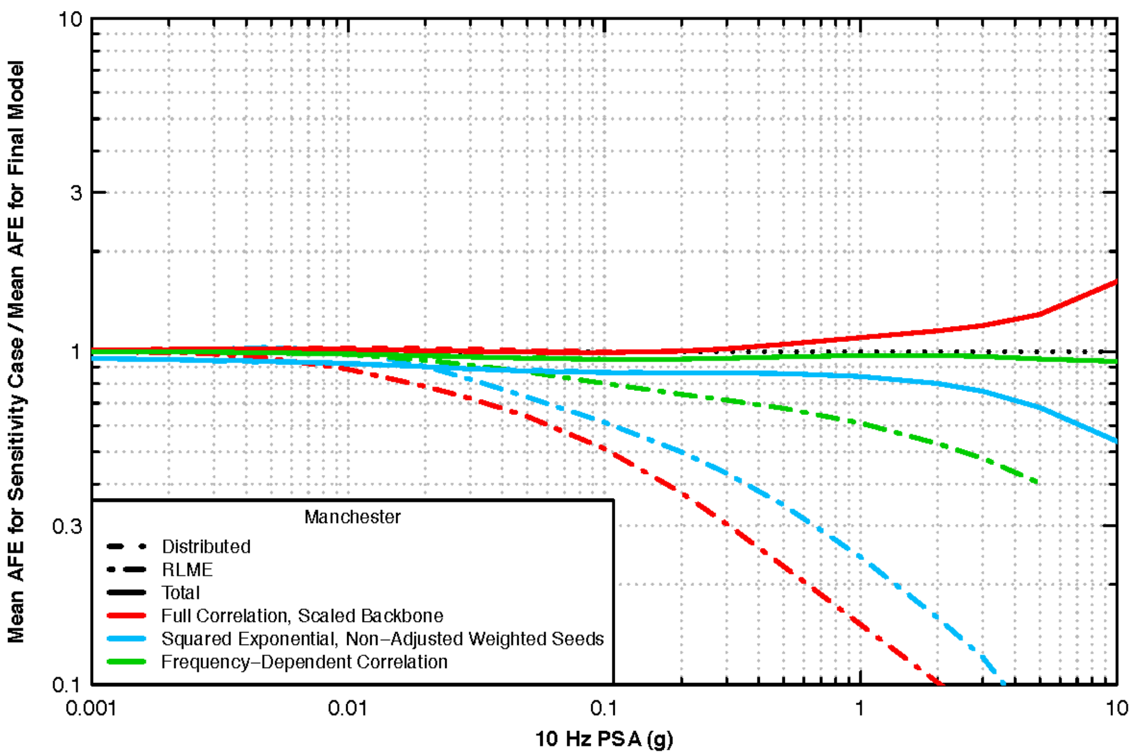
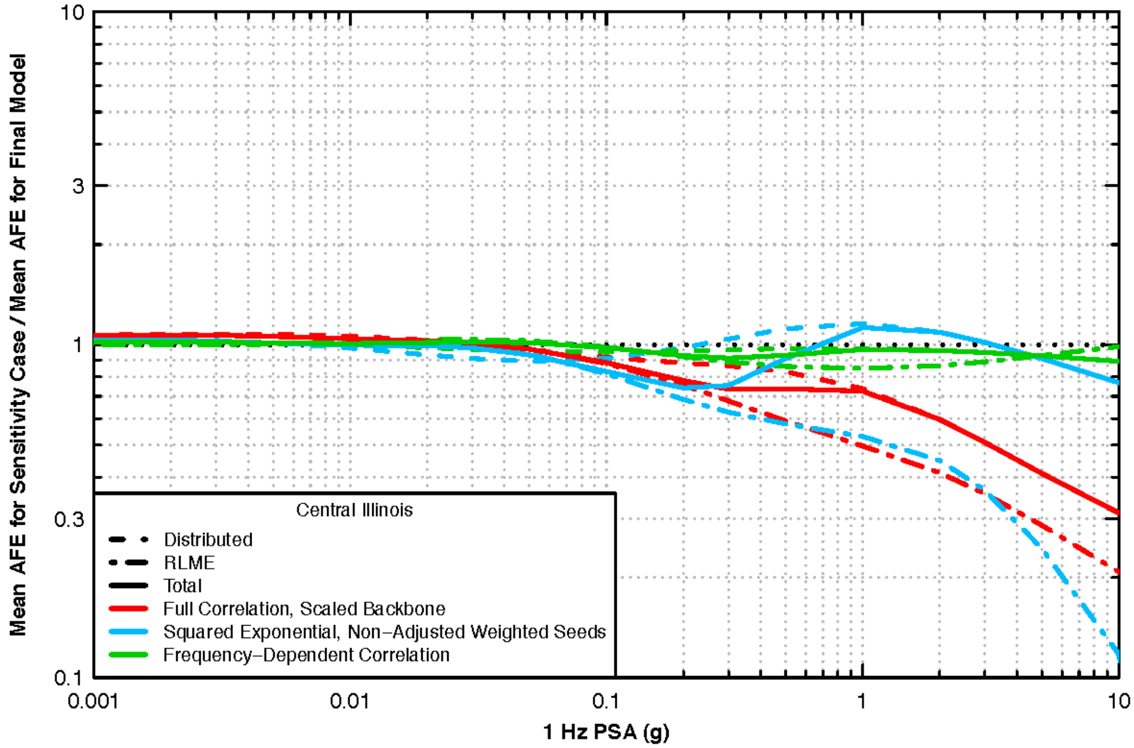


Figure E.3–13(b) Hazard ratio plots for correlation models in the GMM sampling for 1 and 10 Hz at Central Illinois.



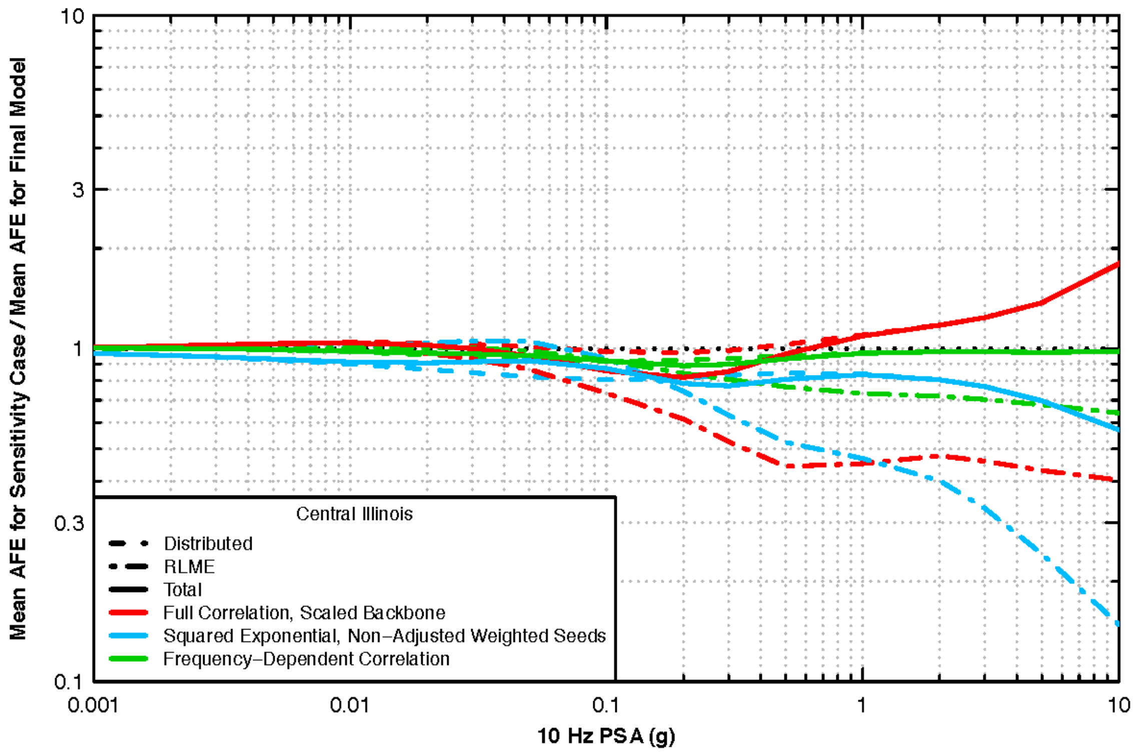
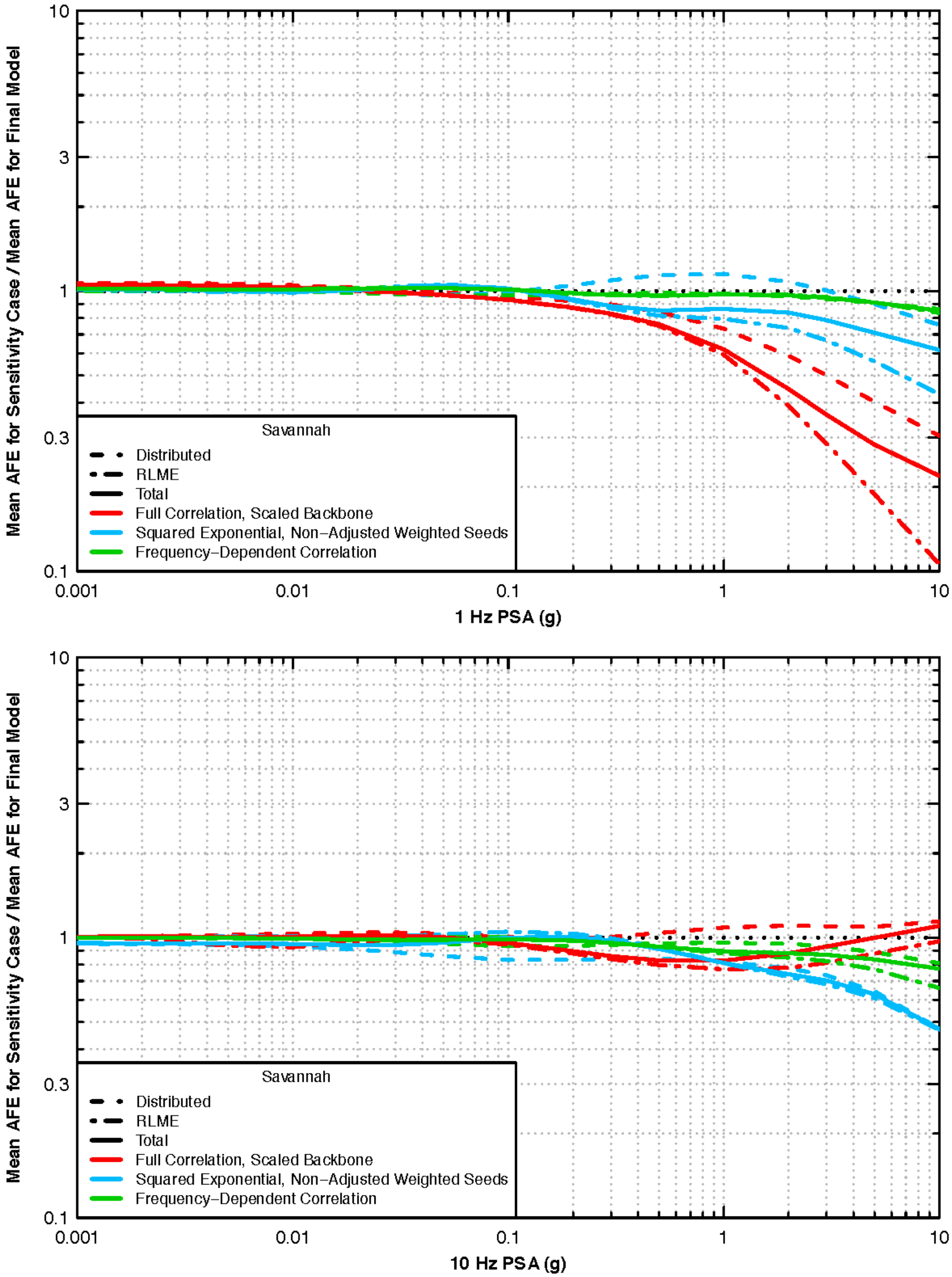


Figure E.3–13(c) Hazard ratio plots for correlation models in the GMM sampling for 1 and 10 Hz at Savannah.



E.4 Sensitivity to Initial Weights

Section 8.3.1 explained how the proximity in Sammon's map space was used to define the initial weight assigned to each seed GMM for the sampling process (Figure 8–27). Also shown were hazard sensitivity results for the Manchester site. This section shows the hazard sensitivity results for all three sites in Figures E.4–1 to E.4–3, with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz, and part (c) showing the hazard ratio for both frequencies.

Results for three cases are presented:

- Grid-based weights as used in the Final Model development (black)
- Alternate grid-based weights (blue)
- Equal weights to all the seed GMMs (red)

Overall, the results show minimal differences in the mean hazard. Differences between alternate grids are not very significant in terms of shape (blue), although the lower fractiles are somewhat sensitive to the weighting models. For the 10-Hz case, the results are not very different between the three alternatives. The equal case weight provides the most difference with the largest difference seen in the upper fractile between the equally-weighed seeds relative to the final models for the RLME and total hazard at 1 Hz. The results are as expected and infer that giving similar GMMs the same weight instead of dividing the weight among them tends to narrow the distribution and, hence, the hazard for certain scenarios. The equal weight case effectively translates the assumption of *confirmatory* GMMs into the hazard curves. As discussed in Chapter 8, the TI team didn't agree that this was supported by data. Hence, the grid-weighting approach achieved the TI team's goal of getting a distribution closer to a mutually exclusive, collectively exhaustive one.

Figure E.4–1(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Manchester.

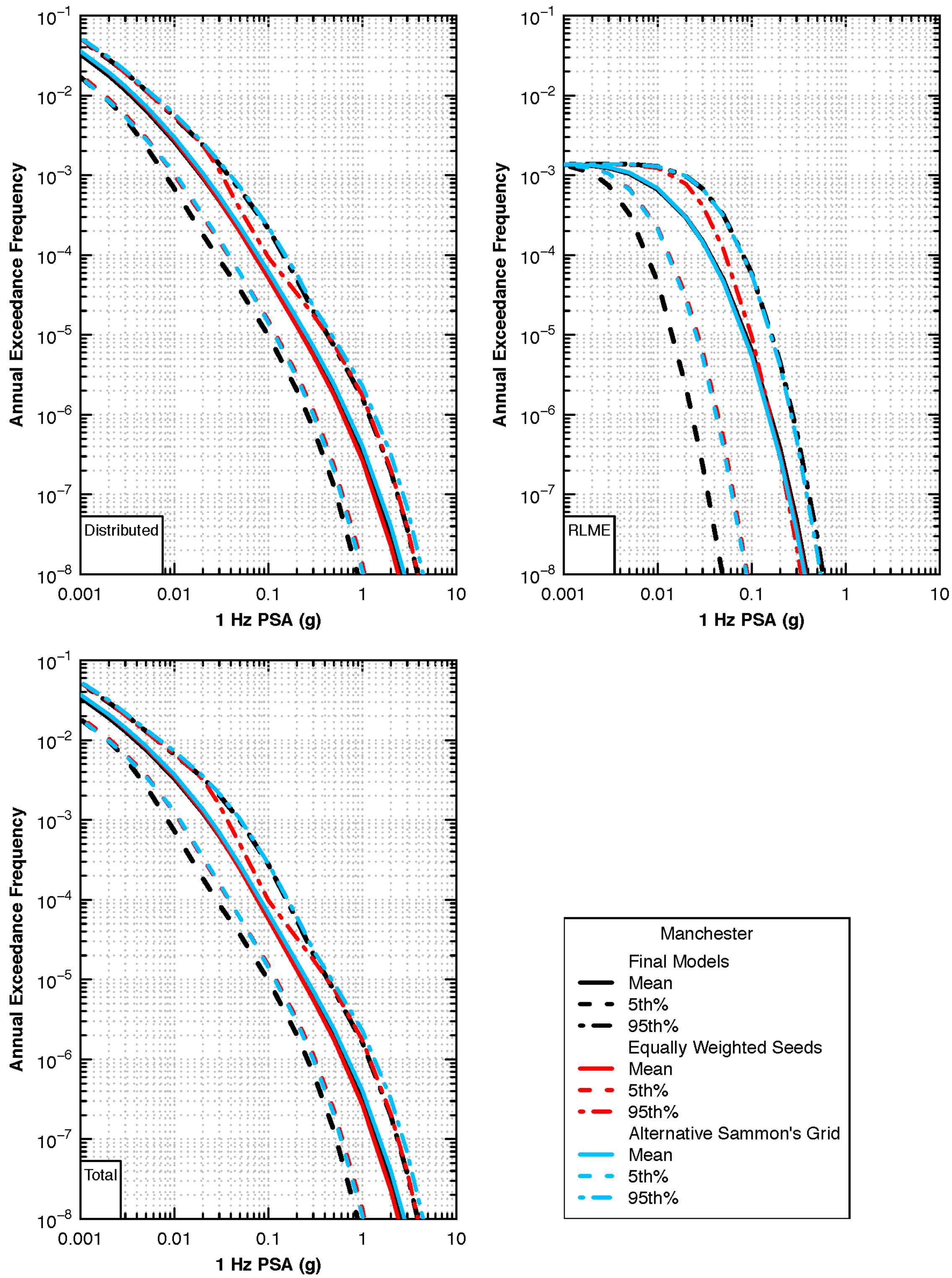


Figure E.4–1(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Manchester.

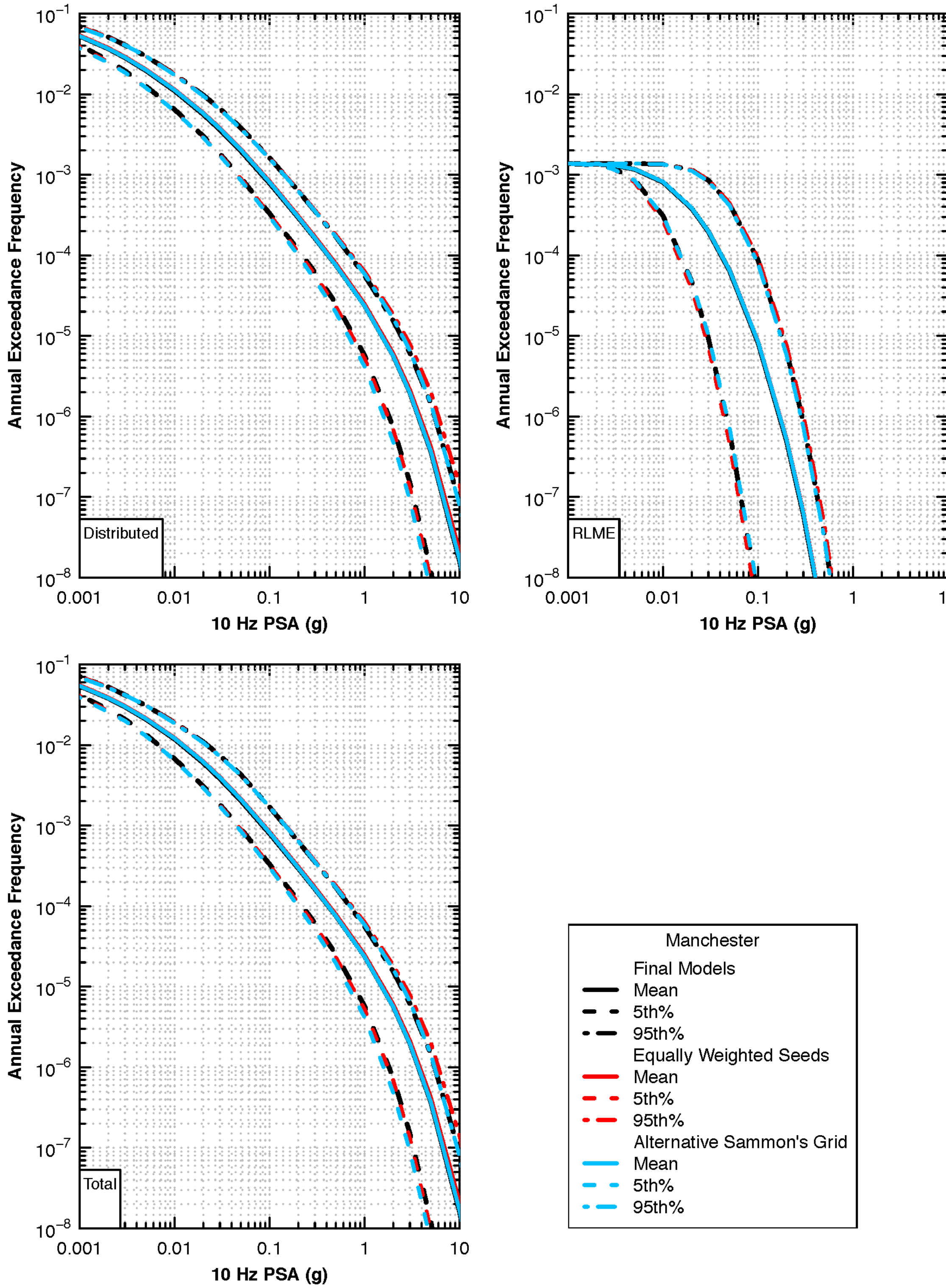
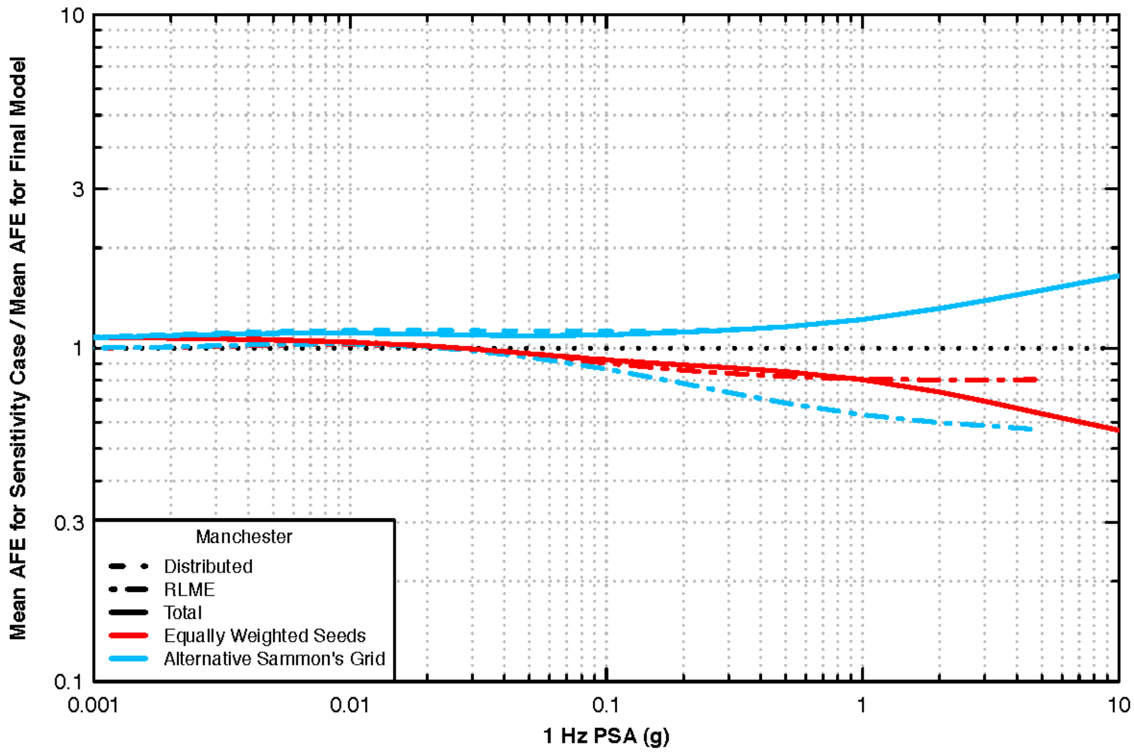


Figure E.4–1(c) Hazard ratio for the frequency-dependent correlation model parameters in the GMM sampling for 1 and 10 Hz at Manchester.



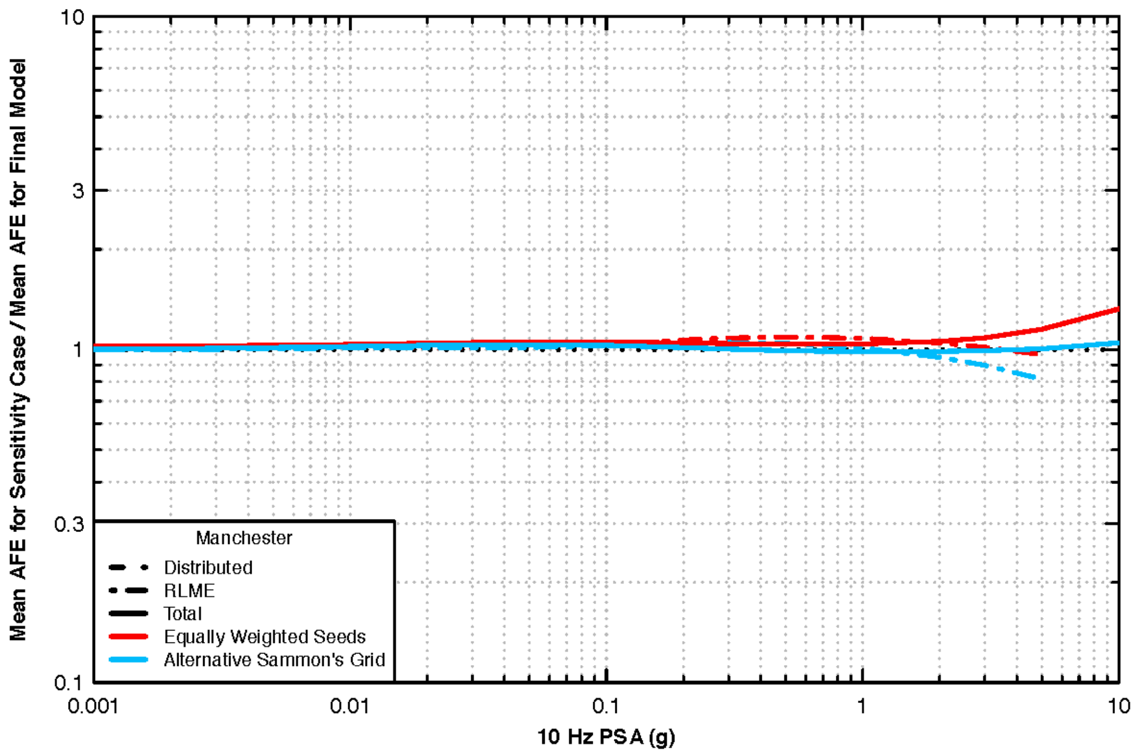


Figure E.4–2(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Central Illinois.

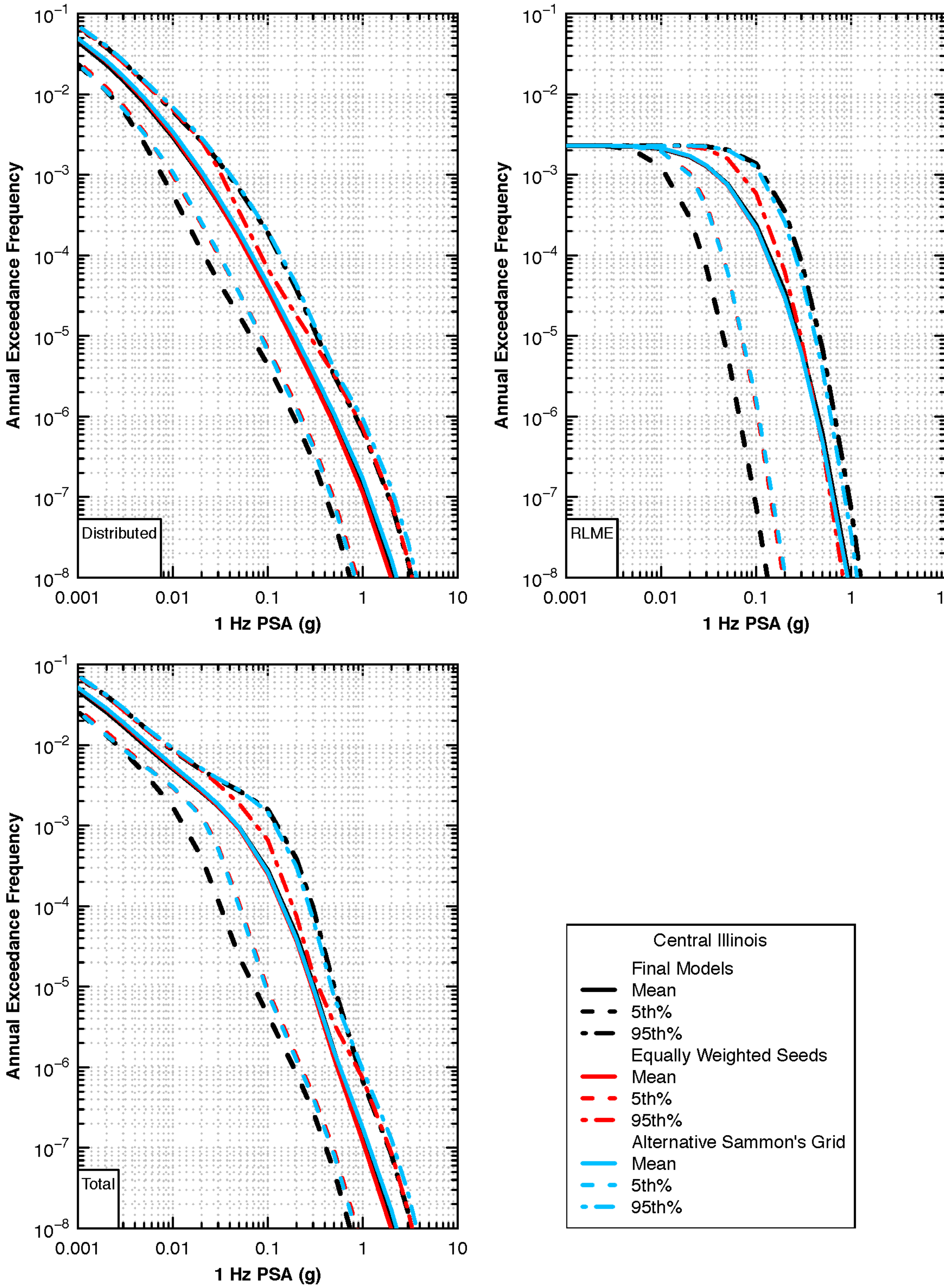


Figure E.4–2(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Central Illinois.

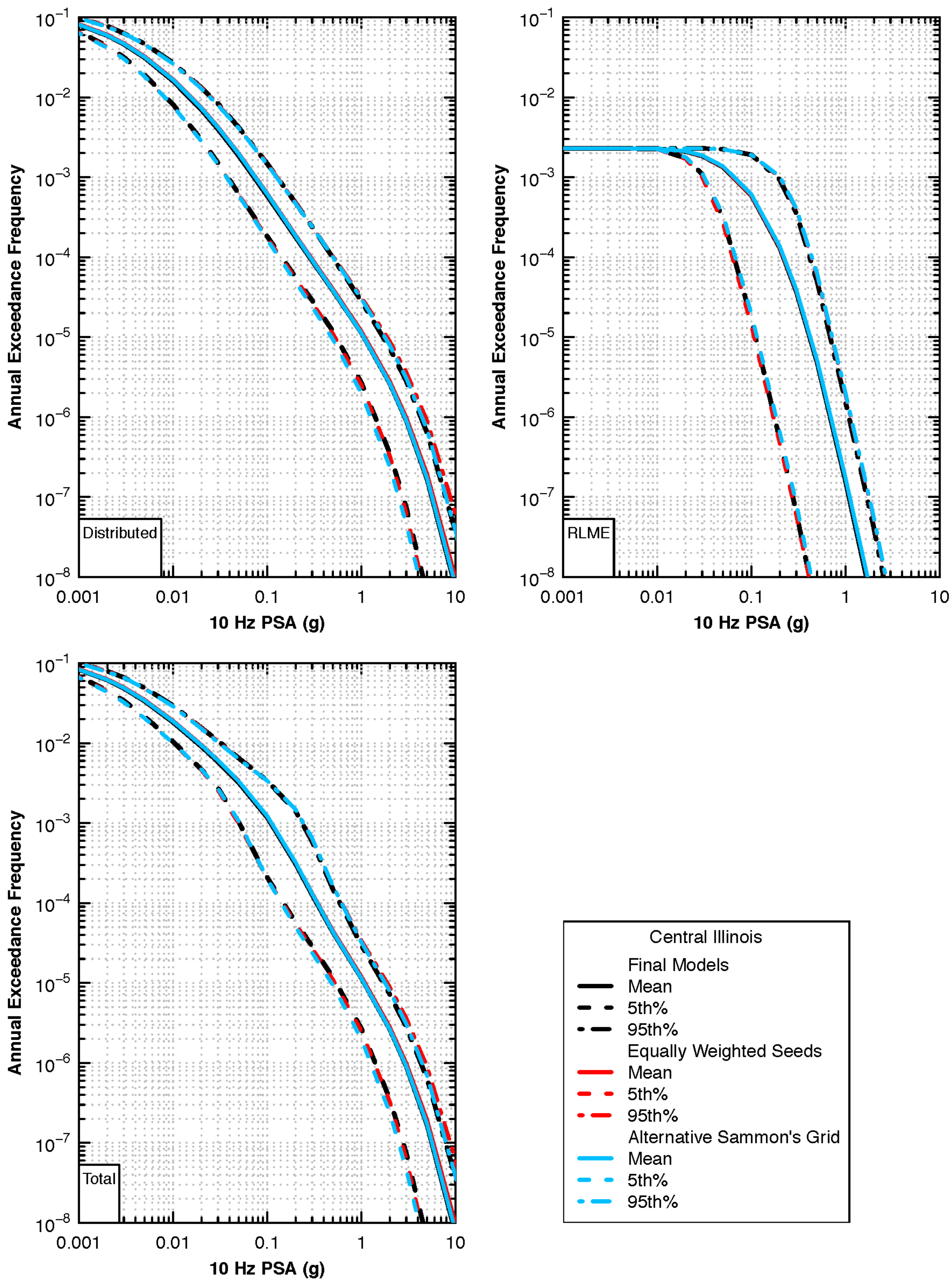
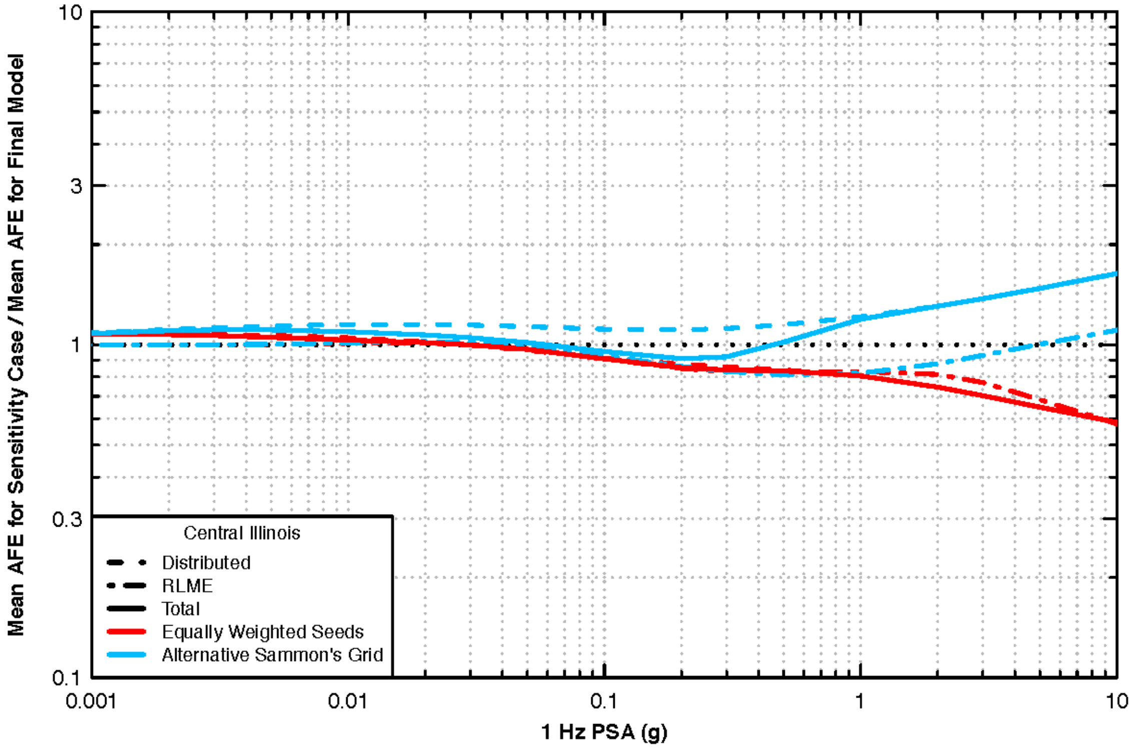


Figure E.4–2(c) Hazard ratio for the frequency-dependent correlation model parameters in the GMM sampling for 1 and 10 Hz at Central Illinois.



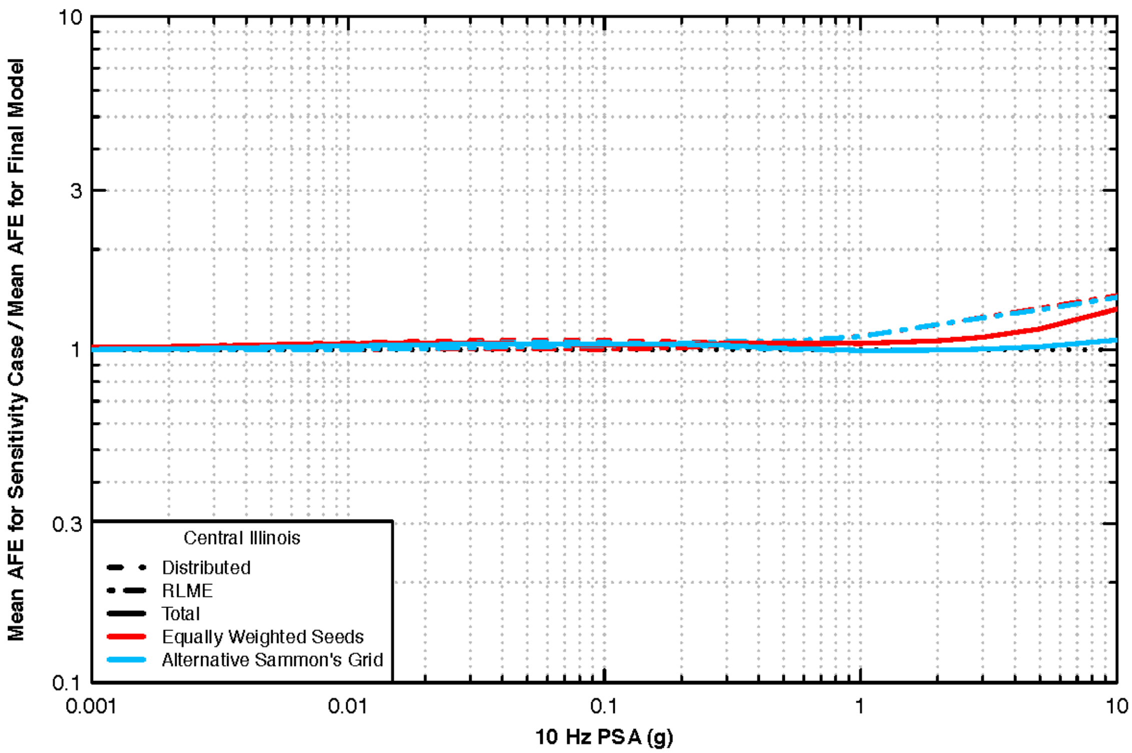


Figure E.4–3(a) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 1 Hz at Savannah.

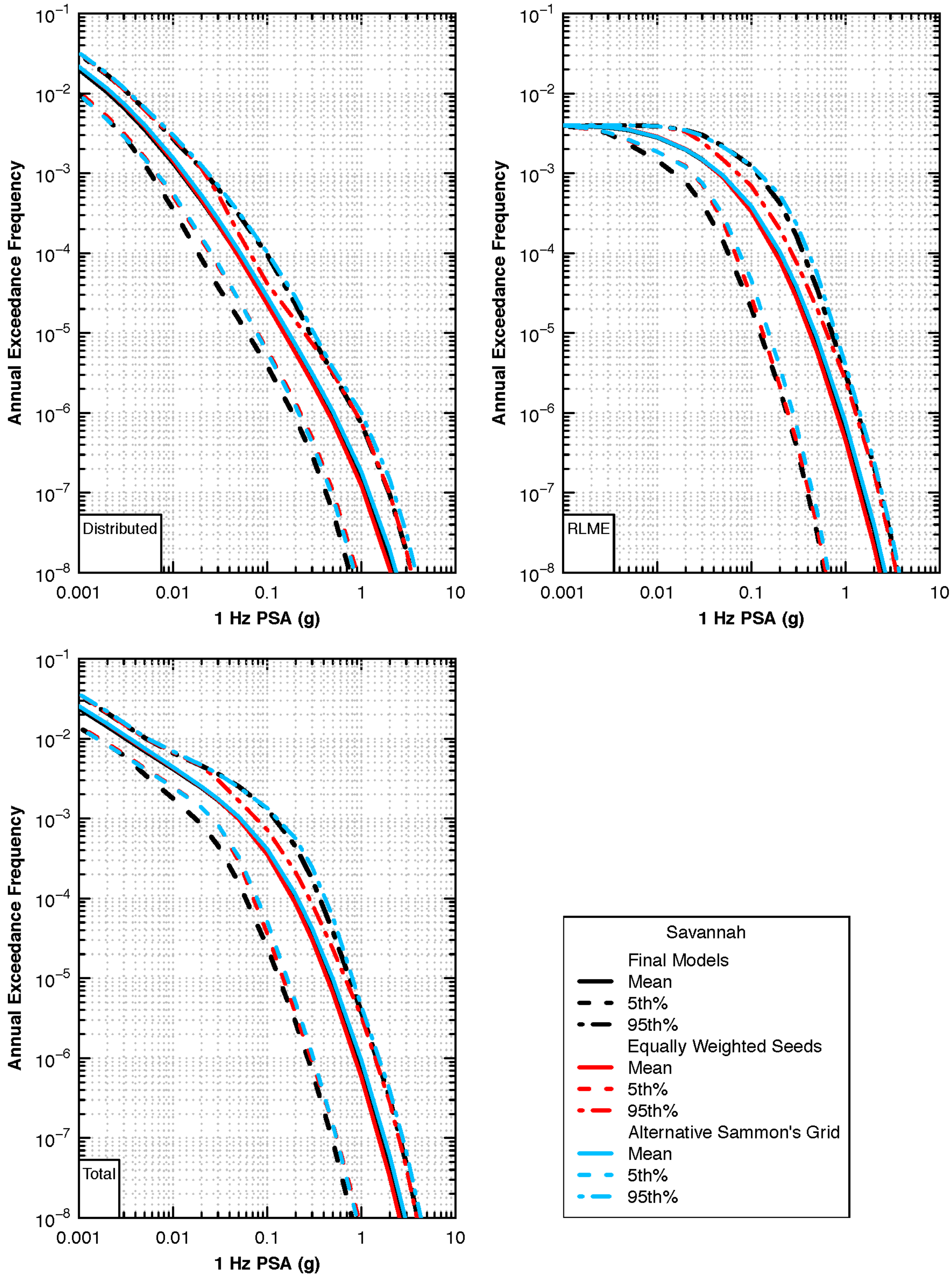


Figure E.4–1(b) Hazard results using the frequency-dependent correlation model parameters in the GMM sampling for 10 Hz at Savannah.

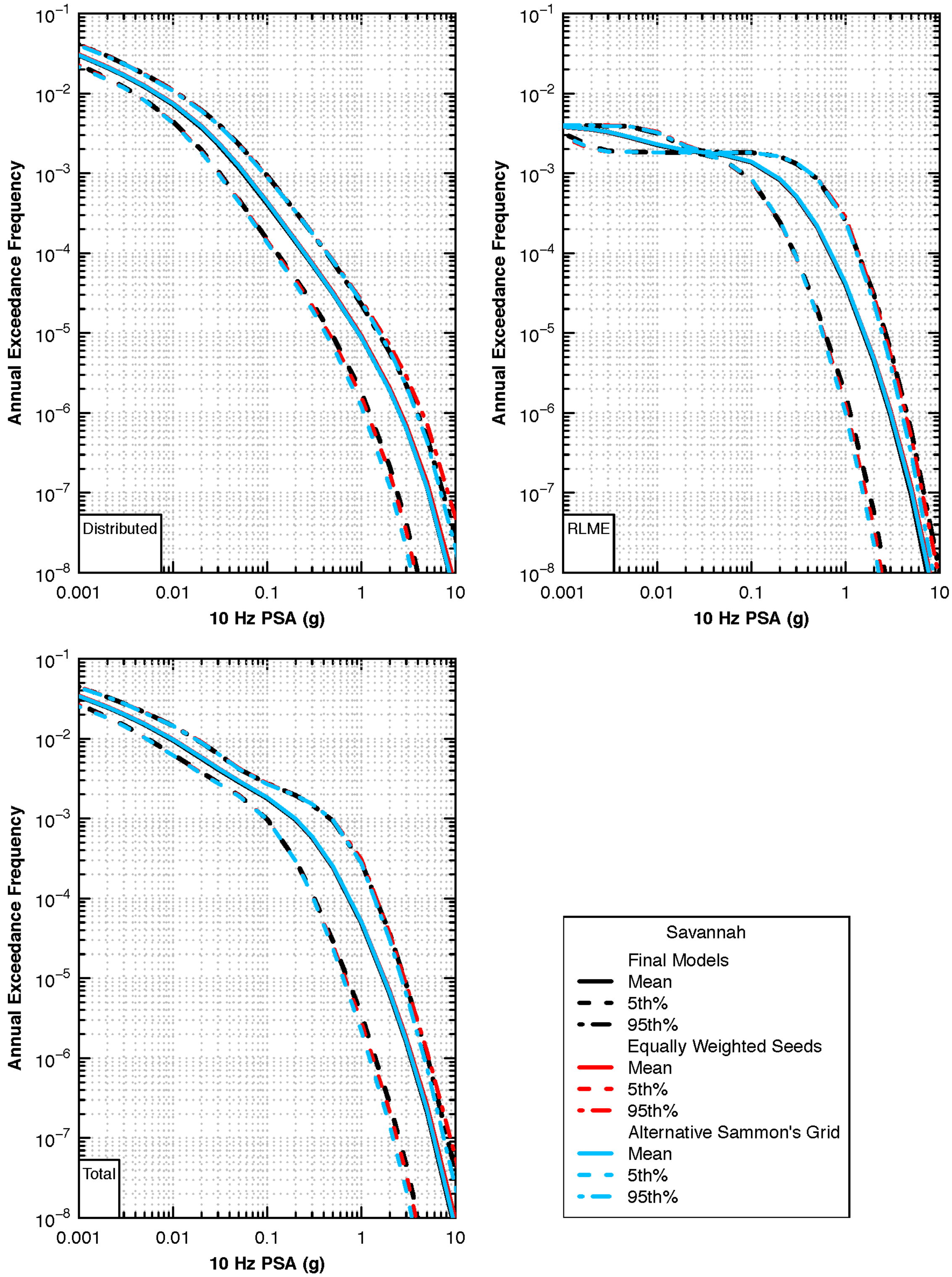
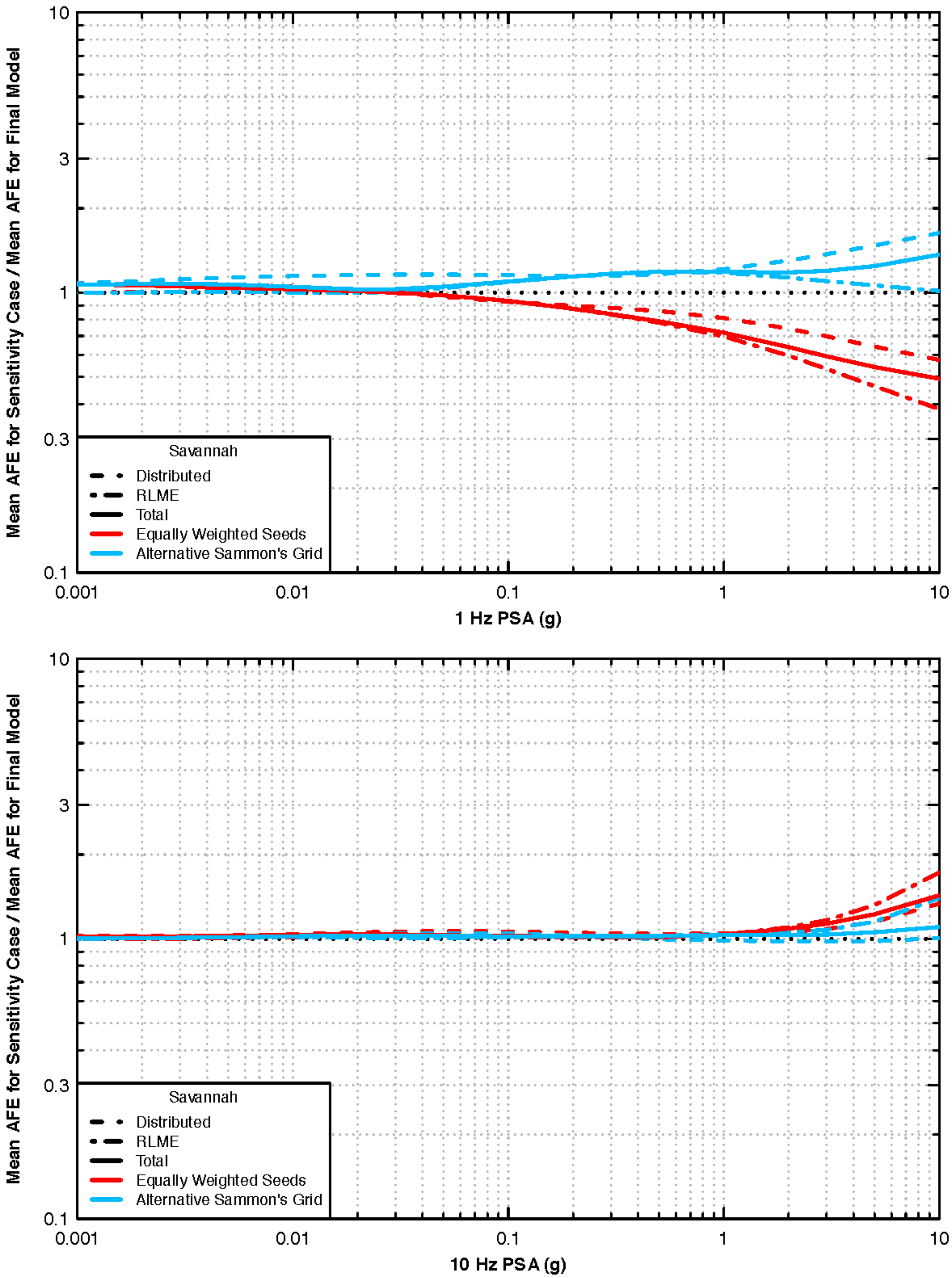


Figure E.4–3(c) Hazard ratio for the frequency-dependent correlation model parameters in the GMM sampling for 1 and 10 Hz at Savannah.



E.5 Sensitivity to Scenarios Considered in Sammon's Maps

In this section, the sensitivity with respect to the scenarios underlying the calculation of the Sammon's maps (1969) is investigated. For the NGA-East GMMs, Sammon's maps were calculated for 220 scenarios with $4 \leq \mathbf{M} \leq 8$, and $1 \leq R_{RUP} \leq 1500$ km. In this section, models are generated based on maps that use a different number of scenarios. The correlation function and its parameters are the same as for the NGA-East GMMs.

The selection of scenarios for the Sammon's map computation has an impact on the distribution of the resulting GMMs. The TI team investigated alternative weighting of the **M** and R_{RUP} scenarios in the development of the Sammon's maps. The primary approach was to assign equal weight to all of the 220 scenarios. However, an alternative interpretation may be that because a scenario such as **M**4 at R_{RUP} = 1000 km has essentially zero contribution to hazard, it should have much lower (or no) weight in defining the Sammon's maps compared to other scenarios (e.g., **M**6 at R_{RUP} = 50 km) that have a significant contribution to hazard. This important issue was evaluated by the TI team, as described in the following sub-sections. Two alternative scenario weighting alternatives were considered. Section E.5.1 discusses an alternative where only scenarios relevant to hazard are used to develop the Sammon's maps and Section E.5.2 discusses an alternative where a relative weights are assigned based on scenario relevance to hazard in the construction of the Sammon's maps. Section E.5.3 presents the interpretation and justification for the TI team choice of using all 220 scenarios.

E.5.1 Sammon's Maps Based on Scenario Importance to Hazard

The first alternate scenario set considered is one in which only scenarios deemed relevant to hazard are used to develop the Sammon's maps. For a site-specific study, this could be achieved through disaggregation with each scenario being assigned a weight associated to its contribution. This is not feasible in the case of NGA-East, for which the GMC is developed for a large part of the continent. Instead the process was based on hazard analyses conducted for five of the demonstration sites located outside of the Gulf Coast Region. For each of the sites and at five different AFEs (10^{-3} to 10^{-7}), the distance was determined beyond which the contribution to hazard was less than 1% of the total AFE for one-unit magnitude increments. Table E.5–1 shows the results from these analyses and Table E.5–2 presents a summarized version that aggregate results for all five sites and all three GMIMs selected (1 and 10 Hz PSA and PGA). The TI team used the 10^{-4} AFE to select the distances to exclude from the original 220 scenarios. This resulted in a subset of 140 scenarios.

Hazard curves were computed using these scenarios and a new suite of 17 GMMs were obtained. The achieved variance from this set of GMMs is shown in Figure E.5–1 for 1 and 10 Hz. Figure E.5–1 also shows the variance from the seed GMMs and the variance from the final NGA-East GMMs. Because the scenarios at large distances are not considered for the Sammon's maps, the variance at large distances tends to be low, lower than that of the seed GMMs themselves.

E.5.2 Sammon's Maps Based on Weighted Importance to Hazard

The second approach we considered was to use the 140 hazard-relevant scenarios with a full weight and the remaining 80 scenarios from the original list of 220 with a half weight. This approach was evaluated because the TI team felt that considering only the hazard-relevant scenarios obliterated too much of the variance present in the seed GMMs at large distances. Figure E.5–2 shows the achieved variance from this approach, again with the seed GMMs variance and the final GMM variance as reference. In this case, the variance is closer to the one of the final GMMs suite. However, nonlinearity in the Sammon's map process didn't allow preservation of the original seed variance as it was originally expected. The obtained variance at large magnitude was also lower than desired, and the TI team preferred the variance obtained from the 220-scenarios case.

E.5.3 Discussion

Figures E.5–3 to E.5–5 show hazard sensitivity results for the different sets of scenarios, with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz, and part (c) showing the hazard ratio for both frequencies. For both cases described above, the mean hazard curves are very similar to those from the final NGA-East GMMs, at least for AFEs larger or equal to 10^{-5}. The alternative choices illustrated here show that the mean hazard results are relatively insensitive to those choices. The differences are easier to see on the uniform hazard response spectra (UHRS) shown in Figures E.5–6. The UHRS tend to be highest when only the hazard-relevant scenarios are considered for all sites, for frequencies above 10 Hz (Figure E.5–6). At the 10^{-4} AFE level, the differences are negligible. As mentioned above, the TI team preferred the achieved variance for the 220-scenario case, which was (a) closer to the target defined in Chapter 8 and (b) didn't obliterate the variability contained in the seeds. In addition, the TI team didn't believe that constraining hazard-relevant scenarios from five sites—when the NGA-East GMMs are to represent a very large region—was justifiable. These observations provided enough justification for the TI team to select the Sammon's maps based on the 220 scenarios for their model development.

Table E.5–1 Distance beyond which hazard contributions are less than 1% of the total annual frequency of exceedance (AFE) for five sites.

Site	GMIM	M range	Distance beyond which hazard contribution < 1% for AFE:				
			10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Central Illinois	PGA	5 – 5.9	200	100	25	15	15
		6 – 6.9	300	200	50	25	15
		7 – 8.2	500	500	100	25	15
	10 Hz	5 – 5.9	200	100	25	15	15
		6 – 6.9	300	200	50	25	15
		7 – 8.2	500	400	200	50	25
	1 Hz	5 – 5.9	15	15	15	15	15
		6 – 6.9	400	200	50	50	25
		7 – 8.2	500	500	500	500	400
Chattanooga	PGA	5 – 5.9	200	50	25	15	15
		6 – 6.9	200	100	50	25	15
		7 – 8.2	500	50	25	25	15
	10 Hz	5 – 5.9	200	50	25	15	15
		6 – 6.9	300	100	50	25	15
		7 – 8.2	500	100	50	25	25
	1 Hz	5 – 5.9	25	15	15	15	15
		6 – 6.9	500	100	50	50	25
		7 – 8.2	1000	1000	500	500	50
Manchester	PGA	5 – 5.9	200	50	25	15	15
		6 – 6.9	300	100	50	15	15
		7 – 8.2	500	200	50	25	15
	10 Hz	5 – 5.9	200	50	25	15	15
		6 – 6.9	300	200	50	25	15
		7 – 8.2	500	200	50	25	25
	1 Hz	5 – 5.9	200	50	15	15	15
		6 – 6.9	1000	400	100	50	25
		7 – 8.2	1000	1000	500	200	50
Savannah	PGA	5 – 5.9	100	25	25	15	15
		6 – 6.9	200	100	50	25	25
		7 – 8.2	200	200	100	100	50
	10 Hz	5 – 5.9	100	25	15	15	15
		6 – 6.9	200	200	50	25	25
		7 – 8.2	200	200	200	100	100
	1 Hz	5 – 5.9	100	25	15	15	15
		6 – 6.9	200	200	25	25	25
		7 – 8.2	1000	200	200	200	100
Topeka	PGA	5 – 5.9	200	100	50	25	15
		6 – 6.9	300	200	50	25	15
		7 – 8.2	1000	1000	50	25	25
	10 Hz	5 – 5.9	300	200	50	25	15
		6 – 6.9	400	200	100	25	15
		7 – 8.2	1000	1000	100	50	25
	1 Hz	5 – 5.9	15	15	15	15	15
		6 – 6.9	1000	200	100	50	25
		7 – 8.2	1000	1000	1000	1000	50

Table E.5–2 Summary of distance beyond which hazard contributions are less than 1% of the total annual frequency of exceedance (AFE).

Site	GMIM	M range	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
All	PGA, 10 Hz, 1 Hz	5 – 5.9	300	200	50	25	15
		6 – 6.9	1000	400	100	50	25
		7 – 8.2	1000	1000	1000	1000	400

Figure E.5–1 Variance for GMMs from hazard-relevant scenarios only (top), original weighted seed GMMs variance (top), and achieved weighted variance of the NGA-East final GMMs (bottom) for 1 Hz (left) and 10 Hz (right).

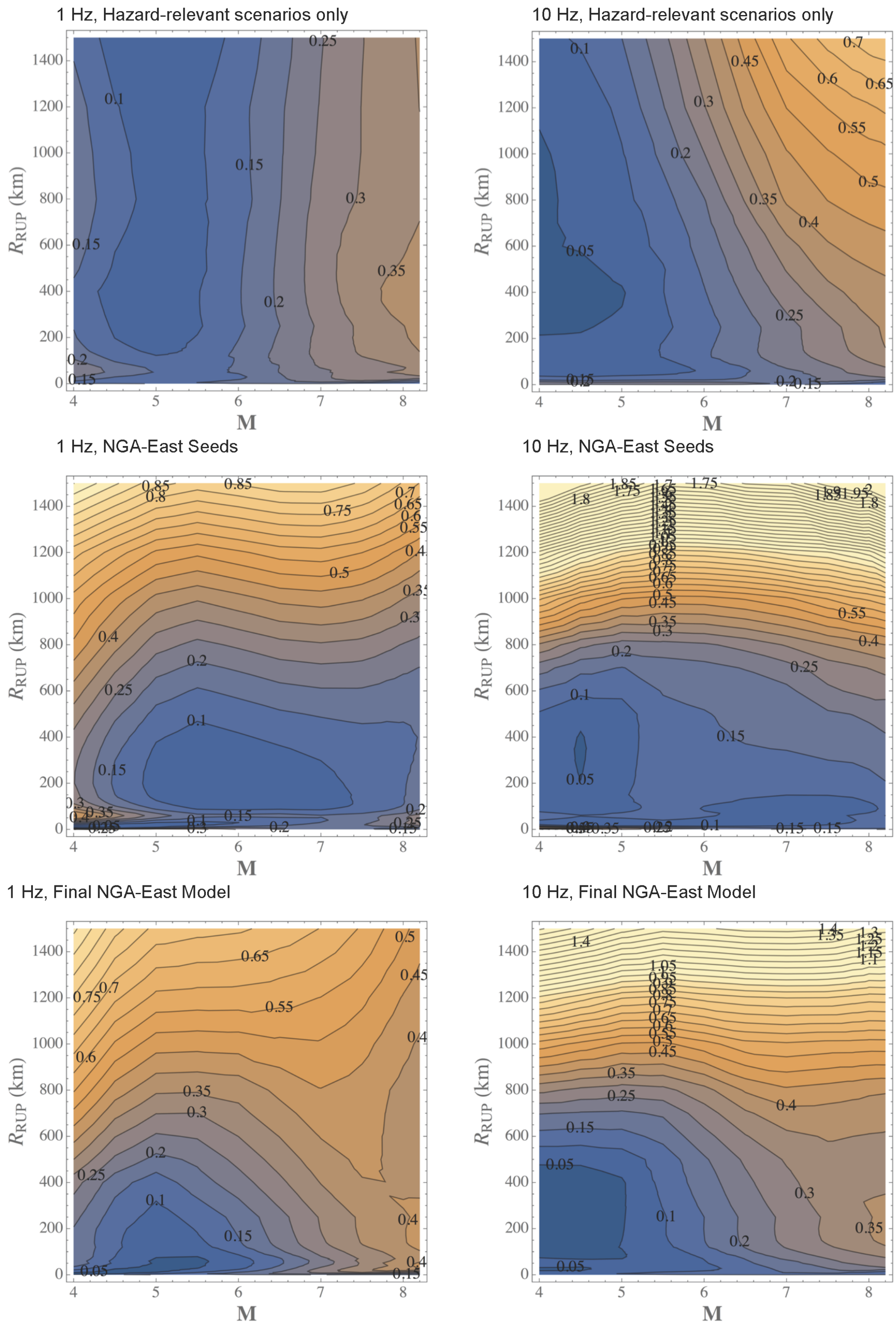


Figure E.5–2 Variance for GMMs from weighted hazard-relevant scenarios (top), original weighted seed GMMs variance (top), and achieved weighted variance of the NGA-East final GMMs (bottom) for 1 Hz (left) and 10 Hz (right).

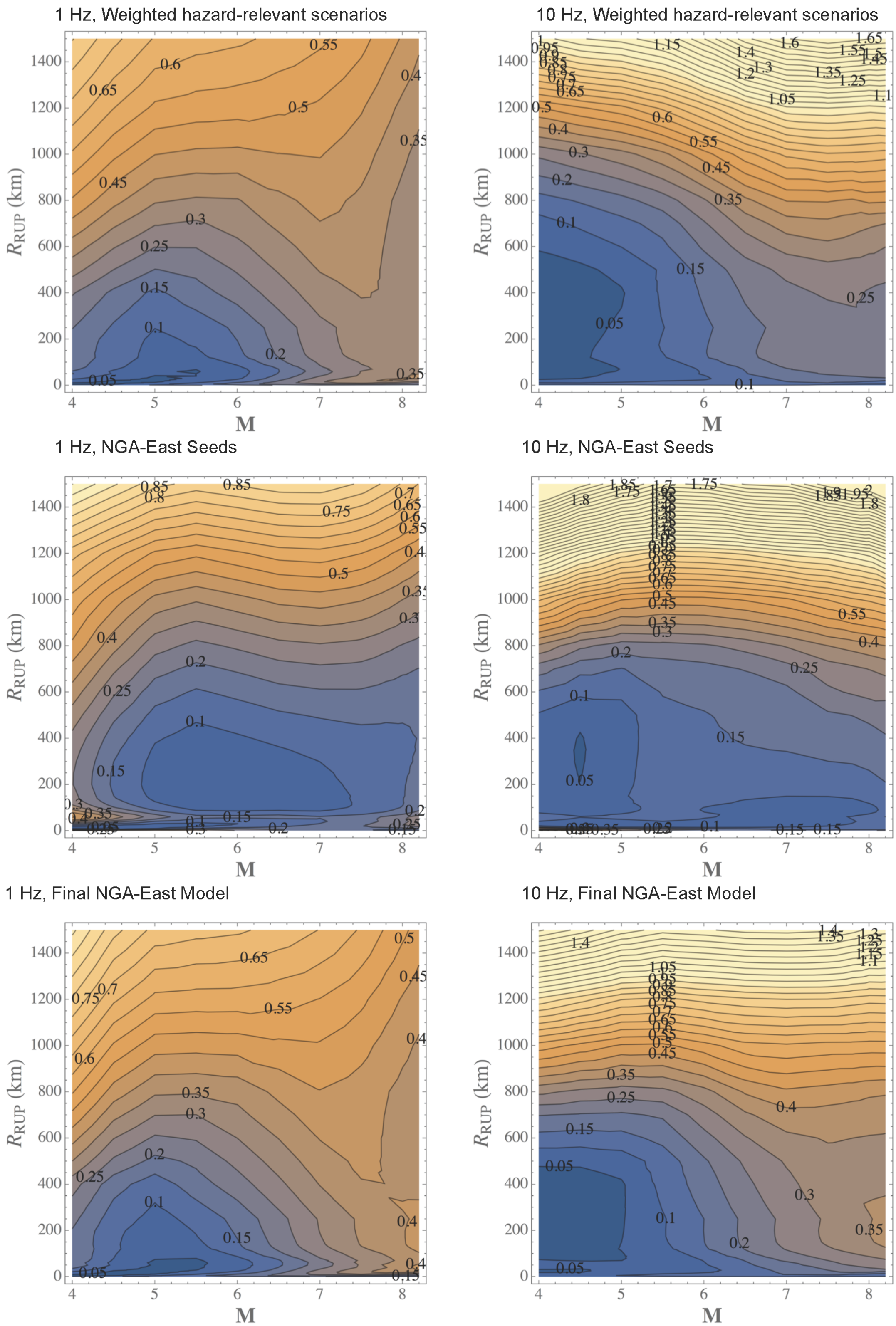


Figure E.5–3(a) Hazard results using different scenarios for the Sammon's maps for 1 Hz at Manchester.

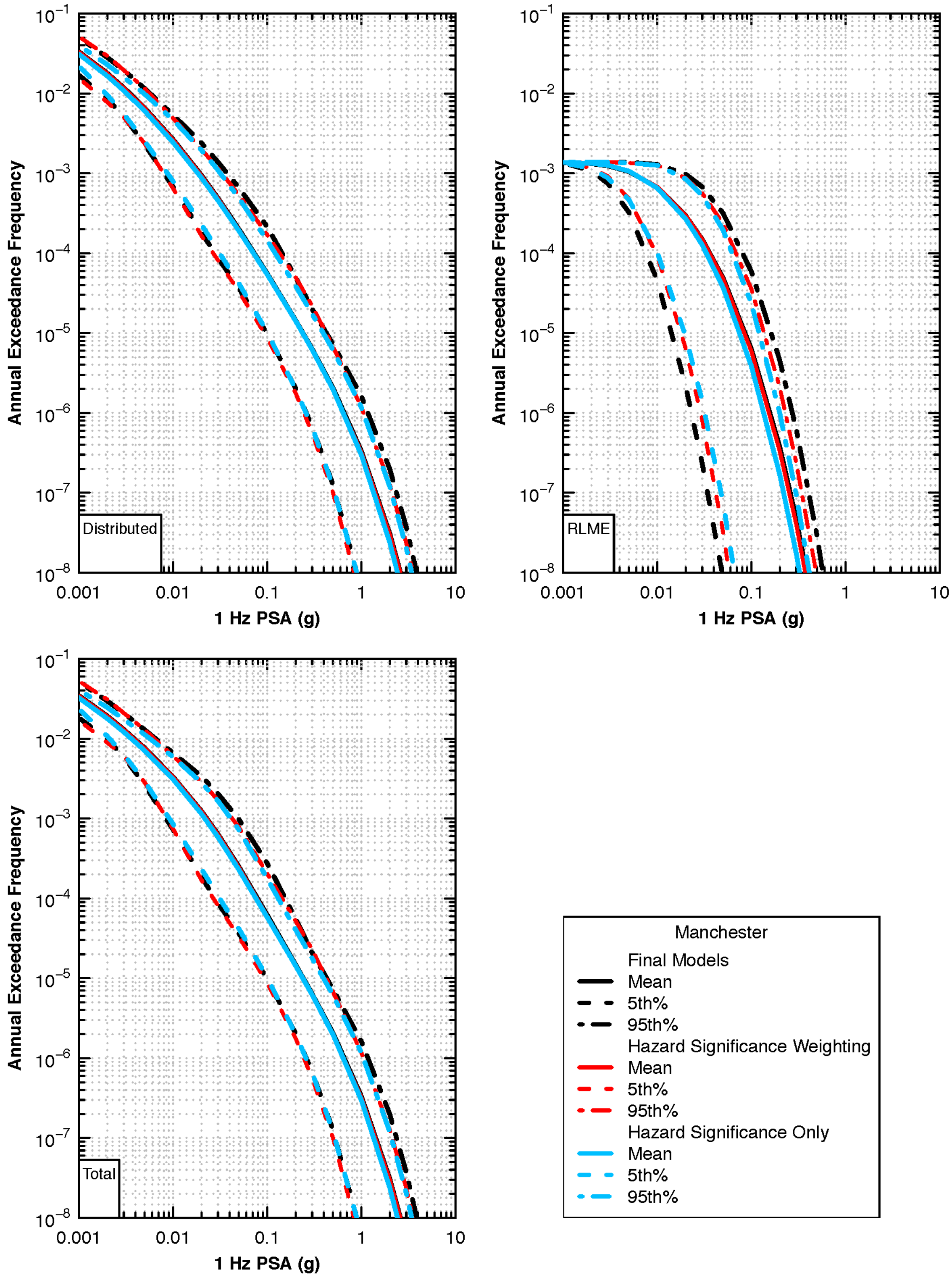


Figure E.5–3(b) Hazard results using different scenarios for the Sammon's maps for 10 Hz at Manchester.

