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Civilian Radioactive Waste Management System
Management & Operating Contractor

Annotated Outline for Topical Report Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain

REV 01

September 2000

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Approved by:

Stephan Brocoum, Assistant Manager
Office of Licensing and Regulatory Compliance

9/14/00
Date

ABSTRACT

This abstract is a summary of the seismic topical report and its conclusions. This abstract describes the structure and content of a topical report to present the preclosure seismic design inputs for a potential geologic repository for high-level radioactive waste at Yucca Mountain, Nevada. It briefly explains that the *Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain* (referred to hereafter as Seismic Topical Report III) is to present the results of a probabilistic seismic hazard analysis for Yucca Mountain; describe the methodology for development of seismic design inputs and its implementation; and provide an overview of how seismic design inputs will be used in postclosure analyses.

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ACRONYMS AND ABBREVIATIONS

PSHA	Probabilistic Seismic Hazard Analysis
STR	Seismic Topical Report
STR I	Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain
STR II	Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain
STR III	Preclosure Seismic Design Inputs for a Geologic Repository at Yucca Mountain

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1. INTRODUCTION

1.1 BACKGROUND

This section will explain that this report is the third in a series of three topical reports on seismic hazards and preclosure seismic design of the proposed geologic repository at Yucca Mountain, Nevada. This third and final report will summarize the seismic hazard at the site and present the preclosure seismic design inputs. The seismic hazard was determined through application of the probabilistic seismic hazard methodology described in the first seismic topical report (STR), *Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain*, (referred to hereafter as STR I) (YMP 1997a). The preclosure seismic design inputs were determined following the second STR, *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (referred to hereafter as STR II) (YMP 1997b), which defines the frequencies of exceedance for vibratory ground motion and fault displacement corresponding to Frequency-Category-1 and Frequency-Category-2 events. The history of the STR submittals, reviews, and revisions will be summarized, and the scopes of the predecessor STRs will be described. This section will state that the three STRs together constitute supporting technical documentation for satisfying the U.S. Nuclear Regulatory Commission's regulatory requirements of the seismic design fault displacement and ground motion for the proposed repository at Yucca Mountain.

This section will explain that the seismic hazard analysis results are applicable to postclosure as well as preclosure design and analyses; however, the design methodology and design input to be described are for the preclosure operational period only. Separate analyses of the effects of earthquakes on postclosure repository performance will be conducted to support total system performance assessments, and any postclosure seismic design criteria will be developed on the basis of the performance assessment results. Planned documentation of these postclosure analyses will be identified.

This section will also give a brief overview of the organization of the STR. The overview gives a short description of the contribution of each chapter of the STR to accomplishing the objectives of the report.

1.2 REGULATORY REQUIREMENTS

This section will summarize the applicable regulatory requirements to identify Frequency-Category-1 and Frequency-Category-2 design events and to develop a seismic design for those structures, systems, and components that are important to safety. The summary will be brief and will refer the reader to STR II (YMP 1997b) for a detailed discussion of regulatory requirements. This document is an inclusionary record and will be submitted to the Records Processing Center upon completion.

2. SEISMIC HAZARD ANALYSIS

2.1 PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA) PROCESS DESCRIPTION

2.1.1 Objectives

This section will describe the objective of the PSHA, which is a scientific evaluation of the hazard at Yucca Mountain expressed as annual frequency of exceeding vibratory ground motion levels and fault displacement levels, with explicit expression of the aleatory and epistemic uncertainties associated with the hazard assessment. The meaning of vibratory ground motion and fault displacement hazard curves will be explained. The distinction between aleatory and epistemic uncertainties will be explained and references provided for more details. The PSHA material will be presented in a concise manner.

