White Paper on

Guidance for Updating Accepted Existing Seismic Source Models, Given New Data or New Information

Prepared for

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I. INTRODUCTION

The motivation for this white paper is to provide additional material and information for support of ongoing efforts by the Nuclear Energy Institute (NEI) and the Nuclear Regulatory Commission (NRC) to resolve open generic seismic issues and to develop guidance acceptable to the NRC for meeting the requirements of the seismic regulations. A meeting between the NRC and NEI on February 13, 2008 held to further this effort identified the need for more detailed guidance on acceptable procedures and evaluations for determining whether updating of *Accepted PSHA Models*[1] is required. NEI took the action to prepare this white paper to provide a basis for establishing an appropriate level of more detailed procedure and evaluation guidance. The purpose of this paper is to provide additional detailed procedure and evaluation guidance for determining whether new data[2] or new information[3] (e.g., new evaluations of seismic sources or new probabilistic seismic hazard studies) require updating the seismic source component of an accepted existing PSHA model. The focus of the proposed guidance is on the seismic source component of accepted PSHA models, as the ground motion component for sites located in the central and eastern United States recently has been updated[4]. The procedures and evaluations for updating accepted existing seismic source models described below may be used to elaborate the guidance currently contained in Regulatory Guide (RG) 1.208.

II. OVERVIEW OF RG 1.208 GUIDANCE FOR UPDATING ACCEPTED EXISTING SEISMIC SOURCE MODELS

General discussion and general guidance for updating seismic source models that have been previously reviewed and accepted by the NRC can be found in several locations in RG 1.208.

- Regulatory Position 2.1 - Evaluation of New Seismic Sources

  "*For sites in the CEUS, existing databases may be used to*

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[1] Accepted PSHA Model is adopted from Regulatory Guide 1.208, Appendix A. (The complete definition is given in this paper.) PSHA Model is used in this document to be equivalent to the more commonly used term "Seismic Hazard Model".

[2] New data are data that have become available subsequent to the NRC's acceptance of the accepted PSHA model under consideration.

[3] New information is used in this paper to mean interpretations of PSHA models that have become available subsequent to the NRC's acceptance of the PSHA model under consideration. See Section III for discussion.

[4] EPRI TR-1009684: "CEUS Ground Motion Project Final Report", 2004.

identify seismic sources to perform PSHA. Previously unidentified seismic sources that were not included in these databases should be appropriately characterized and sensitivity analyses performed to assess their significance to the seismic hazard estimate. The results of investigation discussed in Regulatory Position 1 should be used, in accordance with Appendix C to this regulatory guide, to determine whether the seismic sources and their characterization should be updated. The guidance in Regulatory Positions 2.2 and 2.3 (below) and the methods in Appendix C to this regulatory guide may be used if additional seismic sources are to be developed as a result of investigations."

In the context of this position statement "existing databases" should be interpreted to include accepted existing seismic source models. RG 1.208 Appendix C, which is referred to for guidance to determine whether a previously accepted seismic source model should be updated, primarily contains additional guidance for data compilation. Appendix C.3, included in full below, provides general guidance on new elements and parameters that should be evaluated using new data to determine whether accepted existing seismic source assessments require updating. But the guidance lacks details on procedures and evaluations acceptable to the NRC for determining whether an accepted existing source model requires updating (see Appendix C.3, below).

- Regulatory Position 2.2 - Use of Alternative Seismic Sources

"When existing methods and databases are not used or are not applicable, the guidance in Regulatory Position 2.3 should be used for identification and characterization of seismic sources. The uncertainties in the characterization of seismic sources should be addressed. "Seismic sources" is a general term that is equivalent to capable tectonic sources.

Identification and characterization of seismic sources should be based on regional and site geological and geophysical data, historical and instrumental seismicity data, the regional stress field, and geological evidence of prehistoric earthquakes. Investigations to identify seismic sources are described in Appendix C to this regulatory guide. The bases for the identification of seismic sources should be described. A general list of characteristics to be evaluated for seismic sources is presented in Appendix C."

This regulatory position provides guidance for development of a site-specific seismic source model for sites when an accepted existing seismic source model is not available or is not used as the starting basis. It points to Regulatory Position 2.3 and also to Appendix C for guidance on the scope of data to be evaluated for the development of a site-specific seismic source model, and to Appendix C.3 for a list of source model parameters that should be evaluated and characterized.