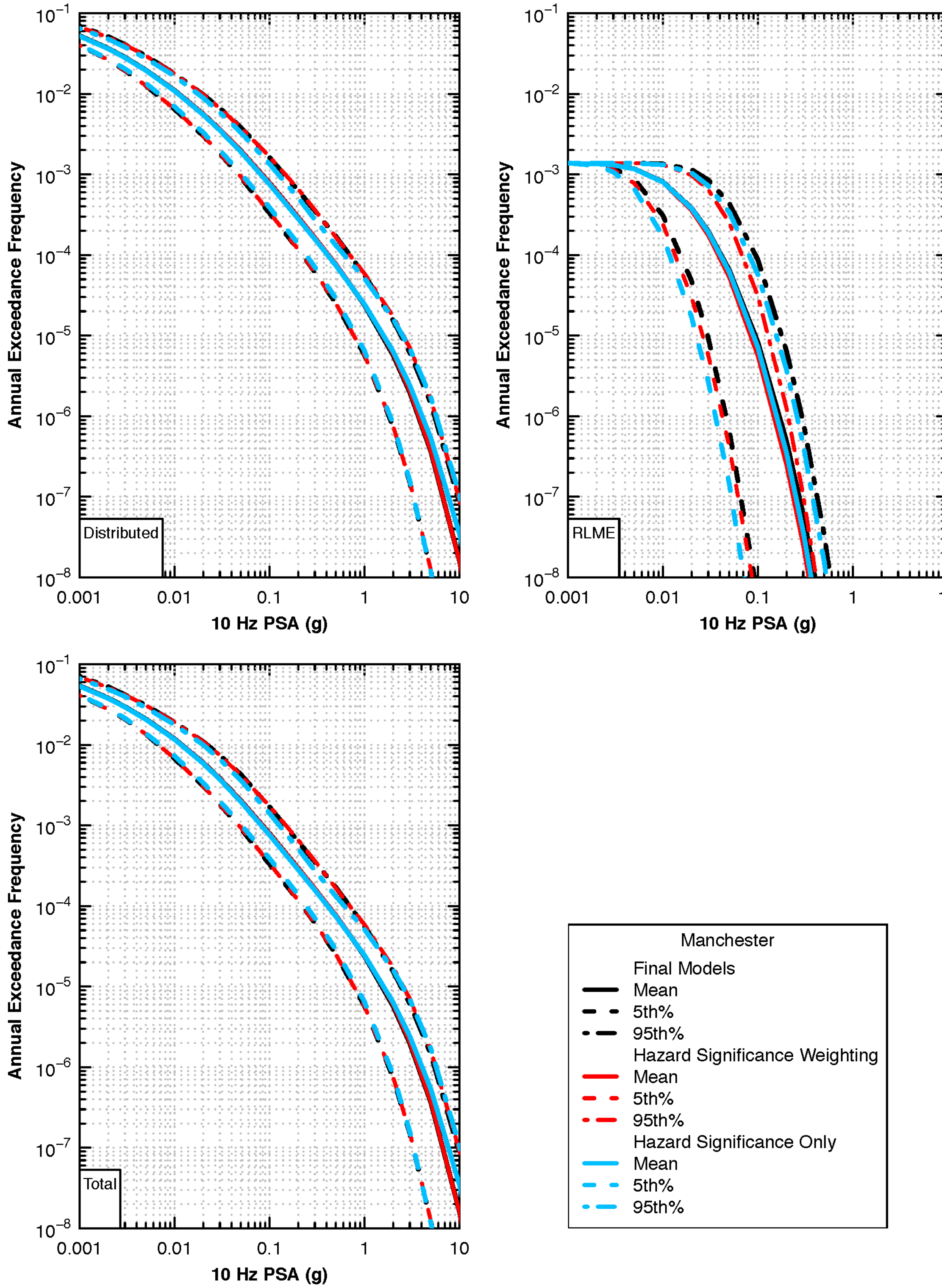
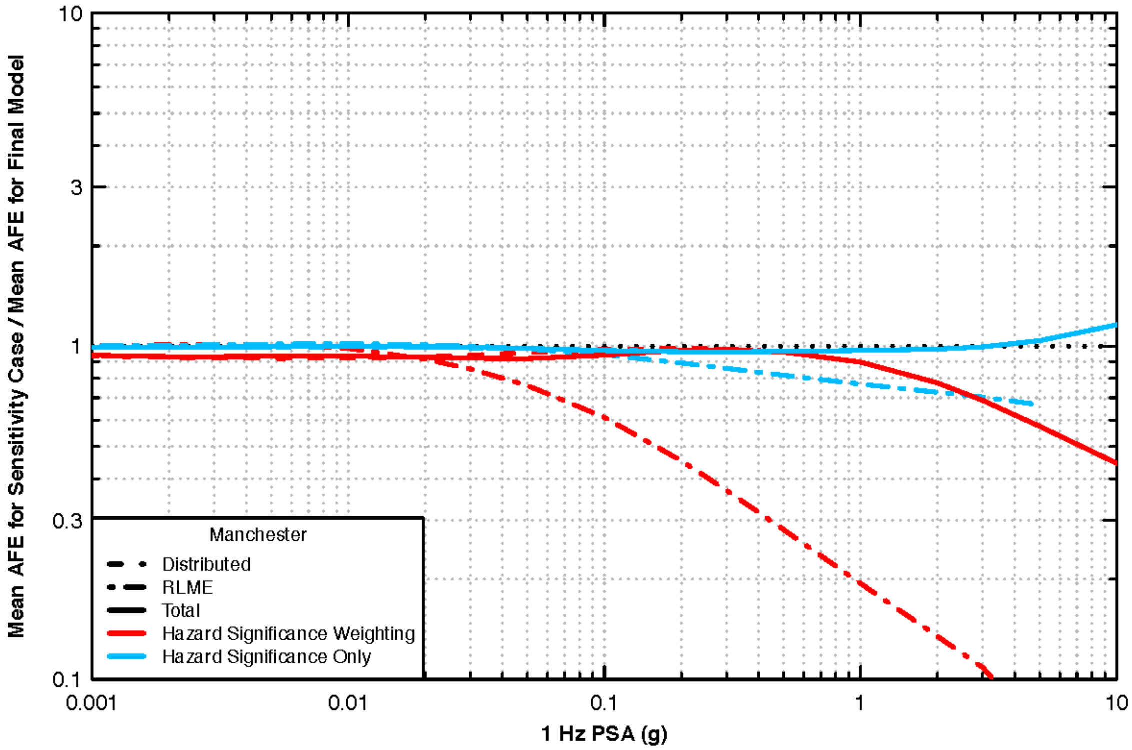


Figure E.5–3(c) Hazard results using different scenarios for the Sammon's maps for 1 and 10 Hz at Manchester.



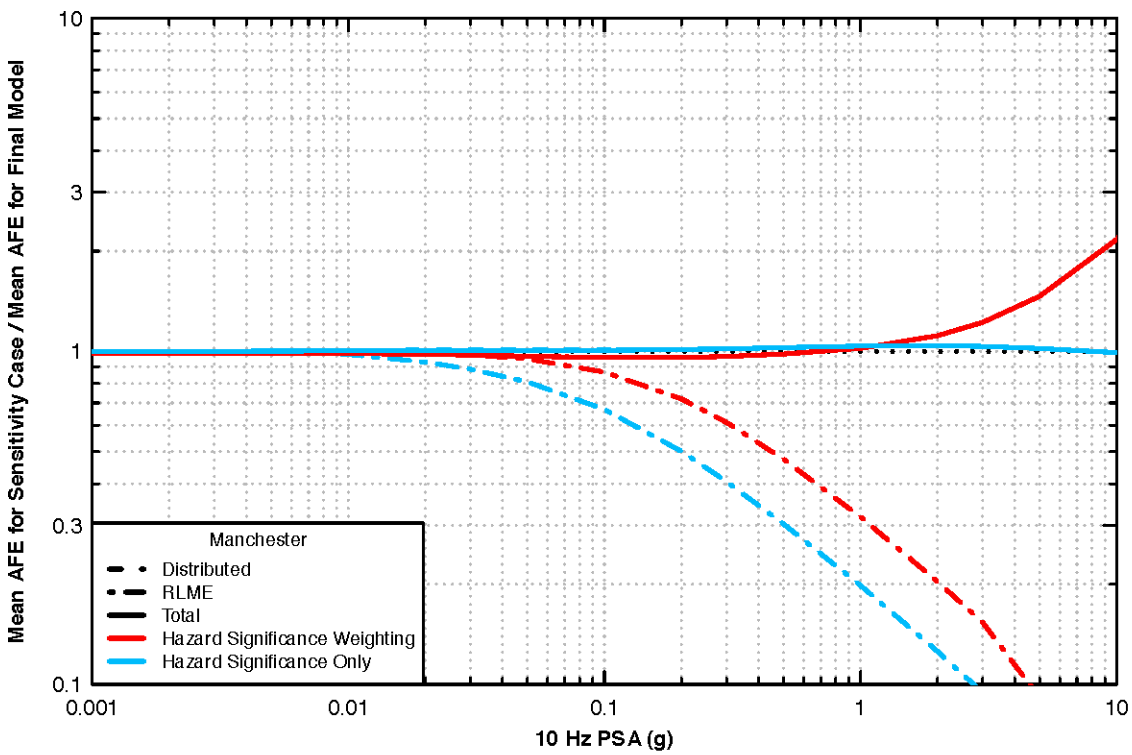


Figure E.5–4(a) Hazard results using different scenarios for the Sammon's maps for 1 Hz at Central Illinois.

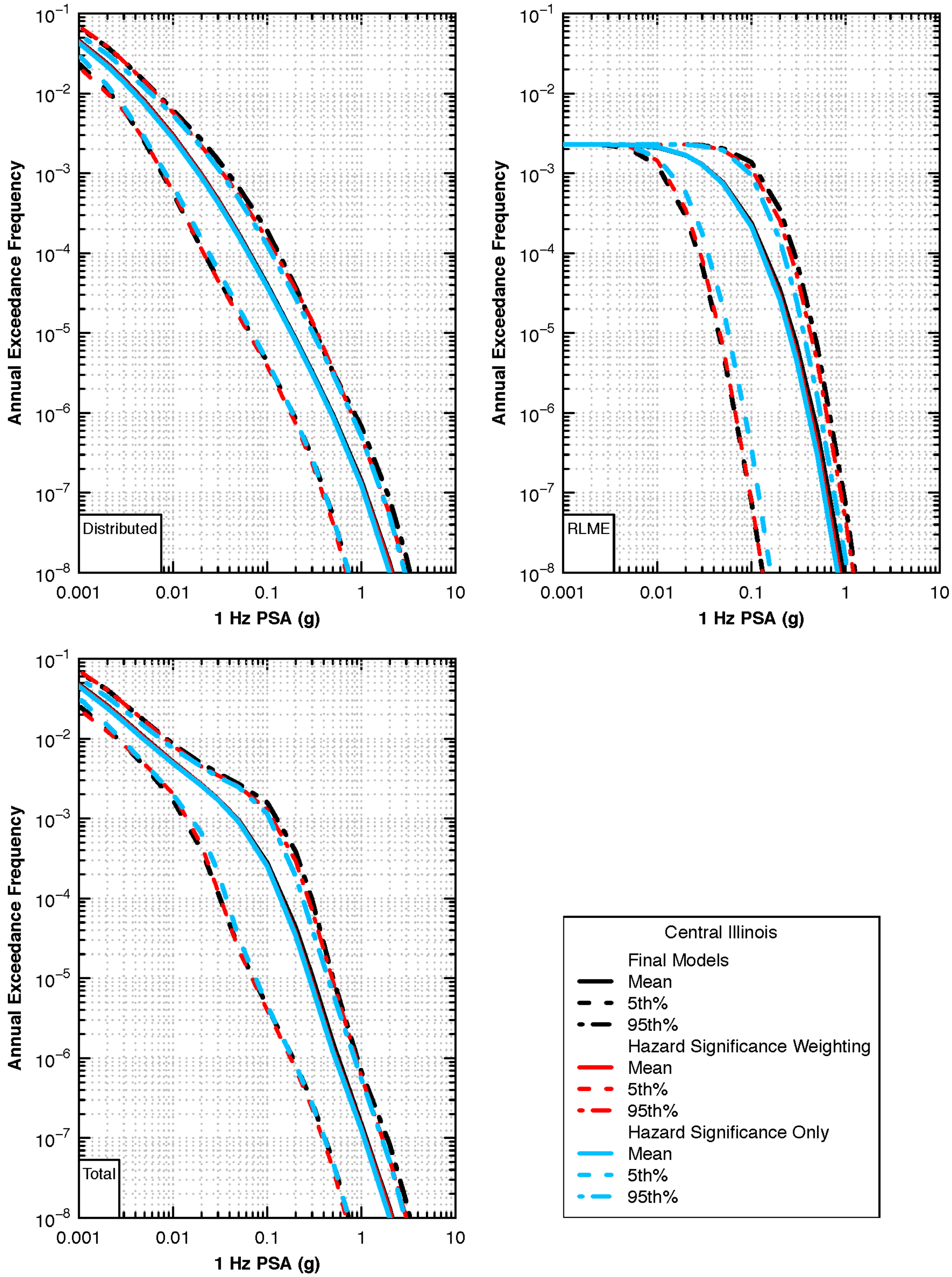


Figure E.5–4(b) Hazard results using different scenarios for the Sammon's maps for 10 Hz at Central Illinois.

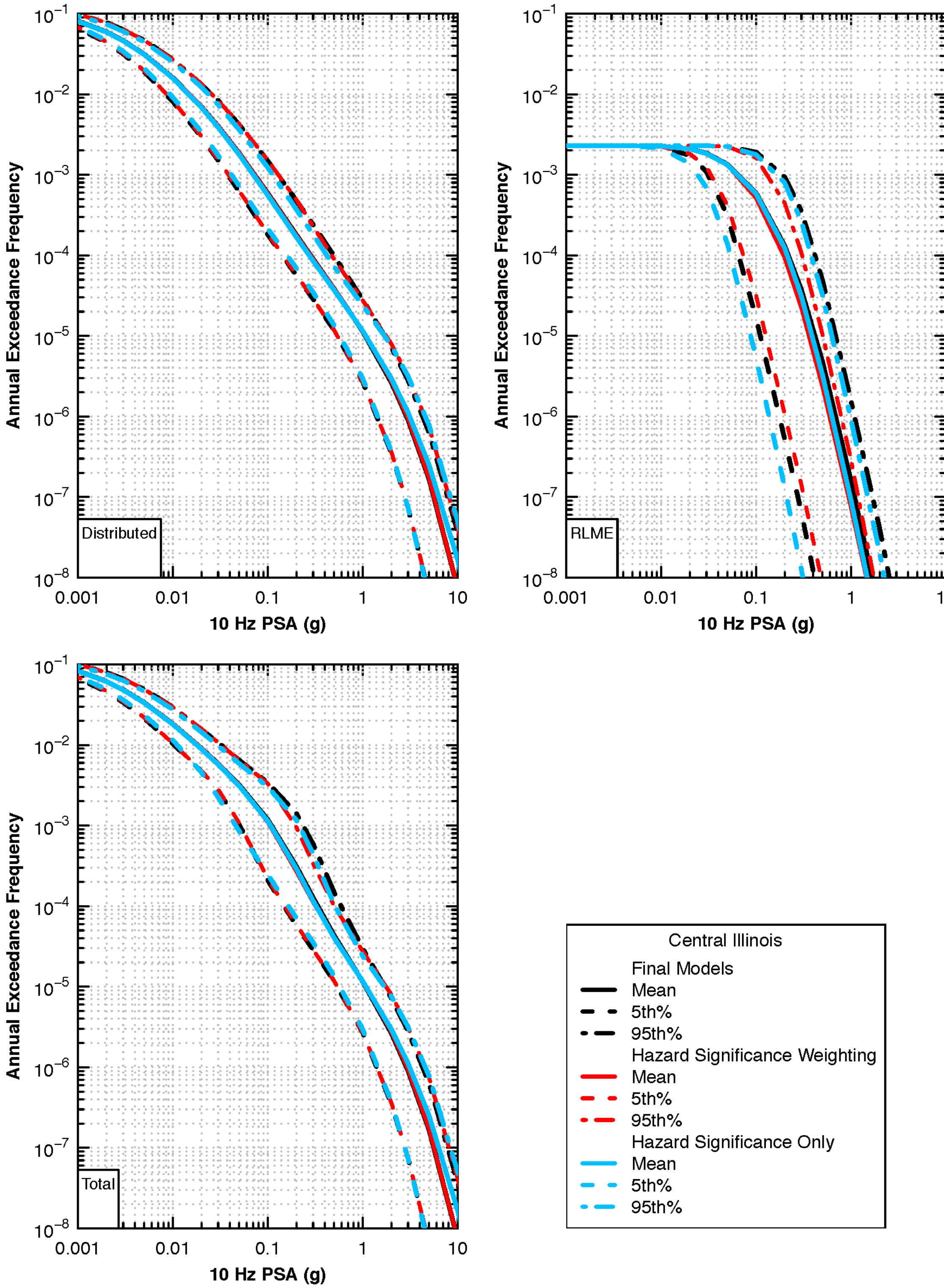


Figure E.5–4(c) Hazard results using different scenarios for the Sammon's maps for 1 and 10 Hz at Central Illinois.

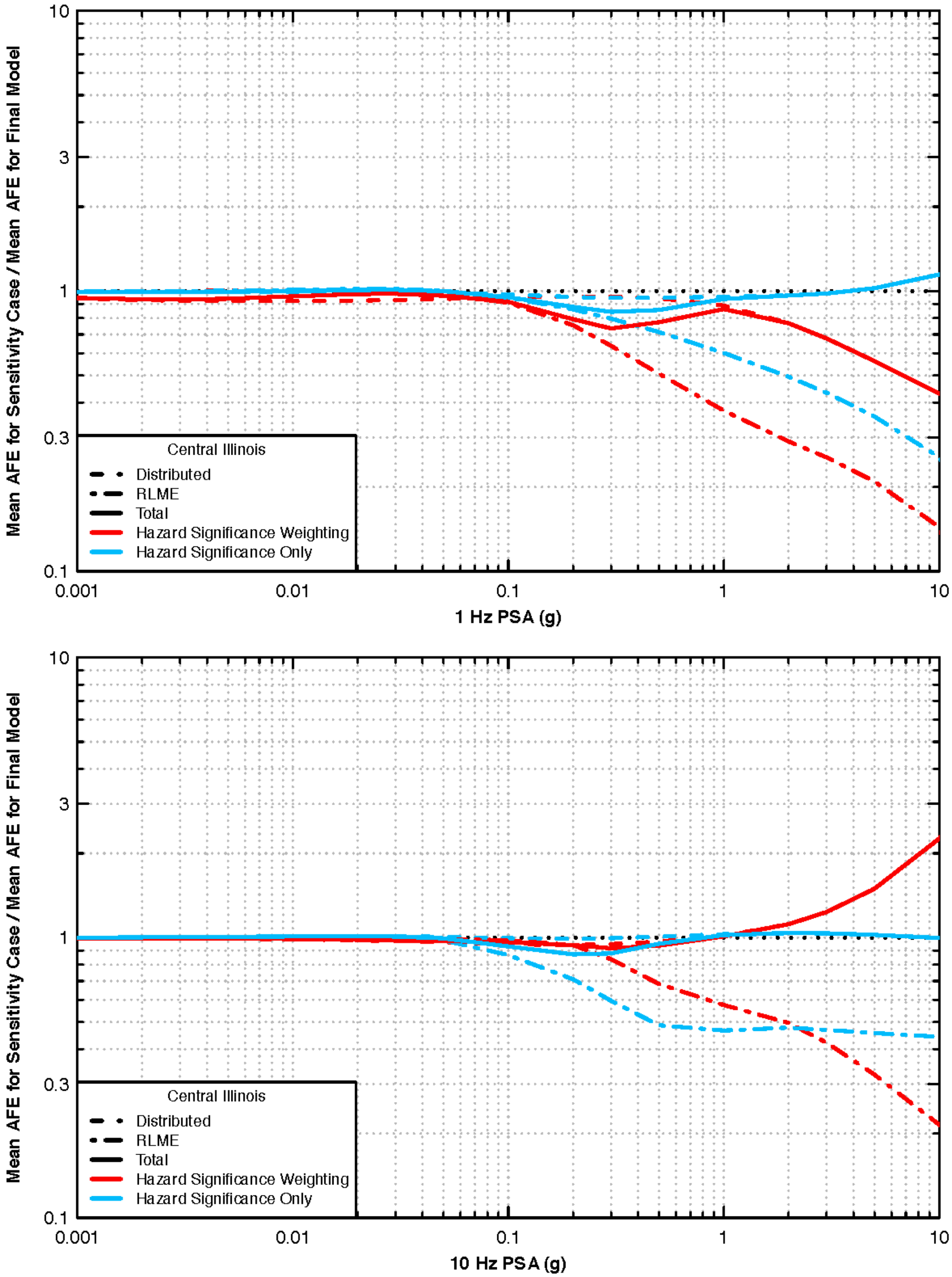


Figure E.5–5(a) Hazard results using different scenarios for the Sammon's maps for 1 Hz at Savannah.

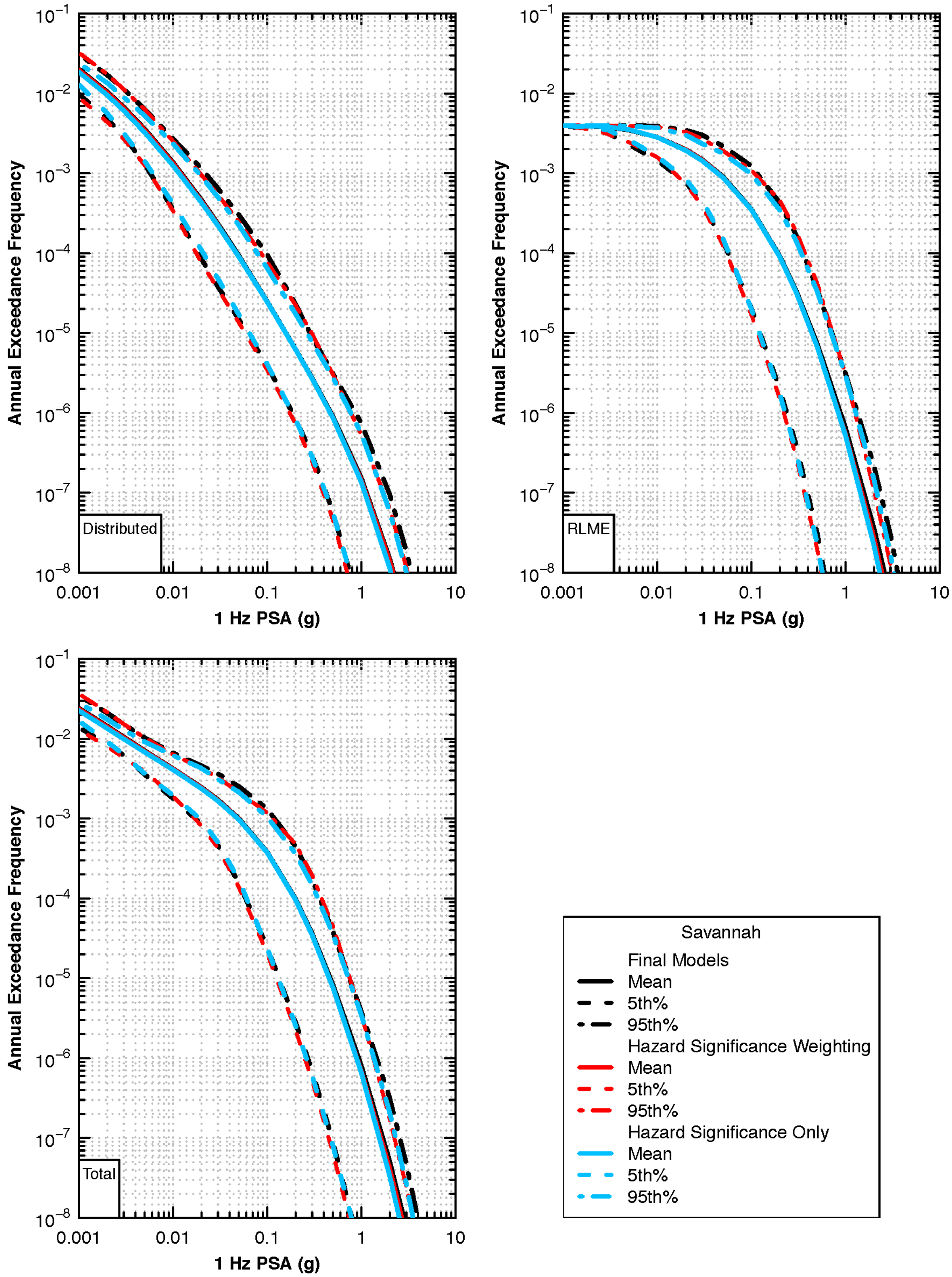


Figure E.5–5(b) Hazard results using different scenarios for the Sammon's maps for 10 Hz at Savannah.

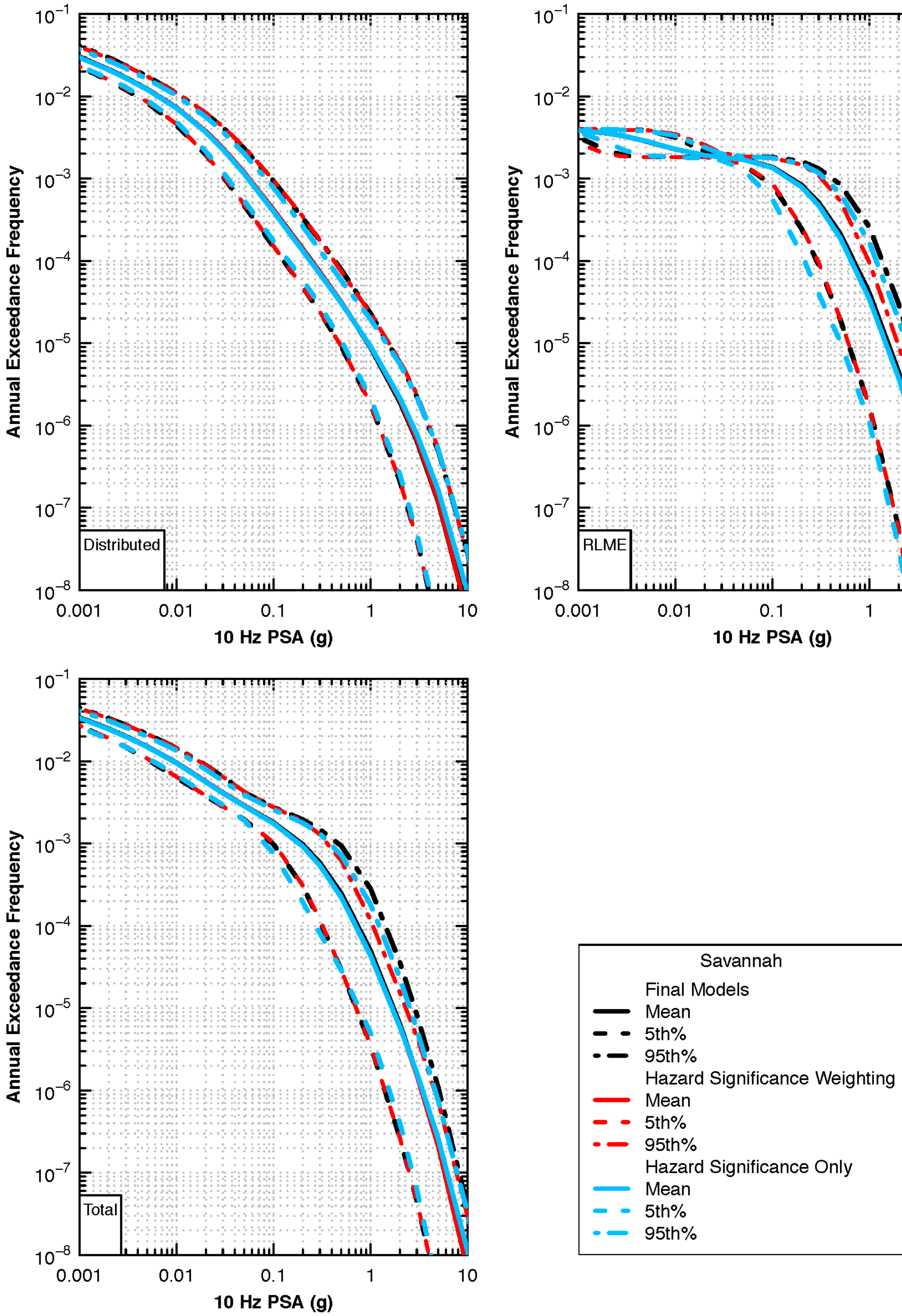
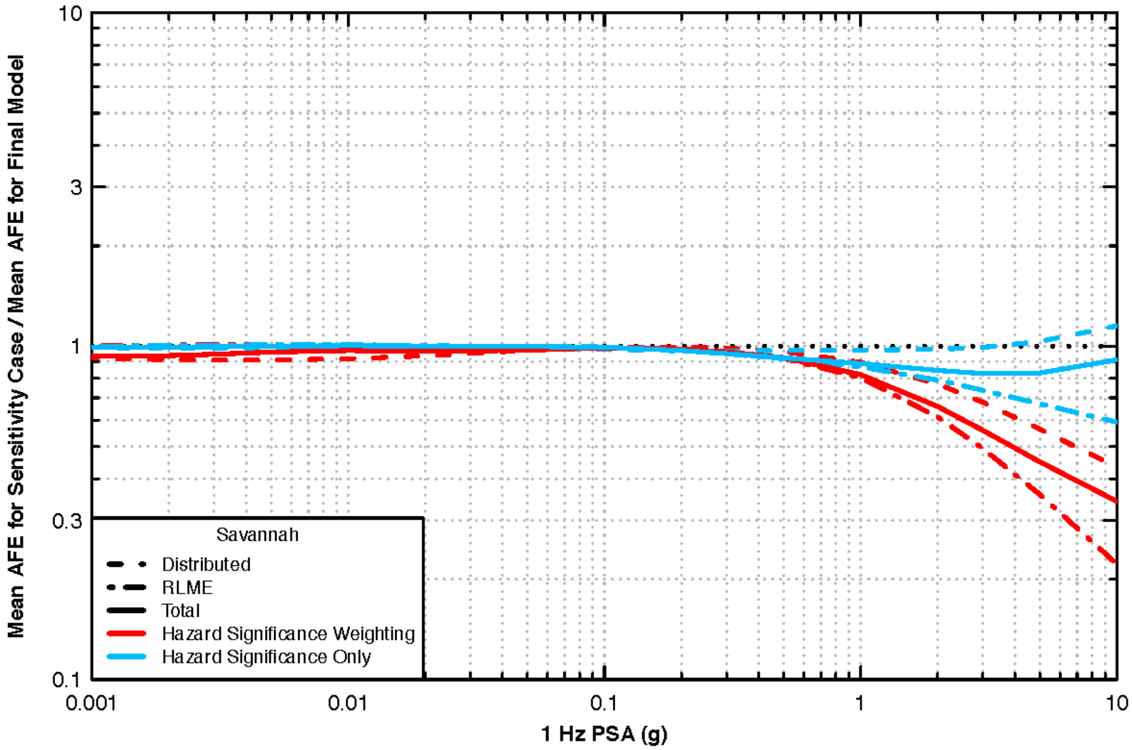


Figure E.5–5(c) Hazard results using different scenarios for the Sammon's maps for 1 and 10 Hz at Savannah.



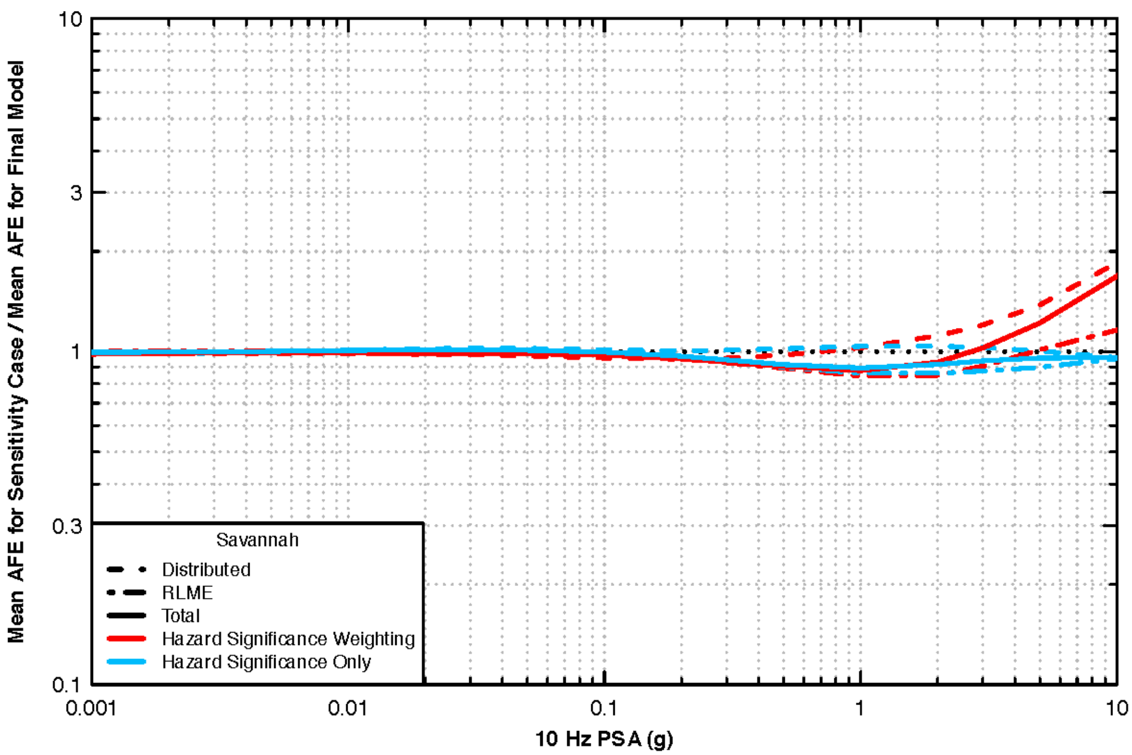


Figure E.5–6 (a) Uniform hazard response spectra for Manchester for alternate suite of scenarios considered in the Sammon's maps computations.

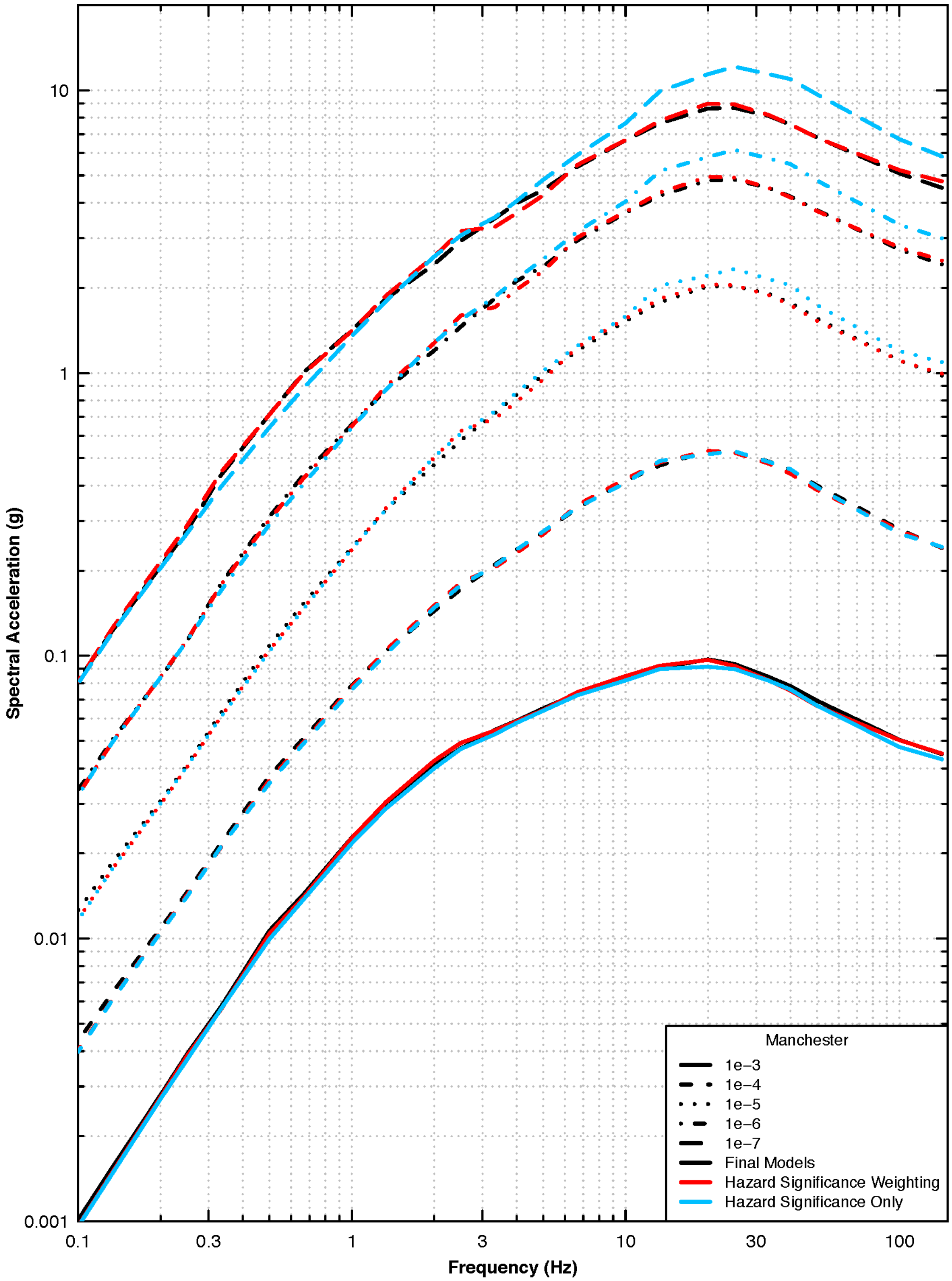


Figure E.5–6 (b) Uniform hazard response spectra for Central Illinois for alternate suite of scenarios considered in the Sammon's maps computations.

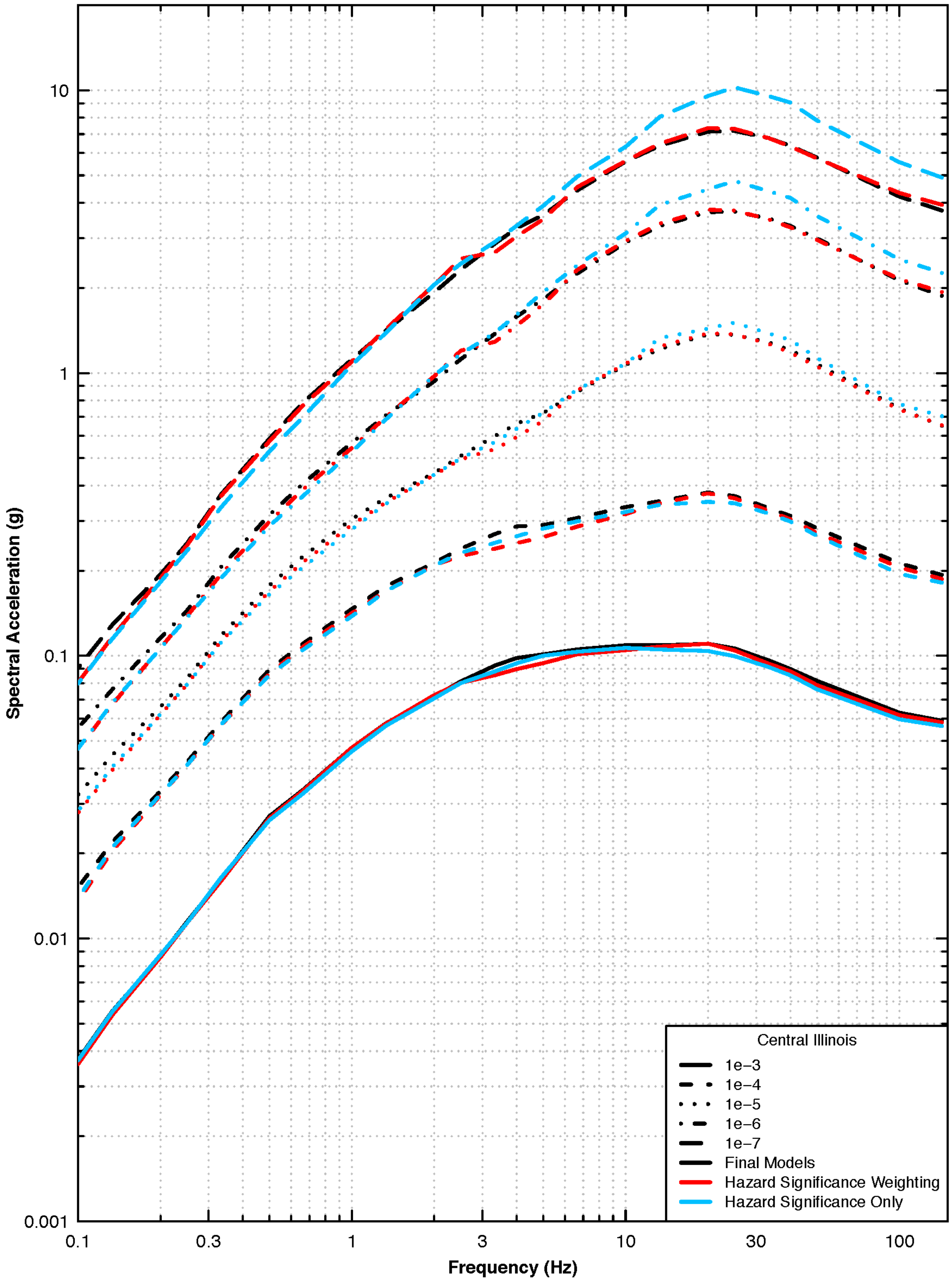
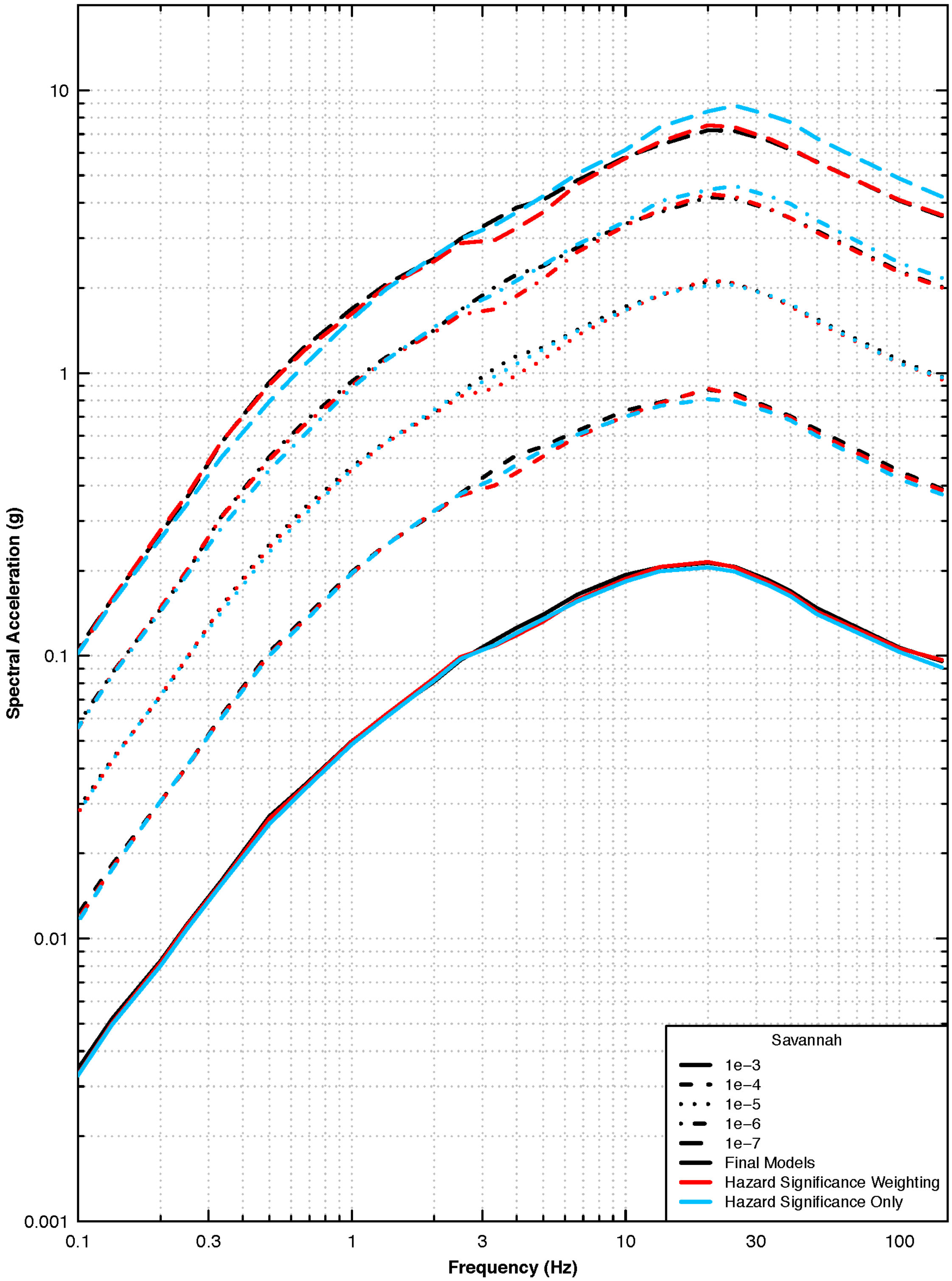


Figure E.5–6 (c) Uniform hazard response spectra for Savannah for alternate suite of scenarios considered in the Sammon's maps computations.



E.6 Sensitivity to the Number of Cells

The procedure used by the TI team for the NGA-East GMC development was introduced early on in the project, and it went through various refinements over time. The selected approach, which is documented in this report, makes use of the Sammon's map to discretize the ground motion space into 17 cells, resulting in 17 median GMMs (Section 8.4).

Initially the TI team utilized 29 cells, as shown at the top of Figure E.6–1. The resulting set of models contained a number of cells in the outer ring with weights lower than 0.005. It was assessed that this discretization produced too many models with insignificant weight, resulting in an excessive hazard computational burden. In addition, many of the models in the outer ring were defined by only a limited number of sampled GMMs such that the average behaved poorly in terms of magnitude and/or distance scaling.

To address these issues, the TI team investigated the use of a 13-cell discretization, shown by the center image of Figure E.6-–1, developed by combining the outer two rings of the 29-cell discretization. The 13-cell discretization produced models with improved behavior to represent the cells in the outer ring as they were based on a larger number of sampled GMMs. The 13-cell discretization also greatly reduced the hazard computation burden while producing a mean hazard that was essentially the same as the 29-cell discretization for AEF ≥ 10^{-4}. Therefore, the 13-cell discretization results were provided as interim GMMs for use in the USGS National Seismic Hazard Mapping Program (NSHMP) (Goulet et al. 2017).

Further review of the results by the TI team suggested that the 13-cell discretization provided a somewhat coarse representation of the body of the GMM distribution as it contained only 5 cells within the outer ring. Therefore, the discretization was revised to 17 cells, as shown at the bottom of Figure E.6—1. In this discretization the body of the GMM distribution is represented by 9 cells that cover a greater probability mass (approximately 75%) that the 5 central cells of the 13-cell discretization, which covered only approximately 50% of the probability mass. The outer range of the GMM distribution is represented by 7 cells that are somewhat smaller in size compared to those of the 13-cell discretization but are large enough to include sufficient GMM samples to produce representative models with reasonable magnitude and distance scaling behavior.

Figures E.6–2 to E.6–4 show hazard sensitivity results for the different cell configurations (29-cell, 13-cell, and 17-cell), with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz and part (c) showing the hazard ratio for both frequencies. For all cases, the mean hazard is virtually the same at least down to 10^{-5} AFE, indicating that it is not sensitive to the number of cells used. The range in hazard as expressed by the 5^{th} and 95^{th} percentile curves is also similar, with the fractiles for 17-cell discretization generally providing a somewhat better representation of those for the 29-cell discretization than do the fractiles for the 13-cell discretization.

The TI team selected the 17-cell discretization for the final model on the basis that it provided a good representation of the center, body, and range of the GMM distribution to capture the epistemic uncertainty in terms of magnitude and distance scaling without imposing an undue burden for PSHA computation.

Figure E.6–1 Alternate discretization of the Sammon's maps space considered by the TI team.

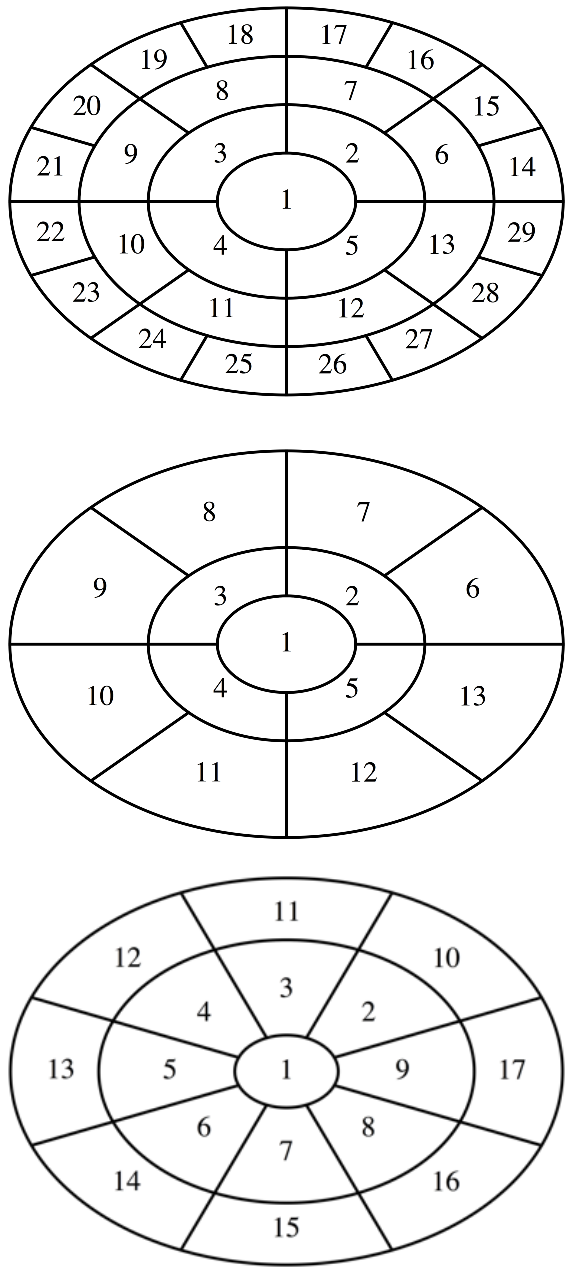


Figure E.6–2(a) Hazard results for 13, 17 (Final Models), and 29 GMMs for 1 Hz at Manchester.

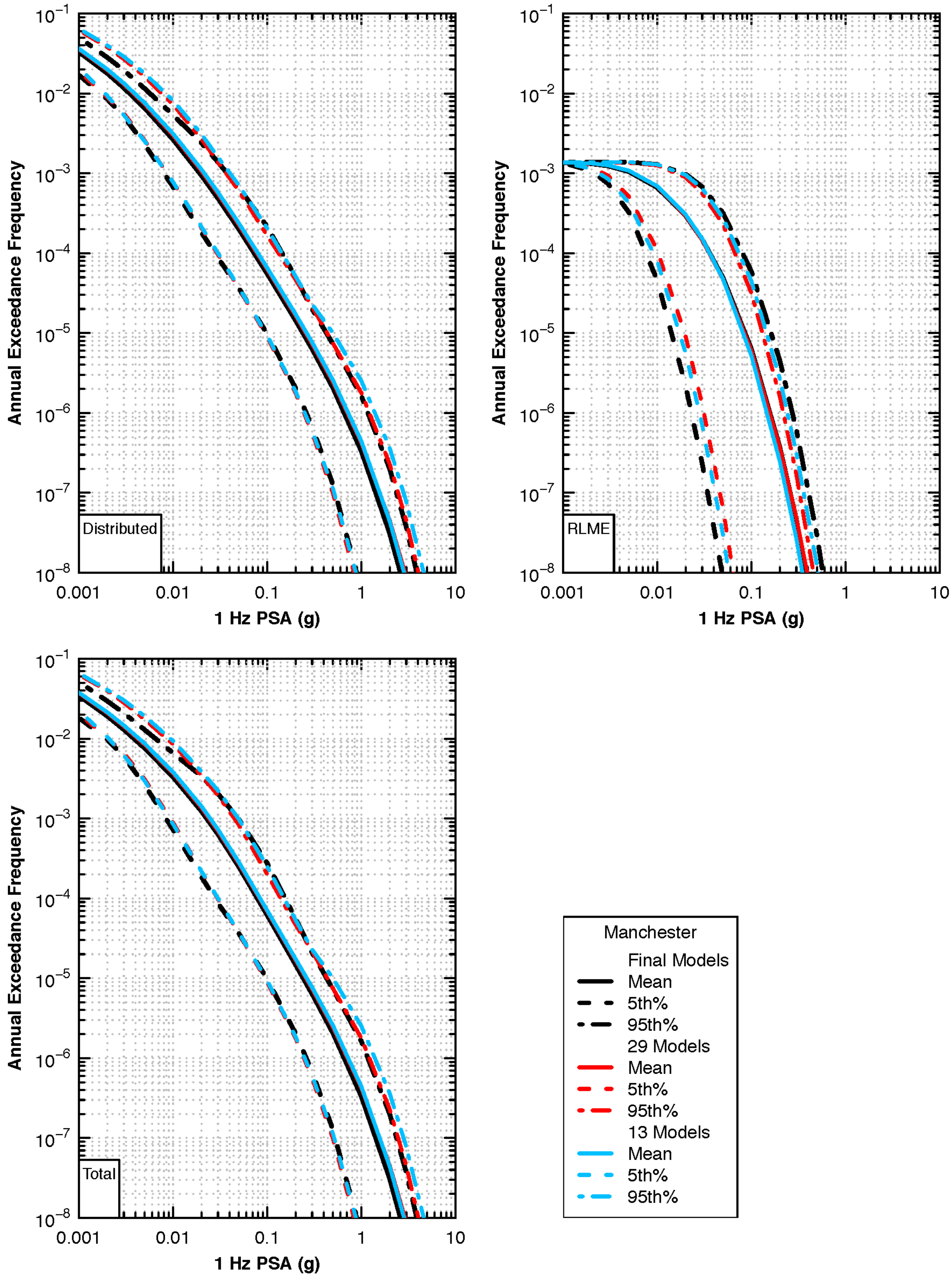


Figure E.6–2(b) Hazard results for 13, 17 (Final Models), and 29 GMMs for 10 Hz at Manchester.

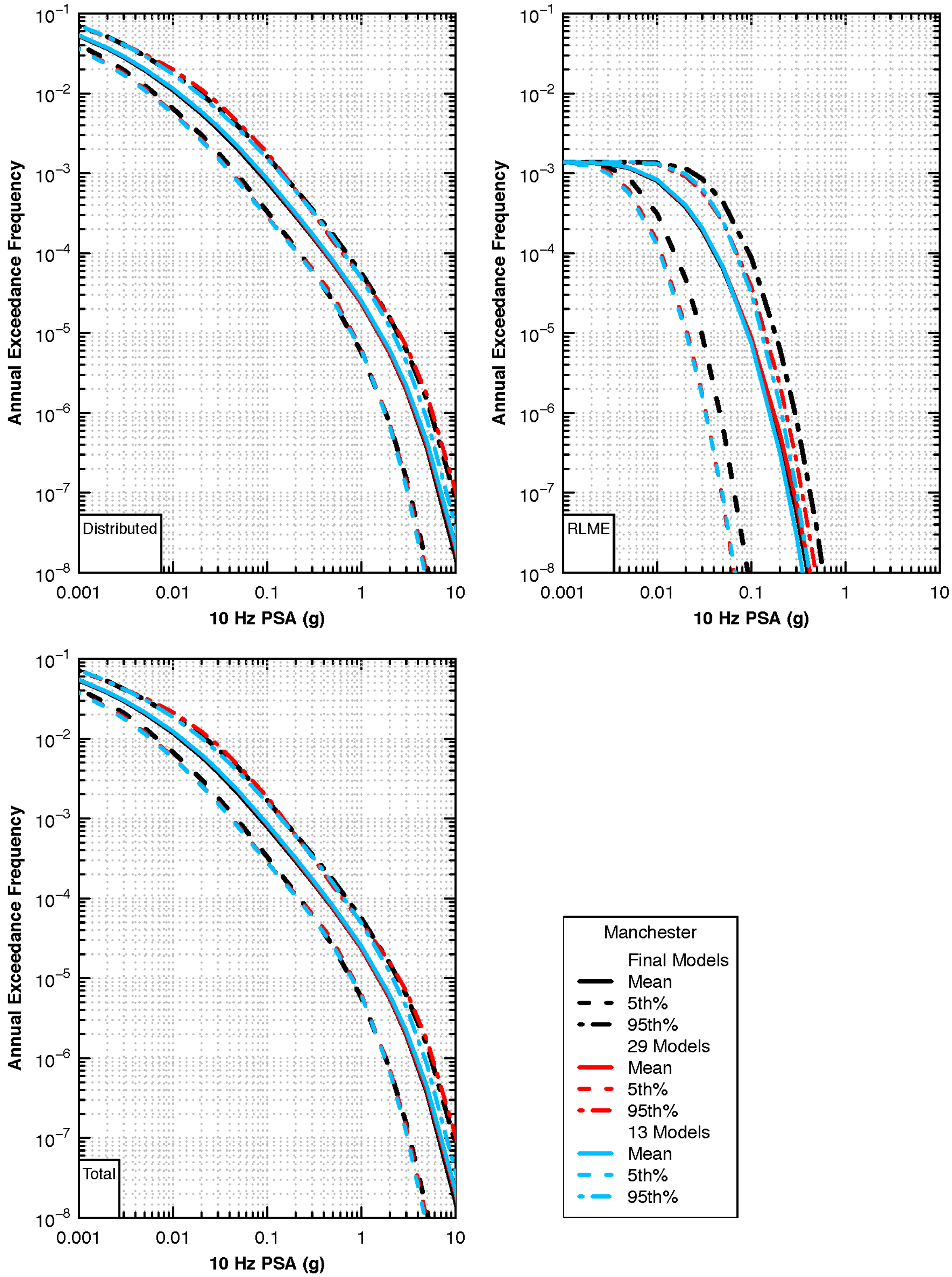
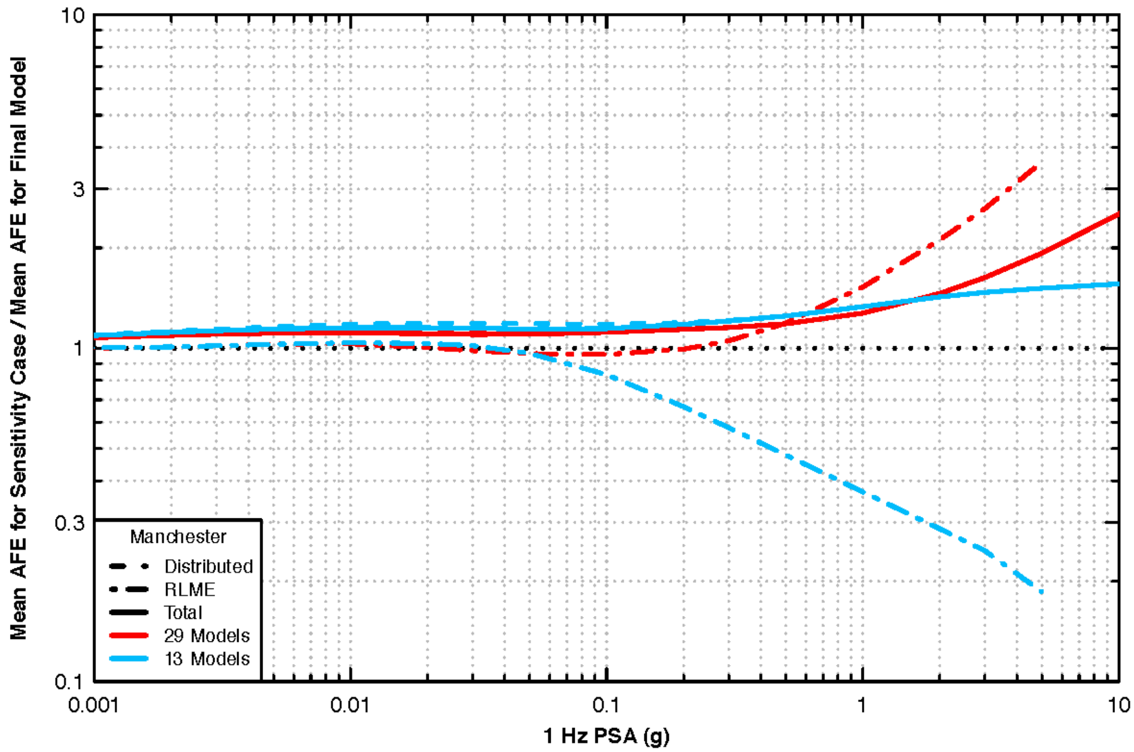


Figure E.6–2(c) Hazard ratios for 13, 17 (Final Models), and 29 GMMs for 1 and 10 Hz at Manchester.



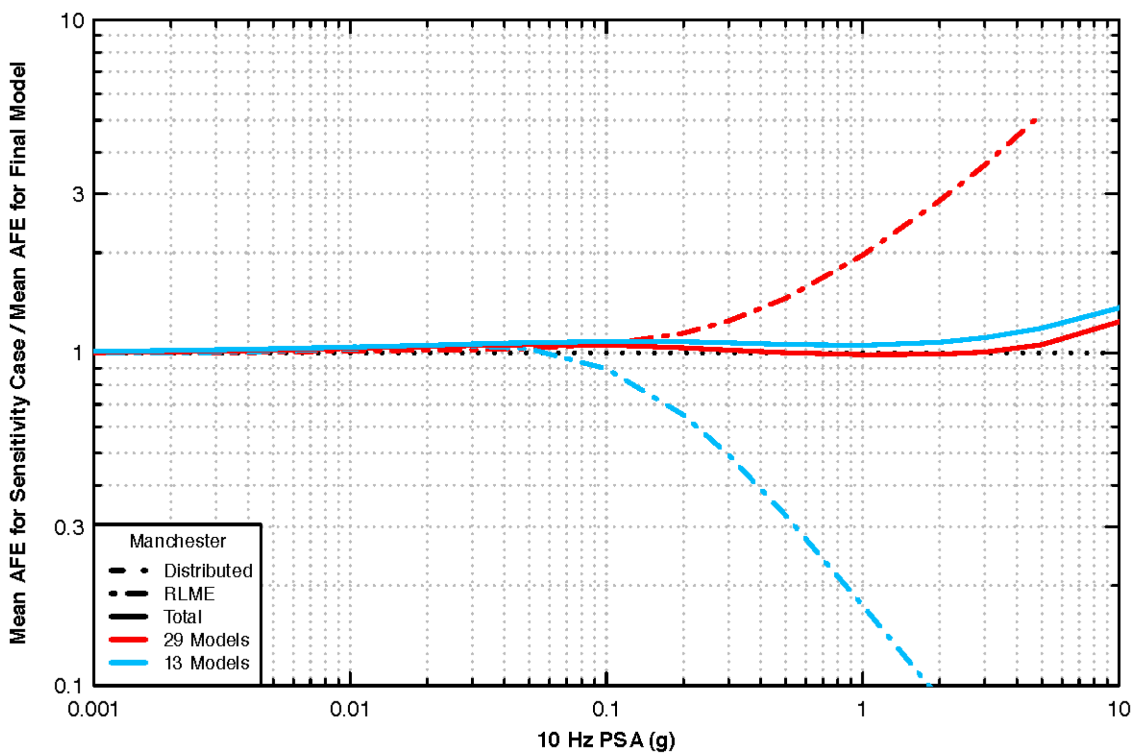


Figure E.6–3(a) Hazard results for 13, 17 (Final Models), and 29 GMMs for 1 Hz at Central Illinois.

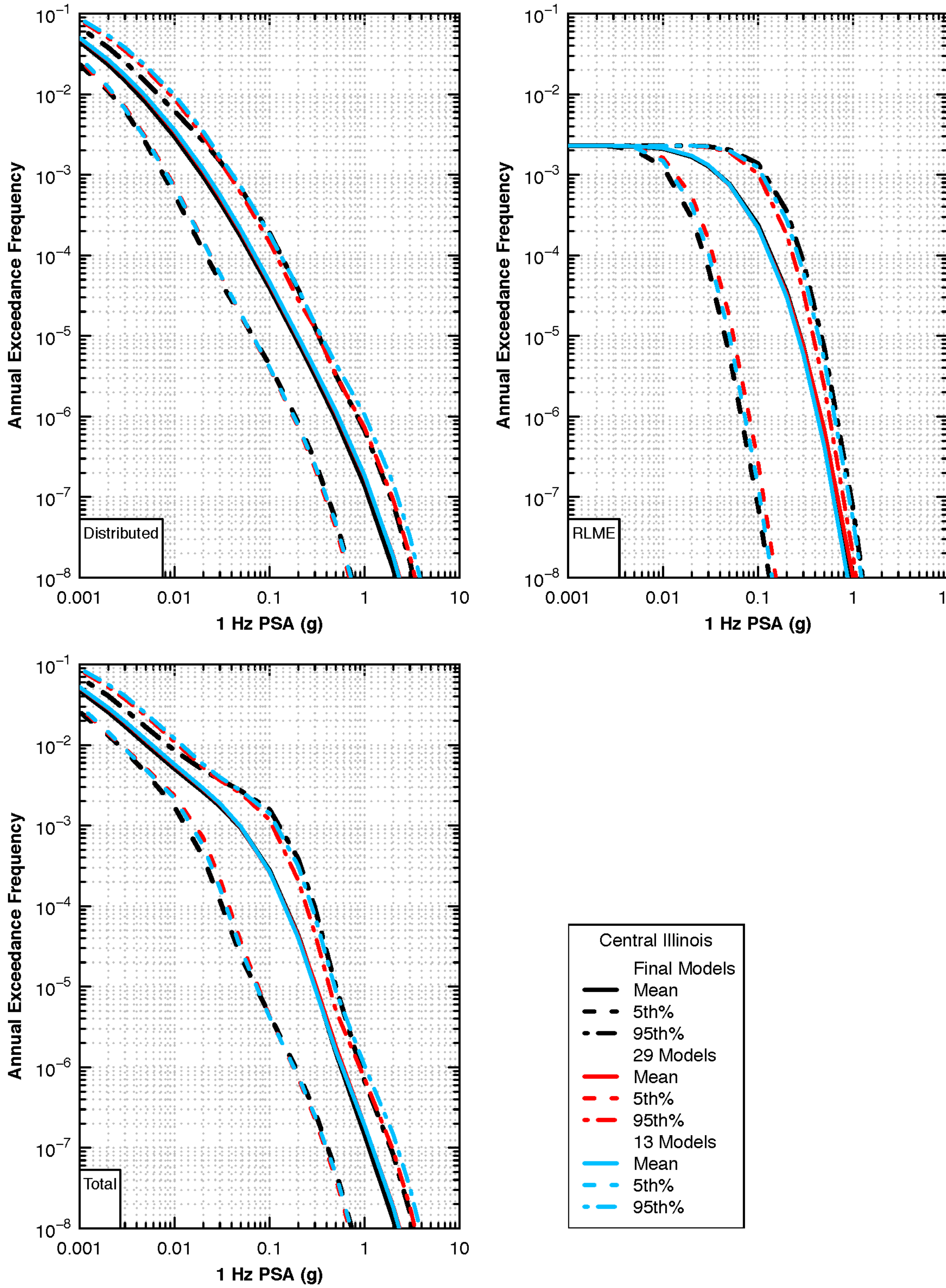


Figure E.6–3(b) Hazard results for 13, 17 (Final Models), and 29 GMMs for 10 Hz at Central Illinois.