2.1.2 Expert Inputs to PSHA

This section will describe experts' evaluations of seismic sources, evaluations of the potential for fault displacement, and evaluations of vibratory ground motion attenuation for input to PSHA. The process for identifying experts to perform the input evaluations will be described, including the selection criteria. Roles in the PSHA of review and management panels, proponents, evaluators, and facilitators will be explained. The process of identifying data needs, compiling and presenting information, facilitating interpretations, and reviewing hazard results will be described. Use of the guidance in NUREG-1563, *Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program* (NRC 1996), will be discussed. A reference will be provided to Appendix A, which will identify the participants, their roles, affiliations, and references where the qualifications of the experts are documented. Appendix A will also provide the agenda, date of each workshop, and references to workshop summaries.

This section will describe the experts' characterizations of fault displacement potential as input to fault displacement hazard analysis. It will describe consideration of the Nuclear Regulatory Commission guidance in NUREG-1451, *Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository* (NRC 1992), and NUREG-1494, *Staff Technical Position on Consideration of Fault Displacement Hazards in Geologic Repository Design*, (NRC 1994), in the PSHA.

2.1.3 Hazard Calculation Methodology

2.1.3.1 Mathematical Model

This section will review the mathematical model for the seismic hazard calculations and will refer to Appendix C of STR I (YMP 1997a) for details.

2.1.3.2 Expression and Propagation of Uncertainties

This section will explain how epistemic uncertainties in input interpretations are propagated through the analysis by means of logic trees to generate distributions of hazard curves, and that each hazard curve expresses aleatory uncertainty, and that the distribution of hazard curves

expresses epistemic uncertainty. How the hazard curves of the different expert panels are aggregated to form composite hazard curves will be explained.

2.1.3.3 Parameterization of Interpretations

This section will describe how the seismic sources, fault displacement potential, and ground motion attenuation interpretations are parameterized for input to the hazard calculation model. Specifically, it will describe how fault- and areal-source geometries, probabilities that sources exist or are active, earthquake recurrence relationships, and multiple-faulting potential interpretations are parameterized and expressed in logic trees. Ground motion attenuation relationships, as well as the distance measures in attenuation relationships, will be discussed.

2.1.3.4 Hazard Calculation Computer Code

This section will identify the hazard calculation computer code and describe the quality control and quality assurance procedures that were applied to its application.

2.2 SEISMIC SOURCE INTERPRETATIONS

2.2.1 Arabasz, Anderson, Ramelli Team

This section will present a map, or maps, of the locations of the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.2.2 Ake, Slemmons, McCalpin Team

This section will present a map, or maps, of the locations of the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.2.3 Doser, Fridrich, Swan Team

This section will present a map, or maps, of the locations of the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.2.4 Rogers, Yount, Anderson Team

This section will present a map, or maps, of the locations of the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and

maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.2.5 Smith, Bruhn, Knuepfer Team

This section will present a map, or maps, of the locations the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.2.6 Smith, de Polo, O'Leary Team

This section will present a map, or maps, of the locations of the Team's interpreted seismic sources and the Team's logic tree, which document the source-activity probabilities (weights), fault geometries, segmentation, rupture behavior, earthquake recurrence relationships, and maximum magnitude distributions. Potential multiple-faulting interpretations, if any, will be described. References will be provided for detail of the interpretations.

2.3 VIBRATORY GROUND MOTION HAZARD

2.3.1 Ground Motion Attenuation Models

The experts' point estimates of ground motion will be described. The description will address how the experts estimated median ground motion, aleatory uncertainty, and epistemic uncertainties for a matrix of event magnitudes, distances, and faulting styles.

The evaluations of class and model weights will be described, and the weighting approaches employed by the experts to develop their point estimates will be summarized. A reference will be provided indicating where the experts' point estimates are tabulated.

Adjustments to the point estimates for interpretations of simultaneous faulting on multiple faults and for faulting geometry will be discussed. The experts' adjustment factors or a reference to them will be provided.

The parameterization of the experts' point estimates in the form of attenuation relations will be described. The regression model used by the facilitation team will be described and the results will be presented and compared to the point estimates. The required adjustments to apply the attenuation relations to areal sources and the corresponding hypocentral distance metric, in addition to fault sources and the closest-distance metric, will be discussed.

