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Contract No. NRC–02–02–012
Account No. 06002.01.061

U.S. Nuclear Regulatory Commission
ATTN: Dr. Philip S. Justus
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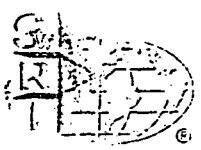
Subject: Submittal of "Review by the Office of Nuclear Material Safety And Safeguards of the U.S. Department of Energy's Responses to Key Technical Issue Agreements SDS.2.01 and SDS.2.02 for a Potential Geologic Repository at Yucca Mountain, Nevada." (IM 06002.01.061.440)

Dear Dr. Justus:

The purpose of this letter is to transmit Intermediate Milestone 06002.01.061.440 "Review by the Office of Nuclear Material Safety And Safeguards of the U.S. Department of Energy's Responses to Key Technical Issue Agreements SDS.2.01 and SDS.2.02 for a Potential Geologic Repository at Yucca Mountain, Nevada." This review provides CNWRA staff assessment of the DOE responses to the SDS agreement items, as contained in Technical Basis Document 14: Low Probability Seismic Events (Bechtel SAIC Company, LLC, 2004). The review also pertains to similar agreements RDTME.2.01, RDTME.2.02, and RDTME.3.03. CNWRA staff from the RDTME KTI have reviewed this milestone with regard to the RDTME agreement responses.



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Sincerely,

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REVIEW BY THE OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS OF THE U.S. DEPARTMENT OF ENERGY'S RESPONSES TO KEY TECHNICAL ISSUE AGREEMENTS SDS.2.01 AND SDS.2.02 FOR A POTENTIAL GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN, NEVADA, PROJECT NO. WM–011

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–02–012

Prepared by

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September 2004

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) issue resolution goal during this interim prelicensing period is to ensure the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a license application for review. Resolution by the NRC staff during prelicensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Also, and just as important, resolution of an issue by NRC during prelicensing does not prejudge the NRC staff evaluation of the issue during the licensing review. Issues are considered resolved by the NRC staff during prelicensing when the staff have no further questions or comments about how DOE is addressing an issue. Pertinent new information, however, could raise new questions or comments about a previously resolved issue.

By letter dated June 29, 2004, DOE submitted the report, *Technical Basis Document No. 14: Low Probability Seismic Events, Revision 1* (Bechtel SAIC Company, LLC, 2004). The DOE responses to eight DOE and NRC key technical issue (KTI) agreements are contained in the appendixes to the report.

This report contains a staff review of the DOE responses to two of the eight agreements discussed in Bechtel SAIC Company, LLC (2004). Wordings of the agreement items and brief summaries of the information provided by DOE are contained in Section 2.0. Section 3.0 provides the NRC evaluations of the DOE responses.

2.0 TECHNICAL INFORMATION PROVIDED IN THE DOE AGREEMENT RESPONSES

2.1 Agreement SDS.2.01 and AIN–1

Agreement SDS.2.01 was reached at a meeting, held October 11–12, 2000, to discuss the Structural Deformation and Seismicity (SDS) KTI (Schlueter, 2000). The wording of this agreement is as follows:

> SDS.2.01: "Regarding ground motion, provide documentation, or point NRC to the documentation on the expert elicitation process, regarding the feedback to the subject matter experts following the elicitation of their respective judgements. DOE will provide documentation demonstrating the adequacy of the elicitation feedback process by December 2000."

After the technical exchange, additional information from two seismic workshops (Whitney, 1997a,b) was provided by DOE to NRC as enclosures to a letter from Brocoum (2000). Staff reviewed this information and considered it insufficient for a potential licensing review. The staff review identified an Additional Information Need (AIN) as reported in Reamer (2001). The wording of the AIN is as follows:

> SDS2.01 AIN–1: "DOE needs to provide clear documentation of the expert elicitation process and its implementation, specifically with regard to the feedback process associated with the experts' interpretation, evaluation, and validation of their ground motion models. Documentation of the experts' reasoning is as important as the elicitation process. Therefore, the documentation should include: the experts' rationale for their interpretations, evaluations, and validations based on feedback; rationale for the experts'

understanding and acknowledgment of how their results would be used by DOE to develop seismic design input values for pre-closure and post-closure analyses. Documentation should be consistent with the guidelines in NUREG–1563 (e.g., section on post-elicitation feedback, p. 28)."