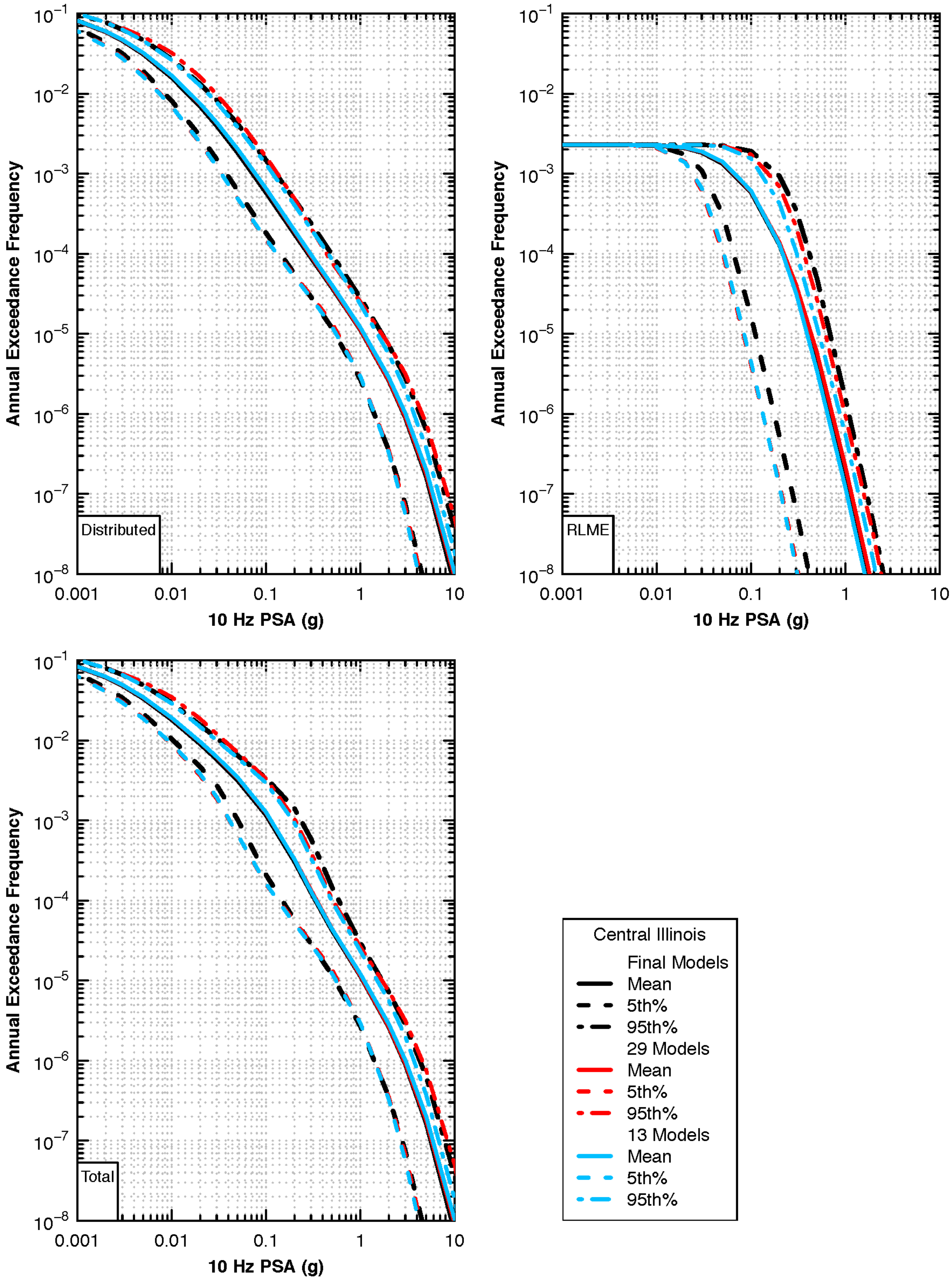
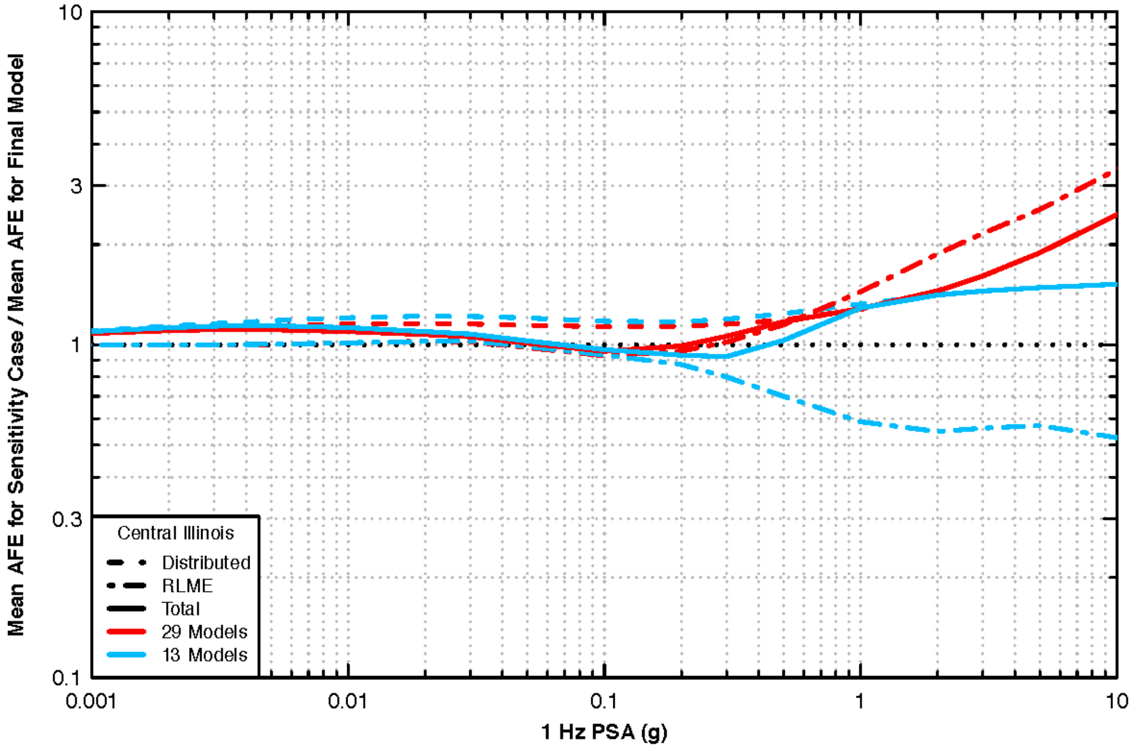


Figure E.6–3(c) Hazard ratios for 13, 17 (Final Models), and 29 GMMs for 1 and 10 Hz at Central illinois.



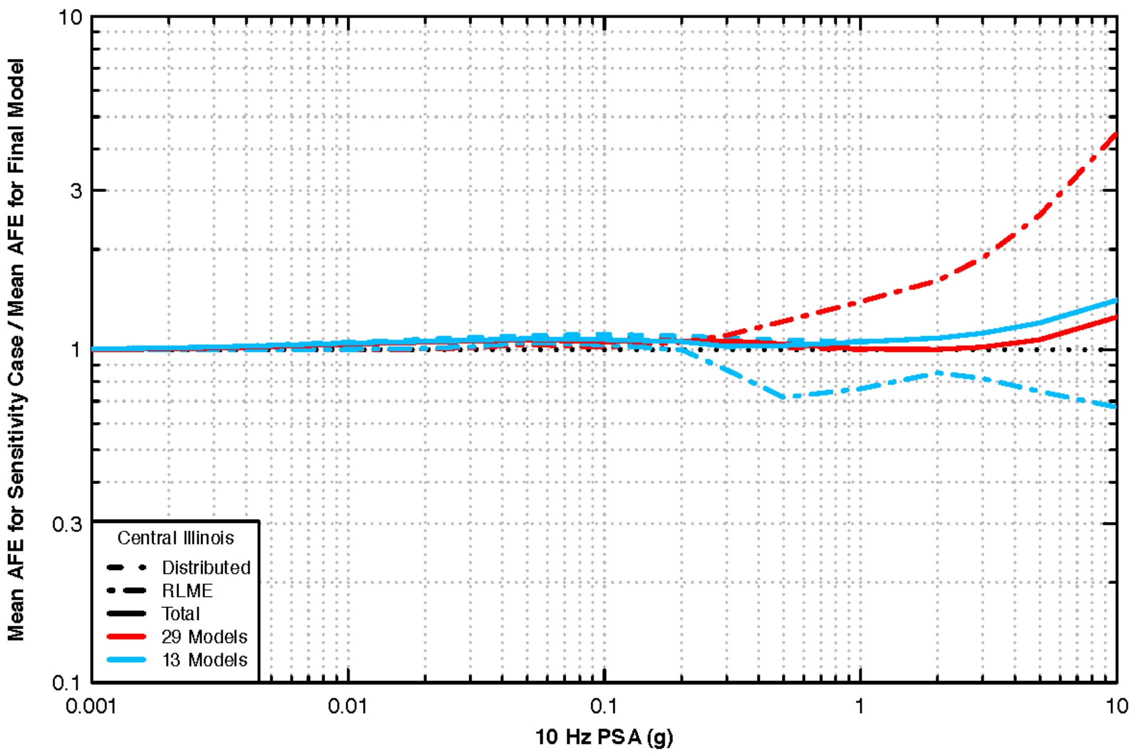


Figure E.6–4(a) Hazard results for 13, 17 (Final Models), and 29 GMMs for 1 Hz at Savannah.

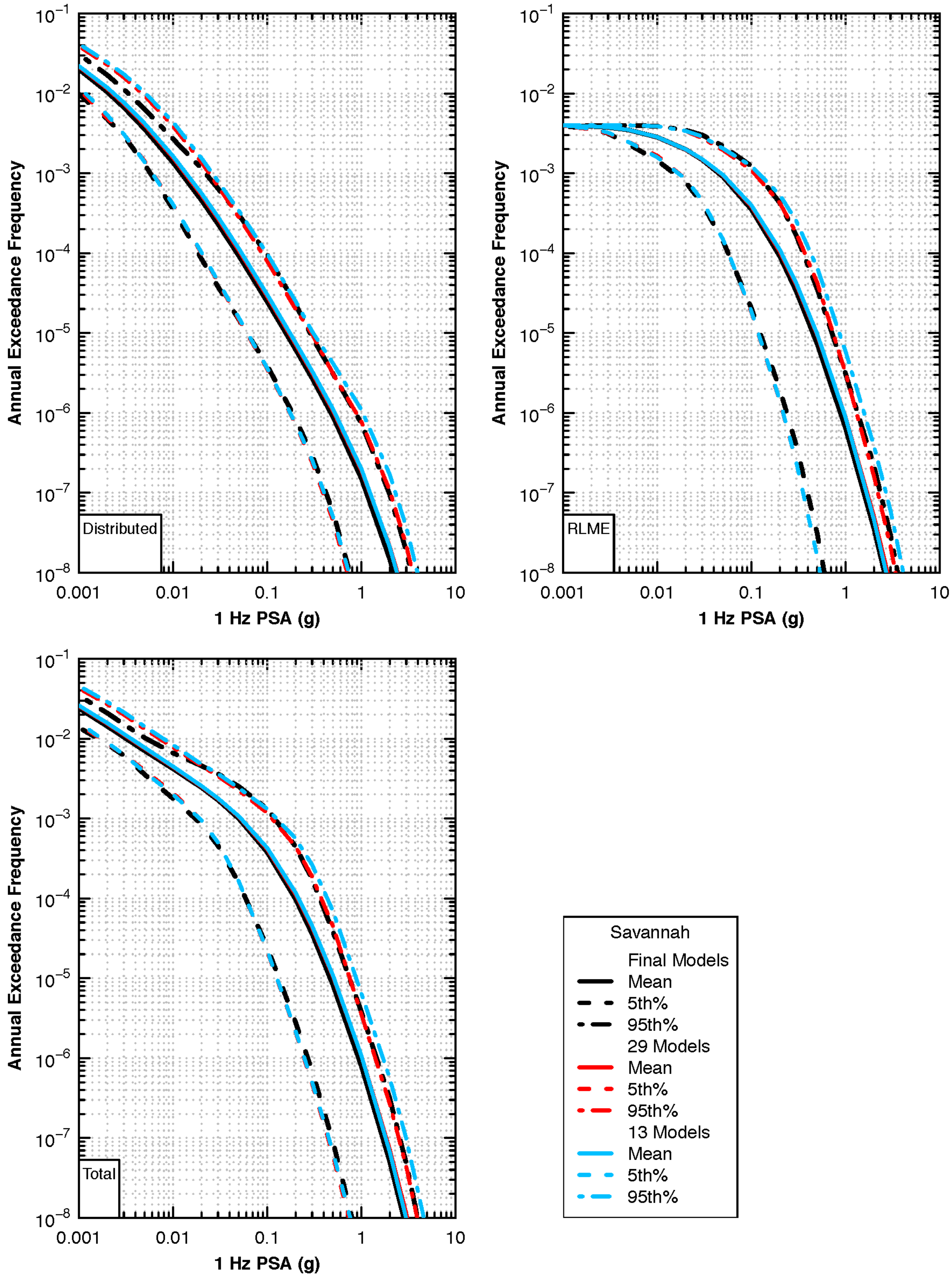


Figure E.6–4(b) Hazard results for 13, 17 (Final Models), and 29 GMMs for 10 Hz at Savannah.

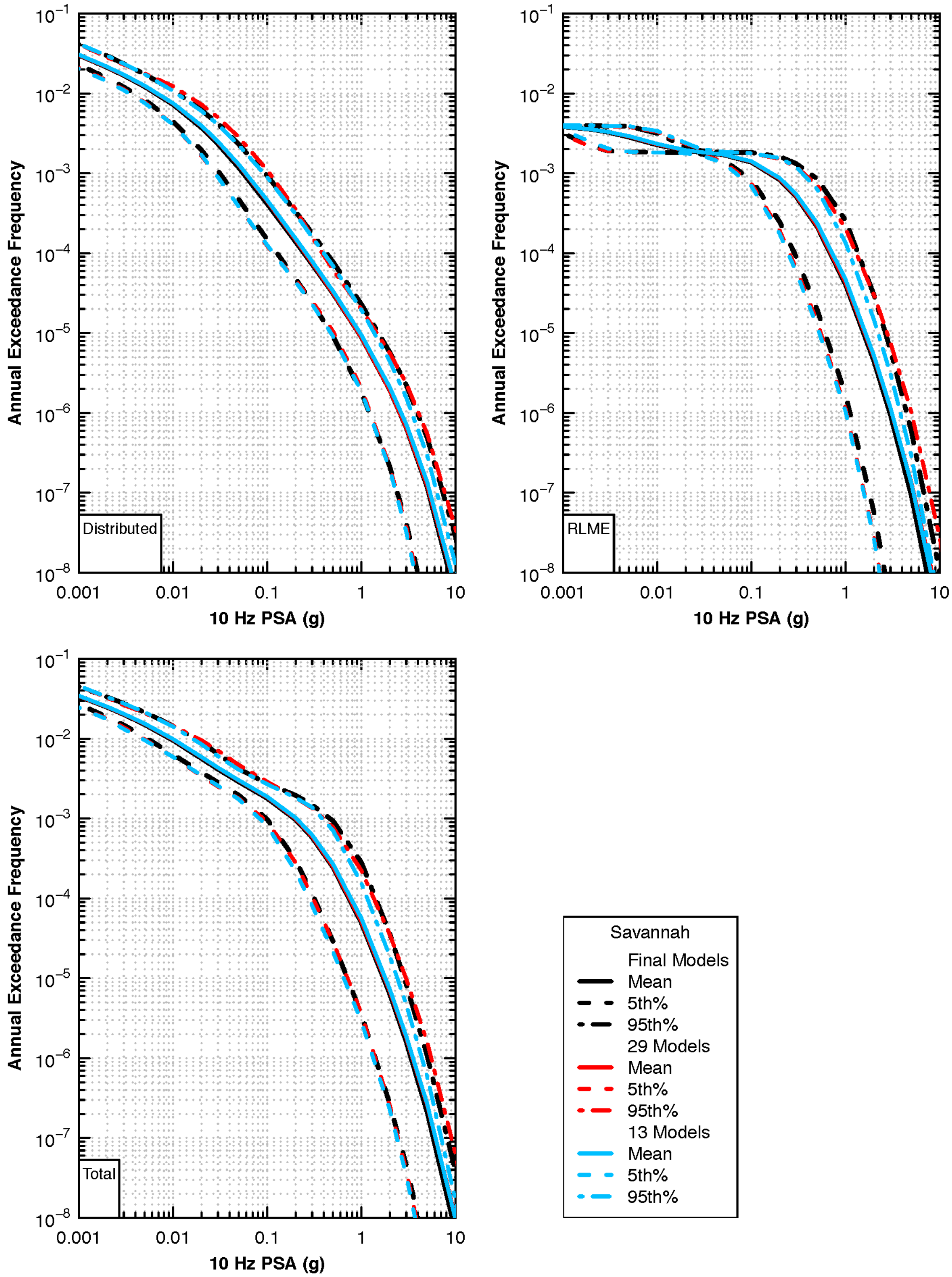
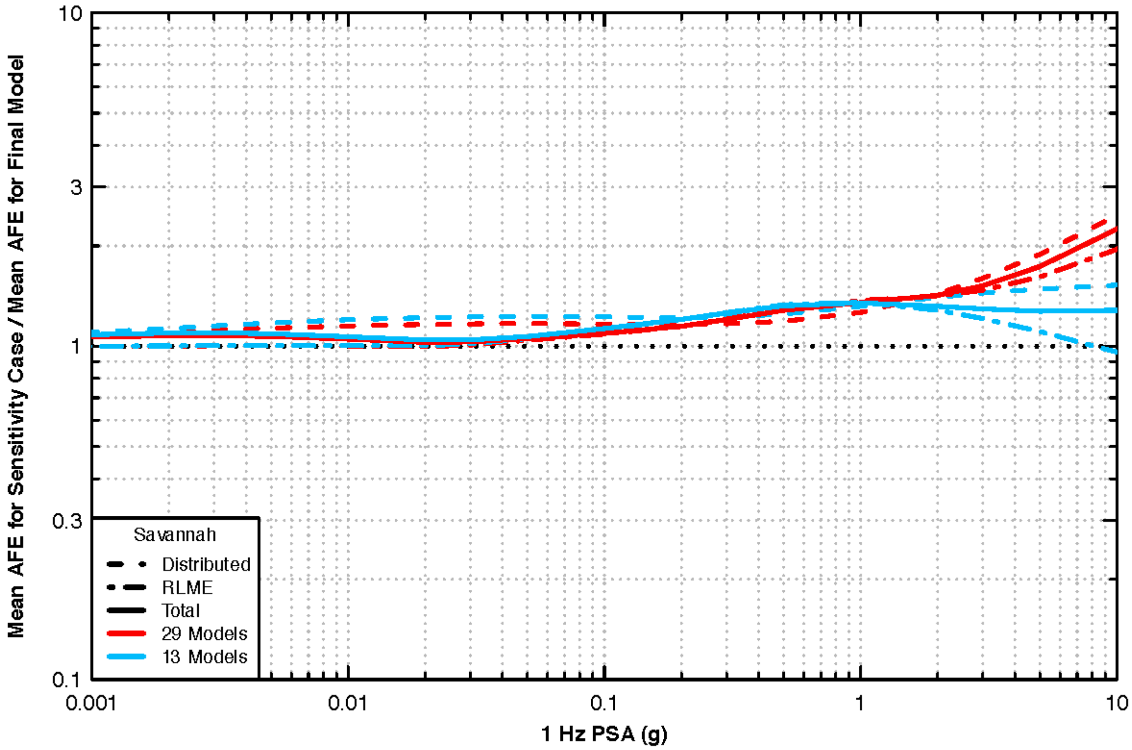
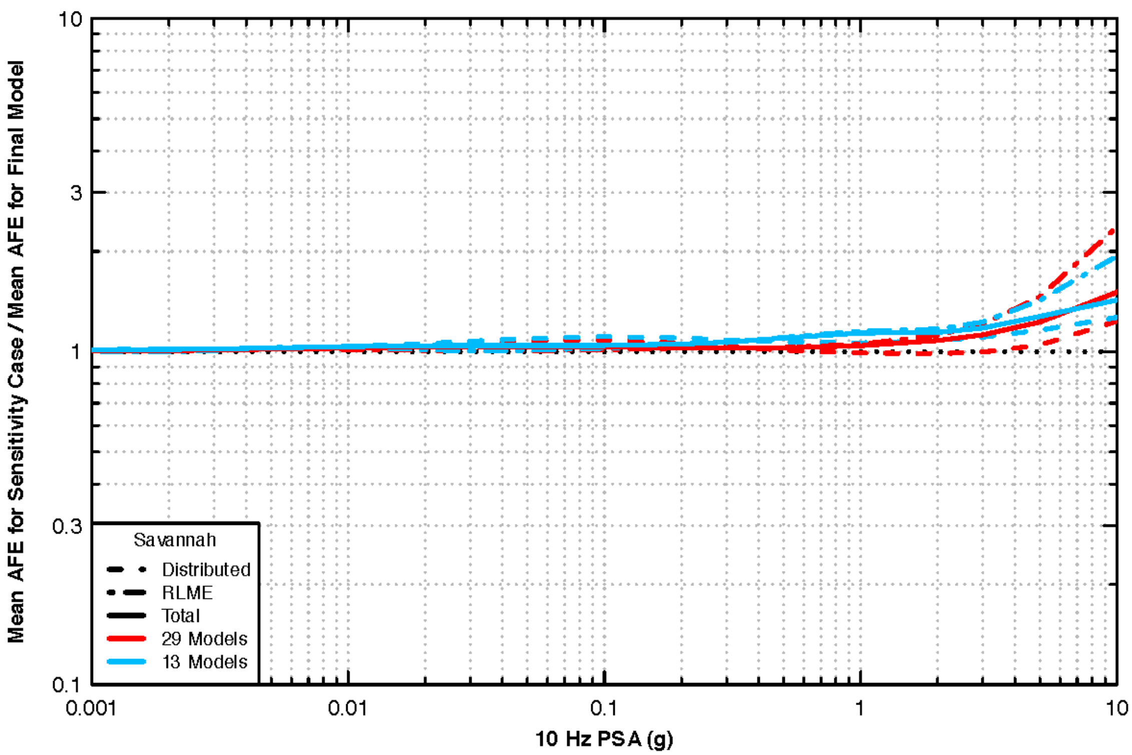


Figure E.6–4(c) Hazard ratios for 13, 17 (Final Models), and 29 GMMs for 1 and 10 Hz at Savannah.





E.7 Definition of PGA Frequency

As discussed in Section 8.6, the generation and smoothing of response spectral shapes required an assessment of the ground-motion frequency corresponding to PGA. For the NGA-East project, this assessment was provided by a small study conducted by Dr. David Boore. Dr. Boore's letter report summarizing the results of the study is presented below.

Updating notes on the period at which PSA comes within a factor of 1.02 of PGA (at short periods)

Dave Boore

ROUGH DRAFT: 22 March 2017

These notes will expand on daves_notes_at_what_period_does_psa_equal_pga.pdf, available on my web site (http://www.daveboore.com). Those notes considered the PSA/PGA ratio for two magnitudes (5.5, 7.5) and two distances (10 km and 100 km). Christine Goulet requested that I consider distances to 1500 km. Given that the notes on my website showed that PSA/PGA is insensitive to **M** at short periods, these rough notes only considered **M** = 5.5. Also, the Boore and Thompson adjustments for random vibration simulations are only available for distances to 1262 km, so I limited my analysis to 9 log-spaced distances between 5 and 1260 km.

I used the random vibration program tmrsk_loop_rv_drvr, with the BS11 params file used in the NGA-East project, with k_0 = 0.006 and site amps for V_{S30}=3000 m/sec. Figure E.7–1 shows a plot of the PSA/PGA ratios vs period for the nine distances.

Although I've always thought that the SMSIM simulations had uncertainties of about 1%, I was surprised to see that the short-period asymptotes of the ratio generally did not approach 1.0 (as they did in the notes on my website). The new results make use of the Boore and Thompson (2015) oscillator adjustments, and the none-unity intercept might indicate a slight error in either PSA or PGA. As a fast check, I used a_ts_drvr to generate 10 time series (at 1000 sps) for R_{RUP} = 5 km and 158 km. I computed the average of the PSA/PGA ratio for these simulations, with the results in Figure E.7–2 and Figure E.7–3. The time domain ratios (in blue) tend to approach unity (using more realizations would improve the average ratios, but I don't have a program ready to compute the average of many simulations; I used Excel to make the averages, but this was a somewhat tedious manual process, so I am not doing more simulations at present). I decide to adjust the ratios in Figure E.7–1 so that they approach unity for short periods. I did this by choosing a scalar multiplicative adjustment factor, giving Figure E.7–4.

I picked off the periods at which the curves crossed 1.02, and made a plot of these periods versus distance. I played around with linear and log axis, finally deciding on log-log axes, with the results shown in Figure E.7–5. The R_{RUP} axis limits are 5 km and 1500 km; it will be easy to extrapolate the curves to 1500 km to determine the period for which PSA comes within a factor of 1.02 of PGA. I would use the adjusted ratios (Table E.7–1).

Table E.7–1 Recommended values of frequency corresponding to PGA

R_{RUP}	T	f
5.0	0.0028	357.2
10.0	0.0029	339.3
19.9	0.0033	306.1
39.8	0.0037	269.1
79.4	0.0047	213.4
158.4	0.0071	140.1
316.2	0.0142	70.5
631.2	0.0362	27.6
1260.0	0.0947	10.6
1500.0	0.1250	8.0*

* Extrapolated

Figure E.7–1 **PSA/PGA ratios against period for nine distances.**

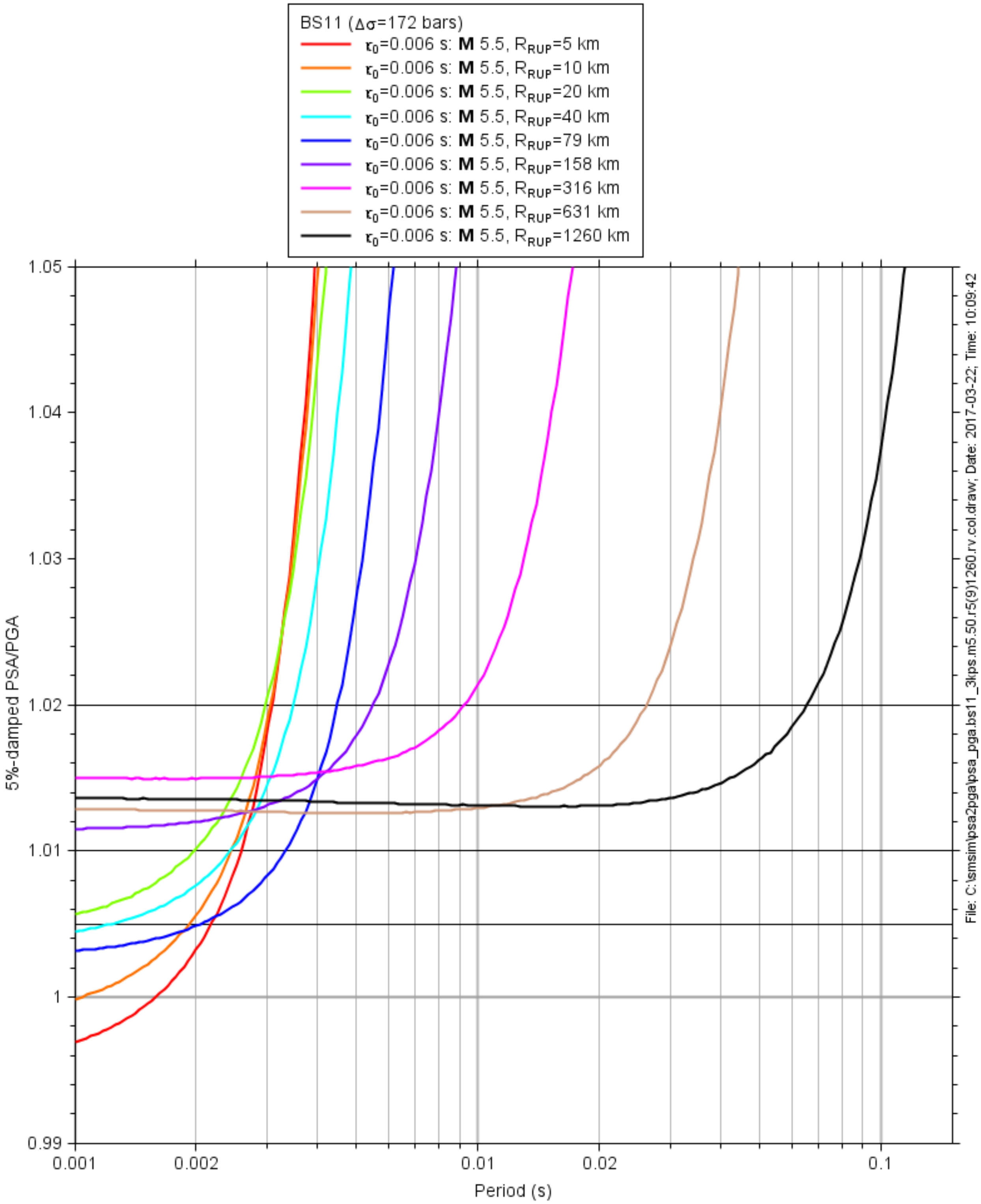


Figure E.7–2 PSA/PGA ratios from SMSIM simulations, R_{RUP} = 5 km.

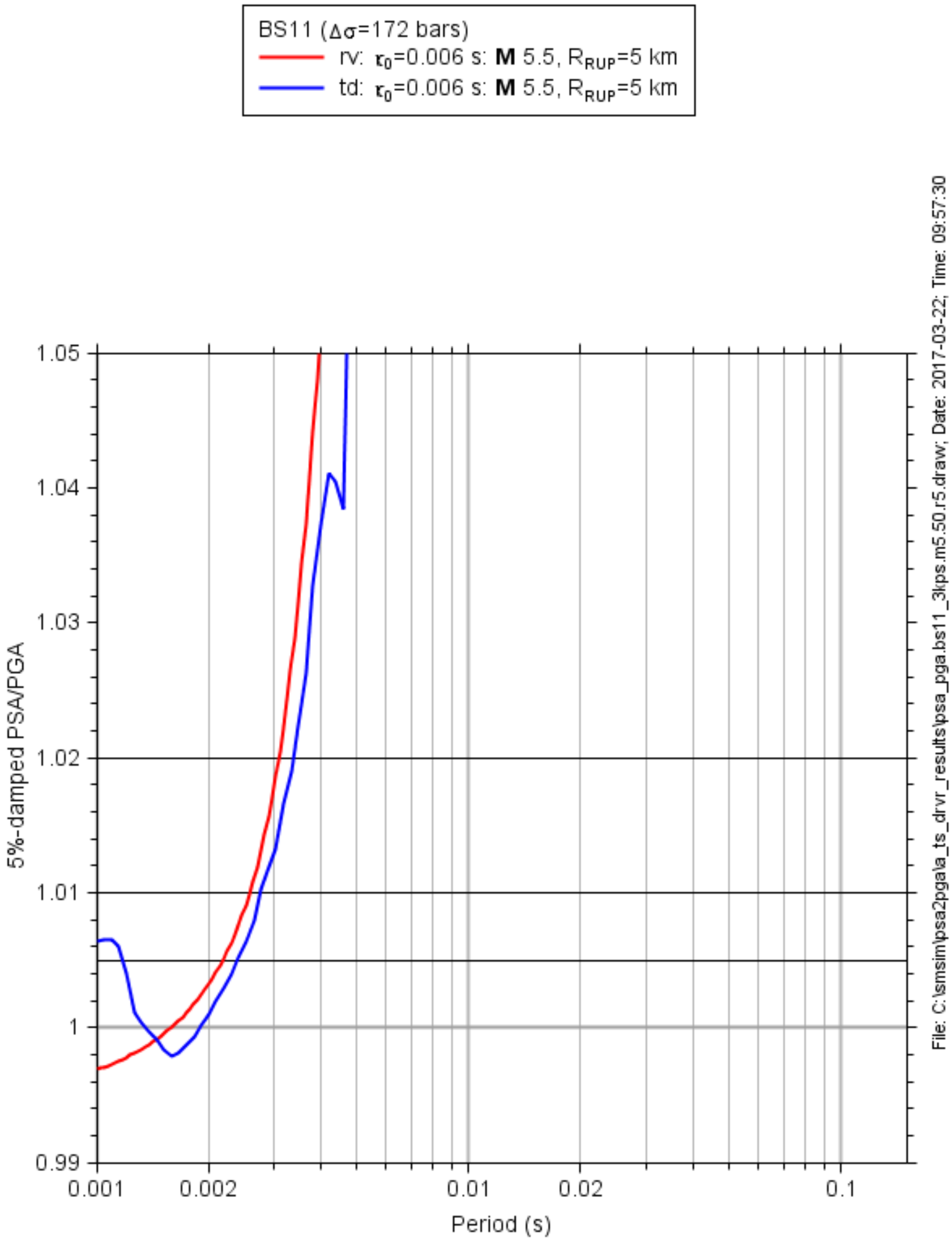


Figure E.7–3 PSA/PGA ratios from SMSIM simulations, R_{RUP} = 158 km.

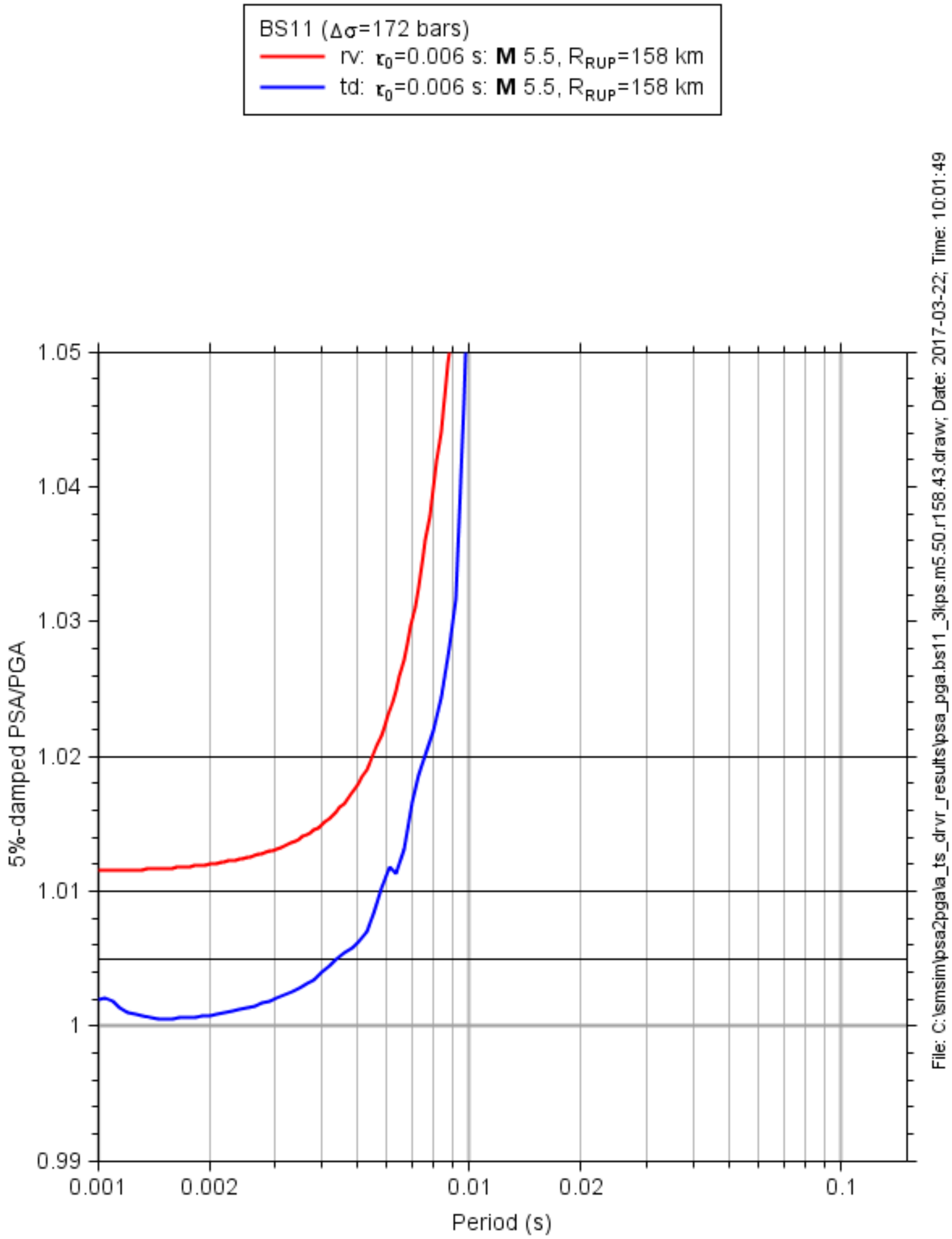


Figure E.7–4 PSA/PGA ratios from SMSIM simulations, various distances.

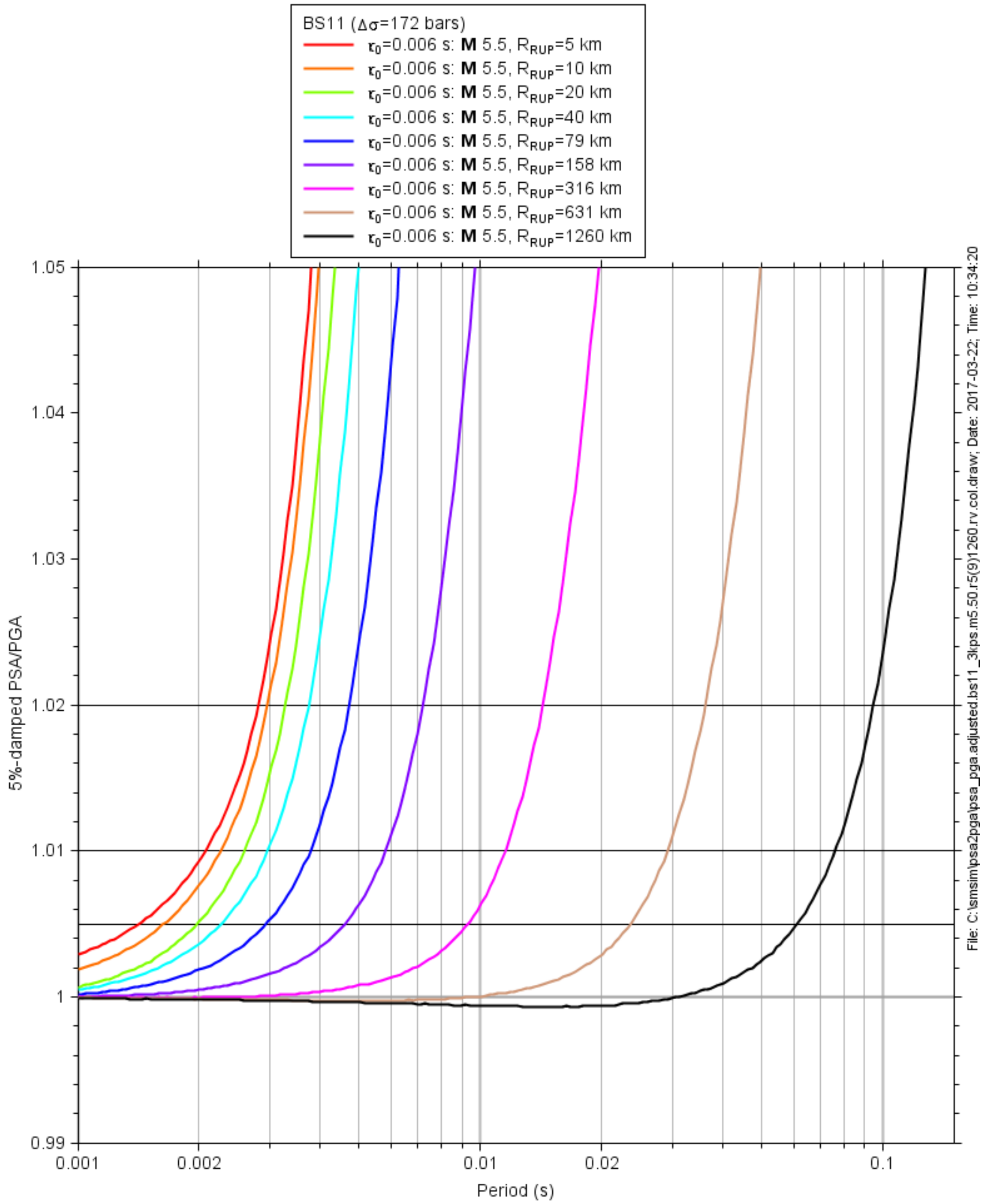
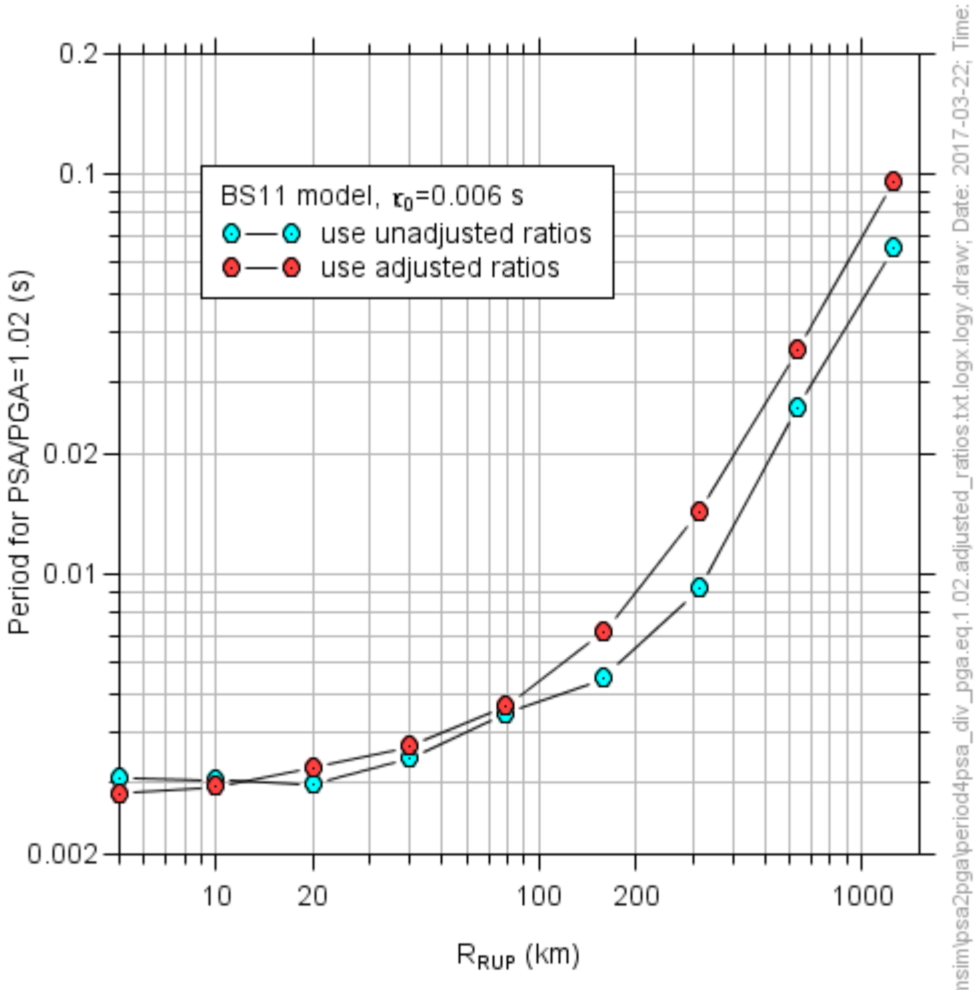


Figure E.7–5 Summary of crossings for PSA/PGA ratios of 1.02, based on Figure E.7–4.



E.8 Sensitivity to GMM Weighting Approaches

E.8.1 Results

This section is a supplement to Section 9.4 and presents sensitivity results to alternate weighting schemes. As described in Section 9.4, the weights assigned to the 17 GMMs in the frequency band with reliable data (1–10 Hz) were assigned based on giving 80% weight to the relative number of sample GMMs in each cell, 10% weight to the inverse of the average residual of the GMMs in each cell, and 10% weight to the average relative likelihoods of the GMMs in each cell. Outside of the 1–10 Hz bandwidth, 100% weight was assigned to the number of samples in the cell because the NGA-East ground-motion data are not considered adequate for assessing GMMs for frequencies above 10 Hz or below 1 Hz. The TI team assigned low weight (20%) to the combined data-based weights (average residual and relative likelihood) because of the limited extent of the ground-motion data for CENA in terms of magnitudes and distances important to hazard assessment, the uncertainty in the site correction adjustments applied to the recorded data, and the limited bandwidth.

Sensitivity analyses were conducted to investigate the effect of two alternative approaches to the data-based weights. One alternative was to give 100% weight to the relative number of models for all frequencies. This alternative has the attribute that the same weighting scheme is applied to all frequencies. The second alternative was to assign all of the data-based weight (20%) to relative likelihood weights using the argument that the relative likelihood approach measures both the average fit and the dispersion of the fit to data, and thus may already account for the average residual.

Figures E.8–1 to E.8–3 compare the hazard results at the three demonstration sites for the three alternative weighting approaches, with part (a) for hazard curves at 1 Hz, part (b) for hazard curves at 10 Hz and part (c) showing the hazard ratio for both frequencies. The three alternative weighting approaches produce essentially the same mean hazard. Some differences in fractiles are produced at various points. For example, assigning 20% weight to relative likelihood produced lower 95th fractile hazard curves for some ground-motion levels. However, when this was observed, the other fractiles were essentially the same as the other weighting approaches such that very similar values of the variance in AFE are computed. On this basis, it was concluded that the three weighting approaches produced very similar hazard. The TI team selected to use the combination of average residual and relative likelihood data-based weights because it tended to produce a slightly wider distribution of GMMs.

E.8.2 Subsets of Data for Data-Based Weights in Chapter 9

The files below contain the data subsets used for defining the residual- and likelihood- based weights defined in Chapter 9. Data are provided in coma-separated variable format.

E.8.2.1 Contains the uncorrected data

File: E.8.1.1_Data_Subset_UNCorrected_to_RefSite.csv

E.8.2.2 Contains the site-corrected data presented in Table 9–1

File: E.8.1.2_Data_Subset_Corrected_to_RefSite.csv

Figure E.8–1(a) Hazard sensitivity to alternative model weighting approaches for 1 Hz at Manchester.

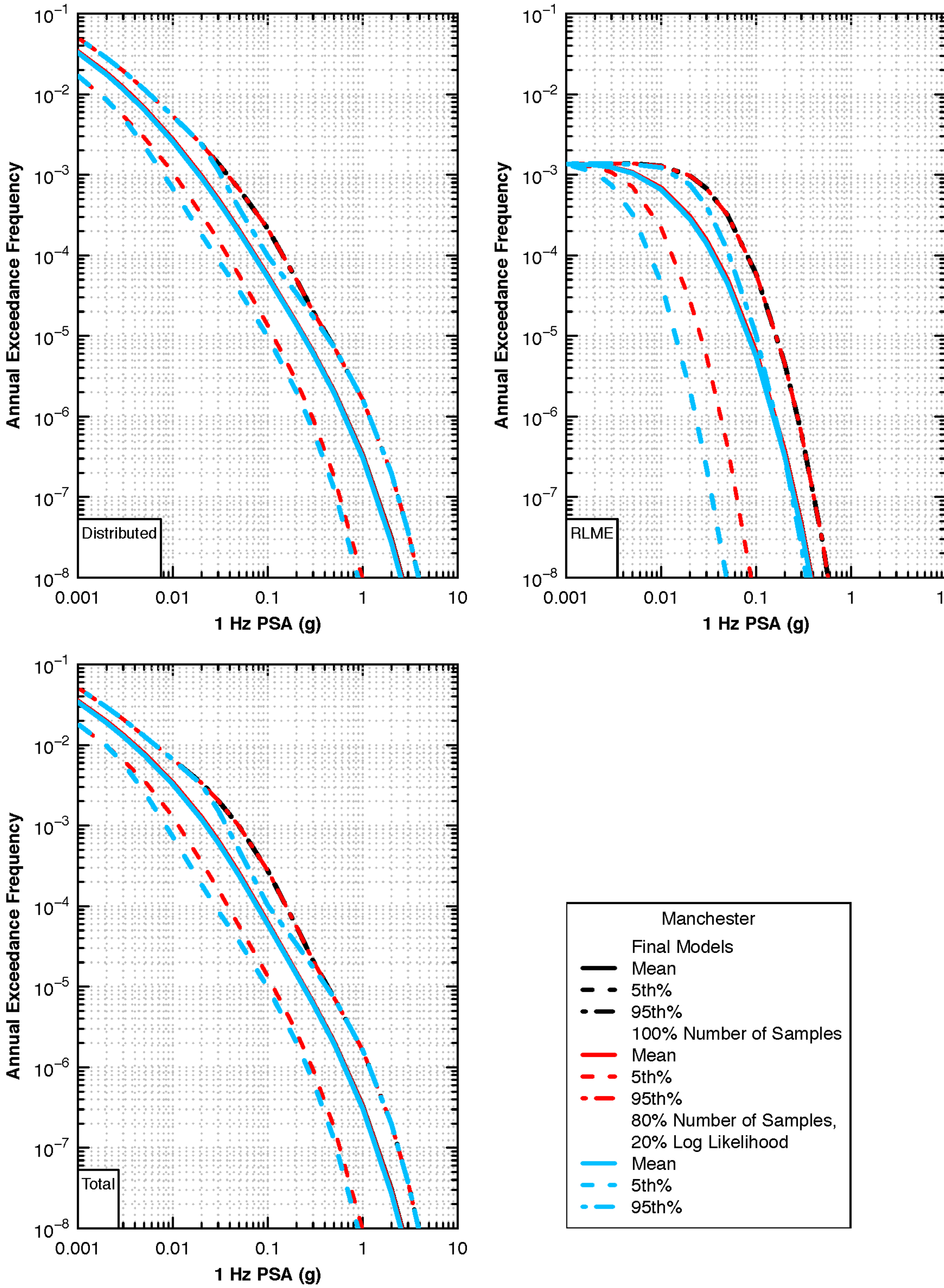


Figure E.8–1(b) Hazard sensitivity to alternative model weighting approaches for 10 Hz at Manchester.

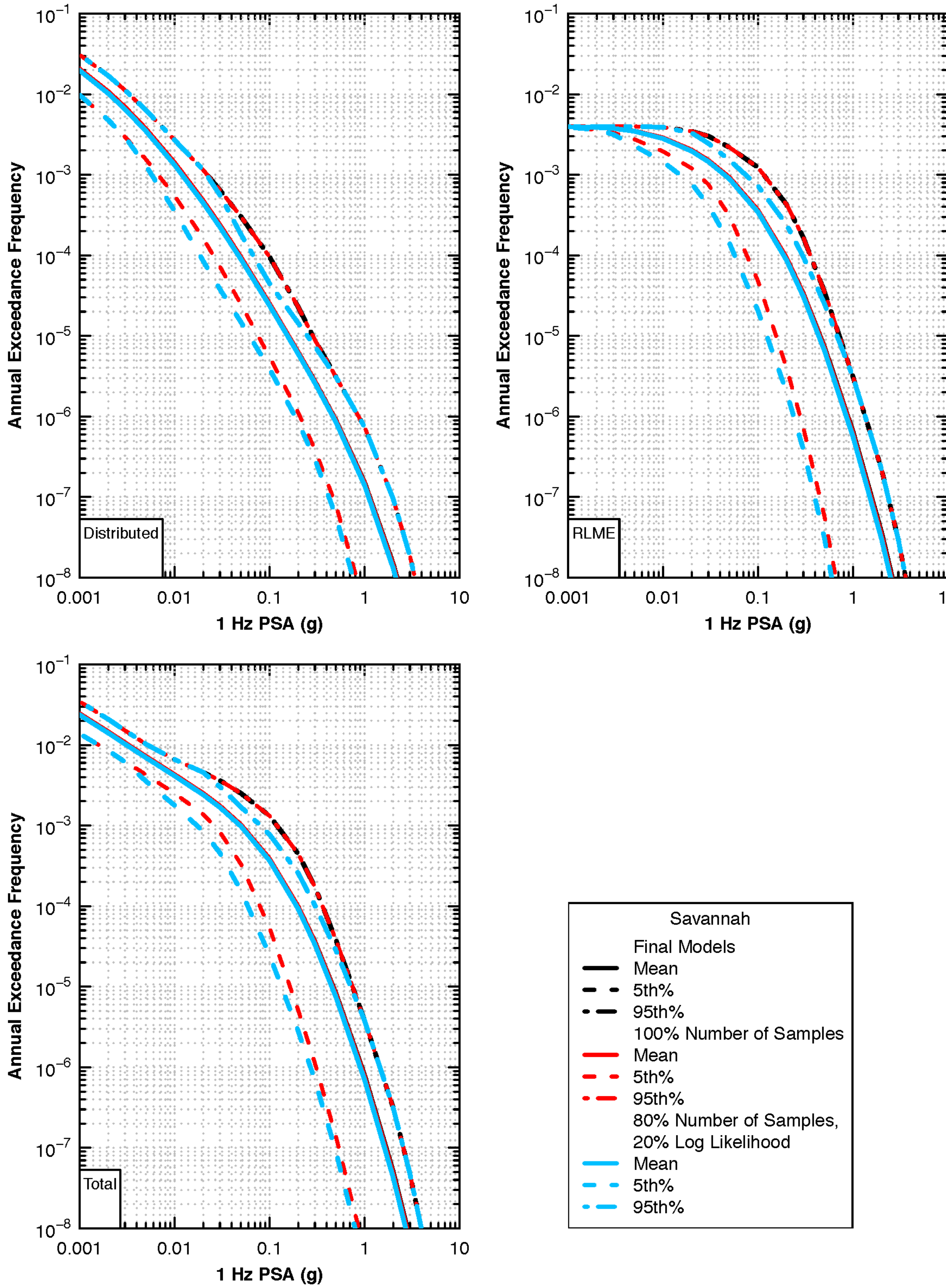
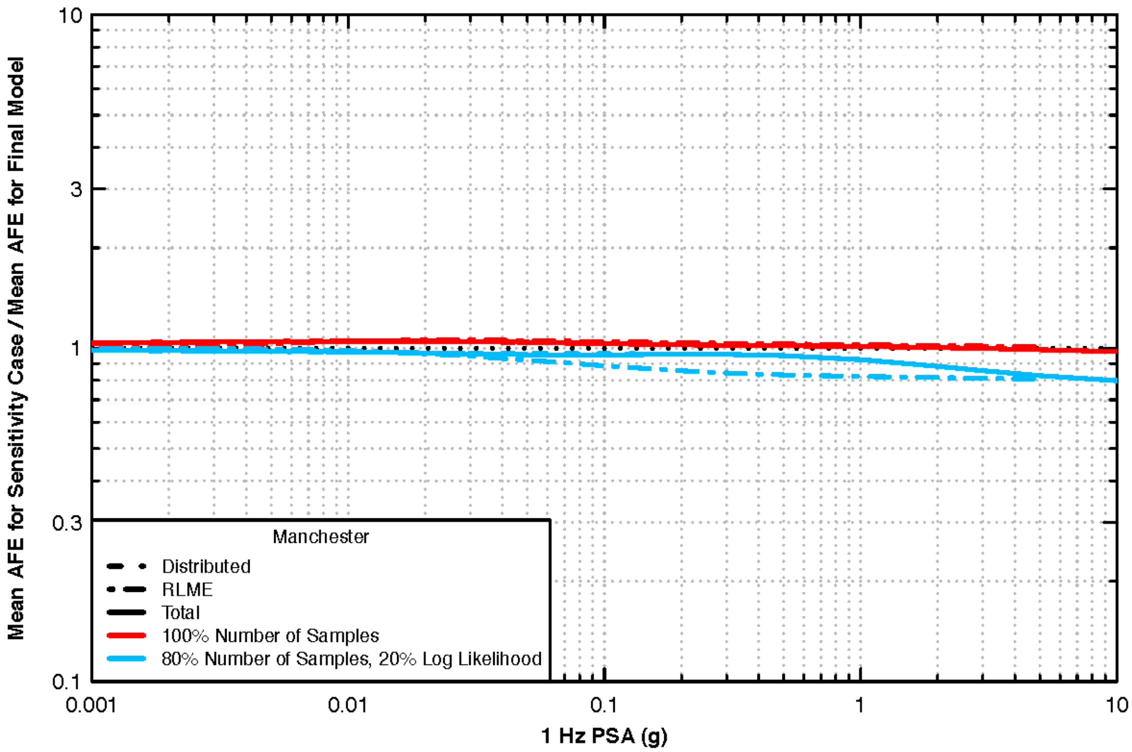


Figure E.8–1(c) Hazard ratios for alternative model weighting approaches for 1 and 10 Hz at Manchester.



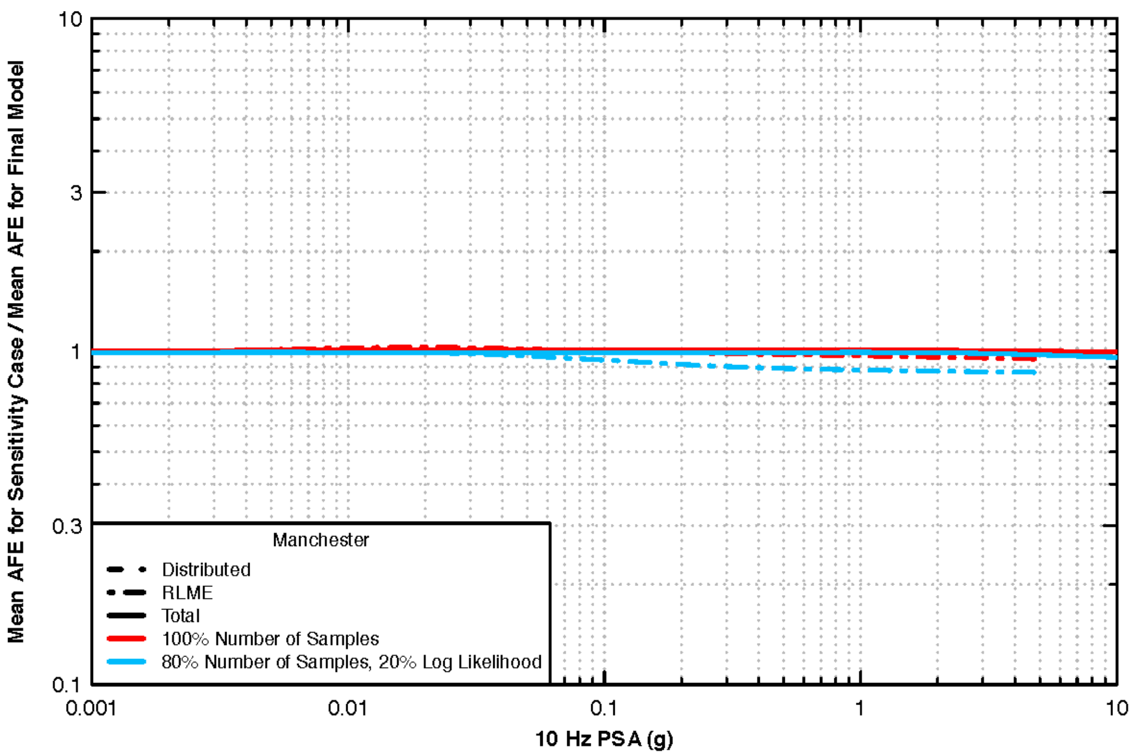


Figure E.8–2(a) Hazard sensitivity to alternative model weighting approaches for 1 Hz at Central Illinois.

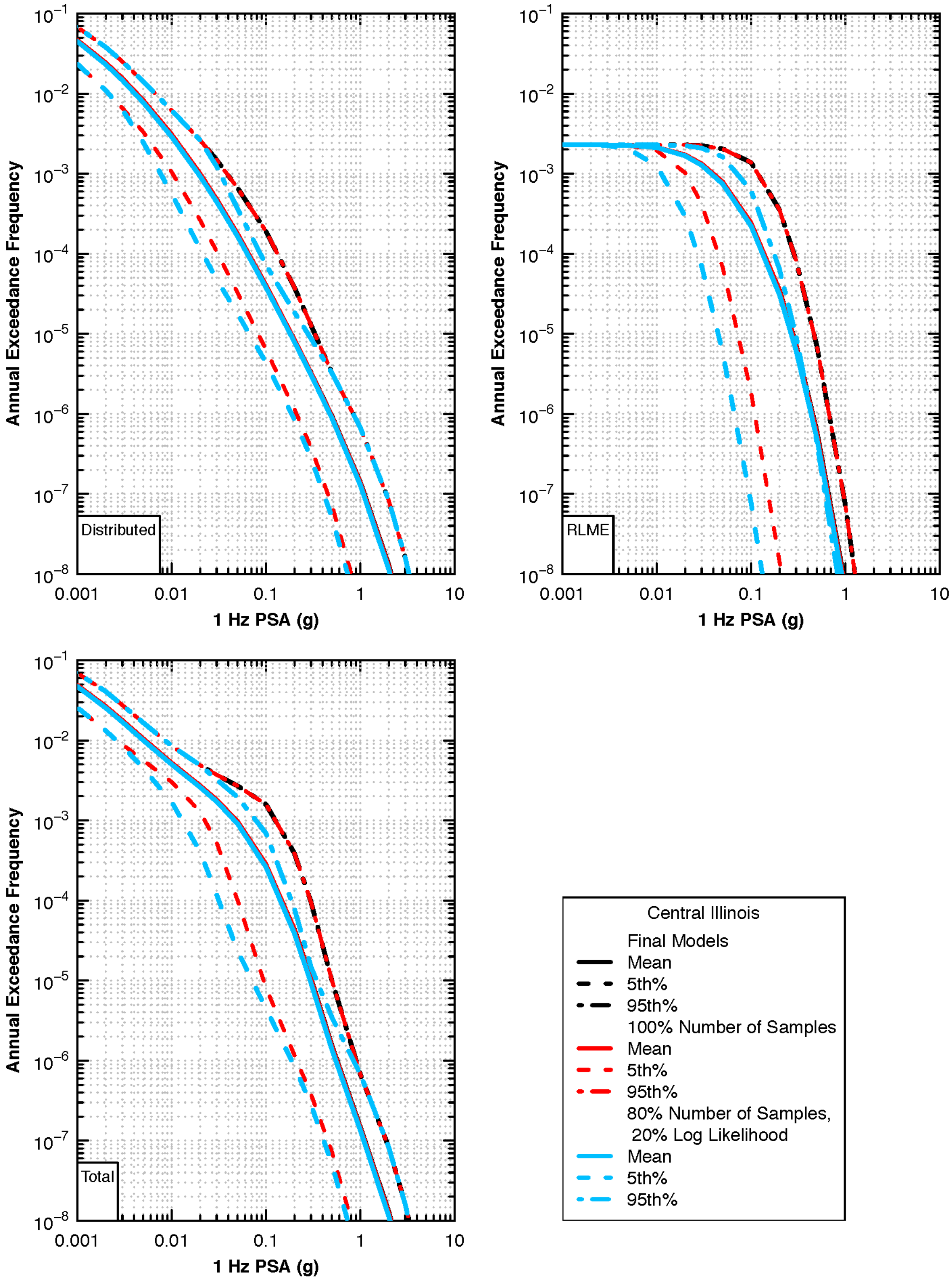


Figure E.8–2(b) Hazard sensitivity to alternative model weighting approaches for 10 Hz at Central Illinois.

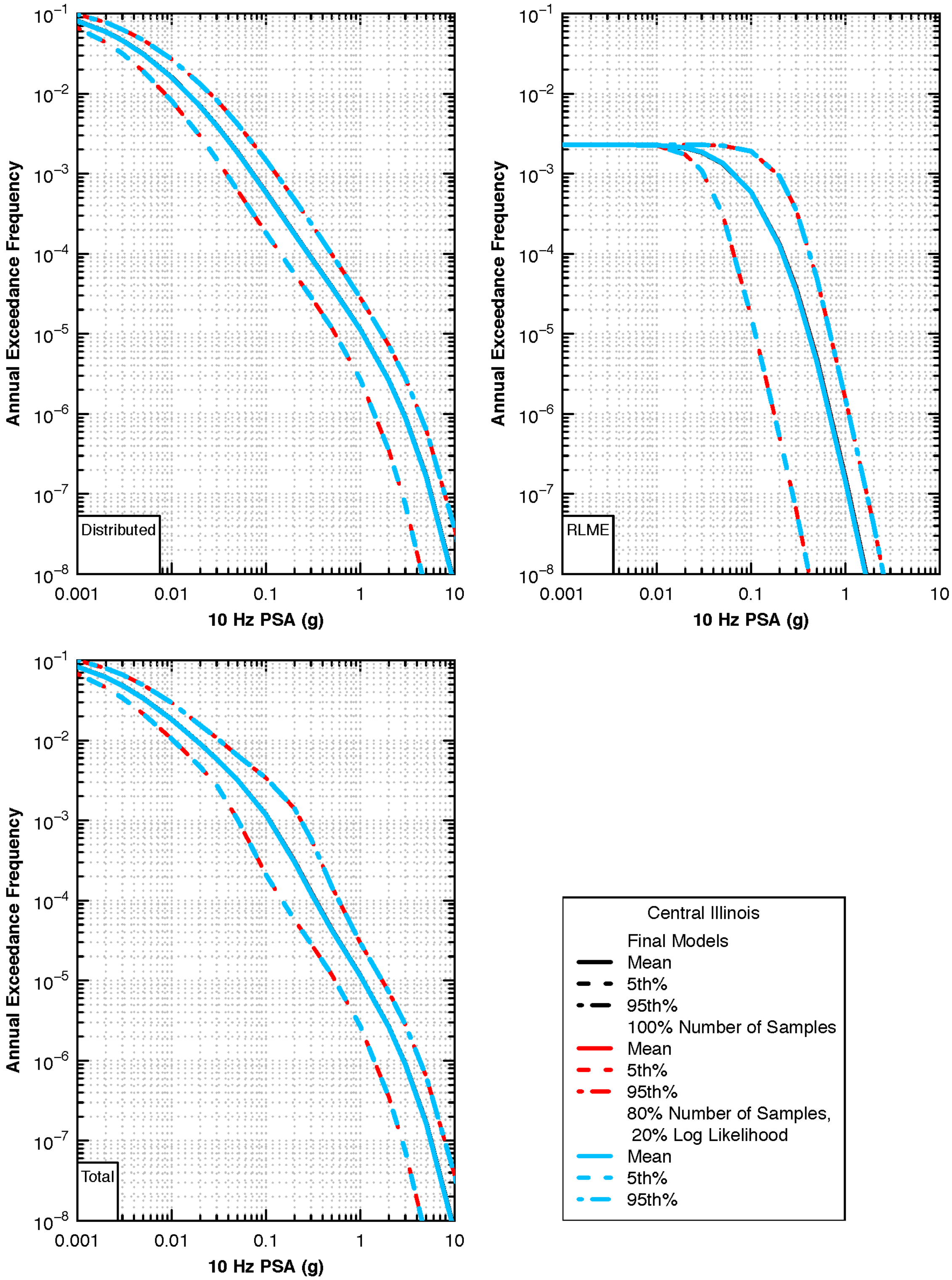
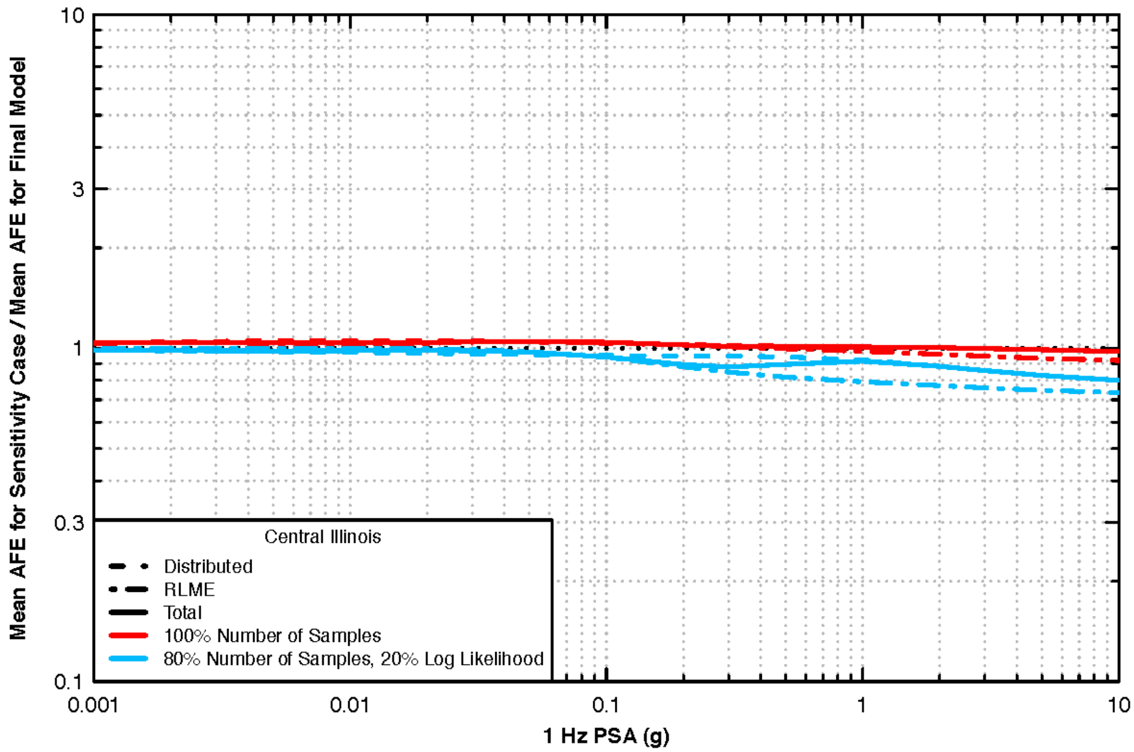


Figure E.8–2(c) Hazard ratios for alternative model weighting approaches for 1 and Hz at Central Illinois.