- Regulatory Position 2.3.1 - Characterizing Seismic Potential When Alternative Methods and Databases Are Used

The relevant part of Regulatory Position 2.3.1 is the following:

"For sites in the CEUS, the seismic sources and data accepted by the NRC in past licensing decisions may be used as a starting point, along with the data gathered from the investigations carried out as described in Regulatory Position 1."

Regulatory Position 2.3.1 restates a portion of Regulatory Position 2.1 with minor differences

- Appendix C.3 - Evaluation of New Information Obtained from the Site-specific Investigations

"The first step in reviewing the new information obtained from the site-specific investigations with previous interpretations is determining whether the following existing parameters are consistent with the new information: (1) the range of seismogenic sources as interpreted by the seismicity experts or teams involved in the study, (2) the range of seismicity rates for the region around the site as interpreted by the seismicity experts or teams involved in the studies, (3) the range of maximum magnitudes determined by the seismicity experts or teams, and (4) attenuation relations. The new information is considered not significant and no further evaluation is needed if it is consistent with the assumptions used in the PSHA, no additional alternative seismic sources or seismic parameters are needed, or it supports maintaining the site mean seismic hazard."

Appendix C.3 identifies the seismic source model parameters that should be evaluated to determine whether new data and information indicate that they need to be modified. Detailed guidance is lacking on procedures acceptable to the NRC for performing the evaluations as well as on acceptable criteria for determining whether assessments of new data require updating of elements or parameters of an accepted

existing seismic source model.

- Appendix A - Definitions

<u>Accepted PSHA Model</u> *"An accepted PSHA model is a method of conducting a Probabilistic Seismic Hazard Analysis (including the seismic sources and ground motion equations) that has been developed using Senior Seismic Hazard Analysis Committee (SSHAC) guidelines and that has been reviewed and accepted by the NRC in the past either for generic application (e.g., the 1989 studies by LLNL and EPRI, with the inherent seismic source description for the CEUS) or as part of an ESP or COL application. Accepted PSHA models are starting points for developing probabilistic seismic hazard calculations for new ESP or COL applications, yet must be updated with new information on seismicity, geology, geophysics, and ground motion equations, as appropriate for a site that is being reviewed. The term accepted PSHA model should not be assumed to imply that the model can be used without updates or reviews as discussed RG 1.208."*

The term "PSHA Model" as defined in RG 1.208 is consistent with the term "Seismic Hazard Model" that is more generally used by the seismic hazard community. The definition provides the important guidance that an Accepted PSHA Model is one that 1) has been developed implementing the SSHAC guidelines and 2) has been reviewed and accepted by the NRC for generic application or as part of a past site-specific ESP or COL application. This definition clearly accepts the EPRI/SOG generic regional seismic source model as a starting basis for performing new site-specific PSHAs for sites located in the CEUS.

III. DISTINCTION BETWEEN DATA AND INFORMATION

The terms "data" and "information" are used in both their normal meanings and somewhat interchangeably in the guidance provided in RG 1.208. No clear distinction is made between "new data" and "new information" for determining whether accepted existing seismic source models require updating. An example of the uses of these terms in their normal meanings is in RG 1.208 (B. DISCUSSION).

"*Geological, seismological, and geophysical investigations are performed to develop an up-to-date, site-specific, earth science database that supports site characterization and a PSHA. The results of these investigations will also be used to assess whether new data and their interpretation are consistent with the information used in*

probabilistic seismic hazard studies previously accepted by the NRC."

Here the term data is used in its normal meaning in scientific discourse and interchange: physical data obtained from investigations that may be used as the basis for calculations or as the basis for evaluations or interpretations. The term information is used here consistent with its normal more general meaning, to refer to totality of the data, data evaluations, interpretations and assessments that are captured in a seismic hazard model previously accepted by the NRC.

An example of the interchangeable use of the terms "data" and "information" is given in Appendix C.1, first paragraph.

"….. Geological, seismological, and geophysical investigations provide the information needed to identify and characterize source zone parameters, such as size and geometry, and to estimate earthquake recurrence rates and maximum magnitudes. The amount of data available …."