Technical Information Provided in the DOE Agreement Responses to SDS.2.01 and AIN–1

Additional information to address SDS.2.01 and AIN–1 was provided by DOE in Appendix C of *Technical Basis Document No. 14: Low Probability Seismic Events, Revision 1* (Bechtel SAIC Company, LLC, 2004), within which DOE states, "the experts were adequately prepared and that they received adequate feedback to their interpretations consistent with state-of-knowledge guidance, which seeks to document the unbiased uncertainty of the informed scientific community about ground-motion estimation." In particular, Appendix C provides additional information to address the NRC concerns raised in Reamer (2001) that there is a large range of differences among experts' interpretations of ground motion effects resulting from varied interpretations of aleatoric and epistemic uncertainties.

The additional information provided by DOE centers on two aspects of the DOE ground motion expert elicitation process: (i) the training and information provided to the experts to help them develop their interpretations of uncertainty and (ii) the feedback the experts received from fellow experts and elicitation facilitators that was then used by the experts to refine their interpretations. Tables in Appendix C provide (i) a summary timeline of the elicitation activities, (ii) definitions of the different types of uncertainty that needed to be defined by the experts during the elicitation, and (iii) summary of the data packages provided to the experts and used in the feedback process. Example plots in Appendix C show median horizontal ground motion point estimates (both spectral acceleration and peak ground velocity) with the associated epistemic and aleatoric uncertainties. The point estimate is for a magnitude 6.5, shallow, strike-slip faulting earthquake at a distance 1 km [0.6 mi] from the site.

2.2 Agreements RDTME.2.01, RDTME.2.02, RDTME.3.03, and SDS.2.02

Agreements RDTME.2.01, RDTME.2.02, and RDTME.3.03 were reached during the DOE/NRC Technical Exchange and Management Meeting on Repository Design and Thermal-Mechanical Effects (RDTME) held February 6–8, 2001, in Las Vegas, Nevada. RDTME KTI subissues 1, 2, 3, and 4 were discussed at that meeting (Reamer and Williams, 2001). The wording of the RDTME agreements is as follows:

RDTME.2.01: "Provide Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide Seismic Topical Report 3, Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, expected to be available to the NRC in January 2002."

RDTME.2.02: "Provide the substantive technical content of Topical Report 3. The DOE will provide the preliminary seismic design input data sets used in Site Recommendation design analyses to the NRC by April 2001. The DOE will provide the draft final seismic design inputs for license application via an Appendix 7 meeting after calculations are complete prior to delivery of Seismic Topical Report 3."

> RDTME.3.03: "Provide the Seismic Design Inputs AMR [analysis and model report] and the Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. Consistent with SDS Subissue 2, Agreement 2, the DOE will provide the Seismic Design Inputs analysis and model report and Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain, Seismic Topical Report 3. These documents are expected to be available to NRC in January 2002."

Agreement SDS.2.02 was reached at a meeting, held October 11–12, 2000, to discuss the Structural Deformation and Seismicity KTI (Schlueter, 2000). The wording of this agreement is as follows:

> SDS.2.02: "Provide the updated FEPs [features, events, and processes]: Disruptive Events AMR, the Seismic Design Input Report, and the update to the Seismic Topical Report. DOE will provide the updated FEPs AMR to the NRC. Expected availability is January 2001. DOE will provide STR 3 to the NRC for their review. Expected availability is January 2002. The Seismic Design Inputs Report is expected to be available to the NRC by September 2001."