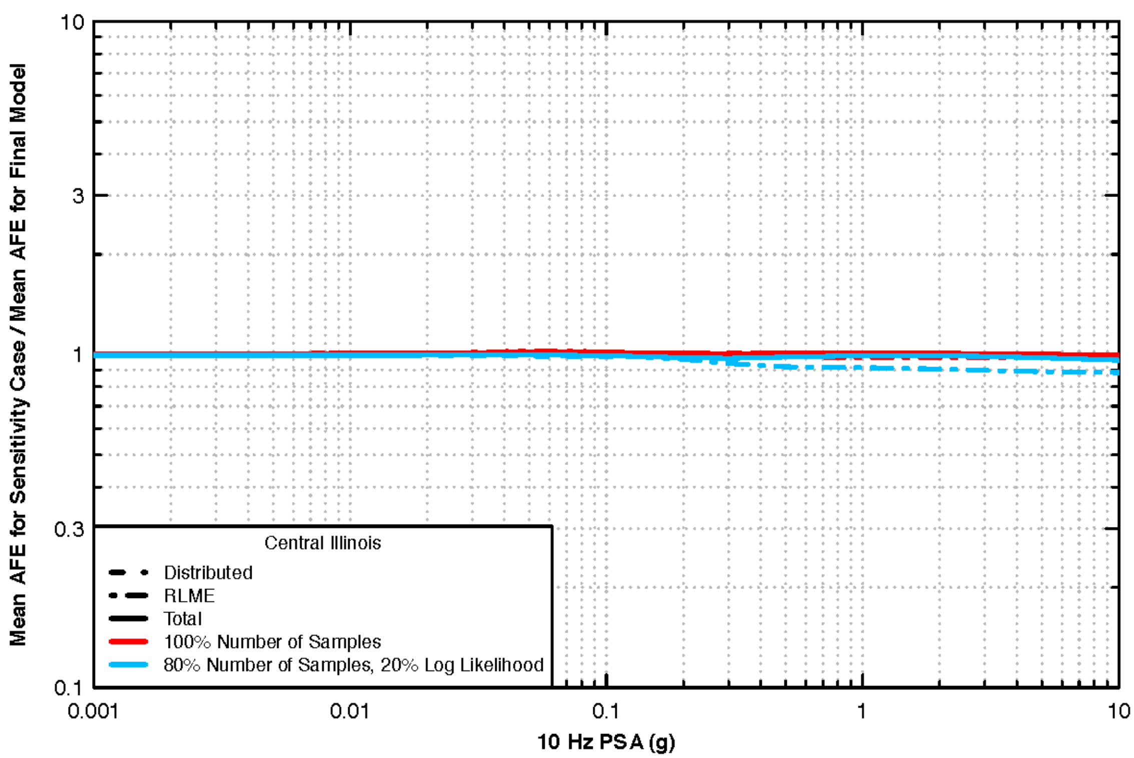


Figure E.8–3(a) Hazard sensitivity to alternative model weighting approaches for 1 Hz at Savannah.

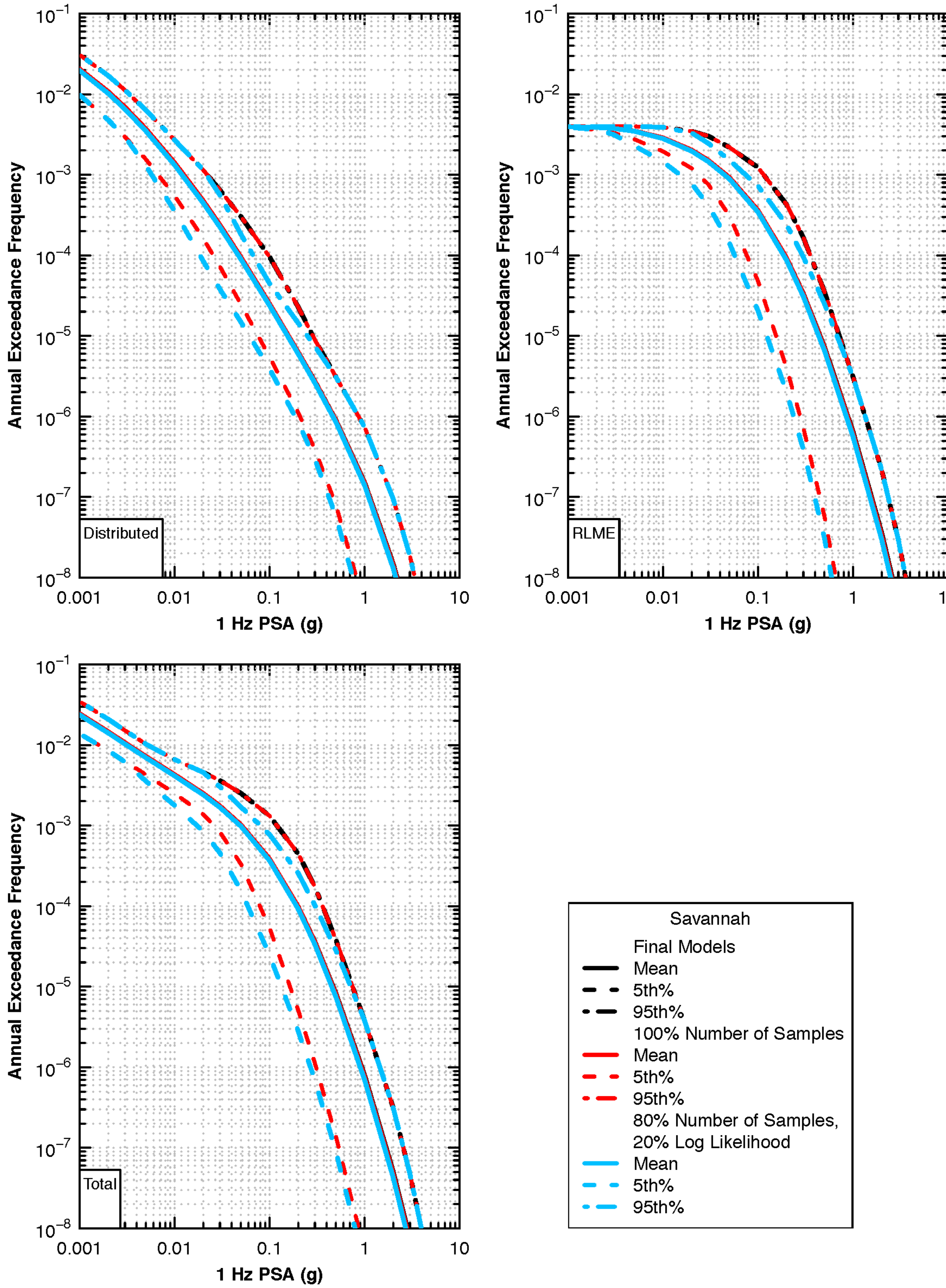


Figure E.8–3(b) Hazard sensitivity to alternative model weighting approaches for 10 Hz at Savannah.

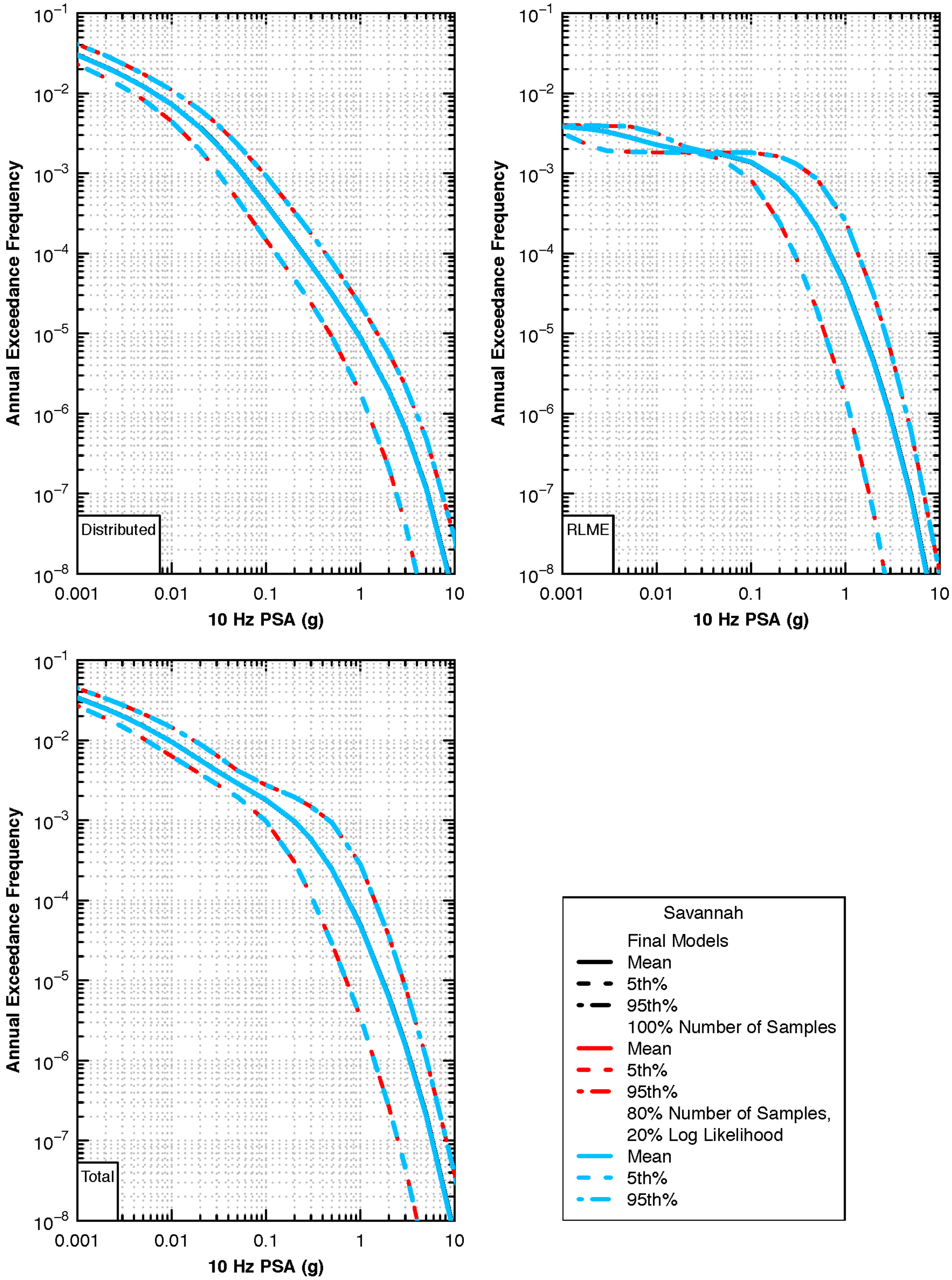
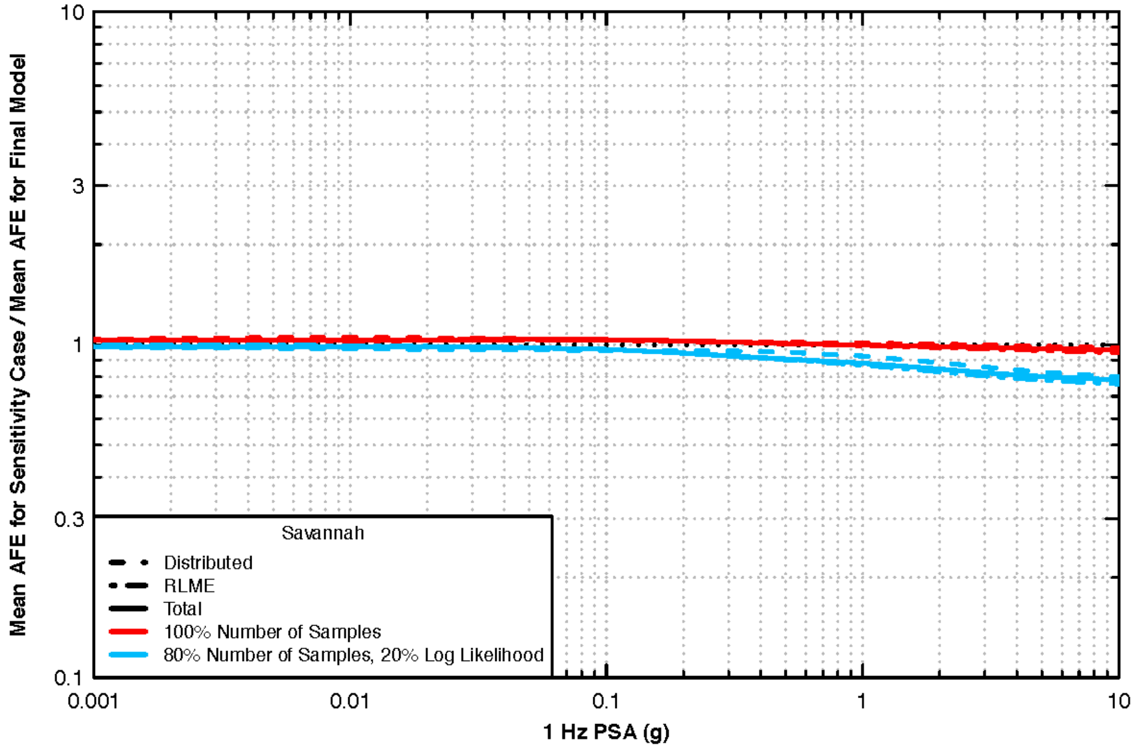
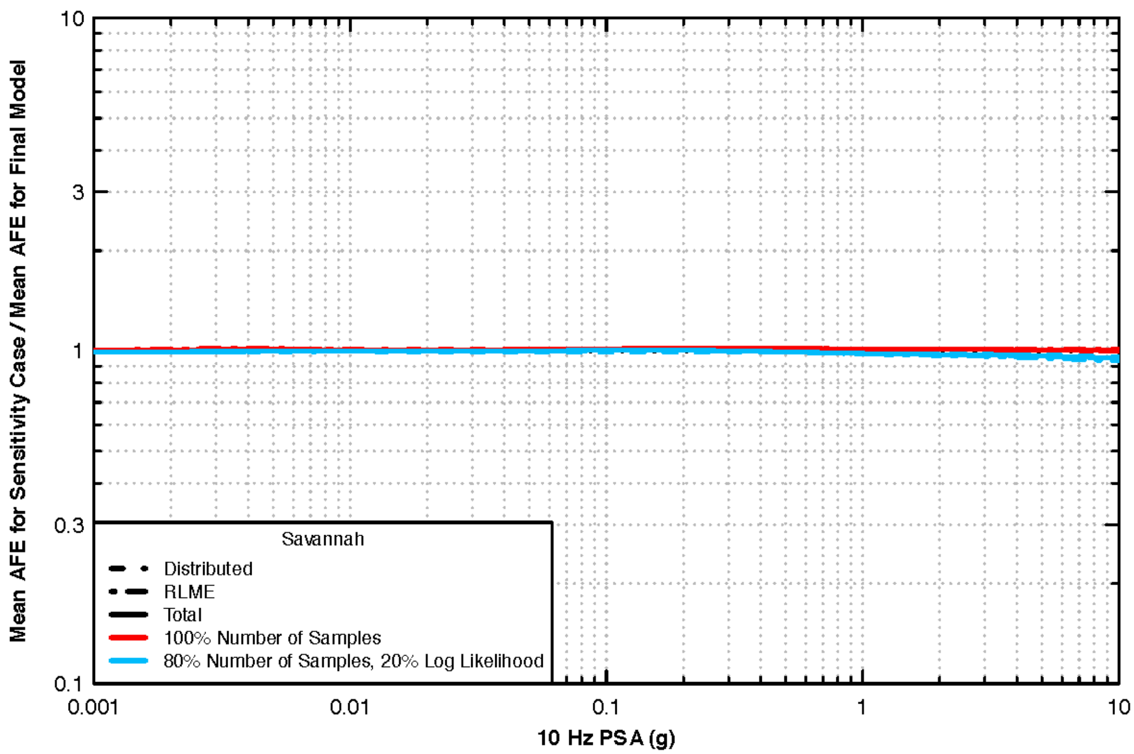


Figure E.8–3(c) Hazard ratios for alternative model weighting approaches for 1 and Hz at Savannah.





E.9 Final Median GMM Plots and Plotting Tools (Electronic Appendices)

Plots and plotting tools are provided as an electronic appendix.

The final median GMMs are provided in electronic format in Appendix H.7.1

E.9.1 Plots of Final Median GMMs

The E.9.1_Plots_NGA-East_Final_GMMs.pdf file contains plots organized in the following sections:

1 Magnitude Scaling of Final GMMs

2 Distance Scaling of Final GMMs

3 Plots of Cumulative Distribution Function (Seed and Final GMMs)

4 Plots of Fractiles vs. Magnitude (Seed and Final GMMs)

5 Plots of Fractiles vs. Distance (Seed and Final GMMs)

6 Plots of Weighted Mean Spectra (Final GMMs)

Three plotting tools are provided as electronic appendices. They all require a free Wolfram app which is available online at: https://www.wolfram.com/cdf-player/.

E.9.2 Plotting Tool for Final Median GMMs, with M

File: E.9.2_PlottingTool_NGA-East_Final_GMMs_M.cdf

E.9.3 Plotting Tool for Final Median GMMs, with R_{Rup}

File: E.9.3_PlottingTool_NGA-East_Final _GMMs_RRup.cdf

E.9.4 Plotting Tool for Final Median GMMs, with F

File: E.9.4_PlottingTool_NGA-East_Final _GMMs_F.cdf

E.10 References

Al Atik, L., and R.R. Youngs. 2014. “Epistemic Uncertainty for NGA-West2 Models.” Earthq. Spectra, 30 (3): 1301–1318.

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Appendix F Supporting Documentation and Sensitivity Analyses for the Standard Deviation Model Development

F.1 Regional Evaluation of Residuals

This section provides additional documentation related to Section 10.3.4 (ϕ_{S2S} Model). The average of the site terms was calculated for CENA regions 2, 3, and 4 (see Figure 4–4 for the regions map), as shown in Figure F.1–1. Similarly, the average of the event terms for CENA regions 2, 3, and 4 was calculated, as shown in Figure F.1–2. Region 4 has only a few stations and events, hence the large error bars observed on the average site terms and event terms. Figure F.1–1 shows that Region 3 has a negative bias in the average site terms, while the average of the event terms for this region is close to zero between 1 and 10 Hz. Figures F.1–1 and F.1–2 do not show a clear trade-off between the event terms and site terms for Region 3.

Figure F.1–1 Average site terms versus frequency for regions 2, 3, and 4.

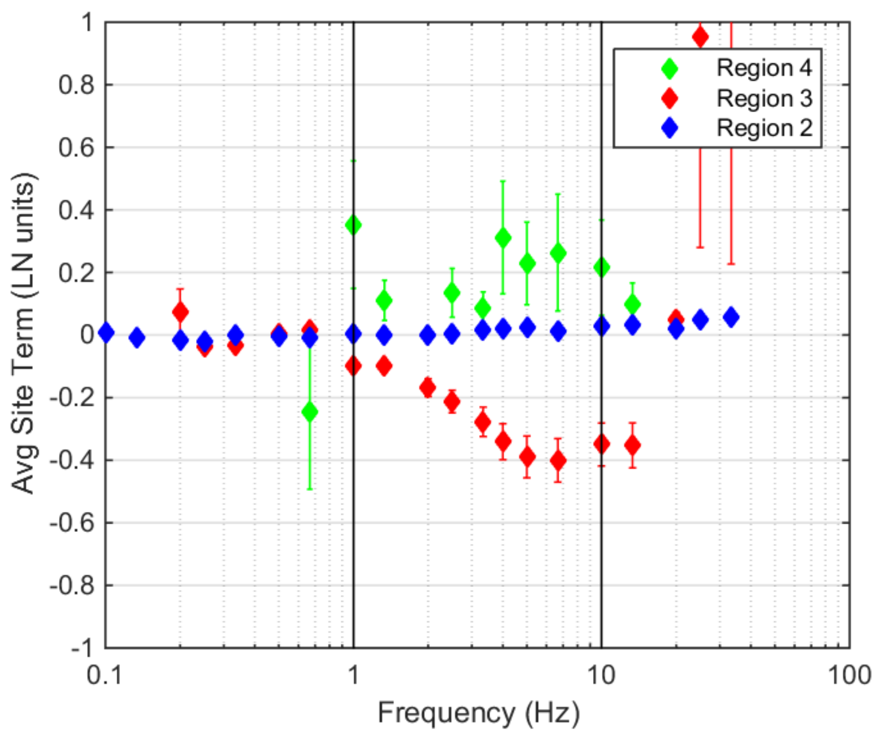
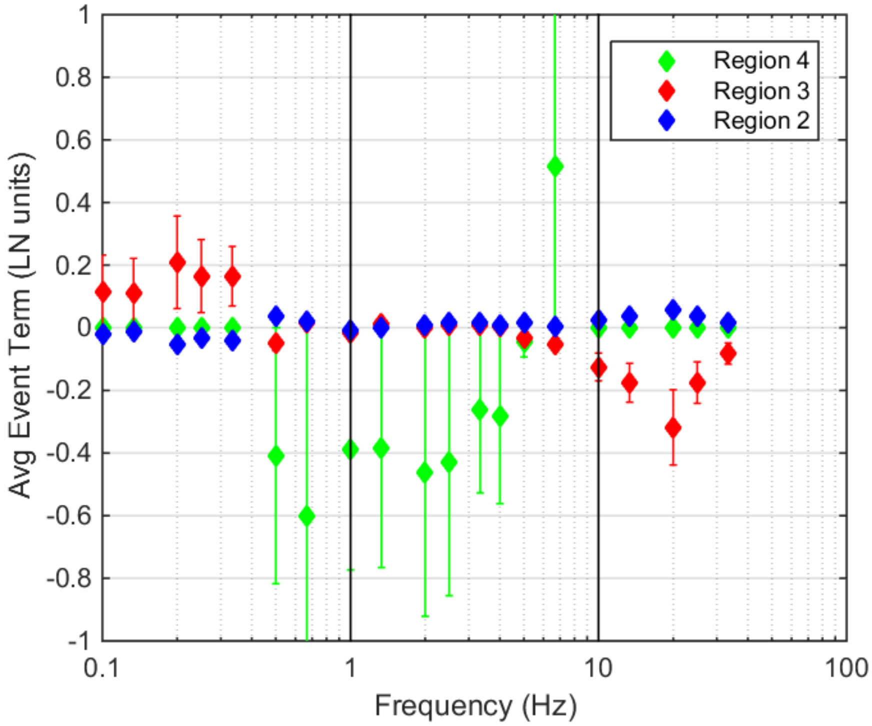


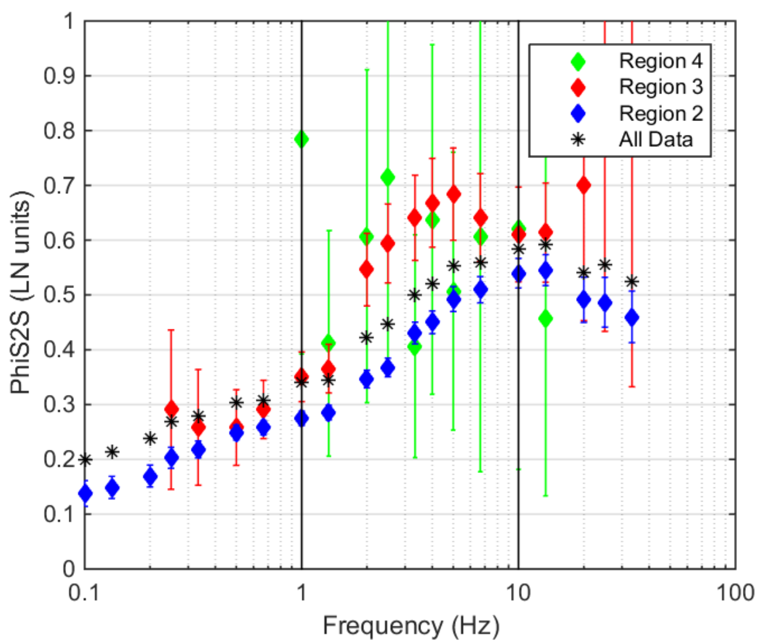
Figure F.1–2 Average event terms versus frequency for regions 2, 3, and 4.



The negative bias in the site terms for Region 3 can be attributed to site response effects. Region 2 has the largest number of stations (237 stations in Region 2 versus only 35 stations in Region 3 at f = 4 Hz). As a result, the derived V_{S30} scaling in the GMM is likely to be controlled by the site response of the sites in Region 2 and not fitting well the average site response in Region 3. Regional differences in the Q attenuation could also contribute to the bias in the average site term for Region 3. An attempt was made to investigate the presence of regional Q differences by running the regression with data with a maximum distance of 200 km and computing the average site terms for regions 2, 3, and 4. If the average bias in the site terms is still observed when using data with limited distance, then the effects of regional Q differences on the average site terms can be ruled out. Using data with maximum distance of 200 km, however, severely limits the number of stations leading to 76 stations in Region 2, and one station in each of regions 3 and 4 at f = 4 Hz. As a result, no definitive conclusion can be made regarding the potential effect of regional Q differences on the bias in the site terms observed for Region 3.

Figure F.1–3 shows the ϕ_{S2S} values for regions 2 and 3, as well as the values used to build the CENA ϕ_{S2S} model. The PPRP expressed concern that the ϕ_{S2S} model is inflated compared the values observed for Region 2. Recall, that the ϕ_{S2S} model uses both tectonic and potentially induced event (PIE) data in order to maximize the number of stations available for the regression. ϕ_{S2S} obtained using PIE data was observed to be smaller than that obtained with tectonic data, which is likely due to the distribution of the stations that recorded only PIEs over a relatively small geographic area compared to the rest of the CENA stations. Small magnitude and site conditions were found to have an impact on the relatively large ϕ_{S2S} values for CENA and were corrected for as documented in Chapter 10. Figure F.1–4 compares the ϕ_{S2S} data used to build the CENA model to the ϕ_{S2S} values for regions 2 and 3 obtained using data from tectonic events only. Figure F.1–4 shows that the ϕ_{S2S} values used to derive the CENA model represent well the ϕ_{S2S} values for Region 2 obtained using tectonic data only. ϕ_{S2S} values for Region 3 are larger than the proposed CENA ϕ_{S2S} model. Due to data limitations, the TI team combined all the CENA stations together to build a CENA ϕ_{S2S} model that is region-independent. Regional differences cannot be reliably resolved using the available data.

Figure F.1–3 PhiS2S (ϕ_{S2S}) versus frequency for regions 2, 3, and 4 compared to the values used to build the CENA ϕ_{S2S} model (all data).



F.2 Hazard Sensitivity Results to the Standard Deviation Models

This appendix shows the results of hazard sensitivities to the three branches (low, central, and high) of the composite single-station sigma model (Section 11.6.1) as well as to the distribution of the single-station sigma model (Section 11.10).

Hazard sensitivity analyses are presented for three of the demonstration sites, covering different types of sources and seismicity: Manchester, Central Illinois, and Savannah. Manchester is representative of a moderate seismicity site with contributions from a distant (~500 km) repeated large magnitude earthquake (RLME) source with a moderate rate of activity, Central Illinois is in an area of moderate to low seismicity with a very active RLME (New Madrid) at a distance of ~ 400 km), and Savannah is close to the Charleston RLME source. All calculations are performed considering only the epistemic uncertainty in ground motion characterization using the mean predicted seismicity rates from the CEUS SSC model. Hazard sensitivities are performed for 1 and 10 Hz at the three sites listed above.

In Figures F.2–1 to F.2–3), the plots on the left shows hazard from the distributed seismicity, the RLME sources and the combined total hazard. The plots on the right shows each of the 17 median models, the impact of the low, central and large sigma branch and finally the impact of the mixture model on hazard.

The plots in Figures F.2–1 to F.2–3 show small to negligible difference in the hazard due to the distribution of the single-station sigma model (traditional lognormal versus mixture model).

Figure F.2–1(a)   Hazard results the NGA-East final GMMs for 1 Hz at Manchester (see text for figure description).

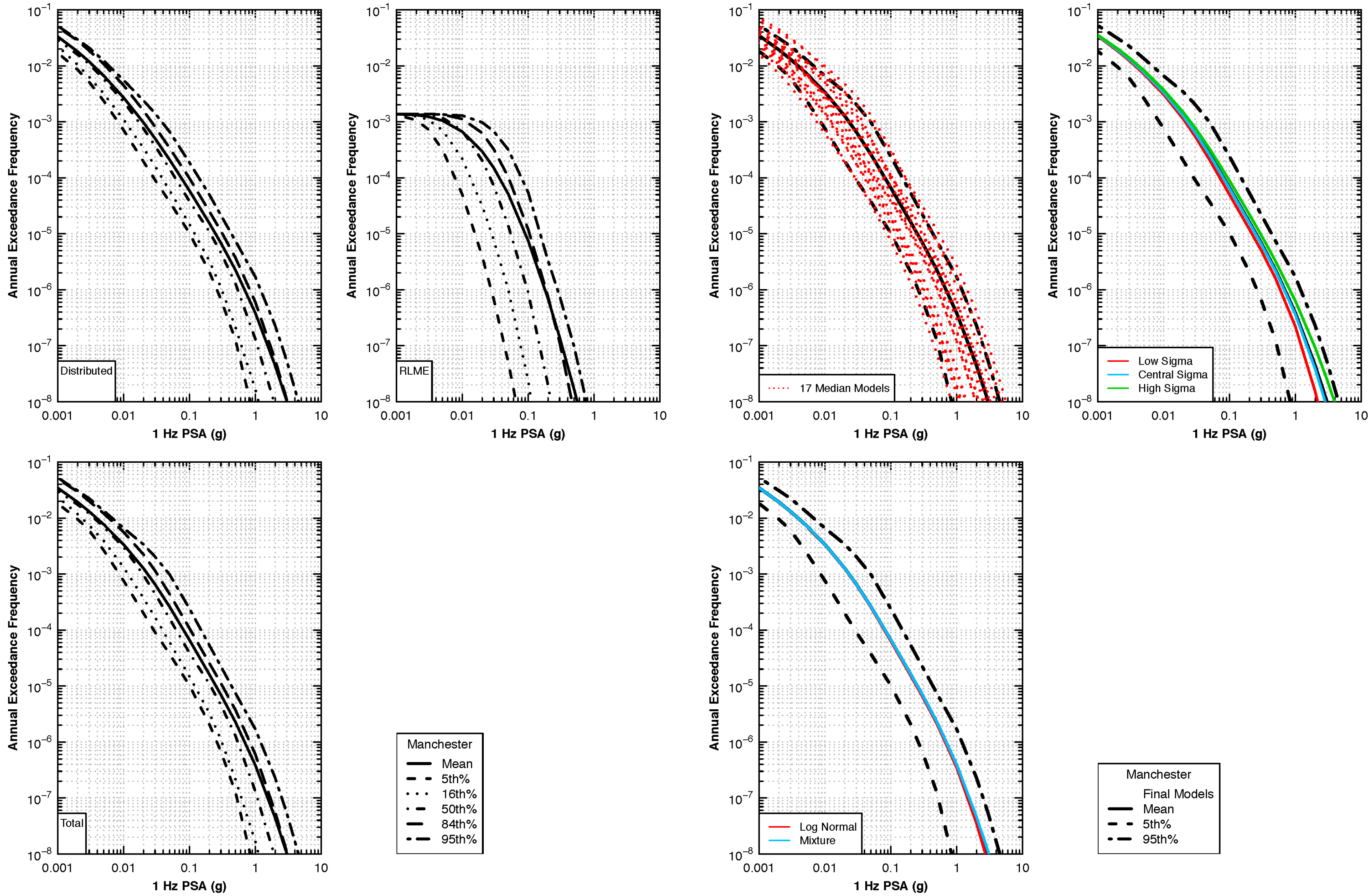


Figure F.2–1(b) Hazard results the NGA-East final GMMs for 10 Hz at Manchester (see text for figure description).

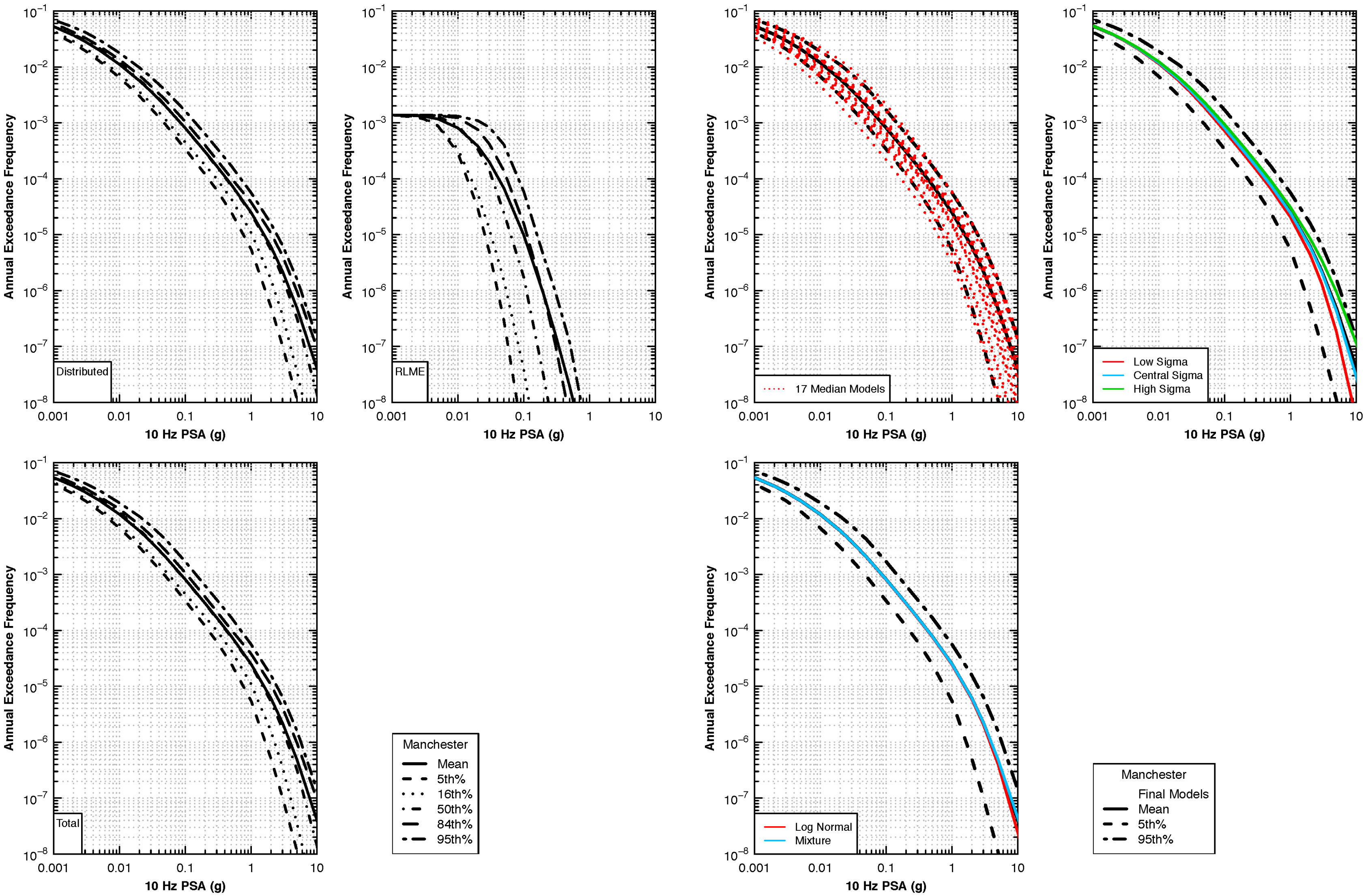


Figure F.2–2(a) Hazard results the NGA-East final GMMs for 1 Hz at Central Illinois (see text for figure description).

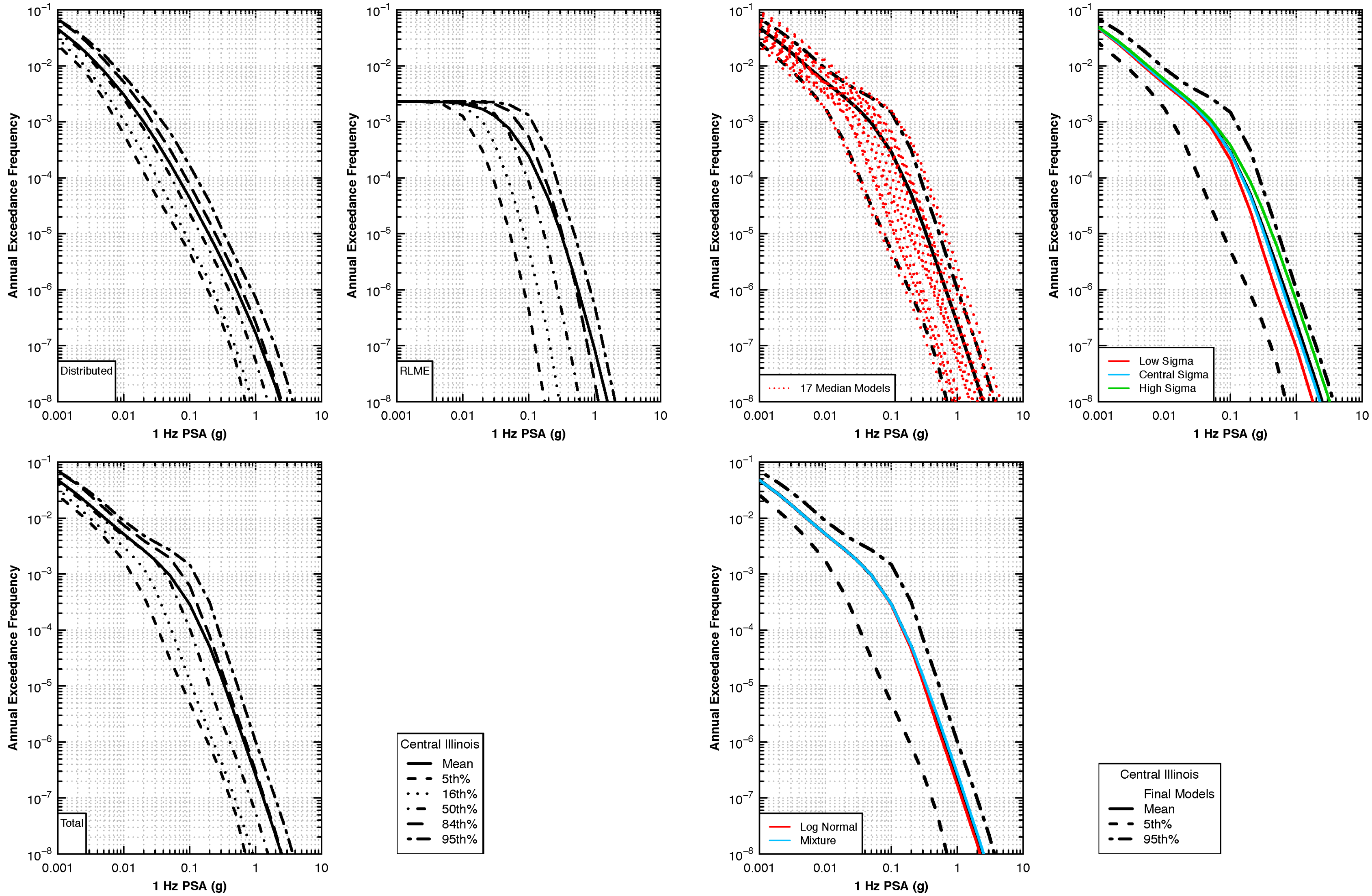


Figure F.2–2(b) Hazard results the NGA-East final GMMs for 10 Hz at Central Illinois (see text for figure description).

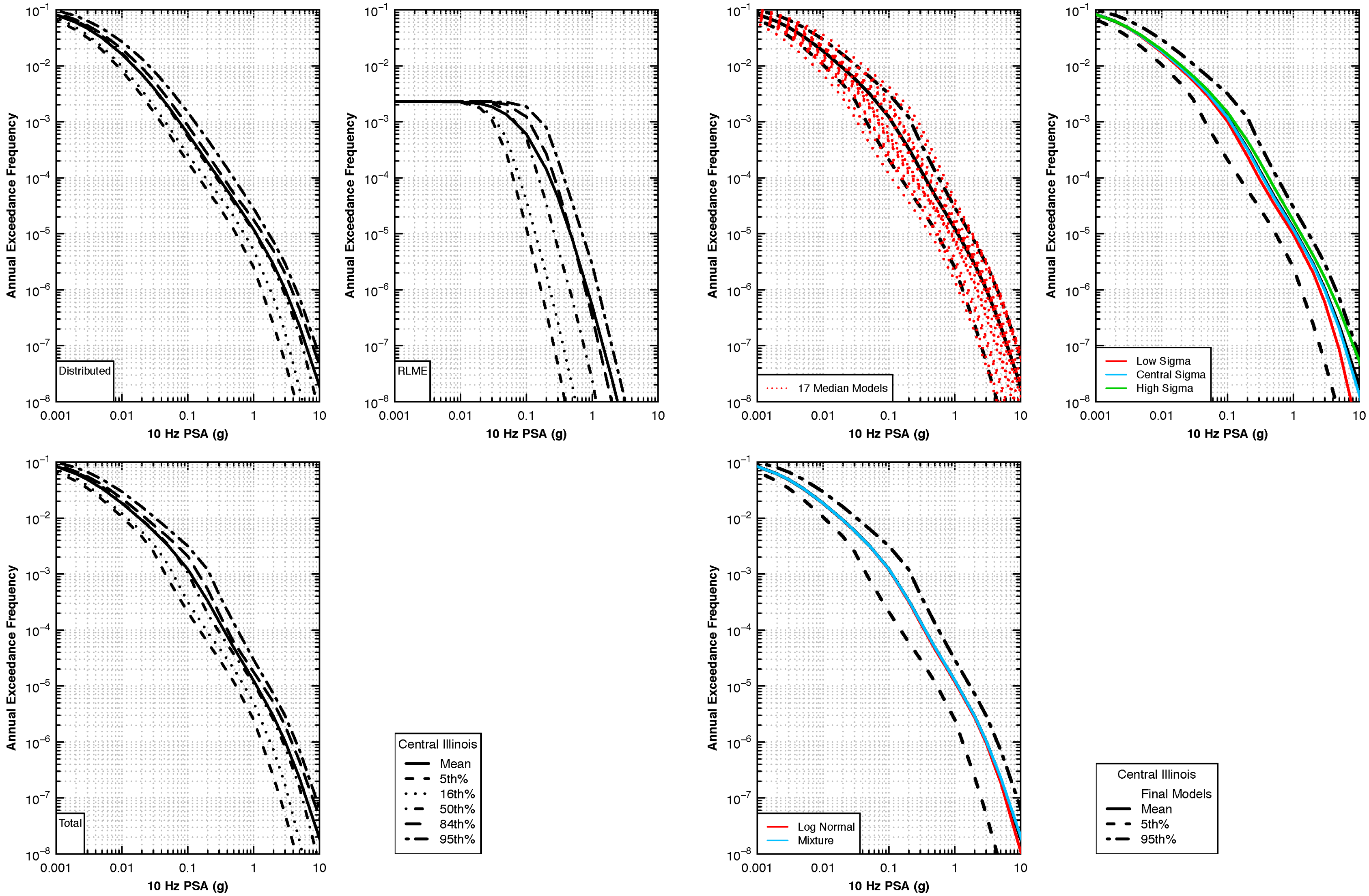


Figure F.2–3(a) Hazard results the NGA-East final GMMs for 1 Hz at Savannah (see text for figure description).

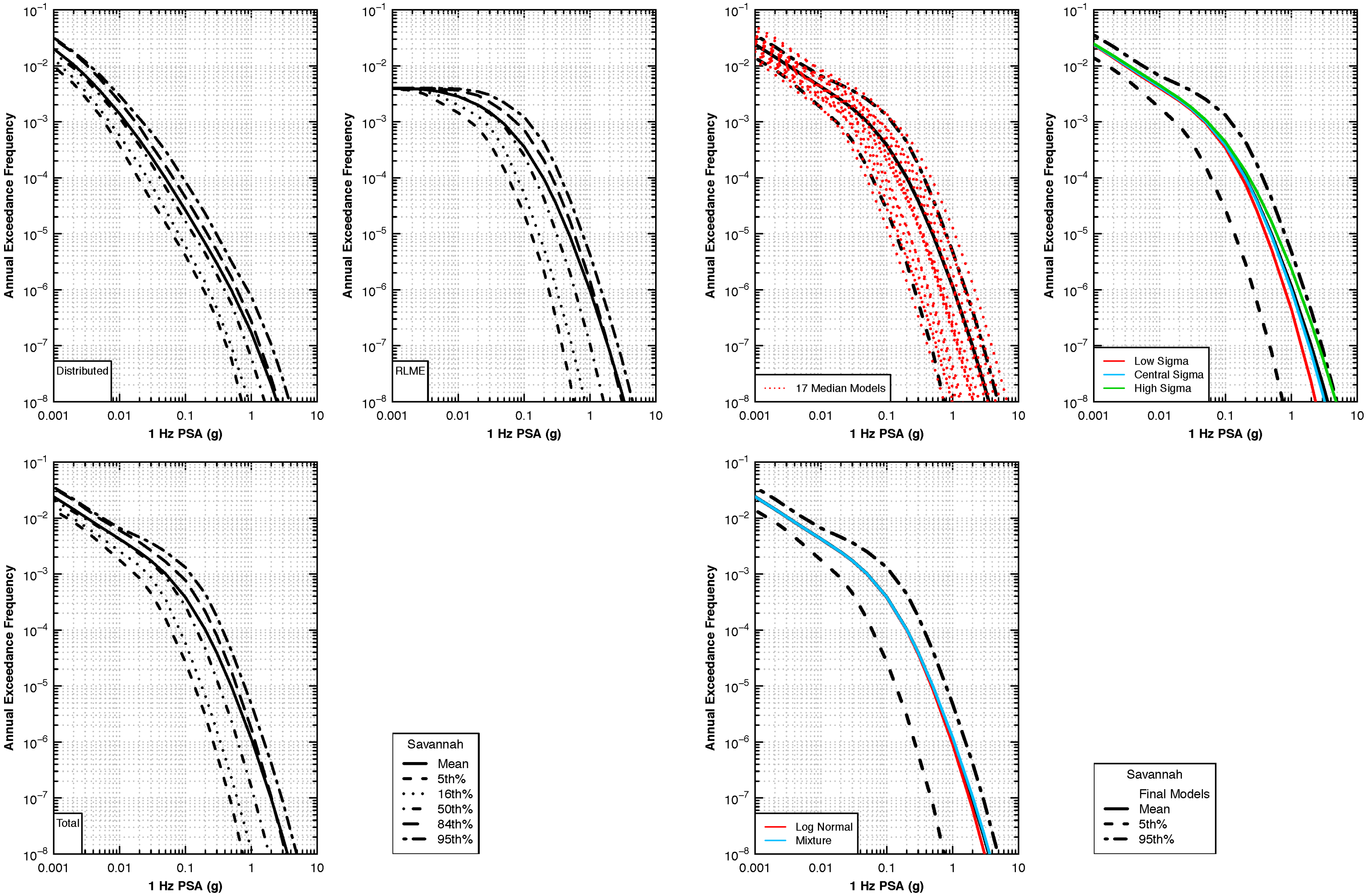
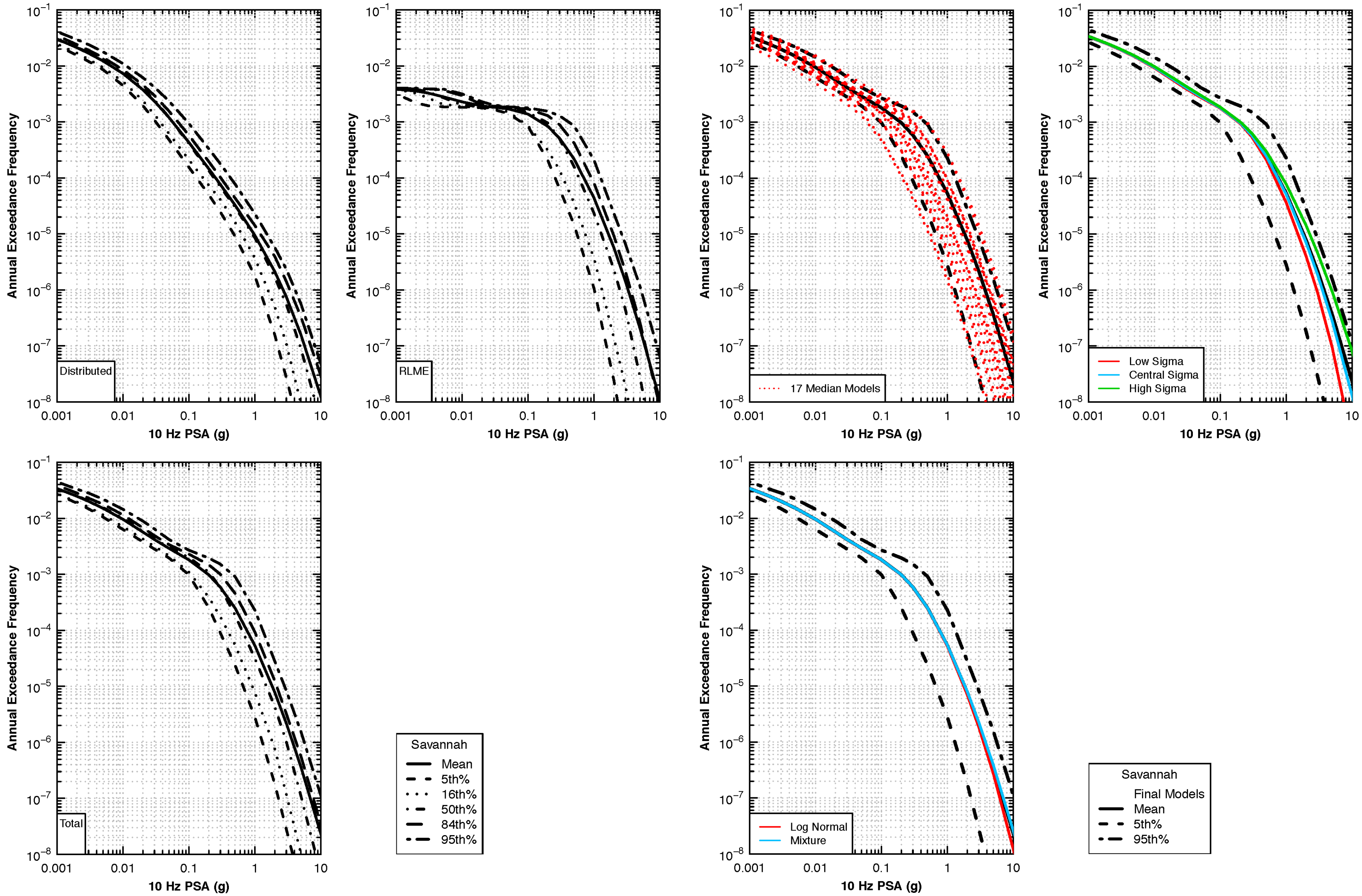


Figure F.2–3(b) Hazard results the NGA-East final GMMs for 10 Hz at Savannah (see text for figure description).



Appendix G Investigation of Additional Depth Effects Issues

This section is devoted to additional depth issues considered and investigated by the NGA-East at the PPRP request. This appendix supplements the documentation provided in Chapter 13 regarding source-depth effects. Two topics are discussed below. The consideration of Rg waves in modeling (G.1.1) and the evaluation of simulations in providing an alternative depth-effects model (G.1.2).

G.1 Effect of Rg Waves

Modeling for Rg wave effects was considered but not retained as part of NGA-East. The following discussion briefly summarizes the reasons leading to this decision.

G.1.1 Definition and Basic Conditions for the Presence of Rg Waves

The Rg phase is defined by Kafka (1990) as fundamental mode Rayleigh waves with periods between about 0.4 and 2.5 sec that are often observed on seismograms of explosions and very shallow-focus earthquakes. The Rg phase can be prominent on seismograms of quarry blasts, but the radiation patterns of Rg are likely to be asymmetric for earthquakes (and possibly also asymmetric for some quarry blasts), making them sometimes difficult to identify. The excitation of Rg is very dependent on focal depth such that the amplitude of short-period Rg waves diminishes rapidly for sources deeper than about 3–4 km (Bath 1975; Kafka 1990; Ma et al. 2008). Many studies have observed Rg at local and regional distances and due to its depth sensitivity; it is particularly useful as a depth discriminant for earthquakes and explosions (Bath 1975; Kafka 1990; Saikia 1992; Kocaoglu and Long 1993; Goforth and Bonner 1995; McLaughlin et al. 2004; Malovichko 2005; Goforth et al. 2006; Ma et al. 2008; Ma and Eaton 2009; Atkinson and Kraeva 2010).

Kafka (1990) states that in their analyses of Rg in New England, they performed calculations using numerous one-dimensional (1D) velocity models with the results suggesting little sensitivity of the Rg displacement versus depth across the considered models. We note that the velocity model profiles shown in that publication all contain a significant reduction in velocity (~10–20%) in the upper 1 km, which can trap and amplify wave energy. This structure is similar to the superficial low-velocity layer described by Bath (1975) in his analysis of Rg recorded in Sweden. However, it is not clear how important this type of feature may be in accentuating the generation of Rg in CENA. A velocity profile with little or no lateral variations (such as a simplified 1D velocity structure) will tend to favor Rg wave development and propagation. A structure that allows lateral variations and/or significant surface topography would likely generate weaker Rg or no Rg at all [e.g., Myers et al. (1999)]. Assuming the Q of the upper layers is relatively low, then Rg tends to attenuate with distance relatively quickly, meaning that its impact will likely only occur within ~200 km (Lay and Wallace 1995).

Smaller shallow events, for which the rupture area is mostly contained in the shallow layers described above, are expected to generate stronger Rg relative to the rest of the spectrum. Allen et al. (2006) analyzed numerous small magnitude, shallow (depth < 3 km) events in western Australia and found strong Rg in several of the records. They also found that these shallow events are characterized by very low stress parameter, meaning their ground motions are relatively deficient in high-frequency energy. One implication of this result is that the Rg phase may be accentuated due to the relative depletion of higher-frequency energy in the motions. In the case of larger events, deeper source contributions may overshadow the Rg phase.

In summary, the impact of Rg waves in its intrinsic frequency range (0.4 Hz < f < 2.5 Hz) will probably be most significant when the limited set of conditions listed below are all met:

- very shallow source depth (< 4 km)
- small source magnitude (< **M**5), ~point source
- little surface topography and laterally homogeneous velocity structure
- distances less than 150–200 km

G.1.2 Available Observational Data from Earthquake Recordings

The recorded dataset from shallow earthquakes showing the Rg phase is fairly limited. A few recorded earthquakes showing the presence of the Rg phase have been documented (Kafka 1990; and Allen et al. 2006).

We performed a simple evaluation of the NGA-East database to identify records potentially affected by Rg effects. The analysis was as follow:

- Started from the complete NGA-East database flatfile (9382 horizontal pairs)
- Sorted and retained all the records matching the criteria described above:
  - **M** ≤ 5
  - hypocentral depth less than 6 km (went below the 4 km suggested above to account for uncertainty in depth estimation)
  - rupture distance within 200 km
- Plotted the response spectra ($RotD_{50}$ PSA) for the ~280 records flagged above and performed a visual inspection to identify anomalous spectra (larger than expected response in the period range of 0.4–2.5 sec)
- Plotted the acceleration and displacement time series for 16 records identified in step above for further inspection.

The flagging based on response spectra was performed by two independent TI members. The evaluation is subjective in nature, but their selection largely overlapped, leading to 16 records with peaks somewhere in the range of 0.4–2.5 sec, with 12 of those records having their entire spectrum below 1% g. Some of these records can potentially contain an Rg phase, but the large response could be due to site effects or other wave phase combinations. To be able to attribute the exact source of the observations to a specific effect would require more extensive analyses. Even if this was possible, the data is not available in large enough quantities to lead to model development.

G.1.3 Available Data from Numerical Simulations

The Frankel NGA-East GMM (PEER 2015a; 2015b) is based on finite-fault simulations and was considered as a possible approach to investigate Rg effects. Frankel's simulation method is considered a broadband "hybrid" method with frequencies lower than about 1 Hz coming from deterministic wave propagation with high frequencies from a stochastic method. For NGA-East, Frankel simulated a suite of events using a 1D velocity structure. The simulation runs are summarized in Table G.1–1. The events for all the magnitudes were simulated using a Z_{TOR} of 5 km and additional runs were completed with Z_{TOR} = 1 km for **M**7.5 and **M**8.

The velocity model used by Art Frankel for his deterministic simulations includes the two key features expected to promote Rg wave propagation: the structure is a 1D-layered model and has decreasing shear-wave velocity near the surface.

Figure G.1–1 shows comparison plots for Frankel Z_{TOR} = 1 versus 5 km; **M**7.5 and **M**8 are in separate panels. The Z_{TOR} = 1 km results are systematically larger for f < 1 Hz, even out to 500 km. Those results will not provide a complete picture on Rg because they:

- have significant depth extent of the rupture
- only use the full Green's function waveform for f < 1 Hz

Because of these limitations, it is inconclusive on whether this elevation in ground motion is strictly due to Rg. More generically, it may be due to the contribution of surface waves, which are relatively stronger for the shallower source depth. Therefore, the overall depth-effects implied by the simulations were investigated instead of partitioning the effects into phases. This is documented in Section G. 2.

G.2 Consideration of Alternate Depth-Effects Model Based on Simulations

The TI Team evaluated the possibility of using Frankel's simulations to develop an alternative depth-scaling model. Ratios of Frankel's simulations were computed for both depths (Z_{TOR} =1/ Z_{TOR} = 5) and normalized in a manner consistent with the metric shown in Figure 13–8. These ratios are plotted in Figure G.2–1, which also shows the model from Figure 13–8 as a reference. Note the difference in vertical scale between Figures 13–8 and G.2–1. The following observations can be made on the Frankel-based scaling shown in Figure G.2–1:

- It is negative at all frequencies, and it never overlaps with the NGA-West2-based model.
- The effect is more important for **M**7.5 than **M**8.0. This trend with magnitude is opposite to that of the NGA-West2-based model.
- The effect at low frequencies is about four-fold compared to the other model.

The Frankel simulations could provide an alternative scaling approach for depth effects and based on the limited simulation results available, the effect appears to be important. Note that these results are based on a single simulation approach and are tied to the method used and the developer's modeling assumptions. This includes, for example, the assumption that the stress parameter is constant with depth (Frankel, personal communication). The simulations were performed for a single 1D (layered) crustal velocity structure, with fixed properties (shear wave velocity, Q), which may emphasize the effect of trapped waves (this applies to frequencies below 0.8 Hz, which correspond to the deterministic part of the hybrid model). A very limited number of scenarios were simulated (Table G.1–1), with no variation in the magnitude-area relation and fault plane attitude with only two depth cases (Z_{TOR} of 1 and 5 km).

On the model-development side, these limitations raise the following important questions:

- What frequency range would the model be applicable to? If only in the deterministic part of the model (f < 0.8 Hz), how would one reconcile model differences at larger frequencies?
- If a branch is created for **M** >7.5, how would one tie-in to the model at lower **M**?
- What is the range of depth applicability for the model? Is going from 5 to 9 km the same as 1 to 5 km? How can the model be extrapolated without constraints?

Given these limitations, the TI team has concluded that it is not currently feasible to develop a defensible model based on Frankel's simulations that is applicable to the range of depths and magnitudes appropriate for CENA. Nonetheless, the Frankel model is used as a seed and directly impacts the scaling of new sampled models. To make sure to preserve the depth-scaling trends provided by the Frankel model, the TI team chose to combine the **M**7.5/8.0 for Z_{TOR} = 1 km to the other magnitudes' simulations for Z_{TOR} = 5 km into a new model. This new version of the Frankel model was used in lieu of the original one (Z_{TOR} = 5 km for all magnitudes). Dr. Frankel agreed with the TI team conclusions and with this proposed update to his model.

Table G.1–1 Earthquake scenarios simulated for the development of the Frankel GMM. In some cases, multiple slip distributions and hypocenter locations were used for a given scenario [Table 6.2 from PEER (2015a; 2015b)].

Magnitude	Fault dimensions (km)	Fault mechanism	Z_{TOR} (km)	Approximate distance range (R_{RUP}, km)
8.0	160 × 40	Strike–slip, 90° dip	1	2–1000
8.0	160 × 40	Thrust, 45° dip	1	2–200
8.0	160 × 40	Thrust	5	5–200
8.0	160 × 40	Strike–slip	5	5–1000
7.5	80 × 25	Strike–slip	1	2–1000
7.5	80 × 25	Thrust	1	2–200
7.5	119 × 12	Strike–slip slip	5	5–1000
7.5	80 × 25	Strike–slip slip	5	5–1000
7.5	80 × 25	Thrust	5	5–200
6.5	14 × 10	Strike–slip	5	5–1000
6.5	14 × 10	Thrust	5	5–200
5.5	3.9 × 3.9	Strike–slip	5	5–1000
5.5	3.9 × 3.9	Thrust	5	5–200
5.5	3.9 × 3.9	Strike–slip	9	9–200
4.5	1.2 × 1.2	Strike–slip	5	5–1000
4.5	1.2 × 1.2	Thrust	5	5–200
4.5	1.2 × 1.2	Strike–slip	12	12–200

Figure G.1–1 Comparison of ground motions from Frankel simulations for Z_{TOR} of 1 and 5 km.

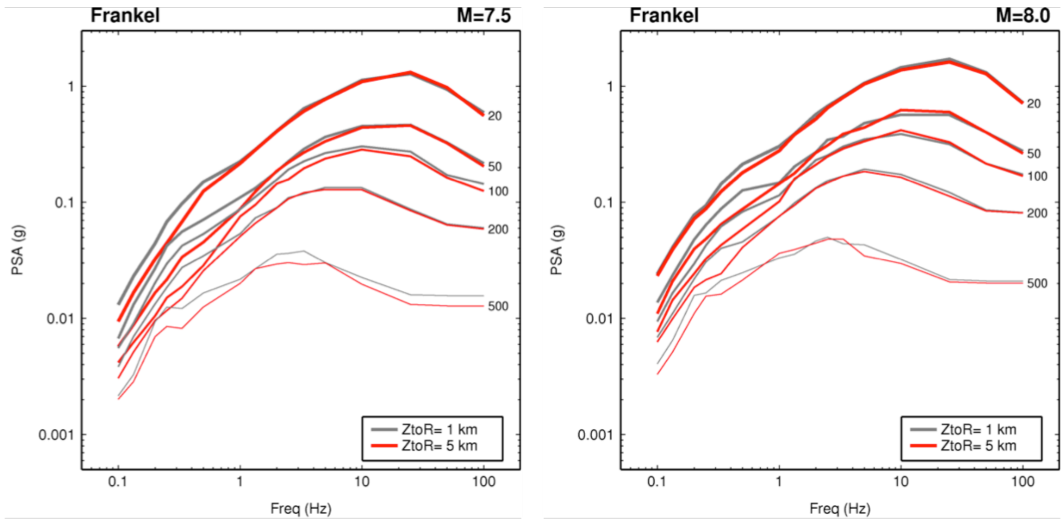
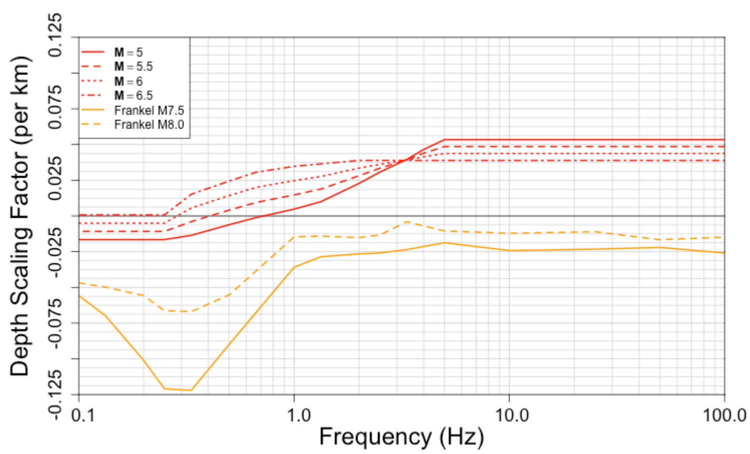


Figure G.2–1 Frankel's simulations overlaid on the PEER source-depth model (Figure 13–8).



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Appendix H. NGA-East Final Model Hazard Input Document (HID)

This appendix presents the Hazard Input Document (HID) for the NGA-East Ground Motion Model (GMM). Ground Motion Models are provided for PGA, PGV, and pseudo-spectral acceleration at 23 periods: 0.01, 0.02, 0.025, 0.03, 0.04, 0.05, 0.075, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, 0.5, 0.75,1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 7.5, and 10 sec (frequencies of 100, 50, 40, 33.333, 25, 20, 13,333, 10, 6.667, 5, 4, 3.333, 2.5, 2, 1.333, 1, 0.667, 0.5, 0.333, 0.25, 0.2, 0.133, and 0.1 Hz). All of the model parameters are provided in ACSII coma separated variable (csv) files in electronic appendices, as elaborated in the following sub-sections. The results of PSHA calculations at the seven demonstration sites using this model are provide in Appendix I.

H.1 Models for Median Ground Motions

The median ground motion models are presented in the form of tables of median motions at 11 magnitudes and 34 rupture distances. The magnitudes are **M** 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, and 8.2. The values of R_{RUP} are 0.01, 1, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, and 1500 km. The tables contain the values of **M**, R_{RUP}, and ln(GM), where GM is either PGV (cm/sec) or PGA and PSA (units of g). Ground motions for other magnitudes are obtained by linear interpolation of ln(GM) with magnitude, and ground motions for other distances are obtained by linear interpolation of ln(GM) with ln(R_{RUP}).

The median ground-motion tables are organized in folders, as indicated in Table H–1 and located in Electronic Appendix H.7.1_Median_Models. The first record is a header for the data columns with triplets of **M**, R_{RUP}, and ln(GM).

Epistemic uncertainty in the median ground motions is modeled using 17 alternative tables of median ground motions for each ground motion measure listed in Table H–1. Table H–2 lists the weights assigned to each of the 17 models for each ground-motion measure. These weights are contained in the file Median_Weights.csv located in Electronic Appendix H.7.1_Median_Models.

Table H–1 Folders located in folder Median_Models Containing Median Model Tables.

Period (sec)	Frequency (Hz)	Folder
PGA	PGA	PGA
PGV	PGV	PGV
0.01	100	F100.000
0.02	50	F50.000
0.025	40	F40.000
0.03	33.333	F33.333
0.04	25	F25.000
0.05	20	F20.000
0.075	13.333	F13.333
0.1	10	F10.000
0.15	6.667	F6.667
0.2	5	F5.000
0.25	4	F4.000
0.3	3.333	F3.333
0.4	2.5	F2.500
0.5	2.0	F2.000
0.75	1.333	F1.333
1.0	1.0	F1.000
1.5	0.667	F0.667
2.0	0.5	F0.500
3.0	0.333	F0.333
4.0	0.25	F0.250
5.0	0.2	F0.200
7.5	0.133	F0.133
10	0.1	F0.100

Table H-2 Weights assigned to median GMM tables.