Data, data evaluations, and data interpretations all can reasonably be considered to be "data" for the purpose of providing regulatory guidance and may be evaluated and treated the same for determining whether updating of accepted existing seismic source models is required. In contrast to new data, new information such as a new seismic hazard model that is the product of an integrated assessment of data using a selected SSHAC assessment process (e.g., as indicated in the given definition for an *Accepted PSHA Model*) involves different evaluation procedures for determining whether the information requires updating of an accepted seismic hazard model. The different evaluation procedures are needed independently of whether the new PSHA model is based on old data, i. e., data that were assessed for development of the accepted existing PSHA model or incorporates assessment of new data. Similarly, new information such as PSHA studies that do not meet the standard for an *Accepted PSHA Model* require still different procedure and evaluation guidance.

The examples given above illustrate the need to make a distinction between new data and new information for the purpose of developing guidance on procedures and evaluations to be followed for determining whether accepted existing seismic sources require updating.

IV. PROPOSED GUIDANCE FOR PROCEDURES AND EVALUATIONS FOR UPDATING ACCEPTED EXISTING SEISMIC SOURCE MODELS

RG 1.208 provides general guidance, as discussed above, for determining whether an accepted existing seismic source model requires updating, given new data or new information. As stated in the introduction to this paper, discussions during the meeting between the NRC and NEI on February 13, 2008 identified the need for more specific guidance than currently is contained in RG 1.208 on acceptable procedures and evaluations to determine whether accepted existing seismic sources require updating. Proposed more detailed procedure and evaluation guidance is described in the remainder of this paper.

A. Procedure and Evaluation Guidance for New Data

Updating the Database for a Site Region

Updating the geology, seismology and geophysics databases for a site region must be performed for every ESP or COL application. RG 1.208 Regulatory Position 1 together with Appendix C provides adequately detailed guidance for satisfying this requirement. The updated database, including the updated earthquake catalog for the site region must be evaluated to determine whether any element or parameter of an accepted existing seismic source model for the site requires updating.

Proposed Procedure and Evaluation Guidance for New Data

RG 1.208 provides clear guidance that accepted existing seismic source models, including the EPRI/SOG generic CEUS seismic source model and any site-specific seismic source models that have been reviewed and accepted by the NRC, may be used as the starting basis for development of a site-specific seismic source model for a new application. But more detailed specific procedure and evaluation guidance is needed to facilitate orderly review. Well-structured procedure and more detailed evaluation guidance for determining whether the updated database for a site region requires an accepted existing seismic source model to be modified is provided in RG 1.165, Appendix E.3. The guidance in Appendix E.3 is generally consistent with the more general guidance provided in RG 1.208 and it is clear that the intent of the guidance for performing this evaluation contained in the two regulatory guides is the same.

The evaluation guidance below presented as a three-step procedure, is consistent with procedures that have been followed and evaluations that have been performed for the preparation of seismic sections of recent ESP and COL applications to determine whether new data required accepted existing seismic source models to be modified. Except for the addition of Step 1, the guidance described in these steps has been adopted from RG 1.165 Appendix E.3 with modification as appropriate to reflect current state of practice for developing site-specific performance goal-based ground motion response spectra (GMRS).

Step 1: The purpose of Step 1 is to develop site-specific generic rock GMRS and sensitivity results using the accepted existing seismic source model. These results will be used for comparison with the results of subsequent steps of the proposed evaluation procedure to determine whether any updating of the site-specific GMRS is needed. The site-specific generic rock GMRS[5] is an acceptable basis for this comparison. Site-specific generic rock GMRS computations for a new application (a Greenfield site or new units at an existing operating plant site) should be based on hazard at 10^{-4} and 10^{-5} annual exceedance frequencies obtained using the site-specific accepted existing seismic source model. Sensitivity evaluations should be in enough detail to illustrate the sensitivity of the generic rock GMRS to elements and parameters of the accepted existing seismic source model and to serve as benchmark results for comparison with the affect of any changes in elements or parameters of the model that may result from evaluations of new data or new information as described in the following steps.

Step 2: This step consists of evaluating new data and determining whether elements or parameters of the accepted existing seismic source model should be modified. The proposed evaluations are consistent with the general guidance contained in RG 1.208 Appendix C.3. For performing a PSHA for an ESP or COL application, RG 1.208 guidance is to start with an accepted existing seismic source model. Data that have become available in the site region subsequent to the NRC's review of the accepted seismic source model must be evaluated and assessed to determine whether any element or parameter of the accepted existing model should be modified. Consistent with the definition of "*Accepted PSHA Model*" given in RG 1.208, a SSHAC Level

[5] Generic Rock for the CEUS is defined as rock having defined properties that were used to develop the EPRI 04 Ground Motion Model.