Technical Information Provided in the DOE Agreement Responses to RDTME.2.01, RDTME.2.02, RDTME.3.03, and SDS.2.02

To partially fulfill agreement RDTME.2.02, DOE provided preliminary seismic design input data sets used in site recommendation design analyses (Brocoum, 2001). Staff reviewed those data and informed DOE they did not need any additional information pertaining to those data (Reamer, 2002). The status of the agreement was listed as "Partly Received."

To help address these RDTME and SDS agreements, DOE and NRC held an Appendix 7 meeting August 6–8, 2002, at which time DOE provided staff with draft information intended to be documented in the Seismic Design Inputs AMR (analysis and model report) and Seismic Topical Report. Topics included results of surface facility geotechnical investigations that support development of seismic design inputs and an overview of the approach to be used. The geotechnical investigations discussed at that meeting are described in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project* (Bechtel SAIC Company, LLC, 2002).

The updated features, events, and processes AMR on disruptive events (CRWMS M&O, 2000a) was provided to NRC in 2001. Staff concluded this aspect of the agreement was complete (Reamer, 2002).

In October 2000, DOE provided staff with an annotated outline for the third seismic topical report (Brocoum, 2000). Since then, however, DOE has revised its approach to documentation of preclosure seismic information (Ziegler, 2004a). DOE intends to revise *Seismic Topical Report #2, Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (CRWMS M&O, 1997). The updated topical report (Revision 3) is intended to be more consistent with the regulatory concepts in 10 CFR 63.102 and the performance objectives in 10 CFR 63.111. In addition, DOE no longer intends to issue the third seismic topical report. Instead, DOE intends to provide the seismic information, which originally was to be contained in Seismic Topical Report No. 3, in three alternative documents: (i) *Characterize Framework for Seismicity and Structural Deformation at Yucca Mountain, Nevada, Rev. 0,*

ANL–CRW–GS–000003 (CRWMS M&O, 2000b); (ii) *Technical Basis Document No. 14: Low Probability Seismic Events, Revision 1* (Bechtel SAIC Company, LLC, 2004); and (iii) *Development of Earthquake Ground Motions for Preclosure Seismic Design and Postclosure Performance Assessment at Yucca Mountain, NV, Rev. 0*, MDL–MGR–GS–000003. The first two of these documents have been delivered to the NRC staff for review. The third report, which documents details of the seismic analyses used to develop ground motion inputs for both postclosure performance assessment and preclosure design and performance analyses, has not yet been made publicly available by DOE.

3.0 EVALUATION AND COMMENT

Agreements RDTME.2.10, RDTME.2.02, RDTME.3.03, SDS.2.01, and SDS.2.02 are all related to the development of technically defensible seismic information used in postclosure performance assessment and preclosure design and performance analyses. These agreements also pertain to the DOE seismic design methodologies. For preclosure, seismic inputs are used to support the design and performance analyses of systems, structures, and components deemed important to safety. For the postclosure period, seismic motions with mean annual exceedance greater than 10^{-8} are used to evaluate seismic effects on the engineered barrier system.

3.1 Structural Deformation and Seismicity Key Technical Issue Agreement 2.01

DOE conducted a probabilistic seismic hazard assessment for Yucca Mountain (CRWMS M&O, 1998). Results of this assessment were probabilistic assessments of fault displacements and earthquake-induced vibratory ground motions that could occur at Yucca Mountain. These hazards are defined using fault displacement and seismic hazard curves, in which the increasing levels of fault displacement or vibratory ground motion (usually expressed in units of acceleration) are plotted as a function of annual exceedance probability. This hazard assessment was accomplished through expert elicitation.

DOE concludes its expert elicitation, including treatment of uncertainty and expert feedback, follows the guidance provided in both NUREG/CR–6372 (Budnitz, et al., 1997) and NUREG–1563 (NRC, 1996), with the exception that the interim interpretations by the experts are not required to be documented. This exception allows the experts to freely change their interpretations during the elicitation feedback and, thereby, avoid the possibility that the experts would prematurely anchor their positions.