Model number	Median models in folder												
	F0.100	F0.133	F0.200	F0.250	F0.333	F0.500	F0.667	F1.000	F1.333	F2.000	F2.500	F3.333	F4.000
1	0.0955	0.0941	0.1030	0.0994	0.0941	0.0945	0.1032	0.0998	0.1116	0.1044	0.1009	0.1013	0.0921
2	0.0833	0.0930	0.0846	0.0904	0.0617	0.0897	0.0706	0.0749	0.0721	0.0852	0.0841	0.0683	0.0585
3	0.0837	0.0790	0.0914	0.0935	0.0709	0.0783	0.0683	0.0684	0.0568	0.0844	0.0675	0.0732	0.0632
4	0.0904	0.0787	0.1071	0.1056	0.1037	0.0978	0.0970	0.0922	0.0860	0.0639	0.0785	0.0824	0.0739
5	0.0666	0.0617	0.0638	0.0673	0.0701	0.0679	0.0903	0.0917	0.0947	0.0953	0.0885	0.0733	0.0731
6	0.0914	0.0898	0.0658	0.0650	0.0847	0.0717	0.0884	0.0885	0.0889	0.0820	0.0770	0.0692	0.0965
7	0.0969	0.0993	0.0828	0.0776	0.0990	0.0842	0.0941	0.0878	0.0893	0.0787	0.0889	0.1082	0.1198
8	0.0778	0.0822	0.0873	0.0844	0.0878	0.0922	0.0869	0.0794	0.0956	0.0849	0.0839	0.1023	0.1123
9	0.0924	0.0991	0.1056	0.1114	0.0900	0.1017	0.0743	0.0841	0.0808	0.0827	0.0918	0.0899	0.0774
10	0.0204	0.0111	0.0047	0.0087	0.0040	0.0127	0.0121	0.0116	0.0189	0.0384	0.0225	0.0171	0.0123
11	0.0086	0.0072	0.0075	0.0077	0.0052	0.0058	0.0077	0.0096	0.0120	0.0155	0.0155	0.0212	0.0185
12	0.0233	0.0224	0.0438	0.0375	0.0347	0.0233	0.0223	0.0278	0.0242	0.0201	0.0199	0.0359	0.0344
13	0.0196	0.0181	0.0183	0.0185	0.0245	0.0153	0.0287	0.0392	0.0243	0.0241	0.0230	0.0182	0.0191
14	0.0516	0.0562	0.0395	0.0360	0.0530	0.0478	0.0470	0.0416	0.0435	0.0411	0.0372	0.0214	0.0208
15	0.0464	0.0514	0.0416	0.0430	0.0577	0.0548	0.0545	0.0463	0.0469	0.0450	0.0518	0.0355	0.0418
16	0.0202	0.0267	0.0263	0.0239	0.0352	0.0328	0.0318	0.0280	0.0255	0.0239	0.0353	0.0532	0.0606
17	0.0319	0.0300	0.0269	0.0301	0.0237	0.0295	0.0228	0.0291	0.0289	0.0304	0.0337	0.0294	0.0257

Model number	Median models in folder											
	F5.000	F6.667	F10.000	F13.333	F20.000	F25.000	F33.333	F40.000	F50.000	F100.000	PGA	PGV
1	0.0737	0.0683	0.1047	0.1068	0.0998	0.1069	0.1078	0.0987	0.0949	0.0935	0.1009	0.0976
2	0.0994	0.1530	0.1175	0.1311	0.1315	0.1256	0.1316	0.1453	0.1176	0.1462	0.1606	0.0678
3	0.0892	0.0863	0.0723	0.0697	0.0965	0.0880	0.0883	0.0996	0.0985	0.1230	0.1151	0.0738
4	0.0691	0.0834	0.0676	0.0651	0.0686	0.0680	0.0673	0.0653	0.0704	0.0981	0.0970	0.0756
5	0.0456	0.0342	0.0677	0.0735	0.0540	0.0579	0.0512	0.0396	0.0407	0.0472	0.0548	0.0702
6	0.1095	0.0960	0.0553	0.0519	0.0559	0.0600	0.0509	0.0620	0.0666	0.0330	0.0376	0.0916
7	0.1020	0.0894	0.0725	0.0917	0.0649	0.0586	0.0627	0.0609	0.0643	0.0522	0.0507	0.0980
8	0.0876	0.0550	0.0642	0.0506	0.0743	0.0784	0.0727	0.0838	0.0984	0.0629	0.0497	0.1054
9	0.0859	0.0860	0.1075	0.0938	0.1136	0.1221	0.1205	0.1057	0.1064	0.1092	0.0986	0.0956
10	0.0281	0.0212	0.0254	0.0190	0.0374	0.0298	0.0245	0.0278	0.0246	0.0372	0.0372	0.0108
11	0.0214	0.0056	0.0088	0.0008	0.0191	0.0087	0.0016	0.0030	0.0147	0.0123	0.0100	0.0197
12	0.0293	0.0139	0.0175	0.0048	0.0178	0.0139	0.0055	0.0059	0.0174	0.0271	0.0167	0.0274
13	0.0176	0.0109	0.0158	0.0126	0.0117	0.0082	0.0057	0.0045	0.0098	0.0076	0.0119	0.0117
14	0.0366	0.0630	0.0820	0.0980	0.0406	0.0473	0.0703	0.0648	0.0512	0.0368	0.0436	0.0257
15	0.0368	0.0688	0.0649	0.0800	0.0430	0.0549	0.0758	0.0626	0.0466	0.0418	0.0504	0.0365
16	0.0328	0.0196	0.0179	0.0226	0.0268	0.0272	0.0236	0.0345	0.0419	0.0266	0.0282	0.0567
17	0.0354	0.0454	0.0384	0.0280	0.0445	0.0445	0.0400	0.0360	0.0360	0.0453	0.0370	0.0359

H.2 Adjustments to Median Models for Gulf Coast Region

Two alternative models are used to define the adjustments to the median ground motions for travel paths through the Gulf Coast Region (GCR). The PEER GCR adjustment model is given by the relationship:

$$\ln\left(\frac{PSA_{GCR}}{PSA_{MCR}}\right) = -0.00221 \times \max\left\{0, R_{JB\_GCR} - 100\right\} \qquad \text{(H–1)}$$

and the DASG model is given by the relationship:

$$\ln\left(\frac{PSA_{GCR}}{PSA_{MCR}}\right) = \gamma(f) R_{JB\_GCR} \qquad \text{(H–2)}$$

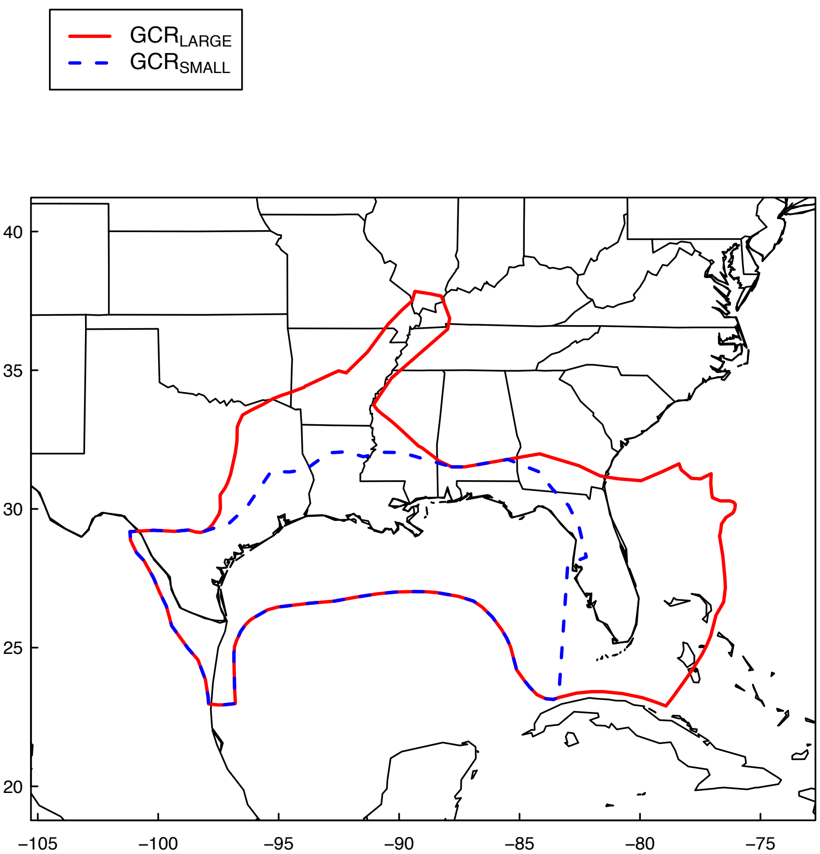
Where R_{JB_GCR} is the length of the horizontal travel path from earthquake rupture to the site within the GCR in km. PSA_{GCR} is the median ground motion in the GCR, and PSA_{MCR} is the median ground motion in the mid-continent region defined in H.1. The values of $\gamma(f)$ are listed in Table H–3 and are contained in file DASG_GCR_Adjustment.csv located in Electronic Appendix H.2.1_GCR_Adjustments. The PEER and DASG GCR adjustment models are assigned relative weights of 0.67 and 0.33, respectively.

Two alternative boundaries for the GCR are defined. These are shown on Figure H–1. The larger region is weighted 0.6, and the smaller region is weighted 0.4. The coordinates of the two GCR boundaries are contained in files NGAE_GCR_Large.csv and NGAE_GCR_Small.csv located in Electronic Appendix H.7.2_GCR_Adjustments.

Table H–3 Coefficients for DASG GCR adjustment model [Equation (13–3)].

Ground-motion frequency (Hz)	$\gamma(f)$
0.1	-2.67E-04
0.133	-2.92E-04
0.2	-3.35E-04
0.25	-3.65E-04
0.333	-4.07E-04
0.5	-4.85E-04
0.667	-5.40E-04
1	-6.42E-04
1.333	-7.20E-04
2	-8.42E-04
2.5	-9.02E-04
3.333	-9.71E-04
4	-1.02E-03
5	-1.06E-03
6.667	-1.09E-03
10	-1.11E-03
13.333	-1.10E-03
20	-1.06E-03
25	-1.04E-03
33.333	-1.01E-03
40	-9.97E-04
50	-9.74E-04
100	-9.20E-04
PGA	-9.12E-04
PGV	-4.95E-04

Figure H–1 Alternative Gulf Coast Regions.



H.3 Effect of Depth to Top of Rupture, Z_{TOR}

The source depth adjustment consists of an adjustment factor that is added to the natural log of the median ground motions defined in Section H.1. The adjustment factor, $f_{Z_{TOR}}$, is given by

$$f_{Z_{TOR}} = f_{Z_{TOR,M}} \times \Delta Z_{TOR} \quad \text{(H–3)}$$

where $f_{Z_{TOR,M}}$ is the magnitude-dependent source-depth scaling factor, and ΔZ_{TOR} is the depth deviation from the centered Z_{TOR} value. The magnitude-dependent source-depth scaling factor, $f_{Z_{TOR,M}}$ is given by

$$f_{Z_{TOR,M}} = \begin{cases} b_1 & \text{for } M \le 5.0 \\ b_1 + b_2 \dfrac{M-5}{1.5} & \text{for } 5.0 < M \le 6.5 \\ b_1 + b_2 & \text{for } M > 6.5 \end{cases} \quad \text{(H–4)}$$

where b_1 and b_2 are frequency-dependent coefficients listed in Table H–4. The coefficients are contained in file f_Ztor_M_coeff.csv located in Electronic Appendix H.7.3_Depth_Effects.

The term ΔZ_{TOR}, is given by:

$$\Delta Z_{TOR} = \begin{cases} Z_{TOR} - E[Z_{TOR}] + 2 & \text{for } Z_{TOR} < E[Z_{TOR}] - 2 \\ 0 & \text{for } E[Z_{TOR}] - 2 \le Z_{TOR} \le E[Z_{TOR}] + 2 \\ \min\{10, Z_{TOR}\} - E[Z_{TOR}] - 2 & \text{for } Z_{TOR} > E[Z_{TOR}] + 2 \end{cases} \quad \text{(H–5)}$$

where $E(Z_{TOR})$ is the magnitude-dependent centering depth (magnitude-dependent expected Z_{TOR}), and Z_{TOR} is the actual depth-to-top-of-rupture of the earthquake source, as provided in a seismic source model. The units of $E[Z_{TOR}]$ and Z_{TOR} are km. Table H–5 and Electronic Appendix H.7.3_Depth_Effects lists the values of $E[Z_{TOR}]$ for specific magnitudes. Values for other magnitudes can be obtained by linear interpolation with respect to magnitude. An example of application of the depth effects model is provided in Section 13.3.7. Guidance on the effect of applying the depth effects model is provided in Section 14.4.

Application of the depth effects model in a PSHA requires a representation of the distribution of Z_{TOR} for the seismic sources. Section 13.3.5 presents a generalized model that can be used to apply the depth adjustments given by Equations H–3, H–4, and H–5 in conjunction with the CEUS SSC model (EPRI/DOE/NRC, 2012). If more detailed local information is available, it can be used in lieu of these generalized distributions.

Table H–4 Coefficients for source-depth scaling factor model, Equation (H–4).

Ground-motion frequency (Hz)	b_1	b_2
0.1	-0.01653	0.0173
0.133	-0.01653	0.0173
0.2	-0.01653	0.0173
0.25	-0.01653	0.0173
0.333	-0.01351	0.02875
0.5	-0.00607	0.03055
0.667	-0.00111	0.03174
1.0	0.00479	0.02996
1.333	0.01003	0.02646
2.0	0.02279	0.0161
2.5	0.03069	0.00821
3.333	0.03958	-0.00069
4.0	0.04658	-0.00768
5.0	0.05346	-0.01457
6.667	0.05346	-0.01457
≥10.00	0.05346	-0.01457
PGA	0.05346	-0.01457
PGV	0.03693	-0.01011

Table H–5 Magnitude dependence of $E(Z_{TOR})$.

M	$E(Z_{TOR})$ (km)
4	10.0
4.5	10.0
5	8.9
5.5	8.0
6.0	6.7
6.5	4.3
7	2.0
7.5	0.0
8	0.0
8.2	0.0

H.4 Hanging-Wall Adjustment Model

The hanging-wall (HW) adjustment model consists of an adjustment factor f_{HW} that is added to the natural log of the median ground motions. The adjustment factor is given by the expression

$$f_{HW}=\begin{cases} C_1\cos(dip)\times\left[C_2+(1-C_2)\tanh\left(\frac{C_3R_X}{W\cos(dip)}\right)\right]\times[1+C_4(M-7)]\times \\ \qquad \left[1-\frac{R_{JB}}{R_{RUP}+0.1}\right]\times\max\left\{0,1-\frac{Z_{TOR}}{12\text{ km}}\right\} & \text{for } R_X\geq 0 \\ 0 & \text{for } R_X<0 \end{cases} \quad \text{(H-6)}$$

where W is rupture width (km); Rx is the horizontal distance (km) to the site from the surface projection of the rupture measured perpendicular to the rupture strike, with positive values of R_X on the hanging wall side and negative values on the footwall site; and Z_{TOR} is again the depth to top of rupture in km. Table H–6 lists the coefficients of equation (H-6). These are contained in file HW_Model_Coef.csv located in Electronic Appendix H.4.1_HW.

Epistemic uncertainty in f_{HW} is modeled by the five equally likely values of coefficient C_1 listed in Table H-6. These values are assigned to the 17 median models such that each HW adjustment occurs with approximately equal probability. Table H-7 lists the assignments. The assignments are contained in file HW_Model_Assign.csv located in Electronic Appendix H.7.4_HW. Guidance on application of the HW model is given in Section 14.4.

Table H–6 Parameters of the HW effects model (Equation H–6).

Period (sec)	Frequency (Hz)	Model-dependent C1 coefficients					Coefficients held constant for all five models		
		C_1_HW1	C_1_HW2	C_1_HW3	C_1_HW4	C_1_HW5	C_2	C_3	C_4
PGA		0.868	0.982	1.038	1.095	1.208	0.2160	2.0289	0.1675
PGV		0.260	0.391	0.457	0.522	0.654	0.1588	1.7368	0.3280
0.01	100	0.868	0.982	1.038	1.095	1.209	0.2160	2.0289	0.1675
0.02	50	0.867	0.987	1.046	1.106	1.226	0.2172	2.0260	0.1666
0.025	40	0.861	0.993	1.058	1.124	1.255	0.2175	2.0207	0.1668
0.03	33.33	0.856	0.997	1.067	1.138	1.278	0.2178	2.0163	0.1670
0.04	25	0.847	1.014	1.097	1.181	1.348	0.2190	1.9998	0.1686
0.05	20	0.840	1.027	1.121	1.215	1.402	0.2199	1.9870	0.1699
0.075	13.33	0.857	1.041	1.133	1.226	1.410	0.2218	1.9906	0.1817
0.1	10	0.848	1.040	1.135	1.231	1.422	0.2213	1.9974	0.1717
0.15	6.67	0.868	1.009	1.080	1.150	1.292	0.2169	2.0162	0.1814
0.2	5	0.850	1.005	1.082	1.160	1.315	0.2131	1.9746	0.1834
0.25	4	0.868	0.985	1.044	1.102	1.219	0.1988	1.9931	0.1767
0.3	3.33	0.839	0.974	1.041	1.108	1.242	0.2019	2.0179	0.1658
0.4	2.5	0.780	0.934	1.011	1.089	1.243	0.2090	2.0249	0.1624
0.5	2	0.741	0.902	0.982	1.063	1.223	0.2053	2.0041	0.1719
0.75	1.33	0.613	0.869	0.997	1.125	1.380	0.1713	1.8697	0.1866
1	1	0.621	0.788	0.872	0.955	1.123	0.1571	1.8526	0.3143
1.5	0.67	0.506	0.662	0.740	0.818	0.974	0.1559	1.8336	0.3195
2	0.5	0.391	0.537	0.609	0.682	0.828	0.1559	1.7996	0.3246
3	0.33	0.128	0.245	0.304	0.362	0.480	0.1616	1.6740	0.3314
4	0.25	0	0.034	0.088	0.138	0.231	0.1616	1.6740	0.3314
5	0.2	0	0	0	0	0.040	0.1616	1.6740	0.3314
7.5	0.13	0	0	0	0	0	0.1616	1.6740	0.3314
10	0.1	0	0	0	0	0	0.1616	1.6740	0.3314

Table H–7 Assignment of HW models to NGA-East medians.

NGA-East median model	HW C_1 coefficient Table H–6
1	3
2	5
3	1
4	3
5	4
6	4
7	1
8	2
9	2
10	5
11	5
12	2
13	4
14	5
15	4
16	3
17	1

H.5 Aleatory Variability Model

The aleatory variability model logic tree is shown on Figure H–2. The aleatory variability model developed for use is a partially non-ergodic, single-station sigma model, σ_{SS}, representing variability in ground motions at a single site. The aleatory variability model is given by the relationship:

$$\sigma_{SS} = \begin{cases} \sigma_{SS_1} & \text{for } M \le 4.5 \\ \sigma_{SS_1} + (\sigma_{SS_2} - \sigma_{SS_1}) * \dfrac{(M - 4.5)}{0.5} & \text{for } M \le 5.0 \\ \sigma_{SS_2} + (\sigma_{SS_3} - \sigma_{SS_2}) * \dfrac{(M - 5.0)}{0.5} & \text{for } M \le 5.5 \\ \sigma_{SS_3} + (\sigma_{SS_4} - \sigma_{SS_3}) * \dfrac{(M - 5.5)}{1.0} & \text{for } M \le 6.5 \\ \sigma_{SS_4} & \text{for } M > 6.5 \end{cases} \tag{H–7}$$

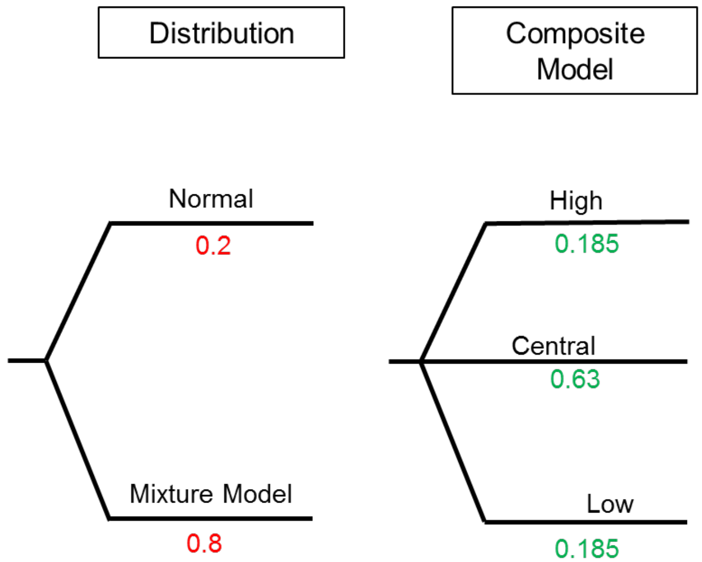
Epistemic uncertainty in the values of σ_{SS1}, σ_{SS2}, σ_{SS3}, and σ_{SS4} are defined by a central set of values, weighted 0.63, and a high set and low set, each weighted 0.185, as shown on the right-hand side of Figure H–2. Table H–8 lists the coefficients. These are contained in file SS_Sigma_Model.csv located in Electronic Appendix H.7.5_Sigma.

The left-hand site of the logic tree on Figure H–2 addresses the epistemic uncertainty in the form of the distribution for the aleatory variability in ln(GM). A weight of 0.2 is assigned to a standard normal distribution with sigma values given by Equation (H–6). A weight of 0.8 is assigned to an equally weighted mixture of two normal distributions with one component having 0.8 times the normal σ_{SS} and one component having 1.2 times the normal σ_{SS}.

Table H–8 Composite single-station sigma model.

Period (sec)	Frequency (Hz)	Central Set (Weight 0.63)				High Set (Weight 0.185)				Low Set (Weight 0.185)			
		SigSS1_C	SigSS2_C	SigSS3_C	SigSS4_C	SigSS1_H	SigSS2_H	SigSS3_H	SigSS4_H	SigSS1_L	SigSS2_L	SigSS3_L	SigSS4_L
PGA		0.7006	0.6846	0.6127	0.4973	0.8193	0.8075	0.7348	0.6377	0.5879	0.5682	0.4981	0.3901
0.01	100	0.7006	0.6846	0.6127	0.4973	0.8193	0.8075	0.7348	0.6377	0.5879	0.5682	0.4981	0.3901
0.02	50	0.6998	0.6838	0.6122	0.4974	0.8183	0.8064	0.7343	0.6379	0.5873	0.5676	0.4976	0.3899
0.025	40	0.6994	0.6833	0.6119	0.4974	0.8178	0.8059	0.7340	0.6381	0.5870	0.5672	0.4973	0.3898
0.03	33.333	0.6990	0.6829	0.6116	0.4974	0.8173	0.8054	0.7338	0.6382	0.5867	0.5669	0.4970	0.3897
0.04	25	0.6981	0.6820	0.6110	0.4975	0.8162	0.8043	0.7333	0.6384	0.5860	0.5662	0.4964	0.3895
0.05	20	0.6974	0.6813	0.6105	0.4975	0.8153	0.8034	0.7329	0.6385	0.5855	0.5657	0.4960	0.3893
0.075	13.333	0.6955	0.6793	0.6092	0.4977	0.8129	0.8010	0.7317	0.6390	0.5840	0.5641	0.4946	0.3887
0.1	10	0.6935	0.6773	0.6079	0.4978	0.8106	0.7986	0.7306	0.6395	0.5825	0.5626	0.4933	0.3882
0.15	6.667	0.6898	0.6735	0.6063	0.5007	0.8061	0.7941	0.7292	0.6413	0.5795	0.5595	0.4917	0.3904
0.2	5	0.6862	0.6698	0.6066	0.5092	0.8019	0.7899	0.7295	0.6453	0.5765	0.5564	0.4921	0.3994
0.25	4	0.6827	0.6662	0.6068	0.5171	0.7980	0.7859	0.7297	0.6492	0.5736	0.5533	0.4924	0.4079
0.3	3.333	0.6794	0.6628	0.6072	0.5254	0.7943	0.7822	0.7300	0.6537	0.5707	0.5503	0.4928	0.4168
0.4	2.5	0.6730	0.6563	0.6075	0.5399	0.7876	0.7753	0.7305	0.6623	0.5650	0.5444	0.4931	0.4326
0.5	2	0.6671	0.6502	0.6060	0.5482	0.7816	0.7693	0.7295	0.6681	0.5595	0.5387	0.4913	0.4411
0.75	1.333	0.6541	0.6369	0.5999	0.5577	0.7697	0.7572	0.7256	0.6762	0.5467	0.5253	0.4837	0.4504
1	1	0.6432	0.6256	0.5921	0.5576	0.7611	0.7484	0.7209	0.6772	0.5354	0.5135	0.4741	0.4508
1.5	0.667	0.6262	0.6082	0.5781	0.5510	0.7502	0.7373	0.7137	0.6743	0.5171	0.4944	0.4566	0.4482
2	0.5	0.6143	0.5959	0.5674	0.5436	0.7444	0.7313	0.7093	0.6738	0.5037	0.4803	0.4433	0.4416
3	0.333	0.5998	0.5811	0.5517	0.5267	0.7391	0.7258	0.7033	0.6698	0.4870	0.4628	0.4243	0.4226
4	0.25	0.5925	0.5736	0.5438	0.5181	0.7372	0.7237	0.7009	0.6687	0.4784	0.4538	0.4148	0.4124
5	0.2	0.5889	0.5698	0.5397	0.5138	0.7364	0.7228	0.6999	0.6682	0.4740	0.4491	0.4101	0.4071
7.5	0.133	0.5858	0.5666	0.5364	0.5102	0.7358	0.7222	0.6990	0.6679	0.4702	0.4451	0.4061	0.4025
10	0.1	0.5853	0.5661	0.5357	0.5095	0.7357	0.7221	0.6989	0.6679	0.4695	0.4444	0.4053	0.4017
PGV		0.6303	0.6247	0.5765	0.4896	0.7480	0.7431	0.6960	0.6419	0.5220	0.5159	0.4703	0.3928

Figure H–2 Logic tree structure for NGA East single-station aleatory variability model.



H.6 References

EPRI/USDOE/USNRC. 2012. "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities." U.S. Nuclear Regulatory Commission Report, NUREG-2115; EPRI Report 1021097, 6 Volumes; DOE Report# DOE/NE-0140, Washington, D.C.

H.7 List of Electronic Appendices for Appendix H

The organization of the files is described in each of the relevant subsection above.

Electronic Appendix H.7.1_Median_Models

Electronic Appendix H.7.2_GCR_Adjustments

Electronic Appendix H.7.3_Depth_Effects

Electronic Appendix H.7.4_HW

Electronic Appendix H.7.5_Sigma

Appendix I Demonstration Calculations

I.1 Demonstration Calculations

This appendix presents the results of demonstration calculations performed at the seven demonstration sites to provide users of the NGA-East GMM information with which to compare their implementation. Following the precedent of EPRI/DOE/NRC (2012) and EPRI (2013), the calculations are performed for three ground-motion measures, PGA, and spectral acceleration at frequencies of 10 Hz and 1 Hz. The calculations are performed using the full GMM model logic trees in combination with the full seismic source characterization (SSC) logic trees developed in EPRI/DOE/NRC (2012). The calculations were performed using the rupture geometry aleatory distributions defined in Tables 5.4-1 and 5.4-2 of EPRI/DOE/NRC (2012) and the implementation of the Z_{TOR} distributions as described in Section 13.2. For the two GCR sites, Houston and Jackson, the hazard calculations also implemented the full GCR adjustment logic tree described in Section H.2. The hazard calculations were performed including the contributions of those portions of the distributed seismicity sources that lie within 640 km of the demonstration sites and those RLME sources that lie within 1000 km of the demonstration sites. The calculations also included the corrections to the distributed seismicity source M_{max} distributions given in EPRI (2015). The demonstration calculations do not include implementation of the hanging wall model. The locations of the seven demonstration sites are listed in Table I–1.

The demonstration calculations are presented in the following sequence for each ground-motion measure and each site. The first plot shows the mean, 16th percentile, 50th percentile, and 84th percentile hazard curves computed using the full GMM and SSC logic trees. The second plot in each set shows the contributions of the individual distributed seismicity sources to the total mean hazard. All distributed seismicity sources included are listed on the figure. The mean hazard curves from the alternative distributed seismicity sources are weighted by the probability that the source is assigned in the CEUS SSC logic tree such that the sum of the weighted hazard curves equals the total mean hazard from the distributed seismicity sources. Table I–2 provided the assigned weights based on the CEUS SSC logic trees given in EPRI/DOE/NRC (2012). The third plot in each set shows the contributions of the individual RLME sources to the total mean hazard at each site. The included RLME sources are listed on the figure. Figures I–1 through I–60 present the results for the seven demonstration sites. Note that for Manchester, there are only two figures for each ground-motion frequency as there is only one RLME source included in the hazard: the Charlevoix RLME source.

Finally, Tables I–3 through I–9 present mean, 16th percentile, 50th percentile, and 84th percentile hazard results for the three ground-motion measures at the seven demonstration sites.

I.2 References

EPRI. 2013. “Ground-Motion Model (GMM) Review Project.” Electrical Power Research Institute, EPRI Report 3002000717, Palo Alto, CA.

EPRI/USDOE/USNRC. 2012. "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities." U.S. Nuclear Regulatory Commission Report, NUREG-2115; EPRI Report 1021097, 6 Volumes; DOE Report# DOE/NE-0140, Washington, D.C.

EPRI. 2015. "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities: Review for Reservoir-Induced Seismicity (RIS) in the Southeast and Earthquakes in South Carolina Near the 1886 Charleston Earthquake." Final Report Project 3002005288. September 2015, Electric Power Research Institute, Palo Alto, CA.

Table I–1 Demonstration site locations.

Demonstration site	Longitude (deg East)	Latitude (deg North)
Savannah	-81.097	32.082
Central Illinois	-90.000	40.000
Manchester	-71.463	42.991
Chattanooga	-85.255	35.064
Topeka	-95.682	39.047
Houston	-95.363	29.760
Jackson	-90.178	32.312

Table I–2 Logic tree weights for CEUS SSC distributed seismicity sources

Distributed seismicity source	Logic tree weights
AHEX	0.6
ECC-AM	0.6
ECC-GC	0.6
GHEX	0.6
GMH	0.6
IBEB	0.6
MIDC-A	0.32
MIDC-B	0.16
MIDC-C	0.08
MIDC-D	0.04
NAP	0.6
OKA	0.6
PEZ-N	0.48
PEZ-W	0.12
RR	0.4
RR-RCG	0.2
SLR	0.6
MESE-N	0.192
MESE-W	0.048
NMESE-N	0.192
NMESE-W	0.048
Study Region	0.16

Table I–3 Demonstration calculation results for Savannah site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	2.49E-02	2.04E-02	2.69E-02	3.39E-02
	0.002	1.76E-02	1.41E-02	1.95E-02	2.51E-02
	0.003	1.38E-02	1.05E-02	1.51E-02	2.00E-02
	0.005	9.81E-03	6.76E-03	1.05E-02	1.48E-02
	0.01	5.75E-03	3.55E-03	5.75E-03	8.91E-03
	0.02	3.36E-03	1.82E-03	3.24E-03	5.25E-03
	0.03	2.53E-03	1.18E-03	2.40E-03	3.98E-03
	0.05	1.77E-03	6.03E-04	1.59E-03	3.02E-03
	0.1	9.34E-04	1.66E-04	6.76E-04	1.74E-03
	0.2	3.46E-04	3.16E-05	1.55E-04	6.61E-04
	0.3	1.59E-04	1.07E-05	5.50E-05	2.69E-04
	0.5	4.89E-05	2.51E-06	1.45E-05	7.08E-05
	1	7.34E-06	2.51E-07	1.95E-06	1.02E-05
	2	8.45E-07	1.35E-08	1.78E-07	1.26E-06
10 Hz PSA	0.001	3.14E-02	2.40E-02	3.39E-02	4.27E-02
	0.002	2.37E-02	2.00E-02	2.57E-02	3.24E-02
	0.003	1.94E-02	1.62E-02	2.14E-02	2.75E-02
	0.005	1.46E-02	1.18E-02	1.62E-02	2.09E-02
	0.01	9.25E-03	6.76E-03	9.77E-03	1.35E-02
	0.02	5.47E-03	3.63E-03	5.62E-03	8.13E-03
	0.03	4.03E-03	2.46E-03	4.07E-03	6.03E-03
	0.05	2.83E-03	1.45E-03	2.75E-03	4.37E-03
	0.1	1.78E-03	6.03E-04	1.59E-03	2.95E-03
	0.2	9.49E-04	1.59E-04	6.92E-04	1.78E-03
	0.3	5.57E-04	6.03E-05	3.09E-04	1.07E-03
	0.5	2.26E-04	1.59E-05	8.32E-05	4.17E-04
	1	4.31E-05	2.04E-06	1.18E-05	6.31E-05
	2	5.47E-06	1.91E-07	1.38E-06	7.08E-06
1 Hz PSA	0.001	2.04E-02	1.51E-02	2.09E-02	2.88E-02
	0.002	1.31E-02	9.33E-03	1.35E-02	1.91E-02
	0.003	9.95E-03	6.76E-03	1.02E-02	1.45E-02
	0.005	6.97E-03	4.17E-03	7.08E-03	1.05E-02
	0.01	4.25E-03	2.04E-03	3.98E-03	6.92E-03
	0.02	2.49E-03	8.71E-04	2.19E-03	4.27E-03
	0.03	1.73E-03	4.37E-04	1.41E-03	3.09E-03
	0.05	9.96E-04	1.35E-04	6.92E-04	1.95E-03
	0.1	3.68E-04	1.86E-05	1.45E-04	7.41E-04
	0.2	9.14E-05	1.95E-06	1.78E-05	1.51E-04
	0.3	3.29E-05	4.57E-07	4.57E-06	4.57E-05
	0.5	7.46E-06	5.89E-08	7.59E-07	8.32E-06
	1	7.55E-07	2.19E-09	4.68E-08	6.61E-07
	2	5.72E-08	3.80E-11	1.74E-09	3.80E-08

Table I–4 Demonstration calculation results for Central Illinois site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	5.97E-02	5.01E-02	6.61E-02	8.51E-02
	0.002	3.83E-02	3.02E-02	4.37E-02	6.03E-02
	0.003	2.78E-02	2.04E-02	3.09E-02	4.57E-02
	0.005	1.76E-02	1.12E-02	1.86E-02	2.95E-02
	0.01	8.93E-03	4.79E-03	8.71E-03	1.41E-02
	0.02	4.28E-03	1.70E-03	3.89E-03	7.08E-03
	0.03	2.66E-03	7.76E-04	2.14E-03	4.79E-03
	0.05	1.33E-03	2.63E-04	8.13E-04	2.57E-03
	0.1	3.99E-04	6.31E-05	1.91E-04	6.46E-04
	0.2	9.00E-05	1.55E-05	4.79E-05	1.29E-04
	0.3	3.65E-05	6.61E-06	2.14E-05	5.75E-05
	0.5	1.23E-05	1.91E-06	7.41E-06	2.19E-05
	1	2.70E-06	2.24E-07	1.35E-06	5.13E-06
	2	4.33E-07	1.35E-08	1.45E-07	8.13E-07
10 Hz PSA	0.001	7.86E-02	6.76E-02	8.51E-02	1.02E-01
	0.002	5.90E-02	5.01E-02	6.61E-02	8.32E-02
	0.003	4.66E-02	3.89E-02	5.37E-02	7.08E-02
	0.005	3.23E-02	2.51E-02	3.72E-02	5.25E-02
	0.01	1.77E-02	1.18E-02	1.91E-02	2.95E-02
	0.02	8.93E-03	4.90E-03	8.91E-03	1.41E-02
	0.03	5.78E-03	2.69E-03	5.50E-03	9.12E-03
	0.05	3.17E-03	1.05E-03	2.69E-03	5.50E-03
	0.1	1.18E-03	2.40E-04	7.24E-04	2.19E-03
	0.2	3.10E-04	5.50E-05	1.62E-04	5.01E-04
	0.3	1.25E-04	2.34E-05	6.92E-05	1.91E-04
	0.5	3.88E-05	7.94E-06	2.40E-05	6.17E-05
	1	8.28E-06	1.48E-06	5.25E-06	1.45E-05
	2	1.56E-06	1.62E-07	8.32E-07	2.88E-06
1 Hz PSA	0.001	4.35E-02	3.24E-02	4.68E-02	6.46E-02
	0.002	2.45E-02	1.66E-02	2.57E-02	3.98E-02
	0.003	1.68E-02	1.07E-02	1.74E-02	2.75E-02
	0.005	1.03E-02	6.03E-03	1.05E-02	1.70E-02
	0.01	5.32E-03	2.57E-03	5.25E-03	8.91E-03
	0.02	2.78E-03	7.76E-04	2.51E-03	5.01E-03
	0.03	1.83E-03	2.88E-04	1.38E-03	3.63E-03
	0.05	9.66E-04	6.61E-05	4.68E-04	2.04E-03
	0.1	2.88E-04	7.41E-06	6.03E-05	5.13E-04
	0.2	4.97E-05	7.41E-07	6.03E-06	5.89E-05
	0.3	1.39E-05	1.70E-07	1.59E-06	1.41E-05
	0.5	2.40E-06	2.19E-08	2.69E-07	2.46E-06
	1	1.98E-07	8.13E-10	1.70E-08	2.04E-07
	2	1.49E-08	1.32E-11	6.46E-10	1.38E-08

Table I–5 Demonstration calculation results for Manchester site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	3.86E-02	3.47E-02	4.47E-02	5.75E-02
	0.002	2.48E-02	2.19E-02	3.02E-02	4.07E-02
	0.003	1.84E-02	1.51E-02	2.24E-02	3.16E-02
	0.005	1.20E-02	8.51E-03	1.45E-02	2.19E-02
	0.01	6.17E-03	3.55E-03	6.61E-03	1.12E-02
	0.02	2.81E-03	1.45E-03	2.63E-03	4.68E-03
	0.03	1.68E-03	8.13E-04	1.51E-03	2.69E-03
	0.05	8.47E-04	3.80E-04	7.41E-04	1.32E-03
	0.1	3.20E-04	1.23E-04	2.69E-04	5.13E-04
	0.2	1.15E-04	3.63E-05	9.12E-05	1.95E-04
	0.3	6.07E-05	1.59E-05	4.57E-05	1.07E-04
	0.5	2.52E-05	4.90E-06	1.70E-05	4.57E-05
	1	6.20E-06	6.31E-07	3.39E-06	1.18E-05
	2	1.05E-06	3.98E-08	3.89E-07	2.00E-06
10 Hz PSA	0.001	5.16E-02	4.79E-02	5.75E-02	7.24E-02
	0.002	3.72E-02	3.47E-02	4.37E-02	5.62E-02
	0.003	2.92E-02	2.69E-02	3.55E-02	4.68E-02
	0.005	2.06E-02	1.82E-02	2.57E-02	3.47E-02
	0.01	1.18E-02	8.13E-03	1.41E-02	2.09E-02
	0.02	5.98E-03	3.55E-03	6.17E-03	1.02E-02
	0.03	3.78E-03	2.14E-03	3.72E-03	6.17E-03
	0.05	2.00E-03	1.05E-03	1.86E-03	3.09E-03
	0.1	7.72E-04	3.55E-04	6.92E-04	1.18E-03
	0.2	2.78E-04	1.10E-04	2.40E-04	4.47E-04
	0.3	1.48E-04	5.25E-05	1.23E-04	2.46E-04
	0.5	6.37E-05	1.91E-05	5.01E-05	1.07E-04
	1	1.76E-05	3.80E-06	1.26E-05	3.09E-05
	2	3.71E-06	4.68E-07	2.24E-06	6.76E-06
1 Hz PSA	0.001	3.02E-02	2.40E-02	3.39E-02	4.68E-02
	0.002	1.75E-02	1.29E-02	1.95E-02	2.88E-02
	0.003	1.21E-02	8.13E-03	1.35E-02	2.09E-02
	0.005	7.28E-03	4.27E-03	7.76E-03	1.32E-02
	0.01	3.32E-03	1.41E-03	3.16E-03	6.46E-03
	0.02	1.29E-03	3.63E-04	1.02E-03	2.63E-03
	0.03	6.69E-04	1.55E-04	4.57E-04	1.35E-03
	0.05	2.63E-04	5.01E-05	1.55E-04	5.13E-04
	0.1	6.35E-05	1.05E-05	3.55E-05	1.18E-04
	0.2	1.43E-05	1.82E-06	7.76E-06	2.63E-05
	0.3	5.93E-06	5.50E-07	2.88E-06	1.12E-05
	0.5	1.86E-06	9.55E-08	6.92E-07	3.47E-06
	1	3.11E-07	5.13E-09	6.46E-08	5.13E-07
	2	3.53E-08	1.15E-10	3.31E-09	4.47E-08

Table I–6 Demonstration calculation results for Chattanooga site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	6.55E-02	5.13E-02	6.92E-02	8.71E-02
	0.002	4.07E-02	3.02E-02	4.27E-02	5.75E-02
	0.003	2.98E-02	2.09E-02	3.09E-02	4.27E-02
	0.005	1.96E-02	1.32E-02	2.04E-02	2.95E-02
	0.01	1.07E-02	6.46E-03	1.12E-02	1.70E-02
	0.02	5.38E-03	2.40E-03	5.13E-03	9.12E-03
	0.03	3.42E-03	1.20E-03	2.95E-03	6.03E-03
	0.05	1.79E-03	4.90E-04	1.35E-03	3.16E-03
	0.1	6.32E-04	1.59E-04	4.17E-04	1.07E-03
	0.2	2.01E-04	4.79E-05	1.26E-04	3.63E-04
	0.3	1.01E-04	2.24E-05	6.17E-05	1.86E-04
	0.5	4.09E-05	6.92E-06	2.40E-05	7.41E-05
	1	9.80E-06	8.71E-07	4.79E-06	1.78E-05
	2	1.61E-06	5.37E-08	5.37E-07	2.82E-06
10 Hz PSA	0.001	1.00E-03	9.09E-02	7.76E-02	9.55E-02
	0.002	2.00E-03	6.38E-02	5.13E-02	6.76E-02
	0.003	3.00E-03	4.89E-02	3.80E-02	5.13E-02
	0.005	5.00E-03	3.35E-02	2.46E-02	3.55E-02
	0.01	1.00E-02	1.92E-02	1.29E-02	2.00E-02
	0.02	2.00E-02	1.03E-02	6.31E-03	1.07E-02
	0.03	3.00E-02	6.87E-03	3.63E-03	6.92E-03
	0.05	5.00E-02	3.87E-03	1.51E-03	3.55E-03
	0.1	1.00E-01	1.52E-03	4.47E-04	1.18E-03
	0.2	2.00E-01	4.99E-04	1.38E-04	3.47E-04
	0.3	3.00E-01	2.50E-04	6.76E-05	1.66E-04
	0.5	5.00E-01	1.03E-04	2.63E-05	6.61E-05
	1	1.00E+00	2.76E-05	5.50E-06	1.66E-05
	2	2.00E+00	5.65E-06	6.61E-07	2.95E-06
1 Hz PSA	0.001	5.02E-02	3.63E-02	5.01E-02	7.08E-02
	0.002	2.88E-02	2.00E-02	2.88E-02	4.27E-02
	0.003	2.02E-02	1.35E-02	2.04E-02	3.09E-02
	0.005	1.27E-02	7.76E-03	1.29E-02	2.00E-02
	0.01	6.72E-03	3.31E-03	6.61E-03	1.10E-02
	0.02	3.37E-03	9.77E-04	3.02E-03	6.03E-03
	0.03	2.11E-03	3.80E-04	1.59E-03	4.17E-03
	0.05	1.04E-03	1.05E-04	5.25E-04	2.19E-03
	0.1	2.93E-04	1.62E-05	8.51E-05	5.13E-04
	0.2	5.27E-05	2.29E-06	1.29E-05	7.24E-05
	0.3	1.65E-05	6.46E-07	4.17E-06	2.34E-05
	0.5	3.67E-06	9.77E-08	8.71E-07	5.50E-06
	1	4.53E-07	4.27E-09	6.92E-08	6.46E-07
	2	4.47E-08	7.76E-11	2.95E-09	4.90E-08

Table I–7 Demonstration calculation results for Topeka site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	1.61E-02	1.07E-02	1.51E-02	2.09E-02
	0.002	1.14E-02	7.76E-03	1.15E-02	1.62E-02
	0.003	7.35E-03	4.47E-03	7.94E-03	1.18E-02
	0.005	3.81E-03	1.59E-03	3.72E-03	6.92E-03
	0.01	1.69E-03	4.90E-04	1.23E-03	3.24E-03
	0.02	9.37E-04	2.46E-04	6.03E-04	1.66E-03
	0.03	3.97E-04	1.05E-04	2.51E-04	6.31E-04
	0.05	1.16E-04	3.31E-05	8.13E-05	1.86E-04
	0.1	3.72E-05	9.55E-06	2.75E-05	6.31E-05
	0.2	1.94E-05	4.07E-06	1.38E-05	3.39E-05
	0.3	8.01E-06	1.18E-06	5.01E-06	1.45E-05
	0.5	1.94E-06	1.35E-07	9.33E-07	3.63E-06
	1	3.21E-07	7.76E-09	9.77E-08	5.89E-07
	2	1.61E-02	1.07E-02	1.51E-02	2.09E-02
10 Hz PSA	0.001	4.11E-02	3.02E-02	4.07E-02	5.13E-02
	0.002	2.52E-02	1.66E-02	2.40E-02	3.16E-02
	0.003	1.84E-02	1.20E-02	1.74E-02	2.29E-02
	0.005	1.21E-02	8.32E-03	1.20E-02	1.62E-02
	0.01	6.57E-03	3.89E-03	7.24E-03	1.10E-02
	0.02	3.19E-03	1.32E-03	3.02E-03	6.03E-03
	0.03	1.91E-03	6.92E-04	1.55E-03	3.55E-03
	0.05	8.88E-04	3.02E-04	6.61E-04	1.51E-03
	0.1	2.78E-04	9.33E-05	2.14E-04	4.47E-04
	0.2	8.90E-05	2.82E-05	6.92E-05	1.48E-04
	0.3	4.65E-05	1.35E-05	3.55E-05	7.76E-05
	0.5	1.99E-05	4.79E-06	1.45E-05	3.39E-05
	1	5.42E-06	8.91E-07	3.55E-06	9.55E-06
	2	1.11E-06	9.55E-08	5.75E-07	2.04E-06
1 Hz PSA	0.001	2.49E-02	1.51E-02	2.24E-02	3.47E-02
	0.002	1.38E-02	8.13E-03	1.26E-02	2.00E-02
	0.003	9.69E-03	5.37E-03	9.12E-03	1.41E-02
	0.005	6.19E-03	3.09E-03	5.89E-03	9.55E-03
	0.01	3.34E-03	1.07E-03	3.02E-03	5.75E-03
	0.02	1.62E-03	2.09E-04	1.10E-03	3.24E-03
	0.03	9.56E-04	7.08E-05	4.27E-04	2.00E-03
	0.05	4.08E-04	1.74E-05	1.02E-04	7.76E-04
	0.1	8.45E-05	2.51E-06	1.41E-05	1.07E-04
	0.2	1.10E-05	3.02E-07	2.09E-06	1.23E-05
	0.3	3.09E-06	7.08E-08	6.46E-07	3.89E-06
	0.5	6.49E-07	8.71E-09	1.20E-07	9.33E-07
	1	8.10E-08	2.75E-10	8.13E-09	1.10E-07
	2	8.22E-09	3.63E-12	2.95E-10	7.76E-09

Table I–8 Demonstration calculation results for Houston site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	Mean
PGA	0.001	7.69E-03	3.39E-03	6.03E-03	1.05E-02
	0.002	4.60E-03	1.91E-03	3.63E-03	6.61E-03
	0.003	3.21E-03	1.35E-03	2.46E-03	4.90E-03
	0.005	1.87E-03	7.76E-04	1.51E-03	3.09E-03
	0.01	7.65E-04	2.75E-04	6.61E-04	1.41E-03
	0.02	2.59E-04	8.91E-05	2.09E-04	5.01E-04
	0.03	1.32E-04	4.47E-05	1.05E-04	2.46E-04
	0.05	5.61E-05	1.82E-05	4.37E-05	1.00E-04
	0.1	1.77E-05	5.13E-06	1.35E-05	3.09E-05
	0.2	5.59E-06	1.32E-06	4.17E-06	9.77E-06
	0.3	2.82E-06	5.50E-07	2.04E-06	5.01E-06
	0.5	1.14E-06	1.59E-07	7.59E-07	2.09E-06
	1	2.84E-07	1.91E-08	1.51E-07	5.62E-07
	2	5.01E-08	1.18E-09	1.70E-08	9.77E-08
10 Hz PSA	0.001	1.05E-02	4.57E-03	7.94E-03	1.45E-02
	0.002	6.65E-03	2.75E-03	5.01E-03	9.12E-03
	0.003	4.84E-03	2.00E-03	3.55E-03	6.76E-03
	0.005	3.04E-03	1.35E-03	2.24E-03	4.27E-03
	0.01	1.43E-03	6.92E-04	1.26E-03	2.09E-03
	0.02	5.82E-04	2.63E-04	5.75E-04	1.10E-03
	0.03	3.28E-04	1.45E-04	3.09E-04	6.76E-04
	0.05	1.53E-04	6.03E-05	1.38E-04	3.02E-04
	0.1	5.09E-05	1.70E-05	4.17E-05	9.33E-05
	0.2	1.58E-05	4.57E-06	1.23E-05	2.75E-05
	0.3	7.76E-06	2.04E-06	5.89E-06	1.35E-05
	0.5	3.10E-06	6.92E-07	2.29E-06	5.50E-06
	1	8.17E-07	1.26E-07	5.75E-07	1.48E-06
	2	1.76E-07	1.45E-08	1.02E-07	3.31E-07
1 Hz PSA	0.001	7.17E-03	3.55E-03	6.03E-03	9.77E-03
	0.002	4.49E-03	1.91E-03	3.98E-03	6.76E-03
	0.003	3.30E-03	1.10E-03	2.82E-03	5.50E-03
	0.005	2.10E-03	4.68E-04	1.55E-03	3.89E-03
	0.01	9.65E-04	1.18E-04	4.37E-04	2.00E-03
	0.02	3.35E-04	2.40E-05	9.33E-05	5.37E-04
	0.03	1.51E-04	8.91E-06	3.72E-05	1.91E-04
	0.05	4.53E-05	2.51E-06	1.07E-05	5.13E-05
	0.1	6.73E-06	4.47E-07	1.95E-06	9.12E-06
	0.2	1.01E-06	7.08E-08	3.80E-07	1.66E-06
	0.3	3.65E-07	2.04E-08	1.35E-07	6.46E-07
	0.5	1.06E-07	3.39E-09	3.24E-08	1.91E-07
	1	1.76E-08	1.66E-10	3.02E-09	2.82E-08
	2	2.05E-09	3.72E-12	1.51E-10	2.46E-09

Table I-9 Demonstration calculation results for Jackson site.

Ground-motion measure	Peak or spectral acceleration (g)	Annual frequency of exceedance			
		Mean	16th percentile	50th percentile	84th percentile
PGA	0.001	1.70E-02	2.14E-02	3.09E-02	4.27E-02
	0.002	8.32E-03	1.10E-02	1.74E-02	2.51E-02
	0.003	5.50E-03	7.41E-03	1.18E-02	1.78E-02
	0.005	3.16E-03	4.47E-03	7.41E-03	1.15E-02
	0.01	1.23E-03	2.09E-03	4.07E-03	6.76E-03
	0.02	2.95E-04	6.31E-04	1.95E-03	4.17E-03
	0.03	1.18E-04	2.51E-04	9.55E-04	2.95E-03
	0.05	3.63E-05	7.59E-05	3.02E-04	1.48E-03
	0.1	6.92E-06	1.70E-05	5.50E-05	2.88E-04
	0.2	1.23E-06	3.98E-06	1.32E-05	4.07E-05
	0.3	3.89E-07	1.62E-06	6.03E-06	1.62E-05
	0.5	7.76E-08	4.47E-07	2.09E-06	5.89E-06
	1	5.89E-09	5.13E-08	3.89E-07	1.45E-06
	2	2.14E-10	3.02E-09	4.27E-08	2.51E-07
10 Hz PSA	0.001	4.81E-02	3.55E-02	4.68E-02	6.03E-02
	0.002	3.02E-02	2.04E-02	2.88E-02	3.89E-02
	0.003	2.18E-02	1.41E-02	2.09E-02	2.88E-02
	0.005	1.40E-02	8.71E-03	1.35E-02	1.91E-02
	0.01	7.56E-03	4.37E-03	7.08E-03	1.07E-02
	0.02	4.10E-03	2.00E-03	3.89E-03	6.46E-03
	0.03	2.80E-03	1.02E-03	2.57E-03	4.79E-03
	0.05	1.60E-03	3.39E-04	1.18E-03	3.09E-03
	0.1	5.76E-04	6.76E-05	2.46E-04	1.12E-03
	0.2	1.32E-04	1.48E-05	4.47E-05	1.91E-04
	0.3	4.67E-05	6.31E-06	1.86E-05	6.03E-05
	0.5	1.23E-05	2.04E-06	6.76E-06	1.70E-05
	1	2.35E-06	3.47E-07	1.55E-06	3.98E-06
	2	4.53E-07	3.80E-08	2.63E-07	8.51E-07
1 Hz PSA	0.001	2.62E-02	1.59E-02	2.40E-02	3.72E-02
	0.002	1.42E-02	7.94E-03	1.29E-02	2.09E-02
	0.003	9.77E-03	5.25E-03	8.91E-03	1.48E-02
	0.005	6.20E-03	3.16E-03	5.75E-03	9.55E-03
	0.01	3.53E-03	1.41E-03	3.24E-03	5.75E-03
	0.02	2.03E-03	3.98E-04	1.62E-03	3.72E-03
	0.03	1.37E-03	1.35E-04	8.71E-04	2.75E-03
	0.05	7.31E-04	2.63E-05	2.69E-04	1.51E-03
	0.1	2.10E-04	2.63E-06	2.88E-05	3.47E-04
	0.2	3.41E-05	2.88E-07	2.46E-06	3.47E-05
	0.3	9.11E-06	7.24E-08	6.31E-07	7.24E-06
	0.5	1.46E-06	1.02E-08	1.15E-07	1.07E-06
	1	1.04E-07	4.37E-10	8.13E-09	9.12E-08
	2	6.88E-09	8.51E-12	3.63E-10	6.31E-09

Figure I–1 **Mean and fractile hazard curves for PGA for Savannah site.**

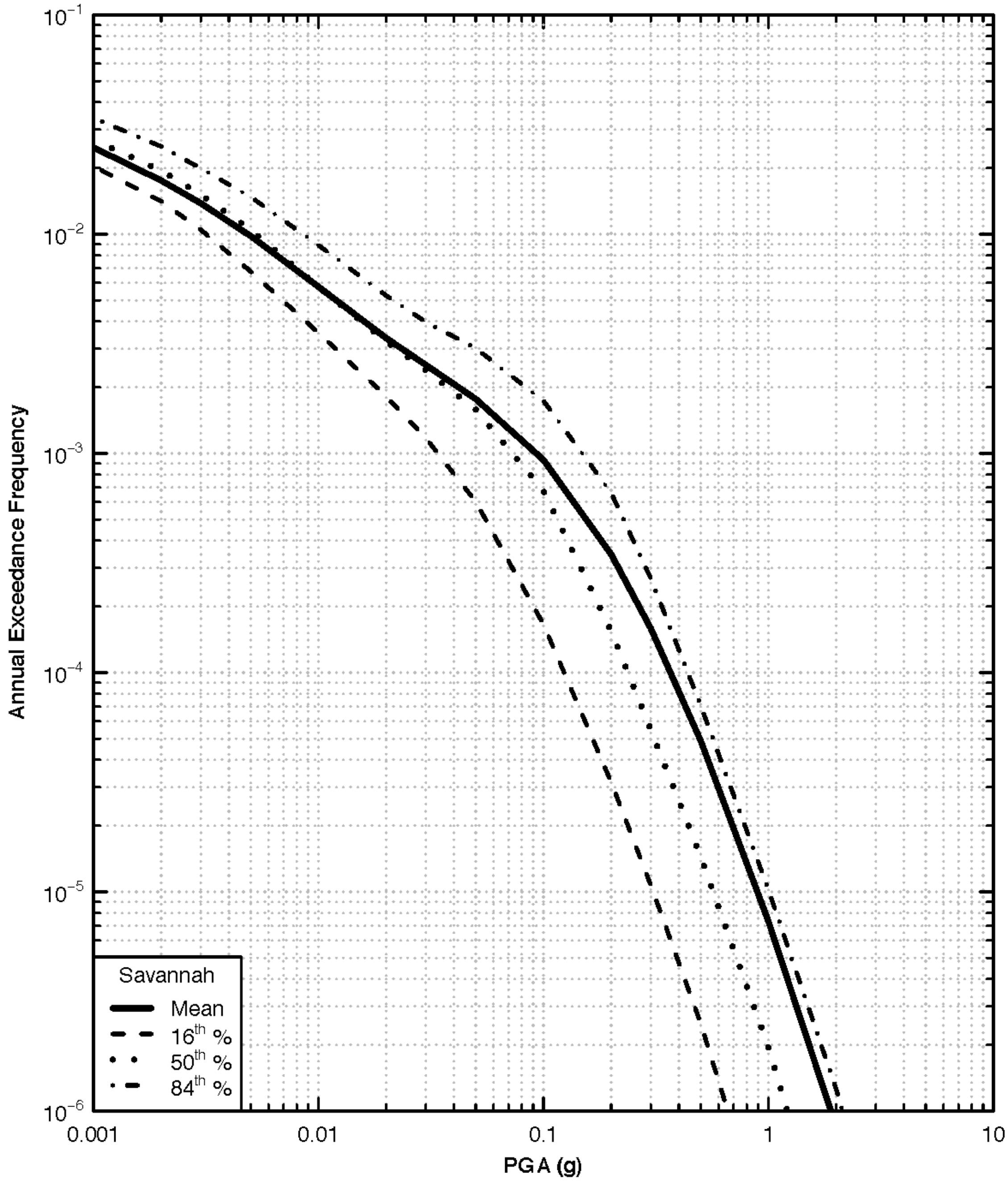


Figure I–2 **Distributed seismicity source contributions to mean PGA hazard for Savannah site.**

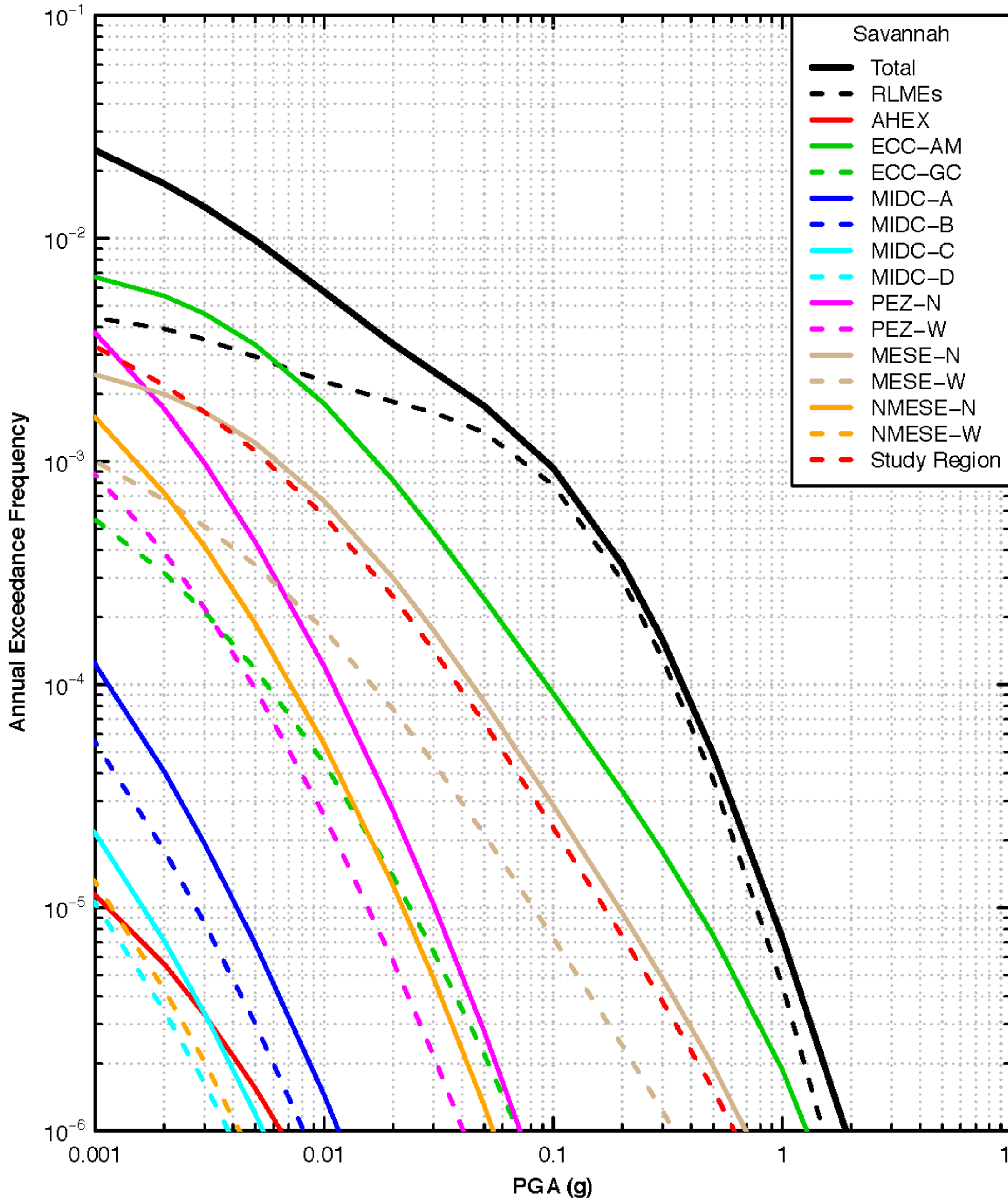


Figure I–3 RLME source contributions to mean PGA hazard for Savannah site.

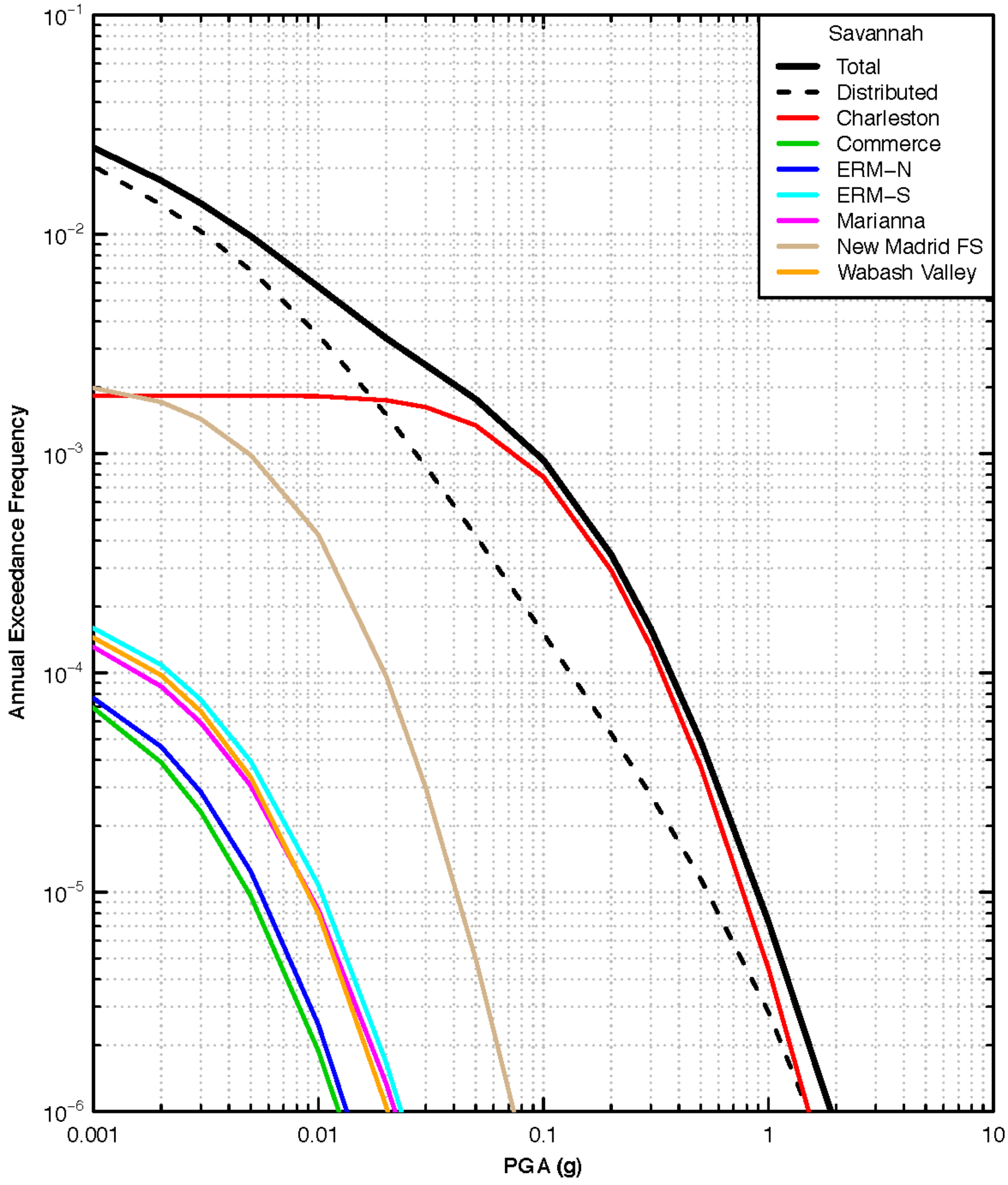


Figure I–4 Mean and fractile hazard curves for 10 Hz PSA for Savannah site.

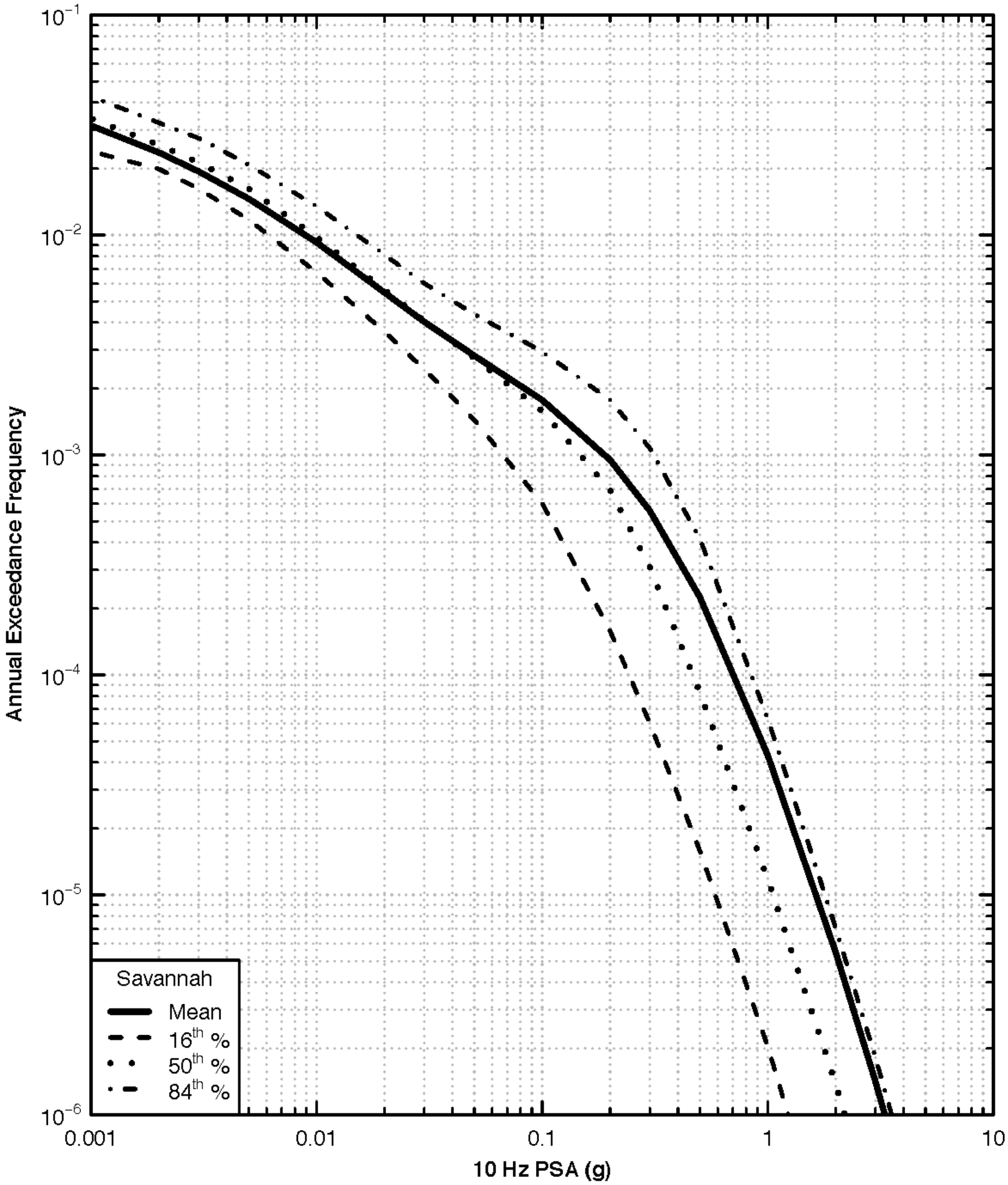


Figure I–5 **Distributed seismicity source contributions to mean 10 Hz PSA hazard for Savannah site.**

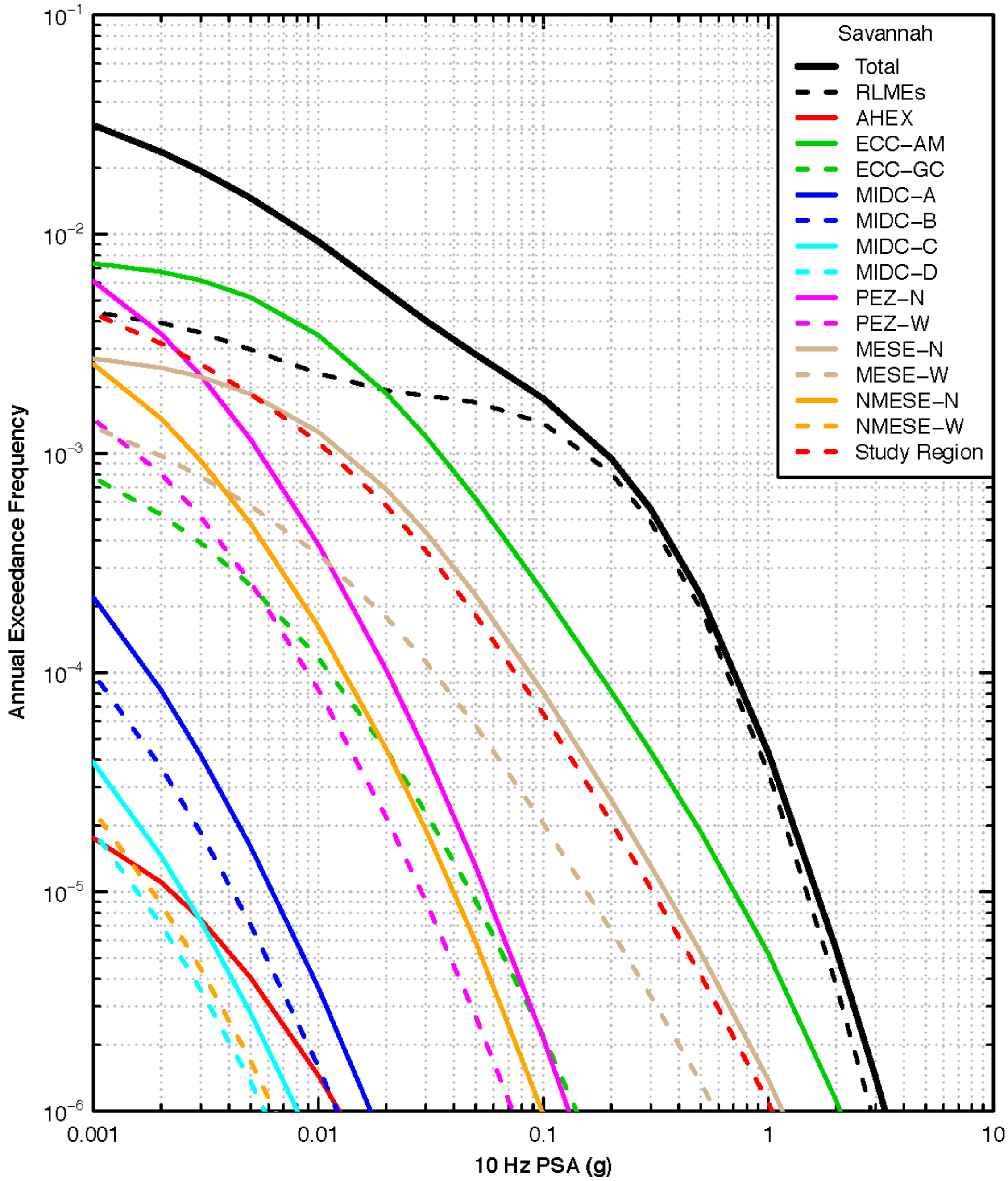


Figure I–6 RLME source contributions to mean 10 Hz PSA hazard for Savannah site.