2 or a higher level assessment process is appropriate for evaluating any new data and for assessing any new seismic source model parameters for comparison with those of the accepted existing seismic source model used in Step 1. A SSHAC Level 2 assessment is considered appropriate because it assures appropriate thoroughness, assessment rigor, and level of documentation for development of a site-specific seismic source model and determination of a site-specific GMRS for nuclear facilities.

In a Level 2 process an experienced Technical Integrator (TI) team performs the evaluations and uncertainty assessments. The Level 2 evaluation and assessment process includes comprehensive consultations with scientists and seismic hazard experts who are informed about the new data, including authors of published studies and seismic source characterization experts. The goal of the TI's evaluations is: 1) to develop a comprehensive understanding of the quality of any new data or interpretations of new data in the site region, 2) to capture the range of informed experts' understandings of the degree of scientific support for any new data interpretations, and 3) to weight any new data or interpretations properly accounting for informed experts' understanding of the credibility of the new data and interpretations in the context of the informed scientific community's understanding of regional tectonic and earthquake processes. The assessments performed by the TI address uncertainty in the new data, the uncertainty in scientific support for any interpretations of the new data considering the level of uncertainty in the data and in models used, and importantly, addresses whether the new data or any interpretations of the new data are inconsistent with the informed scientific community's understanding of the fundamental regional tectonic and earthquake processes. Thus, the SSHAC Level 2 process assures a fully balanced assessment in which the TI performs as the integrator and assesses uncertainty that properly captures the range of understanding of the informed experts. Additionally, a Level 2 assessment requires full documentation of the evaluation process and of the bases for the assessments.

If after completing the evaluations and assessments as described in this step it is determined that assessed parameters based on new data are within the range of parameters of the accepted existing seismic source model (for example, the updated earthquake catalog does not result in an increase in the earthquake activity rate or contain earthquake magnitudes larger than the maximum magnitude of the assessed maximum magnitude distribution for an element of the seismic source model), the accepted existing seismic source model

may be used as in Step 1 for determination of the GMRS for the site of interest and no additional evaluations are required.

If after completing the evaluations and assessments of new data as described in this step it is determined that the new data have been adequately vetted and have broad acceptance in the informed community, elements or parameters of the accepted existing seismic source model should be modified consistent with the results of the Level 2 assessment and this updated seismic source model should be used for sensitivity evaluations as described in Step 3 of this procedure to determine whether it results in a significant increase in the generic rock GMRS at the site.

Step 3: This step consists of sensitivity evaluations to determine whether any increase in the site-specific generic rock GMRS obtained using the updated seismic source model from Step 2 is significant with respect to seismic risk. These evaluations may be made using the site-specific generic rock GMRS since the GMRS properly incorporates the slopes of the hazard curves between 10^{-4} and 10^{-5} annual exceedance frequencies. Any changes in the generic rock GMRS should be determined by comparing the generic rock GMRS obtained using the modified site-specific seismic source model developed in Step 2 with the generic rock GMRS obtained in Step 1. For this comparison, when a site of interest is located far away from seismic zones such as the New Madrid and Charleston Seismic Zones that contribute to the hazard at distant sites, a simplified composite source geometry representing alternative assessments of seismic sources for these seismic zones may be used. In addition sensitivity evaluations should be performed as in Step 1 to determine the sensitivity of the generic rock GMRS to the modified elements or parameters of the site-specific accepted existing seismic source model. The significance of any increase in site-specific generic rock GMRS should be based on a risk informed criterion. A sensitivity analysis resulting in less than a 20% cumulative change in the mean annual frequency of exceedance of the GMRS defined in Step 1 is sufficiently small as to not warrant revision of the GMRS. Such a change has only a minor effect on the achieved performance goal and is accommodated by the conservatism built into the performance goal methodology. The Design Factors (DF) used to define the GMRS from the UHRS are conservatively biased such that the achieved Frequency of Onset of Significant Inelastic Deformation (FOSID) levels are on average 20% less than target level of $1x10^{-5}$/yr. In addition, Seismic Core Damage Frequency (SCDF) levels are a factor of 2 to 10 times less than FOSID levels; therefore, a sensitivity study resulting in a 20% cumulative change in the mean

annual frequency of exceedance of the GMRS would not warrant revision of the GMRS[6].