Staff concerns regarding the elicitation process arose because of questions about the scientific basis for several of the experts' ground motion assessments. In particular, staff noted large differences in predicted ground motion estimates and associate epistemic and aleatoric uncertainties among experts, as summarized in NUREG–1762 (NRC, 2002, pp. 3.3.2-22 through 3.3.2-25). These differences in approach among the experts and their treatments of uncertainties affect the levels of predicted ground motions at low annual exceedance probabilities (below approximately 10^{-6}). Large differences among the ground motion experts lead to a seismic hazard curve with a relatively shallow slope, large uncertainties about the mean and median values, and a skewed distribution of the mean toward the upper uncertainty limits (e.g., Stepp, et al., 2001, Figure 10).

Although the probabilistic seismic hazard assessment was completed in 1998, DOE revised its plans to use the ground motion expert elicitation results, especially as they pertain to postclosure performance assessments. In *Technical Basis Document No. 14: Low Probability Seismic Events, Revision 1* (Bechtel SAIC Company, LLC, 2004), DOE concludes the large ground motions predicted by the probabilistic seismic hazard assessment at annual exceedance probabilities of 10^{-6} and below are unrealistic and greatly exaggerate the ground motions that could occur at Yucca Mountain. Thus, DOE has adopted an approach to limit the upper range of ground motion at Yucca Mountain to values considered more representative of site conditions. In (Bechtel SAIC Company, LLC (2004), DOE states,

> "Large ground motion predicted by the PSHA [probabilistic seismic hazard assessment] at annual exceedance probabilities of 1.0×10^{-6} and below overestimates the severity of low-probability ground motion at Yucca Mountain. This overestimation of ground motion is being addressed through determination of constraints on maximum ground motion imposed by the stress-release characteristics of seismic sources and by limits on strain that can be propagated by seismic waves through rocks at Yucca Mountain. The constraint on maximum ground motion will be incorporated in the abstraction of seismic consequences that feeds TSPA [Total System Performance Assessment]."

In the performance assessment calculations for the license application, DOE intends to cap the ground motions, limiting peak ground velocities to an upper-bound range of 250–500 cm/sec [8.2 to 26.4 ft/sec]. This approach effectively restricts application of the 1998 probabilistic seismic hazard assessment to ground motions with annual exceedance probabilities greater than 10^{-6}. For ground motions with annual exceedance probabilities between 10^{-6} and 10^{-8}, DOE will instead use the 250–500 cm/sec [8.2 to 26.4 ft/sec] upper-bound values. Technical bases for these upper-bound values are to be developed by DOE through ongoing studies of the stress-release characteristics of seismic sources and by limits on strain that can be propagated by seismic waves through rocks similar to those at Yucca Mountain.

DOE is taking this action because most technical experts (including comments from the NRC and Center for Nuclear Waste Regulatory Analyses staffs) conclude the ground motion values at small annual exceedance probabilities are unrealistically large. For example, in the DOE postclosure performance assessment, strong motion recordings of acceleration and velocity scaled to the seismic hazard at 10^{-7} annual exceedance probability, yield peak ground acceleration as high as 20g [~640 ft/s^2] and peak ground velocities up to 1,800 cm/sec [~60 ft/s]. These values are well beyond the limits of existing earthquake accelerations and velocities from even the largest recorded earthquakes worldwide, and the values are nearly one order of magnitude larger than those observed for earthquakes with moment magnitudes between 6.5 and 7.0. These large ground motions also are deemed physically unrealizable because they require a combination of stress drop, strain, and rupture propagation that cannot be sustained without wholesale fracturing of the bedrock (e.g., Kana, et al., 1991). Finally, these unrealistic ground motions perplex and misconstrue realistic performance assessments because little is known about how the natural environment will be altered by such large ground shaking.