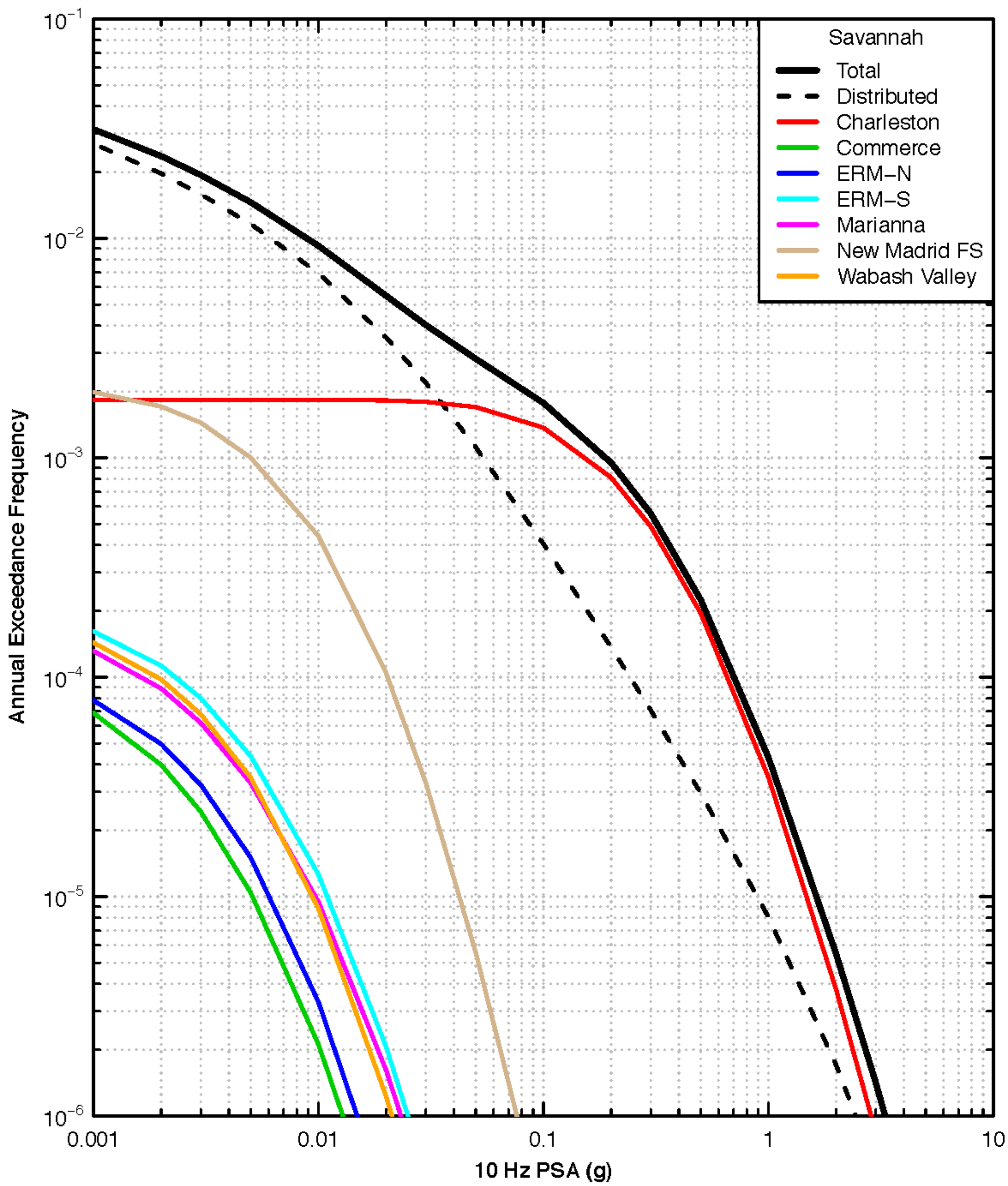


Figure I–7 Mean and fractile hazard for 1 Hz PSA for Savannah site.

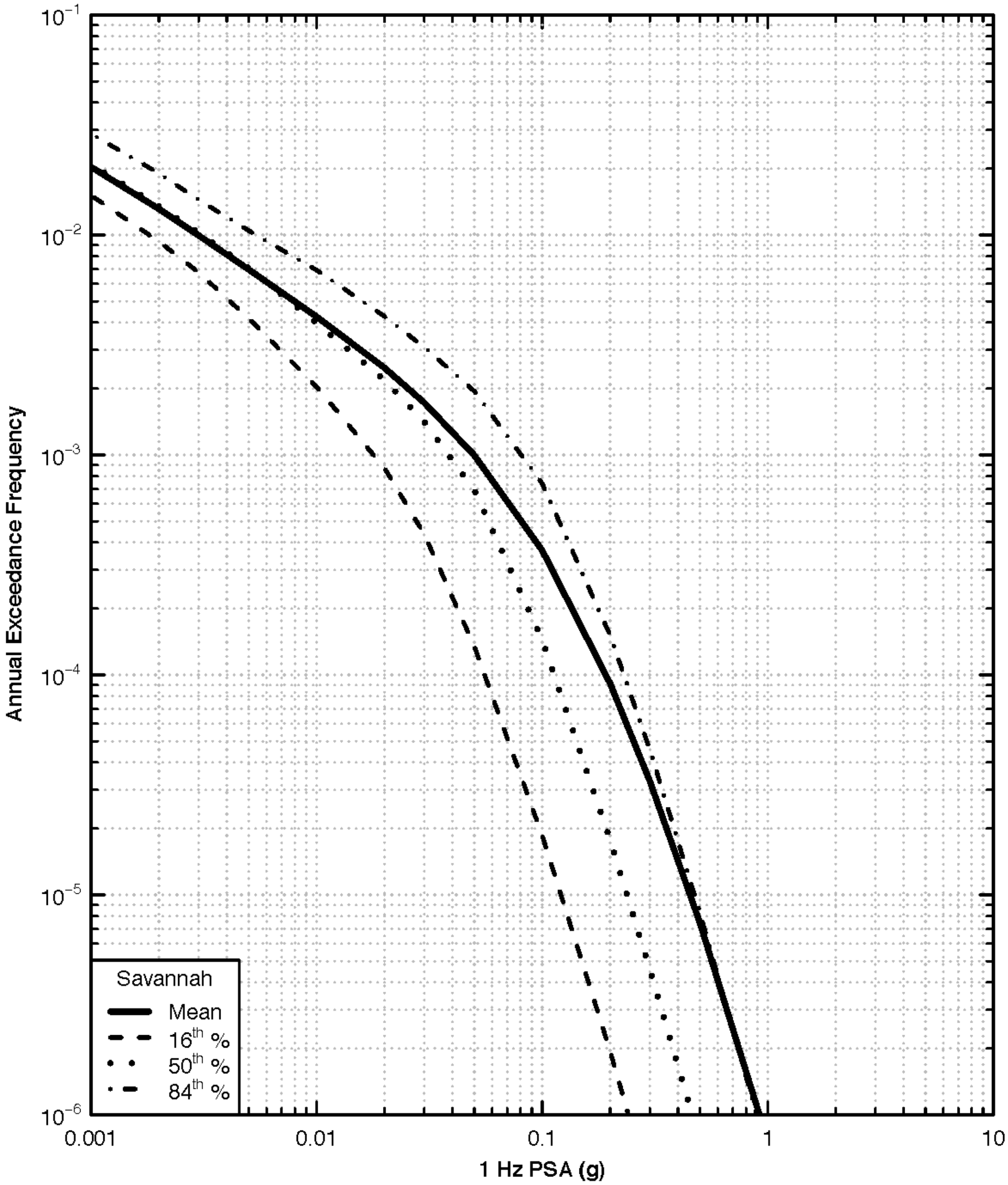


Figure I–8 **Distributed seismicity source contributions to mean 1 Hz PSA hazard for Savannah site.**

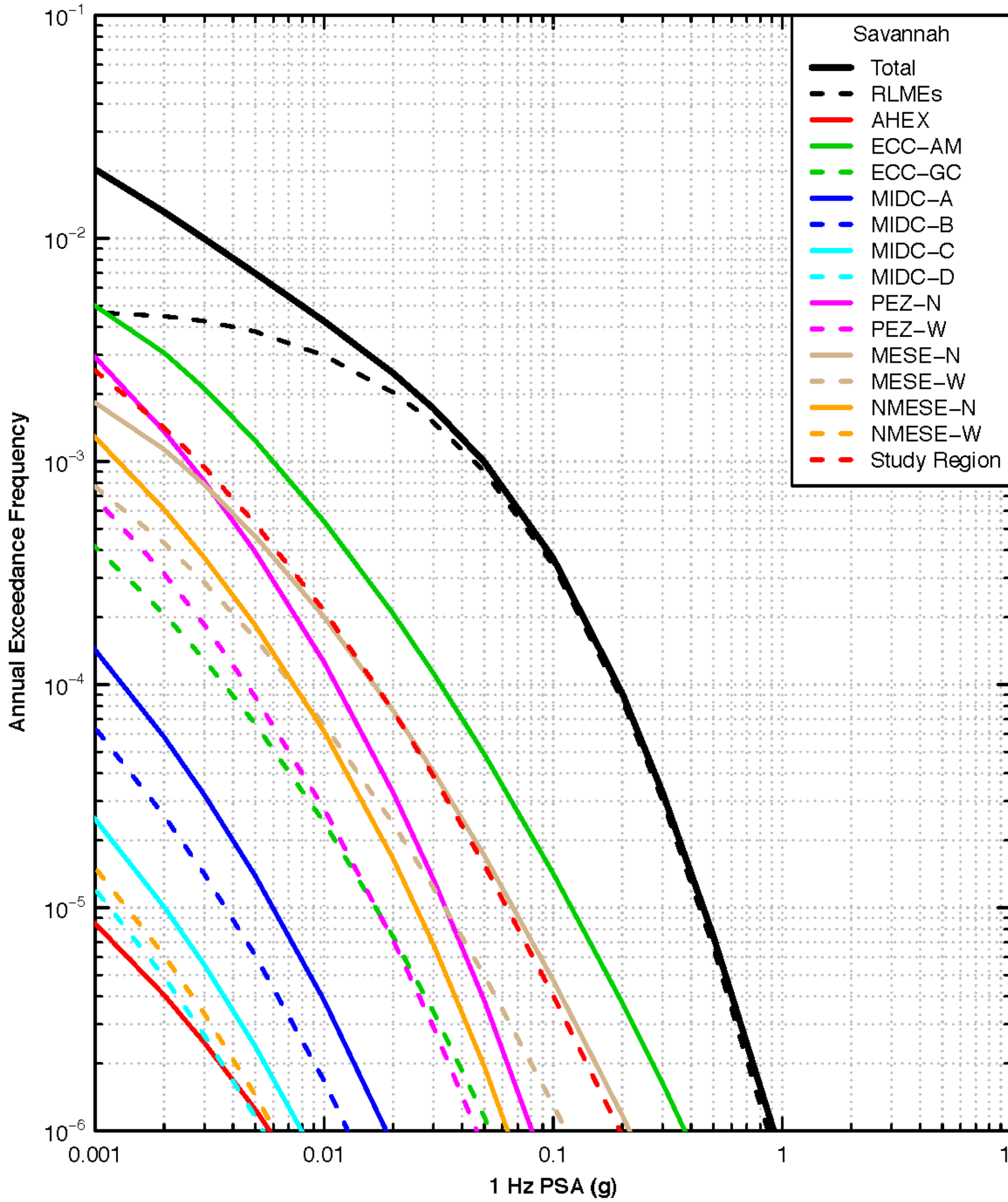


Figure I–9 RLME source contributions to mean 1 Hz PSA hazard for Savannah site.

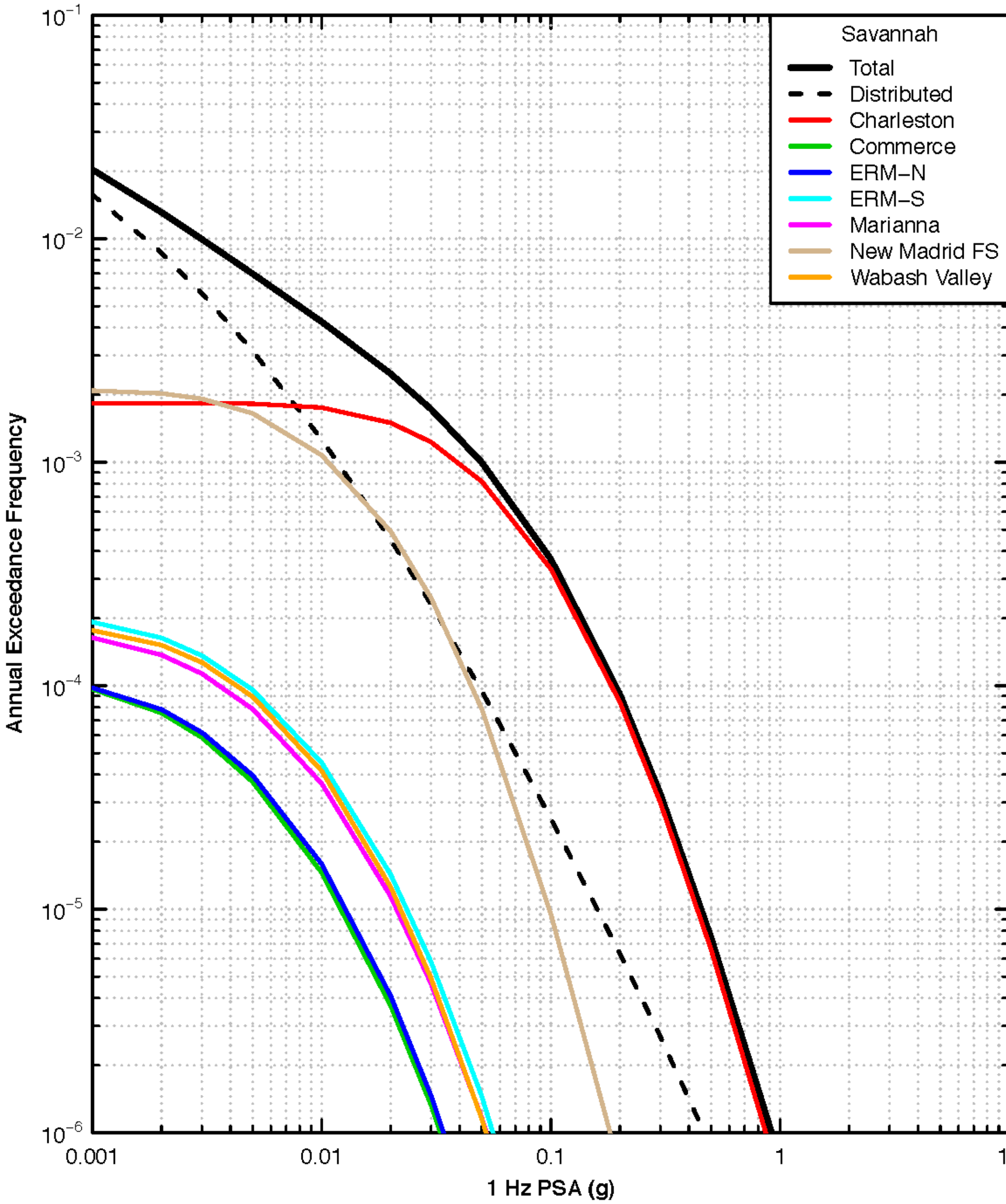


Figure I–10 **Mean and fractile hazard curves for PGA for Central Illinois site.**

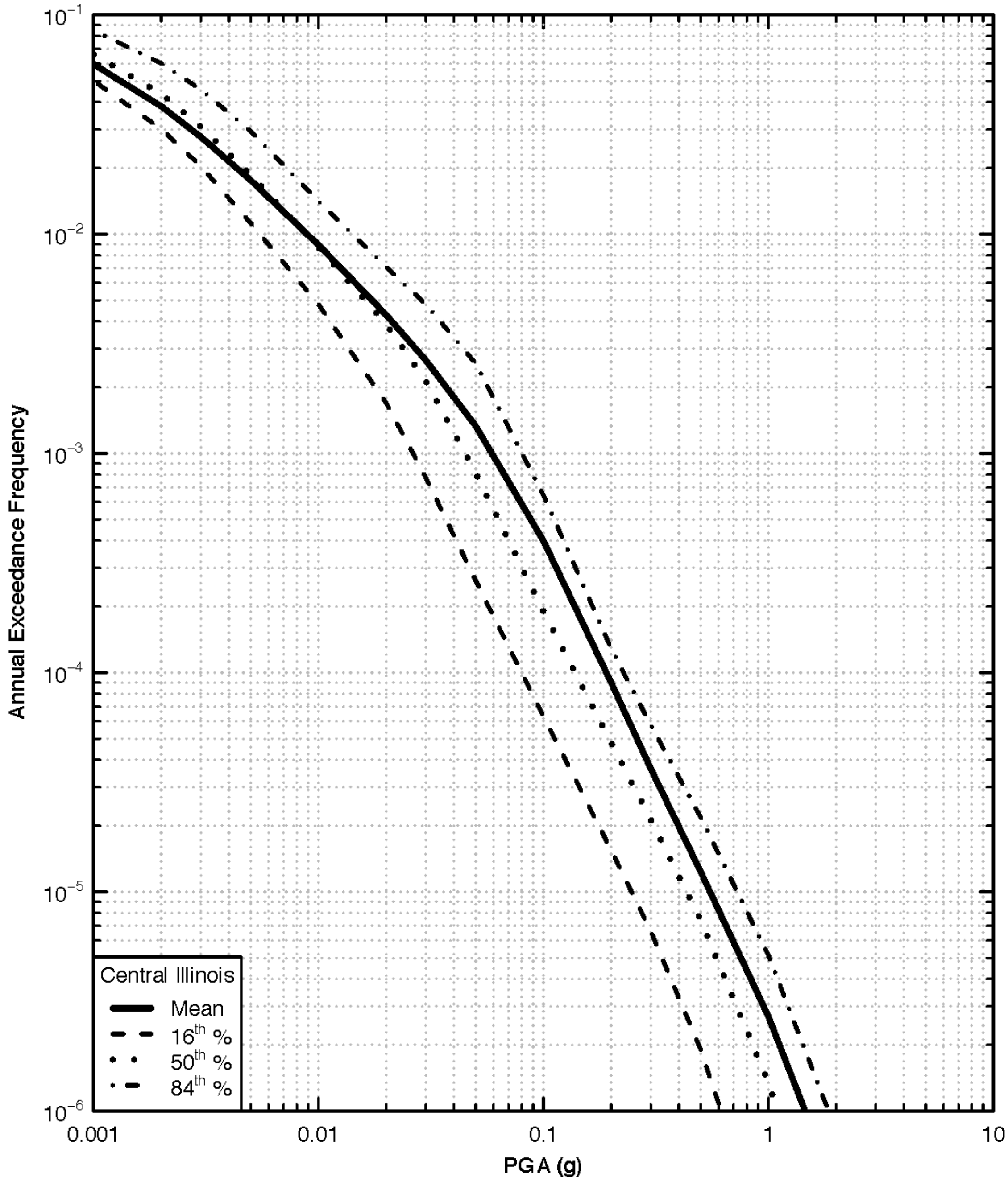


Figure I–11 Distributed seismicity source contributions to mean PGA Hazard for Central Illinois site.

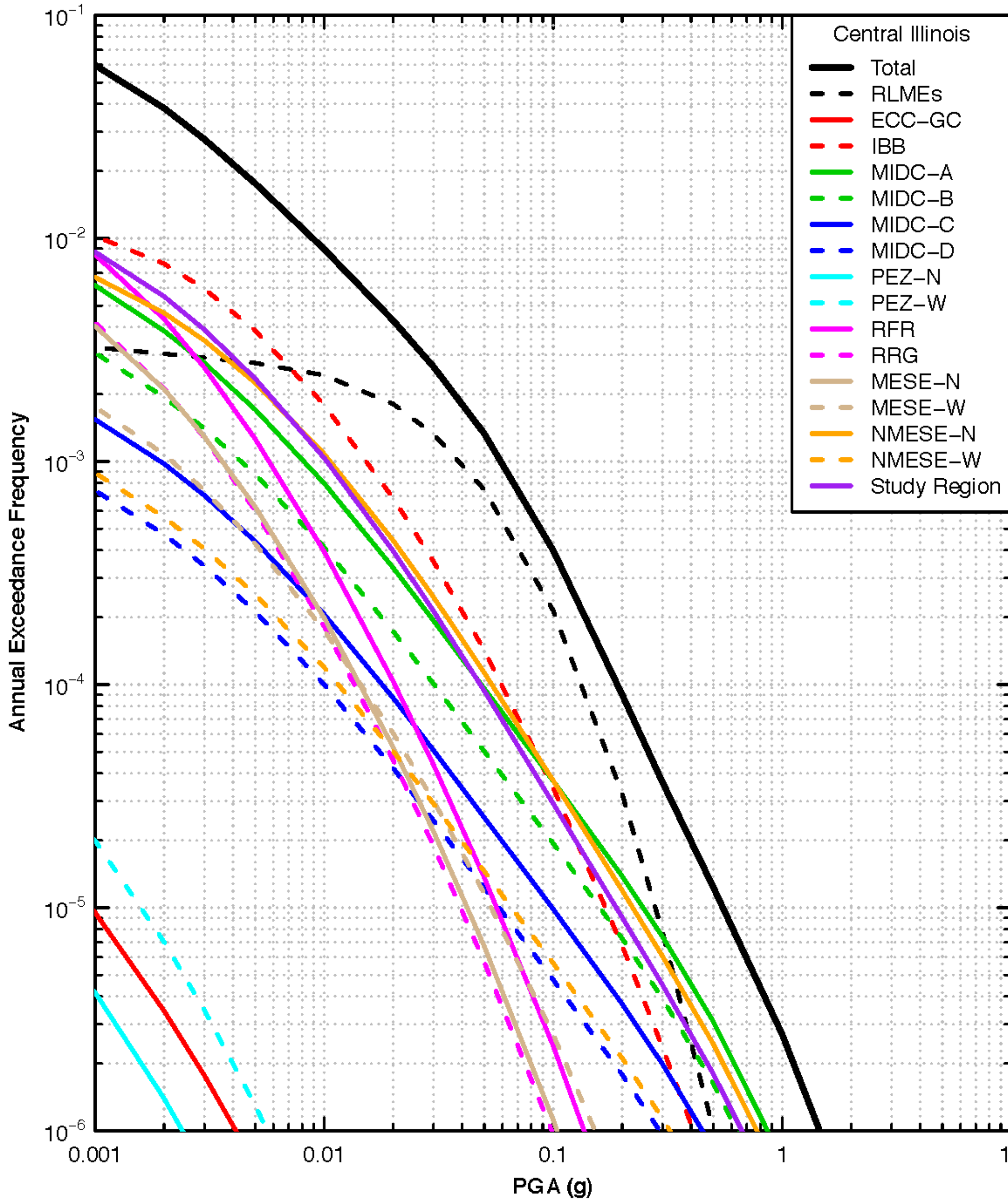


Figure I–12 RLME source contributions to mean PGA hazard for Central Illinois site.

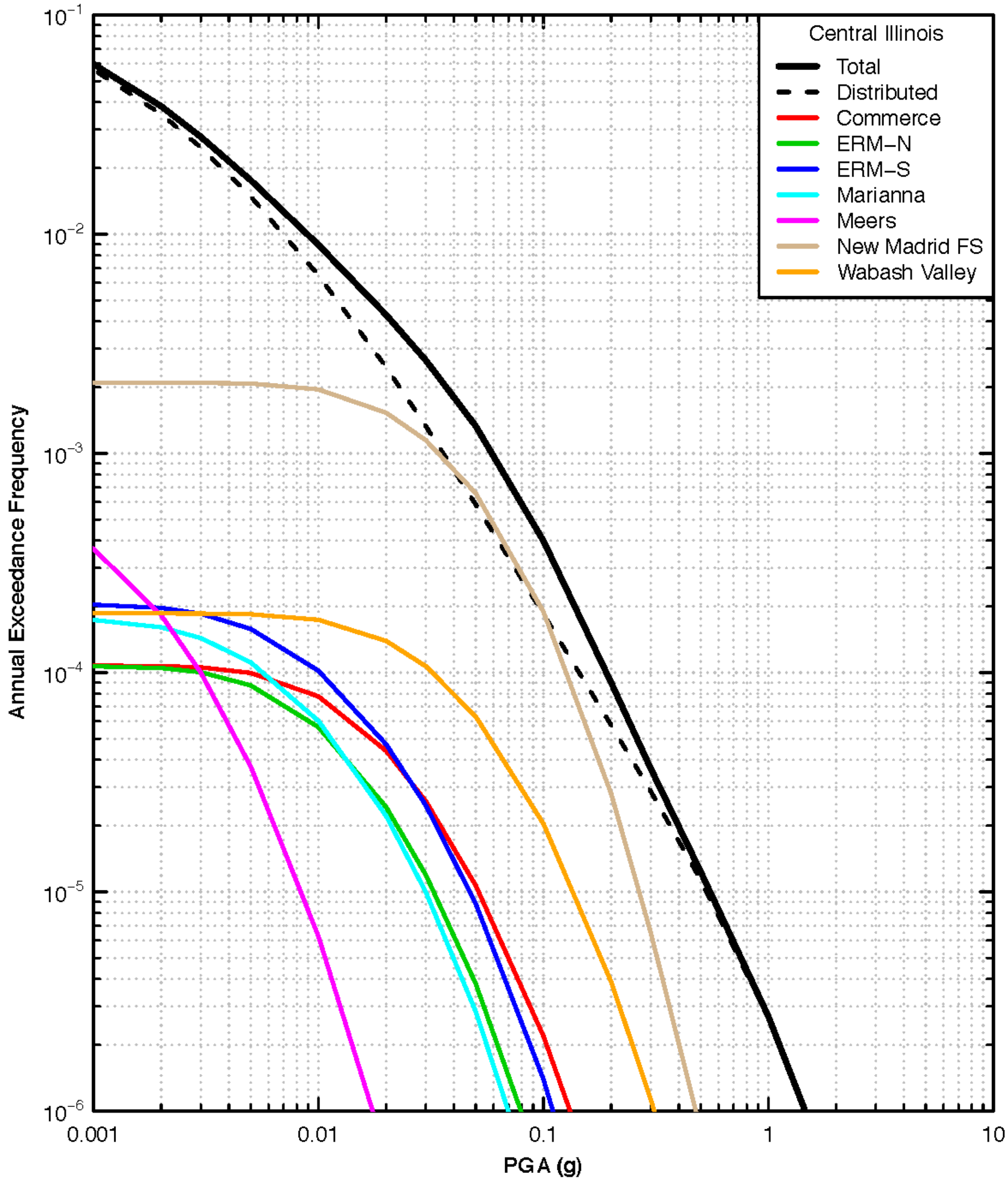


Figure I–13 Mean and fractile hazard curves for 10 Hz PSA for Central Illinois site.

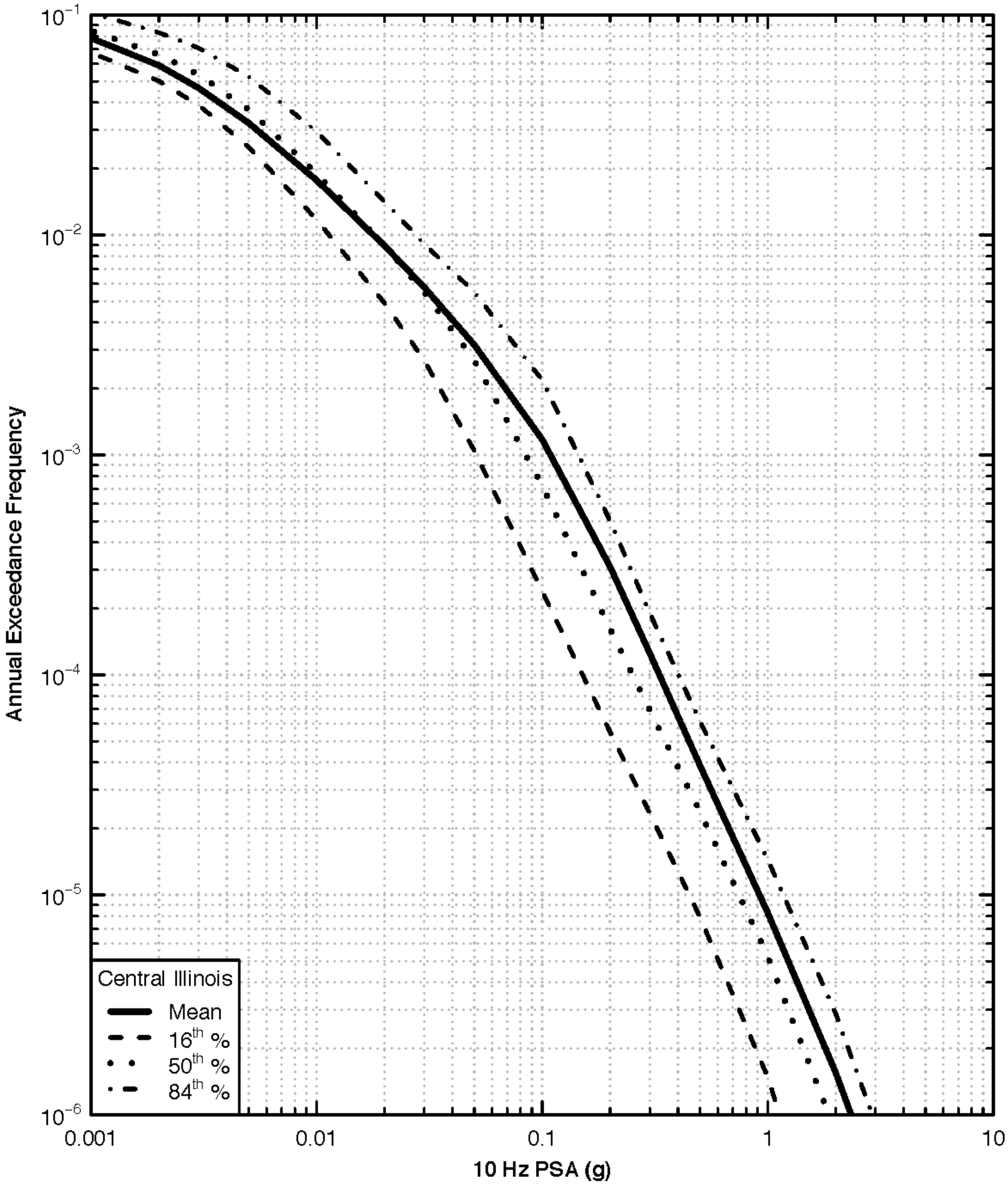


Figure I–14 Distributed seismicity source contributions to mean 10 Hz PSA hazard for Central Illinois site.

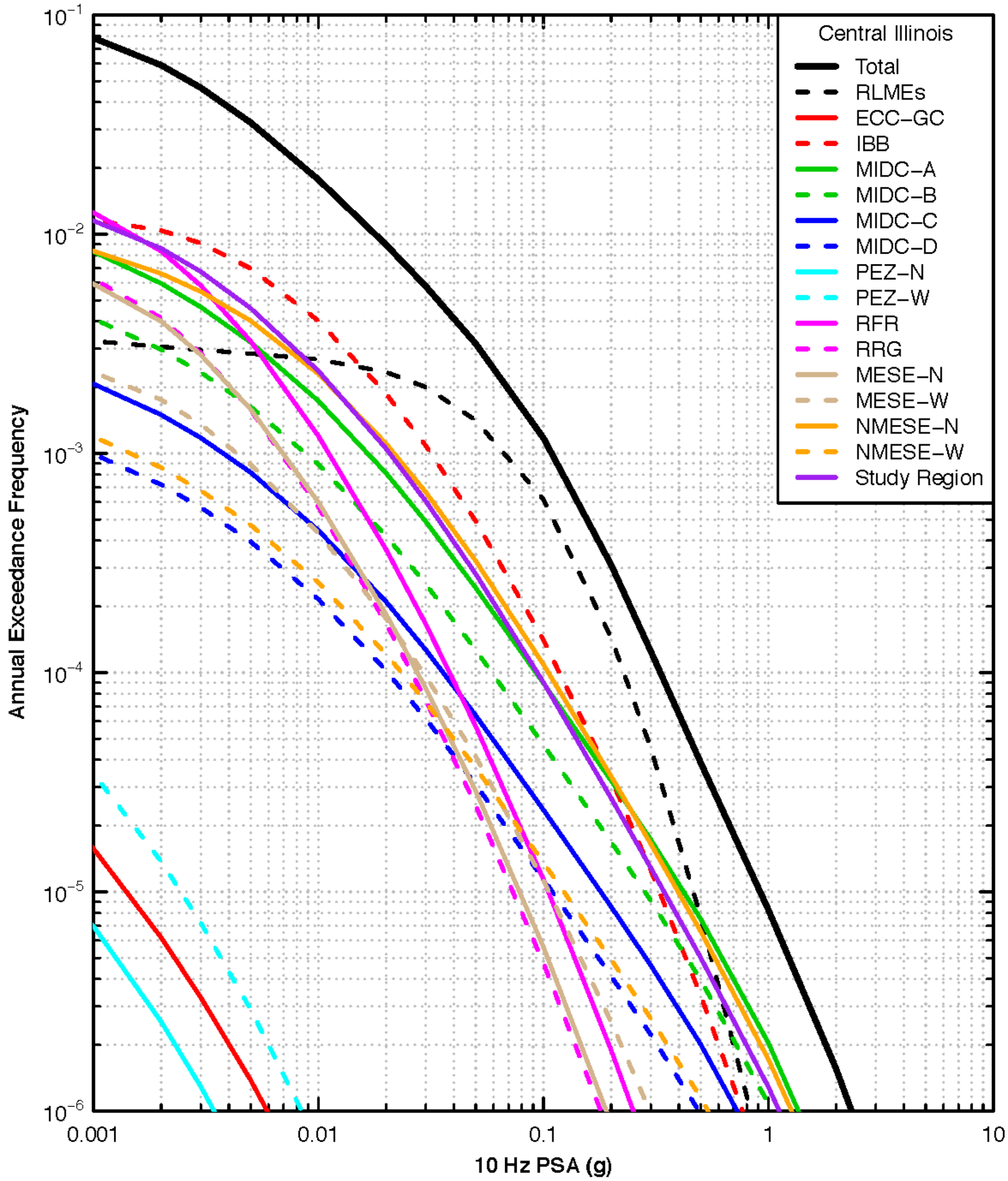


Figure I–15 RLME source contributions to mean 10 Hz PSA hazard for Central Illinois site.

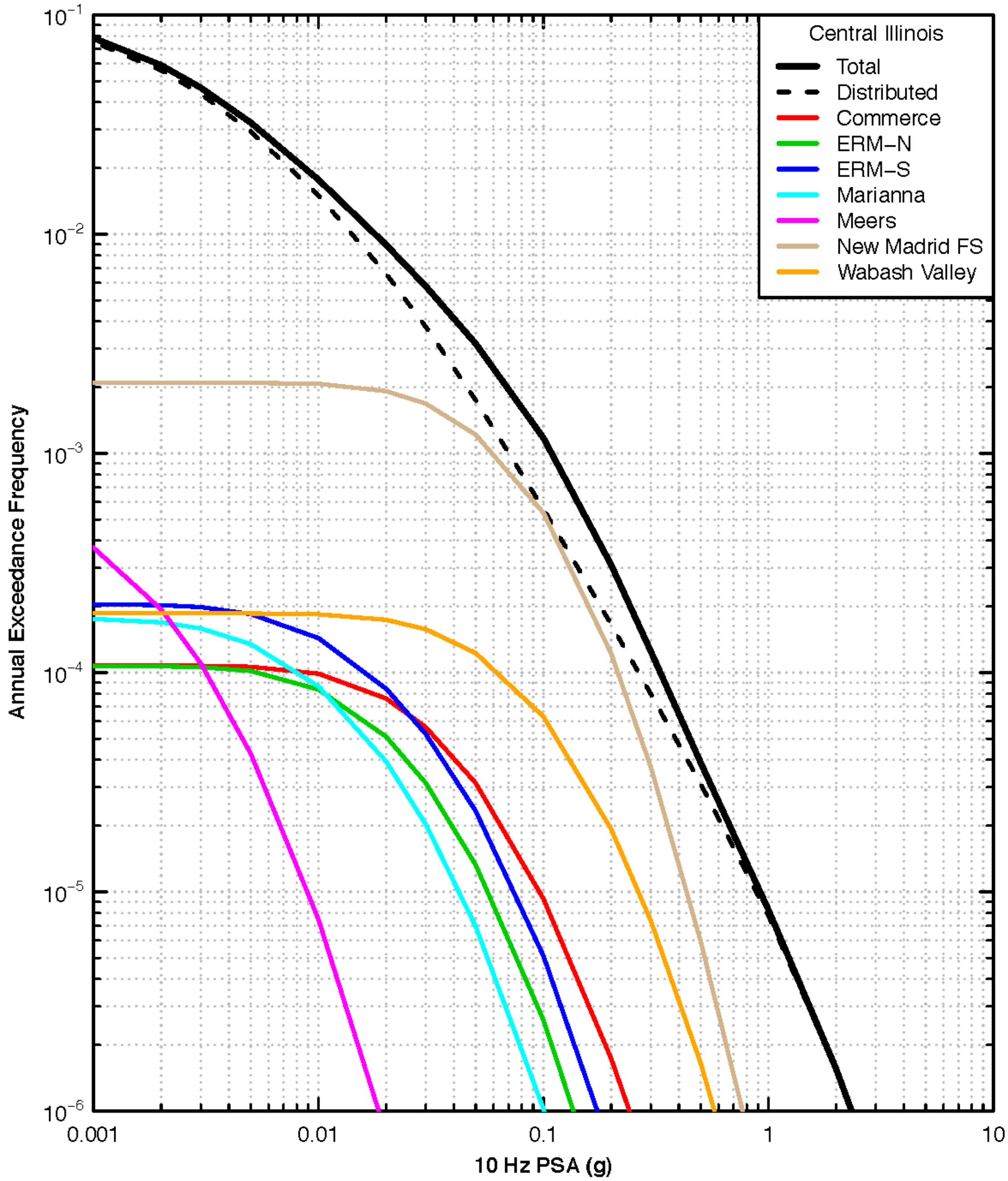


Figure I–16 Mean and fractile hazard curves for 1 Hz PSA for Central Illinois site.

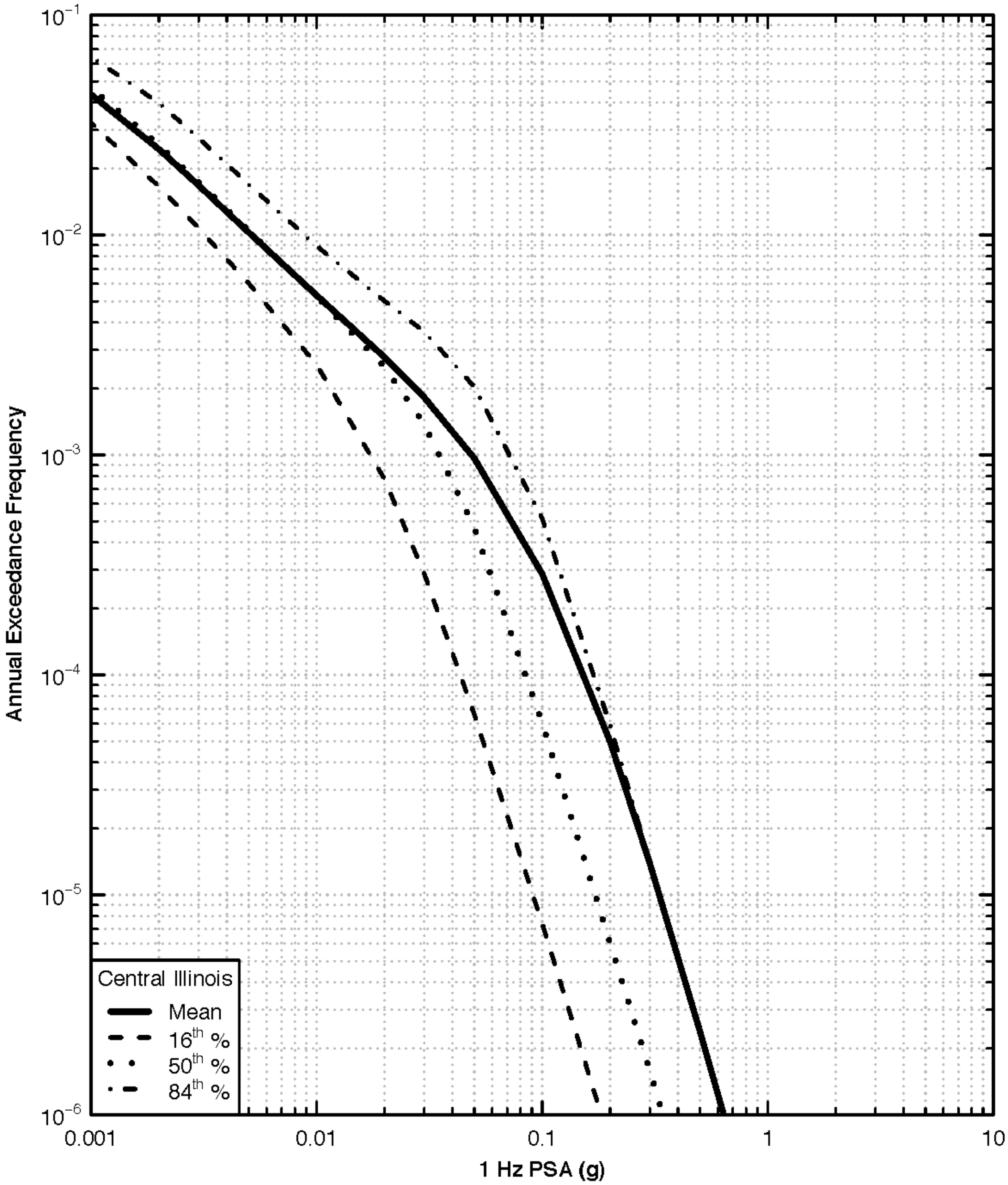


Figure I–17 Distributed seismicity source contributions to mean 1 Hz PSA hazard for Central Illinois site.

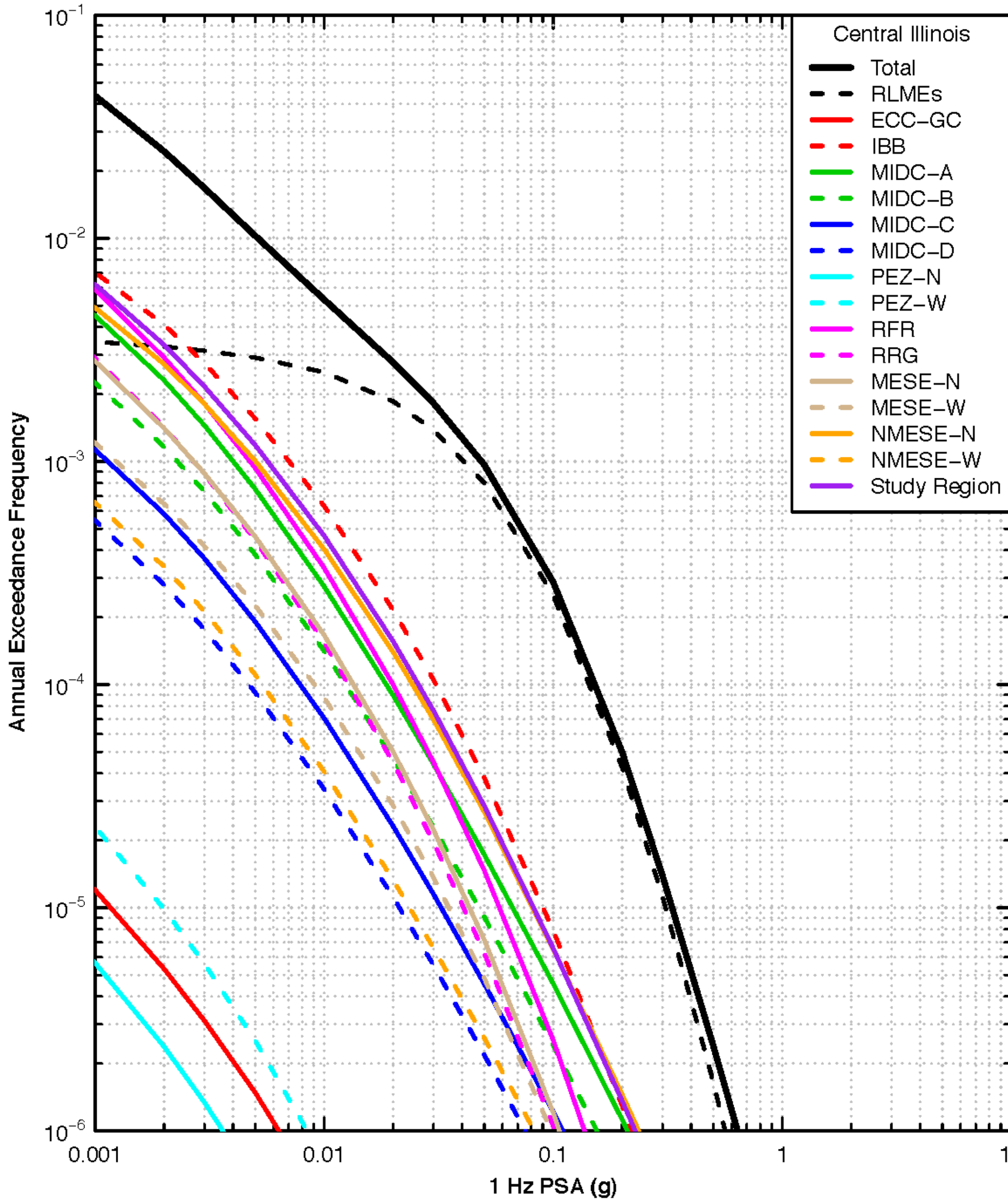


Figure I–18 RLME source contributions to mean 1 Hz PSA hazard for Central Illinois site.

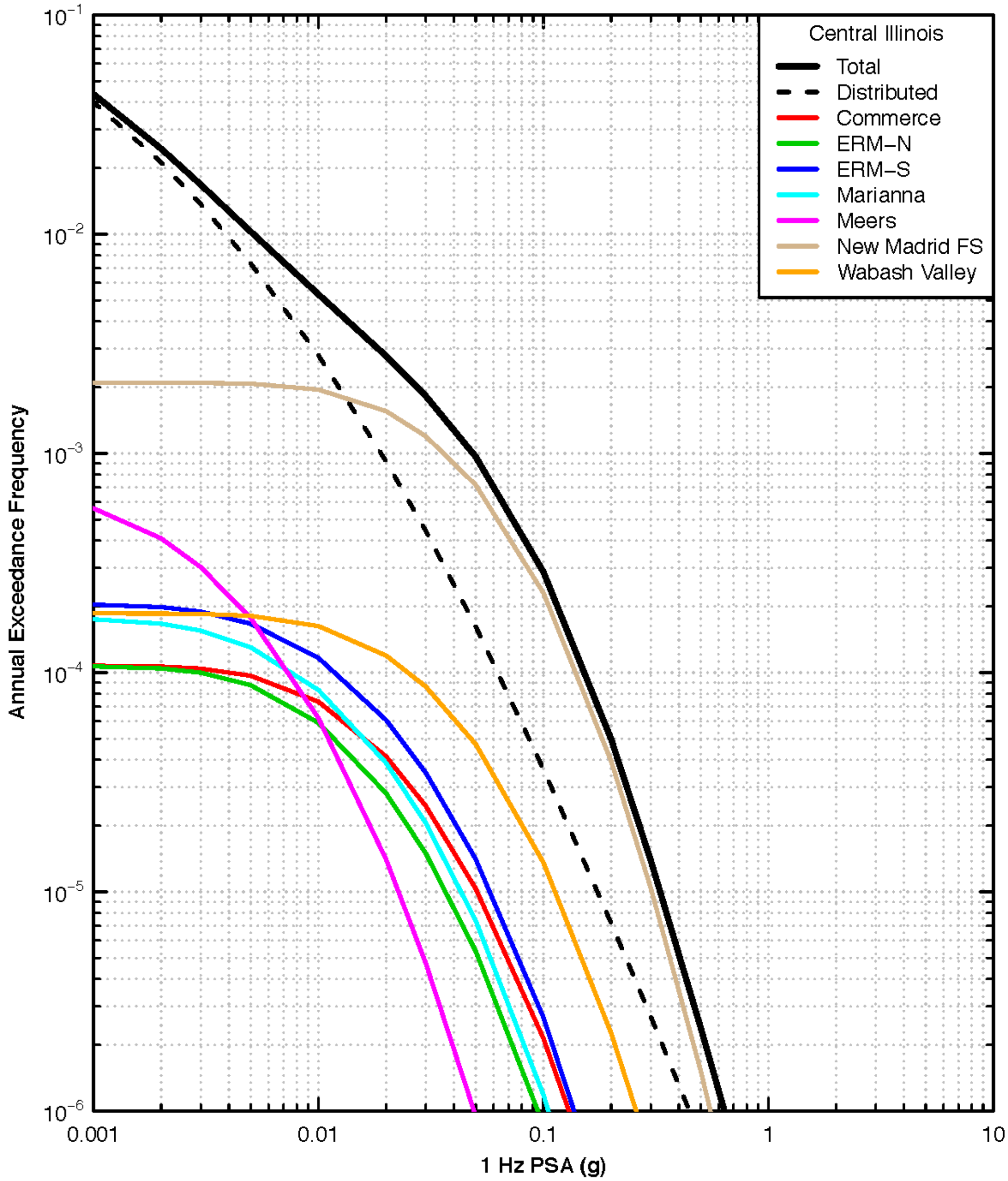


Figure I–19 Mean and fractile hazard curves for PGA for Manchester site.

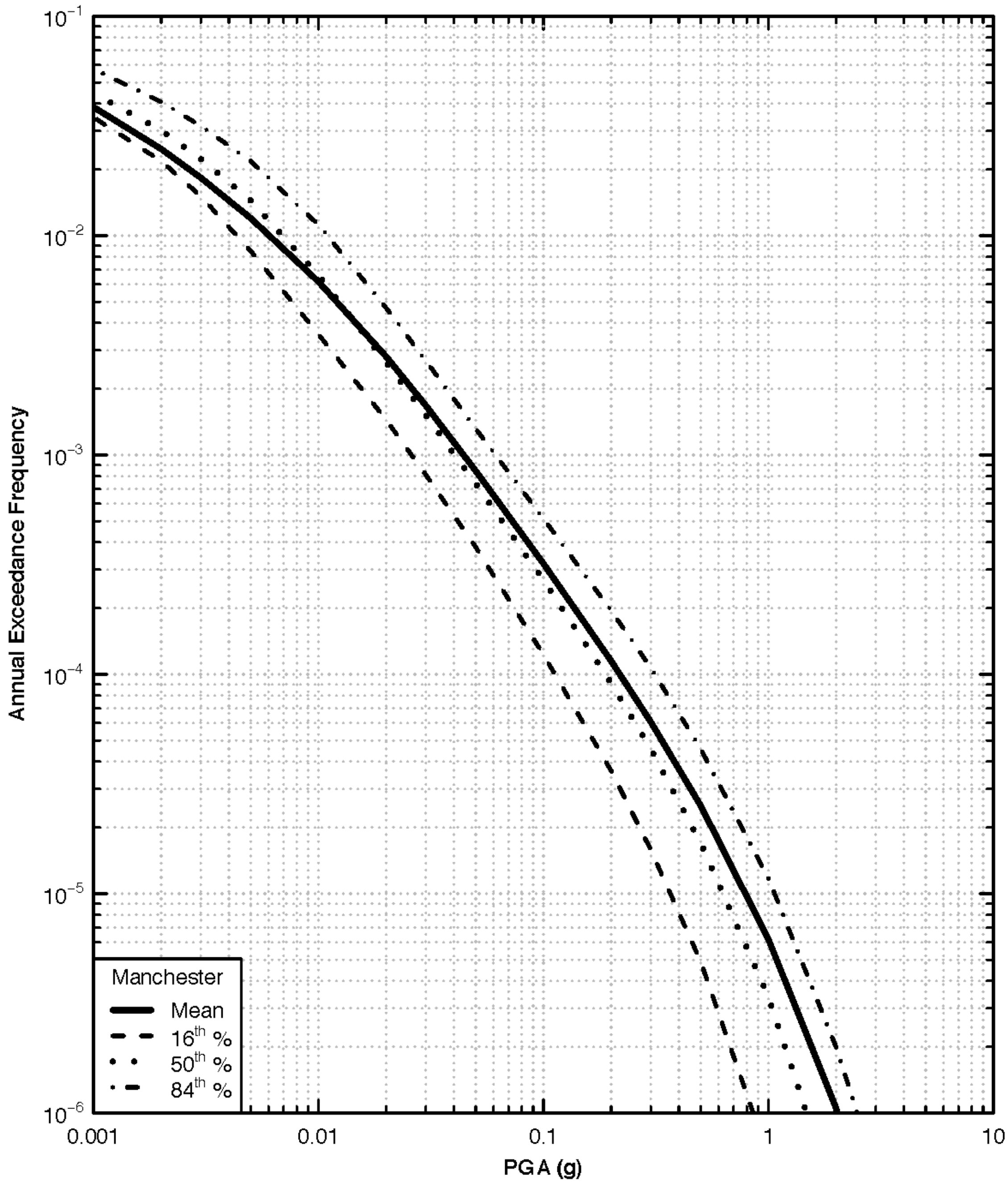


Figure I–20 Distributed seismicity and RLME source contributions to mean PGA hazard for Manchester site.

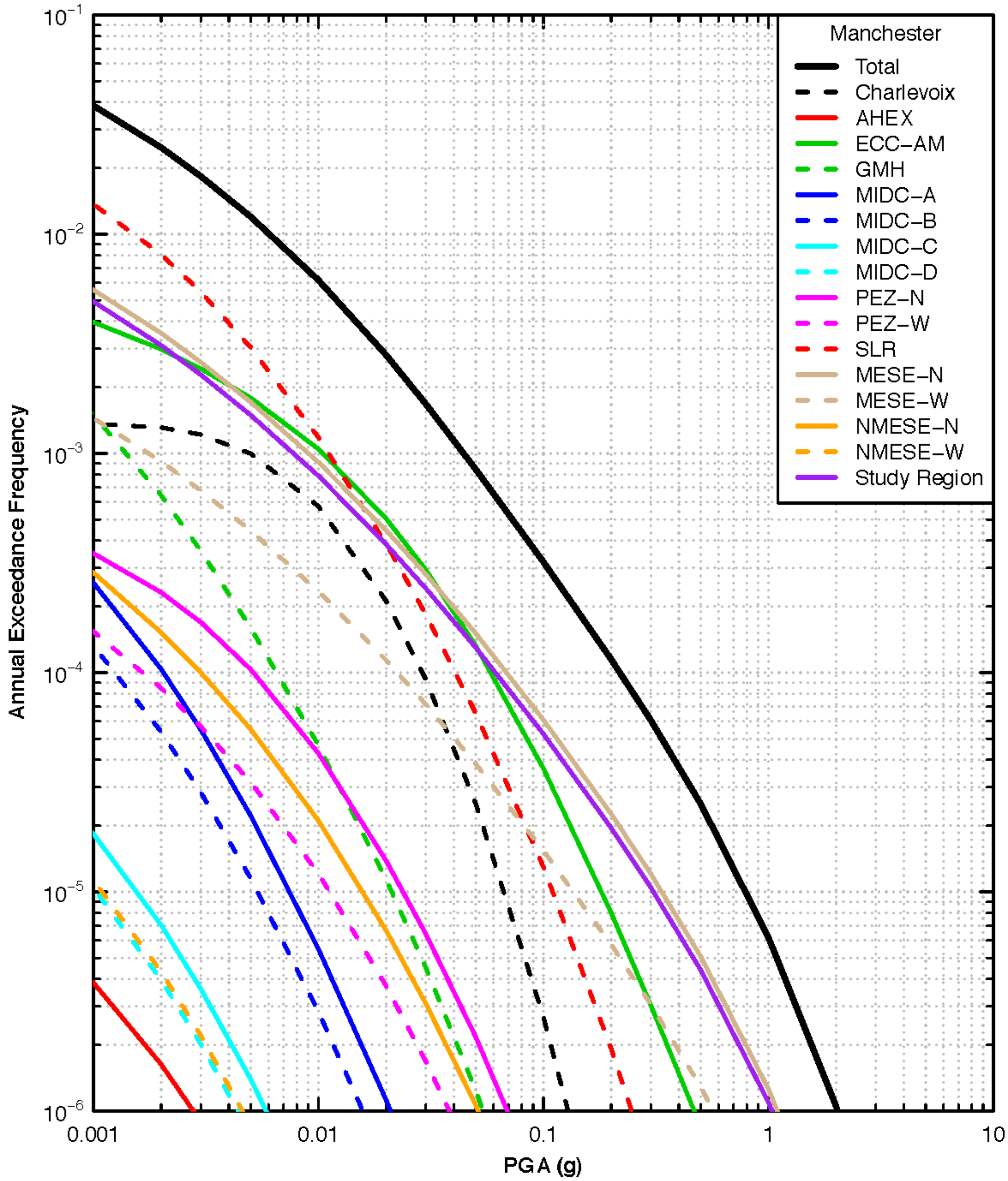


Figure I–21 Mean and fractile hazard curves for 10 Hz PSA for Manchester site.

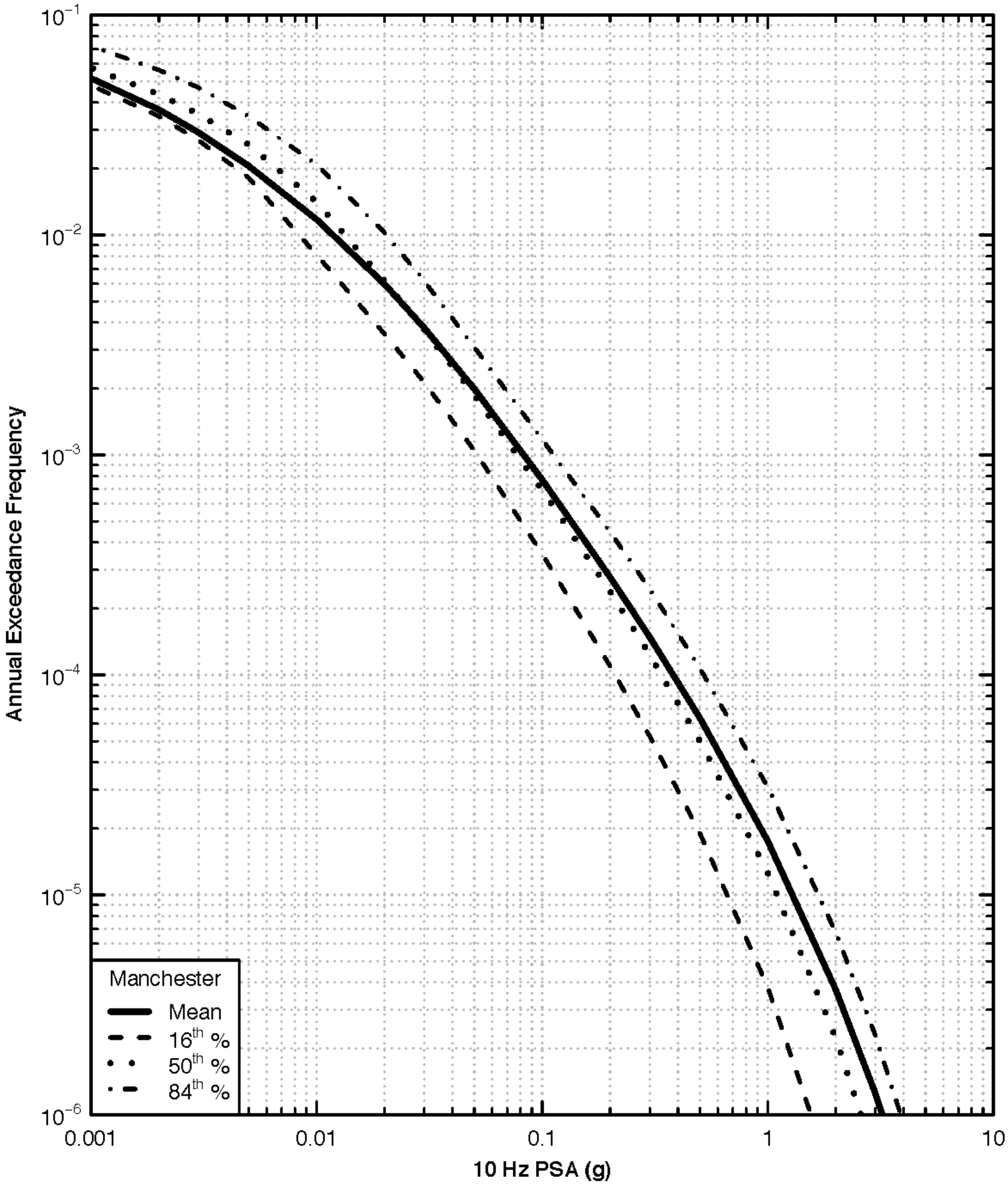


Figure I–22 Distributed seismicity and RLME source contributions to mean 10 Hz PSA hazard for Manchester site.

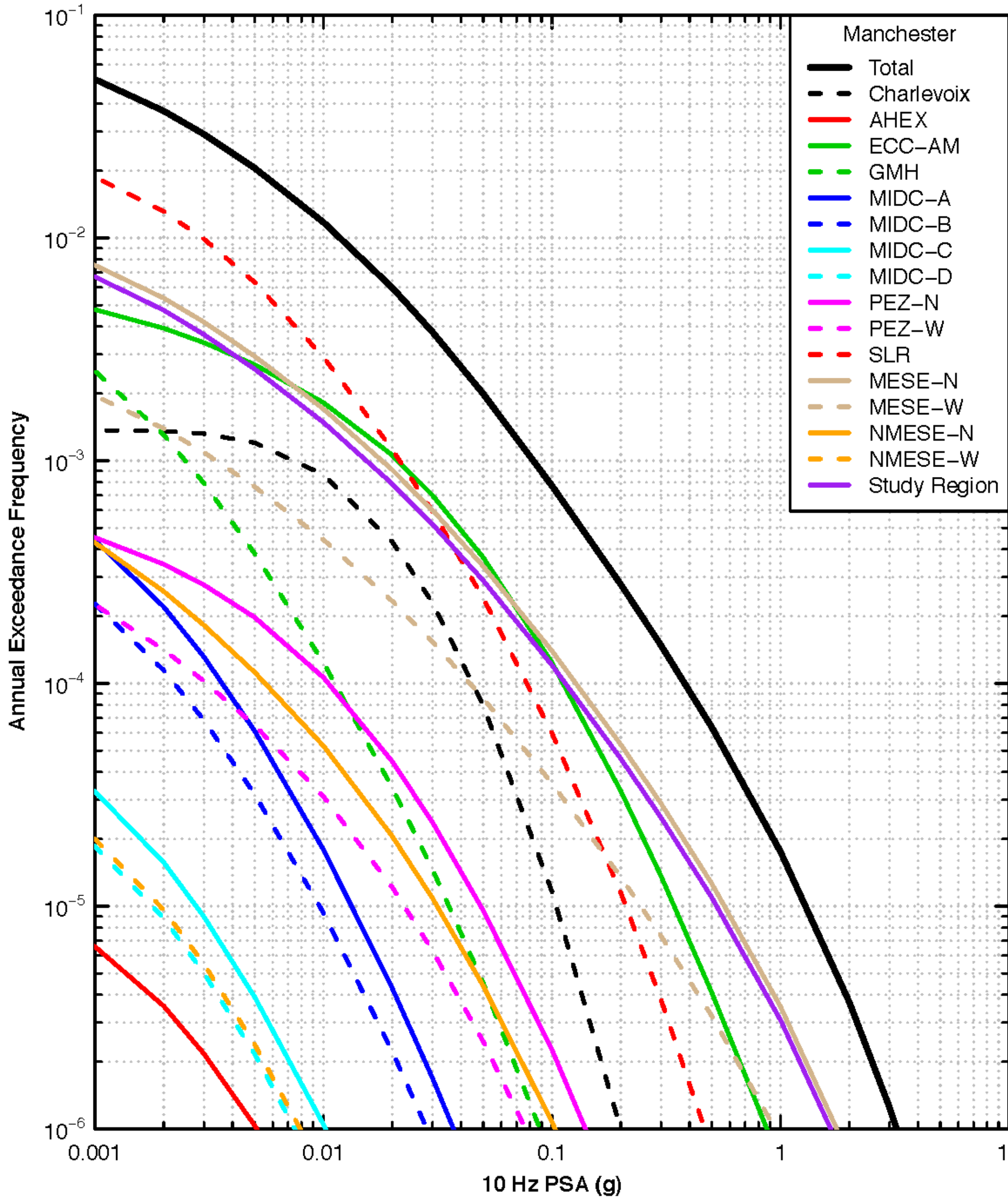


Figure I–23 Mean and fractile hazard curves for 1 Hz PSA for Manchester site.