2.3.2 Hazard Curves

This section will present vibratory ground motion hazard curves calculated by using the seismic source experts' source interpretations and the attenuation relations that were developed from the ground motion experts' point estimates. Aggregated curves for all experts and all seismic sources will be presented along with example curves for individual seismic source teams, individual ground motion experts, and individual seismic sources. References will be provided for the complete collection of hazard curves. The procedure for generating aggregated curves will be

described. Curves will be presented for vertical and horizontal ground motion, for peak ground acceleration, peak ground velocity, and spectral accelerations at relevant frequencies. Uncertainties as expressed by differences between mean, median, and other fractile curves will be illustrated.

2.4 FAULT DISPLACEMENT HAZARD

2.4.1 Characterization of the Potential for Fault Displacement

This section will describe the approaches used by the expert teams to characterize the potential for fault displacement at different locations on the Yucca Mountain site. Example approaches that are based on displacements observed in the geologic record and approaches that are based on earthquake recurrence will be illustrated. References will be provided to the teams' detailed characterizations.

2.4.2 Hazard Curves

This section will present fault-displacement hazard curves for selected locations at the Yucca Mountain site. It will be explained that the locations span the range of fault displacement potential at the site (i.e., from locations on primary faults to locations in intact rock). The method of developing the aggregated curves will be described and examples will be provided for demonstrating the aggregated curves compared to the curves of individual expert teams. Differences between mean, median, and other fractile curves will be illustrated. References will be provided to the complete set of derived hazard curves.

3. PRECLOSURE SEISMIC DESIGN INPUTS

3.1 VIBRATORY GROUND MOTION

3.1.1 Hazard Disaggregation and Design Response Spectra

This section will state that Frequency-Category-1 and Frequency-Category-2 design vibratory ground motions are associated with mean annual exceedance probabilities of 10^{-3} and 10^{-4}, respectively, and refer to STR II (YMP 1997b) for the details and the rationale. Mean uniform hazard spectra for these annual exceedance probabilities will be presented. The procedure that was followed to disaggregate the hazard results will be described and discussed in relation to the U.S. Nuclear Regulatory Commission's guidance in Regulatory Guide 1.165, *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion*. Three-dimensional plots that show the relative contribution of earthquakes in different magnitude, distance, and epsilon bins to the overall hazard at specific frequencies will be presented. (Epsilon is a measure of the degree to which ground motion deviates from the mean.) The magnitudes, distances, and scale factors associated with the Frequency-Category-1 and Frequency-Category-2 reference response spectra will be presented, and mean spectra from these earthquakes will be compared to the corresponding uniform hazard spectra.

3.1.2 Local Site Response

This section will describe the methodology used to propagate the reference response spectra to surface locations (rock and soil), and subsurface (repository horizon) rock locations. For the surface soil inputs, conditions at the Waste Handling Building site will be used. References will be provided for details of the methodology. Results will be based on shear-wave velocity profiles that represent the properties of the shallow rock and soil at the site. Results will be presented for both Frequency-Category-1 and Frequency-Category-2 events and both vertical and horizontal ground motion. References will be provided to source documents.

3.1.3 Ground Motions, Strains, Curvatures with Depth, and Time Domain Ground Motions

This section will describe the procedure used to compute the variations of motions, strains, and curvatures with depth, consistent with a given design response spectrum. Time histories will be presented for Frequency-Category-1 and Frequency-Category-2 design spectra, at the repository horizon, a surface rock site above the repository, and a surface soil location, such as may be appropriate for the Waste Handling Building. Horizontal and vertical time histories will both be developed. The peak accelerations and velocities associated with these time histories will be identified. Peak strains and peak curvatures as a function of depth will also be presented for each of the Frequency-Category-1 and –2 design motions. References will be provided to source documents.