These overly conservative earthquake ground motions arise in the DOE study because the seismic hazard curves are constructed as unbounded lognormal distributions. In past practice, probabilistic seismic hazard curves were used to estimate ground motions with an annual

exceedance probability down to 10^{-4} (a typical annual exceedance probability value designated for nuclear power plant design). Ground motions for hazards at the 10^{-4} level matched expected values for the largest earthquakes that could affect a given site. For Yucca Mountain, however, the seismic hazard curves are extrapolated to estimate ground motions with annual exceedance probabilities as low as 10^{-8}. At these low probabilities, the seismic hazard estimates are driven by the tails of the untruncated Gaussian distributions of the input ground motion attenuation models (e.g., Bommer, et al., 2004). As pointed out by Anderson and Brune (1999), overestimates of the hazards also may arise because experts improperly distributed uncertainty in the inputs between the aleatoric and epistemic uncertainties.

Similar comments and questions about the seismic hazard were raised at the February 24, 2003, Nuclear Waste Technical Review Board Panel on Natural System and Panel on Engineered Systems joint meeting about seismic issues. The Board's seismic meeting foxused on the large vibratory ground motions predicted by the DOE probabilistic seismic hazard assessment at annual exceedance probabilities below 10^{-6} per year. In a letter from the Nuclear Waste Technical Review Board to DOE (Coraddini, 2003), the Board stated

> "...although the probabilistic seismic hazard assessment is, in general, sound, extending it to very low probabilities results in ground-motion estimates about which there are serious technical questions. These relate to the lack of physical realism and the implication of these unrealistic estimates for performance assessment, design, and scientific confidence."

The Board notes that application of a physically unrealistic or highly conservative approach, even if acknowledged as such by DOE, could lead to numerous problems including a skewed understanding of repository behavior and the significance of different events, consideration of events for which there is little or no understanding or engineering practice, and undermined confidence in the scientific basis of the process being considered.

This change in the DOE approach effectively resolves the staff concerns raised in SDS.2.01. The staff question regarding the expert elicitation is no longer relevant because DOE no longer relies on expert elicitation results as a basis for estimates of the low probability vibratory ground motions, those with annual exceedance probabilities between approximately 10^{-6} and 10^{-8}. Therefore, staff conclude that SDS KTI agreement SDS.2.01 is complete. At this time, staff have no further questions concerning the probabilistic seismic hazard assessment elicitation process.

3.2 Repository Design and Thermal-Mechanical Effects Key Technical Issue Agreements RDTME.2.01, RDTME.2.02, RDTME.3.03, and Structural Deformation and Seismicity Key Technical Issue Agreement SDS.2.02

Information needs related to these agreements remain incomplete. DOE has not yet provided two important documents that ~~it now says replace the information~~ it initially intended to provide in Topical Report No. 3. These two documents are (i) revised (Revision 3) *Seismic Topical Report #2, Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* and (ii) *Development of Earthquake Ground Motions for Preclosure Seismic Design and Postclosure Performance Assessment at Yucca Mountain, NV, Rev. 0,* MDL–MGR–GS–000003. Both these documents are needed for staff to begin reviewing information in the potential DOE license application. Therefore, staff consider the status of

these agreements as "Needs Additional Information." These agreements will be considered complete once DOE makes the two aforementioned documents available to the public.

In a recent letter from DOE to NRC (Ziegler, 2004b), DOE states, "any questions or concerns of the NRC will be addressed within the context of the licensing process" and also, "DOE does not intend to provide direct responses to any additional KTI agreement AINs received after the date of this letter." Therefore, staff anticipate the information needs discussed in this agreement response, including the additional documentation of the DOE seismic design methodology, ground motion inputs for preclosure safety and postclosure performance assessments, and technical bases supporting the bounds on the low probability ground motion, will be included in the DOE license application.

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