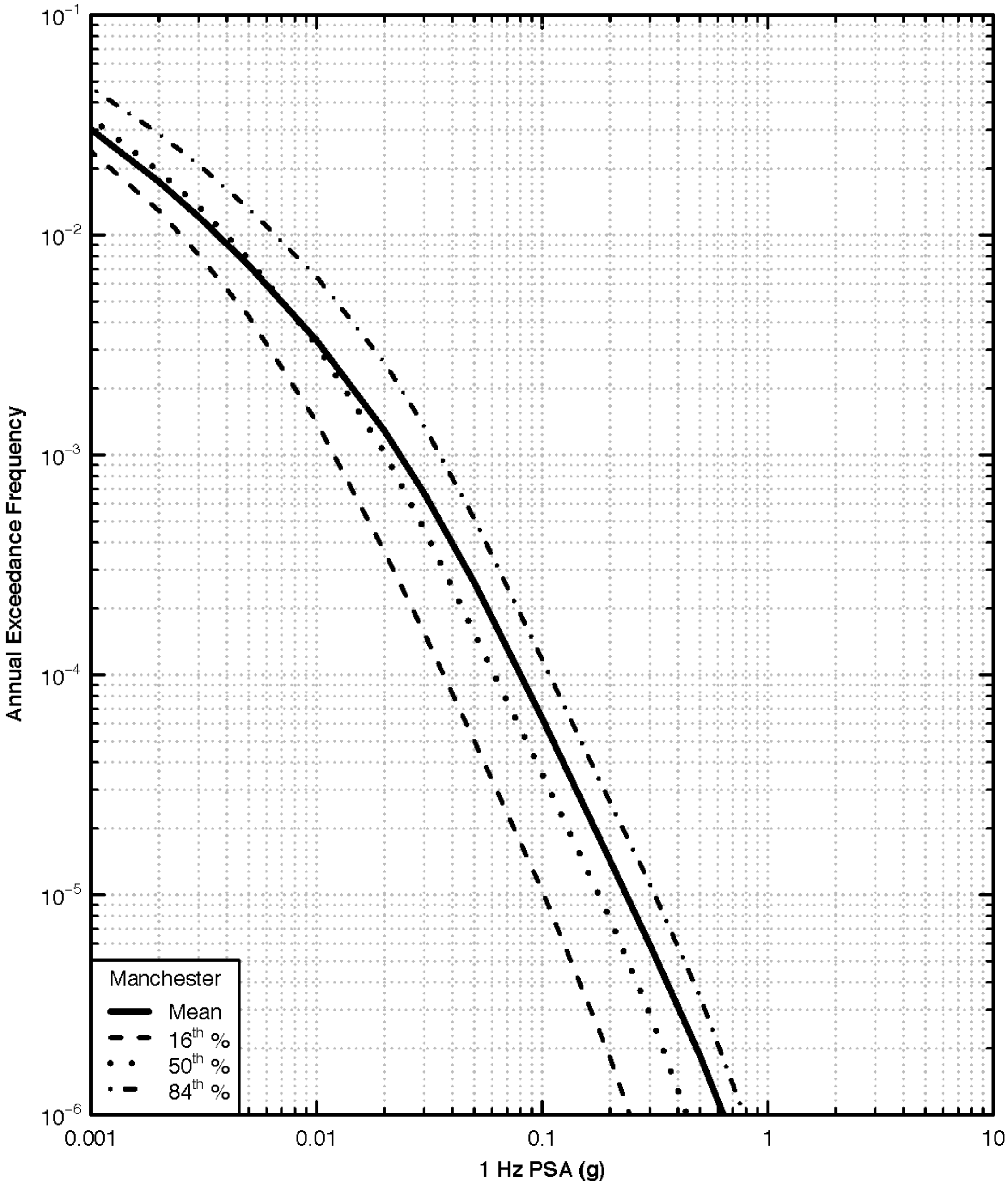


Figure I–24	**Distributed seismicity and RLME source contributions to mean 1 Hz PSA hazard for Manchester site.**

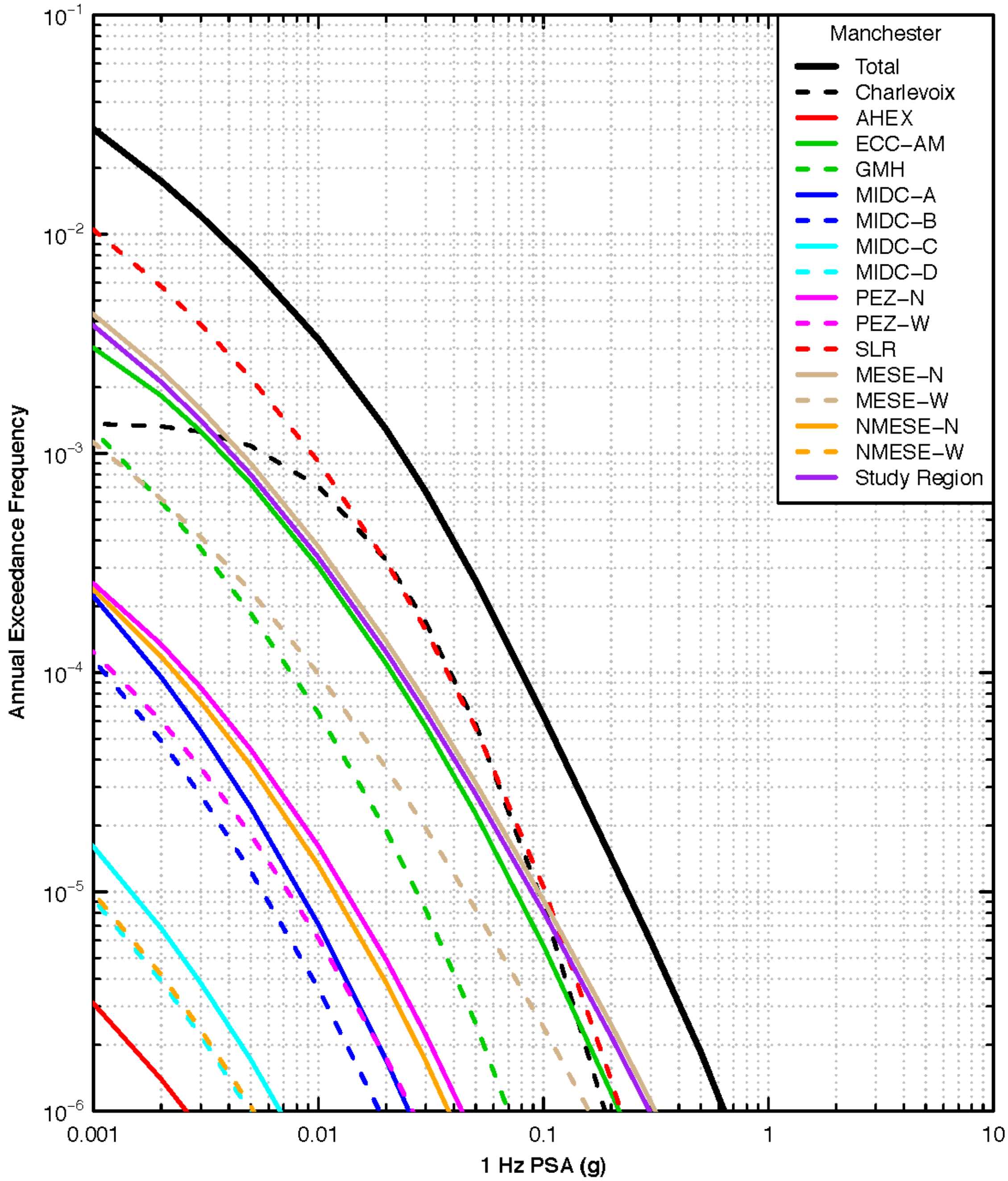


Figure I–25 **Mean and fractile hazard curves for PGA for Chattanooga site.**

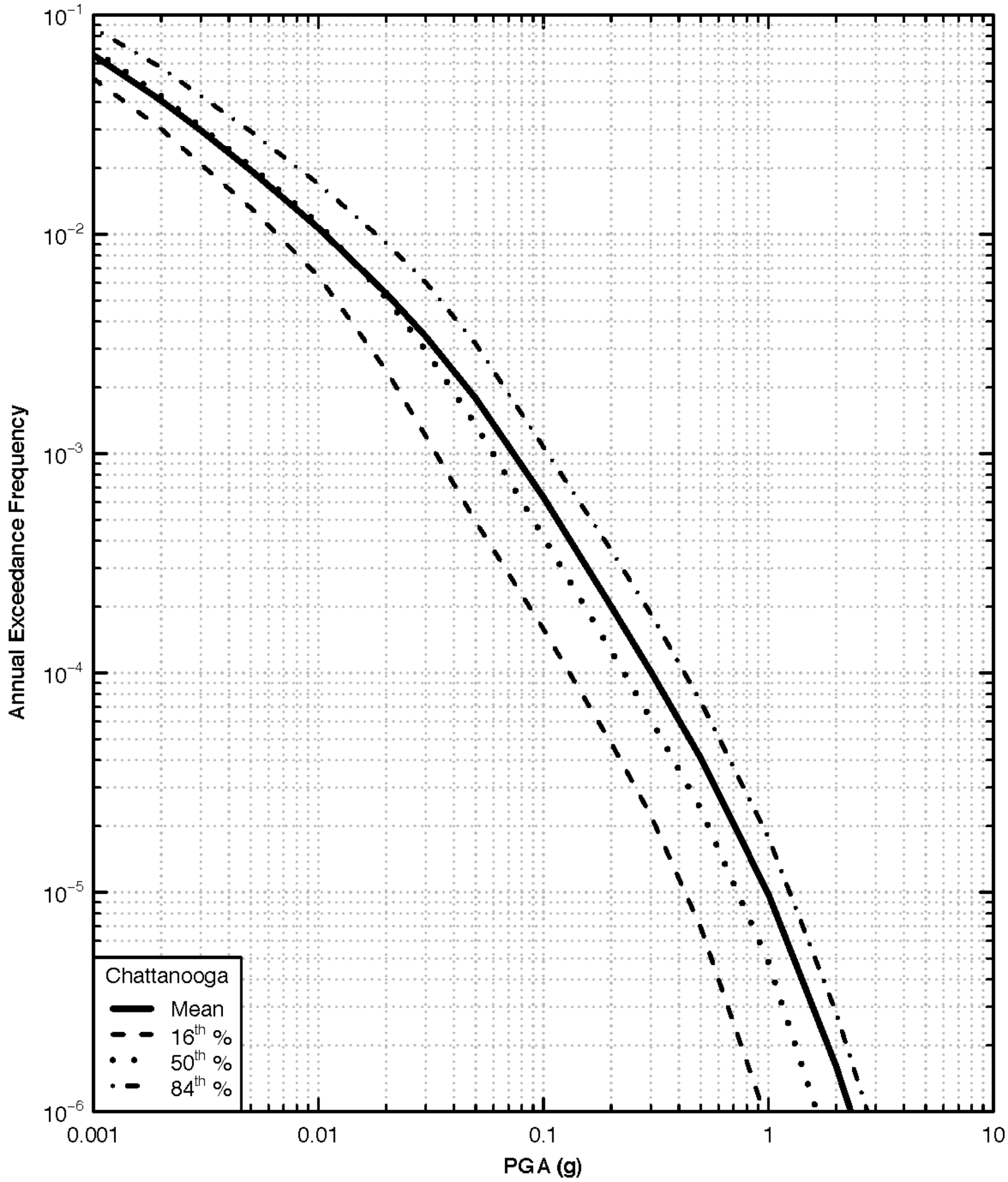


Figure I–26 Distributed seismicity source contributions to mean PGA hazard for Chattanooga site.

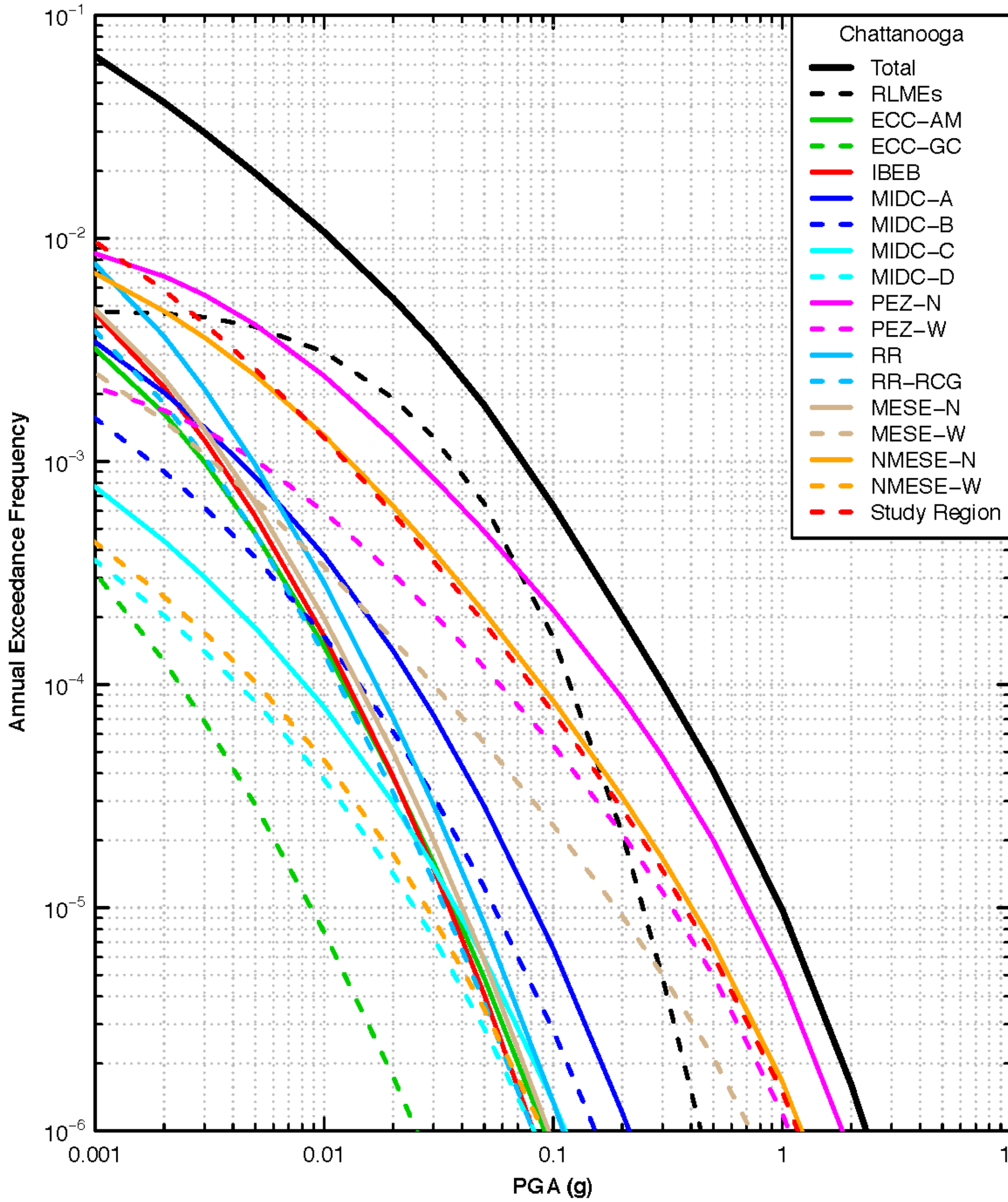


Figure I–27 RLME source contributions to mean PGA hazard for Chattanooga site.

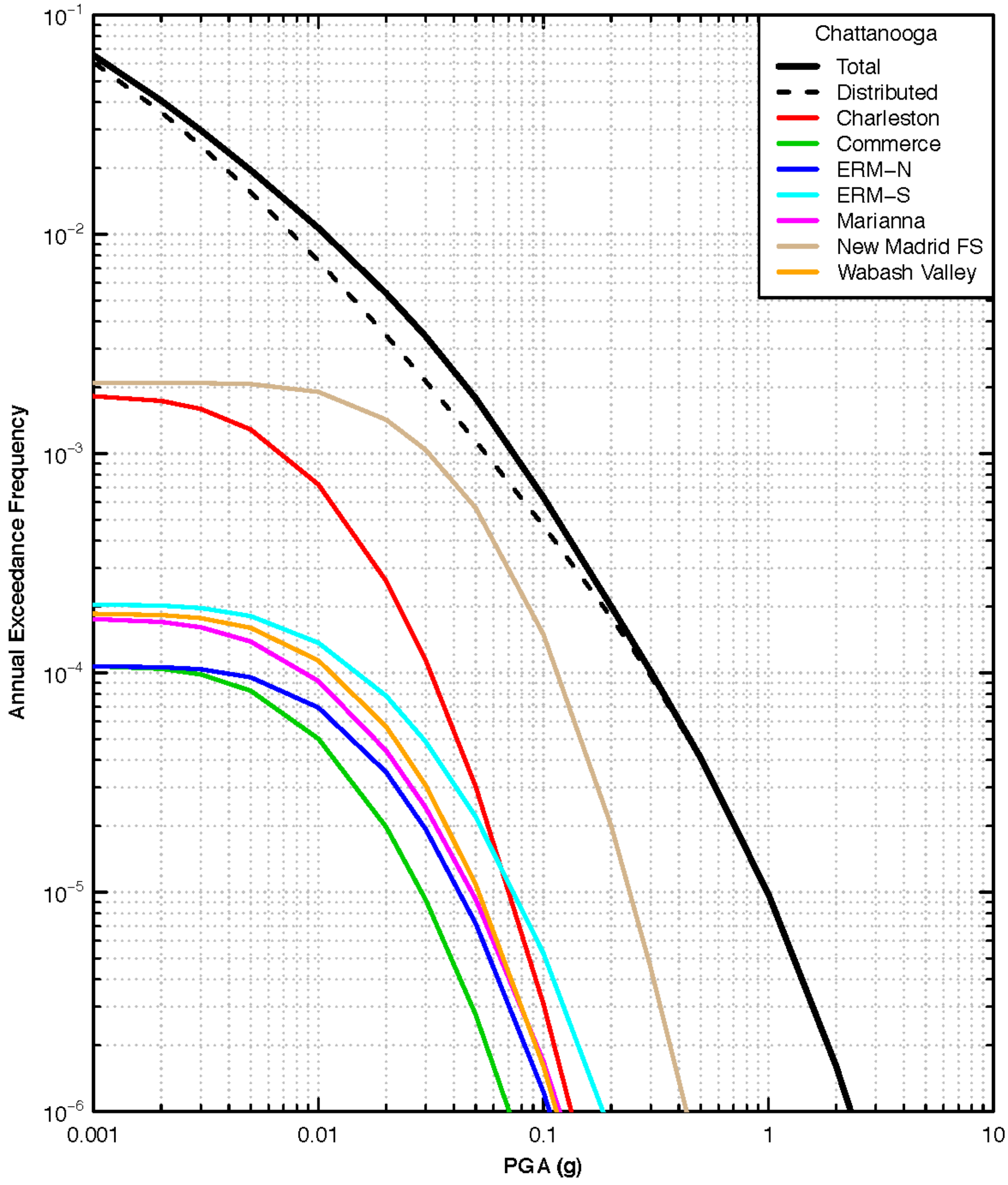


Figure I–28 Mean and fractile hazard curves for 10 Hz PSA for Chattanooga site.

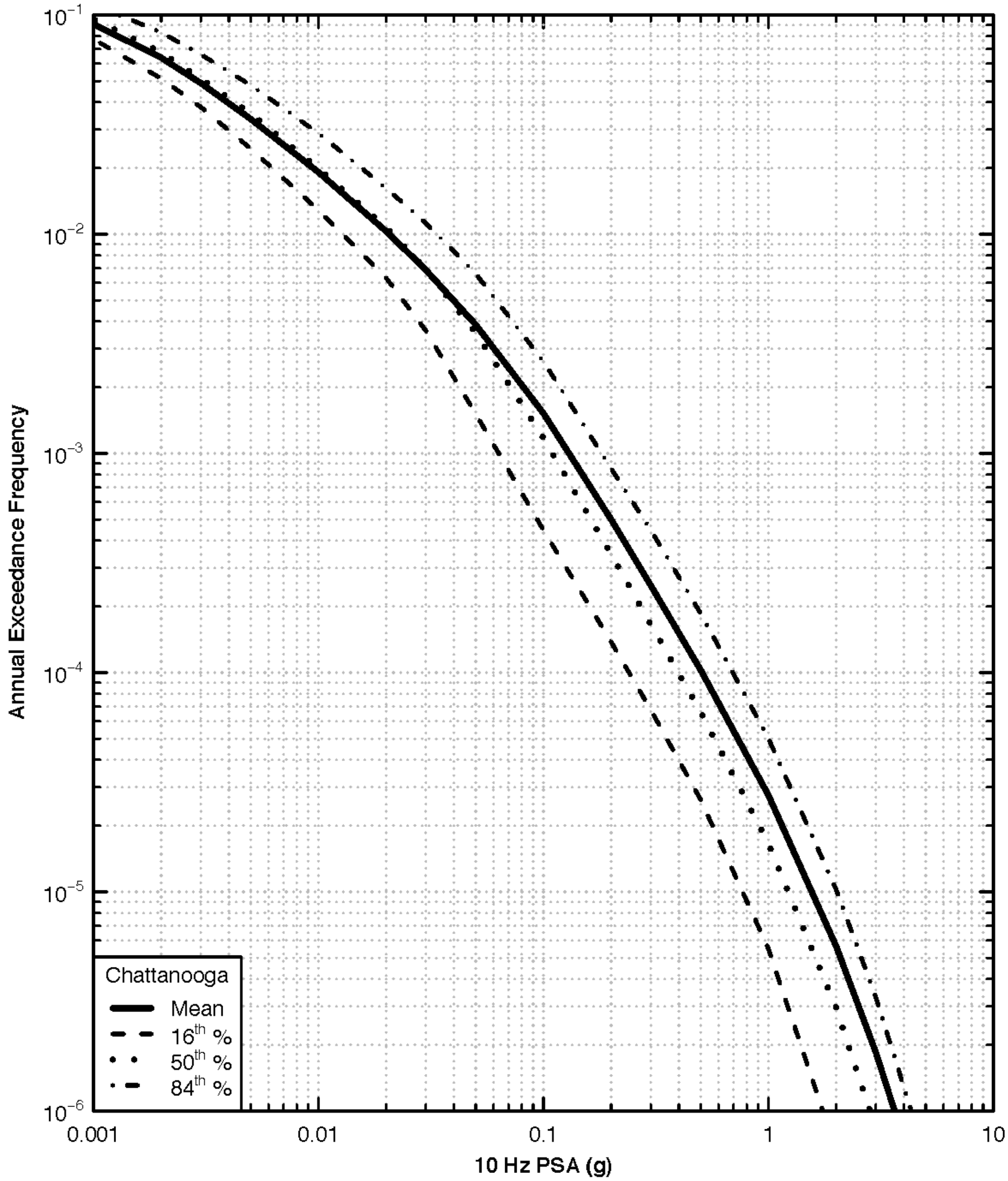


Figure I–29 Distributed seismicity source contributions to mean 10 Hz PSA hazard for Chattanooga site.

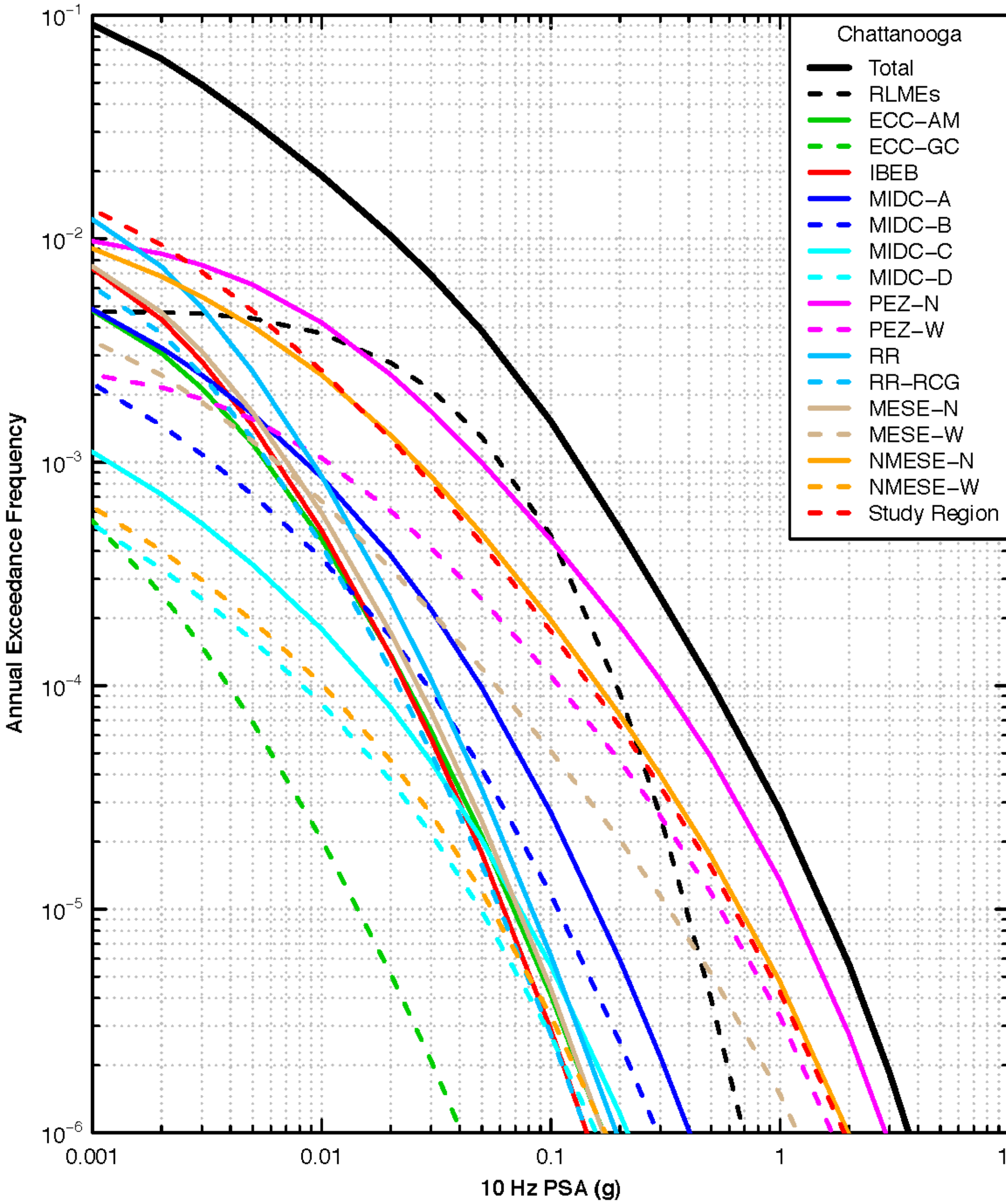


Figure I–30 RLME source contributions to mean 10 Hz PSA hazard for Chattanooga site.

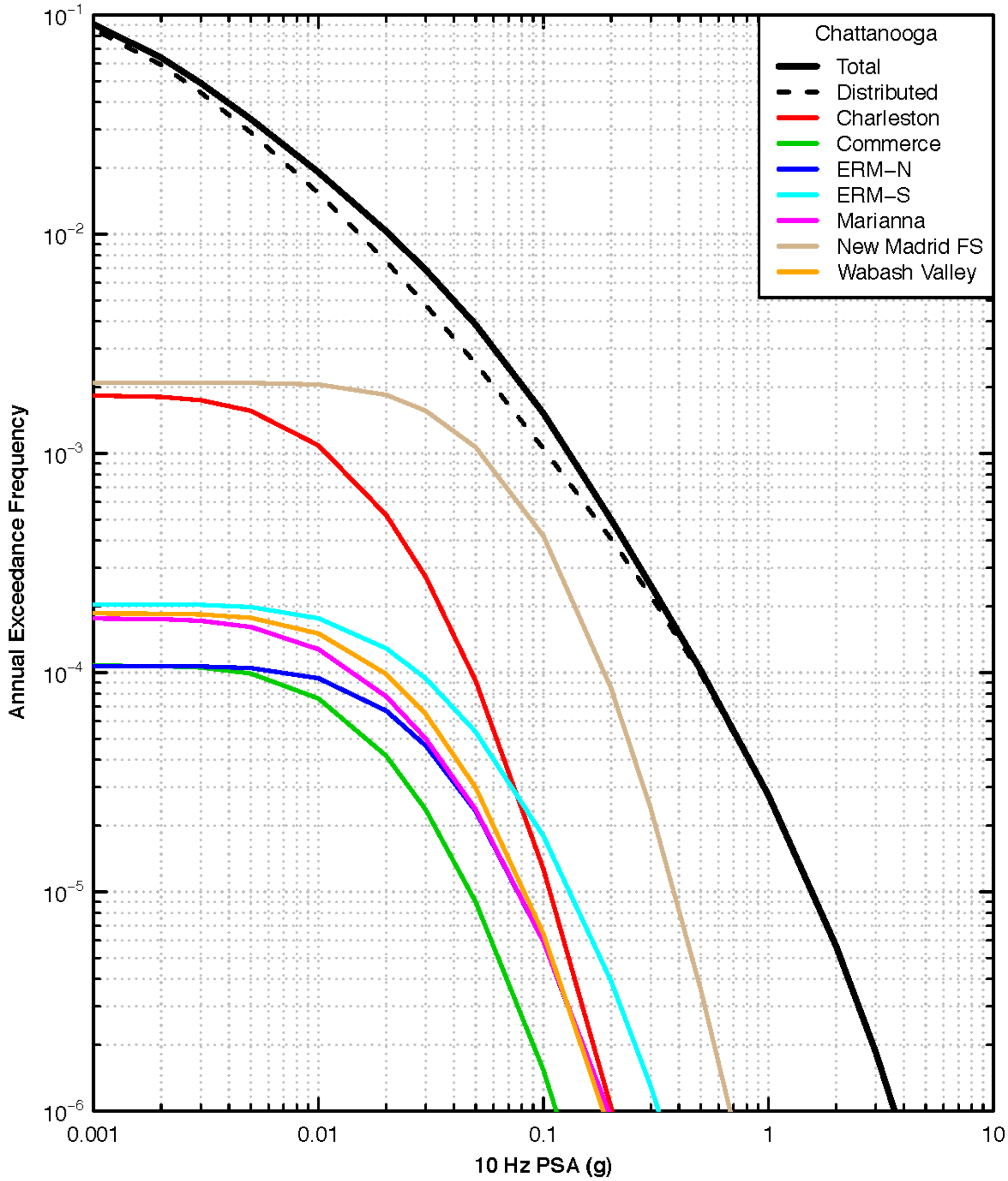


Figure I–31 Mean and fractile hazard curves for 1 Hz PSA for Chattanooga site.

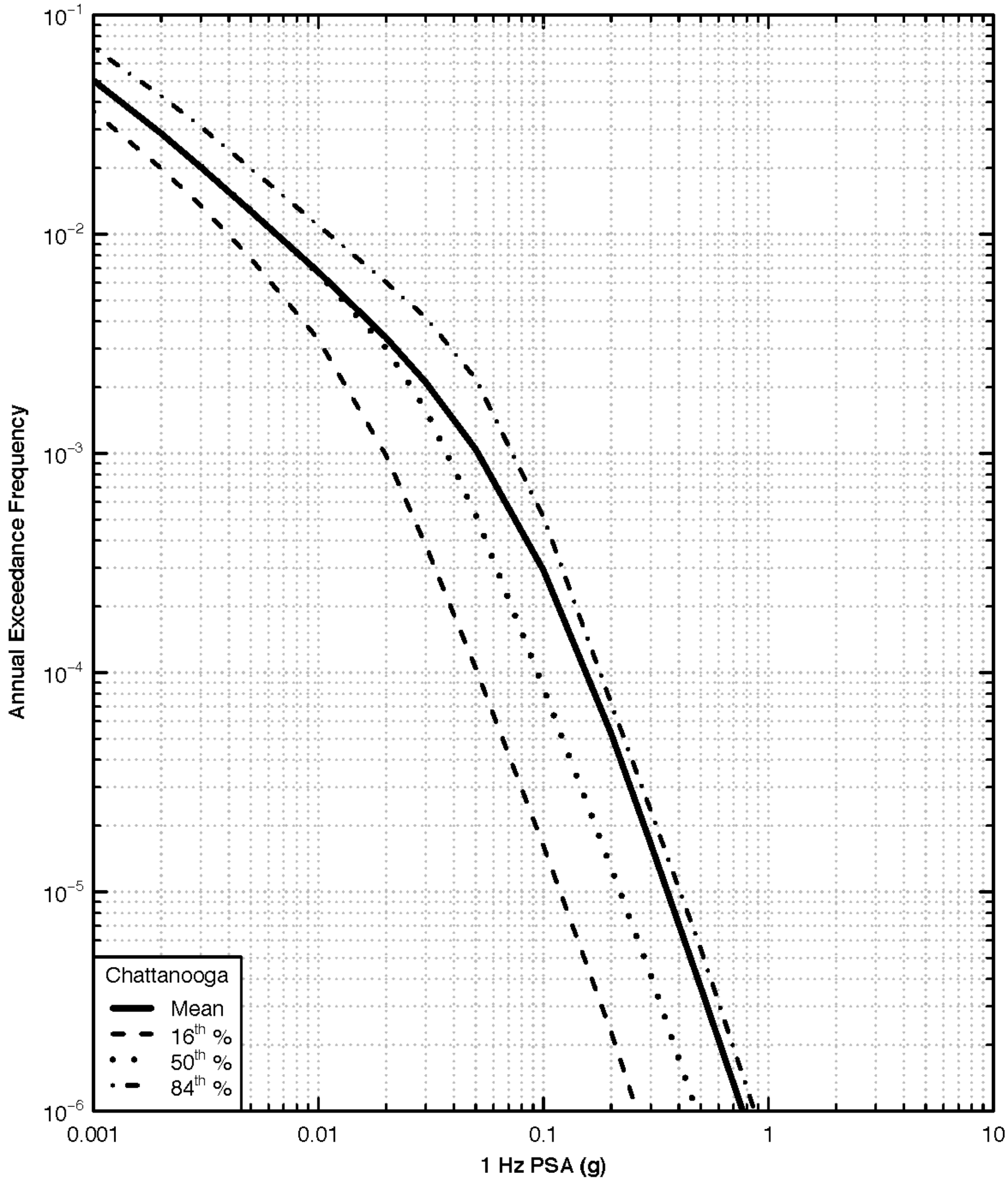


Figure I–32 Distributed seismicity source contributions to mean 1 Hz PSA hazard for Chattanooga site.

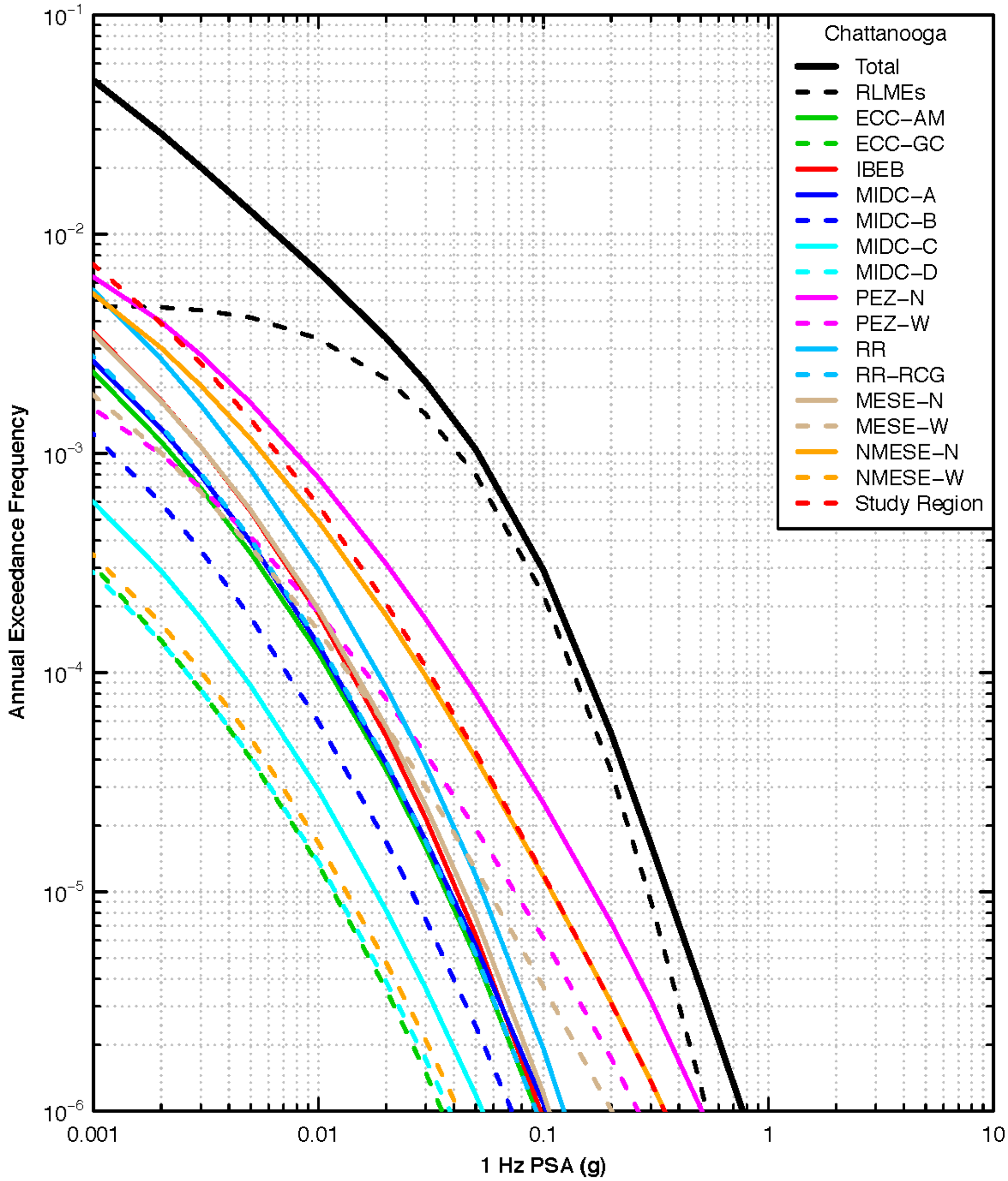


Figure I–33 RLME source contributions to mean 1 Hz PSA hazard for Chattanooga site.

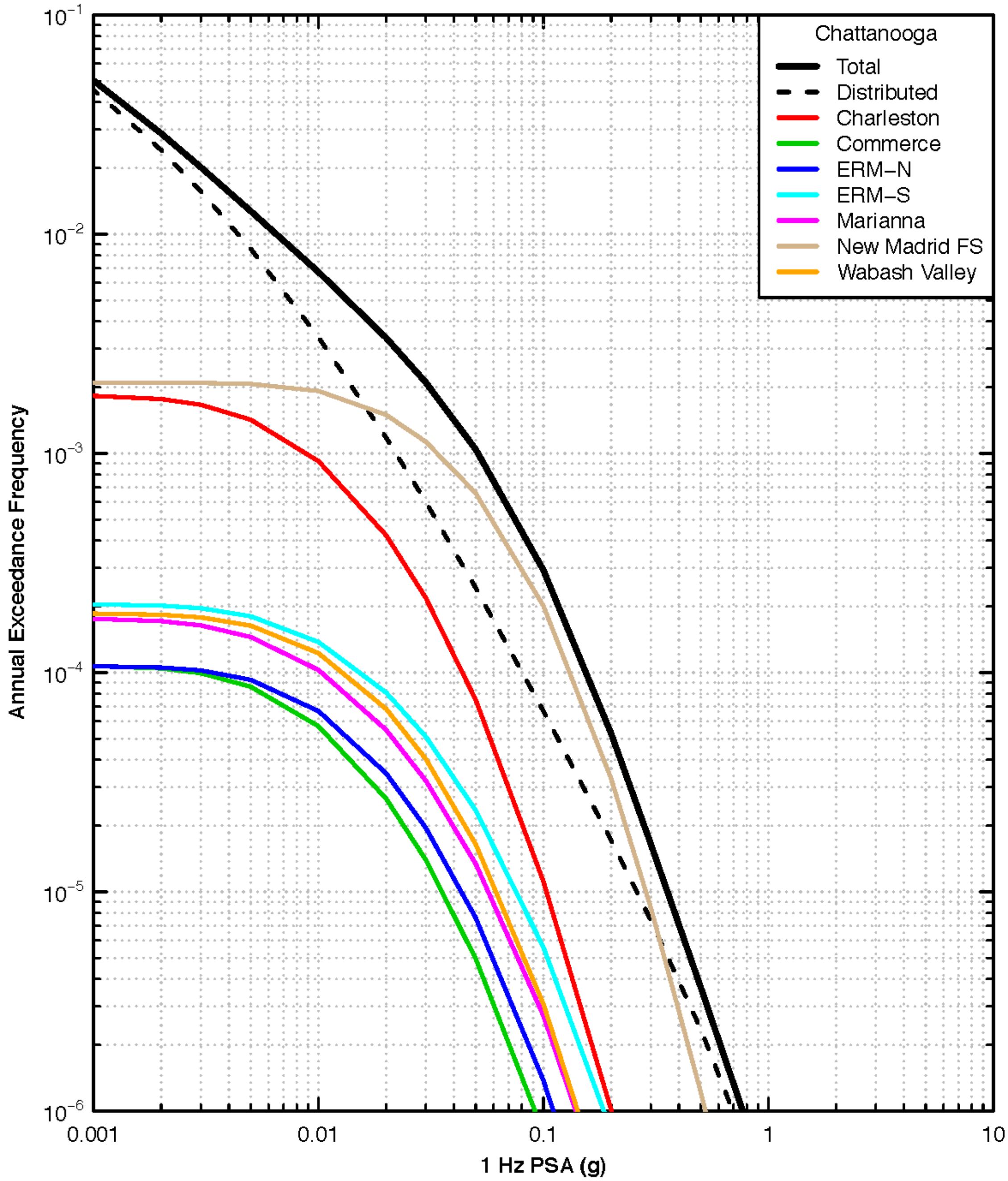


Figure I–34 Mean and fractile hazard curves for PGA for Topeka site.

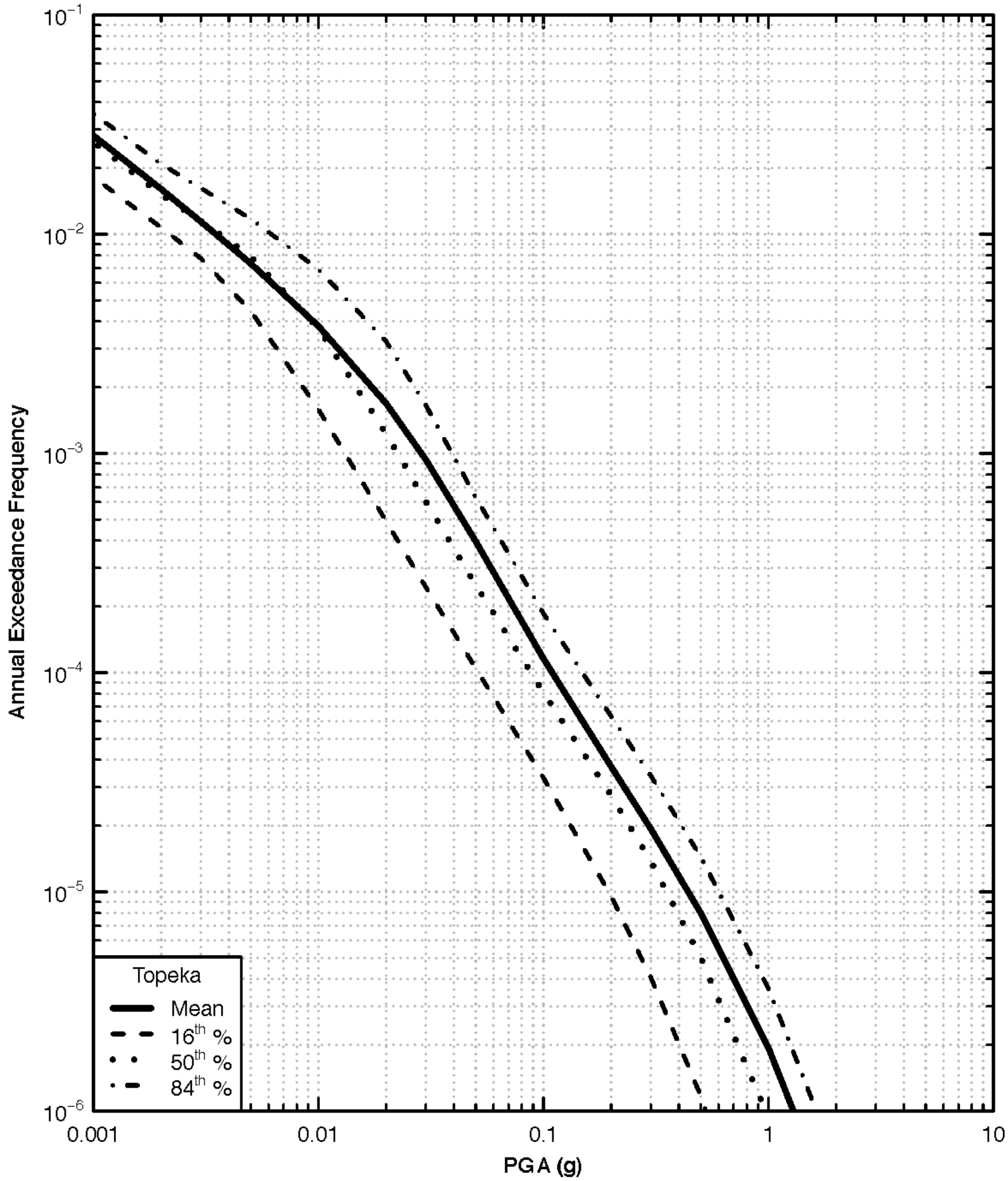


Figure I–35 Distributed seismicity source contributions to mean PGA hazard for Topeka site.

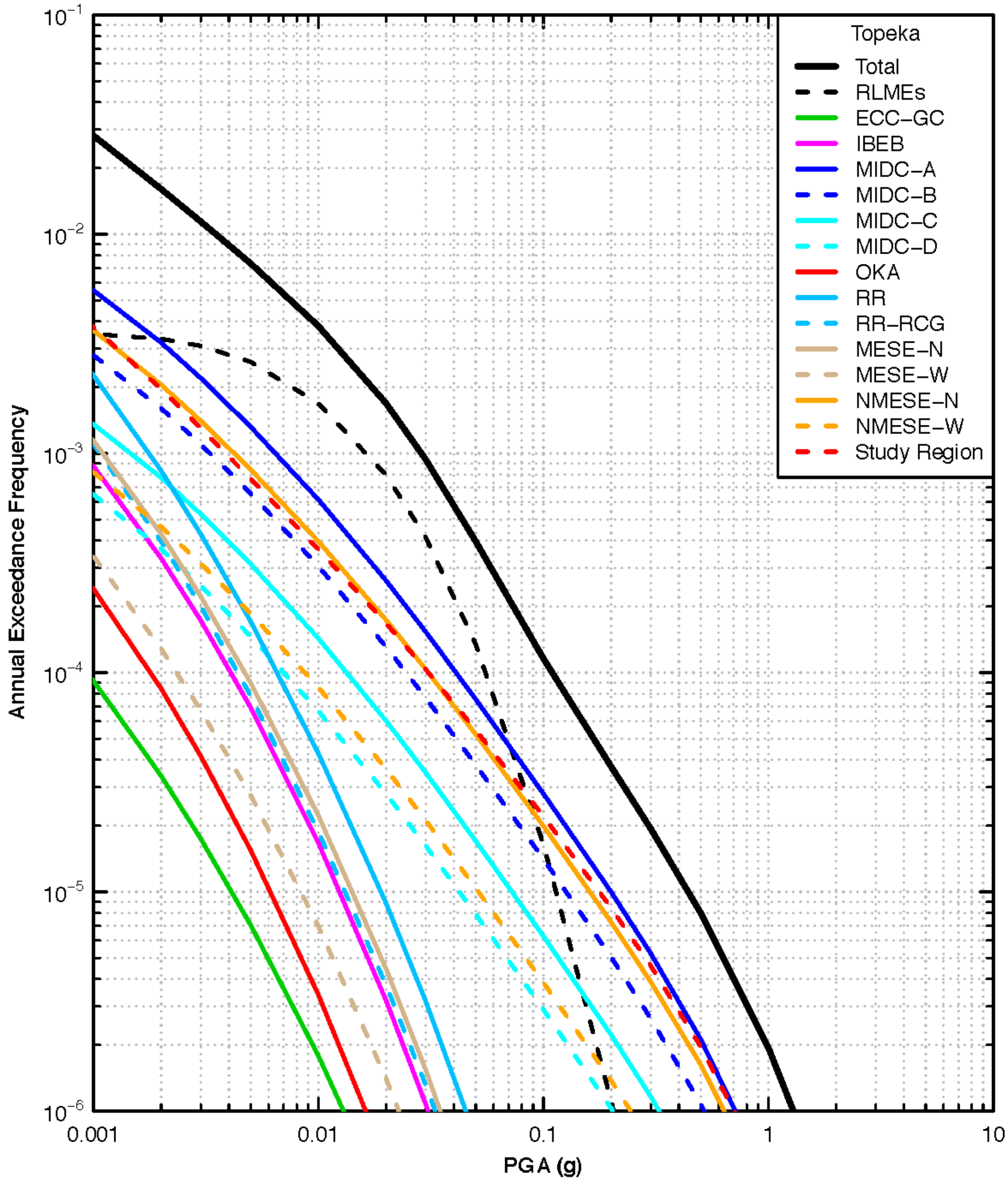


Figure I–36 RLME source contributions to mean PGA hazard for Topeka site.

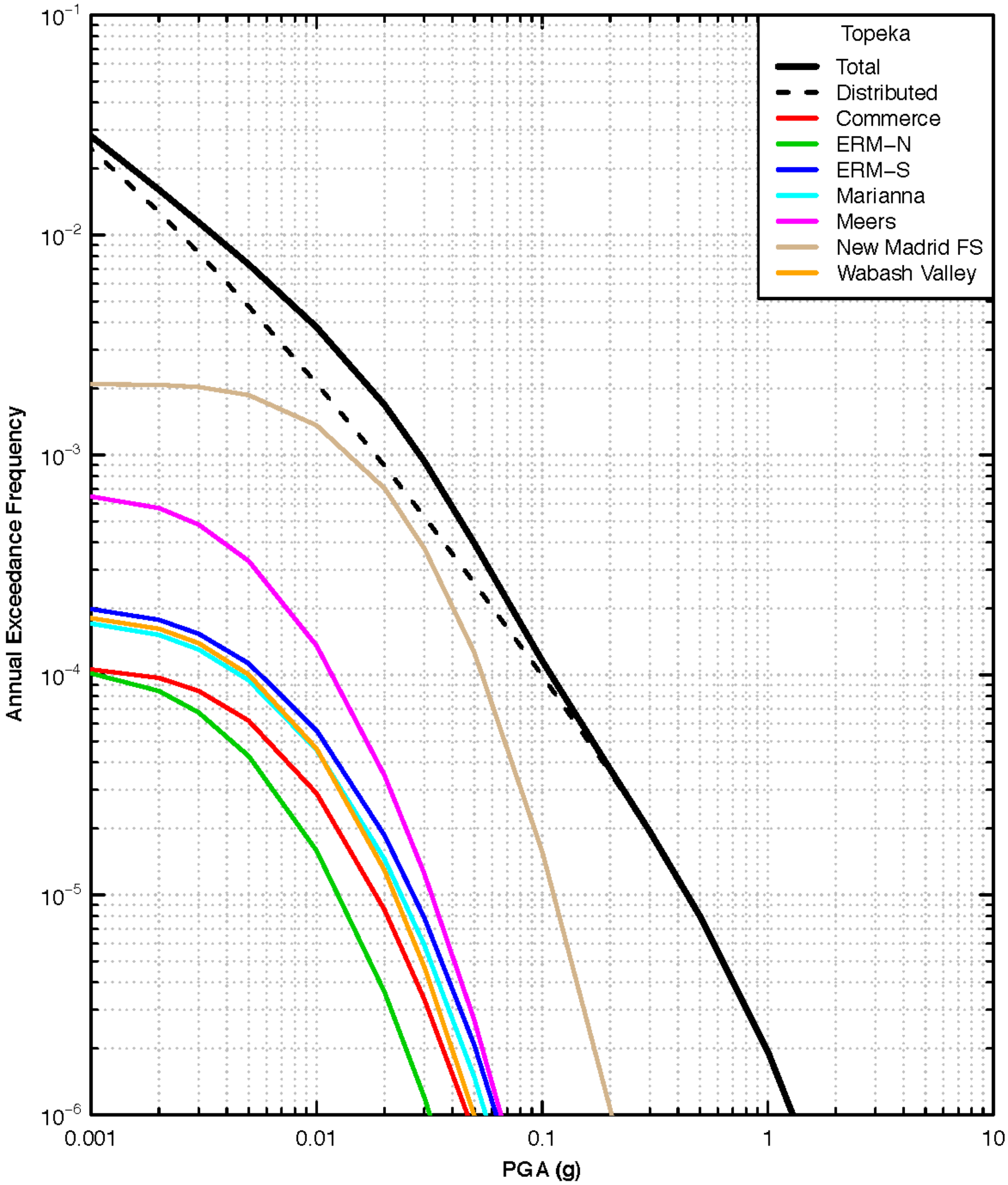


Figure I–37 **Mean and fractile hazard curves for 10 Hz PSA for Topeka site.**

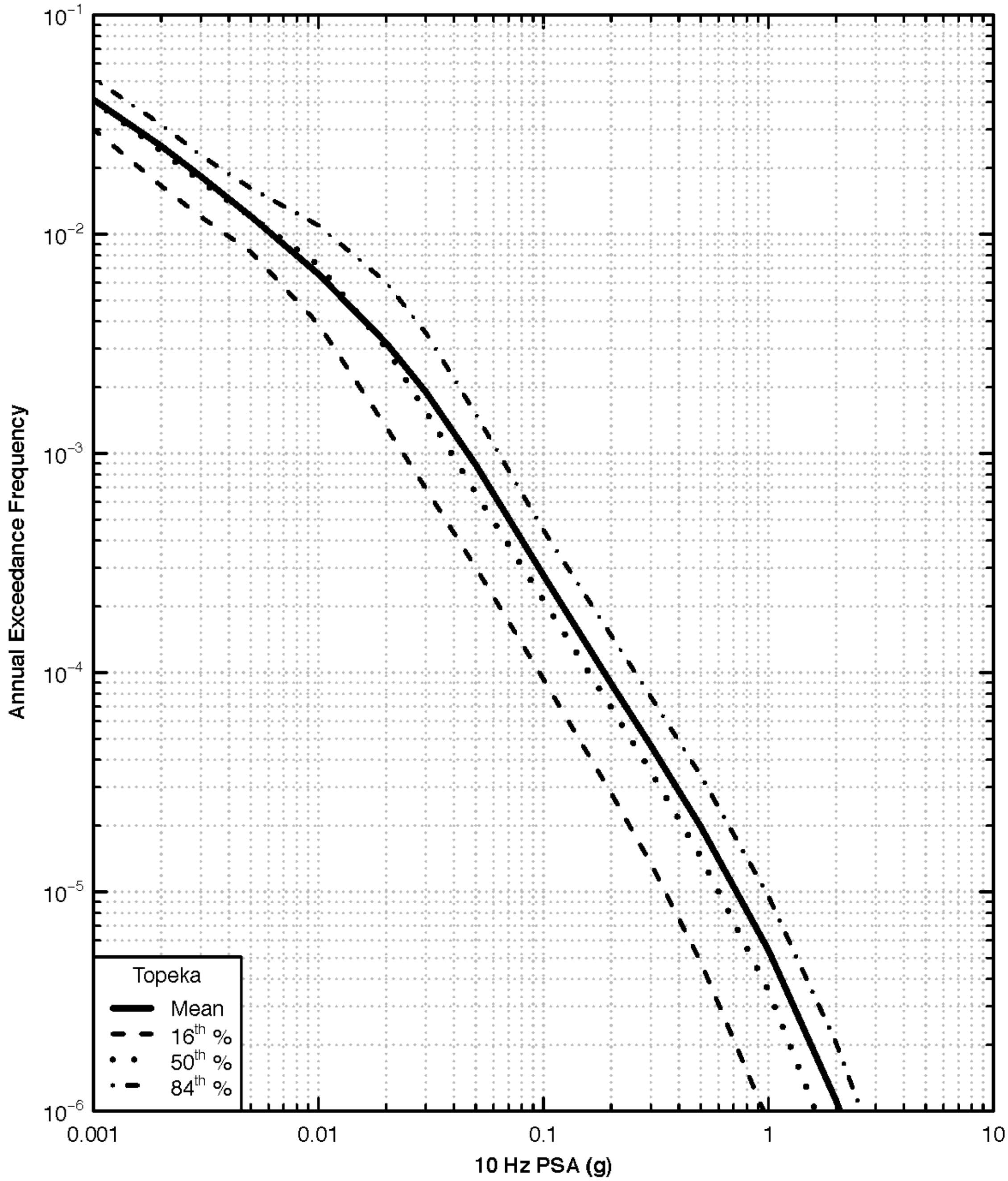


Figure I–38 **Distributed seismicity source contributions to mean 10 Hz PSA hazard for Topeka site.**

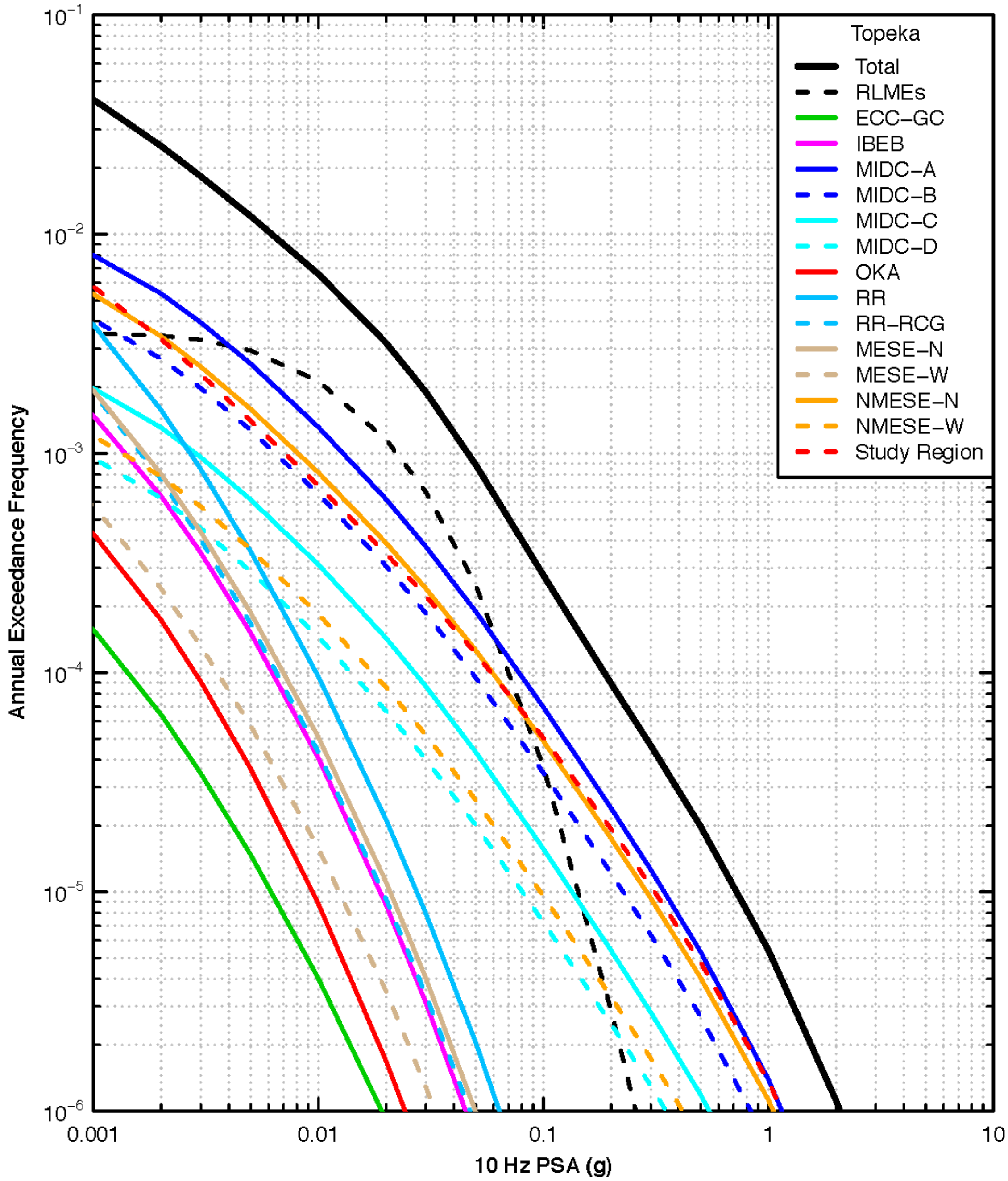


Figure I–39 RLME source contributions to mean 10 Hz PSA hazard for Topeka site.

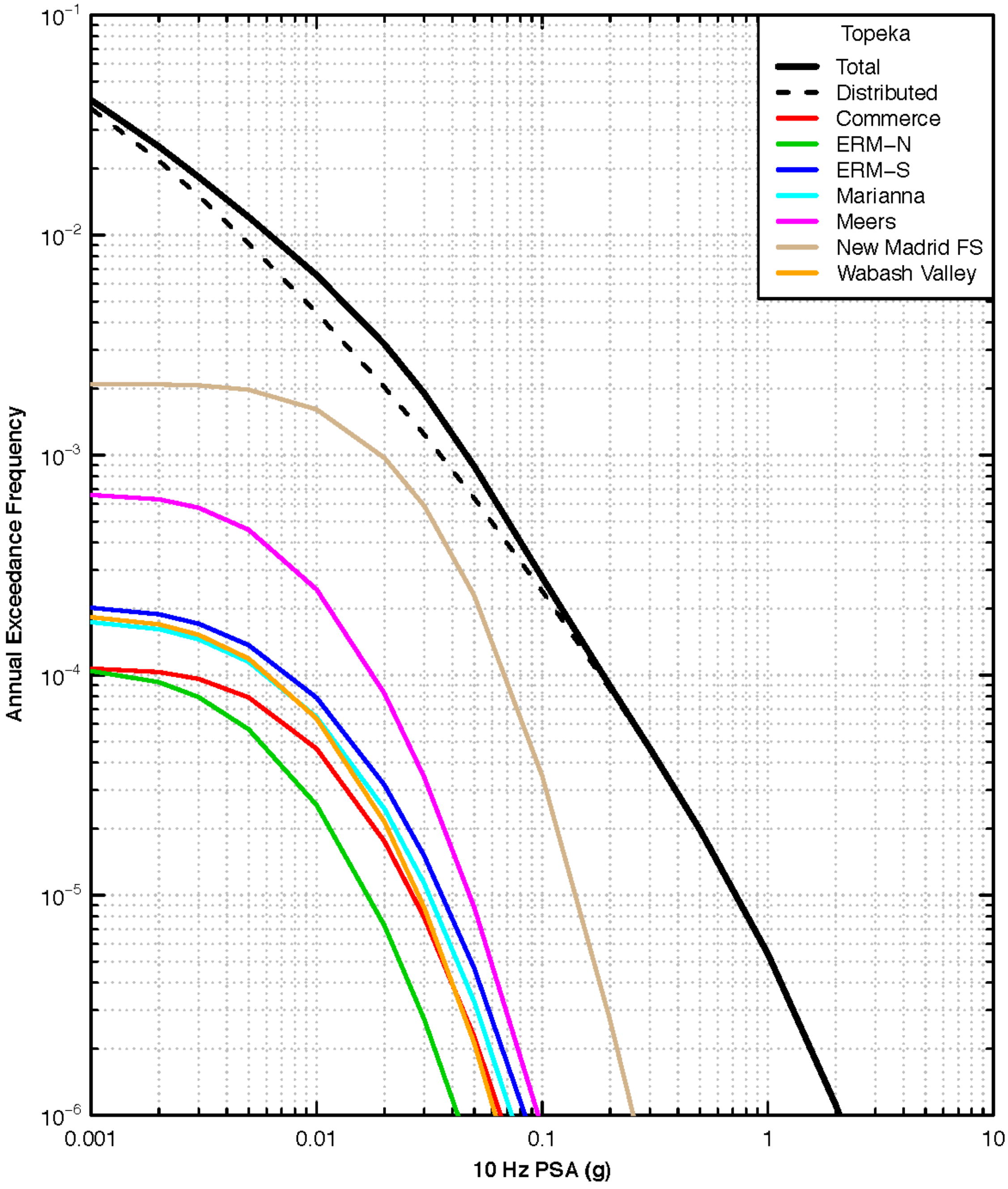


Figure I–40 Mean and fractile hazard curves for 1 Hz PSA for Topeka site.

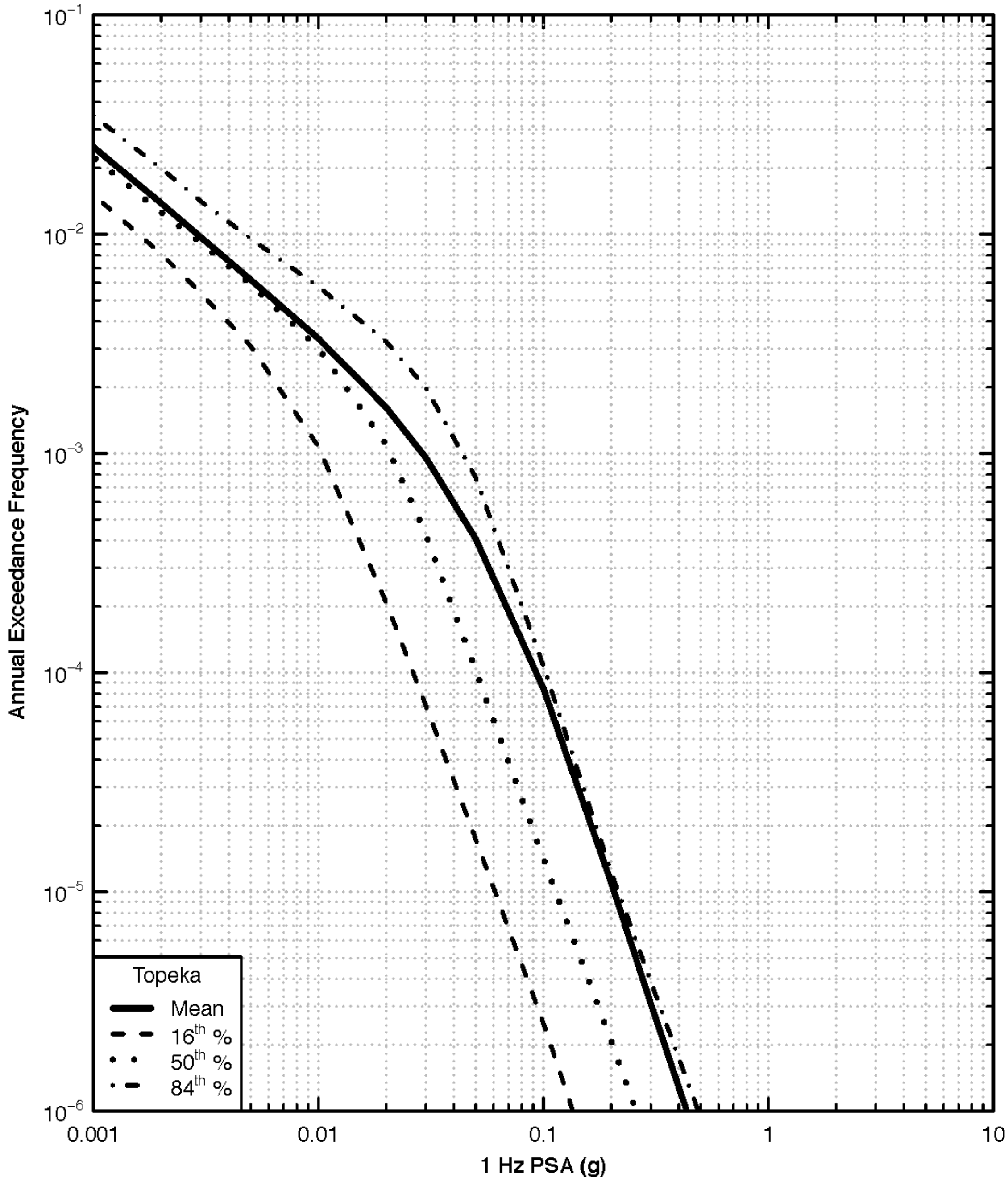


Figure I–41 Distributed seismicity source contributions to mean 1 Hz PSA hazard for Topeka site.

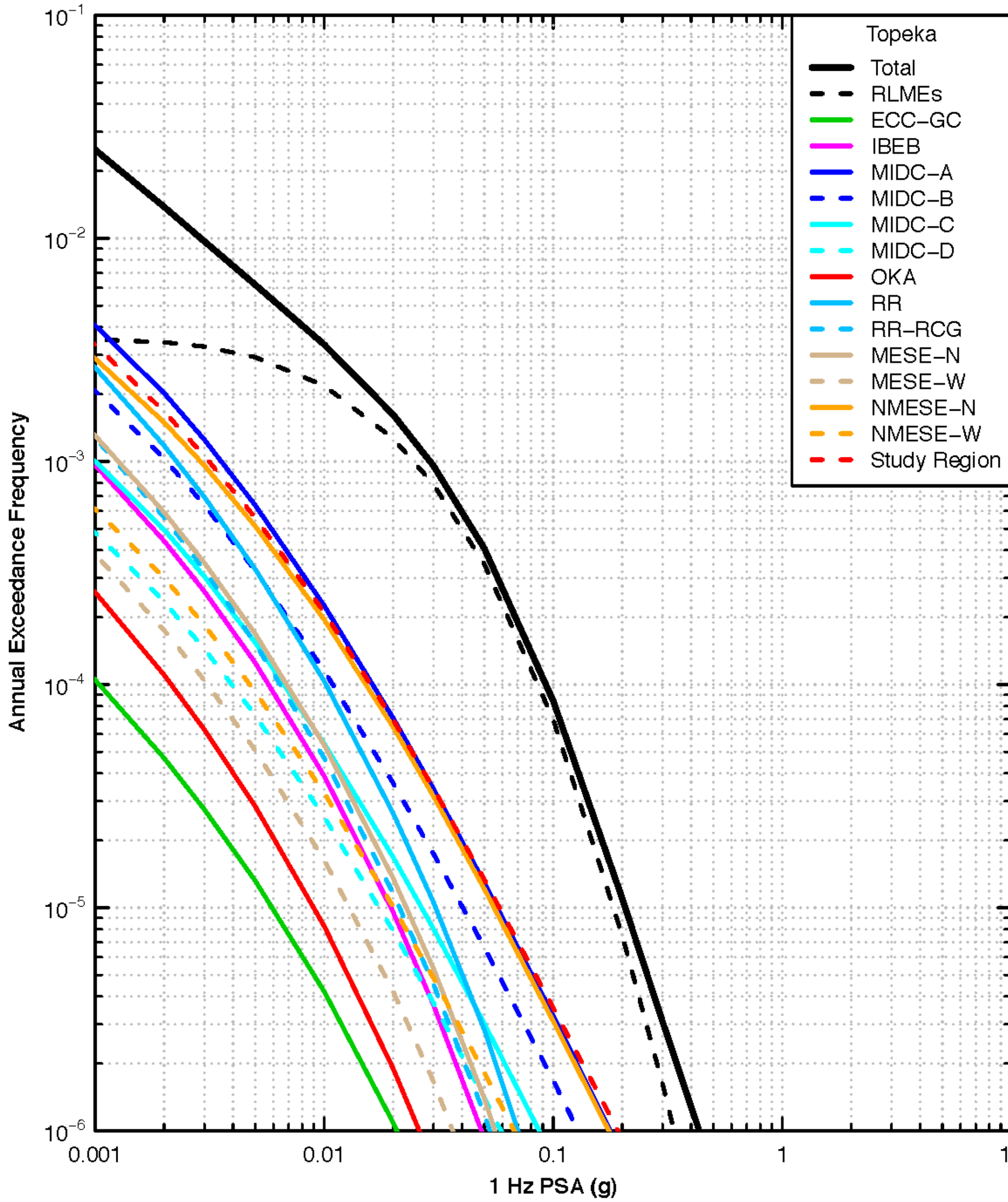


Figure I–42 RLME source contributions to mean 1 Hz PSA hazard for Topeka site.