3.2 FAULT DISPLACEMENT

3.2.1 Design Fault Displacements

This section will state that Frequency-Category-1 and Frequency-Category-2 design fault displacements are associated with mean annual exceedance probabilities of 10^{-4} and 10^{-5}, respectively, and refer to STR II (YMP 1997b) for the details and the rationale. If fault displacement hazard is significant, Frequency-Category-1 and Frequency-Category–2 design fault displacements will be presented for specific faulting conditions that are discussed in Section 2.4.2. Guidance will be provided regarding the distance (fault-zone width) over which the displacements should be assumed to occur.

3.2.2 Implications for Fault Displacement Design

In this section the fault displacement design requirements described in STR II (YMP 1997b) will be evaluated for faulting conditions encountered at the repository and specific fault displacement design requirements will be described. Engineering analyses supporting set back from faults and/or design of components for fault displacement will be described.

3.3 UNDERGROUND NUCLEAR EXPLOSIONS

In this section, ground shaking expected from underground nuclear explosions will be described together with consideration of this ground motion in the seismic design of the Yucca Mountain

facility. The evaluation will include the determination of motions resulting from explosion induced earthquakes.

4. SEISMIC HAZARD RESULTS FOR POSTCLOSURE PERFORMANCE ASSESSMENT

4.1 VIBRATORY GROUND MOTION HAZARD

This section will be designed to provide a roadmap to relevant Analysis Model Reports and Process Model Reports that include the vibratory ground motion hazard results to be used as input to postclosure performance assessment. It will state why postclosure performance assessment needs this information and how it will be used, and will reference the appropriate Yucca Mountain Site Characterization Project documentation for the details.

4.2 FAULT DISPLACEMENT HAZARD

This section will be designed to provide a roadmap to relevant Analysis Model Reports and Process Model Reports that include fault displacement hazard results that are inputs to postclosure performance assessment. It will state why postclosure performance assessment needs this information and how it will be used, and will reference appropriate Project documentation for the details.

5. REFERENCES

All cited references will be entered into the Document Input Reference System database. The references will be listed following the format of the Management and Operating Contractor *Style Manual for the Civilian Radioactive Waste Management System* (CRWMS M&O 1999) or superseding guidance, and AP-17.1Q, *Record Source Responsibilities for Inclusionary Records*. The reference list will be consistent with the information in the Document Input Reference System database. All references will include a Records Information System accession number or a Technical Information Center catalog number, as applicable.

5.1 DOCUMENTS CITED

CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor). *Style Manual for the Civilian Radioactive Waste Management System*, B00000000-01717-3500-00004 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990824.0240.

NRC (U.S. Nuclear Regulatory Commission) 1992. *Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository*. NUREG-1451. Washington, D.C.: NRC. TIC: 204829.

NRC 1994. *Staff Technical Position on Consideration of Fault Displacement Hazards in Geologic Repository Design*. NUREG-1494. Washington, D.C.: NRC. TIC: 212360.

NRC 1996. *Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program.* NUREG-1563. Washington, D.C.: NRC. TIC: 226832.

YMP (Yucca Mountain Site Characterization Project) 1997a. *Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain.* YMP/TR-002-NP Rev.1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19971016.0777.

YMP 1997b. *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain.* YMP/TR-003-NP Rev.2. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19971009.0413.

5.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

AP-17.1Q, Rev. 1, ICN 2. *Record Source Responsibilities for Inclusionary Records.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19991217.0505.

Regulatory Guide 1.165. 1978. *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion.* Washington, D.C.: U.S. Nuclear Regulatory Commission. Readily available.

APPENDIX A

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APPENDIX A

This appendix will identify the experts and the members of the management and review panels. The members of each seismic source characterization expert team will be listed. The affiliations of all participants will be identified and references will be provided indicating where the qualifications of the experts are documented. Appendix A will also provide the agenda, date of each workshop, and references to workshop summaries.