B. Procedure and Evaluation Guidance for New Information

New information such as new seismic source assessments developed to support PSHAs for non-nuclear facilities, for research, or for demonstration purposes should require separate procedures and additional evaluations that are not described in RG 1.208. The procedures should include evaluations that consider the purpose of the seismic source assessment, the SSHAC level implemented for conducting the assessment, the scope and completeness of documentation, and whether the assessment included evaluations of new data not previously evaluated for assessment of the accepted existing seismic source model. Seismic source assessments for PSHAs that support seismic design evaluations for facilities such as bridges and the normal building inventory do not have the overall public safety assurance requirements of nuclear facilities. These evaluations normally employ a SSHAC Level 1 assessment procedure or alternatively, may rely substantially or completely on a procedure such as spatial smoothing of historical seismicity. For a Level 1 assessment, the analyst performs a literature review and develops a seismic source model for the site of interest. While a Level 1 assessment is expected to incorporate the uncertainty of the informed scientists and seismic hazard assessment experts, normally it does not involve the level of rigor and documentation required for higher level SSHAC assessments that are required for nuclear facilities. Also, while a simplified evaluation may involve interactions between the analyst and informed scientists and hazard assessment experts, the evaluations typically are not structured following the SSHAC guidelines. While these assessments are accepted for PSHAs that support building codes, which do not require definition of hazard at very low annual exceedance frequencies, they do not satisfy the defined requirements for an *Accepted PSHA Model* contained in the RG 1.208 guidance.

An applicant should evaluate such new information and document the evaluation in enough detail to support orderly review by the NRC staff.

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[6] Robert P. Kennedy. "Risk (Performance-goal) Based Approach for Establishing the SSE Design Response Spectrum for Future Nuclear Power Plants", Appendix A in R. McGuire 2005. "Assessment of a Performance-Based Approach for Determining the SSE Ground Motion for New Plant Sites, V1: Performance-Based Seismic Design Spectra", EPRI TR-1012044, Electric Power Research Institute, Palo Alto, CA.

The scope of documentation should include the purpose of the seismic source evaluation, the evaluation procedures used, the level of documentation, and any other information that would support informed review of the application. If such evaluations include new data that were not evaluated as part of the assessment of the accepted existed seismic source model, such new data should be evaluated following the procedure and evaluation guidance described in Steps 1 through 3 above.

New seismic sources developed using a fully implemented SSHAC Level 2 assessment process or higher are expected to satisfy the requirements for nuclear facility application. The assessment performed for development of such new seismic sources may or may not include evaluations of new data not previously evaluated for characterizing the accepted existing seismic source model. The procedures and evaluation for these cases should be as follows:

1) When the new seismic source assessment using a SSHAC Level 2 process or higher does not include evaluations of new data not previously evaluated for assessment of the accepted existing seismic source model, the new seismic source assessment should be combined with the accepted existing seismic source model giving it weight equal to a single additional seismic source assessment team. For example, when the EPRI SOG seismic source model (which is constituted of six expert teams' models) is the accepted existing seismic source model, the new seismic source assessment will become the seventh team and each of the seven teams will be equally weighted. This model becomes the updated site-specific seismic source model for the site. The evaluations described in Step 3 above are then made using this updated site-specific seismic source model.

2) When the new seismic source assessment using a SSHAC Level 2 process or higher does incorporate evaluations of new data, the applicant should independently evaluate the new data as described in Step 2 above. If after completing the evaluations and assessments described in Step 2, it is concluded that the accepted existing seismic source model should be modified, the model should be updated as supported by the Level 2 assessment performed by the applicant. This updated site-specific seismic source model should be used together with the appropriately weighted new seismic source assessment to perform the evaluations described in Step 3 above. The appropriate weight for combining the new seismic source with

the applicant's updated site-specific seismic source model will be determined by the degree to which the new source assessment satisfies the procedure and documentation requirements for a full SSHAC Level 2 assessment or higher.

When a new seismic source assessment potentially affects multiple nuclear plant sites, a generic sensitivity evaluation may be performed assuming a geographic location for a hypothetical site that maximizes the affect of the new source assessment. This generic sensitivity assessment can be used for the multiple potentially affected sites.