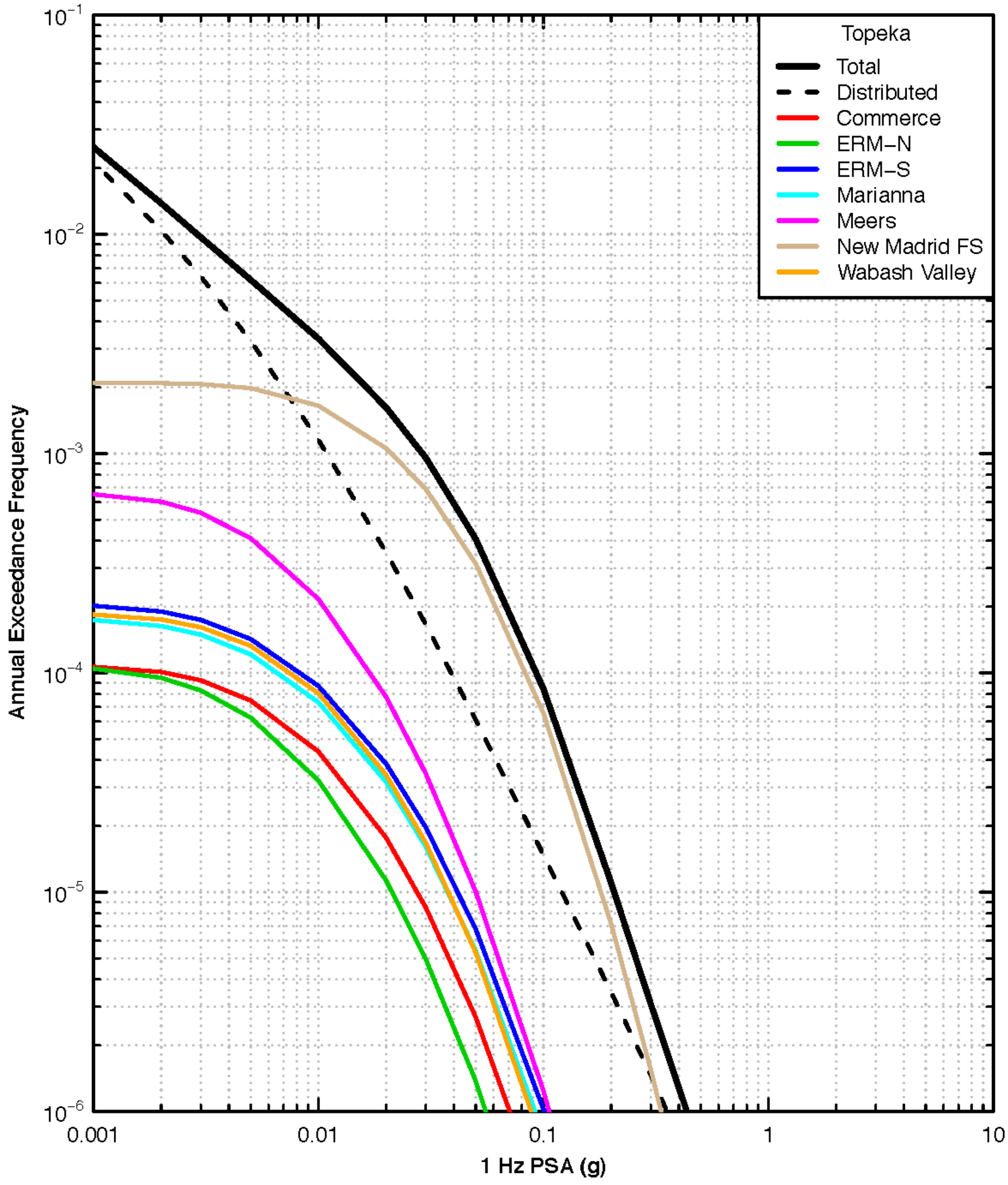


Figure I–43 **Mean and fractile hazard curves for PGA for Houston site.**

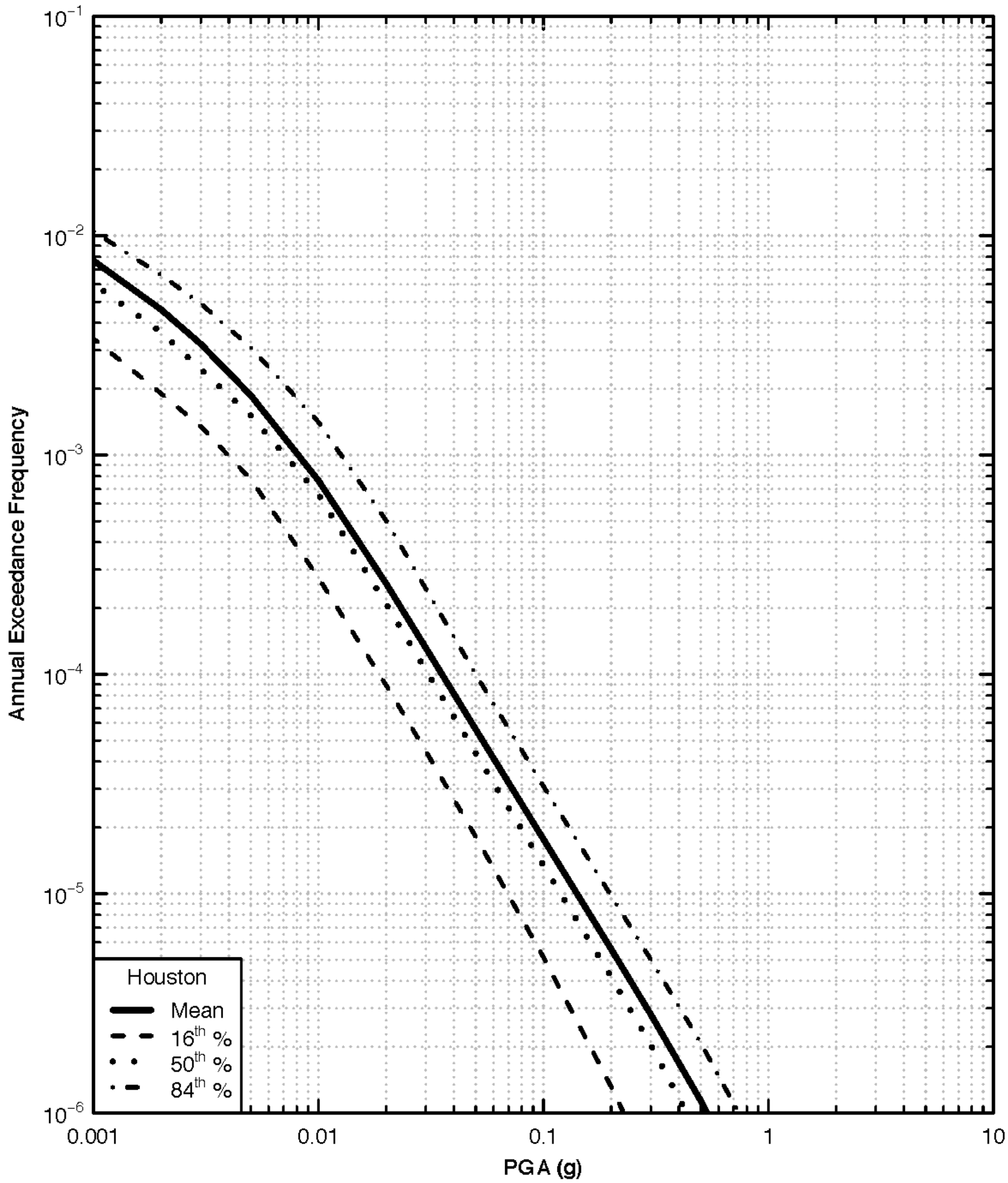


Figure I–44 **Distributed seismicity source contributions to mean PGA hazard for Houston site.**

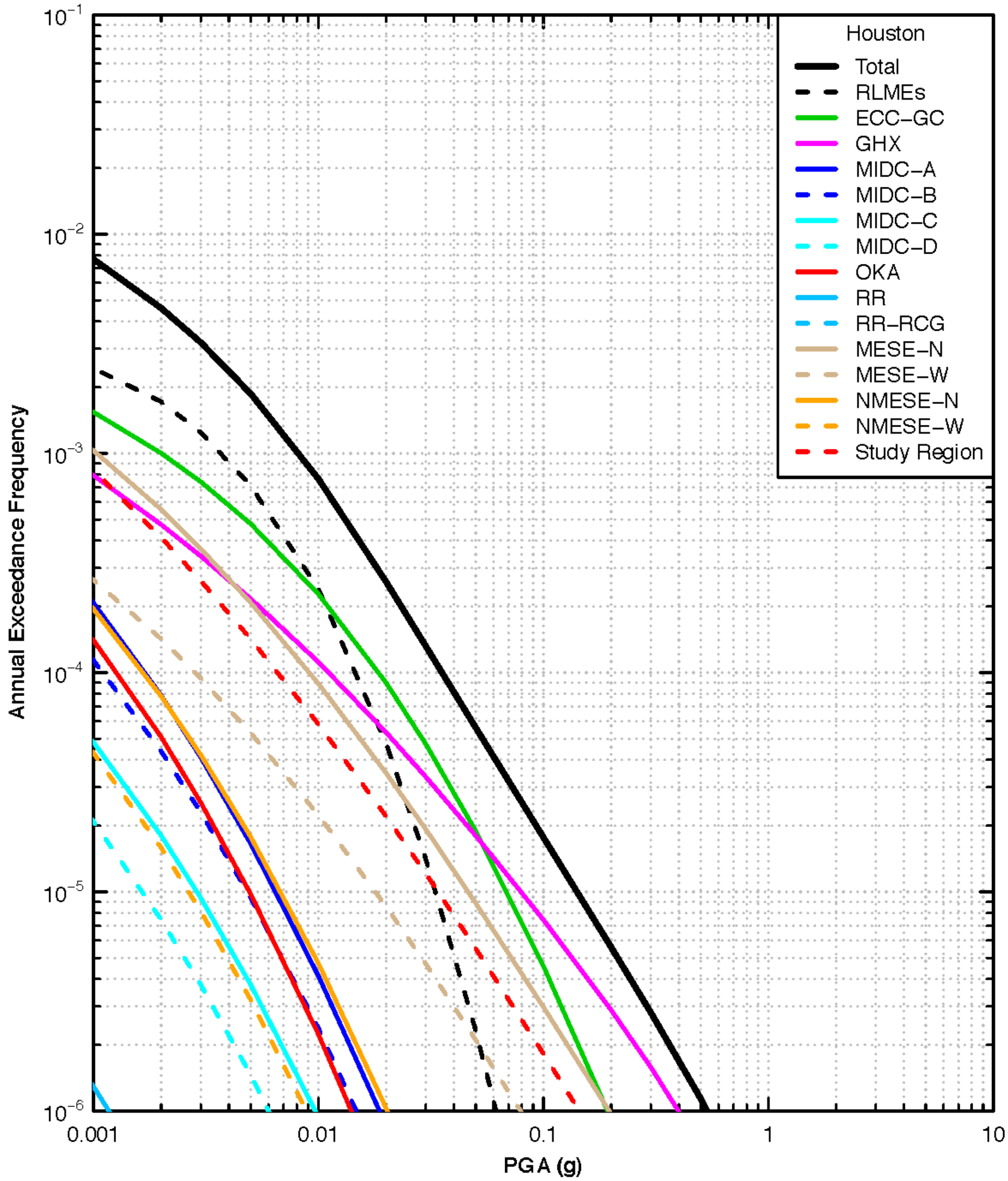


Figure I–45 RLME source contributions to mean PGA hazard for Houston site.

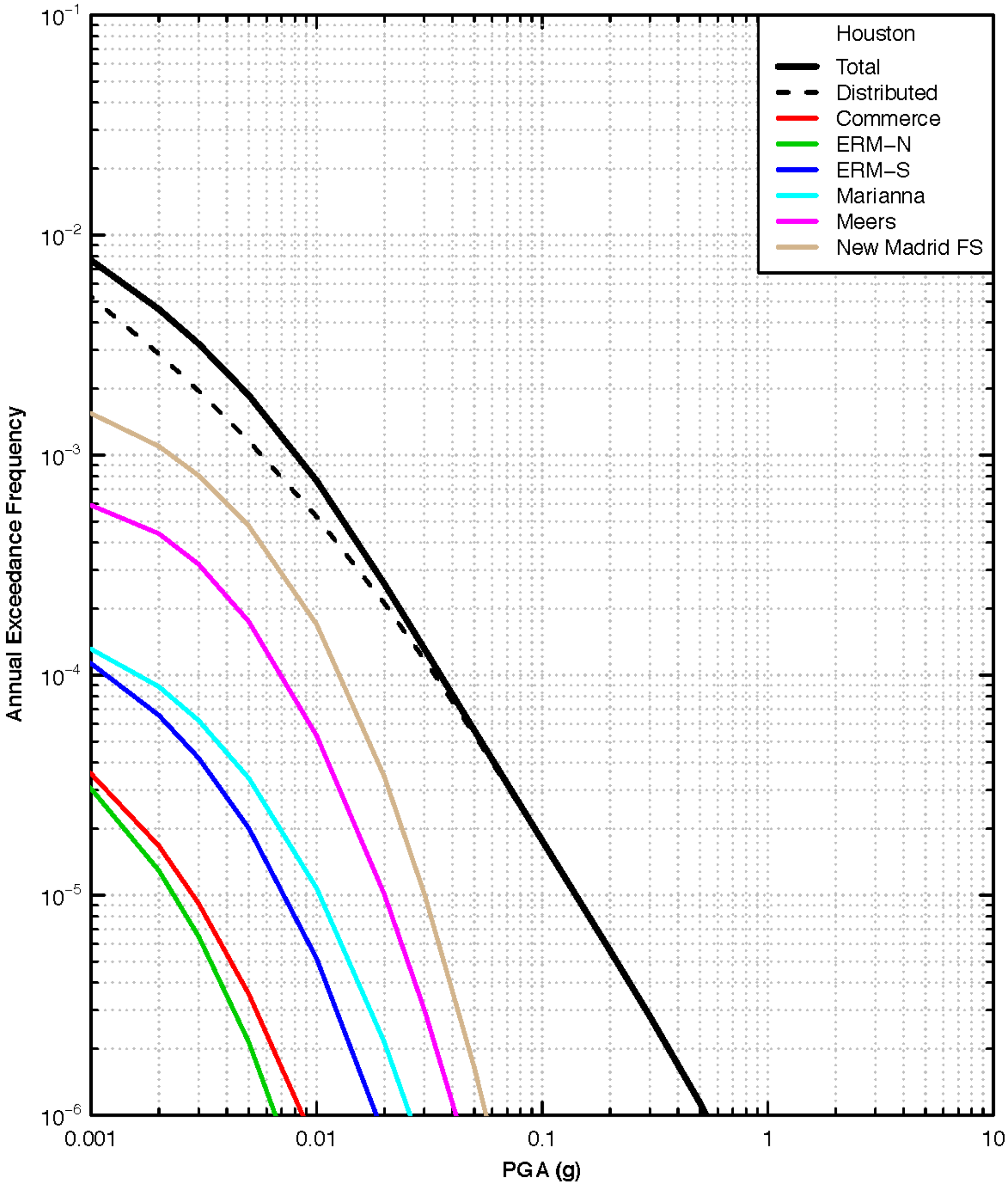


Figure I–46 Mean and fractile hazard curves for 10 Hz PSA for Houston site.

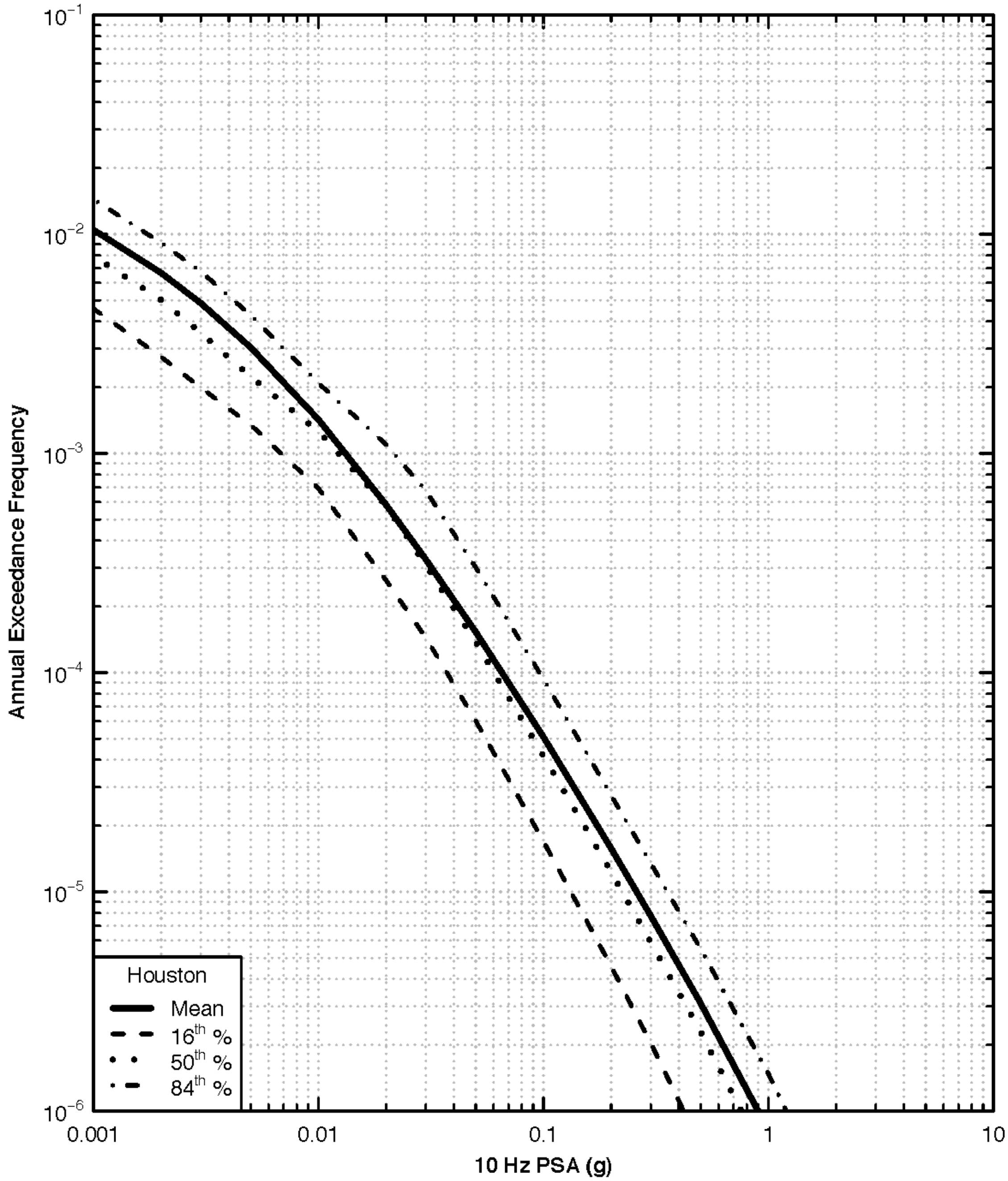


Figure I–47 Distributed seismicity source contributions to mean 10 Hz PSA hazard for Houston site.

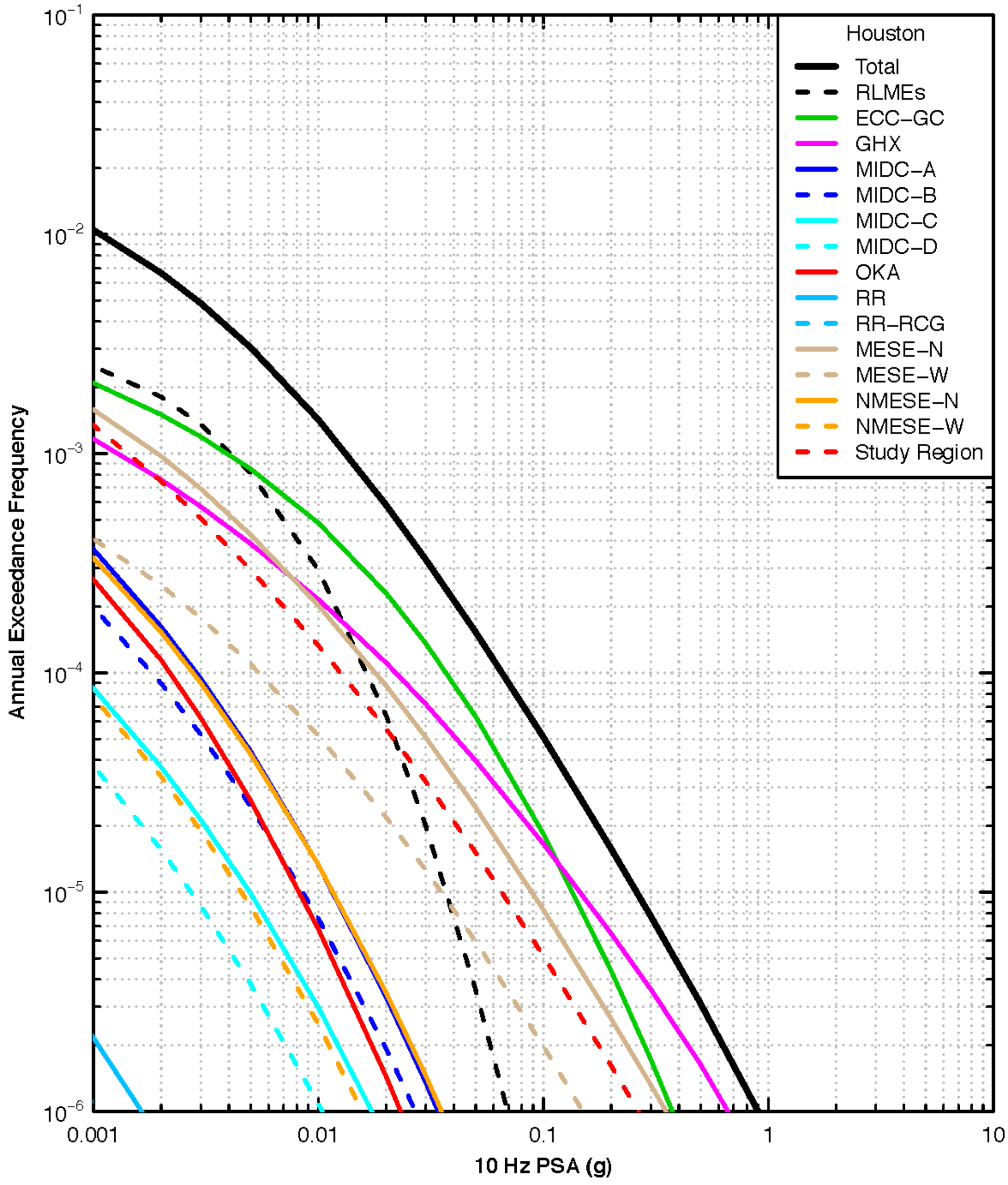


Figure I–48 RLME source contributions to mean 10 Hz PSA hazard for Houston site.

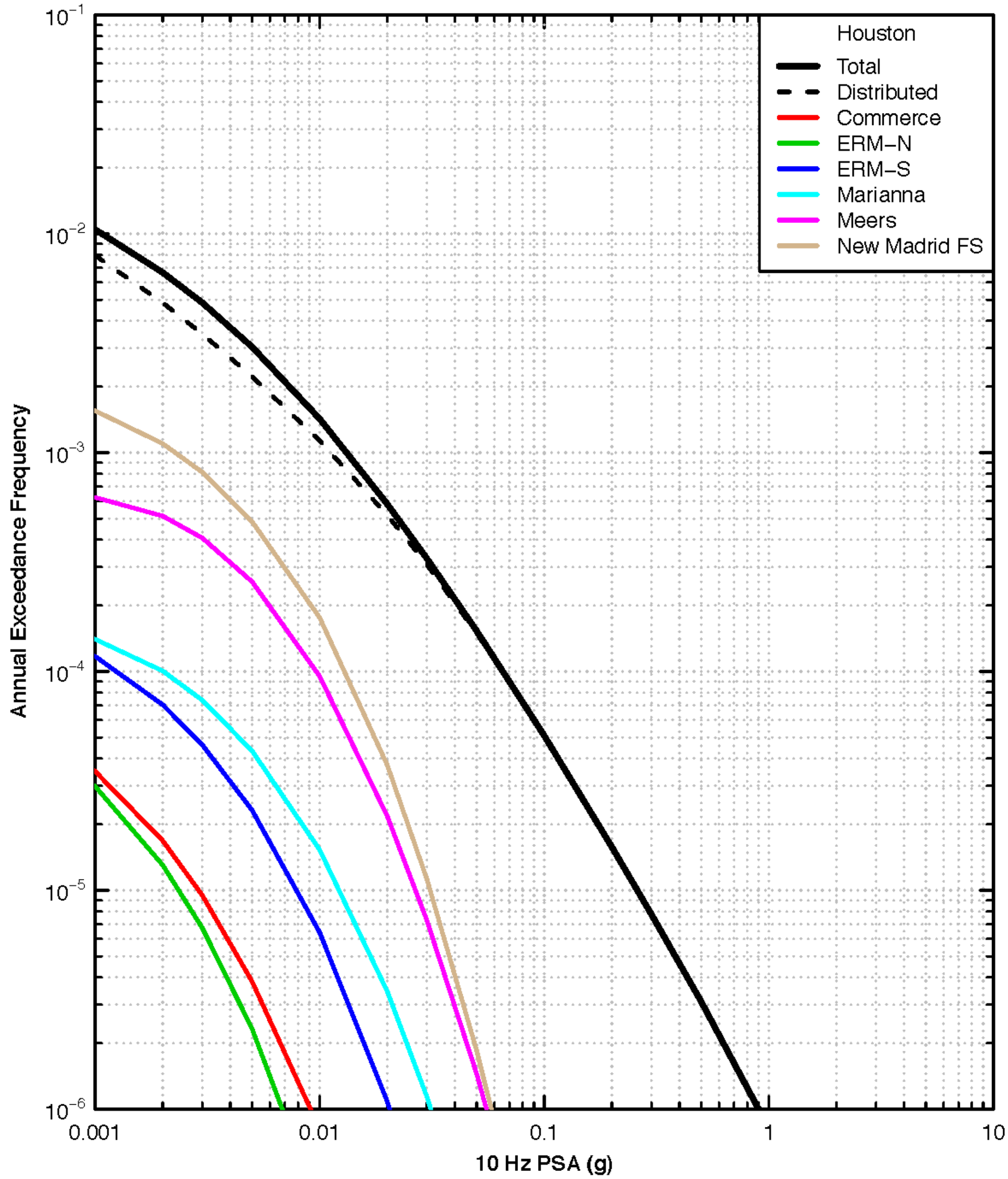


Figure I–49 Mean and fractile hazard curves for 1 Hz PSA for Houston site.

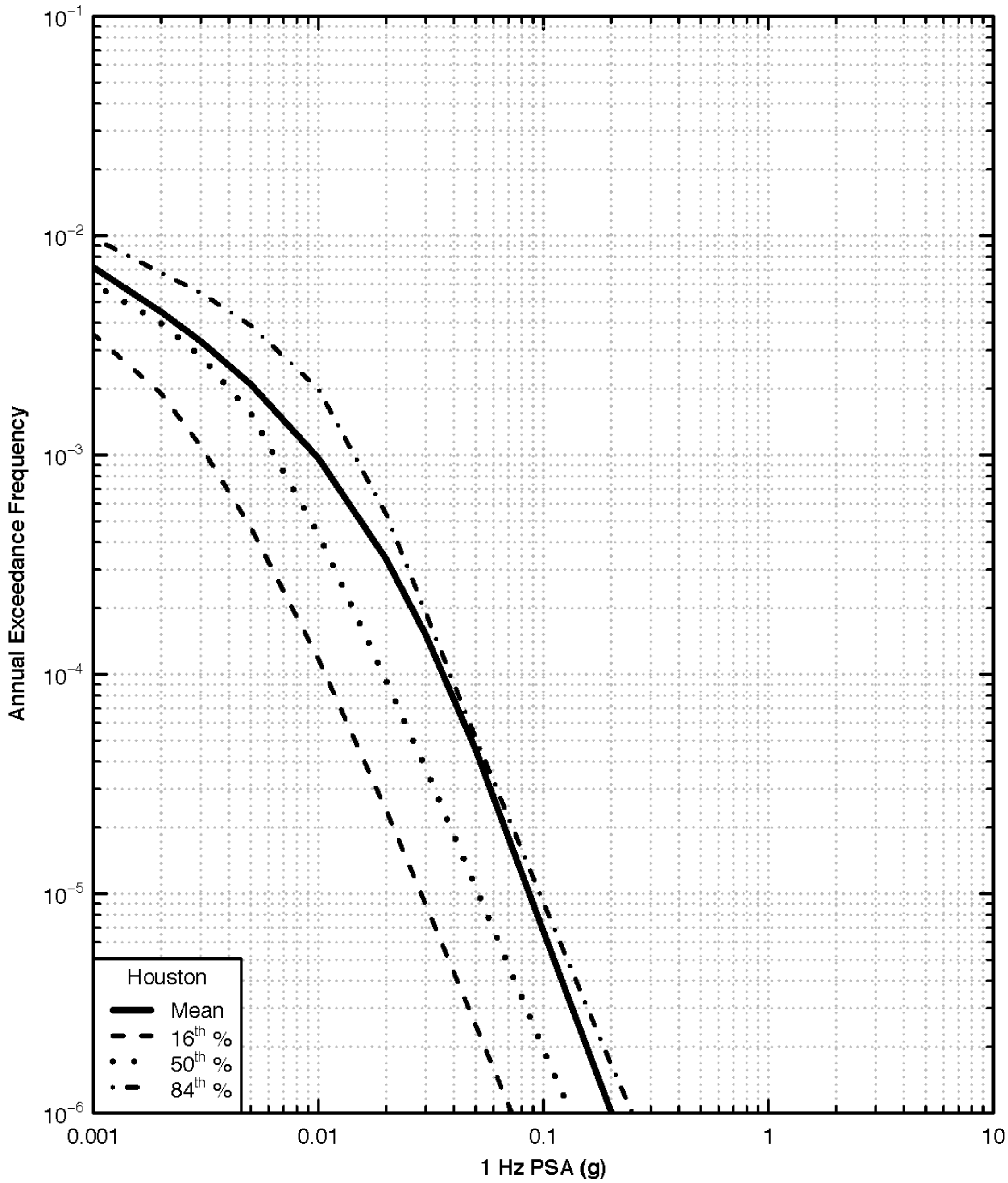


Figure I–50 Distributed seismicity source contributions to mean 1 Hz PSA hazard for Houston site.

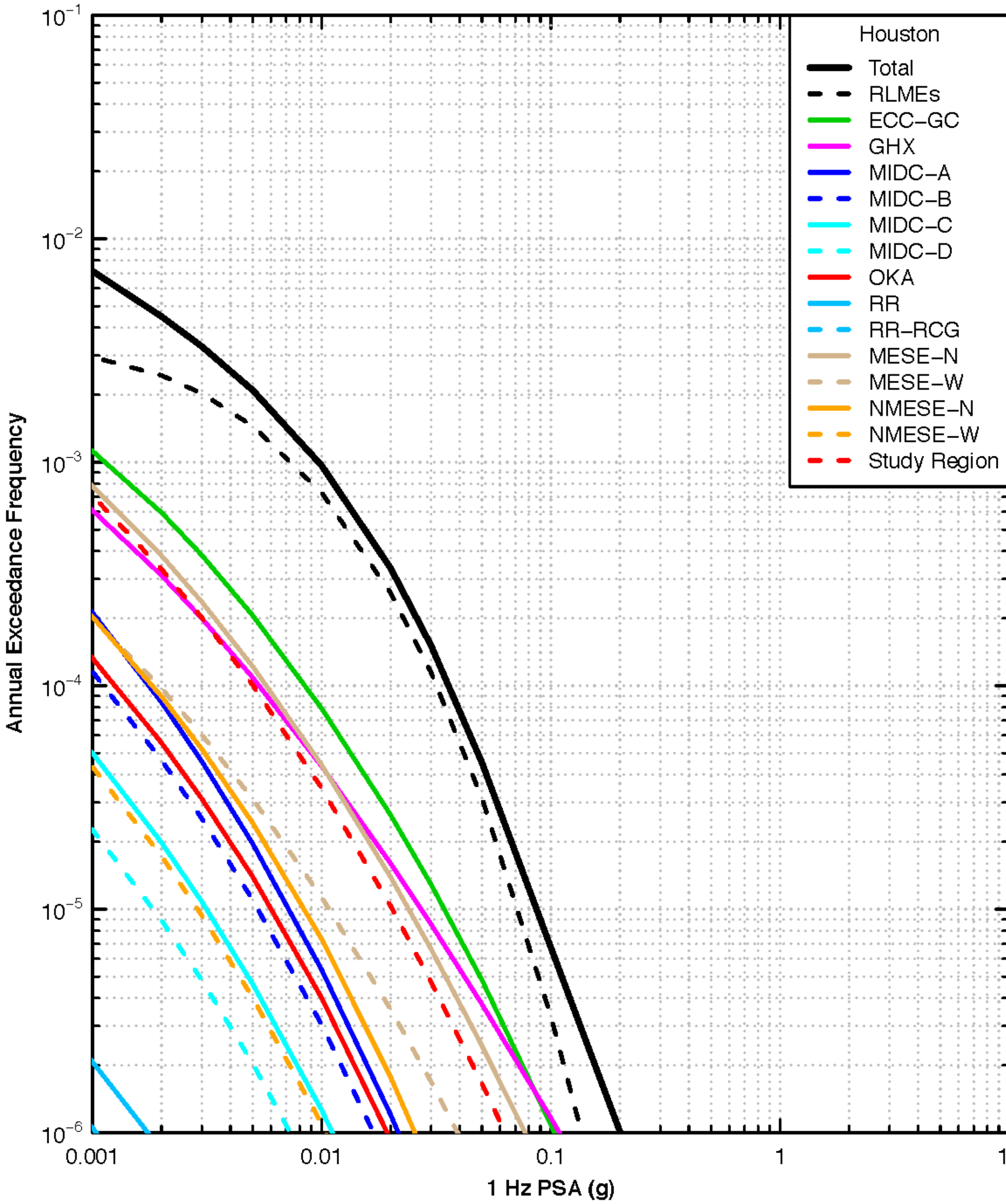


Figure I–51 RLME source contributions to mean 1 Hz PSA hazard for Houston site.

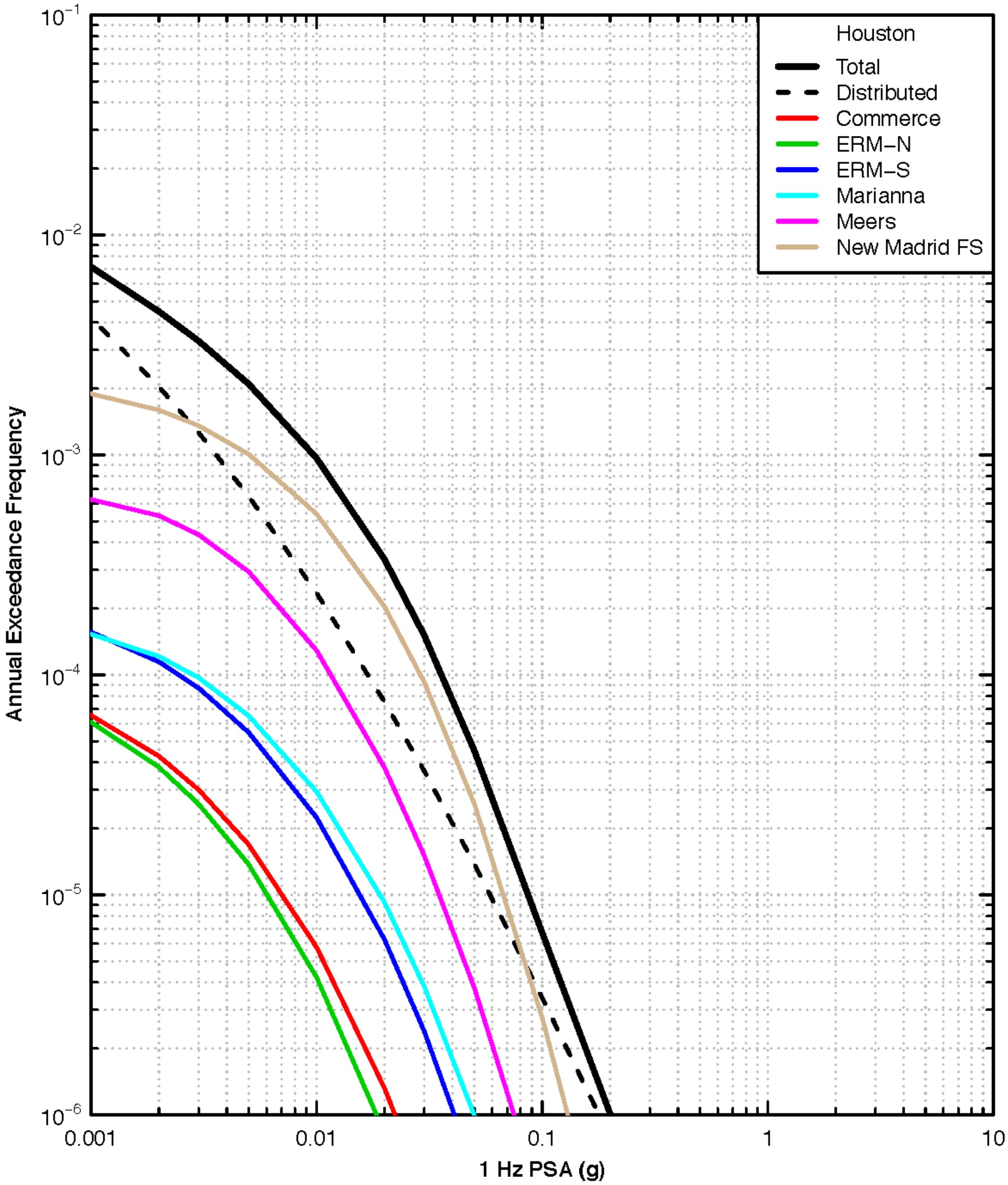


Figure I–52 Mean and fractile hazard curves for PGA for Jackson site.

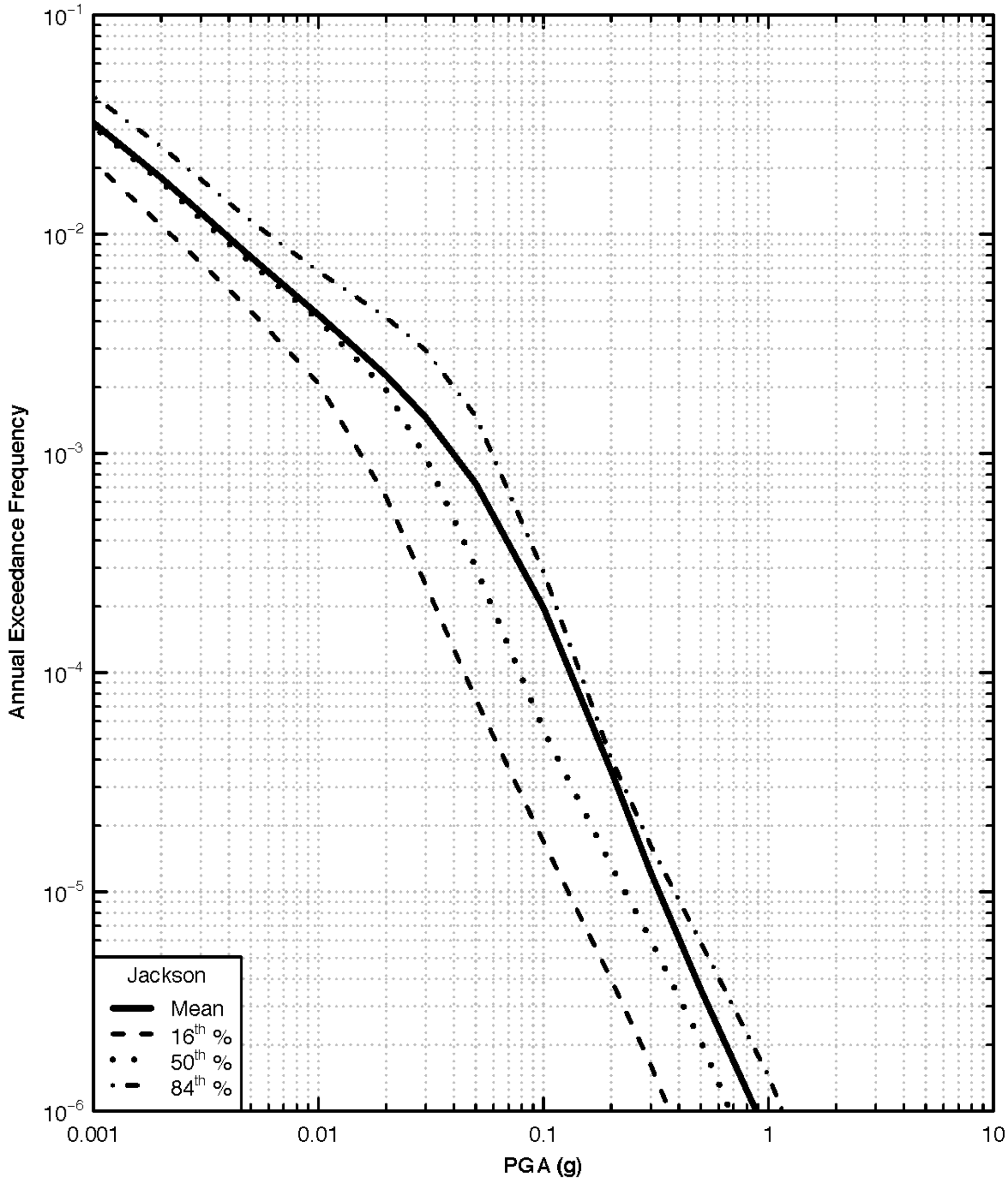


Figure I–53 Distributed seismicity source contributions to mean PGA hazard for Jackson site.

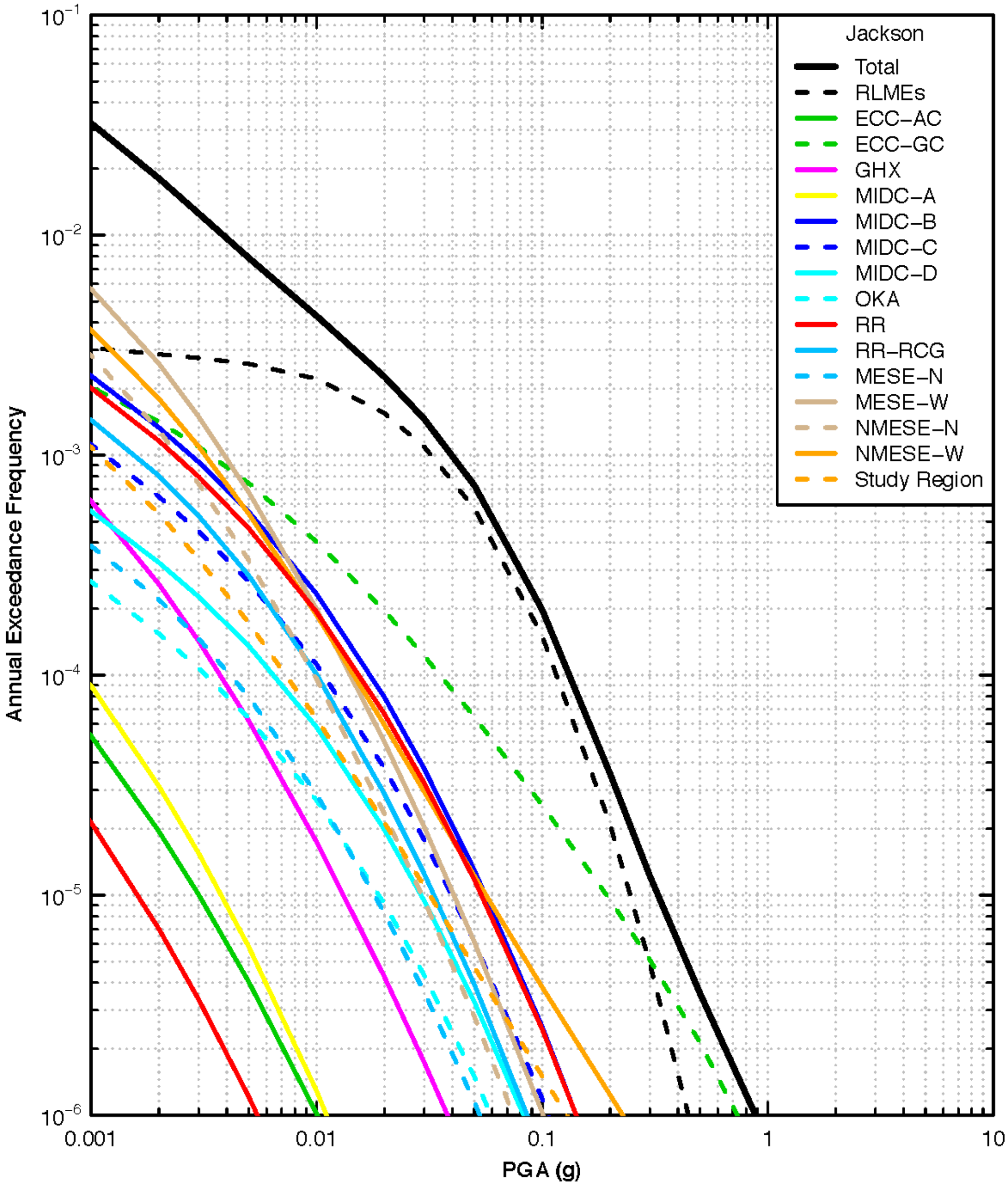


Figure I–54 RLME source contributions to mean PGA hazard for Jackson site.

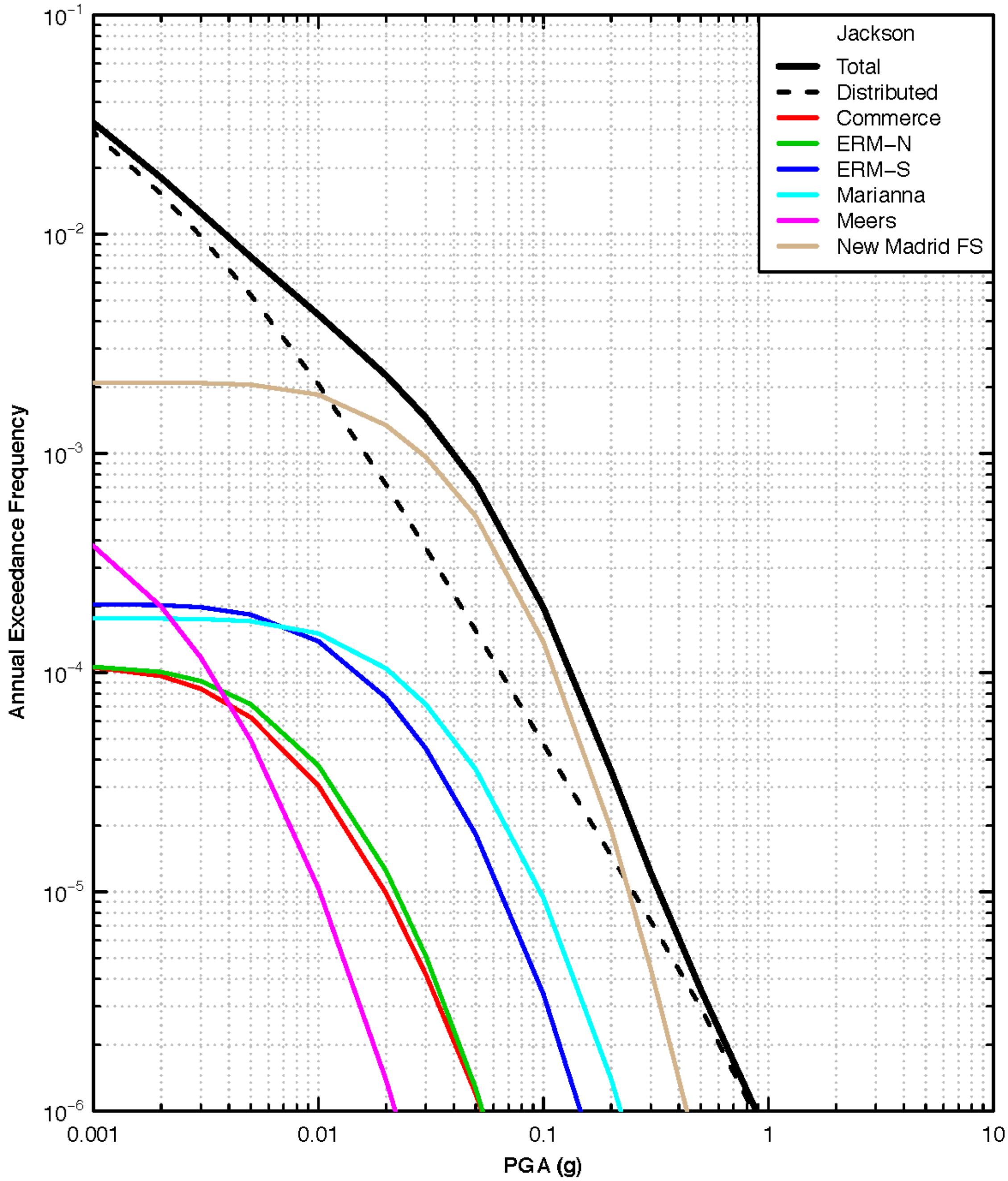


Figure I–55 Mean and fractile hazard curves for 10 Hz PSA for Jackson site.

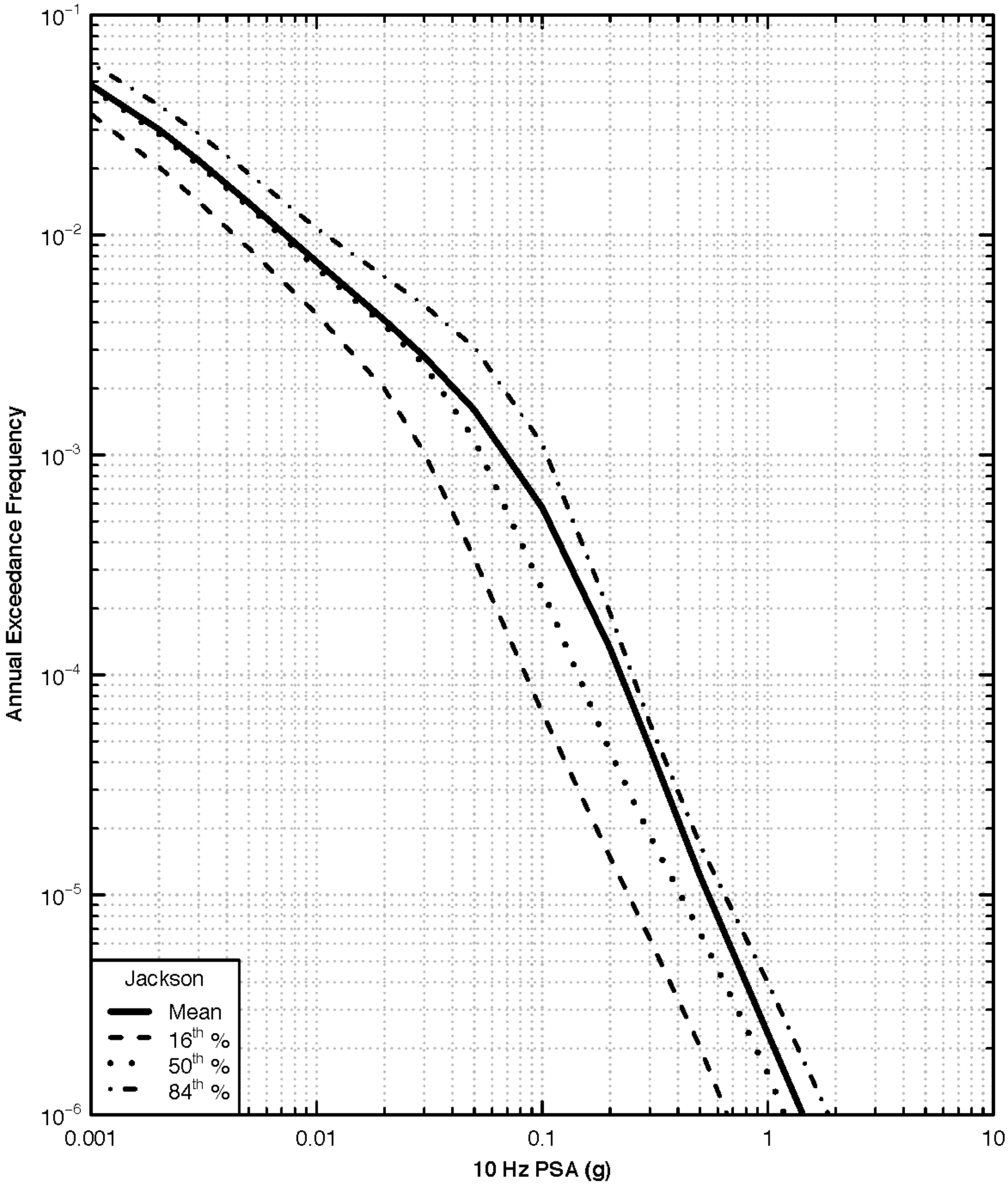


Figure I–56 Distributed seismicity source contributions to mean 10 Hz PSA hazard for Jackson site.

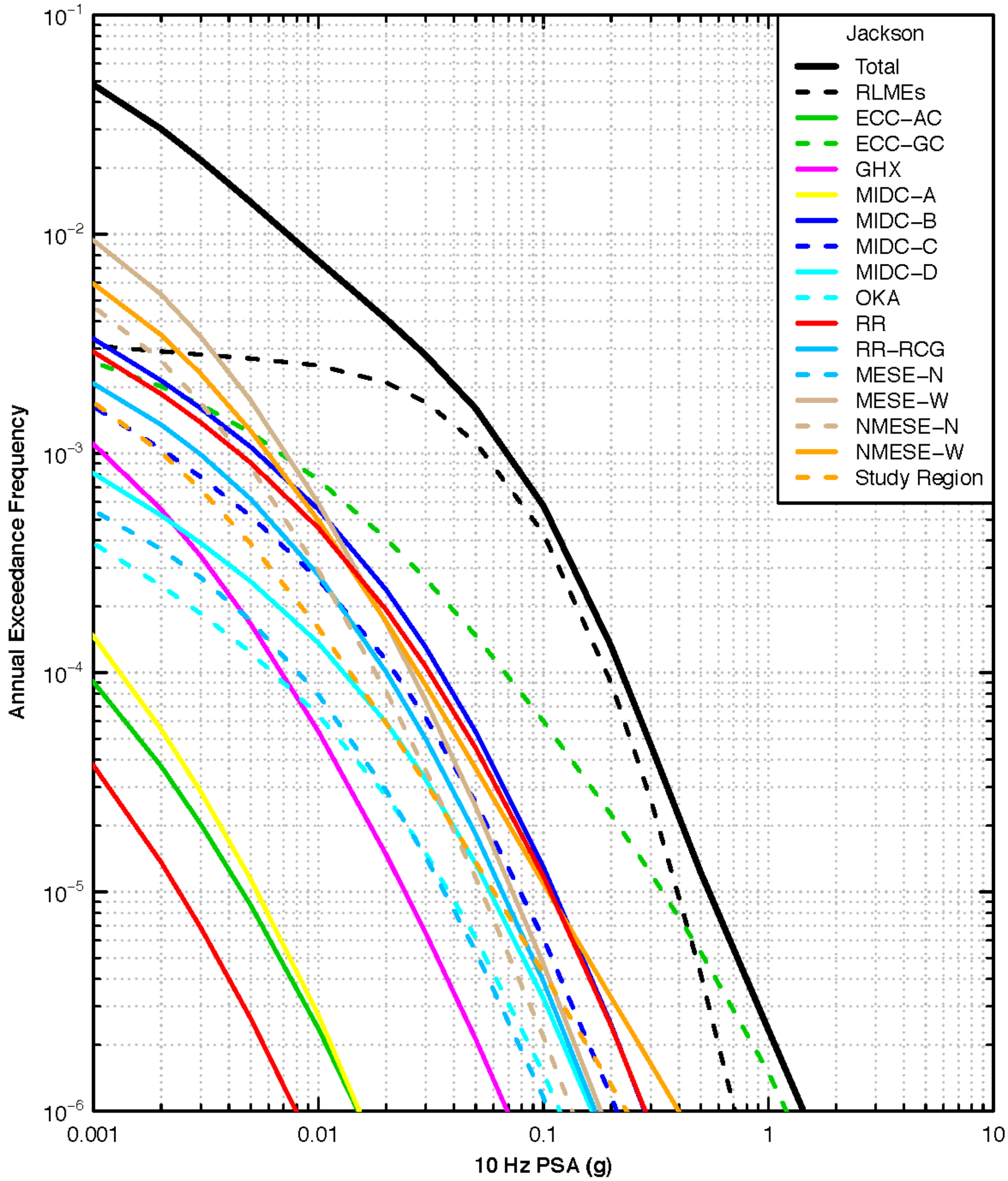


Figure I–57 **RLME source contributions to mean 10 Hz PSA hazard for Jackson site.**

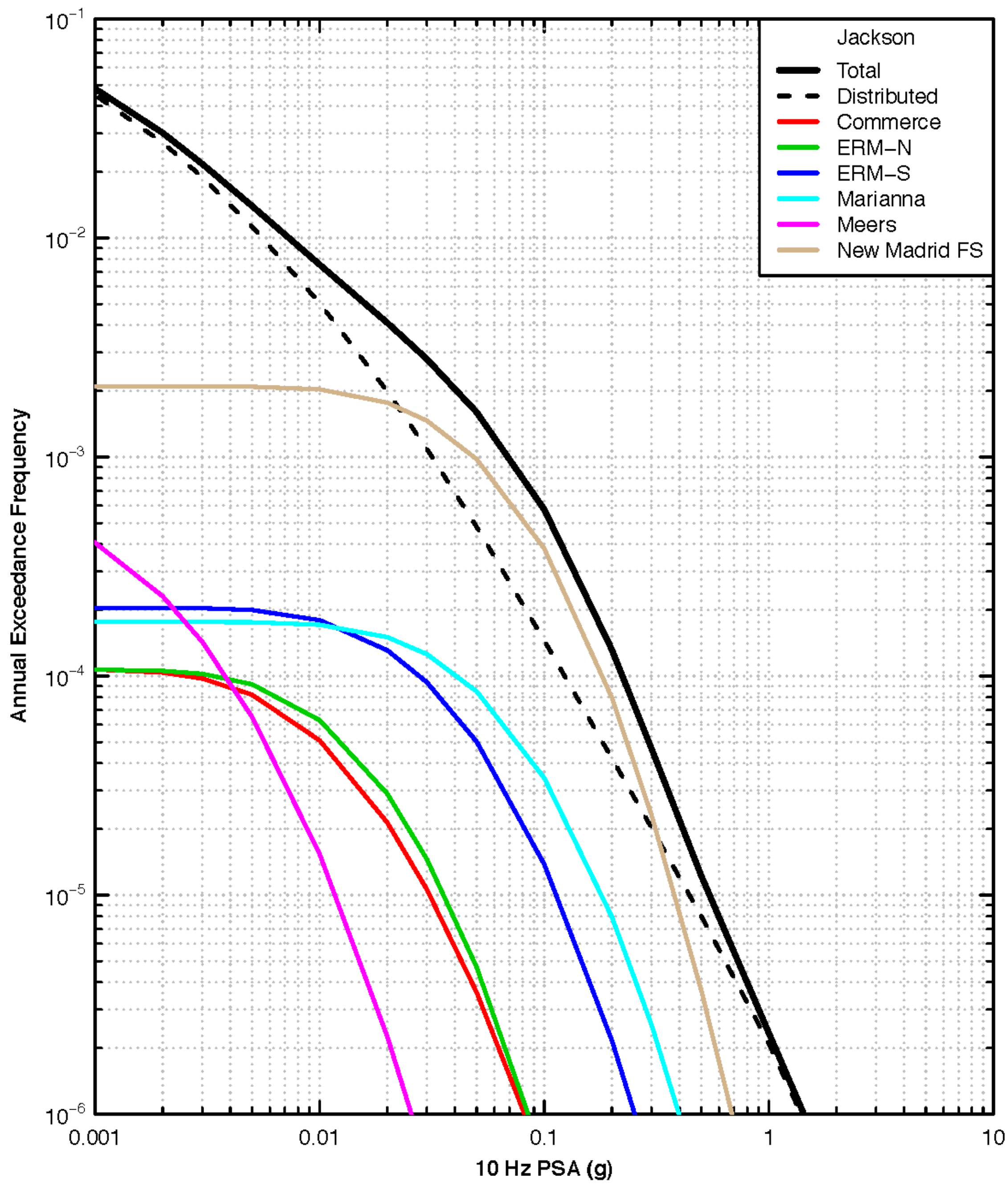


Figure I–58 Mean and fractile hazard curves for 1 Hz PSA for Jackson site.

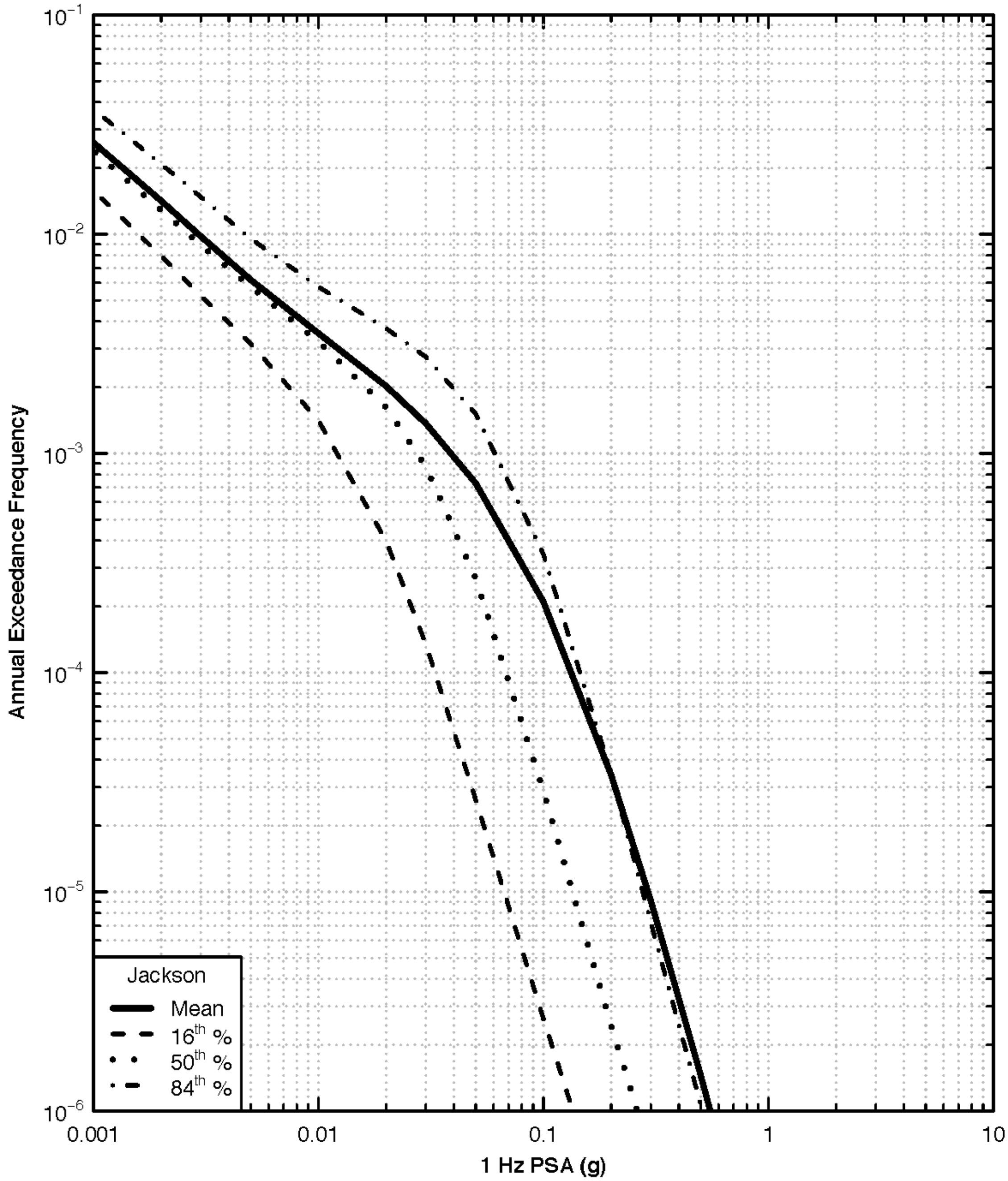


Figure I–59 **Distributed seismicity source contributions to mean 1 Hz PSA hazard for Jackson site.**

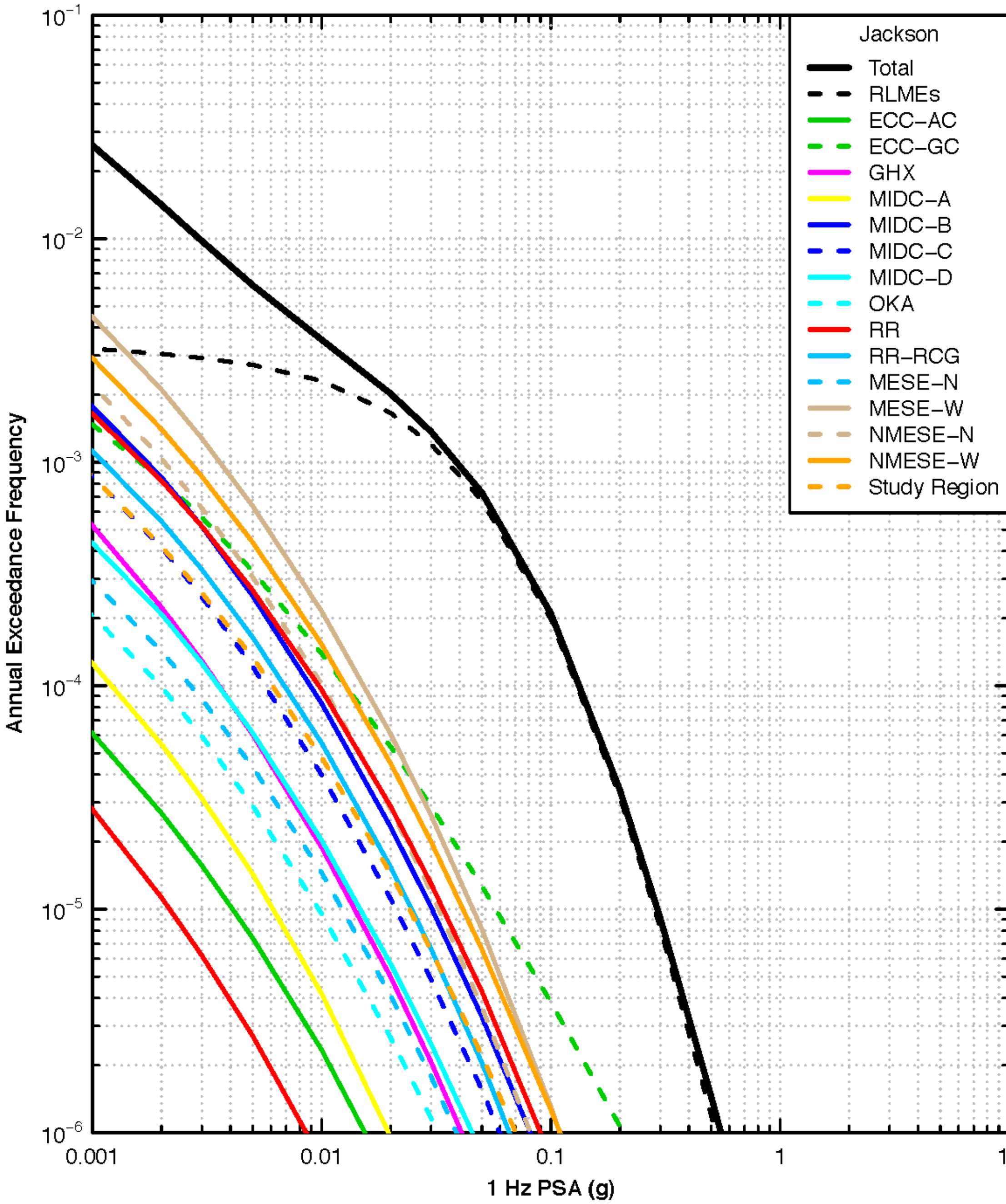
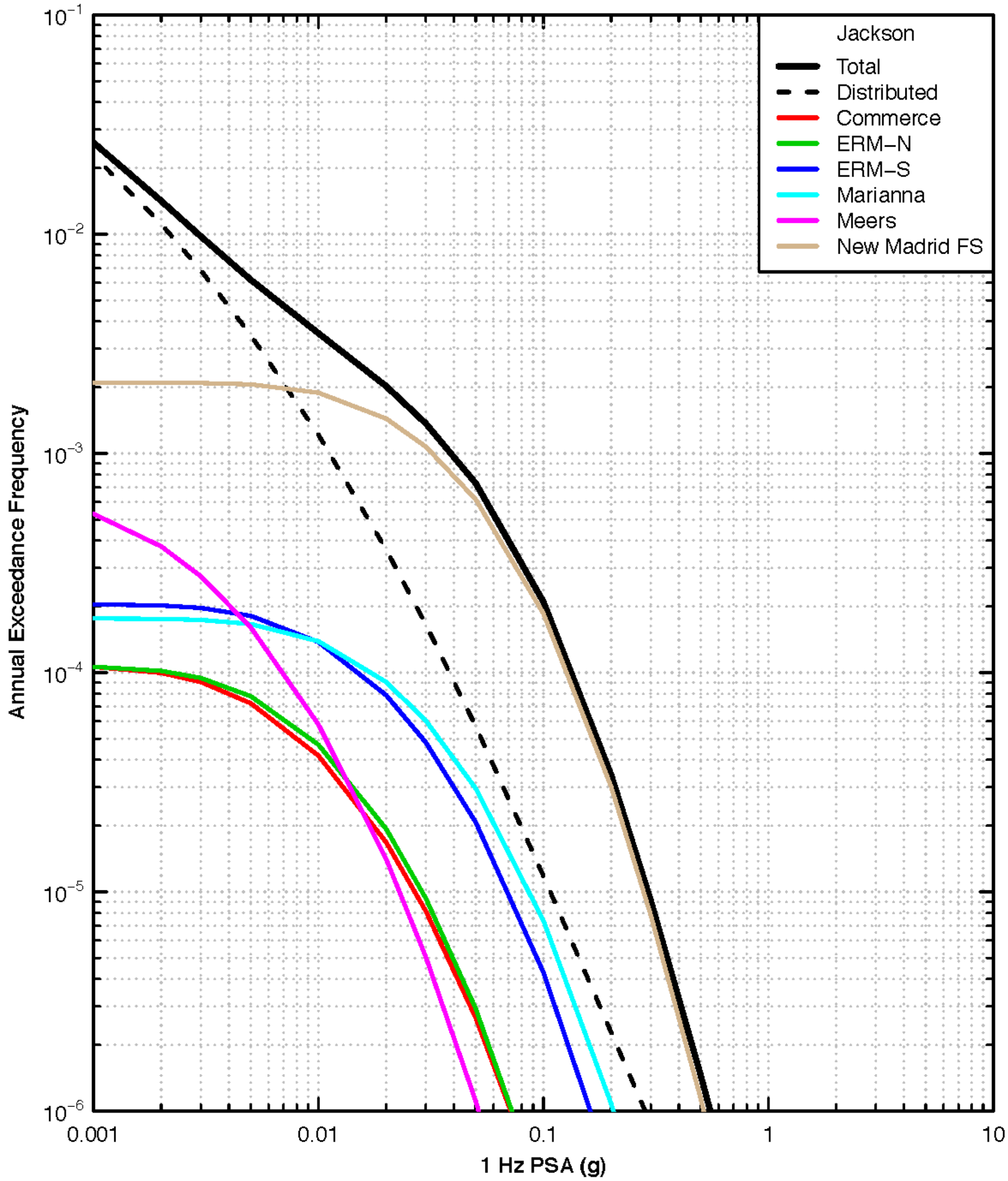


Figure I–60 RLME source contributions to mean 1 Hz PSA for Jackson site.



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